Consolidated EPA Region III Response to the Advanced Notice of Proposed Rulemaking on the Clean Water Act Regulatory Definition of "Waters of the United States"

Consolidated EPA Region III Response to the Advanced Notice of Proposed Rulemaking on the Clean Water Act Regulatory Definition of "Waters of the United States"

Introduction:

The enclosed report represents the Region III response to the advanced notice of proposed rulemaking (hereinafter: ANPRM) on the Clean Water Act regulatory definition of "waters of the United States." This report represents the collective efforts of regional staff from the Office of Regional Counsel, Water Division, Environmental Services Division (including the professional staff of the Wheeling, WV lab), and agency and contract support staff from the Geographic Information System (GIS) unit.

The following outline describes how this report is organized and the primary features of each part:

I. Executive Summary: A synopsis of the regional response with comments and recommendations based on the finding in the report.

II. Highlights of GIS Analysis

III. Response to the Questions Posed in the ANPRM
   A. Response with regard to issues concerning wetland ecology
   B. Response with regard to issues concerning stream ecology
   C. Response with regard to legal issues

IV. Case Studies: Field observations of ecological relations between headwater streams and headwater and isolated wetlands

V. Appendices
   A. GIS Analysis (Methods, Tables, and Stream Report)
   B. Detailed Photo Interpretation of Selected Field Sites
   C. Field Data from Wetland Sites in PA/DE/MD/VA (available upon request)
   D. Wetland Ecology Literature Review
   E. Stream Ecology Literature Review
   F. Legal Analysis
   G. Christina River Basin TMDL Case Study
   H. Tygart River TMDL Case Study
   I. Threatened and Endangered Species
   J. Potential changes on the scope of Clean Water Act jurisdiction on the NPDES and Safe Drinking Water programs
   K. State Programs in Region III

Executive Summary
EPA Region III Comments on
Advance Notice of Proposed Rulemaking
on the Clean Water Act Regulatory Definition of "Waters of the United States"

The Environmental Protection Agency's (EPA) Office of Water (OW) and the Army Corps of Engineers have proposed to initiate rule-making to "clarify" the scope of federal Clean Water Act (CWA) jurisdiction following the Supreme Court's decision in the Solid Waste Agency of Northern Cook County (SWANCC) v US Army Corps of Engineers. In SWANCC, the Court held that the Corps had exceeded its authority under the CWA by asserting jurisdiction over what the Court characterized as isolated, intrastate ponds based solely on their use as a habitat for migratory birds pursuant to the so-called "Migratory Bird Rule." EPA Region III has conducted a comprehensive analysis in response to the January 15, 2003 Advanced Notice of Proposed Rule-making (ANPRM) issued by the EPA Office of Water and the U.S. Army Corps of Engineers. This analysis evaluates the potential effects of changes in the current regulations on wetland and stream resources in the Middle Atlantic States, with particular attention to the functions of these resources and their value in protecting human health.

The ANPRM sets out two specific questions for which the EPA and the United States Department of the Army Corps of Engineers ("Corps") specifically solicit comment: whether the regulations should define "isolated" waters, and what factors should be considered for determining CWA jurisdiction over such waters. The ANPRM also solicits data regarding the extent of resource impacts to isolated, intrastate, non-navigable water and information on the functions and values of wetlands and other waters that may be affected by the issues discussed in the ANPRM.

Current administration of the CWA rules and regulations has resulted in significant progress toward restoration and maintenance of the chemical, physical and biological integrity of the Nation's waters. The current CWA jurisdictional scope, including navigable waters and their tributaries, is supported by the science which includes the hydrology and ecology of watersheds.

Definition of Isolated Waters

In specific response to the ANPRM's question regarding definition of so called "isolated" waters, any definition of these waters should take into account the hydrologic cycle and the inter-relationships among waterbodies (surface and groundwater). Any definition of "isolated" waters should include only truly "isolated" waters, outside the hydrologic cycles of navigable waters. If there is an attempt to define "isolated" waters, the role of groundwater in connecting waterbodies must be considered. Groundwater is a major feature in watersheds and frequently serves as a permanent hydrological connection between wetlands and surface water tributaries. Although some waters and wetlands may not exhibit a perennial surface water connection, they are closely integrated to the larger watershed network via groundwater and non-perennial surface connections and, as such, are not isolated from the larger hydrologic cycle.

If "isolated waters" are to be defined, Region III recommends the following:

> Completely isolated: perched systems that are entirely self-contained and have no hydrological (surface or groundwater) connection to other waters.

Under this definition, most intrastate, non-navigable waters are not, in fact, isolated.

An attempt to develop a generalized definition of "isolated" waters predicated on physical proximity, flow, or some other factor will create an arbitrary cut-off (not scientifically based) that may fail to take into account the role of certain waters in the overall hydrologic cycles that Congress clearly intended to regulate. Although the CWA refers to "navigable" waters, the Supreme Court in SWANCC affirmed that the jurisdiction of the CWA extends beyond those waters that are deemed traditionally navigable-in-fact. Congress' declaration of goals and policy in CWA Section 101(a) as protecting the physical, chemical and biological integrity of the waters of the United States extends beyond the mere protection of navigation. The legislative history clearly states that Section 101(a) addresses the protection of the natural structure and function of ecosystems. As currently administered, the CWA, by including a broader interpretation of "waters of the United States", has made significant progress in achieving the goals articulated by Congress. Region III's suggestion for a definition of "isolated" waters should not be construed as a suggestion that such waters are not within the jurisdiction of the Clean Water Act.

In terms of implementing any regulatory program regarding "isolated" wetlands it should be noted that generally there are no discrete, scientifically supportable boundaries or criteria along the continuum of wetlands to separate them into meaningful ecological or hydrological compartments. Applying any set of field methods (as yet undeveloped) would be problematic.

Jurisdictional Factors

To the extent a decision is made to change the current regulations regarding CWA jurisdiction, including developing a definition for "isolated" waters, it will be important to keep in mind the purposes underlying the CWA. Controlling pollution at its source is paramount in order to restore and maintain the chemical, physical and biological integrity of the Nation's waters. The relationship of all waters within the watershed must be recognized and their contribution not only to water quality control but also pollution discharge must be acknowledged. Commerce of all kinds: intrastate, interstate and international - will be severely affected if commercial, industrial and municipal waters are adversely impacted by uncontrolled pollution in headwater areas. Wetlands and small, headwater streams serve a multitude of water quality functions. As part of an ecological/hydrological network, watersheds containing small perennial and intermittent streams and wetland systems (surface and groundwater connected) have bearing on interstate or foreign commerce. As such, the effects that small or non-navigable waterbodies have on the downstream water quality should be considered as factors to provide a basis for jurisdiction where such interstate commerce occurs. Region III's suggestion for a definition of "isolated" waters should not be construed as a suggestion that such waters are not within the jurisdiction of the Clean Water Act.

Extent of Resource Impacts

Although the U.S. Supreme Court's decision in SWANCC did not directly address tributaries and adjacent wetlands, most of the post-SWANCC case law has addressed these waters rather than the isolated waters at issue in SWANCC. Because of the uncertainty regarding the scope of "isolated" waters resulting from the post- SWANCC rulings and the use of the broad term "other waters" in the ANPRM, Region III has provided a fairly broad analysis of potential effect of new rule making as it relates to "isolated intrastate non-navigable waters". We have examined a range of scenarios, from narrow to broad, in responding to the ANPRM. A comprehensive analysis drawing from the literature, geographic information systems (GIS) analyses, aerial photo interpretation (API), field studies, and many years of professional experience is provided in the attached response.

Although Region III has provided analysis of potential scenarios that may be realized as a result of new rule-making, it should be made clear that we do not consider these waters to be "isolated" in the hydrologic sense (see above). Many of these small headwater wetlands and streams experience a range of hydrological connectivity with downstream waters which in turn depends on a number of region-specific factors (precipitation, catchment area, topography, geology, etc.).

Because the nature of any proposed regulatory change is unknown, Region III's analysis necessarily required some assumptions. In keeping with the limited scope of waters affected under SWANCC, Region III's-narrow interpretation of "isolated" wetlands includes wetland areas that do not exhibit a perennial or intermittent surface water connection to traditional "navigable waters". The broad interpretation includes smaller perennial streams and intermittent or ephemeral "headwaters" and their adjacent wetlands as well as the wetlands analyzed in the narrow interpretation described above.

A range of profound aquatic resource impacts are exhibited when analyzing the potential effects of new rule-making on waters and wetlands described above. Using region-wide GIS data, approximately 438,000 acres of wetlands, or roughly 12% of the wetland resource in Region III, could be adversely affected under the narrow interpretation. If one considers the broad interpretation, that number increases to 1.3 million acres of wetlands, or roughly 36% of all wetlands in the Region. Both figures represent a significant portion of wetlands within Region III. Furthermore, these numbers may be conservative estimates considering that studies have shown that the maps used to generate these figures may underestimate actual wetland acreage by as much as 50%.

Regional GIS analysis shows that the majority of total stream miles in Region III are small, headwater streams. Approximately 52% of the total stream resource (as measured in stream miles) in Region III are first order, headwater streams at the 1:100,000 mapping scale[1]. Approximately 106,000 miles of headwater[2] streams in Region III could be affected by changes in CWA jurisdiction and could therefore be afforded no protection under CWA authorities. As the beginning of a watershed, headwaters function in many ways that are critical to the ecosystem (e.g., moderation of downstream flow, moderation of thermal regime, removal of pollutants, influence on the storage, transportation and export of organic matter). These physical and biological attributes are integral to healthy, self-sustaining watersheds.

Numerous studies have shown that both the stream and wetlands mapping available on a regional or national basis underestimate the extent of both stream and wetland resources. Aerial photography interpretation (API) was used as a tool by Region III to more accurately determine the potential effects of the reduction in the scope of CWA jurisdiction. The API analysis complemented the GIS analysis described above by developing and analyzing site-specific data at four relatively small study areas in Region III. The API study showed a greater range of potential wetland impact. The impact was shown to be greater in the study areas that were located in headwater settings. Up to 100% of localized areas within small first and second order watersheds consist of isolated waters, smaller perennial streams and intermittent or ephemeral streams and their adjacent wetlands.. Using API the potential impact of the reduction in the scope of CWA jurisdiction on streams is also significant. The API has shown that between 88%-92% of all stream resources consist of smaller perennial streams and intermittent or ephemeral streams and their adjacent wetlands. Up to 100% of stream resources could also be affected in small, localized watersheds. This analysis shows that the higher resolution the wetlands and stream data, the greater the potential impact of reduction in the scope of CWA jurisdiction.

Any changes made to the federal regulatory definition of "waters of the United States" will also affect progress achieved under the Safe Drinking Water Act (SDWA). Region III's analysis found that, when considering a reduction in CWA jurisdiction that excluded smaller perennial streams and intermittent or ephemeral streams and their adjacent wetlands, significant degradation to drinking water sources is likely to occur. Removal of the source water protection measures afforded by the Clean Water Act increases risks to human health and may require additional infrastructure expenditures by public utilities using surface water intakes. In EPA Region III, between 148 and 526 surface drinking water intakes, serving populations ranging from 535,000 to 3 million people, would potentially be affected if headwater streams were

---

[1]This coarse scale of mapping (1:100K) may underestimate the number and length of small streams by a large amount. This problem appears to vary by watershed, with some underestimates exceeding 150%. For example, in Pennsylvania, the total length of stream miles increased 50% when moving from coarser scale mapping to one with more refined accuracy. Furthermore, we know from case studies that this coarse scale coverage does not accurately map intermittent streams.

[2]The term "headwaters" is used to describe the dendritic pattern of small streams, swales and wetlands that form the beginnings of most watersheds. Use of the term does not imply reference to the regulatory definition set forth at 33 C.F.R 330.2(d)

removed from Clean Water Act jurisdiction. Without federal limits or controls on these segments, point and non-point sources of contamination could likely increase. Public water suppliers would need to increase treatment of source water to ensure that public safety requirements were met. Contaminants such as Cryptosporidium and E. coli would likely increase in streams where municipal discharges and treatment facilities handling animal waste and animal by-products discharge into headwater streams.

Functional Analysis

Most of the headwater streams and wetlands potentially affected by changes in CWA jurisdiction comprise networks that function in a manner analogous to the capillaries in a blood circulatory system. Just as capillaries act as the interface between our organs and our circulatory system, these systems act as the interface between the uplands and the surface water networks that comprise the watersheds of our Nation. These small but numerous systems act both individually and cumulatively, to provide the full range of important wetland functions (e.g., flood reduction, water quality, nutrient retention/transformation, habitat, primary productivity) in a watershed. Moreover, a large number of endangered or threatened plant and animal species utilize these habitats which demonstrates their critical biodiversity function. These streams and wetlands perform and deliver ecological functions that promote the biological, physical and chemical integrity of receiving waters in a manner that is dependent on their unique place in the landscape.

Potential Ramifications to other CWA Programs

Reduction in the scope of jurisdictional waters could have profound and far reaching affects to many CWA programs including section 303, 311, 401, 402, and 404 because many of the sources of pollution may no longer be regulated under the CWA. Any changes made to the CWA regulatory definition of "waters of the United States" will apply to all programs under the Clean Water Act. Although some states may have authorities to regulate waters of their state, their ability to regulate these areas effectively may be compromised as a result of the loss of CWA authority.

Regarding water quality in general, it is well recognized that controlling pollution at its source is the most effective way to achieve the goals of the Clean Water Act. In many watersheds, the sources of pollution and the majority of the pollutant loadings are in small streams. If ephemeral, intermittent or small perennial headwaters and, in some cases headwater wetlands, were no longer jurisdictional under the CWA, and unpermitted discharges were allowed in these waters, it could be very difficult to attain water quality standards or implement effective pollutant loading limits, known as Total Maximum Daily Loads (TMDL), in downstream waters. Considerable resources at both the Federal and State level have been expended on the development of TMDLs for impaired streams. Recent gains in water quality resulting from the TMDL program could be seriously jeopardized by any reduction in the scope of "waters of the United States".

State Programs

Although in many cases, states have authorities to control pollution discharges to streams and wetlands, state programs historically have relied upon CWA authorities as an important "backstop" with respect to state water quality programs. This is especially true in the development of water quality standards and related programs such as TMDL. Region III has developed a number of TMDLs for states in various watersheds in the Region. Furthermore, the District of Columbia has not sought authorization to implement certain water quality programs, the NPDES program among them, and Pennsylvania is not authorized to administer the industrial pretreatment program. The Oil Pollution Act (33 U.S.C. 1321-1322) does not provide for delegation to the states. As a result, state laws often lack counterparts to the types of protections required by the Federal Oil Pollution Act.

The effect of narrowing the jurisdictional scope of waters of the United States will also impact the areas and activities subject to Clean Water Act Section 401 programs which require State approval for federally permitted activities. Additional state programs could be required to "recapture" isolated waters and wetland areas. While three of the five States in Region III (Pennsylvania, Maryland and Virginia) have programs that provide some protection for headwater streams and wetlands, Delaware and West Virginia do not have programs that effectively regulate freshwater wetlands. Furthermore, the federal wetland program is an important complement to state programs, often sharing the burden of assessment, permitting and enforcement. The result of narrowing the CWA definition of "waters of the United States" will shift more of the economic burden for regulating wetlands and headwater streams to states and local governments.

Conclusion and Recommendations

Any definitions or factors used to assert CWA jurisdiction over "waters of the United States" should be interpreted comprehensively in order to maintain CWA protections currently in place. From a science perspective, if a definition of "isolated" waters is to be promulgated, Region III recommends it include only truly "isolated" waters outside the hydrologic cycles (surface and groundwater) of navigable waters. With this definition, most intrastate, non-navigable waters in Region III would <u>not</u> be considered isolated. The extent of aquatic resources in Region III lacking <u>any</u> hydrologic connection to surface or groundwater would be considered small. However, if a reduced CWA jurisdictional scope is applied, Region III's wetland and stream impact analysis indicates profound and far reaching impacts. This reduction in scope will have serious effects on the progress made during the last 30 years to restore and maintain the chemical, physical and biological integrity of the Nation's waters.

2

GEOGRAPHIC INFORMATION SYSTEM (GIS) HIGHLIGHTS

The January 15, 2003 Advanced Notice for Proposed Rulemaking requests information on the scope of "Waters of the United States" in response to the Supreme Court's SWANCC decision. As part of our response, EPA Region 3 has performed several GIS and aerial photography analyses to estimate the extent of wetlands and streams that could be affected by changes in the scope of waters subject to jurisdiction under the Clean Water Act (CWA). This "highlights" section includes examples of potentially affected wetlands, streams, and drinking water intakes. Additional information can be found in the GIS and Aerial Photography Appendices.

LIST OF FIGURES AND TABLES

Fig. 1. Surface Drinking Water Intake Map (Narrow Estimate)
Fig. 2. Surface Drinking Water Intake Map (Broad Estimate))
Fig. 3. Potentially Affected Wetlands by State (Narrow Interpretation), Bar Graph
Fig. 4. Potentially Affected Wetlands by State (Broad Interpretation), Bar Graph
Fig. 5. Potentially Affected Wetlands in the Vicinity of Salisbury, MD (Narrow Interpretation)
Fig. 6 Potentially Affected Wetlands in the Vicinity of Salisbury, MD (Broad Interpretation)
Fig. 7. Wetlands in the Vicinity of Millington, MD, Broad Interpretation
Fig. 8. Wetlands in the Vicinity of Church View, VA, Broad Interpretation)
Fig. 9. Stream Miles by Stream Order, Bar Graph
Fig. 10. First Order Streams in the Vicinity of Salisbury, MD
Fig. 11. Headwater Stream Network, West Virginia Case Study

Table 1. Region 3 Analysis of Surface Water Intakes by State
Table 2. Region 3 Potentially Affected Wetland Acreages by State
Table 3. Region 3 Stream Miles by State

PUBLIC HEALTH: SURFACE DRINKING WATER INTAKES

- **Between 148 and 526 surface drinking water intakes, serving populations from 535,000 to three million people, are potentially affected.**

Several GIS analyses were performed to identify EPA Region III drinking water intakes located on small or unmapped streams. The first drinking water map shows 148 water intakes, serving 535,000 people, that could be affected under a narrow interpretation of the Advanced Notice of Proposed Rulemaking. Under this interpretation, intakes located at least 500 feet from mapped streams were identified. (See Fig. 1, Table 1.) It was the professional assessment of EPA staff that the majority of these intakes are located on unmapped tributary streams. The second drinking water map shows 526 water intakes, serving three million people, that could be affected under a broad interpretation of the Advanced Notice of Proposed Rulemaking. (See Fig. 2, Table 1.). Under this interpretation, intakes associated with unmapped streams and mapped 1st and 2nd order streams were identified. First order streams are the smallest streams in a watershed. When two first order streams flow together, they form a 2nd order stream. When two 2nd order streams flow together, they form a 3rd order stream, and so on.

POTENTIALLY AFFECTED WETLANDS

- **Between 12 and 36 percent of the wetlands in Region 3 are potentially affected.**

In our wetlands analyses, we examined a range of scenarios, from narrow to broad. Under the narrow interpretation, only National Wetland Inventory (NWI) wetlands located at least 100 feet from any mapped streams or other waters were identified. We found that 438,000 acres of wetlands, or 12 percent of the Region 3 wetland resource, met this criterion. Under the broad interpretation, all NWI waters/wetlands not associated with streams, and all waters/wetlands associated with 1st and 2nd order streams were identified. We found that 1.3 million acres of wetlands, or 36 percent of the Region 3 wetland resource, met this criterion. (See Table 2.)

Bar Graph, Potentially Affected Wetlands, Narrow Interpretation

This graph shows the extent of potentially affected wetlands by state for each of the five states in Region 3 using the narrow interpretation. The percentages range from a low of 10 percent for Virginia to a high of 17 percent for Pennsylvania. The regional average is 12 percent. (See Fig. 3.)

Bar Graph, Potentially Affected Wetlands, Broad Interpretation

This graph shows the extent of potentially affected wetlands by state for each of the five states in Region 3 using the broad interpretation. The percentages range from a low of 27 percent for West Virginia to a high of 45 percent for Delaware. The Regional average is 36 percent. (See Fig. 4.)

Maps Showing Potentially Affected Wetlands in the Vicinity of Salisbury, Maryland

The area surrounding Salisbury MD was selected to illustrate typical landscape position and extent of those Region III wetlands that could be affected by changes in Clean Water Act jurisdiction. Salisbury is located on the Delmarva Peninsula, and is in the coastal plain ecoregion. The coastal plain has a high concentration of wetland resources. At the same time, many cities in the coastal plain (e.g., Dover, DE, Salisbury, MD, Virginia Beach, VA) are experiencing rapid growth. We present two maps showing narrow and broad interpretations of potentially affected wetlands in the vicinity of Salisbury.

Narrow Interpretation: Under the narrow interpretation, we identified NWI waters/wetlands located at least 100 feet from any mapped streams or other waters using the National Hydrography Dataset (NHD). Under this interpretation, 18 percent of the mapped NWI wetlands are potentially affected. (See Fig. 5.)

Broad Interpretation. Under our broad interpretation, all NWI waters/wetlands not associated with streams plus all waters/wetlands associated with 1st and 2nd order mapped streams are considered vulnerable. Under this interpretation, 43 percent of the mapped NWI wetlands/waters could be affected. As shown on the map, large areas of riparian (stream side) wetlands become vulnerable under this scenario. The large red area in the upper right portion of the map is the State of Delaware's largest wetland area, the Great Cypress Swamp. (See Fig. 6.)

Air Photo Analysis, Broad Interpretation, Millington, MD

Aerial photography can be used to provide more accurate information than can be derived from National Wetland Inventory or National Hydrography Dataset maps. We analyzed aerial photography to estimate potential wetland impacts in a 30 square mile area near Millington, Maryland. This area features a high concentration of regionally rare Delmarva Bay wetlands. Red areas on the map are wetlands potentially affected by a narrow interpretation of proposed changes in jurisdictional waters. In this example, 3793 acres, or 94 percent of all the wetlands identified, are potentially affected. (See Fig. 7.)

Air Photo Analysis, Broad Interpretation, Church View, VA

We analyzed aerial photography to estimate potential wetland impacts in a 30 square mile area near Church View, Virginia. This area includes a significant concentration of wetlands along a 4th order stream (Dragon Run), which are not likely to be affected by changes in CWA jurisdiction. Red areas on the map are wetlands potentially affected by a narrow interpretation of proposed changes in jurisdictional waters. In this example, 1110 acres or 50 percent of all the wetlands identified, are potentially affected. (See Fig. 8.)

POTENTIALLY AFFECTED STREAMS

- **52 percent of the streams in Region 3 are potentially affected.**

Region 3 Stream Order Graph

This graph depicts the number of Region 3 stream miles broken down by stream order. The left-hand (tallest) bar shows the number of miles of first order streams. Region 3 has approximately 106,000 miles of first order streams, or 52 percent of the total stream resource in the Region. (See Fig. 9, Table 3.)

Map of First Order Streams in the Vicinity of Salisbury, MD

The Salisbury area is used to illustrate potential impacts to first order streams. In this example, first order streams (highlighted in red) account for 63 percent of all the stream miles within 20 miles of Salisbury, Maryland. (See Fig. 10.)

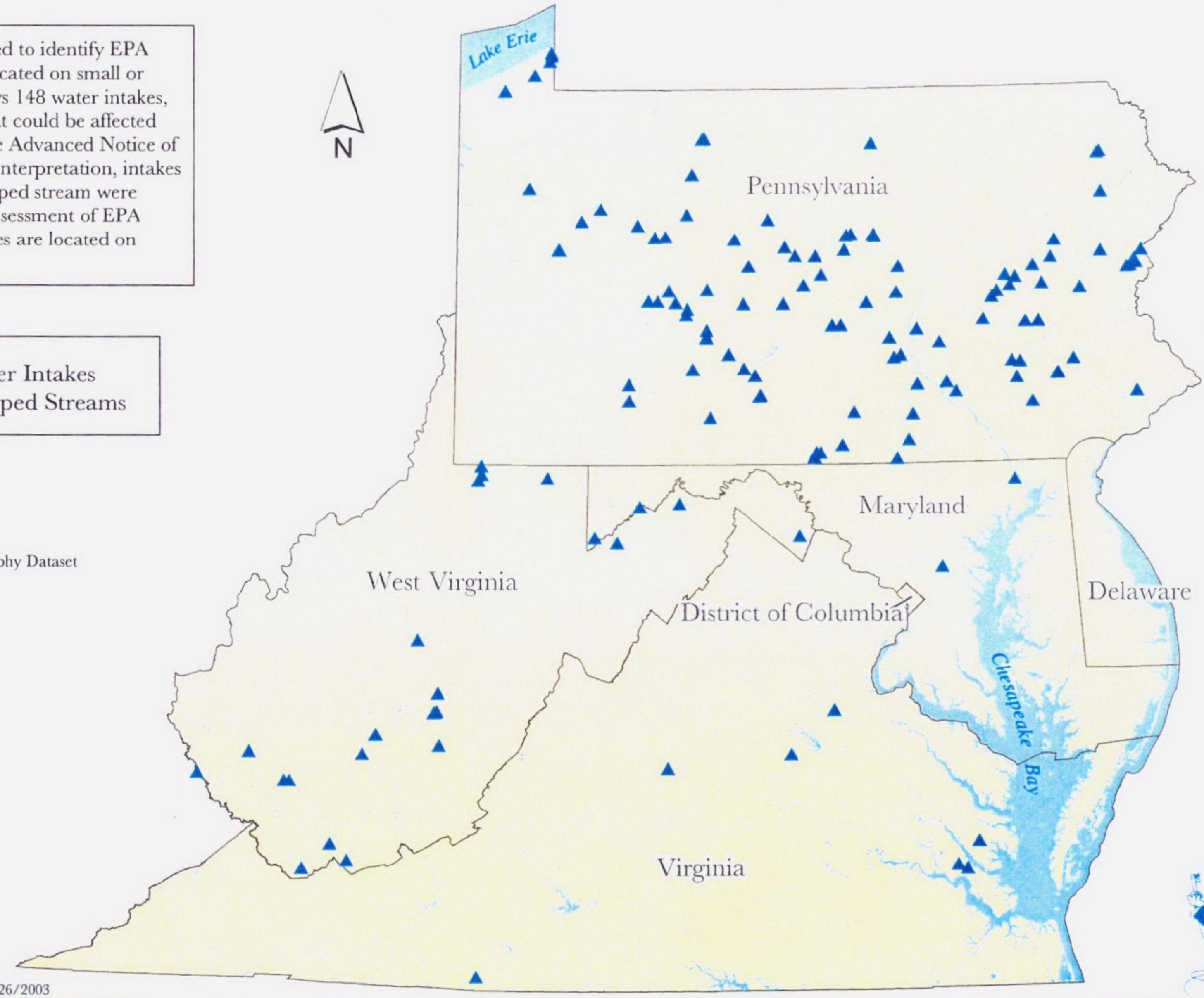
Map of Headwater Stream Networks, West Virginia Case Study

We conducted a detailed computer modeling case study (with field verification) of stream networks in Logan County, West Virginia. Our computer model used National Elevation Data (NED) to generate perennial and intermittent stream segments, using United States Geological Survey determined points of intermittent and perennial flow origin for headwater streams in the same region.

We found that the National Hydrography Dataset (NHD) greatly underestimates total stream miles in this region. The NHD shows 6, 240 miles of streams in the region. In contrast, our study showed a total of 10,638 miles of perennial streams (a 70 percent increase). Yellow lines on Fig. 11 show the added perennial stream segments. When intermittent streams were added, our model showed a total of 16,094 miles of streams (a 158 percent increase). Red lines on Fig. 11 show the intermittent stream segments. (See GIS Appendix for additional details).

Fig. 1. 148 SURFACE DRINKING WATER INTAKES, SERVING A POPULATION OF 535,000, COULD BE AFFECTED BY CWA JURISDICTIONAL CHANGES (NARROW ESTIMATE)

Several GIS analyses were performed to identify EPA Region III drinking water intakes located on small or unmapped streams. This map shows 148 water intakes, serving a population of 535,446, that could be affected under a narrow interpretation of the Advanced Notice of Proposed Rulemaking. Under this interpretation, intakes located at least 500 feet from a mapped stream were identified. It was the professional assessment of EPA staff that the majority of these intakes are located on unmapped tributary streams.



▲ Surface Drinking Water Intakes > 500 Feet From Mapped Streams

Data Sources:
U.S. EPA: Surface Drinking Water Intakes
U.S. Geological Survey: National Hydrography Dataset

0 25 50 100 Miles

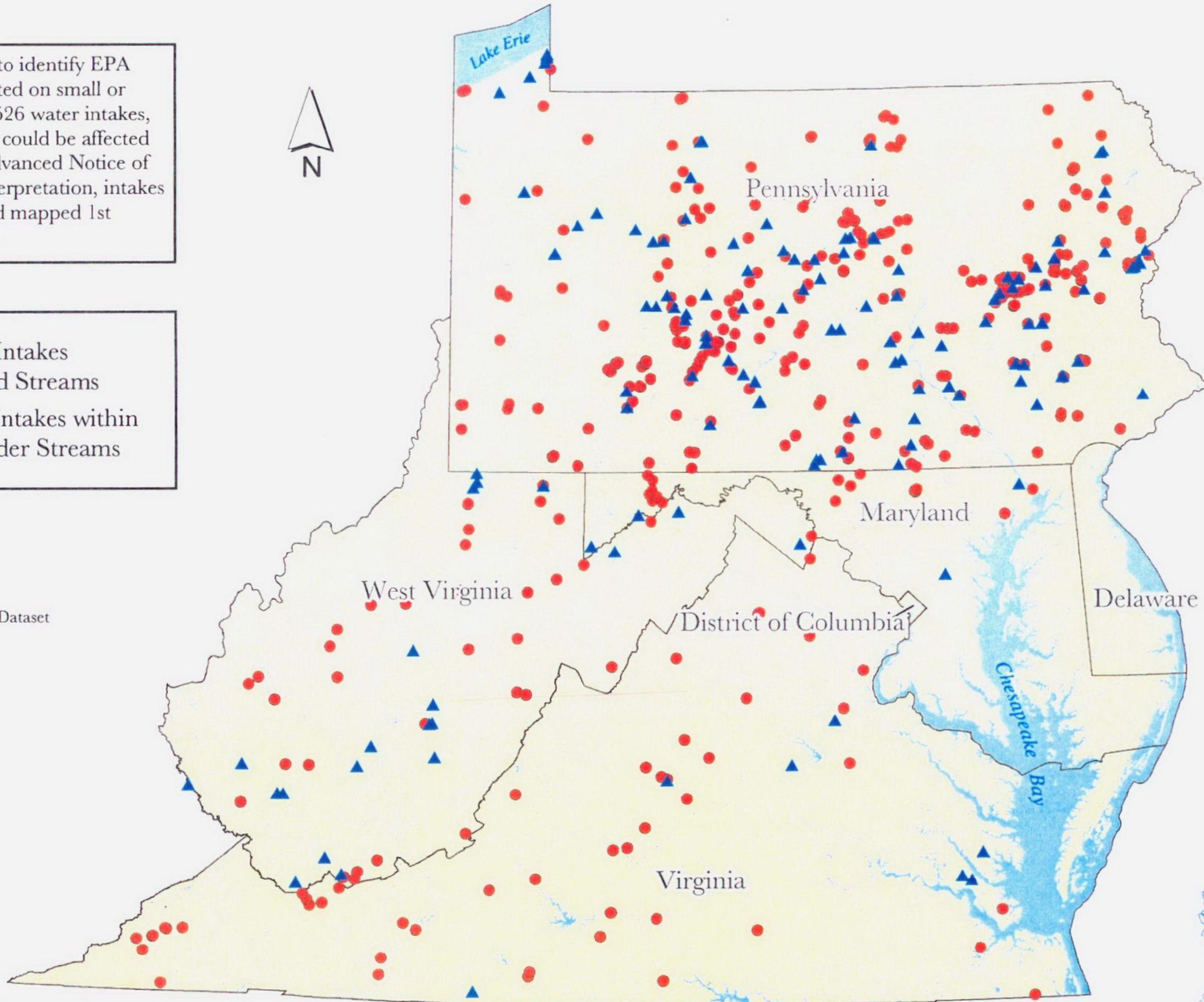
0 25 50 100 Kilometers

EPA R3 GISTeam SIG1217 M Frank Map#1967 3/26/2003

Fig. 2. 526 SURFACE DRINKING WATER INTAKES, SERVING A POPULATION OF 3 MILLION, COULD BE AFFECTED BY CWA JURISDICTIONAL CHANGES (BROAD ESTIMATE)

Several GIS analyses were performed to identify EPA Region III drinking water intakes located on small or unmapped streams. This map shows 526 water intakes, serving a population of 3,016,316 that could be affected under a broad interpretation of the Advanced Notice of Proposed Rulemaking. Under this interpretation, intakes associated with unmapped streams and mapped 1st and 2nd order streams were identified.

N



▲ Surface Drinking Water Intakes > 500 Feet From Mapped Streams

● Surface Drinking Water Intakes within 500 Feet of 1st & 2nd Order Streams

Data Sources:
U.S. EPA: Surface Drinking Water Intakes
U.S. Geological Survey: National Hydrography Dataset

0 25 50 100 Miles

0 25 50 100 Kilometers

EPA R3 GISTeam SIG1217 M Frank Map#1968 3/26/2003

Fig. 3. Potentially Affected Wetlands by State (Narrow Interpretation)

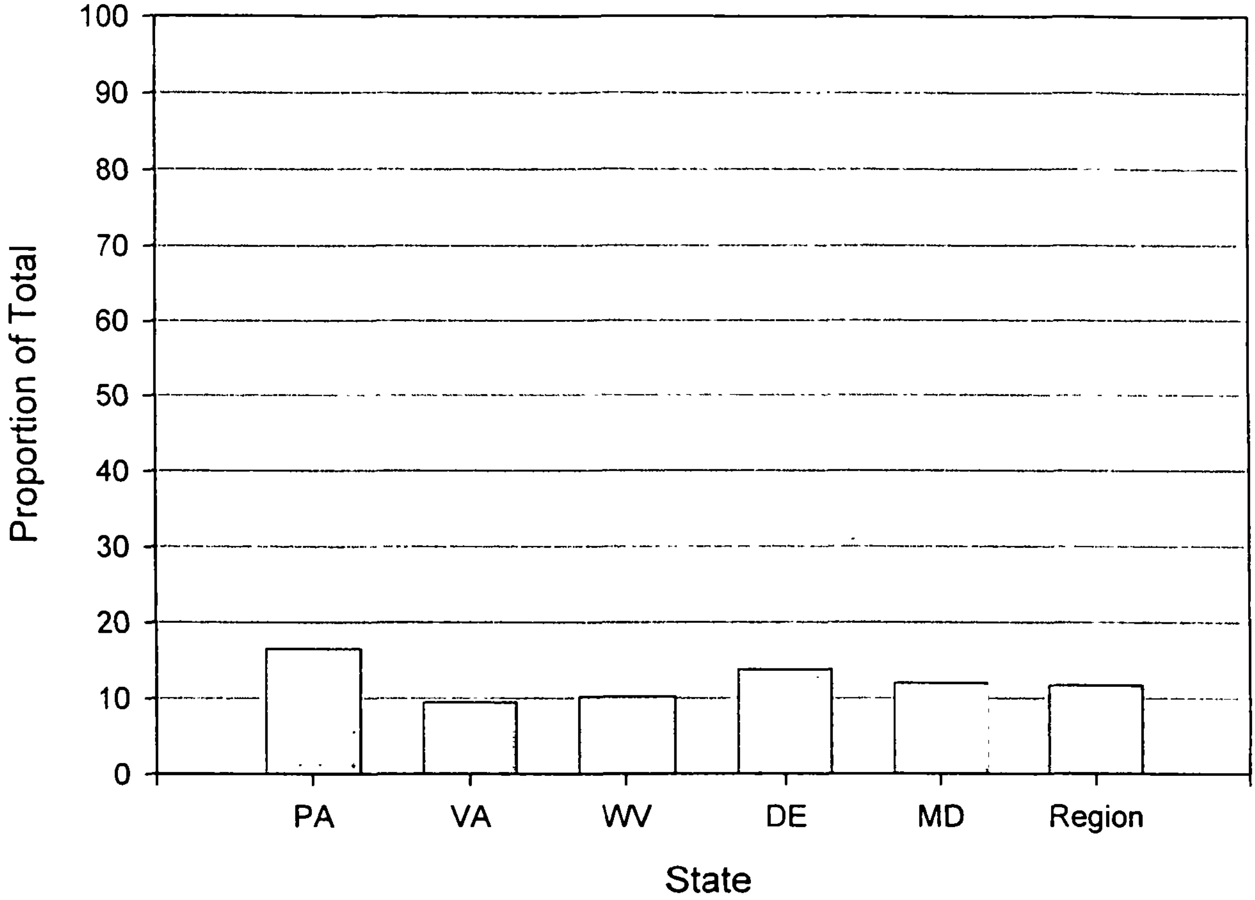


Fig. 4. Potentially Affected Wetlands by State (Broad Interpretation)

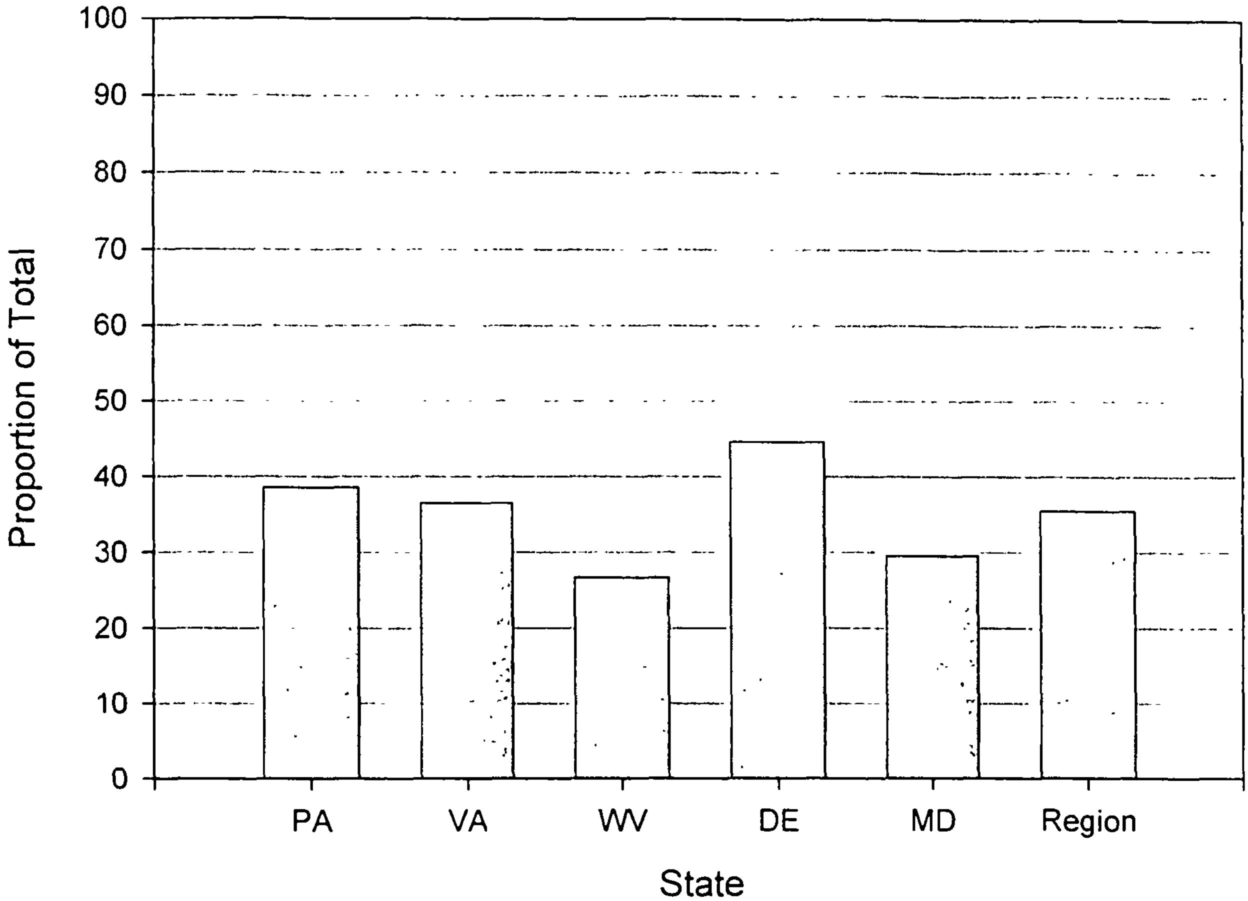
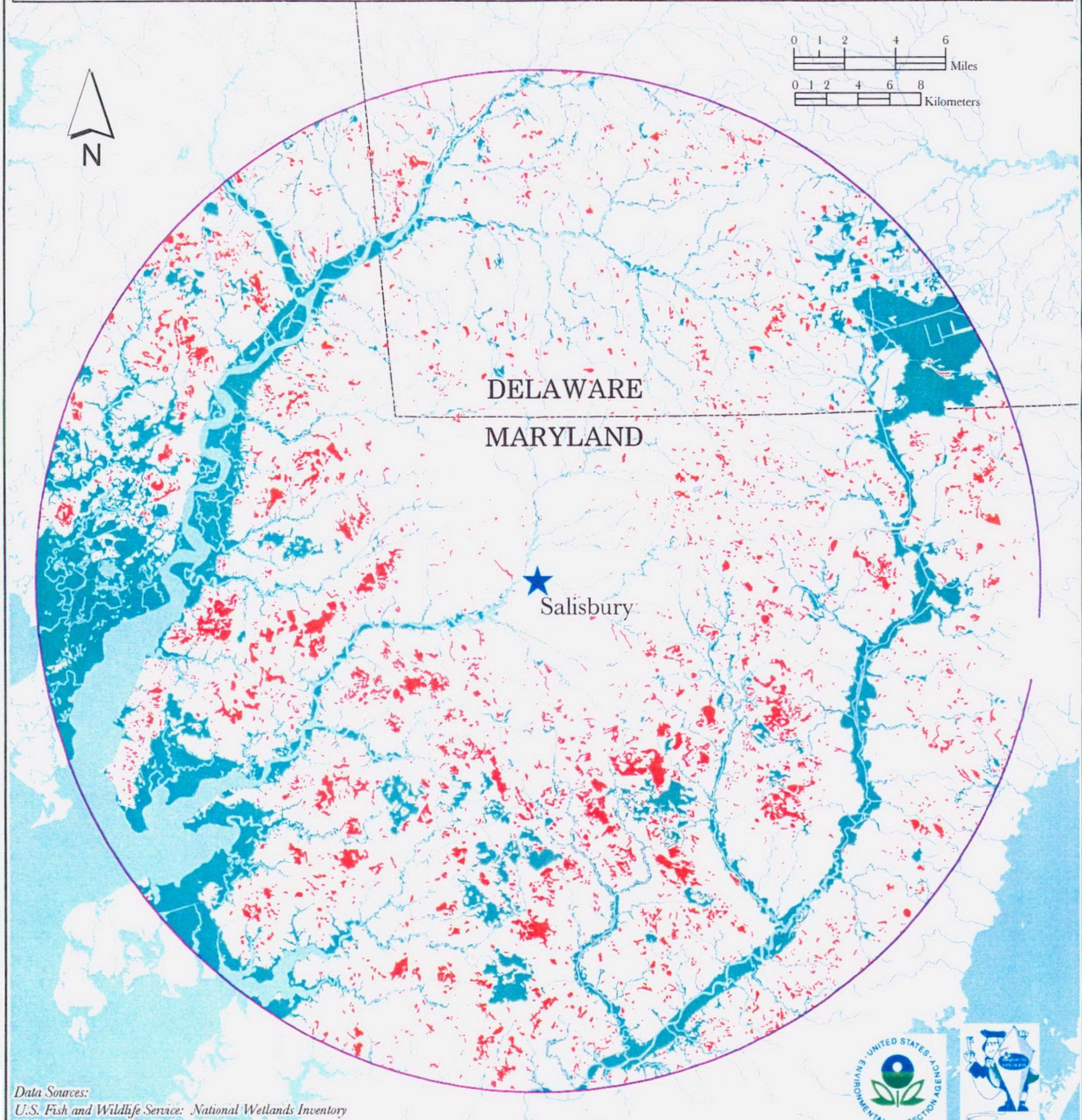


Fig. 5. POTENTIALLY AFFECTED WETLANDS IN THE VICINITY OF SALISBURY, MD (NARROW INTERPRETATION)



Data Sources:
U.S. Fish and Wildlife Service: National Wetlands Inventory
U.S. Geological Survey: National Hydrography Dataset

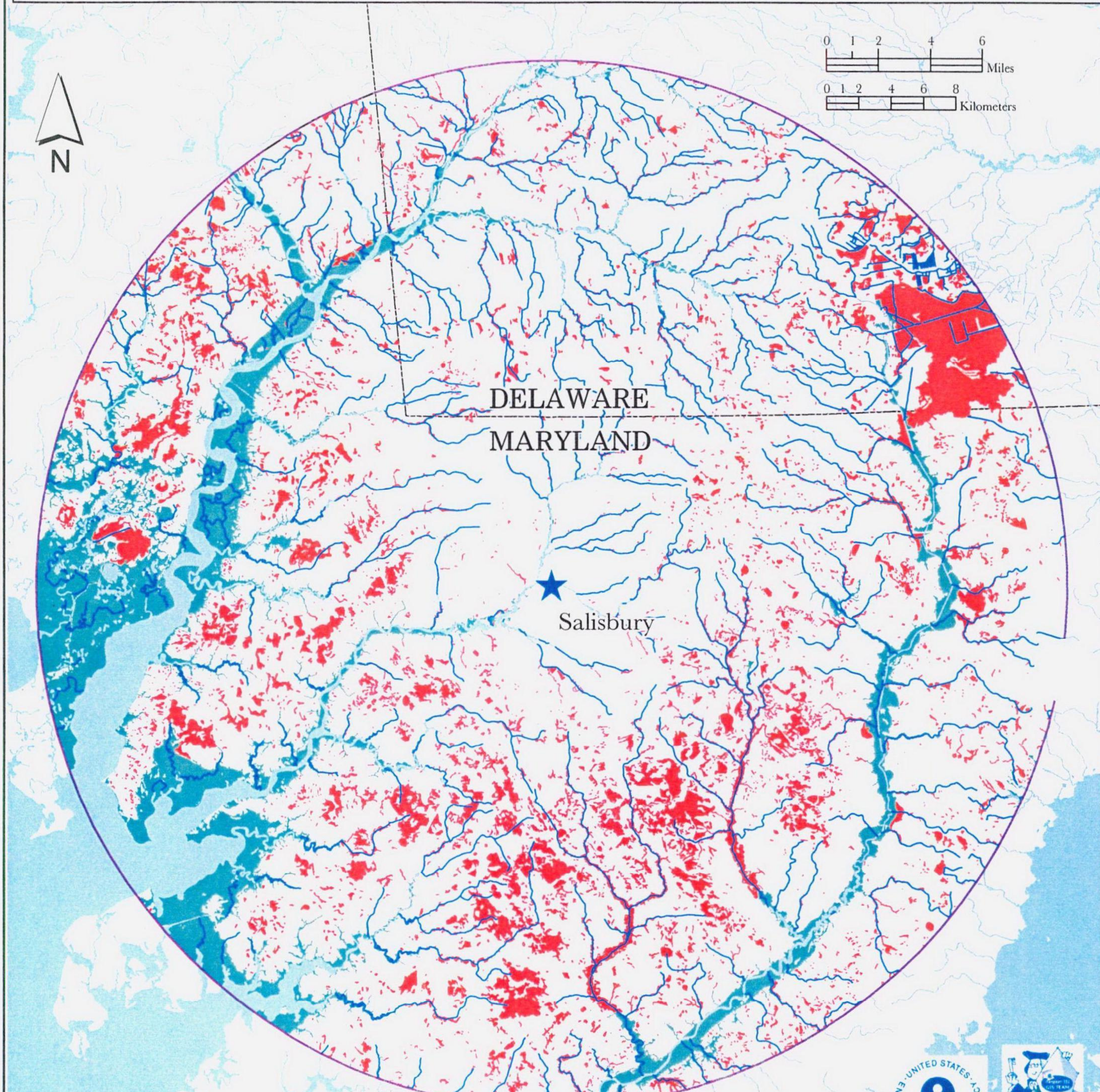
Total Wetland Acreage:	**187,000**
Isolated Wetland Acreage:	**34,000**
Percent Isolated Wetlands:	**18%**

Narrow Interpretation: Under the narrow interpretation of the Advanced Notice of Proposed Rulemaking, NWI waters/wetlands located at least 100 feet from any mapped streams or other waters were identified. Under this interpretation, 18 percent of the mapped NWI wetlands in the vicinity of Salisbury, MD, are considered potentially affected.

- Potentially Affected Wetlands
- All NWI Wetlands
- 20 Mile Radius
- Hydrography

EPA R3 GIS Team SIG1217 M Frank Map#1961 3/5/2003

Fig. 6 POTENTIALLY AFFECTED WETLANDS IN THE VICINITY OF SALISBURY, MD (BROAD INTERPRETATION)



Data Sources:
U.S. Fish and Wildlife Service: National Wetlands Inventory
U.S. Geological Survey: National Hydrography Dataset

Total Wetland Acreage:	**187,000**
Headwater & Isolated Wetland Acreage:	**81,000**
Percent Headwater & Isolated Wetlands:	**43%**

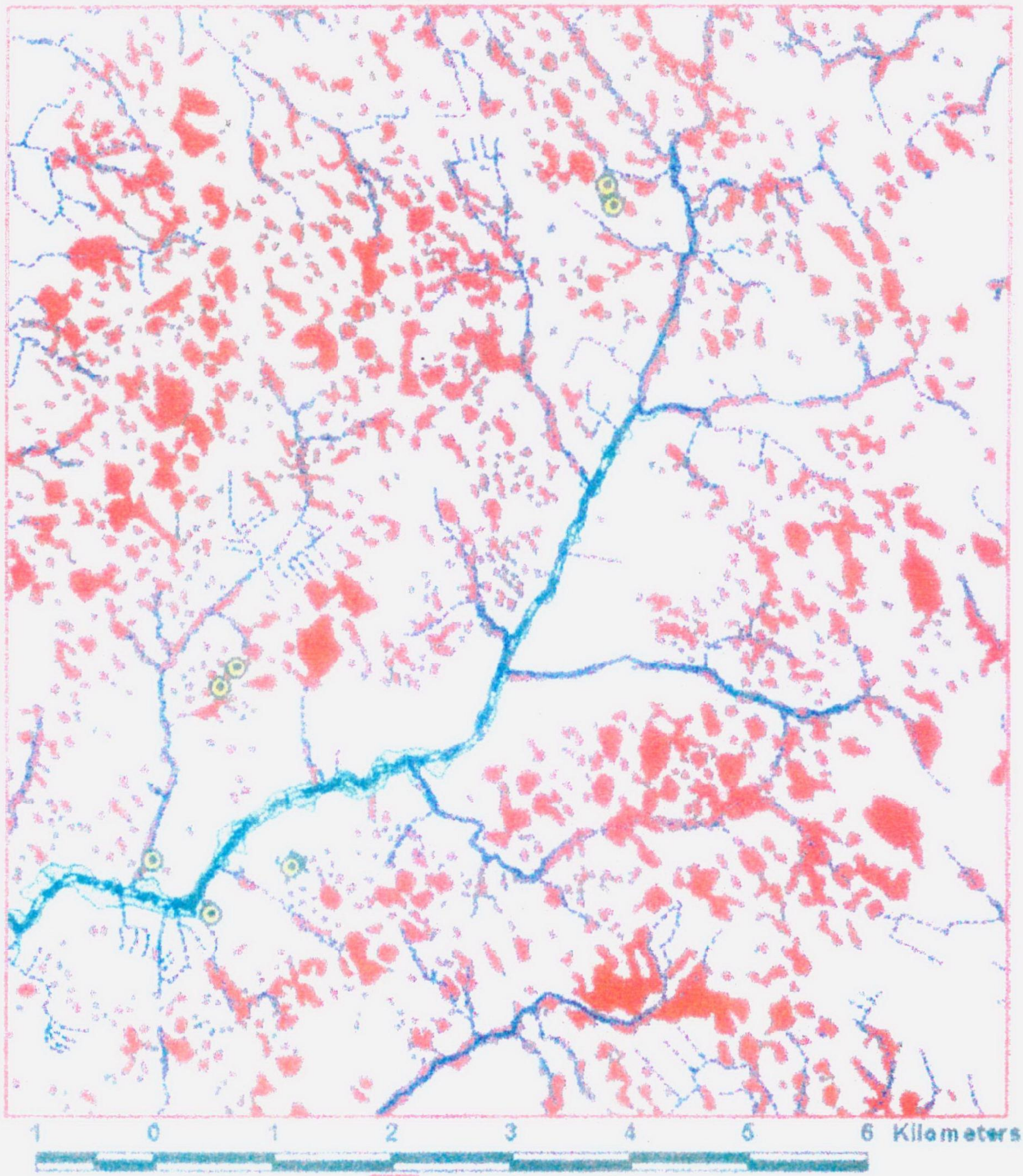
Broad Interpretation: Under the broad interpretation of the Advanced Notice of Proposed Rulemaking, all NWI waters/wetlands not associated with streams plus all waters/wetlands assocated with 1st and 2nd order streams were identified. Under this interpretation, 43 percent of the mapped NWI wetlands in the vicinity of Salisbury, MD, are considered potentially affected.

- 1st & 2nd Order Streams (NHD)
- Potentially Affected Wetlands
- All NWI Wetlar
- 20 Mile Radius
- Hydrography

EPA R3 GIS Team SIG1217 M Frank Map#1963 3/5/2003

Fig. 7.

Wetlands in the Vicinity of Millington, MD (Broad Interpretation using Aerial Photo Interpreted Wetlands and Drainage)



Study Area

Field Sites

Photo Interpreted Drainage Order

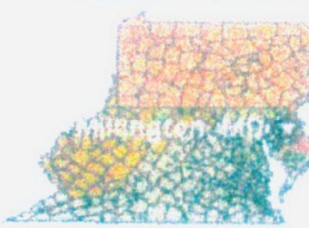
First

Second

Third

PI Broad Interpretation = 3793 Acres / 94% of Total

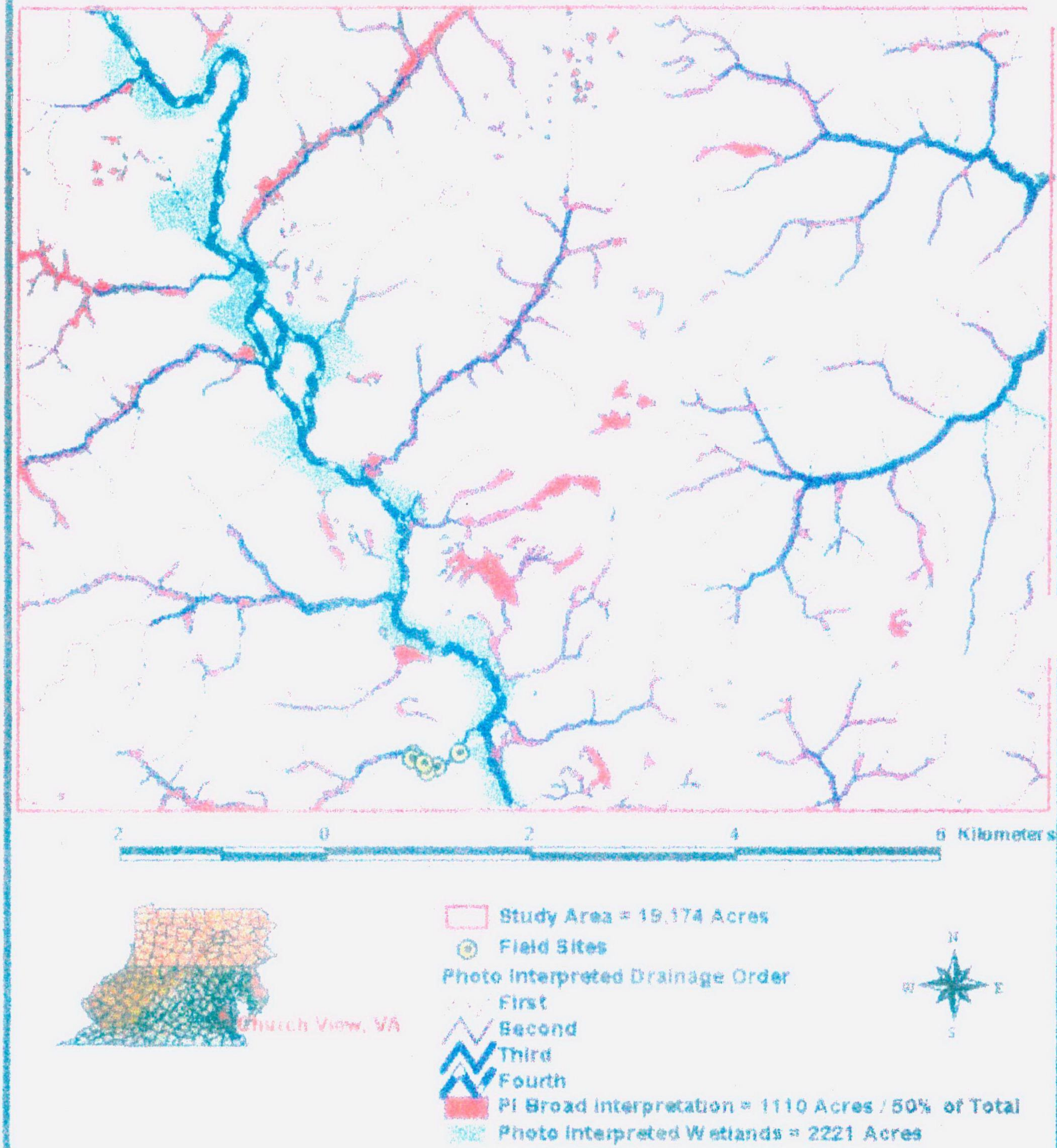
Photo Interpreted Wetlands = 4056 Acres



Broad Interpretation of ANPRM. PI mapped wetlands located over 100 feet from PI mapped drainage plus all wetlands associated with first and second order streams

Source Data:
B&W NAPP Aerial Photography
4-17-88
USGS Hydrography
National Wetland Inventory NWI
Map Prepared by Peter Stokely
EPA Region 3 703-648-4292

Fig. 8. **Wetlands in the Vicinity of Church View, VA (Broad Interpretation using Aerial Photo Interpreted Wetlands and Drainage)**



Source Data
CIR NAPP Aerial Photography 3-11-95
USGS Hydrography Data
National Wetland Inventory (NWI)
Map Prepared by Peter Stokely
EPA Region 3 703-648-4292

Broad Interpretation of ANPRM. PI mapped wetlands located over 100 feet from PI mapped drianage plus all wetlands associated with with first and second order stream watershd

Fig. 9. USEPA Region 3
Stream Miles by Stream Order
Source: National Hydrology Dataset

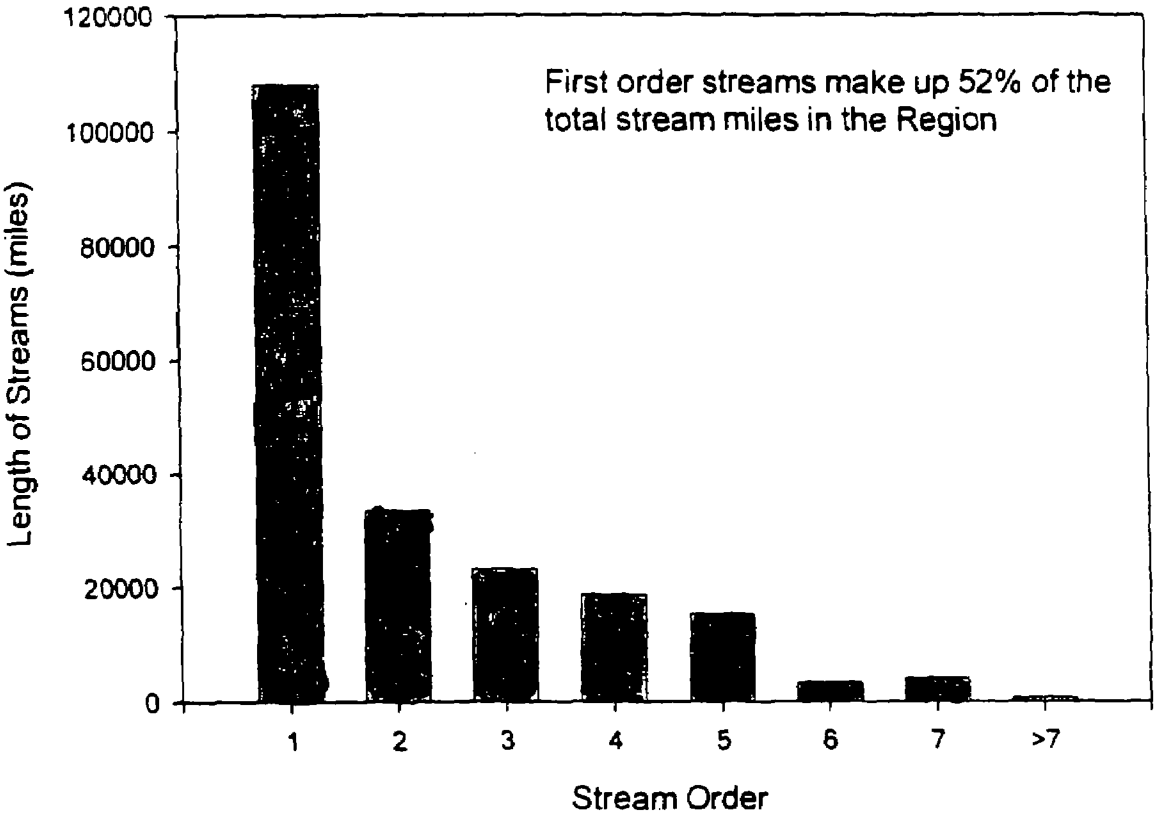


Fig. 10. FIRST ORDER STREAMS IN THE VICINITY OF SALISBURY, MD

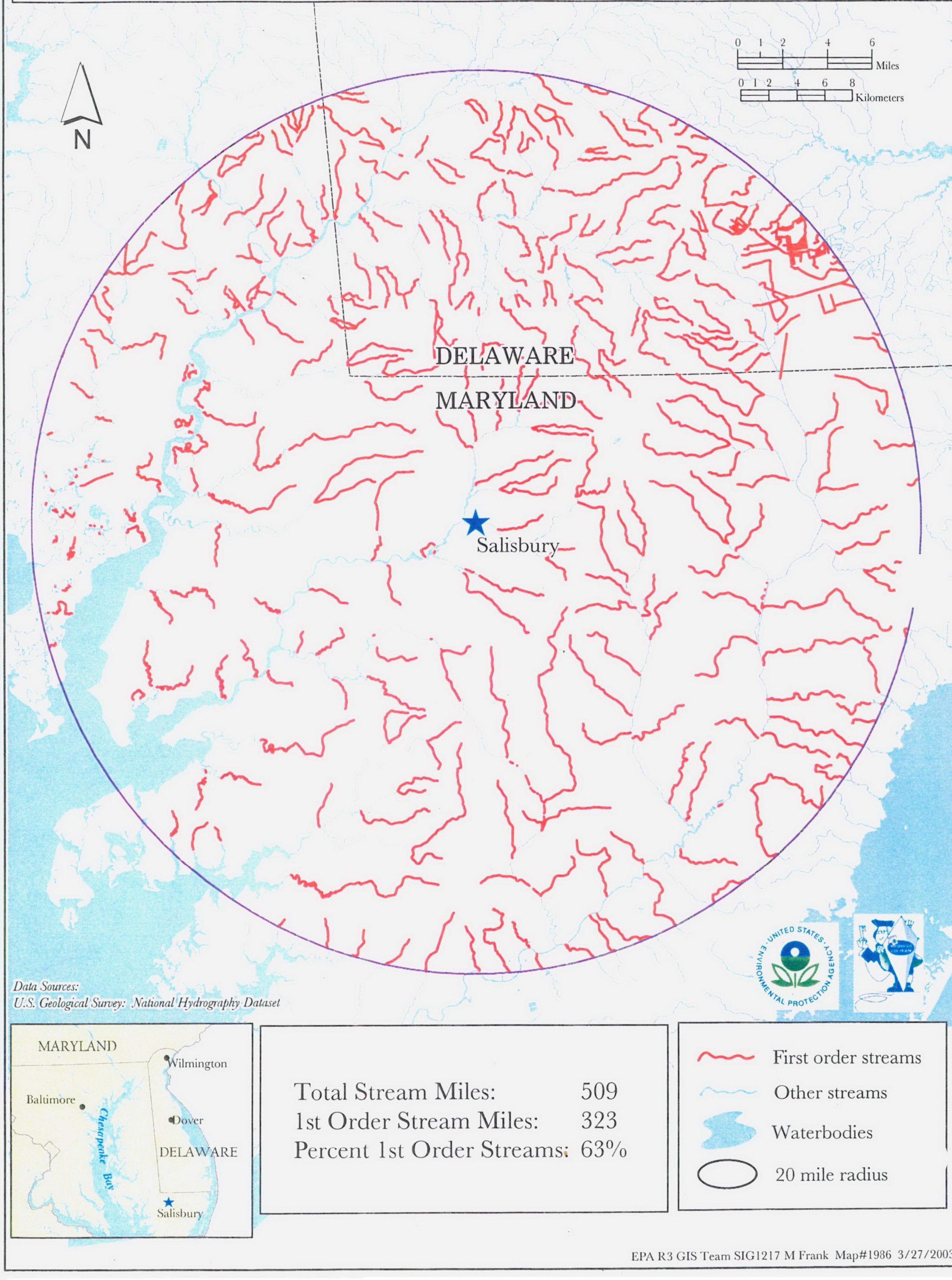


Figure 11. NED-Derived Headwater Stream Networks and Field Survey Sites in Logan County, WV

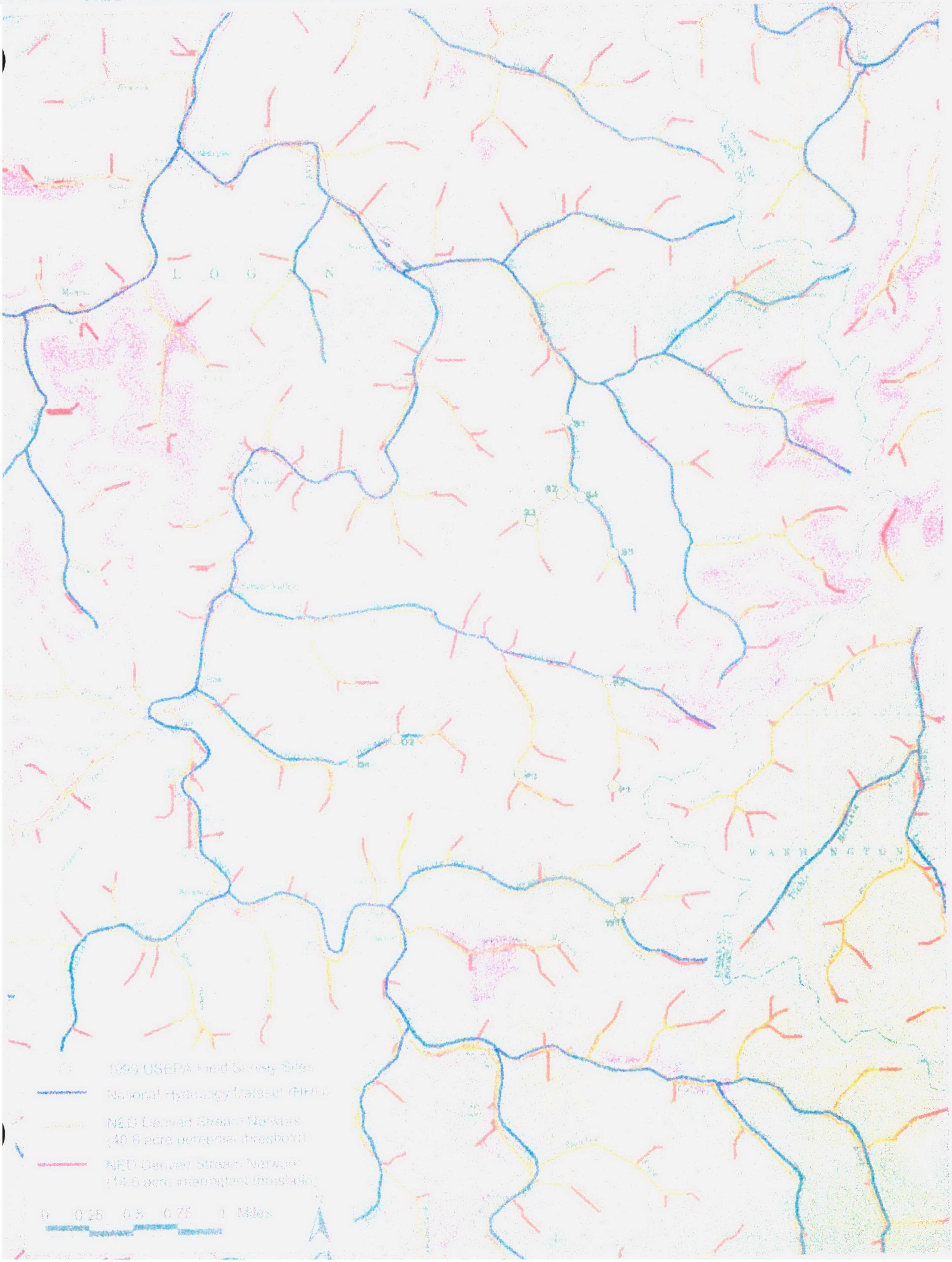


Table 1. Region 3 Analysis of Surface Water Intakes by State

State	*Narrow Interpretation* # of Intakes	*Narrow Interpretation* People Served	*Intermediate Interpretation* # of Intakes	*Intermediate Interpretation* People Served	*Broad Interpretation* # of Intakes	*Broad Interpretation* People Served
PA	115	367,034	317	1,519,694	391	2,244,486
VA	7	66,308	34	185,142	56	452,634
WV	23	39,871	47	101,182	58	129,690
DE	0	0	0	0	0	0
MD	3	62,233	18	184,108	21	189,506
Region 3 Totals:	148	535,446	416	1,990,126	526	3,016,316

Notes:

Narrow Interpretation
Intakes located at least 500 feet from a mapped stream (i.e. located on small unmapped streams) were identified .

Intermediate Interpretation
Intakes associated with unmapped streams and mapped 1st order streams were identified.

Broad Interpretation
Intakes associated with unmapped streams and mapped 1st and 2nd order streams were identified.

Data Sources:
U.S. EPA Region 3 SDWIS Database: Surface Water Intakes
U.S. Geological Survey: National Hydrography Dataset

Table 2. Region 3 Potentially Affected Wetland Acreages By State (Narrow, Intermediate, & Broad Interpretations)

Narrow Interpretation

Under the narrow interpretation of the Advanced Notice of Proposed Rulemaking, NWI waters/wetlands located at least 100 feet from any mapped streams or other waters were identified.

State	Isolated Wetlands (Acres)	Total Wetlands (Acres)	Percent of Total
PA	123,732	744,632	16.62
VA	167,654	1,760,704	9.52
WV	17,190	167,851	10.24
DE	33,419	241,435	13.84
MD	96,094	798,611	12.03
Region	438,089	3,713,234	11.80

Intermediate Interpretation

Under the intermediate interpretation of the Advanced Notice of Proposed Rulemaking, all NWI waters/wetlands not associated with streams plus all waters/wetlands associated with 1st order streams were identified.

State	Isolated Wetlands (Acres)	Total Wetlands (Acres)	Percent of Total
PA	232,082	744,632	31.17
VA	524,416	1,760,704	29.78
WV	33,000	167,851	19.66
DE	90,799	241,435	37.61
MD	195,372	798,611	24.46
Region	1,075,669	3,713,234	28.97

Broad Interpretation

Under the broad interpretation of the Advanced Notice of Proposed Rulemaking, all NWI waters/wetlands not associated with streams plus all waters/wetlands assocated with 1st and 2nd order streams were identified.

State	Isolated Wetlands (Acres)	Total Wetlands (Acres)	Percent of Total
PA	288,030	744,632	38.68
VA	644,196	1,760,704	36.59
WV	44,979	167,851	26.80
DE	108,008	241,435	44.74
MD	236,444	798,611	29.61
Region	1,321,657	3,713,234	35.59

Data Sources:
U.S. Fish and Wildlife Service: National Wetlands Inventory
U.S. Geological Survey: National Hydrography Dataset

Table 3. Region 3 Stream Miles By State Using The National Hydrography Dataset (1:100K)

	Stream Order									
	1st	2nd	3rd	4th	5th	6th	7th	8th	Total Stream Miles	1st Order As Percent Of Total Stream Miles
PA	35,597	11,323	7,131	5,431	3,511	991	1,365	150	65,498	54.3
VA	37,923	11,913	8,804	7,617	8,327	1,280	1,685	189	77,737	48.8
WV	21,264	6,008	4,069	2,717	1,891	742	333	202	37,226	57.1
DE	1,950	552	392	295	58				3,246	60.1
MD	9,507	2,976	2,159	2,143	1,172	204	189	64	18,414	51.6
Region 3	106,241	32,772	22,555	18,203	14,959	3,217	3,572	604	202,121	52.6

Data Sources:

U.S. Fish and Wildlife Service: National Wetlands Inventory

U.S. Geological Survey: National Hydrography Dataset

US EPA Region III Response to
Advance Notice of Proposed Rulemaking
on the Clean Water Act Regulatory Definition of "Waters of the United States"

The Environmental Protection Agency's (EPA) Office of Water (OW) and the Army Corps of Engineers have proposed to initiate rulemaking to "clarify" the scope of federal Clean Water Act (CWA) jurisdiction following the Supreme Court's decision in the Solid Waste Agency of Northern Cook County (SWANCC) v US Army Corps of Engineers. In SWANCC, the Court held that the Corps had exceeded its authority under the CWA by asserting jurisdiction over what the Court characterized as isolated, intrastate ponds (actually abandoned sand and gravel pits) based solely on their use as a habitat for migratory birds pursuant to the so-called "Migratory Bird Rule."

In order to clarify and implement the SWANCC decision across CWA programs, an Advanced Notice for Proposed Rule Making (ANPRM) was issued on January 15, 2003. The ANPRM outlined the background of the Supreme Court Decision and solicited public comment on the definition of isolated waters and issues associated with the scope of waters that are the subject to the CWA in light of the SWANCC decision. The ANPRM posed several questions relating to the definition of isolated waters and the potential impacts of the decision.

The ANPRM sets out two specific questions for which EPA and the Corps of Engineers (collectively, the "Agencies") specifically solicit comment. However, the text appears to invite comment on a number of other issues. Region III has provided views on all issues for which the ANPRM appears to solicit comment. Any revision to the current regulations would affect the definition of waters for all programs in the Clean Water Act including point source discharge permits as well as wetland fill permits. Programs under the Safe Drinking Water Act (SDWA) may also be affected.

Region III has provided an analysis of potential effects from a wetland and stream resource perspective with a focus on impacts to human health and the environment. Finally, an analysis of legal implications has been included. The analyses draw from current literature and case studies along with the information and data collected in the field.

SPECIFIC QUESTIONS POSED BY THE ANPRM

Whether the regulations should define "isolated waters," and if so, what factors should be considered in determining whether a water is or is not isolated for jurisdictional purposes?

Summary of Region III Recommendations for "Isolated" Waters Definition

- If a definition of "isolated" waters is to be considered, Region III recommends the following - "Completely isolated: perched systems that are entirely self-contained and never have a hydrological (surface or groundwater) connection to other waters".

- Any definition of isolated waters should take into account the hydrologic cycle and the inter-relationships among water bodies.
- If the Agencies attempt to define "isolated" waters, the role of subsurface or interstitial flow in connecting waterbodies should be considered.
- Region III's suggestions for a definition of "isolated" waters should not be construed as a suggestion that such waters are outside the jurisdictional scope of the Clean Water Act. To the contrary, as set forth below, Region III believes it is appropriate and consistent with SWANCC to consider interstate commerce factors in determining whether a particular water is subject to jurisdiction under the CWA.

Defining "Isolated Wetlands"

Any definition of "isolated" waters should take into account the hydrologic cycle and the inter-relationships among waterbodies (surface and groundwater). Any definition of "isolated" waters should include only truly "isolated" waters, outside the hydrologic cycles of navigable waters. If there is an attempt to define "isolated" waters, the role of groundwater in connecting waterbodies should be considered. Groundwater is a major feature in watersheds and frequently serves as a permanent hydrological connection between wetlands and surface water tributaries. Although some waters and wetlands do not exhibit a perennial surface water connection, they are closely integrated with the larger watershed network via groundwater and non-perennial surface connections and, as such, are not isolated from the larger hydrologic cycle. Additionally, wetlands may be temporarily isolated (e.g., during episodic dry seasons - some of which are seasonal, others, longer term) but perform significant additional functions during seasonal or episodic high water events.

If "isolated" waters are to be defined, Region III recommends the following:

> Completely isolated: perched systems that are entirely self-contained and never have a hydrological (surface or groundwater) connection to other waters.

Under this definition most intrastate, non-navigable waters in Region III are not, in fact, isolated. All references herein to "isolated" waters refer to this definition.

An attempt to develop a generalized definition of "isolated" waters predicated on physical proximity, flow, or some other factor will create an arbitrary cut-off (not scientifically based) that may fail to take into account the role of certain waters in the overall hydrologic cycles that Congress clearly intended to regulate. Although the CWA refers to "navigable" waters, Congress' declaration of goals and policy in the CWA Section 101(a) as protecting the physical, chemical and biological integrity of the waters of the United States extends beyond the mere protection of navigation. The legislative history clearly states that Section 101(a) addresses the protection of the natural structure and function of ecosystems. As currently administered, the CWA, by including a broader interpretation of "waters of the United States", has made significant progress in achieving the goals articulated by Congress.

With regard to discussions concerning "intrastate, isolated, non-navigable waters", the question continually arises as to what definition is appropriate for these waterbodies. As a starting point, if isolated implies a lack of a perennial surface water connection to traditional "navigable waters" (e.g., relevant to the 1899 Rivers and Harbors Act and subsequent supporting case law), then large, regionally significant classes of wetlands fall into the "isolated" category. These classes include pocosins, prairie potholes, peat bogs, vernal pools (both classic Mediterranean climate pools of California and the forested vernal pools of the eastern U.S.), playas, wetlands of the Nebraska Sandhills, and Carolina/Delmarva Bays (and comparable coastal plain depressions). In addition, a significant number of montane wetlands, forested floodplain wetlands, fens, coastal plain flats and slope wetlands may also be considered "isolated". Moreover, in developed areas where significant streambed down cutting, levee construction and impoundment has occurred, formerly connected wetlands may now be disconnected from adjacent waterbodies. Despite the lack of obvious perennial surface connection, these wetland types, as significant features in the landscape, are connected to the larger hydrologic network and, as such, Region III does not believe that these wetlands are truly isolated.

In terms of implementing any regulatory program regarding "isolated" wetlands it should be noted that generally there are no discrete, supportable boundaries or criteria along the continuum of wetlands lacking surface water connection and headwater streams to separate them into meaningful ecological or hydrological compartments. Applying any set of field methods (as yet undeveloped) would, by definition, be arbitrary. A confounding factor is that field conditions would change dramatically over the year and the confidence in a single site assessment would be extremely limited.

Defining "Other Waters"

In addition to wetlands, the ANPRM referred generally to "other waters" without defining that term. Region III has interpreted the term-"other waters": to include small perennial streams and intermittent or ephemeral headwater streams. We based this interpretation on accompanying materials USEPA HQ distributed to the regions.

We have used the term "headwaters" throughout our analysis to represent small headwater perennial, intermittent and ephemeral waters. Although the term "headwaters" has a regulatory meaning (33 C.F.R. Section 330.2(d)), use of the term in this response does not refer to the regulatory definition, but rather to the concept of headwaters as the dendritic system of wetlands, swales and small streams that make up the beginnings of most watersheds.

Although Region III has provided analysis of the extent of resource impact on headwater areas, it should be made clear that we do not consider these areas to be "isolated" in the hydrologic sense. Many of these small headwater streams experience a range of hydrological connectivity with downstream waters which depend on a number of region-specific factors (precipitation, catchment area, topography, geology, etc.). The location or point at which a stream is perennial, intermittent or ephemeral also varies both temporally and spatially, as local ground water tables vary. These terms (i.e., perennial, intermittent or ephemeral) generally are not useful in either a technical or legal sense, because they do not provide a good indication of connectivity to downstream waters or potential for aquatic life use. Legally, there is no uniform regulatory definition of these terms, as various state and federal government programs define these terms differently, some using biological indicators, others referencing flow or watershed area.[1].

Furthermore, regulation of these areas based on flow duration would be problematic for several reasons. Duration of surface flow is not a good indicator of actual hydrological connectivity to downstream waters. Intermittent streams are difficult to classify because they include such a wide gradient of surface flow permanence, and many local abiotic factors are important for determining aquatic life habitat potential. Additionally, permanence of water is not a good indicator of the aquatic habitat potential of headwater streams. It is instructive to note that streams which lack perennial surface flow still support a variety of aquatic invertebrates and vertebrates. The following analysis of stream function provides more information on this issue.

Due to the confusion with "intermittent" definitions and the wide gradient of flow permanence this term represents, many state and academic biologists suggest that environmental protection laws and rules not be based solely on hydrology terms such as perennial, intermittent, ephemeral, summer-dry, etc. Many biologists believe that water protection rules and laws should be based on the native resident biota, in combination with other factors (e.g., hydrological and thermal). Some states (e.g., Ohio EPA, PA DEP and WV DEP) use biological factors to help define or classify headwater streams since the biology is the long-term indicator of hydrological conditions in a stream. Region III recommends that the jurisdictional status of headwaters be tied in part to the biology of streams, especially where the programs are protecting aquatic life use potential.

Furthermore, Region III has limestone or karst regions where segments of streams and rivers disappear into underground channels for some length before they emerge as a surface stream some distance downstream. One of the best examples of this is the Lost River in West Virginia. The Lost River is a tributary to the Cacapon River, which flows to the Potomac River and eventually into the Chesapeake Bay. At the Route 55 bridge west of Wardensville, West Virginia, the robust Lost River appears to suddenly dry up. The Lost River, however, does not cease flowing at this point. The water actually flows underground into cracks and solution channels in the underlying limestone. For much of the year, the river appears dry for about 2.5 miles, while its flow is subsurface. When the river flow returns to the surface and "reappears"

---

[1]For purposes of response, Region III defines the terms "perennial," "intermittent," and "ephemeral" as follows. Perennial headwater streams are always longitudinally connected to downstream waters of the United States either through surface flow or contiguous subsurface flow. Intermittent streams are clearly connected to downstream waters of the United States for at least part of the year, through surface flow or subsurface flow. Ephemeral streams are connected to downstream waters of the United States for a shorter part of the year, by definition, only through surface flow.

just north of Wardensville, it is called the Cacapon River. Clearly these types of streams are connected to downstream surface waters via the subsurface and groundwater flow and it would be inappropriate to consider them isolated from the downstream surface waters.

Whether, and, if so, under what circumstances, the factors listed in 33 CFR 328.3(a)(3)(i)-(iii) (i.e., use of the water by interstate or foreign travelers for recreational or other purposes, the presence of fish or shellfish that could be taken and sold in interstate commerce, the use of the water for industrial purposes by industries in interstate commerce) or any other factors provide a basis for determining CWA jurisdiction over isolated, intrastate, non-navigable waters?

Summary of Recommended CWA Jurisdiction "Factors"

- All factors listed in 33 CFR 328.3(a)(3) should be retained and used for asserting CWA jurisdiction over isolated, intrastate, non-navigable waters.
- We specifically recommend the following factors; water quality, flood storage, presence of downstream drinking water intakes, and biological integrity.
- Consideration of interstate commerce factors is consistent with SWANCC.

With respect to the factors listed in Section 328.3(a)(3), many of these have a sufficient nexus to inter-state commerce (e.g., recreational boating, recreational and commercial fishing) that CWA jurisdiction could be asserted over such waters consistent with SWANCC. Any connection to interstate commerce, including recreation, fishing, hunting, trapping, hiking, camping, drinking water, commercial uses, and industrial uses of the waterbody should be considered.

Legal Factors

Consideration of interstate commerce factors is consistent with the stated goal of the CWA and the concept of navigable waters as traditionally defined. In addition, consideration of interstate commerce factors set forth in Section 328.3(a)(3) is not inconsistent with SWANCC.

Congress' declaration of goals and policy in Section 101(a) as protecting the physical, chemical and biological integrity of the waters of the United States extends beyond the mere protection of navigation. The legislative history clearly states that Section 101(a) addresses the protection of the natural structure and function of ecosystems. H.R. Rep. No. 92-911, 92d Cong. 2d Sess. 76 (1972) (quoted in Riverside Bayview Homes, 474 U.S. at 132-33. See also id. H.R. Rep. No. 911, 92d Cong., 2d Sess. 131 (1972)). The legislative history is replete with references to the notion of water moving in hydrologic cycles and the need to control the discharge of pollutants at the source. See, e.g., S. Rep. No. 92-414, p. 77 (1972), U.S.C.C.A.N. 1972, pp. 3668, 3742 (quoted in Riverside Bayview Homes, 474 U.S. at 133); 2 Legislative History of the Water Quality Act of 1987, at 1495.

Moreover, the Supreme Court, in discussing the term "navigable", has repeatedly referred to the inextricable connection between navigation and interstate commerce. See, e.g., The Daniel Ball v. United States, 77 U.S. (10 Wall.) 557, 563, 19 L.Ed. 999 (1871);Leovy v. United States, 177 U.S. 621, 633, 20 S.Ct. 797, 801, 44 L.Ed. 914 (1900). Regulation of navigable waters as channels of interstate commerce is one of three broad categories of activities regulated under the commerce clause. Even after *SWANNC,* at least one court has used the other broad categories of interstate commerce analysis, including the potential impact to interstate commerce, to determine that jurisdiction over a small non-navigable tributary is appropriate. *United States v. Buday*, 138 F.Supp. 2d 1282, 1292-93 (D. Mont. 2001). Accordingly, use of factors related to interstate commerce appears consistent with the CWA and traditional concepts of navigation.

In addition, the Court's discussion in SWANCC clearly was limited to the "application" of Section 328.3(a)(3) as embodied in the Migratory Bird Rule. See 531 U.S. at 173 ("an administrative interpretation of a statute [that] invokes the outer limits of Congress' power," and "[there] are significant constitutional questions raised by respondents application of their regulations"). 531 U.S. at 173. The Court, however, did not directly address Section 328.3(a)(3) on its face or hold that the regulation on its face or consideration of interstate commerce factors was beyond the scope of the CWA.

Although the CWA refers to "navigable waters," the Court in *SWANCC* confirmed that CWA jurisdiction extends beyond traditionally navigable waters. Consideration of interstate commerce factors is consistent with the goals of the CWA, and the concept of navigation as historically understood. Consideration of interstate commerce factors is consistent with SWANCC.

Water Quality Factors

To the extent a decision is made to develop a rule for asserting CWA jurisdiction, including developing a definition for isolated waters, it will be important to keep in mind the purposes underlying the CWA. As set forth in Section 101(a), "The objective of [the Clean Water Act] is to restore and maintain the chemical, physical and biological integrity of the Nation's waters." 33 U.S.C. § 1251(a). Controlling pollution at the source is paramount in order to achieve clean waters for the Nation. The relationship of all waters within the watershed must be recognized and their contribution not only to water quality control but also pollution discharge must be acknowledged. Commerce of all kinds - intrastate, interstate and international - will be severely affected if commercial, industrial and municipal waters are impacted by uncontrolled pollution.

As the ANPRM makes clear, there is some uncertainty as to what are "isolated, intra-state, non-navigable waters." As set forth above, Region III recommends that "isolated" waters be defined as perched systems lacking any hydrologic connection (either by surface water or groundwater) to any other waters. Region III recognizes, however, that a more narrow interpretation of CWA jurisdiction, which does not extend to other waters, such as small streams located at the beginnings of watersheds (referred to throughout as "headwater streams") and their adjacent wetlands, has been suggested. Region III respectfully disagrees with any such suggestion as not based in science. As noted below and in the attached literature review, these areas, headwaters and adjacent and spatially discrete wetlands, are significant features in watersheds and serve a multitude of water quality functions. As such, the effects that small or non-navigable waterbodies have on the downstream water quality should be considered as factors to provide a basis for jurisdiction, in addition to the impact on interstate commerce.

In addition, in considering the scope of CWA jurisdiction, Region III believes the use of the resource as a drinking water source should also be considered, particularly as the CWA should complement the Safe Drinking Water Act to ensure a supply of safe drinking water. In the case of water supply, some water authorities have attempted to acquire, or otherwise control, the watersheds that supply their water. By controlling the quality of the water at its source (source water protection), water supply authorities avoid expensive treatment costs and ensure that drinking water MCLs (i.e., maximum contaminate levels) are attained to meet human health standards for the users.

Two classic examples of watershed control are the Quabbin Reservoir watershed that supplies drinking water to Boston and the Catskill watersheds that serve New York City. In both cases, headwater and non-navigable waters and wetlands form a substantial part of the watershed area. Smaller water authorities often seek comparable control, or at least monitor upstream conditions (e.g., Newport News, VA and the upper Chickahominy River basin). In cases of the many direct withdrawals of water from streams, there is the lack of the buffering effect of the water volumes held in a reservoir thereby making such intakes vulnerable to more immediate quality and quantity impacts.

Many businesses that engage in interstate commerce could not do so without a source of clean drinking water. Clean and reliable sources of drinking water require source water protection as described above. It is proving more effective and less expensive to protect drinking water at its source rather than treating contaminated raw water to make it potable. Without federal limits or controls on headwater streams and adjacent wetlands, point and non-point sources of contamination could likely increase, not only in those waters but in downstream waters as well. Public water suppliers could be required to do more testing and treatment of source water to ensure that public safety requirements were met. Contaminants such as Cryptosporidium and E. coli could likely increase in streams where municipal discharges and treatment facilities handling animal waste and animal by-products discharge into headwater streams.

Region III's GIS analysis shows that many drinking water intakes are located in headwater streams. Between 148 and 526 surface drinking water intakes, serving populations ranging from 535,000 to 3 million people, are potentially affected by the changes in the jurisdictional status of "waters of the United States". Removal of the source water protection measures afforded by the Clean Water Act may increase risks to human health and will likely require additional infrastructure expenditures by public utilities using surface water intakes.

One recent and poignant example of how waterborne disease outbreaks can be caused by untreated or partially treated municipal sewage entering the source water occurred in the Town of

Battleford, Saskatchewan, Canada where hundreds of persons were hospitalized and over 1,000 persons became ill in March and April 2001 from crpytosporidiosis. The investigation determined that the raw water contained Crpytosporidium oocysts, the source of which was a sewage treatment plant upstream (City of North Battleford) of the drinking water treatment plant. The drinking water plant was not operating properly and this resulted in the waterborne disease outbreak. But, even if the plant was operating properly, most epidemiologists and scientists would agree that Cryptosporidium could have been passing through the treatment process and into the distribution system where low levels of the disease could have been occurring and not have been picked up as an outbreak. The official government investigation resulted in recommendations that the City of North Battleford construct a new sewage treatment plant downstream of the Town of Battleford's drinking water intake. The lawsuit settlements could reach between $700,000 and $1,000,000.

Although the Battleford water supply is not on a headwater stream, it does give us hard evidence that waterborne disease outbreaks can be caused by untreated or partially treated municipal sewage entering into the source water. For pathogens such as Cryptosporidium, the likelihood of them surviving a long trip down a stream is very high since they are extremely small (3-5 microns) and won't settle easily out in the stream bed. Cryptosporidium is very hardy and can live in straight household bleach for 90 days and still remain infectious. Regardless if the discharge is one mile upstream on a main stem or is 10 miles upstream on a first or second order stream (as is the case with many sewage treatment plants in Region III) these pathogens are routinely found in human sewage and can show up in finished tap water as a result.

With regard to flood control, cumulative wetland losses in watershed headwaters, and in the natural floodplain, can exacerbate flooding events and result in concomitant commercial losses and displacements. Navigable waterways are directly affected by disruption of commercial waterborne traffic while other commercial activities are discontinued or otherwise diminished by flooding impacts. Furthermore, sediment inputs from headwaters and smaller streams affect the navigability of downstream waters. Loss or lack of regulation in these important filtering areas may result in the need for more extensive and recurrent dredging.

In terms of recreational fishing, certain types of angling only take place in small headwater streams. The native brook trout fisheries in Region III are often confined to smaller headwater streams or to spring fed larger streams and rivers. Headwater streams are a critical habitat of our native trout fishery. Naturally reproducing trout fisheries are so important to state governments, that states commonly have specific "designated uses" and more stringent chemical water quality criteria in their standards to protect them. These waters are usually designated separately from trout stocked waters. For example, in Pennsylvania, the protected use "Cold Water Fishes" (CWF) protects the maintenance and/or propagation, of fish species including the family Salmonidae and additional flora and fauna which are indigenous to a cold water habitat. The protected use "Trout Stocking Fishes" (TSF) only protects for the maintenance of stocked trout from late winter to early summer, and for warm water adapted flora and fauna the rest of the year. The numeric criteria for dissolved oxygen and temperature are more stringent in waters designated as CWF. High quality waters are therefore essential to the native trout fishing industry which serves not only in-state users but out-of-state anglers as well.

Biological Integrity Factors

With regard to the ecosystem functions of biodiversity, nutrient transformation and primary production, headwater and non-navigable waters and wetlands, by virtue of their unique position in the landscape, provide support functions to biota that is of local, regional or global significance. Some of the species supported currently provide commercial value (e.g., hunting, recreational photography, fishing) while others have unrealized potential (e.g., genetic stock, pharmaceuticals).

The task of ascribing an interstate or foreign commercial nexus to any individual wetland is very difficult. In many cases it is the cumulative impacts of continuing use, degradation or destruction that result in the disruption of commerce. Frequently, undetected cumulative losses of wetland function have to exceed a threshold before negative impacts to commercial interests are appreciated. At that point rehabilitation may prove costly, particularly when compared to less expensive impact avoidance or minimization measures that could have been applied prior to the system reaching a critical condition. A regulatory system is essential to monitor such trends in function and is an important mechanism for keeping all interested parties informed.

To date, some quantitative studies and anecdotal data provide early estimates of potential resource implications of the SWANCC decision. One of the purposes of the ANPRM is to solicit additional information, data, or studies addressing the extent of resource impacts to isolated, intrastate, non-navigable waters.

Summary of Wetland Resource Impacts

- Under a narrow interpretation, approximately 438,000 acres of wetlands or roughly 12% of all wetlands in the Region could be affected by the SWANCC ruling.
- Under the broad interpretation, that number increases to 1.3 million acres or roughly 36% of the wetland resource in Region III.
- These numbers may under-estimate the actual amount of wetland impacts because studies have shown that NWI underestimates actual wetland acreage by as much as 50%. Small, headwater wetlands are the type most frequently missed by NWI and are the wetlands at issue in the ANPRM.
- Depending on the outcome of certain regulatory options, the ecological ramifications to large categories of wetlands, including vernal pools, peat bogs and prairie potholes, could be wide ranging and profound.

Summary of Stream Resource Impacts

- First order streams make up over 50% of the total resource in Region III Middle Atlantic States based on 1:100,000 scale National Hydrography Datasets.
- A case study in southern West Virginia (study area, 4,527 mi^2) indicates intermittent streams make up 5,456 miles (33.9% of the total) and 1st order perennial streams make up 5,049 miles (31.4% of the total).
- The Delaware Department of Natural Resources and Environmental Control has estimated over 24.3% of the stream length in the state of Delaware is represented by streams that are considered intermittent (based on 1:24K scale).
- Ohio EPA has estimated over 50% of the stream length in the state of Ohio is represented by streams that might be ephemeral or summer-dry.
- Many of these streams support abundant and diverse aquatic life and are connected to downstream waters through surface or subsurface flow for some portion of the year.
- If headwater streams were removed from jurisdiction, the majority of the aquatic life habitat in streams could be removed. Protection of the aquatic life in downstream waters could be severely compromised if such a large portion of the upstream resource were not protected. Attainment of water quality standards would likely become more difficult.

Summary of Human Health Impacts

- Between 148 and 526 surface drinking water intakes, serving populations ranging from 535,000 to 3 million people, are potentially affected by the potential changes in CWA jurisdiction.
- Removal of the source water protection measures afforded by the Clean Water Act is likely to increase risks to human health and require additional infrastructure expenditures by public utilities using surface water intakes.

Wetland Impacts

Because the nature of any proposed regulatory change is unknown, Region III's analysis necessarily required some assumptions. In keeping with the limited scope of waters affected under SWANCC, Region III's-narrow interpretation of "isolated" wetlands includes wetland areas that do not exhibit a perennial or intermittent surface water connection to traditional "navigable waters". The broad interpretation includes smaller perennial streams and intermittent or ephemeral "headwaters" and their adjacent wetlands as well as the wetlands analyzed in the narrow interpretation described above.

A range of profound aquatic resource impacts are exhibited when the potential effects of new rule-making on waters and wetlands described above is analyzed. Using region-wide GIS data, approximately 438,000 acres of wetlands, or roughly 12% of the wetland resource in Region III, could be adversely affected under the narrow interpretation. If one considers the broad interpretation, that number increases to 1.3 million acres of wetlands, or roughly 36% of all wetlands in the Region. Both figures represent a significant portion of wetlands within Region III. Furthermore, these numbers may be conservative estimates considering that studies have shown that the maps used to generate these figures may underestimate actual wetland acreage by as much as 50%.

Numerous studies have shown that both the wetlands and stream mapping available on a regional or national basis underestimate the extent of both stream and wetland resources. Aerial photography interpretation (API) was used as a tool by Region III to more accurately determine the potential effects of the reduction in the scope of CWA jurisdiction (see Appendix B). The API analysis complemented the GIS analysis described above by developing and analyzing site-specific data at four relatively small study areas in Region III. The four study areas, established around wetland field sites investigated by Region III, had an average size of approximately 30 square miles (19,200 acres). The API study demonstrated a greater range of potential wetland impact. The impact was shown to be greater in the study areas that were located in headwater settings. Using the broad interpretation potential impact to wetlands, ranging up to 100%; can be expected in localized areas within small first and second order watersheds.

The extent to which a change in the regulation may impact of adverse resource impacts to wetlands is highly dependent on the definition of the terms "isolated, intrastate, non-navigable". In some parts of the nation the majority of the wetland systems consist of wetlands that are discrete communities on the landscape (e.g., prairie potholes, playa, pocosins, bogs, Carolina/Delmarva Bays), thereby falling into the "narrow" interpretation described above.

A wide ranging variety of significant wetland types (e.g., coastal plain interfluvial flats, wooded wetlands in glaciated landscapes, slope and montane wetlands) may be characterized as wetlands with non-traditional linkages. For the sake of brevity, the term "non-traditional linkages" refers to wetlands that are hydrologically connected to other waters by non-perennial surface and/or groundwater flows. Wetlands with non-traditional linkages do not exhibit a perennial surface water connection yet they are closely integrated to the larger watershed network via groundwater and non-perennial surface connections. Thus, most wetlands that do not exhibit a perennial surface connection are not truly "isolated" in the ecological and hydrological sense.

Selected examples from the scientific literature are included below. These studies exemplify the long-term forces that formed these wetlands and the widespread nature of their distribution. It logically follows that the ecological ramifications of certain regulatory changes to such wetland categories are potentially wide ranging and profound (see Appendix D for more detail).

In the glaciated northeast, the geomorphological processes that promoted prairie pothole and pocosin formation created a wide diversity of wetland settings that do not exhibit surface water connections. Certain landforms that were created during the close of the last glacial epoch 10,000 years ago promoted the formation of wetland communities as widely divergent as prairie potholes and bog communities. Creation of moraines (e.g., ground, washboard, thrust, dead ice and terminal) and meltwater (e.g., glacial outwash plain, collapsed glacial outwash, glacial lake plains) landforms promoted the formation of potholes (Kantrud et al. 1989) throughout the Dakotas and other parts of the upper Midwest and Canada. Comparable glacial phenomena, combined with the topographic heterogeneity of the northeast promoted the formation of northeastern bog communities.

For example Kantrud et al. (1989) cited studies that indicated that in the 1960's and 1970's 2.3 million temporary, seasonal and semipermanent wetland basins were found in the Prairie Pothole region of the Dakotas. Approximate basin numbers and areas by water regime were: 698,000 temporary (113,000 hectares), 1,474,000 seasonal (583,000 hectares), and 127,000 semipermanent (345,000 hectares). These basins were estimated to compose 84.8% of the area and 89.3% of the number of natural basins in the region. They also note that subsequent drainage and filling has further reduced the number of wetlands.

Pocosin communities began to develop after the Wisconsin Ice age, about 15,000 years ago and are now found in flat areas associated with blocked stream drainage on the lower terraces, areas of ridge and swale topography between relict beaches and dune ridges and at springs and springheads of the upper Coastal Plain. In the pocosin region, Richardson et al., (1981) cites historic studies that estimated that pocosin ecosystems once covered more than 3 million acres. In 1962 nearly 70% of all the existing pocosins (2,243,500 acres) occurred in North Carolina. They were rapidly developed and by 1979 only 31% of this ecosystem remained in its natural state. Nevertheless they still comprise more that 50% of North Carolina's wetlands.

In another example in Region III, Tiner and Burke (1995) indicate that of the 598,388 acres of wetlands inventoried in Maryland (1981-1982 data), palustrine wetlands composed 342,626 (57%) of the total wetland resource. Furthermore, of the palustrine wetlands, the three water regimes toward the dry end of the hydrological spectrum (temporarily flooded, saturated, intermittently flooded) comprised 189,410 acres—55% of the palustrine total.

It may be generally assumed that southeastern bottomland hardwood swamps are tightly linked to their river systems, thereby forming "classic" navigable systems. However, some floodplains in the southeast exhibit significant post glacial landscape features (Wharton et al. 1982). Many modern floodplains are "underfitted" as the forces that produced them ceased thousands of years ago (Dury 1977). Such modern floodplains, embedded in ancient floodplains, promote broader spatial separation of landforms. Step like terraces are also remnants of prehistoric surfaces and separate communities from direct spatial linkages to modern streams. On a smaller scale, features such as scour channels, oxbows, hummocks, ridge and swale topography and mini-basins are all potential sites for wetlands exhibiting non-perennial surface connections or groundwater water connections.

Given the wide diversity of ecological and hydrological relationships described above, most seemingly "isolated" wetlands are not truly isolated from the ecological and hydrological networks of waters of the United States. See Appendix D for more information on ecology of these systems.

Stream Impacts

As noted above, in addition to truly isolated wetlands, Region III has analyzed "other waters", including smaller perennial streams and intermittent or ephemeral "headwaters". Although Region III included these areas for the purposes of this analysis, these waters are not hydrologically isolated. To the contrary, small perennial streams and intermittent or ephemeral headwaters are hydrologically connected to downstream waters for at least part of the year.

The GIS analysis of potential impacts to streams shows that the majority of total stream miles in Region III are small, headwater streams. Approximately 52% of the total stream resource (as measured in stream miles) in Region III are first order streams at the 1:100,000 mapping scale. Approximately 106,000 miles of headwater streams in Region III could be affected by changes in CWA jurisdiction and could therefore be afforded no protection under CWA authorities. This coarse scale of mapping (1:100K) may underestimate the number and length of small streams by a large amount. This problem appears to vary by watershed, with some underestimates exceeding 150%. For example, in Pennsylvania, the total length of stream miles increased 50% when moving from coarse scale mapping to one with more refined accuracy. Furthermore, we know from case studies that this coarse scale coverage does not accurately map intermittent streams. Although we know that many small streams are not included in these regional and national maps, these estimates are supported by other studies, which have been conducted at finer scales in various states and regions (e.g., Ohio, Pennsylvania, West Virginia, North Carolina, etc. See Appendix E for more detail).

It is very difficult to quantify the extent of ephemeral, intermittent and perennial streams on a regional or national basis. In order to make more accurate estimates of ephemeral, intermittent and perennial headwater streams, Region III looked at smaller regions to develop defensible case studies. A GIS case study (Childers and Passmore 2003) was developed in the southern West Virginia coalfields in the area of mountain top coal mining to determine the extent of ephemeral and intermittent streams that could be affected if they were removed from jurisdiction. The study area encompasses 4,527 mi^2. USGS modeling coupled with field survey work in this region was used to generate stream networks on GIS maps based on watershed size[2] (see Appendix E for detail on methods). The results of this exercise indicate that a total of 16,094 miles of streams exist in the mountaintop mining coal region of West Virginia. Intermittent streams make up 5,456 miles (33.9% of the total) and first order perennial streams make up 5,049 miles (31.4% of the total). Ephemeral stream miles could not estimated from the available data with any known accuracy.

---

[2]USGS studies indicate that the ephemeral/intermittent boundary occurs at a point where the median drainage area upstream of the boundary is 14.5 acres and that the intermittent/perennial boundary occurs at a point where the median drainage area upstream of the boundary is 40.8 acres.

Using aerial photography interpretation (API), as described above (see Appendix B), the potential impact of the reduction in the scope of CWA jurisdiction on streams is also significant. At four of our study sites the API has demonstrated that between 88%-92% of all stream resources were potentially impacted using the broad interpretation. Up to 100% of stream resources could also be affected in small, localized watersheds. This analysis shows that the higher resolution of the wetlands and stream data, the greater will be the observed potential impact of reduction in the scope of CWA jurisdiction.

Ohio EPA has tried to classify and estimate the extent of headwater streams. They found that traditional hydrological definitions of perennial, intermittent and ephemeral were not adequate to describe the hydrological, longitudinal connectivity in a stream and did not reflect the actual or potential use of the stream by aquatic life. Ohio EPA defined headwater streams as those which have a defined bed and bank and a watershed less than 1 mi^2 .and maximum water depth of 40 cm or less. Based on their estimates, over 50% of the stream length in Ohio is represented by streams that might be ephemeral or summer-dry. Many of these streams support abundant and diverse aquatic life and are connected to downstream waters through surface or subsurface flow for some portion of the year (see the attached literature review for more detail and other examples).

As the beginning of a watershed, headwaters function in many ways that are critical to the ecosystem (e.g., moderation of downstream flow, moderation of thermal regime, removal of pollutants, influence on the storage, transportation and export of organic matter). These physical and biological attributes are integral to healthy, self-sustaining watersheds. See Appendix E for more on the ecology of these systems.

The ANPRM seeks information regarding the functions and values of wetlands and other waters that may be affected by the issues discussed in this ANPRM.

Summary of Wetland Functions

- The wetlands at issue in the ANPRM perform and deliver ecological functions to waters of the United States that promote the chemical, physical and biological integrity of these waters in a manner that is dependent on their unique place in the landscape.
- The full range of important wetland functions (e.g,. flood reduction, nutrient retention/transformation, habitat. primary productivity) is usually demonstrated by headwater wetlands and wetlands with non-traditional linkages[3], both individually and in combination with other aquatic and terrestrial features in a watershed.
- Water quality improvement functions are performed individually and cumulatively by headwater wetlands and wetlands with non-traditional linkages via the treatment of

[3]For the sake of brevity. the term non-traditional linkages will hereinafter refer to wetlands hydrologically connected by non-perennial surface and/or groundwater flows.

pollutant-laden water and sediments arising from diffuse surface and groundwater inflows.

- Studies have demonstrated a link between cumulative losses of headwater wetlands and wetlands with non-traditional linkages and increases in downstream flooding.
- A high percentage of endangered or threatened plant and animal species utilize wetlands with non-traditional linkages, which demonstrates their critical biodiversity function.
- Groundwater seeps are frequently where wetlands begin and where streams originate. Both communities are part of a continuum in which upstream riparian and wetland communities support and protect the biological, chemical and physical features that are critical to the well being of downstream waters.
- By virtue of the unique landscape position and ecological processes of headwater wetlands and wetlands with non-traditional linkages, a wide variety of faunal communities (e.g., amphibians, wading birds, waterfowl) are dependent on them for their survival.

Summary of Headwater Stream Functions

- Headwater streams provide maximum interface with the terrestrial environment with large inputs of organic matter from the surrounding landscape.
- Headwater streams serve as storage and retention sites for nutrients, organic matter and sediments
- Headwater streams are sites for transformation of nutrients and organic matter to fine particulate and dissolved organic matter.
- Headwater streams are the main conduit for export of water, nutrients, and organic matter to downstream areas.
- Headwater streams tend to moderate the hydrograph, or flow rate, downstream.
- Headwater streams provide a moderate thermal regime compared to downstream waters - cooler in summer and warmer in winter.
- Biota in headwater streams influence the storage, transportation and export of organic matter.
- Biota in headwater streams enhance nutrient uptake and transformation.
- Headwater streams provide habitat for numerous aquatic species, including fish, amphibians and invertebrates.
- Based on the experience of Region III scientists, under many circumstances, headwater streams represent the highest quality waters in the region.

Wetland Function

Most of the headwater streams and wetlands with non-traditional linkages comprise networks that function in a manner analogous to the capillaries in a blood circulatory system. Just as capillaries act as the interface between our organs and our circulatory system, these systems act as the interface between the uplands and the surface water networks that comprise the watersheds of our Nation. These small but numerous systems act both individually and cumulatively, to provide the full range of important wetland functions (e.g., flood reduction, water quality, nutrient retention/transformation, habitat, primary productivity) in a watershed. Moreover, a large number of endangered or threatened plant and animal species utilize these habitats which demonstrates their critical biodiversity function. These streams and wetlands perform and deliver ecological functions that promote the chemical, physical and biological integrity of receiving waters in a manner that is dependent on their unique place in the landscape.

Regarding wetland functions and values, many studies focus on the wetlands in a hydrological unit (e.g., watershed, physiographic province, basin) and do not arbitrarily distinguish between surface connected systems and other hydrologic relationships. In such cases it is difficult to tease out the level of ecological function directly attributable to only headwater wetlands and those wetlands with non-traditional linkages, as opposed to wetlands with more traditional surface hydrologic linkages.

In cases where the research is focused on a wetland class that has predominantly wetlands with non-traditional linkages (e.g., prairie potholes, pocosins), the full range of important wetland functions is usually demonstrated (e.g., flood reduction, nutrient retention/transformation habitat, primary productivity), both individually and in combination with other aquatic and terrestrial features in a watershed. Although these wetlands may not appear to provide significant services when evaluated individually, cumulatively they are often important components of the larger watershed ecosystem.

In other parts of the nation, where there is a more balanced mix of "connected" wetlands and wetlands with non-traditional linkages, many studies have demonstrated the important range and level of ecological function that is delivered to the environment by wetlands. For example, community profiles of red maple swamps in the glaciated northeast (Golet et al. 1993) and southeastern bottomland hardwoods (Wharton et al. 1982) discuss the wide range of important ecological functions provided by these respective community types. In the discussions of the geological and climatological factors that created these wetland systems, forces that created spatially discrete wetland conditions are substantial in their areal extent. Given that a substantial proportion of the resource in many of these studies lack perennial surface water connections, it is apparent that these types of wetlands provide a significant portion of the functions that are performed and delivered.

Miller and Nudds (1996) studied twelve watersheds near the U. S. - Canadian mid-West border and concluded that landscape alteration (in a region with a high density of Prairie Pothole wetlands) was the cause of increased river flows in 4 of 5 American and 0 of 7 Canadian watersheds. The Canadian watersheds had significantly less alteration than the four American watersheds with higher flows.

With regard to flood attenuation, studies have demonstrated a link between cumulative losses of headwater wetlands and wetlands with non-traditional linkages and increases in downstream flooding (e.g., Gilliam and Skaggs 1981, Miller and Nudds 1996). Studies have also demonstrated that water quality improvement functions are performed individually and cumulatively by these wetlands via the treatment of pollutant-laden water and sediments arising from diffuse surface and groundwater inflows (e.g., Daniel 1981).

In both functional categories mentioned above, the positioning of many headwater wetlands and wetlands with non-traditional linkages (i.e., dispersed throughout the landscape and oriented toward the upper parts of watersheds) enhance the "pre-treatment" of non-point source pollution prior to discharge to receiving water bodies (e.g., Brinson 1993).

Ecosystem support functions, such as nutrient transformation, habitat, and primary productivity are similarly enhanced by the physical and hydrologic location of these wetlands. Studies have demonstrated that the spatial dispersion and wide range of size, surface and groundwater hydrology promote floral and faunal communities that have evolved with them. Critical animal groups or guilds (e.g., waterfowl, wading birds, amphibians) are highly dependent on these wetland characteristics to promote local, regional or continental populations. The proportionally high percentage of all endangered or threatened plant and animal species in such wetlands also demonstrates their critical biodiversity function (e.g., Sharitz and Gibbons 1982, Laderman 1989, Murdock 1994, Colburn 2001). The reproductive and migratory requirements of waterfowl are well documented and dependent on a diversity of wetland sizes and water regimes at critical continental-scale locations (e.g., Smith and Higgins 1990, Patterson 1996). Amphibian biodiversity is critically dependent the distribution of headwater wetlands and those wetlands with non-traditional linkages (e.g., Murdock 1994, Semlitsch 2000). In Florida, wetlands without surface water connections serve vital ecological roles for animal species as widely divergent as alligators and wading birds, as well as a wide range of rare and endangered plant species (Hart and Newman 1995).

In a discussion of the river continuum concept, Vannote et al. (1980) remarked that from headwaters to downstream extent, the physical variables within a stream system present a continuous gradient of conditions including width, depth, velocity, flow volume, temperature, etc. Many headwater streams are strongly influenced by riparian vegetation and receive large amounts of organic material from outside the streams such as leaves and other coarse particulate organic matter. These headwaters represent the maximum interface with the landscape and are therefore accumulators, processors, and transporters of materials from the terrestrial system. As the stream size increases the reduced importance of terrestrial input coincides with in-stream production and organic transport from upstream.

Looking upstream from the headwaters, Pielou (1998) notes that the majority of rivers begin at an indeterminate point in a slight depression in the ground where groundwater is discharged as a seep or spring. Such a depression also serves as a collector of overland flow. Eventually seepage in the bottom of the depression, augmented by the surface flow accumulates sufficiently to erode a self-sustaining, permanent channel through which the water drains away—the origin of a stream. When a stream originates, groundwater seepage is usually far more important than overland flow in bringing it into being. In general only one-fifth of the water that reaches the ground surface as rain collects in streams and rivers.

This mosaic of water pathways includes a mix of communities, all of which serve to support the headwaters. Moreover, the same landscape features that promote the water quality improvement function also enhance the function of these wetlands in transforming pollutants to other forms that are more beneficial to receiving waters downstream (Brinson 1993, Peterjohn and Correll 1984, and others). This is particularly important given the unique interplay of hydrology and biota found in the headwater wetland communities. It is comparable to many transformations performed in headwater streams. These two systems, operating in tandem, promote ecosystem support locally and farther downstream (see Appendices D and E for details).

Stream Function

Headwater streams provide many ecosystem functions that affect downstream waters as well as providing critical habitats for many types of aquatic life. As the beginning of a watershed, headwaters function in many ways that are critical to the ecosystem. In a Symposium on Aquatic Ecosystem Enhancement at Mountain Top Mining Sites, Wallace (2000) described headwater stream aspects:

- Have maximum interface with the terrestrial environment with large inputs of organic matter from the surrounding landscape;
- Serve as storage and retention sites for nutrients, organic matter and sediments;
- Are sites for transformation of nutrients and organic matter to fine particulate and dissolved organic matter;
- Are the main conduit for export of water, nutrients, and organic matter to downstream areas.

The major functions of headwater streams can be summarized into two categories, physical and biological (Wallace 2000). The physical functions of headwater streams include:

- Moderation of the hydrograph, or flow rate, downstream;
- Major areas of nutrient transformation and retention;
- Moderation of thermal regime compared to downstream waters - cooler in summer and warmer in winter; and
- Physical retention of organic material as observed by the short "spiraling length".

The functions performed by biota in streams include:

- Influence on the storage, transportation and export of organic matter;
- Conversion of organic matter to fine particulate and dissolved organic matter;
- Enhancement of downstream transport of organic matter;
- Influence on the accumulation of large and woody organic matter in headwater streams:
- Enhancement of sediment transport downstream by breaking down the leaf material; and

- Enhancement of nutrient uptake and transformation.

As noted earlier, headwater streams represent the majority of the stream resource in the region in terms of length. They provide critical habitat for a variety of aquatic invertebrates and vertebrates. Appendix E provides detail on aquatic life use of very small headwater streams. The literature clearly establishes that many very small streams, even those which do not have continuous surface flow, support diverse and abundant aquatic life.

The Ohio EPA provides an excellent example of a state program that has recognized the aquatic life value of headwater streams. Ohio EPA defines primary headwater habitat as those streams having watersheds less than $1 mi^2$ and maximum water depth of 40 cm or less and having defined bed and banks. They have developed a classification of headwater streams based on the hydrology, the thermal regime, and the invertebrate and vertebrate assemblages that inhabit these streams. Ohio EPA has estimated that 69% of the total streams in their state would have aquatic life uses classified as primary headwater habitat (PHWH). Ohio EPA has estimated that a large proportion of the total streams in the state are ephemeral (22%) or might become summer-dry at the surface (31%). If these streams were removed from jurisdiction, the majority of the aquatic life habitat in the state could be removed. Protection of the aquatic life in downstream waters could be severely compromised if such a large portion of the upstream resource were not protected and attainment of water quality standards could be problematic.

Additionally we invite your views as to whether any other revisions are needed to the existing regulations on which waters are jurisdictional under the CWA.

This is an extremely broad statement, and therefore it is difficult to provide a response. Water moves in hydrological cycles unconstrained by definitions. Although the Supreme Court in SWANCC instructed that the term "navigable" not be read out of the CWA, the terms "waters of the United States" and "restore and maintain the physical, chemical and biological integrity of the Nation's waters" are of equal, if not greater, importance. In this regard, the goals and objectives of the CWA as set forth in Section 101(a) can be achieved only through recognizing the connectivity of the nation's waters and the importance of all waters in a watershed. Any revisions that would reduce the jurisdictional scope of waters of the United States could seriously weaken the CWA and our ability to provide safe and clean water for all Americans. Region III is willing to provide additional data or response in connection with any specific proposals.

The Agencies are also soliciting data and information on the availability and effectiveness of other Federal or State programs for the protection of aquatic resources, and on the functions and values of wetlands and other waters that may be affected by the issues discussed in this ANPRM.

Summary of State Programs

- Two thirds of the states in the Nation currently lack regulatory programs that comprehensively address wetlands and wetlands at issue in SWANCC in particular.

- In Region III, Delaware and West Virginia do not have regulatory programs sufficient to protect wetlands should the scope of federal jurisdiction for section 404 of the CWA program be revised to exclude wetlands lacking surface water connection and wetlands adjacent to non-navigable streams.
- Removing waters from CWA jurisdiction will undermine the federal government's role as a backstop for the states.
- The Courts could construe the geographic jurisdictional scope of state water quality and wetland programs as coextensive with federal authority.
- It cannot be presumed that where there is a gap in federal regulation, the states can or will fill that gap.
- The Oil Pollution Act (33 U.S.C. 1321-1322) statute does not provide for delegation, and there is no delegated, authorized or otherwise approved program in any state.

According to the Association of State Wetland Managers, two thirds of the United States currently lack regulatory programs that comprehensively address wetlands and particularly isolated wetlands or wetlands with non-traditional linkages. The Middle Atlantic States (EPA Region III) paint a similar picture. Currently three states out of five in Region III have some type of wetlands protection program that provides regulation for non-tidal wetlands lacking surface water connections (see Appendix K for specifics regarding state wetland and water quality programs). Those states are Pennsylvania, Maryland and Virginia. Both Delaware and West Virginia lack comprehensive wetland programs. Delaware and West Virginia do not provide any sort of state regulation should the scope of federal jurisdiction for section 404 of the CWA program be revised to exclude these types of wetlands and wetlands adjacent to non-navigable streams. Virginia may not be able to provide state regulation of certain waters, as the geographic jurisdiction of its program has been held by one court to be coextensive with federal jurisdiction. United States v. Newdunn, 195 F. Supp. 2d 751, 768-69 (E.D. Va. 2002).

Furthermore, the federal wetland program has provided an important complement to state programs, often sharing the burden of assessment, permitting and enforcement. The result of narrowing the CWA definition of "waters of the United States" will shift more of the economic burden for regulating wetlands and headwater streams to states and local governments. No Region III state has been authorized, pursuant to Section 33 U.S.C. 1344(g), to assume the Section 404 program.

The effect of narrowing the jurisdictional scope of waters of the United States will also impact the areas and activities subject to Clean Water Act Section 401 programs which require State approval for federally permitted activities. These changes will also limit the areas and activities addressed by State Programmatic General Permits. These changes will be felt most acutely in Delaware and West Virginia which rely on their 401 certification program to ensure that water quality standards are met for wetlands. Moreover, reliance on the 401 water quality program to protect wetland resources is further complicated by the fact that none of the states in Region III have specific water quality standards for wetlands. Additional state programs could be required to "recapture" these waters and wetland areas in Delaware and West Virginia.

With respect to the National Pollutant Discharge Elimination System, most, but not all states, are authorized to implement the NPDES program pursuant to 33 U.S.C. § 1342(b). In Region III, the District of Columbia has not sought authorization to implement the NPDES program. In Pennsylvania, the State is authorized to implement all aspects of the NPDES program except the industrial pretreatment program pursuant to 33 U.S.C. 1317. With respect to the industrial pretreatment program, EPA remains the sole regulatory authority in Pennsylvania. With respect to the Oil Pollution Act (33 U.S.C. 1321-1322), the statute does not provide for delegation, and there is no delegated, authorized or otherwise approved state program.

Even where a state purports to fill a regulatory gap, there is no guarantee that the state has or will successfully do so. Many state programs are "triggered" by federal requirements. To the extent a state's NPDES authority is authorized pursuant to 33 U.S.C. 1342(b), a court may well read the jurisdictional scope of the state program as coextensive with the federal government's. This also may occur in the area of wetlands. For example, Pennsylvania and Maryland both have State Programmatic General Permits ("SPGPs") authorized by the U.S. Army Corps of Engineers and EPA pursuant to 33 U.S.C. 1344(e). These SPGPs are federal permits administered by the States; thus, it seems a court could construe the geographic jurisdictional scope of such permits and the underlying state wetlands programs as coextensive with federal authority.

Even in the absence of a federally authorized program, a court could limit a state program's geographic jurisdiction. For example, Virginia enacted a non-tidal wetlands program governing the excavation and/or filling of non-tidal wetlands in Virginia. Va. Code 62.1-44 et seq. In the Newdunn case, the court held that Virginia's authority was coextensive with the federal government's authority (i.e., Virginia's program did not authorize the state to regulate wetlands that could not be regulated by the federal government). Newdunn, 195 F. Supp. 2d at 768-69.

Finally, the CWA assigns the federal government an important role as a "backstop" for the states. For example, unlike certain other programs, Section 402(b) provides for federal government "authorization" of, not "delegation" to, state NPDES programs. The distinction is important. In a truly "delegated" program, such as that described in the Surface Mining Control and Reclamation Act, the federal agency retains little, if any oversight authority, and the program becomes a truly "state" program. See, e.g., Bragg v. West Virginia Coal Ass'n, 248 F.3d 275 (4th Cir. 2001). Under the CWA, however, particularly with respect to the NPDES program, EPA retains oversight authority over both the permitting and enforcement processes, as well as the ability to issue permits under certain circumstances and to bring enforcement actions, even in states authorized to implement the NPDES program. With respect to enforcement, it is not unusual for the states to request that EPA take an enforcement lead. Removing waters from CWA jurisdiction will undermine the federal government's role as a backstop for the states.

The Agencies are also interested in data and comments from state and local agencies on the effect of no longer asserting jurisdiction over some of the waters (and discharges to those

waters) in a watershed on the implementation of Total Maximum Daily Loads (TMDLs) and attainment of water quality standards.

Summary of Implications for TMDL Program

- In many watersheds, the sources of pollution and the majority of the loadings are in small streams.
- Controlling direct discharges (from both point sources and nonpoint sources) to a large water often will not achieve sufficient pollution reduction in the absence of controls on pollutant loadings upstream.
- Because of the interrelationship of tributaries with the mainstem, the Agency needs to consider sources of pollutants and tributaries on a watershed basis, including intermittent and ephemeral streams sources.
- If ephemeral, intermittent or small perennial headwaters and, in some cases headwater wetlands, were no longer jurisdictional under the CWA, and unpermitted discharges were allowed in these waters, it could be very difficult to attain water quality standards or implement effective TMDLs in downstream waters.

EPA acts as an important "backstop" with respect to water quality standards. Section 303(c) of the CWA specifically requires states to submit new or revised water quality standards for navigable waters to EPA. 33 U.S.C. 1313(c). If EPA determines that such new or revised standards are not consistent with the CWA, EPA must disapprove the standard, and, if the state fails to satisfy EPA's concerns, EPA must develop and publish a water quality standard for the state. 33 U.S.C. § 1313(c)(4). EPA also must develop and publish water quality standards for States in which EPA believes it is necessary for the State water quality program to comply with the goals of the CWA. *Id.* EPA Region III has published anti-degradation procedures for the state of Pennsylvania. In addition, there are currently pending approximately five outstanding water quality standards submittals from the states and one outstanding disapproved state water quality standard in Region III. EPA's ability to disapprove water quality standards and to promulgate its own water quality standards for the state generally has provided incentives to ensure that the standards submitted by the states will comply with the CWA.

A failure to assert jurisdiction over some waters could leave open to question the applicability of water quality standards for some waters. To the extent a water quality standard is submitted by a state and approved by EPA, the question of federal jurisdiction likely would not arise because most state water quality standards apply to "waters of the state." However, where EPA has published a water quality standard for the state, it is not clear whether such standards would apply to all waters. To the extent water quality standards to not apply to headwaters and upstream tributaries, EPA's ability to act as a backstop and to ensure that state water quality standards will achieve the goals of the CWA could be undermined.

TMDLs provide perhaps the most dramatic example of how a decision to exclude some waters from jurisdiction can impact an entire watershed. Region III has developed a number of TMDLs for various watersheds in the Region. In the course of developing TMDLs for large, navigable-in-fact waters, Region III has discovered that the best approach to achieving water quality standards in the mainstem of a large river is through a combination of allocations to direct (point and nonpoint source) discharges and allocations to tributaries. Therefore, if smaller tributaries such as ephemeral, intermittent or small perennial headwaters were no longer jurisdictional under the CWA, and unpermitted discharges were allowed in these waters, it could be very difficult to attain water quality standards or implement effective TMDLs in downstream waters. In many watersheds, the sources of pollution and the majority of the loadings are in the small streams. If smaller upstream tributaries are excluded from the concept of "navigable waters," an argument could be made that states need not list them on their list of impaired waters pursuant to Section 303(d) and that TMDLs need not be established. As demonstrated in the TMDL case studies below, exclusion of smaller upstream tributaries could result in an inability to control water quality in large mainstem waters.

TMDL Case Studies

Tygart River Watershed - From 1995 to 1999, WVDEP assessed 136 streams, representing approximately 700 miles of stream length in the Tygart River Valley watershed. Of the 682 miles assessed for support of the aquatic life, 35% of the streams fully supported the aquatic life use, 30% were supporting but threatened, 19% were partially supporting, and 17% did not support the aquatic life use. The principle causes of the impairment were siltation, habitat alteration, metals, and pH. The principle sources of the pollution were abandoned mine drainage, acid mine drainage and unknown sources (WVDEP 2000).

The mainstem Tygart Valley River, Buckhannon River, Ten Mile Creek and Middle Fork River, together with 54 smaller water bodies within the watershed were placed on the West Virginia 1996 303(d) list because of iron, manganese, aluminum, and/or pH violations caused by abandoned coal mine discharges.

When the Tygart River TMDL was developed, impaired headwaters were first analyzed, because their impact frequently had a **"profound"** effect on downstream water quality" (bold emphasis added). The modeling effort indicated that load reductions in both impaired and non-impaired headwaters streams were necessary to attain water quality standards in downstream waters. In other words, load allocation reductions in the downstream reaches alone were not enough to attain water quality standards in downstream waters.

The TMDL for the Tygart was developed without load allocations for specific future development scenarios. The document for the Tygart River watershed makes clear that in order for additional new point sources to be located in headwater reaches, and still attain water quality standards downstream, they may have to attain water quality standards at the end of the effluent pipes. The report states, "A new facility could be permitted anywhere in the watershed, provided that the effluent limitations are based upon the achievement of water quality standards end-of-pipe for the pollutants of concern in the TMDL". Clearly, if headwater streams were no longer regulated, any new mining activity in these areas could discharge to small headwater streams without a permit, and without meeting water quality standards end-of-pipe. The TMDL for and the water quality of the whole Tygart Watershed would be affected. See Appendix H for more detail.

Christina River Watershed - Another example is the TMDL for nutrients and dissolved oxygen developed for the Christina River Basin. This TMDL was prepared by Region III in January 2001 (revised October 2002). Waters from streams and tributaries in three states -- Pennsylvania, Maryland and Delaware -- eventually flow to the Christina River. Thus, for example, discharges that occur in small tributaries in Pennsylvania may flow to the Christina River in Delaware. The TMDL narrative noted:

> As indicated in the data assessment ... the nutrient concentrations of the tidal Christina River are heavily influenced by tributary loads from the Brandywine Creek, Red and White Clay Creeks and nontidal Christina River. .... In any case, the nutrient and biomass loading from inland tributaries contribute to the DO and WQS violations within the tidal Christina River. This further justifies the need to consider sources of pollutants and tributaries on a watershed basis, regardless of whether that waterbody is explicitly listed on a state's 303(d) list.

Modeling conducted in the course of developing the Christina River TMDL demonstrated the interrelationship of tributaries with the mainstem. In order to ensure achievement of water quality standards throughout the Christina River Basin, it was necessary to develop load and waste load allocations for sources on the Brandywine Creek main stem, Brandywine Creek East Branch, Brandywine Creek West Branch, Buck Run, the Christina River West Branch, Little Mill Creek, Burroughs Run, Red Clay Creek West Branch, Red Clay Creek main stem, White Clay Creek Middle Branch, White Clay Creek East Branch, White Clay Creek main stem, Muddy Run, Pike Creek, and Mill Creek, as well as for the main stem of the Christina River.

The modeling analysis for protection of the dissolved oxygen standards for the mainstem Christina River (see Appendix G pages 41-47) showed that treatment reductions in upstream areas, in second order removed tributaries, was necessary to attain standards. The Level 2 allocation analysis (see Appendix G baseline figures 13 and 14) initially showed an area in the lower mainstem Christina not protected for daily average dissolved oxygen (see Appendix G Figure 13). The Level 2 allocation analysis proceeded with additional treatment assessments which added to the treatment recommendations for three facilities and included four other facilities for treatment reductions (see Appendix G Table 11, p. 47). All of these facilities are located on tributary segments (East/West Branches Brandywine Creek and West Branch Red Clay Creek) of tributaries to the Christina River (Brandywine and Red Clay Creeks). These reductions in upstream areas were needed to ensure full protection of the daily average dissolved oxygen for the Christina River.

Mining Region Of West Virginia - Mountaintop mining in the coal regions of southern West

Virginia provides an excellent example of what impacts may occur to water quality if headwater streams are no longer regulated as waters of the United States. During mountaintop coal mining, several thin layers of coal are successively mined via surface removal. The overburden is often deposited in adjacent valleys, which are called valley fills. The valley fills are placed in ephemeral, intermittent and perennial reaches of headwater streams, effectively destroying these streams. This fill requires a CWA Section 404 permit. The water exiting the toe of the fills often enters a sedimentation pond. The discharge from the pond becomes the origin of the stream. These sedimentation ponds and the effluent exiting the pond require a CWA Section 402 NPDES permit.

A study completed by Region III for the Mountaintop Mining/Valley Fill Programmatic EIS found that the waters downstream of some of the fills were impaired and that the impaired biological condition was strongly correlated to the degraded water emerging from the base of the fills. The discharge from the base of the Valley Fill represents the entire stream flow at that point. These streams become effectively "effluent dominated". West Virginia has determined, based on biological thresholds, that downstream segments of some of the Valley Fills are impaired. These waters have been listed on the state's 303(d) list, and will require a TMDL. Under current regulation, the filled stream segments are considered waters of the United States and both 404 permits for the discharge of fill and NPDES permits for the effluent at the base of the fills are required. Even with this regulation, some of the waterbodies downstream of the fills are experiencing impairment. Clearly, if these streams (ephemeral or intermittent streams) were not jurisdictional (i.e., considered non-navigable, isolated, intra-state waters), 404 permits would not required for the Valley Fill and NPDES permits might no longer be needed for the discharges at the toes of fills. This could result in even far worse water quality downstream of the Valley Fills.

Furthermore, variances from the Approximate Original Contour (AOC) of the Surface Mine Control and Reclamation Act's (SMCRA) requirements are often granted to promote industrial post-mining land use at these sites. Removing these potential dischargers from regulatory oversight could have dramatic water quality and public health ramifications.

Effect of reducing the scope of regulatory jurisdiction and the ramifications to other CWA programs.

As discussed at length above, it is well recognized that controlling pollution at its source is the most effective way to achieve the goals of the Clean Water Act. In many watersheds, the sources of pollution and the majority of the pollutant loadings are in small streams. If ephemeral, intermittent or small perennial headwaters and, in some cases headwater wetlands and wetlands with non-traditional linkages, were no longer jurisdictional under the CWA, and unpermitted discharges were allowed in these waters, it could be very difficult to attain water quality standards or implement effective pollutant loading limits known as Total Maximum Daily Loads (TMDL) in downstream waters. This could have profound and far reaching affects to many CWA programs including section 303, 311, 401, 402, and 404 because many of the sources of pollution may no longer be regulated under the CWA. Although some states may have these authorities, it has been discussed above that the states' ability to effectively regulate these areas may be compromised as a result of the loss of CWA authority.

Although in many cases, states have authorities to control pollution discharges to streams, historically they have relied upon federal CWA authorities as an important "backstop" with respect to state water quality programs. This is especially true in the development of water quality standards and related programs such as TMDLs. Region III has, in fact, developed a number of TMDLs for states in various watersheds in the Region. By contrast, in Region III, the District of Columbia has not sought authorization to implement certain water quality programs, the NPDES program among them. With respect to the Oil Pollution Act (33 U.S.C. 1321-1322), this statute does not provide for delegation to the states, so CWA authorities remain the only source of protection for "waters of the United States" potentially impacted by oil spills.

The relationship between the geographic scope of jurisdiction under the CWA and water quality standards also raises questions regarding the implementation of Section 401 of the CWA, 33 U.S.C. 1344, and fairness among states. EPA's role as a "backstop" in the water quality standards area provides a "floor," ensuring that all states achieve minimal water quality standards. Because water by its nature does not recognize state boundaries, Section 401 provides a vehicle for downstream states to ensure that water flowing from upstream states achieves a minimum water quality. Section 401 requires that applicants for federal permits (under any program -- not just the CWA) that are likely to result in a discharge to "navigable waters" obtain a certification from affected states that the discharge will not cause a violation of the affected states' water quality standards. If upstream tributaries or other upstream waters are not deemed "navigable waters", discharges could be authorized by upstream states that could adversely impact the water quality in downstream states. There is a question in that circumstance whether the downstream states would have recourse pursuant to Section 401 or Section 402 (NPDES permits).

Source water protection is a program designed to protect drinking water by reducing the risks of contamination. This program provides a further "measure of protection" in addition to drinking water treatment. Each state is required to complete an assessment of every drinking water system to determine the susceptibility of public drinking water sources to possible contamination. This is done by first determining the land area that is contributing water to the drinking water source, conducting an inventory of potential sources of contamination in the delineated area, and determining the susceptibility of drinking water systems to those potential contaminant sources. This information is used to develop source water protection programs. Stakeholders are encouraged to participate in the development of each local protection plan. The contribution areas to public drinking water supplies should always be treated as unusually sensitive areas in applying other environmental laws and regulations.

Under a broad interpretation of the ANPRM, significant impacts to drinking water sources can also be expected. If regulation of pollutant discharges is compromised by changes in the regulatory definition of "waters of the United States" source water protection programs will likely be affected. Protection of the rivers, streams and lakes that are the sources of our drinking water can prevent contamination at a fraction of the costs of treatment. The Safe Drinking Water Act provides a provision for conducting Source Water Assessments, acquiring land or easements to protect drinking water sources, and provide assistance to small communities.

Under the federal environmental regulatory programs, protecting sources of drinking water is done by first designating surface waters for use as drinking water so that the authority of the Clean Water Act can be used to protect this activity. This designation also allows protection via other environmental laws such as Safe Drinking Water Act (Wellhead Protection, Sole Source Aquifer Protection, Underground Injection Control Programs), RCRA, CERCLA, and FIFRA. These programs provide authorities, financial support and technical assistance to protect sources of drinking water.

Removal of the source water protection measures afforded by the Clean Water Act will likely increase risks to human health and require additional infrastructure expenditures by public utilities using surface water intakes. In EPA Region III, between 148 and 526 surface drinking water intakes, serving populations ranging from 535,000 to 3 million people are potentially affected should first and second order streams be removed from Clean Water Act jurisdiction. Without federal limits or controls on these segments, point and non-point sources of contamination could likely increase. Public water suppliers could be required to do more treatment of source water to ensure public safety requirements were met. Contaminants such as Cryptosporidium and E. coli could likely increase in streams where municipal discharges and treatment facilities handling animal waste and animal by-products discharge into headwater streams.

4

Field Case Studies in Support of the US EPA Region III Response to the Advanced Notice of Proposed Rule making (ANPRM) on the Clean Water Act Regulatory Definition of "Waters of the United States"

Summary:

A total of 37 sites were evaluated in the field in order to provide some current field data to complement other aspects of the regional response to the ANPRM.

The primary findings were the following:

1. There is a wide diversity of wetlands that lack surface water connections or are headwater systems in Region III.
2. The interrelationship between headwater wetlands and wetlands with non-traditional linkages[1] and nearby terrestrial and aquatic systems is very diverse.
3. Groundwater is a major component of the hydrological interaction between wetlands, terrestrial and aquatic systems in the upper part of the watershed. Fully 73% of the assessed sites had groundwater pathways connecting them to downstream water bodies.
4. Many observed interrelationships between headwater wetlands or wetlands with non-traditional linkages and their surroundings require on-site interpretations. Soils data and landscape interpretation in particular were important in understanding hydrological relationships. Furthermore, it was found that the dynamics of the systems vary over time.
5. Many headwater wetlands or wetlands with non-traditional linkages are not displayed on widely used mapping and planning tools (e.g., 1:24,000 NWI or USGS maps).
6. Established wetland assessment methodologies identify a range of important ecological functions that are performed in wetlands (e.g., surface water detention and storage, water quality maintenance and/or improvement, ecosystem support). All 37 sites were found to perform the full range of ecological function on a qualitative basis.
7. The information gathered in the field confirms other aspects of the regional response to the ANPRM.

---

[1]For the sake of brevity, the term non-traditional linkages will hereinafter refer to wetlands hydrologically connected by non-perennial surface and/or groundwater flows.

Introduction:

In preparing for the ANPRM the wetland and stream staff of EPA Region III decided that a field component was necessary to support other aspects of the regional response. However, given the time and resource constraints it was decided to limit the field sites to those that met the following criteria:

1. Sites with existing data or sites that were known to the team members.
2. Sites that were readily accessible (e.g., public land or subject to ongoing studies).
3. Sites in headwater areas with wetlands that are located in landscape positions that are relevant to the issues in question.

Although the immediate question regarding the definition of "Waters of the United States" concerned "isolated" wetlands (i.e., isolated, intrastate, non-navigable waters), it was the opinion of the group that issues concerning headwaters were also relevant.

Preliminary field trials were conducted on 6 January 2003, at French Creek State Park (Berks County) in headwater areas of the Piedmont region of southeastern Pennsylvania. A draft protocol and accompanying forms were reviewed and modified during the field trials. The forms and protocol were put in final form (see attached) and three teams were organized to conduct field case studies in three areas:

1. French Creek and White Clay Creek in the Piedmont region of Pennsylvania and Delaware (PA/DE Team).
2. Several sites distributed throughout the Piedmont and Coastal Plain region of Delaware and Maryland (DE/MD Team).
3. Several sites in the Inner Coastal Plain region of Southeastern Virginia (VA Team).

The location of the field sites are illustrated on the attached map (Overview of Field Site Locations). Participants in the field included professionals from federal and state agencies as well as academic institutions. A total of 48 person days of effort was devoted to the field studies.

Although these selected sites do not represent the entire range of geographic diversity in the region, it is the opinion of the group that the wetlands and streams studied exemplify the characteristic ecological and hydrological relationships of wetlands and streams in isolated and/or headwater situations in EPA Region III.

Results:

A total of 37 sites were evaluated in the field. Appendix C contains the data sheets and functional evaluations and is available on request (Note: Forms A and B for all sites and the accompanying site maps comprise approximately 120 pages; the entire data set is approximately 300 pages long).

Table 1 summarizes the geographic locations of the 37 field sites. With regard to physiographic province, the sites are distributed as follows:

Physiographic Province	Number of field sites
Piedmont	10
Piedmont/Inner Coastal Plain	1
Inner Coastal Plain	11
Outer Coastal Plain	15

With regard to wetland "type" (see Field Protocol Figure 1), the sites are distributed as follows:

Wetland Type (Field Protocol Figure 1)	Number of field sites
Toe of Slope	2
Toe of Slope/Adjacent to Stream	2
Headwaters	7
Adjacent to Stream	6
Immediately Adjacent to Stream	12
Depression in Upland	4
Depression in Wetland	1
Depression in Floodplain	1
Flats	1

Table 2 displays the hydrological relationships between the wetlands and nearby systems (e.g., terrestrial and aquatic systems). With regard to the source of water for the wetlands, 31 of 37 (84%) are dependent on a mix of surface and groundwater sources. In five other cases groundwater is the sole water source and only one site (a perched Maryland headwater site) received all of its water from surface sources. Observations noted in the field indicated that the relative importance of the two water sources varies throughout the year, and on some occasions.

over longer time periods. The significance of groundwater at these sites exemplifies the importance of this hydrological component as a source of water for headwater wetlands or wetlands with non-traditional linkages.

The observed hydrologic connection between the headwater wetlands or wetlands with non-traditional linkages and nearby stream systems is more complex. A wide range of hydrologic pathways and the timing of their interaction were found at the field sites. In six cases (16%) all three of the hydrologic relationships evaluated (surface water, groundwater, overbank flooding) were found.

Fully 73% (27 of 37) of the sites studied had groundwater pathways connecting them to downstream water bodies. As was noted in the hydrological sources, groundwater varied in its importance over the year and frequently was one of several components linking downstream waters (groundwater was the exclusive connection at only three sites). In six (16%) cases the wetlands were totally isolated from downstream systems (five depressions, one flat and one perched headwater). Downstream connections via only surface channels or overbank flooding were found at only four (11%) sites.

On-site inspection was found to be important. On-site interpretation of the soils and the landscape were critical in understanding the hydrological relationships of the subject wetlands and their surroundings.

Table 3 displays the relationship of the 37 field sites with mapped wetland or streams. During the field inspections the longitude and latitude of the sites were determined with the use of the Global Positioning System (GPS). The GPS coordinates were cross referenced with 1:24,000 maps based on the National Wetland Inventory (NWI) and U. S. Geological Service (USGS) topographic maps to determine the proportion of the 37 headwater wetlands or wetlands with non-traditional linkages that had been identified on readily available maps. In both cases 19 of 37 (51%) were not found within mapped NWI polygons or adjacent to mapped streams. Given the scale of the maps and the potential lack of precision in cross referencing data points at the 1:24,000 scale, this information may have some error. Nevertheless, the fact that as many as half of the wetlands and streams in the headwaters may not be displayed on current maps is cause for concern. and highlights the need for on-site inspections. (see Appendix B for a more detailed analysis of this subject).

With regard to the qualitative functional assessment of the sites, all were found to perform the range of ecological function (e.g., surface water detention and storage, water quality maintenance and/or improvement, ecosystem support) that are identified in current wetland functional models to some degree. This was to be expected as the assessment was qualitative and none of the sites were highly degraded. It should be noted that a significant range ecological function is acknowledged for wetlands in this upper part of the landscape (see Appendices D, E and H for more detail).

Overview of Field Site Locations

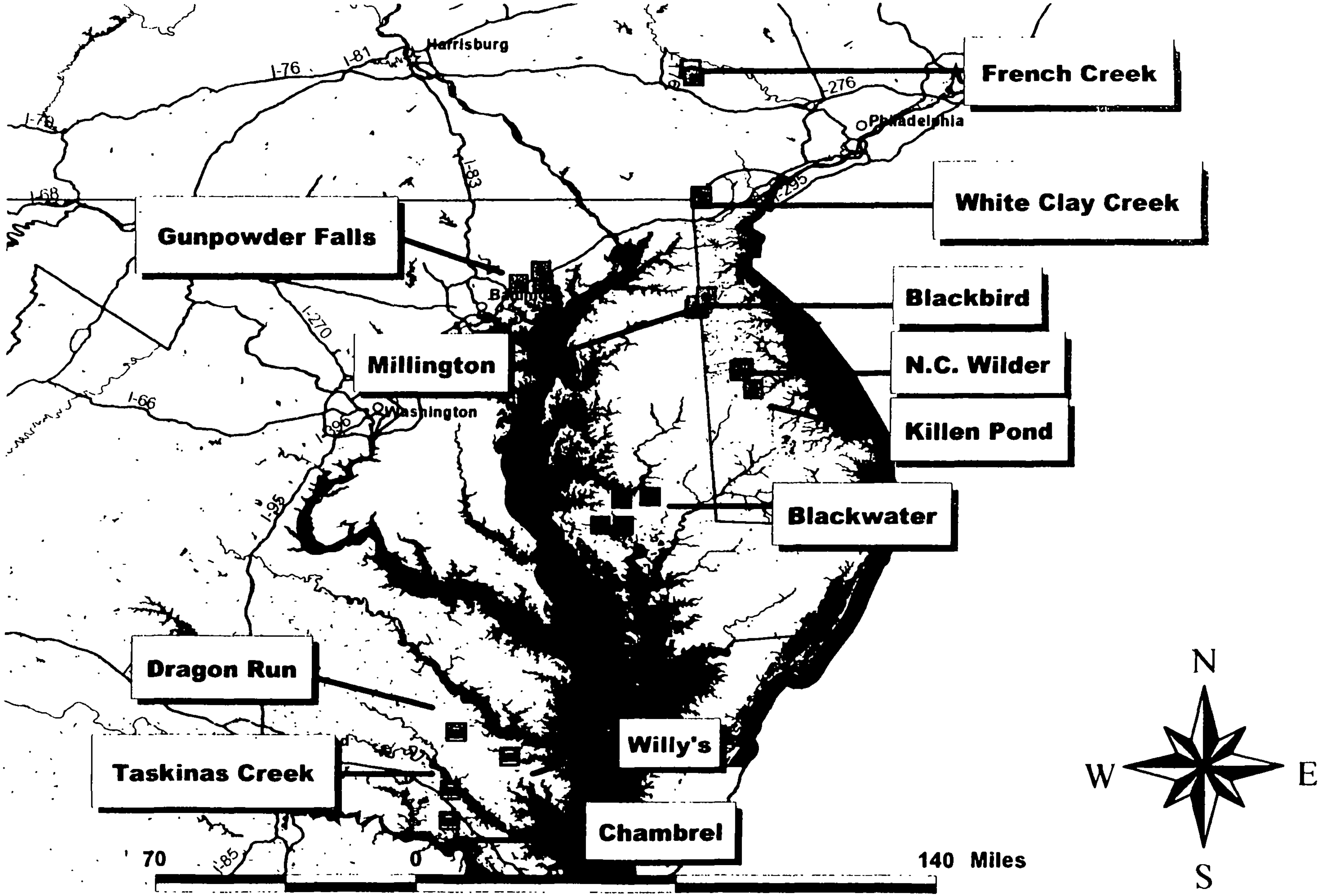


Table 1. Geographic Locations of Field Case Studies in Response to the ANPRM

Site	Name	State	County	Physiographic Province	Wetland Type (Field Protocol Figure 1)
1	Days Cove	MD	Baltimore	Inner Coastal Plain	Depression in upland
2	White Marsh	MD	Baltimore	Piedmont	Toe of slope
3	Gunpowder SE	MD	Baltimore	Piedmont	Headwater
4	Gunpowder NE	MD	Baltimore	Inner Coastal Plain/Piedmont	Immediately adjacent to stream
5	Gunpowder W	MD	Baltimore	Piedmont	Adjacent to stream
6	Blackwater SE	MD	Dorchester	Outer Coastal Plain	Broad mineral flat
7	Blackwater SW	MD	Dorchester	Outer Coastal Plain	Immediately adjacent to stream
8	Blackwater NW	MD	Dorchester	Outer Coastal Plain	Depression in upland
9	Blackwater	MD	Dorchester	Outer Coastal Plain	Depression in floodplain
10	Blackwater	MD	Dorchester	Outer Coastal Plain	Adjacent to stream
11	Killen Pond N	DE	Kent	Outer Coastal Plain	Immediately adjacent to stream
12	Killen Pond S	DE	Kent	Outer Coastal Plain	Headwater
13	N.C. Wilder NE-1	DE	Kent	Outer Coastal Plain	Depression in wetland
14	N.C. Wilder NE-2	DE	Kent	Outer Coastal Plain	Adjacent to stream
15	N.C. Wilder NW	DE	Kent	Outer Coastal Plain	Immediately adjacent to stream
16	N.C. Wilder SW	DE	Kent	Outer Coastal Plain	Mineral flat
17	Millington SC	MD	Kent	Inner Coastal Plain	Depression in upland (Delmarva Bay)
18	Millington SE-1	MD	Kent	Outer Coastal Plain	Immediately adjacent to stream
19	Millington SE-2	MD	Kent	Outer Coastal Plain	Adjacent to stream
20	Millington SW	MD	Kent	Outer Coastal Plain	Toe of slope
21	Millington N-1	MD	Kent	Outer Coastal Plain	Headwater
22	Millington N-2	MD	Kent	Inner Coastal Plain	Depression in upland (Delmarva Bay)
23	Blackbird	DE	New Castle	Inner Coastal Plain	Headwater
24	White Clay Creek-1	DE	New Castle	Piedmont	Immediately adjacent to stream
25	White Clay Creek-2	DE	New Castle	Piedmont	Immediately adjacent to stream (ditch)
26	White Clay Creek-3	DE	New Castle	Piedmont	Adjacent to stream/Toe of Slope
27	White Clay Creek-4	DE	New Castle	Piedmont	Adjacent to stream
28	French Creek-Six Penny-1	PA	Berks	Piedmont	Adjacent to stream/Toe of Slope
29	French Creek-Six Penny-2	PA	Berks	Piedmont	Immediately adjacent to stream
30	French Creek-Pine Swamp	PA	Berks	Piedmont	Headwater
31	Willy's Site	VA	Gloucester	Inner Coastal Plain	Immediately adjacent to stream
32	Dragon Run-1	VA	King and Queen	Inner Coastal Plain	Immediately adjacent to stream
33	Dragon Run-2	VA	King and Queen	Inner Coastal Plain	Adjacent to stream
34	Dragon Run-3	VA	King and Queen	Inner Coastal Plain	Headwater
35	Dragon Run-4	VA	King and Queen	Inner Coastal Plain	Headwater
36	Chambrel	VA	Williamsburg	Inner Coastal Plain	Immediately adjacent to stream
37	Taskinas Creek	VA	James City	Inner Coastal Plain	Immediately adjacent to stream

Table 2. Size and Hydrologic Relationships of Field Case Studies in Response to the ANPRM

Site	Name	Wetland Type (Field Protocol Figure 1)	Wetland Size Class*	Stream Order	Hydrology Source**	Hydrologic Connection***
1	Days Cove	Depression in upland	< 5	1	S/G Mix	G
2	White Marsh	Toe of slope	.5 - 1	---	S/G Mix	G, OVB
3	Gunpowder SE	Headwater	>2	---	S	Perched
4	Gunpowder NE	Immediately adjacent to stream	.5 - 1	2	S/G Mix	G, OVB
5	Gunpowder W	Adjacent to stream	>2	2	S/G Mix	OVB (Less Freq. Than Annual), Gunpowder Creek (> 10 ft.)
6	Blackwater SE	Broad mineral flat	---	2	S/G Mix	OVB
7	Blackwater SW	Immediately adjacent to stream	>2	---	S/G Mix	G, OVB, (Less Freq. Than Annual), Unnamed Stream (5-10 ft.)
8	Blackwater NW	Depression in upland	>2	---	S/G Mix	None
9	Blackwater	Depression in floodplain	5 - 1	2	S/G Mix	G, OVB, (Less Freq. Than Annual), Unnamed Stream (5-10 ft.)
10	Blackwater	Adjacent to stream	>2	2	S/G Mix	S (Perennial, 5-10 ft.), G, OVB (Annual), Chicone Creek (5-10 ft.)
11	Killen Pond N	Immediately adjacent to stream	>2	1 - 2	S/G Mix	G, OVB (Annual), Unnamed Tributary to Murdekill Creek (5-10 ft.)
12	Killen Pond S	Headwater	1 - 2	---	S/G Mix	S (Intermittent, 5-10 ft.), G
13	N.C. Wilder NE-1	Depression in wetland	>2	2	S/G Mix	None
14	N.C. Wilder NE-2	Adjacent to stream	>2	---	S/G Mix	S (Intermittent, 5-10 ft.), Unnamed Tax Ditch
15	N.C. Wilder NW	Immediately adjacent to stream	>2	---	S/G Mix	S (Intermittent, 5-10 ft.), Unnamed Tax Ditch, G
16	N.C. Wilder SW	Mineral flat	>2	---	S/G Mix	None
17	Millington SC	Depression in upland (Delmarva Bay)	5 - 1	---	S/G Mix	None
18	Millington SE-1	Immediately adjacent to stream	5 - 1	3 or 4	S/G Mix	S (Perennial, > 10 ft.), G, OVB (Annual), Unnamed Stream (> 10 ft.)
19	Millington SE-2	Adjacent to stream	>2	3 or 4	S/G Mix	G, OVB (Once Every 2 Years), Unnamed Stream (> 10 ft.)

Table 2. Size and Hydrologic Relationships of Field Case Studies in Response to the ANPRM

e	Name	Wetland Type (Field Protocol Figure 1)	Wetland Size Class*	Stream Order	Hydrology Source**	Hydrologic Connection***
20	Millington SW	Toe of slope	>2	3	S/G Mix	S (Intermittent, < 5 ft), G. OVB (Multiple Events Annually), Cypress Branch (> 10 ft)
21	Millington N-1	Headwater	1 - 2	1	S/G Mix	S (< 5 ft.), G
22	Millington N-2	Depression in upland (Delmarva Bay)	1 - 2	---	S/G Mix	None
23	Blackbird	Headwater	>2	1	S/G Mix	S (Intermittent, 5-10 ft), G
24	White Clay Creek-1	Immediately adjacent to stream	< 5	---	S/G Mix	S (Intermittent, < 5 ft.), G, OVB (Annual), Unnamed Tributary to White Clay Creek (5-10 ft.)
25	White Clay Creek-2	Immediately adjacent to stream (ditch)	< 5	Ditch	S/G Mix	S (Intermittent, < 5 ft.), G
26	White Clay Creek-3	Adjacent to stream/Toe of Slope	1 - 2	---	S/G Mix	S (Intermittent and Ephemeral < 5 ft.), Unnamed Tributary to White Clay Creek (5-10 ft), G
27	White Clay Creek-4	Adjacent to stream	1 - 2	Ditch	S/G Mix	S (Unknown, < 5 ft), G
28	French Creek-Six Penny-1	Adjacent to stream/Toe of Slope	< 5	1	S/G Mix	S (Intermittent, < 5 ft), G
29	French Creek-Six Penny-2	Immediately adjacent to stream	>2	1	S/G Mix	G
30	French Creek-Pine Swamp	Headwater	>2	1	S/G Mix	S (Intermittent, 5-10 ft), Unnamed Tributary to Scots Run (5-10 ft), G
31	Willy's Site	Immediately adjacent to stream	>2	1	G	G
32	Dragon Run-1	Immediately adjacent to stream	>2	2	S/G Mix	S (Perennial, < 5 ft.), G, OVB (Annual). Unnamed Tributary to Dragon Run (5-10 ft)
33	Dragon Run-2	Adjacent to stream	1 - 2	1	G	S (Intermittent 5-10 ft.), Unnamed Tributary to Dragon Run, G
34	Dragon Run-3	Headwater	5'- 1	---	G	S (Ephemeral, < 5 ft.), Unnamed Tributary to Dragon Run (5-10 ft), G
35	Dragon Run-4	Headwater	5 - 1	---	G	S (Intermittent, 5-10 ft), Unnamed Tributary to Dragon Run (5-10 ft), G

Table 2. Size and Hydrologic Relationships of Field Case Studies in Response to the ANPRM

te	Name	Wetland Type (Field Protocol Figure 1)	Wetland Size Class*	Stream Order	Hydrology Source**	Hydrologic Connection***
36	Chambrel	Immediately adjacent to stream	>2	1	G	G, OVB (Annual), Unnamed Tributary to College Creek (5-10 ft.)
37	Taskinas Creek	Immediately adjacent to stream	>2	2	S/G Mix	S (Intermittent, < 5 ft.), G, OVB (Annual). Unnamed Tributary to Taskinas Creek (5-10 ft.)

***Wetland Size Class: Area in Acres**
****Hydrology Source: S-Surface; G-Groundwater**
*****Hydrologic Connection: S-Surface-Indicates Visible Channel Connection; OVB-Indications of Overbank Flooding; G-Groundwater-Indications of Groundwater Discharge Through the Wetland and into the Stream; Distances are Widths between Bank Tops of Associated Streams**

Table 3. Mapped Wetlands and Streams* in Relation to Field Case Study Sites in Response to the ANPRM

Site	Name	Wetland Type (Field Protocol Figure 1)	NWI	Stream	Site	Name	Wetland Type (Field Protocol Figure 1)	NWI	Stream
1	Days Cove	Depression in upland	N	Y	20	Millington SW	Toe of slope	Y	N
2	White Marsh	Toe of slope	N	N	21	Millington N-1	Headwater	N	N
3	Gunpowder SE	Headwater	N	Y	22	Millington N-2	Depression in upland (Delmarva Bay)	N	N
4	Gunpowder NE	Immediately adjacent to stream	N	Y	23	Blackbird	Headwater	Y	N
5	Gunpowder W	Adjacent to stream	N	Y	24	White Clay Creek-1	Immediately adjacent to stream	N	Y
6	Blackwater SE	Broad mineral flat	Y	N	25	White Clay Creek-2	Immediately adjacent to stream (ditch)	Y	N
7	Blackwater SW	Immediately adjacent to stream	Y	Y	26	White Clay Creek-3	Adjacent to stream/Toe of Slope	Y	N
8	Blackwater NW	Depression in upland	N	N	27	White Clay Creek-4	Adjacent to stream	N	N
9	Blackwater	Depression in floodplain	Y	Y	28	French Creek-Six Penny-1	Adjacent to stream/Toe of Slope	N	Y
10	Blackwater	Adjacent to stream	Y	Y	29	French Creek-Six Penny-2	Immediately adjacent to stream	N	Y

Table 3. Mapped Wetlands and Streams* in Relation to Field Case Study Sites in Response to the NPRM

Site	Name	Wetland Type (Field Protocol Figure 1)	NWI	Stream	Site	Name	Wetland Type (Field Protocol Figure 1)	NWI	Stream
11	Killen Pond N	Immediately adjacent to stream	N	N	30	French Creek-Pine Swamp	Headwater	N	Y
12	Killen Pond S	Headwater	N	N	31	Willy's Site	Immediately adjacent to stream	Y	Y
13	N.C Wilder NE-1	Depression in wetland	N	N	32	Dragon Run-1	Immediately adjacent to stream	Y	Y
14	N C Wilder NE-2	Adjacent to stream	N	N	33	Dragon Run-2	Adjacent to stream	Y	Y
15	N C Wilder NW	Immediately adjacent to stream	N	N	34	Dragon Run-3	Headwater	Y	Y
16	N C Wilder SW	Mineral flat	Y	N	35	Dragon Run-4	Headwater	Y	Y
17	Millington SC	Depression in upland (Delmarva Bay)	Y	N	36	Chambrel	Immediately adjacent to stream	N	N
18	Millington SE-1	Immediately adjacent to stream	Y	N	37	Taskinas Creek	Immediately adjacent to stream	Y	Y
19	Millington SE-2	Adjacent to stream	Y	Y					

* Field Case Study Sites Associated with Mapped Wetlands and Streams on National Wetland ventory (NWI) and USGS Topographic Maps at the 1:24,000 Scale

VULNERABLE STREAM AND WETLAND STUDY FIELD PROTOCOL GUIDANCE

In accordance with the objectives of the study the field effort is designed to develop case studies which will exemplify the issues at hand concerning intrastate isolated and headwater wetlands. The guidance below is designed to ensure that the field work and forms are used in as consistent a manner as feasible throughout EPA Region III. Please note on the forms your rationales for decision making. In cases where you determine that interpretations or additions are called for, please note them in sufficient detail that other reviewers can determine your thought process.

Form A is self explanatory as it is designed to identify the site location and general characteristics as well as identify remote sensing and on-site graphic tools that you used.

Form B may require several copies per site depending on the number of discrete wetlands (or wetland classes) that you identify on-site. Of course, some information (e.g. main stem stream characteristics) may be redundant and may require only one entry of such data. Documentation of rationales for decision making is important as best professional judgement of the group may be critical in some circumstances.

By "wetland classes" we mean groups of wetlands that are determined to have the same relative location (see Figure 1), hydrologic relationships (internally, externally and with respect to the stream). For example you may find five wetlands of which one is immediately adjacent, one is adjacent and three are headwaters. In this case you have three classes and though you would identify each separately you are acknowledging that the three headwater wetland have common environmental features.. Please also note that the terms used (e.g. adjacent, headwater) are for descriptive purposes only and to not refer to their use in Clean Water Act regulations.

With regard to the soil characteristics, attention should be given to the evidence interpreted by the soil scientist as it relates to the wetland-stream relationship, on-site hydrology, and the ecological function of the wetland.

Form C is in two versions:

(1) RVP (Ridge and Valley/Piedmont) is based on the HGM (Hydrogeomorphic Approach to the Functional Assessment of Wetlands) models developed at the Penn State Cooperative Wetland Center focusing on the Upper Juniata Watershed and other areas in PA.

(2) CP (Coastal Plain) which is based on comparable HGM work in the Nanticoke Watershed of DE and MD by DNREC, MD DNR and the Smithsonian Environmental Research Center.

The form is designed to **qualitatively** determine whether or not particular functions are being performed by the wetlands studied. Each function has listed the primary factors which make up the individual models. Although the variables are designed for quantitative measures and calculations, this case study is limited to a qualitative assessment only.

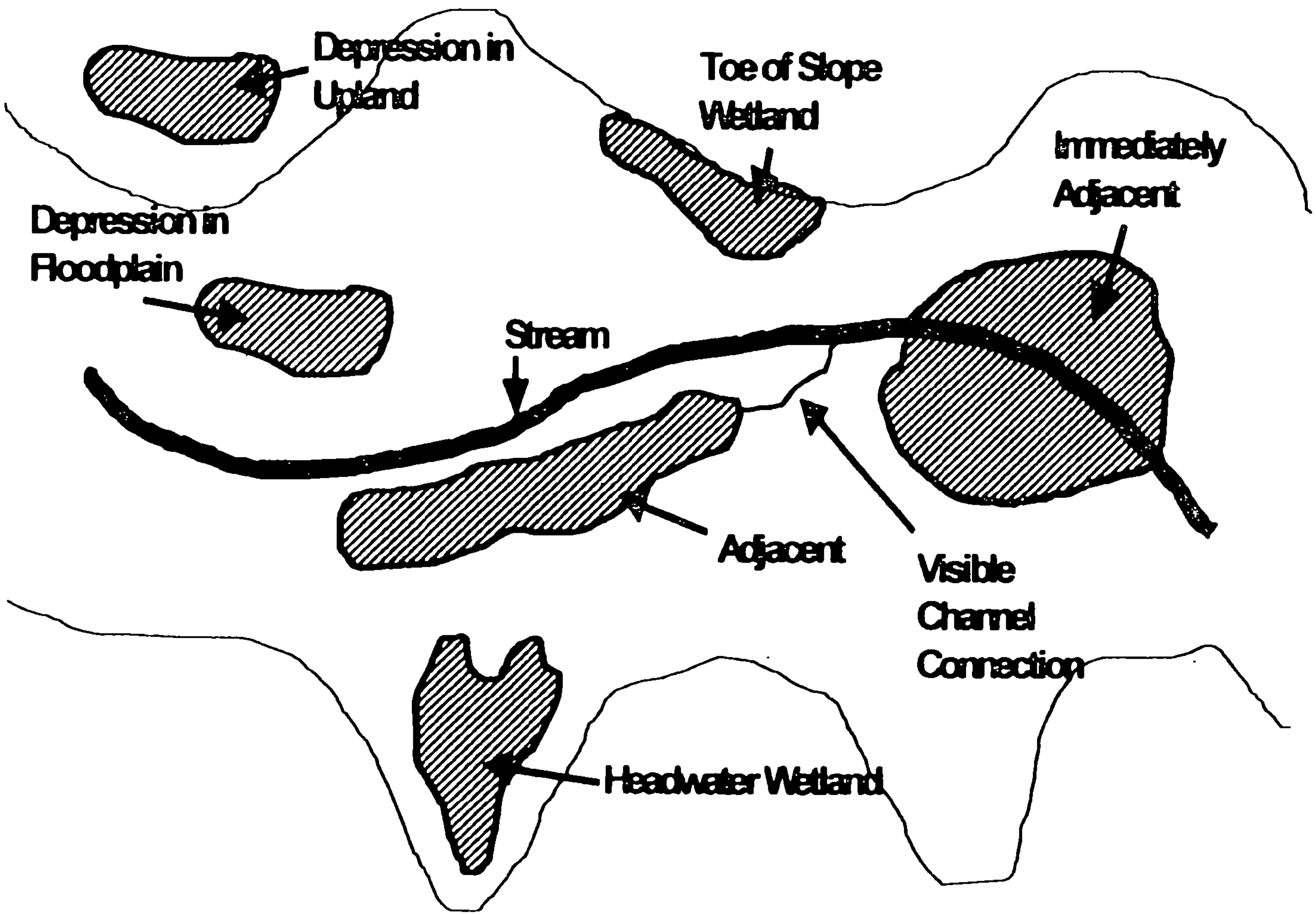
A "Yes" determination indicates that the team has determined that the function is being performed at some level. By checking that all or most of the variables associated with a model are in evidence, the team determines that the function is scored a qualitative "Yes".

A "No" determination indicates that the team does not believe that the function is being performed and that all or most of the relevant variables are **not** observed in any measurable quantity.

An "Unknown" determination indicates that these is insufficient information to make a determination or that wide differences of opinion are found within the team (if so, please document).

A supplemental Form (Site Inspection Map) was discarded from the original form mix but may be useful in documenting photos of the site and wetlands.

Figure 1: Graphic Illustration of Wetland/Stream Relationship in First and Second Order Streams



HEADWATER/ISOLATED WETLAND FIELD PROTOCOL
MAP /GEOGRAPHY INVENTORY (FORM A)

GENERAL LOCATION:

STATE: __DE __MD __PA __VA __WV

COUNTY: ______________________________

PHYSIOGRAPHIC PROVINCE:

__COASTAL PLAIN __Outer/Lower Atlantic __Inner/Upper Atlantic __L. Erie
__PIEDMONT
__RIDGE AND VALLEY
__APPALACHIAN PLATEAU
__BLUE RIDGE
__OTHER ______________________________

LATITUDE/LONGITUDE (GPS) ______________________________

MAPS:

__USGS TOPO QUAD Name: ______________________________

__NATIONAL WETLAND INVENTORY Name: ______________________________

__USDA SOIL SURVEY Publication Date: ______________________________

AERIAL PHOTOGRAPHS:	DATE (S)	SCALE
__BLACK AND WHITE	____________	____________
__COLOR	____________	____________
__FALSE COLOR IR	____________	____________

OTHER MEDIA (DESCRIBE): ______________________________
____
____
____
____
____
____

HEADWATER/ISOLATED WETLAND FIELD PROTOCOL
SITE INSPECTION/EVALUATION (FORM B) 29 Jan 03

Environmental Setting :

Stream: (Avg. Width between bank tops: ___ <5 ft. ___ 5-10 ft. ___ >10 ft.)

___ Named Stream: ______________________________ Ditched? ___Y ___N

___Unnamed Tributary to Named Stream: ______________________ Ditched? ___Y ___N

___ Unnamed Stream Ditched? ___Y ___N

Stream Order: ___ First ___ Second ___ Other Comments: ______________

Wetland Size: ___ <.5 acre ___.5-1 acre ___ 1-2 acres ___>2 acres

Wetland Type: ___ PFO ___ PSS ___ PEM

___ Other Cowardin Cover Type (Specify) ______________________

Wetland Location (see Figure 1):

___ Immediately adjacent to stream (i.e. stream and wetland with no intervening community).
___ Adjacent to stream (i.e. natural levee or other intervening community).
___ Outer part of floodplain (e.g. toe of slope)
___ Depression in uplands (e.g. sloughs, vernal pools embedded in riparian or terrestrial habitat).
___ Headwater wetland to stream (e.g. located at the top of the watershed or subwatershed and discharges to the stream). Or: ___ Other (e.g. depressions in the floodplain) describe:

____

Rationale: ______________________

Hydrology-Wetland/Stream Connection (Check all that apply):

___ Y ___ N Visible channel connection (Avg. Width between bank tops: ___ <5 ft. ___ 5-10 ft. ___ >10 ft.)

Channel hydrology: ___ Perennial ___ Intermittent ___ Ephemeral ___ Unknown?

Rationale: ______________________

___ Y ___ N Overbank flooding from stream--evidence and estimated frequency of occurrence:

___ Annual ___ Less Frequent **Rationale:** ______________________

___ Y ___ N Groundwater discharge through wetland into stream? **Rationale:** ______________

Hydrology-Predominant wetland source: ___ Surface Water ___ Groundwater

___ Surface/Groundwater Mix **Rationale:** ______________________

Hydrology-Wetland Characteristics: ___ Braided Channel Network

___ One or Several Discernable Channels ___ Significant Pit and Mound Microtopography

<u>Soil Characteristics–Wetland:</u>

___ Mapped Hydric Soil ___ Soil w Hydric Inclusions ___ Floodplain Soil ___ Other

Field Indicator______________________________
Landscape Position ______________________________
Taxonomic Classification ______________________________
Soil Series (if applicable) ______________________________
Surface O horizon(s): Thickness ____________________ Color __________
Surface A horizon(s): Thickness ____________________ Color __________
Particle size class: ______________________________
Permeability: ______________________________
Does soil have platy structure at or near the surfacedue to compaction? ___ Yes ___ No

Notes (may include brief description): ______________________________

____

____

____

____

____

Based on the soils information found on site what can a soil scientist conclude about the wetland and stream hydrodynamics. In other words, where is the water coming from, how does it interact with other environmental features on site and how does the water leave the wetland/stream complex? What are the critical soil characteristics that help you in reaching these conclusions (e.g. textures, critical soil factors at certain depths in the profile, etc.)? In your opinion what are the most informative field indicators of hydric soils found at this site? ______________________________

____

____

____

____

____

____

____

HEADWATER/ISOLATED WETLAND FIELD PROTOCOL
SITE INSPECTION/EVALUATION (FORM C) RVP

FUNCTION	Y	N	UNK	FACTORS (Reference: Attached HGM Models and Variable Descriptions)
1.1 Energy Dissipation/Short-Term Surface Water Detention				___ V_{floodp} = Characteristic hydrology of floodplain ___ $V_{unobstruc}$ = affected by higher densities of roads, urban development and hydrologic modifications within a 1 km radius of the site (i.e. less of these adds to function) ___ V_{grad} = Elevational gradient of floodplain based on topographic maps ___ V_{rough} = Manning's coefficient. an aggregate of density of standing wood, basal area of standing wood, shrub cover, percent herb cover, coarse woody debris and microtopography
1.2 Long Term Surface Water Storage				___ V_{floodp} = Characteristic hydrology of floodplain ___ $V_{unobstruc}$ = affected by higher densities of roads, urban development and hydrologic modifications within a 1 km radius of the site ___ V_{macro} = Macrotopographic relief or areas greater that the depression left by a large tree windfall or about 10m^2) ___ V_{redox} = Presence of redoxymorphic features in the upper soil profile based on matrix and mottle chromas, etc.
1.5 Removal of Imported Inorganic Nitrogen				___ V_{redox} = Presence of redoxymorphic features in the upper soil profile based on matrix and mottle chromas, etc. ___ $V_{biomass}$ = Combination of % cover of trees, shrubs, and herbs, to indicate vegetative biomass at the site as well as an indicator of vegetative cover in the roughness variable ___ V_{orgma} = % organic content in the top 5 cm of soil below the organic layer
1.6 Solute Adsorption Capacity (e.g. toxicant retention/removal)				___ V_{floodp} = Characteristic hydrology of floodplain ___ $V_{unobstruc}$ = affected by higher densities of roads, urban development and hydrologic modifications within a 1 km radius of the site (i.e. less of these adds to function) ___ V_{rough} = Manning's coefficient: an aggregate of density of standing wood, basal area of standing wood, shrub cover, percent herb cover, coarse woody debris and microtopography ___ V_{redox} = Presence of redoxymorphic features in the upper soil profile based on matrix and mottle chromas, etc ___ V_{macro} = Macrotopographic relief or areas greater that the depression left by a large tree windfall or about 10m^2) ___ V_{orgma} = % organic content in the top 5 cm of soil below the organic layer ___ V_{tex} = Soil texture determined by feel

FUNCTION	Y	N	UNK	FACTORS (Reference: Attached HGM Models and Variable Descriptions)
I 7 Retention of Inorganic Particulates (e g sediment retention)				___ V_{floodp} = Characteristic hydrology of floodplain ___ $V_{unobstruc}$ = affected by higher densities of roads, urban development and hydrologic modifications within a 1 km radius of the site (i.e. less of these adds to function) ___ V_{rough} = Manning's coefficient an aggregate of density of standing wood, basal area of standing wood, shrub cover, percent herb cover, coarse woody debris and microtopography ___ V_{macro} = Macrotopographic relief or areas greater that the depression left by a large tree windfall or about $10m^2$) ___ V_{grad} = Elevational gradient of floodplain based on topographic maps
I 8a Export of Organic Particulates (e g ecosystem support/primary production)				___ V_{floodp} = Characteristic hydrology of floodplain ___ $V_{unobstruc}$ = affected by higher densities of roads, urban development and hydrologic modifications within a 1 km radius of the site (i e. less of these adds to function) ___ V_{orgma} = % organic content in the top 5 cm of soil below the organic layer ___ V_{FWD} - Visual estimate of depth of litter layer from HSI models ___ $V_{CWD\ BA}$ = Estimate of coverage of coarse woody debris along a transect ___ $V_{CWD\ SZ}$ = Presence of coarse woody debris in three size classes ___ V_{snags} = Presence of dead standing trees in four size classes
I 8b Export of Dissolved Organic Matter (e g ecosystem support/primary production)				___ V_{floodp} = Characteristic hydrology of floodplain ___ $V_{unobstruc}$ = affected by higher densities of roads, urban development and hydrologic modifications within a 1 km radius of the site (i.e less of these adds to function) ___ V_{macro} = Macrotopographic relief or areas greater that the depression left by a large tree windfall or about $10m^2$) ___ V_{redox} = Presence of redoxymorphic features in the upper soil profile based on matrix and mottle chromas, etc ___ V_{orgma} = % organic content in the top 5 cm of soil below the organic layer ___ V_{FWD} = Visual estimate of depth of litter layer from HSI models ___ $V_{CWD\ BA}$ = Estimate of coverage of coarse woody debris along a transect ___ $V_{CWD\text{-}SZ}$ = Presence of coarse woody debris in three size classes ___ V_{snags} = Presence of dead standing trees in four size classes
I 9 Maintain characteristic Native Plant Community Composition and Structure				___ $V_{sppcomp}$ = Adjusted FQAI (Floristic Quality Assessment Index) scores for sites (i.e. proportion of native plant species) ___ V_{regen} = Evidence of regeneration of dominant canopy species in each stratum ___ V_{exotic} = Average % of invasive species in 1 m^2 plots (i e. more invasive species diminishes function)
I 10 Maintain Characteristic Detrital Biomass				___ $V_{CWD\ BA}$ = Estimate of coverage of coarse woody debris along a transect ___ $V_{CWD\ SZ}$ = Presence of coarse woody debris in three size classes

9/4/02

Summary of HGM Functional Assessment Models

F1 – Energy Dissipation/Short term Surface Water Detention

Floodplains (Headwater and Mainstem):

$= (V_{FLOODP} - (1 - V_{UNOBSTRUC})) * (V_{GRAD} + V_{ROUGH})/2$

Slopes:

$= (V_{SLOPE}) * (V_{GRAD} + V_{ROUGH})/2$

F2 – Long-term Surface Water Storage

Floodplains.

$= (V_{FLOODP} - (1 - V_{UNOBSTRUC})) * (V_{MACRO} + V_{REDOX})/2$

***F3 – Maintain Characteristc Hydrology** (non-riverine subclasses)*

$= V_{HYDROCHAR} - V_{HYDROSTRESS}$

F4 – Blank

F5 – Removal of Imported Inorganic Nitrogen

All subclasses:

$= (V_{REDOX} + V_{BIOMASS} + V_{ORGMA})/3$

F6 – Solute Adsorption Capacity

Floodplains:

$= (V_{FLOODP} - (1 - V_{UNOBSTRUC})) * [(V_{ROUGH} + V_{REDOX} + V_{MACRO})/3 + (V_{ORGM} + 1 - V_{TEX})/2]/2$

Slopes:

$= (V_{SLOPE}) * [(V_{ROUGH} + V_{REDOX} + V_{MACRO})/3 + (V_{ORGM} + 1 - V_{TEX})/2]/2$

Riparian Depressions:

$= (V_{HYDROSTRESS}) * [(V_{ROUGH} + V_{REDOX})/2 + (V_{ORGM} + 1 - V_{TEX})/2]/2$

F7 – Retention of Inorganic Particulates

Floodplains:

$= (V_{FLOODP} - (1 - V_{UNOBSTRUC})) * (V_{ROUGH} + V_{MACRO} + V_{GRAD})/3$

Slopes:

$= (V_{SLOPE}) * (V_{ROUGH} + V_{MACRO})/2$

By definition depressions receive a score of 1.

F8a – Export of Organic Particulates

Floodplains:

$= (V_{FLOODP} - (1 - V_{UNOBSTRUC})) * [(V_{ORGM} + V_{FWD}/2) + (V_{CWD\text{-}BA} + V_{CWD\text{-}SZ} + V_{SNAGS}/3)]/2$

01/08/2003 14:00 8146637193

Slopes:
$= V_{SLOPE} * [(V_{ORGM} + V_{FWD}/2) + (V_{CWD\text{-}BA} + V_{CWD\text{-}SZ} + V_{SNAGS}/3)]/2$

F8b – Export of Dissolved Organic Carbon
Floodplains:
$= (V_{FLOODP} + (1\text{-}V_{UNOBSTRUC})) * [(V_{MACRO} + V_{REDOX})/2 + (V_{ORGM} + V_{FWD})/2 + (V_{CWD\text{-}BA} + V_{CWD\text{-}SZ} + V_{SNAGS})/3]/3$

Slopes:
$= (V_{SLOPE}) * [(V_{MACRO} + V_{REDOX})/2 + (V_{ORGM} + V_{FWD})/2 + (V_{CWD\text{-}BA} + V_{CWD\text{-}SZ} + V_{SNAGS})/3]/3$

Riparian Depressions:
$= F3 * [(V_{REDOX} + (V_{ORGM} + V_{FWD})/2 + (V_{CWD\text{-}BA} + V_{CWD\text{-}SZ} + V_{SNAGS})/3]/3$

F9 – Maintain Characteristic Native Plant Community Composition (and Structure)
All Subclasses:
$= [(V_{SPPCOMP} * 0.66 + V_{REGEN} * 0.33) + V_{EXOTIC}]/2$

F10 – Maintain Characteristic Detrital Biomass
All Subclasses:
$= [(V_{CWD\text{-}BA} + V_{CWD\text{-}SIZE}/2) + V_{FWD} + V_{SNAGS} + V_{ORGMA}]/4$

***F11 – Vertebrate Community Structure and Composition* - all subclasses**
Used HSI scores

F12 – Maintain Landscape Scale Biodiversity
All subclasses
$= (V_{AQCON} + V_{UNDEVEL} + V_{SDI} + V_{MPS})/4$

9/4/02

Summary of variables used in HGM functional assessment models

V_{AQCON} – Degree of aquatic connectivity in a 1 km radius circle surrounding site. Made up of a combination of three indices: presence in 100 year floodplain, stream density index, and distance to nearest NWI wetland.

$V_{BIOMASS}$ - Combination of % cover of trees, shrubs, and herbs, to indicate vegetative biomass at the site as well as an indicator of vegetative cover in the roughness variable.

V_{CWD-BA} - Estimate of coverage of coarse woody debris along a transect.

$V_{CWD-SIZE}$ – Presence of coarse woody debris in three size classes.

V_{EXOTIC} - Average % cover of invasive species in 1 m^2 plots

V_{FLOODP} – Presently used as a placeholder for floodplain wetlands, should represent characteristic hydrology of floodplain

V_{FWD} – Visual estimate of depth of litter layer from HSI models

V_{GRAD} – Elevational gradient of the floodplain based on topographic maps

$V_{HYDROCHAR}$ - Presently used as a placeholder for depression wetlands, should represent characteristic hydrology of groundwater supported wetlands

$V_{HYDROSTRESS}$ – Indicators of hydrologic modifications from stressor checklist

V_{MACRO} – Macrotopographic relief identified along a transect

V_{MPS} - Mean forested patch size within a 1 km radius circle

V_{ORGMA} - % organic content in the top 5 cm of soil below organic layer

V_{REDOX} – Presence of redoximorphic features in the upper soil profile based on mottle and matrix chromas.

V_{REGEN} – Evidence of regeneration of dominant canopy species in each stratum

V_{ROUGH} – Based on Manning's roughness coefficient, using a composite weighting score based on flow resistance at the site (CWD, microtopography, and vegetation).

V_{SDI} - Natural log of the Shannon diversity index of eight landscape categories in the a 1 km radius circle around the site

V_{SLOPE} – Percent slope of wetland surface

V_{SNAGS} – Presence of dead standing trees in four size classes

$V_{SPPCOMP}$ – Adjusted FQAI scores for sites

V_{TEX} – Soil texture determined by feel

$V_{UNDEVEL}$ – Landscape variable made up of the average of two sub-variables:

- V_{RDDEN} – density of roads in 1km radius circle
- V_{URB} - % of 1 km radius circle in urban development

$V_{UNOBSTRUC}$ – Used for floodplain wetlands to represent characteristics that would cause a deviation from reference standard in the functioning of the floodplain. Made up of the average of three subvariables:

- V_{RDDENS} – density of roads in a 1 km radius circle surrounding site
- V_{URB} - % of 1 km radius circle in urban developement
- $V_{HYDROSTRESS}$ – indicators of hydrologic modifications from stressor checklist

HEADWATER/ISOLATED WETLAND FIELD PROTOCOL
SITE INSPECTION/EVALUATION (FORM C) CP

FUNCTION	Y	N	UNK	FACTORS (Reference: Attached HGM Models and Variable Descriptions)
Maintain Characteristic Hydrology				____$V_{streamout}$ = Stream condition outside the Assessment Area (AA)(**Best:** No channelization, dams or road crossings within 500m upstream or downstream of the AA; **Worst:** Major channelization of stream within 500m of AA, levees on one or both sides of channel, further reducing overbank flow. ____$V_{floodplain}$ = Floodplain Condition [**Best:** No alterations of the floodplain (i e. ditches, mechanical alterations to substrate, fill, and/or excavations within the AA, **Worst:** >75% of the floodplain within the AA has been altered (i.e ditches that provide effective drainage, impoundment of water, excavation of substrate and/or deposition of fill) and restoration is possible]. ____$V_{streamin}$ = Stream condition inside the AA (**Best: No channelization, dams or road crossings in the AA; Worst:** Major channelization of stream within 500m of AA, levees on one or both sides of channel, further reducing overbank flooding, restoration possible)
Maintain Characteristic Biogeochemistry				____V_{TBA} = Basal area of trees (**Best:** Tree basal area ≥ 35.6 m²/ha in the AA, **Worst:** Tree basal area < 3.56 m²/ha and restoration possible) ____$V_{streamout}$ = Stream condition outside the Assessment Area (**Best:** No channelization, dams or road crossings within 500m upstream or downstream of the AA, **Worst:** Major channelization of stream within 500m of AA, levees on one or both sides of channel, further reducing overbank flow. ____$V_{floodplain}$ = Floodplain Condition [**Best:** No alterations of the floodplain (i e ditches, mechanical alterations to substrate, fill, and/or excavations within the AA; **Worst:** >75% of the floodplain within the AA has been altered (i e. ditches that provide effective drainage, impoundment of water, excavation of substrate and/or deposition of fill) and restoration is possible]. ____$V_{streamin}$ = Stream condition inside the AA (**Best:** No channelization, dams or road crossings in the AA, **Worst:** Major channelization of stream within 500m of AA; levees on one or both sides of channel, further reducing overbank flooding, restoration possible)

Maintain Characteristic Plant Community				___ V_{herb} = Herbaceous vegetation composition (**Best:** *Mitchella repens* present in ≥20% of plots sampled and none of the following genera present; *Andropogon, Dicanthelium, Rhynchospora, Solidago* and *Panicum*, Worst Dominant plants are agricultural species but restoration is possible) ____ V_{tree} = Tree species composition (**Best:** *Chamaecyparis thyoides, Taxodium distichum*, or *Nyssa sylvatica* are present as canopy species in the AA and there are no facultative upland tree species present, **Worst:** No trees present; AA is dominated by herbaceous vegetation and/or saplings, and restoration is possible) ____ $V_{sapling}$ = Sapling species composition (**Best:** *Chamaecyparis thyoides, Taxodium distichum*, or *Nyssa sylvatica* are present as saplings in the AA and there are no facultative upland tree species present as saplings; **Worst:** No saplings present; AA is dominated by herbaceous vegetation and restoration is possible) ____ V_{vine} = Vine and vine-like species (*Rubus* spp. occur in ≤25% of the plots sampled in the AA; Worst *Rubus* spp. occur in all of the plots sampled in the AA) ____ $V_{invasive}$ = Invasive species (**Best:** no invasive species except *Lonicera japonica* which has a mean cover of ≤5% in the sampled area, Worst: Mean invasive species cover for the AA is ≥90%, and the forested floodplain has been converted to another land use, though restoration is possible (i.e. agriculture))

PROPOSED FUNCTIONS AND FORMULA FOR RIVERINE SUBCLASS NANTICOKE RIVER ASSESSMENT STUDY

Maintain Characteristic Hydrology

Logic: Hydrology is perhaps the most important functions to consider on any assessment of riverine wetlands. Three variables (stream condition in the assessment area, floodplain condition in the assessment area, and stream condition outside the assessment area) each differ between Reference and Reference Standard sites. The a-team considered Vstreamin to the most important variable and suggested using it as a multiplier to determine the FCI score. They also considered that the conditions of the floodplain within the Assessment Area should be given higher loading in the equation than $V_{STREAMOUT}$ or $V_{FLOODPLAIN}$. Accordingly, the value for $V_{FLOODPLAIN}$ is given twice the weight as $V_{STREAMOUT}$

$$FCI_{HYDROLOGY} = ((V_{STREAMOUT} + 2(V_{FLOODPLAIN})/3)*V_{STREAMIN})^{*}$$

Maintain Characteristic Biogeochemistry

Logic: Nutrient cycling is an important ecological function in riverine wetlands. The A-team determined that there were not any measurements in the Reference System data set to directly assess this function. They considered using an indirect approach by assessing the structure of the forest, as measured by tree basal area, and incorporating the $FCE_{HYDROLOGY}$ score into the equation. The approach was chosen because of the importance of the hydrologic functions in regulating nutrient cycling processes in riverine wetlands.

$$FCI_{BIOGEOCHEMISTRY} = ((V_{TBA} + FCI_{HYDROLOGY})/2)$$

Maintain Characteristic Habitat

Logic: All of the reference sites were forested and differences between them were mostly in characteristics of the forest such as tree basal area and density and shrub density. The habitat function is mostly a measure of the physical features of the forest. Density of standing snags is including in the formula but may be removed after testing of the model due to lack of sensitivity as a variable.

NEED TO ADD THE HYDROLOGY FUNCITON IN HERE**

$$FCI_{HABITAT} = (2*((V_{TBA} + V_{TDEN})/2 + V_{SHRUB}) + V_{SNAG})/3$$

Maintain Characteristic Plant Community

Logic: The species composition of a forested wetland is an important indicator of its stage of succession or whether or not it has been disturbed. In the Nanticoke watershed, two species (*Chamaecyparis thyoides* and *Taxodium distichum*) are characteristic of riverine wetlands in reference standard condition. Chamaecyparis thyoides is not as widely distributed in the watershed as it once was and sites in which it occurs should be considered to be important. Taxodium distichum stands occur only in the southeastern portion of the watershed. Nyssa sylvatica was the only tree species which occurred in all Reference standard sites and which was not present in many of the other reference sites. Other plant community related variables that differed between reference standard sites were vines, saplings, and herbs (still to be scaled).

$$FCI_{COMMUNITY} = (2*((V_{HERB} + V_{TREE} + V_{SAPLING})/3) * ((V_{VINE} + V_{INVASIVE})/2))^{1/2}$$

Maintain characteristic landscape interspersion and connectivity

Logic: Land-use patterns in the watershed and land-uses adjacent to riverine wetlands play a key role in the movement of organisms, nutrients, and sediments. The physical conditions of the stream corridor outside of the Assessment Area also play an important role in the movement of organisms, particularly aquatic organisms, and the invasion of alien plant species. Land-use patterns adjacent to riverine wetlands associated with first and second order streams are probably more important than those of third order and greater because the smaller size of the floodplain itself to buffer against outside landuse. Accordingly, the FCI score for this function is determined by different equations, depending on stream order.

$$FCI_{LANDSCAPE} = (2*V_{NEARBUFFER} + V_{FARBUFFER} + V_{STREAMOUT})/3)$$

If stream order is greater than 2 then:

$$FCI_{LANDSCAPE} = (V_{NEARBUFFER} + V_{FARBUFFER} - V_{STREAMOUT})/3)$$

Variable: $V_{DISTURB}$

Variable name Vegetation Disturbance

Description The vegetation in most wetlands of the riverine subclass have been directly or indirectly impacted by anthropogenic activities The timing of the disturbance and the type of disturbance varied from site to site. This variable is designed to assess the timing and intensity of anthropogenic disturbances The more recent the disturbance and the more intense it was (e g . clear cutting of the forest), the lower the variable score Scaling of the variable is based on analysis and interpretation of historical and/or ongoing disturbances in Reference Standard sites compared to the other sites within the Reference System

Confidence: The Assessment Team rating of the confidence of the variable scores is medium – high

Protocol for scaling variable.

Examine Site Information data sheet (Vegetation Disturbance Box) to determine which Variable Score to apply using the following table.

Variable scaling:

Var. Score	Description
1	No evidence of human caused vegetation disturbance within past 50 years.
0.75	Evidence of human caused vegetation disturbance within past 15-50 years.
0.5	Evidence of human caused vegetation alteration within past 15 years.
0.25	< 50% of Assessment area disturbed within past 2 years i.e. clearcut or a maintained levee from ditch
0.1	Vegetation clear-cut within past 2 years ***Or*** > 50% of Assessment are disturbed within past 2 years i e. clearcut or maintained levee of ditch
0	Assessment Area had been mapped as wetland on NWI/MD/DE but Site converted to land-use which makes restoration success highly unlikely (e g., urban, suburban, industrial land-uses)

Variable. V FARBUFFER

Variable name Vegetation Buffer Within 20-100 meters of Floodplain

Description of Variable Buffers provide corridors for movement both upstream and laterally through stream corridors Buffers also intercept sediments and nutrients in runoff and buffer wetlands from invasions of exotic plant species. Buffers are especially important along first and second order streams that have very narrow floodplains.

Confidence The Assessment Team rating of the confidence of the variable scores is high.

Protocol for scaling variable:

1. Examine the buffer within 20-100 meters of the floodplain on both sides of the stream using protocols described in the field data sheets.
2. Use procedures in the Buffer Condition field data sheet to determine the Total Far Buffer Score.
3. Use the score determined in step 2 to assign a Variable Score based on the following table.

Variable Scaling

Var. Score	Description
1	Total Far Buffer Score is = 64
	If Var. Score is not equal to 1 or 0 than the Variable Scores is calculated as the Total Far Buffer Score/ divided by 64
0.1	Total Far Buffer Score is ≤ 6 and restoration is possible.
0	No forested land-uses between 20-100 meters of floodplain on both sides of the stream and buffer has been converted to land-use which makes restoration success highly unlikely (i.e. urban, suburban, industrial land-uses).

Variable $V_{FLOODPLAIN}$

Variable name: Floodplain Condition

Description of Variable: The condition of the floodplain is one of the primary determinants of wetland function Within the Reference Domain, floodplains are altered indirectly through modifications of the associated stream and directly through ditching, filling, or excavations on the floodplain surface This variable considers only direct impacts to the floodplain within the Assessment Area and does not consider the impact resultant from modification of the stream channel which is covered in $V_{STREAMIN}$ and $V_{STREAMOUT}$

Confidence: The Assessment Team rating of the confidence of the variable scores is low-medium due to the difficulty in assessing hydrologic conditions in riverine wetlands direct evidence of drainage or impoundment.

Protocol for scaling variable

1. Examine the Floodplain Condition Box on the Site Information data sheet.
2. Use information compiled in the field data sheet to assign a Variable Score using the following table

Variable scaling

Var. Score	Description
1	No alterations of the floodplain (i e . ditches, mechanical alterations to substrate, fill excavations) within the Assessment Area
0 75	Ditches are present on the floodplain surface within the Assessment Area, but they are no longer effective and do not have the ability to drain water (i.e., ditches have become filled with debris and are not maintained) from the floodplain. OR ≤ 10% of the floodplain within the Assessment Area has been altered (i.e., ditches, impoundment of water, excavation of substrate, deposition of fill)
0.25	> 10% and ≤ 75% of the floodplain within the Assessment Area has been altered (i e . ditches that provide effective drainage, impoundment of water, excavation of substrate, deposition of fill)
0 1	> 75% of the floodplain within the Assessment Area has been altered (i.e., ditches that provide effective drainage, impoundment of water, excavation of substrate, deposition of fill) and restoration is possible
0 0	Assessment Area had been mapped as wetland on NWI/MD/DE but site converted to land-use which makes restoration success highly unlikely (i.e. urban, suburban, industrial land-uses)

Variable $V_{INVASIVE}$

Variable name Invasive species

Description of Variable: Many riverine wetlands are degraded by invasive species. Invasive species typically occur where hydrologic conditions have been altered (i.e., sites become wetter or drier), where there has been disturbance to the canopy resulting in higher light conditions in gaps or in areas larger than tree gaps, and where buffer conditions have been altered. The number of invasive species differed between Reference Standard sites and other Reference sites within the Reference Domain.

Confidence: The Assessment Team rating of the confidence of the variable scores is medium because of a medium degree of variability in the occurrence of invasive species at the reference study sites.

Protocol for scaling variable.

1. Examine the Herbaceous and Invasive Species Vegetation field data sheets to determine the average percent cover for all invasive species present in the 12 herb plots.
2. Calcuate the average percent cover for all invasive species by summing all of their midpoint values from all 12 subplots then dividing by twelve.
3. Use information compiled in step 1 to assign a Variable Score using the following table

Variable scaling

Var. Score	Description
1	No invasive species except *Lonicera japonica* which has a mean cover of ≤ 5% in the sampled area.
	Variable Index scores between 0.1 and 1 will be treated as continuous numbers. If $V_{INVASIVE}$ does not equal 0.1 or 1, then. $V_{INVASIVE}$ = 1- mean cover of all listed invasive species in 12 1-m^2 herb plots.
0.1	Mean invasive species cover for the Assessment Area is > 90%; and the forested floodplain has been converted to another land-use, though restoration is possible (i.e. agriculture).
0.0	Assessment Area had been mapped as wetland on NWI/MD/DE but site converted to land-use which makes restoration success highly unlikely (i.e. urban, suburban, industrial land-uses)

Variable V_{NEARBUFFER}

Variable name Vegetation Buffer Within 0-20 meters of Floodplain

Description of Variable Buffers provide corridors for movement both upstream and laterally through stream corridors. Buffers also intercept sediments and nutrients in runoff and buffer wetlands from invasions of exotic plant species. Buffers are especially important along first and second order streams that have very narrow floodplains.

Confidence. The Assessment Team rating of the confidence of the variable scores is high.

Protocol for scaling variable:

1. Examine the buffer within 0-20 meters of the floodplain on both sides of the stream using protocols described in the field data sheets.
2. Use procedures in the Buffer Conditions field data sheet to determine the Total Near Buffer Score.
3. Use the score determined in step 2 to assign a Variable Score based on the following table.

Variable scaling:

Var Score	Description
1	If 1[st] or 2[nd] **order** stream, Total Near Buffer Score = 320. If ≥ 3[rd] **order** stream, Total Near Buffer Score = 192.
	If Variable Score does not equal 1 or 0 then the Variable Score is calculated from the field data sheet by dividing the Total Near Buffer Score by: 320 for 1[st] or 2[nd] **order** stream OR 192 for ≥ 3[rd] **order** stream
0.1	Total score is ≤ 19 for 1[st] or 2[nd] **order** stream OR ≤ 32 for 3[rd] **order** stream and restoration is possible.
0	No forested land-uses between 0-20 meters of floodplain on both sides of the stream and buffer has been converted to land-use which makes restoration success highly unlikely (i.e. urban, suburban, industrial land-uses)

Variable

Variable name Sapling species composition

Description of Variable Riverine wetlands in the Nanticoke watershed are almost all forested. This variable attempts to assess the species composition of the sapling stratum that will contain the next generation of trees Most tree species occur widely as saplings and appear in most wetlands sampled. Data analysis indicated that any one of three species listed below needs to be present to indicate Reference Standard conditions The presence of facultative upland tree species is indicative of conditions other than Reference Standard. Two species (*Chamaecyparis thyoides*, and *Taxodium distichum*) are indicative of wetlands that are Reference Standard. *Ilex opaca* is excluded from this variable due to its presence in both reference and reference standard sites.

Confidence: The Assessment Team rating of the confidence of the variable scores is medium because of a medium degree of variability in the species present as saplings in the Reference System.

Protocol for scaling variable:

1. Examine the Sapling Box of the Trees and Shrubs field data sheets to determine which sapling species are present in each of the three tree plots sampled within the Assessment Area.
2. Use information compiled in step 1 to assign a Variable Score using the following table

Variable scaling:

Var. Score	Description
1 0	*Chamaecyparis thyoides*, *Taxodium distichum*, or *Nyssa sylvatica* are present as saplings in the Assessment Area and there are no facultative upland tree species present as saplings.
0.9	A variable index score of 1 0 and there is 1 facultative upland species present in the sapling layer
0.75	A variable index score of 1 0 and there are 2 facultative upland tree species present as saplings OR *Chamaecyparis thyoides*. *Taxodium distichum*, or *Nyssa sylvatica* are not present as saplings and there are ≤1 facultative upland tree species present as saplings.
0.5	A variable index score of 1 0 and there are 3 facultative upland tree species present as saplings OR *Chamaecyparis thyoides*. *Taxodium distichum*, or *Nyssa sylvatica* are not present as saplings and there are 2 facultative upland tree species present as saplings.
0 25	A variable index score of 1 0 and there are 4 or more facultative upland tree species present as saplings OR *Chamaecyparis thyoides*, *Taxodium distichum*, or *Nyssa sylvatica* are not present as saplings and there are 3 or more facultative upland tree species present as saplings.
0 1	No saplings present. Assesment Area dominated by herbaceous vegetation and restoration possible
0 0	Assessment Area had been mapped as wetland on NWI/MD/DE but site converted to land-use which makes restoration success highly unlikely (i.e. urban, suburban, industrial land-uses)

Variable V_{SHRUB}

Variable name Shrub density

Description of Variable Shrubs are common in riverine wetlands They provide habitat for animals, reduce the flow of surface water through the site, and play a significant role in nutrient cycling. Shrub density was an indicator that varied between Reference Standard sites and other Reference sites within the Reference System.

Confidence The Assessment Team rating of the confidence of the variable scores is medium because of a medium degree of variability in shrub density at the reference study sites.

Protocol for scaling variable:

1 Examine the Shrub Species Box on the Trees and Shrubs field data sheets to determine the average density of shrubs in the three shrub plots sampled in the Assessment Area. The average density is calculated by summing the number of stems for all shrub species in all plots then dividing by three.
2. Calculate shrub density per hectare by multiplying the average density by 628.8
3 Use information compiled in step 1 to assign a Variable Score using the following table

Variable scaling.

Var. Score	Description
1 0	Shrub Density is ≥ 10,000 stems/ha in the Assessment Area
	Variable Scores between 1 and 0 1 will be treated as continuous numbers. If shrub density < 10,000 stems/ha, the Variable Score is calculated as the average density for the three shrub plots divided by 10,000
0 1	Shrubs density ≤ 1000 stems/ ha restoration possible
0 0	Assessment Area had been mapped as wetland on NWI/MD/DE but site converted to land-use which makes restoration success highly unlikely (i.e. urban, suburban, industrial land-uses)

Variable. $V_{STREAMS}$

Variable name Stream condition inside the Assessment Area

Description of Variable Alterations of streams within the Assessment Area were the primary activity that influenced ecological functioning of riverine systems. There were clear differences in the frequency of steam alterations between Reference Standard sites and the other Reference sites. This variable considers physical alterations to the stream channel. alterations in the water level are measured in the floodplain variable ($V_{FLOODPLAIN}$)

Confidence: The Assessment Team rating of the confidence of the variable scores is –medium-high.

Protocol for scaling variable.

3. Examine the stream condition within the Assessment Area and complete the Hydrology field data sheet
4. Use information compiled in the field data sheet to assign a Variable Score using the following table.

Variable scaling

Var. Score	Description
1	No channelization. dams or road crossings in the Assessment Area.
0 75	In first and second order streams, prior channelization(s) of the stream have not been maintained resulting in minimal alterations to hydrologic conditions
0.5	For all stream orders. no channelization is present with Assessment Area. Fill (i e. road crossing) is present within the Assessment Area.
0.25	Stream channelized. no levees present or levee only on one side of stream
0 1	Channelization of stream in Assessment Area. Levees on one or both sides of channel. further reducing overbank flooding, restoration possible.
0	Assessment Area had been mapped as wetland on NWI/MD/DE but site converted to land-use which makes restoration success highly unlikely (i.e. urban, suburban, industrial land-uses)

Variable $V_{STREAMOUT}$

Variable name Stream condition outside the Assessment Area

Description of Variable Alteration of streams upstream or downstream of the Assessment Area result in hydrologic impacts within the Assessment Area Specifically, channelization of upstream areas results in changes in hydrologic patterns in Assessment Area, particularly an overall decrease of overbank flooding and higher stream flow during flood events. Higher peak floods may also result in greater discharge to downstream areas that are not channelized. Undersized road crossings also lead to reductions in peak flows downstream and impoundment of water upstream.

Confidence The Assessment Team rating of the confidence of the variable scores is –medium-high.

Protocol for scaling variable:

1 Examine the stream condition in the Outside Assessment Area (Upstream and Downstream) Boxes on the Hyrdology field data sheet.

2. Use information compiled in the field data sheet to assign a Variable Score using the following table.

Variable scaling:

Var. Score	Description
1	No channelization, dams or road crossings within 500 m upstream or downstream of the Assessment Area.
0.75	In first and second order streams, prior channelization(s) of the stream have not been maintained resulting in minimal alterations of hydrologic conditions within the Assessment Area and no fill present.
0.5	Minimal channelization within 500 m upstream or downstream of Assessment Area, either isolated section or greater than 100m from assessment area OR Fill (i.e., road crossing or dam) present within 500 m of Assessment Area
0.1	Major channelization of stream within 500 m of Assessment Area. Levees on one or both sides of channel, further reducing overbank flow.
0	Assessment Area had been mapped as wetland on NWI/MD/DE but site converted to land-use which makes restoration success highly unlikely (i.e. urban, suburban, industrial land-uses)

Variable V_{TBA}

Variable name Basal area of trees

Description of Variable. Basal area of canopy-sized trees is an indicator of the structure (i.e., habitat quality) of the forest and an indication of its successional stage. Tree basal area (TBA) is a measurement of tree size and is expressed as the cross-sectional area of trees per unit of area sampled. Tree basal area was an indicator that differed between Reference Standard sites and other Reference sites within the Reference Domain.

Confidence: The Assessment Team rating of the confidence of the variable scores is high.

Protocol for scaling variable:

1. Calculate the basal area (cm^2) of each tree listed in Box I.A. Trees.on the Trees and Shrubs field data sheets. Basal area is calculated by
   A. Determining the radius of each tree (divide the diameter by 2),
   B. Squaring the radius,
   C. Multiplying the radius squared by 3.1415.
2. Sum the BA values for each tree listed in Box I.A to determine the total basal area for the plot.
3. Convert the total basal area in cm^2 to basal area in m^2 by multiplying the value in step 2 by 0.0001.
4. Calculate the average basal area for the site by summing the total basal area for each plot and dividing the sum by 3.
5. Calculate the average basal area in m^2 per hectare by multiplying the average by 50.
6. Use the following table to assign a Variable Score using the value calculated in step 5.

Variable scaling:

Var. Score	Description
1	Tree Basal Area ≥ 35.6 m^2/ha in the Assessment Area
	Variable Scores between 1 and 0 will be treated as continuous numbers. If BA < 35.6 m^2/ha then: V_{TBA} = Average BA for the tree plots/35.6
0.1	Tree Basal Area < 3.56 m^2/ha and restoration possible
0	Assessment Area had been mapped as wetland on NWI/MD/DE but site converted to land-use which makes restoration success highly unlikely (i.e. urban, suburban, industrial land-uses)

Variable. V_{TDEN}

Variable name Tree density

Description of Variable Density of canopy-sized trees (≥ 15 cm DBH) is an indicator of the structure (i.e. habitat quality) of the forest and an indication of its successional stage. Tree density was an indicator that differed between Reference Standard sites and other Reference sites within the Reference Domain.

Confidence: The Assessment Team rating of the confidence of the variable scores is high.

Protocol for scaling variable:

1. Calculate the density of trees listed in Box I.A. on the Trees and Shrubs field data sheets. Density is calculated by summing the number of all trees for which there are diameter measurements then dividing by 3
2. Convert the average density for the site into tree density per hectare by multiplying the average by 50
3. Use the following table to assign a Variable Score using the value calculated in step 3

Variable scaling:

Var. Score	Description
1	Tree Density (15cm DBH) is ≥ 475 trees/ha in the Assessment Area
	Variable Index scores between 1 and 0 will be treated as continuous numbers. If tree density < 475 and > 118 trees/ha then: V_{TDEN} = Average Tree Density in tree plots/475
0 1	Tree density ≤ 118 trees/ ha and restoration possible
0	Assessment Area had been mapped as wetland on NWI/MD/DE but site converted to land-use which makes restoration success highly unlikely (i.e. urban, suburban, industrial land-uses)

Variable V-TREE

Variable name: Tree species composition

Description of Variable: Riverine wetlands in the Nanticoke watershed are almost all forested. This variable attempts to assess the species composition of the Assessment Area by examination of the species composition of the canopy trees. Most tree species occur widely and appear in most wetlands included in the Reference System. Analysis of data indicated that there is one species (*Nyssa sylvatica*) which needs to be present in the canopy to indicate Reference Standard conditions. Two species (*Chamaecyparis thyoides* and *Taxodium distichum*) are not as widely distributed as Nyssa *sylvatica* but the A-team considered their presence to be indicative of Reference Standard conditions. *Ilex opaca*, a FACU species, is excluded from this variable because it was found in both reference and reference standard sites.

Confidence. The Assessment Team rating of the confidence of the variable scores is medium because of the relatively small number of species that could be used for purposes of scaling.

Protocol for scaling variable.

1. Examine Box I.A. Trees on the Trees and Shrubs field data sheets that lists the tree species present in each of the three sampled tree plots.
2. Use the list of species present to assign a Variable Score using the following table.
3. Ilex opaca is not used to score this variable, since it was found in both reference and reference standard sites, it is not used to score the variable higher or lower.

Variable scaling:

Var. Score	Description
1.0	*Chamaecyparis thyoides*, *Taxodium distichum*, or *Nyssa sylvatica* are present as canopy species in the Assessment Area and there are no facultative upland tree species present.
0.9	A Variable Index score of 1.0 and 1 facultative upland tree species present in the canopy.
0.75	A Variable Index score of 1.0, and 2 facultative upland tree species present in the canopy OR *Chamaecyparis thyoides*, *Taxodium distichum*, and *Nyssa sylvatica* are not present as canopy species and ≤ 1 facultative upland tree species present in the canopy.
0.5	A Variable Index score of 1.0, and 3 facultative upland tree species present in the canopy OR *Chamaecyparis thyoides*, *Taxodium distichum*, and *Nyssa sylvatica* are not present in the canopy and 2 facultative upland tree species are present in the canopy.
0.25	A Variable Index score of 1.0, and 4 or more facultative upland tree species present in the canopy OR *Chamaecyparis thyoides*, *Taxodium distichum*, and *Nyssa sylvatica* are not present in the canopy and 3 or more facultative upland tree species are present in the canopy.
0.1	No trees present, dominated by herbaceous and/or saplings and restoration possible
0.0	Assessment Area had been mapped as wetland on NWI/MD/DE but site converted to land-use which makes restoration success highly unlikely (i.e. urban, suburban, industrial land-uses)

* *Ilex opaca is not used to score this variable*

Variable V_VINE

Variable name Vine and vine-like species

Description of Variable. Vines and vine-like species such as *Rosa multiflora* and *Rubus* spp., provide valuable wildlife food, but an abundance of vines, especially invasive species, influence succession, and degrade forest ecosystems. Species of *Rubus* are typically indicative of disturbed conditions, and indicated changes in the plant community that represent significant changes from Reference Standard conditions. This variable assesses the number of sampled plots in the Assessment area that contain species of *Rubus*. Scaling of the variable is based on analysis and interpretation of the presence of *Rubus* in Reference Standard sites compared to the other sites within the Reference System

Confidence The Assessment Team rating of the confidence of the variable scores is high.

Protocol for scaling variable:

1. Examine the Blackberry Box on the Trees and Shrubs field data sheets that indicates the presence of Rubus Spp. in each shrub plot.
2. Count the number of plots that contain species of *Rubus*.
3. Use the following table to assign a Variable Score.

Variable scaling.

Var. Score	Description
1	Blackberry (*Rubus* spp) occur in 1 of the plots sampled in the Assessment Area
0 5	Blackberry (*Rubus* spp) occur in 2 of the plots sampled in the Assessment Area
0 1	Blackberry (*Rubus* spp) occur in all of the plots sampled in the Assessment Area
0 0	Assessment Area had been mapped as wetland on NWI/MD/DE but site converted to land-use which makes restoration success highly unlikely (i.e. urban, suburban, industrial land-uses)

Appendix A
Geographic Information Sciences
Supporting Documentation for ANPRM Project

The January 15, 20003 Advanced Notice for Proposed Rulemaking requests information on the scope of "Waters of the United States" in response to the Supreme Court's decision in the Solid Waste Agency of Northern Cook County (SWANCC) v US Army Corps of Engineers. An analysis of aquatic resource impacts was performed using geographic information system (GIS) technology to estimate the extent of wetlands and streams that could be affected by changes in the scope of waters subject to jurisdiction under the Clean Water Act. Key results from our analyses can be found in the "GIS Highlights" section of this report.

The data used for the wetland analyses relied on the National Wetland Inventory (NWI), developed and maintained by the U.S. Fish and Wildlife Service. An analysis of total stream miles affected by potential changes in Clean Water Act jurisdiction was performed by State, using the National Hydrography Data Set (NHD), broken out by stream order. Both data sets are discussed below. They represent the best available data that could be acquired and applied for a regional GIS analysis of "extent of resource impacts."

This appendix includes background information on the methods, GIS data sources, compilation scales, data descriptions, limitations, and caveats, used in our report. Table D1 provides estimates of Region 3 intermittent and perennial stream miles by state. Also included is a separate report by Region 3 staff on "Using GIS Hydrologic Modeling Tools and Field Survey Data to Estimate the Lengths of Intermittent and Perennial Headwater Streams in the Mountaintop Mining Region of Southern West Virginia."

A. *GIS* Shape Files/Coverages/Themes used:

1. National Hydrography Dataset (NHD)
2. National Wetlands Inventory (NWI)
3. Safe Drinking Water Information System (SDWIS) Drinking Water Intakes
4. State Boundaries

B. Compilation Scales:

The concept of scale in GIS generally refers to how many measured units on a map equal how many of those same units on the ground. The most common written form of scale appears as what's called a "representative fraction," or "RF." An example of an RF is **1:24,000**. This is read as "one unit on the map = 24,000 units on the ground." The units can be anything (inches, feet, meters, miles, etc.) but must be the same.

The United States Geological Survey (USGS) has several standard map scales it uses in the majority of its products. These are 1:24,000, 1:100,000, 1:250,000 and 1:2,000,000. There are a few others, but based on their experience, the USGS has concluded that these scales provide the greatest flexibility, utility and level of detail for the vast majority of analyses and applications for which their products are used.

Maps and data sets can be broadly classified as "small scale" and "large scale." Small scale maps generally show larger areas with lesser detail. The smaller the scale, the larger the "units on the ground" value in the RF. For example, a 1:2,000,000 scale map or data set is a much smaller scale than one at a 1:250,000 scale. Conversely, larger scale maps show smaller areas but at greater detail. The concept is more easily conveyed if one imagines an observer in a hot-air balloon. While the balloon is resting on the ground, an observer in the gondola can see a small area but in great detail. Features such as automobiles, individual trees, telephone poles, etc. are clearly visible and discernable. As the balloon rises, more and more of the surrounding area becomes visible while smaller features begin to disappear. At extreme altitudes the observer may be able to see several states or even entire continents at once, yet houses, smaller roads, small streams, etc. are no longer visible. The same concept can be applied to maps. If one were trying to locate and draw small streams, ponds and other wetlands, smaller scale maps would miss many of the details.

The analyses in this project rely heavily on the National Hydrographic Dataset (NHD) at a scale of 1:100,000 and the National Wetlands Inventory (NWI) at a scale of 1:24,000. Caution must be taken when drawing conclusions from analyses conducted on data sets compiled at different scales. The GIS Team was very cognizant of this issue during preparation of maps and tables used in this project.

C. Descriptions/disclaimers/caveats of datasets used:

1. National Hydrography Dataset (NHD)

The version of the NHD used in this project is the circa 2000 issue. This version predates completion of the attribute tables and final reformatting to the "Geodatabase" (Oracle/SDE) environment, which is the version currently available. We selected this version because we needed to access the only attribute available which would identify stream orders, a value critical to the calculations and resulting analyses. That attribute, called the "Strahler Value" was originally contained in the NHD predecessor, the Reach File 3, or "RF3," a product which dates back to the early 1990's. As there were no attributes in common between RF3 and NHD that would provide a direct connection or "table join" between the two files, an alternative method was adopted. By using the spatial analysis tools available in the ArcView 3.2 software, the Strahler values were transferred from the RF3 files to N.D. based on feature proximity.

The vast majority of the lifework within the 2000 N.D. is copied directly from RF3. RF3, however, was inconsistent in several factors depending upon the geographic area. In some cases stream center lines in wide streams are missing or incomplete. In other cases center lines exist but there are no shorelines. There are also no descriptive attributes to indicate the type of waterbed. Also, because both RF3 and N.D. were compiled at a 1:100,000 scale, both underestimate actual stream miles and generally exclude intermittent and ephemeral streams. Despite these issues, the necessity to gain access to the stream order attribute outweighed the other potential shortcomings. For this reason, the 2000 N.D. was determined to be the best available Dataset at the time to perform the required analyses.

2. National Wetlands Inventory (NWI)

NWI data is provided by the U.S. Fish and Wildlife Service and arrives as individual 1:24,000 blocks. Each block is of a different vintage and some adjacent quads can be of quite different age. The quads are appended together and the neatlines (rectangular borders) removed. In some instances wetlands on one quad do not appear on the adjacent one. This is usually a function of the age differences. Manual editing of areas between adjacent quads is sometimes required to address discrepancies. In most cases NWI maps have not been ground-truthed. Based on field research and computer modeling, it has also been determined that NWI can underestimate actual wetland acreage by as much as 50%.

3. Safe Drinking Water Information System (SDWIS)

Safe Drinking Water data are extracted from the SDWIS on a regular basis. The data set used in this analysis is a "subset" of the larger file, that being just the surface drinking water intakes. Besides the general uncertainties associated with intake locations provided by states, only one other obvious discrepancy was identified. The lat/lon of an intake supposedly in Virginia was showing up outside the regional boundary. This point was discarded from the analysis. No other attempt at data quality was made.

One of the major issues with SDWIS is the mixing of intake-level and facility/system-level data in the same attribute table. For example, one of the data items is "population served." This is a facility/system-level attribute. However, this number is duplicated for all intakes that are part of that facility/system. If a facility/system serves one million people and has five intakes, that same one million would appear in the data table 5 times, making it seem like there were really five million people served. Once this problem was identified, only one record per facility/system was selected for those calculations were "population served" was used.

Another issue was the same lat/lon used for multiple intakes. This problem was corrected by selecting only unique lat/lons in maps and tables were distances to streams were analyzed.

4. State Boundaries

The state boundaries used in this project are from the USGS. These have been in use since they were first created back in the 1980's (digital form). The GIS Team is not in a position to dispute any of the linework.

D. Additional Data on Perennial and Intermittent Streams:

Table D1: **Stream Mile Totals by State and Feature Codes of STREAM/RIVERS: National Hydrography Dataset (NHD)**

Feature Code 46000 = STREAM/RIVER; No Attributes
Feature Code 46001 = STREAM/RIVER; Type: Intermittent; Positional Accuracy: Definite
Feature Code 46004 = STREAM/RIVER; Type: Perennial; Positional Accuracy: Definite

	46000		46001		46004		
	mi.	%*	mi.	%*	mi.	%*	TOTALS
Delaware	0.1	< 0.1	316.2	12.3	2,250.3	87.7	**2,566.7**
DC	0.0	0.0	0.0	0.0	34.9	100.0	**34.9**
Maryland	3.0	< 0.1	1,818.2	13.4	11,782.6	86.6	**13,603.8**
Pennsylvania	3.2	< 0.1	15,993.7	26.8	43,720.9	73.2	**59,717.7**
Virginia	7.2	0.1	17,731.1	25.7	51,184.6	74.2	**68,923.0**
West Virginia	4.0	0.1	10,955.9	31.3	24,015.5	68.6	**34,975.4**
TOTALS	**17.4**	**< 0.1**	**46,815.1**	**26.1**	**132,988.9**	**73.9**	**179,821.4**

At a regional level, approximately 74 percent of the mapped streams in Region 3 are perennial, whil percent are intermittent. There is some variability from state to state, as shown in the table. It shou be noted that many intermittent and ephemeral streams are not detected at the 1:100,000 mapping scale. As a result, the intermittent stream estimate of 26 percent is probably conservative.

Values in this table do not include linear features labeled as "Artificial Paths," "Connector," "Canal/Ditches" or "Pipelines." These features were ignored in an attempt to quantify only "natural surface conditions." The discarded features represent approximately 13% of the total linear features.

"Artificial Paths" are typically center lines of wide rivers and bays where shore line features exist. As their name implies, they are not "natural" and serve mainly as network connections for computer routing algorithms or for approximate visual representation of the submerged channel. In Region 3, "Artificial Paths" represent approximately 25,000 miles or roughly 12% of the total linear features, mostly in the coastal areas where wide rivers empty into larger bays and the Atlantic Ocean.

The GIS Team was unable to determine the definition of "Connectors" as they apply to this data set. In Region 3, "Connectors" account for approximately 25 miles or less than .01% of the total linear features.

"Canal/Ditches" are generally manmade water-direction structures used to divert surface water away from its natural flow path. In Region 3, "Canal/Ditches" account for approximately 1,600 miles or 0.77% or the total linear features.

"Pipelines" are manmade structures used primarily to carry water over or under other natural or manmade obstacles. Aqueducts are one example of a "pipeline." In Region 3, "pipelines" represent approximately 97 miles or less than .04% of the total linear features.

Each individual state NHD shape file is loaded into Arcview 3.2, then queried three times, once for each of the Feature Codes. The METERS field is then summed, then converted from meters to miles by dividing the total by 0.000621371.

* Percentages are calculated using state totals

Using GIS Hydrologic Modeling Tools and Field Survey Data to Estimate the Lengths of Intermittent and Perennial Headwater Streams in the Mountaintop Mining Region of Southern West Virginia.

February 2003

Hope Childers
Veridian Corporation IT Services Division at USEPA Wheeling
1060 Chapline Street, Wheeling, WV 26003; (304) 234-0245

and

Margaret Passmore
USEPA
1060 Chapline Street, Wheeling, WV 26003; 304-234-0245

Introduction:

Although field mapping is acknowledged as the most accurate way to determine the extent and hydrologic character of stream channel networks, it is often impractical, especially for large watersheds or regions. The readily available 1:100,000 scale regional and national spatial stream networks underestimate total stream lengths and are not attributed according to intermittent or perennial character. Therefore, in order to accurately estimate the length and proportions of intermittent or perennial stream channels, additional modeling efforts are required.

The increasing availability of digital elevation data (USGS 2003a), increasing computation power available in personal computers, and the underestimates of stream networks relying on blue-line symbols on USGS 1:100,000 or 1:24,000 topographic maps (Paybins 2003 and Stout et al. 2002) have contributed to an increased use of analysis based on digital elevation models in hydrology. The objective of this case study is to provide an example of how a combination of field data and digital elevation data can be used to estimate the extent of intermittent and perennial water resources in a southern region of West Virginia.

Study area:

The study area (Figure 1) encompasses 11,726 km^2 (2,897,521 acres) within the Appalachian Coalfield Region in a portion of West Virginia. It is the same area of West Virginia used in the Landscape Scale Cumulative Impact Study completed for the Interagency Mountaintop Mining Environmental Impact Statement (USEPA 2002). The dominant land cover is forest and nearly all of the study area is within the Cumberland Mountains Level IV Ecoregion (Woods et al. 1996). Although there is some spatial variability, areas within the same ecoregion generally have similar climate patterns, geology, soils, and vegetation.

Stream Definitions:

The USGS determined point of intermittent and perennial flow origin and drainage characteristics fo headwater streams in the same region of West Virginia (Paybins 2003). We used these points to set flow accumulation thresholds for the creation of two National Elevation Data (NED)-derived stream networks. In one of the NED-derived stream networks, the streams in the model originate at the median point of intermittent flow origin (14.5 acre), while the streams in the second network originate at the median point of perennial flow origin (40.8 acres). USGS defined the intermittent point, the boundary between ephemeral and intermittent flow, as the point where base flow begins in the late winter or early spring. The boundary between intermittent and perennial flow, the perennial point, was defined by the lowest water table elevation, where base flow begins in the late summer and early August. This analysis provides a model of the extent of intermittent and perennial streams in the study area, but does not attempt to model the extent of ephemeral streams.

Field observations from a previous and independent USEPA field survey utilizing both a flow and biological definition (Green and Passmore 1999) were used to evaluate the results from the NED-derived streams. The USEPA Field survey defined two types of perennial streams. Type 1 perennial streams were those with continuous surface flow during a September 1998 field visit. Type 2 perennial streams had intermittent surface flow at the time the site was visited, but supported aquatic life whose life history requires residence in flowing waters for at least six months.

GIS Methods:

The National Elevation Dataset (NED), projected as NAD83 UTM Zone 17, was clipped to the study area. ArcView Spatial Analyst and Hydrologic Modeling v1.1 extensions were used to fill the sinks in the clipped NED grid. "Filling the sinks" removes depressions in the elevation grid by increasing the elevations within the depressions to their lowest outflow point. ArcInfo Workstation Grid module was used to create a flow direction grid from the filled elevation grid. In this step, ArcInfo assigns the flow from each grid cell to one of its eight neighbors in the direction with the steepest downward slope. The flow direction grid was then used to create a flow accumulation grid.

In the flow accumulation grid, each pixel has a value equal to the number of pixels that flow into it. In other words, pixels near the ridge-tops have smaller values than the pixels in the valleys. The ArcInfo Grid CON function was used to threshold the accumulation according to the minimum contributing drainage areas chosen for the analysis. In this case, the area of contributing cells required to designate the stream origin from the flow accumulation model, was 14.5 aces (65 pixels) for the intermittent stream network and 40.8 acres (183 pixels) for the perennial stream network. This produced a raster for each threshold scenario where the modeled stream pixels have a value of "1" and the other pixels that are not part of the stream network have a value of "NODATA". The STREAMLINE function with a weed tolerance of 20 was then used on the thresholded stream network grids to create vector coverages from which the cumulative stream lengths could be calculated (Table 1). In addition, the STREAMORDER function, using the Strahler method, was performed on the 40.8 perennial threshold grid so that the first-order lengths in the perennial stream model could be selected and their cumulative lengths calculated (Table 2). The ArcView Projector! Extension was used to create shapefiles in decimal degrees from the vector coverages projected as UTM NAD83 Zone 17 in order to display the NED generated stream networks along with other spatial data such as the USGs Digital Raster Graphics (DRGs), the National Hydrology Dataset (NHD), and field data collected by USEPA freshwater biologists (Figure 2).

Results:

Table 1. Total Stream Lengths within the Study Area for Each Steam Network.

Stream Network	Total Stream Length	
	km	miles
Stream Origin at Intermittent Threshold of 14.5 acres*	25900	16094
Stream Origin at Perennial Threshold of 40.8 acres	17120	10638
National Hydrology Dataset (NHD)	10043	6240

Table 2. Cumulative Lengths within the Study Area Potentially at Risk if Headwater Streams were Considered Non-jurisdictional.

Stream Segment Type	km	miles	Segment Length/Total *
Intermittent Streams	8780	5456	0.3390
1st Order Perennial	8126	5049	0.3137
Intermittent and 1st Order Perennial	16906	10505	0.6527

* *total stream length of the intermittent stream network in Table 1 is the denominator used to calculate the proportions of the total in Table 2.*

Table 1. provides the total length of all of the stream segments within the study area for three different stream models. The first two models listed, where the stream origin is at the intermittent and perennial thresholds of 14.5 and 40.8 acres, are the results for the two networks generated for this case study using the NED and GIS hydrologic modeling tools. The National Hydrology Dataset (NHD) is based upon the content of USGS Digital Line Graph (DLG) hydrography data integrated with reach-related information from the EPA Reach File Version 3 (RF3). The NHD incorporated DLG and RF3 rather than replace them. The NHD is initially based on 1:100,000-scale data, but it has been designed so that it can incorporate higher resolution data (USGS 2003b). As shown in Table 1 and Figure 2, the detail of the NED-derived stream network greatly exceeds that of the NHD. The NED-derived perennial network's total stream length is 70% longer than the NHD and the NED-derived intermittent network's total stream length is 158% longer than the NHD. The detail of the NED-derived streams not only exceeds that of the NHD, but also that of the USGS 1:24,000 topographic maps. Figure 2 is a graphic example of the NED-derived stream networks displayed along with the NHD and a USGS Digital Raster Graphic (DRG) of a topographic quad.

In Table 2, the cumulative length of the intermittent stream segments, 8780 km (5456 miles), is the total of the stream lengths in the study area from the intermittent origin at the 14.5 acre threshold to the perennial origin at the 40.8 acre threshold. The cumulative length of the 1st order perennial stream segments, 8126 km (5049 miles) is the total length of all of the first order segments in the NED-derived, 40.8 acre threshold, stream network. If the waters upstream of the median intermittent-perennial point were nonjurisdictional under the Clean Water Act then this hydrologic model estimates that roughly one-third of the stream resources in the study area would be potentially at risk. If first order perennial streams and the intermittent reaches upstream were considered non-jurisdictional then this model estimates that nearly two-thirds of the water resources would be potentially at risk.

Comparison with the USEPA September 1998 Field Survey :

The NED generated stream networks were then compared to the observations in a USEPA field survey report for four tributaries of Spruce Fork in Logan County West Virginia. The four tributaries are White Oak Branch, Oldhouse Branch, Pigeonroost Branch, and Seng Camp Creek. The field work was done to determine the length of perennial streams that would be adversely affected by the proposed valley fills of a mountaintop coal mining permit. Green and Passmore (1999) used two definitions to determine perennial streams. Type 1 perennial streams were those with continuous surface flow during a September 1998 field visit. Type 2 perennial streams had intermittent surface flow at the time the site was visited, but supported aquatic life whose life history requires residence in flowing waters for at least six months. The Type 2 definition is consistent with West Virginia's definition of intermittent and perennial streams in their water quality standards. Comparing the field designations to the NED generated stream network, 11 of the 12 sites were designated as perennial by both methods. One site was determined to be a perennial Type 1 stream in the field in September 1998 (had continuous surface flow at low flow) but was designated as intermittent by the NED generated stream network. The independent field data generally support the NED generated stream network (92% agreement).

Discussion:

Catchment area, precipitation, and geology are typically the most important characteristics when estimating streamflow. Stream networks generated from an elevation model using a constant threshold area method have found widespread application (Garbrecht and Martz 2000) and can provide a useful surrogate to field mapping. However, there are some limitations. First of all, the NED's horizontal and vertical resolution are adequate to represent elevation differences in regions with mountainous terrain, but may not lend itself well to an accurate representation of drainage slopes, channels, and ridges in a low-relief landscape. Secondly, when the resolution of the delineated network is controlled by a support area threshold, the threshold may impose an arbitrary and spatially constant drainage density (Tarboton and Ames 2001). Topographic texture and drainage density may vary spatially. For the mountaintop coal mining region in southern West Virginia, a change in drainage area is not readily apparent in traditional stream coverages such as the NHD, but the USGS field investigation suggests that the topographic texture of the northeast portion of the study area may vary slightly from the southwest portion. Methods have been introduced in the literature that respect this variability (Tarboton and Ames 2001, Garbrecht and Martz 2000).

Although there are some methodological issues related to the automated extraction of drainage features, stream networks derived from the elevation models and thresholds based on field data can provide a detailed representation of headwater stream networks. Regardless of the intricate hydrologic modeling details, the take-home message is still the same. Intermittent and first-order perennial streams are a large percentage of the water resources in the mountaintop coal mining region of southern West Virginia.

Acknowledgments:

The authors thank Jim Green of USEPA for contributing field survey results and for reviewing the case study analysis; Katherine Paybins and USGS colleagues for sharing the results of their field work: a-- Tom Mastrorocco of OSM for discussions regarding the methodology and for sharing spatial data.

References:

Green. J. and M. Passmore. 1999. An Estimate of Perennial Stream Miles in the Area of the 1997 Proposed Hobet Mining Spruce No.1 Mine. USEPA Field Survey Report. USEPA. Wheeling, WV.

Paybins, K. S. 2003. Flow Origin, Drainage Area, and Hydrologic Characteristics for Headwater Streams in the Mountaintop Coal-Mining Region of Southern West Virginia, 2000-01. Water-Resources Investigations Report 02-4300.

Stout, Wallace and Kirchner?? 2002 ?. A Survey of Eight Major Aquatic Insect Orders Associated with Small Headwater Streams Subject to Valley Fills from Mountaintop Mining. (not sure how to cite yet)

Tarboton, D. G. and D. P. Ames. 2001. "Advances in the mapping of flow networks from digital elevation data" paper submitted for presentation at the World Water and Environmental Resources Congress, May 20-24, 2001. Orlando, Florida.

U.S. Environmental Protection Agency, 2002. Draft Landscape Scale Cumulative Impact Study for the Mountaintop Mining/Valley Fill Environmental Impact Statement.

USGS. 2003a. National Elevation Dataset. http://gisdata.usgs.net/NED/

UGSG. 2003b. National Hydrology Dataset. http://nhd.usgs.gov/

Woods, A.J., J.M. Omernik, D.D. Brown, and C.W. Kiilsgaard. 1996. Level III and IV Ecoregions of Pennsylvania and the Blue Ridge Mountains, the Ridge and Valley, and the Central Appalachians of Virginia, West Virginia, and Maryland: Corvallis, Oregon, United States Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, EPA

Appendix B
Detailed Aerial Photography Interpretation and GIS Analysis of Selected Field Sites in EPA Region 3

Peter Stokely
Environmental Protection Agency
Region 3
Philadelphia, PA
April 2003

Table of Contents

Page

Background..3

Purpose..4

The Study Areas..4

Conclusions..5

Discussion..6

Study Area Impacts..6

The Three Interpretations....................................7

Potential Impacts to First and Second Order Streams....................8

Regional Data Sets Compared to Aerial Photography Data Sets.........8

Methods..11

Data Used..14

Table of Results..16

List of Figures:

Figure 1. French Creek State Park Broad Interpretation 100K Data
Figure 2. French Creek State Park Broad Interpretation API Data
Figure 3. Millington MD Broad Interpretation 100K Data
Figure 4. Millington MD Broad Interpretation API Data
Figure 5. Church View VA Narrow Interpretation API Data
Figure 6. Church View VA Broad Interpretation API Data
Figure 7. French Creek State Park Streams Potentially Impacted

Background:

In response to Congressional direction, The Environmental Protection Agency's (EPA) Office of Water (OW) and the Army Corps of Engineers (COE) have agreed to initiate rulemaking to "clarify" the scope of federal Clean Water Act (CWA) jurisdiction following the Supreme Court's decision in the Solid Waste Agency of Northern Cook County (SWANCC) v US Army Corps of Engineers. This decision found that the CWA does not protect certain "isolated" wetlands under certain conditions. Isolated wetlands have often been interpreted to be those wetlands with no surface water hydrological connection to local streams (a basin with no outlet).

In order to clarify and implement the SWANCC decision across CWA programs, an Advanced Notice for Proposed Rule Making (ANPRM) was issued on January 15, 2003. The ANPRM outlined the background of the Supreme Court Decision and solicited public comment on the definition of isolated wetlands and issues associated with the scope of waters that are the subject to the CWA in light of the SWANCC decision. The ANPRM posed several questions relating to the definition of isolated wetlands and the potential impacts of the decision.

EPA Region III provided a review and comment on the ANPRM. This review included interpretation of the SWANCC decision and its implications for all of the CWA programs, including the NPDES permit program (§ 402), the water quality standards and continuing planning process (§ 303), the TMDL program (§ 303 (d)), the water quality certification provision (§ 401), the oil spill liability provision (§ 311), and others.

The language in the SWANCC decision and the ANPRM left room for interpretation regarding the eventual final rule that would define isolated wetlands and therefore the effect on the geographic scope of jurisdiction of the CWA if isolated wetlands are no longer regulated under the CWA. EPA Region III, therefore, provided comment on three interpretations of the ANPRM, a narrow interpretation, an intermediate interpretation and a broad interpretation. These interpretations, defined below, were developed so that they could be used to guide a Geographic System Analysis (GIS) analysis of the potential impacts of the proposed rulemaking using region wide spatial data sets.

The three interpretations of the ANPRM definition of an isolated wetland:

1) Narrow interpretation: all wetlands located over 100 feet from a stream of any order.

2) Intermediate interpretation: all wetlands located within 100 feet of a first order stream plus the wetlands selected in 1 (narrow interpretation). The merged data set represents all wetlands in first order stream watersheds and those over 100 feet from a stream of any order.

3) Broad interpretation: all wetlands located within 100 feet of first and second order streams plus the wetlands selected in 1 (narrow interpretation). The merged data set represents all wetlands in first and second order stream watersheds and those over 100 feet from a stream of any order.

GIS analysis was used by Region III (and others) to evaluate the potential spatial impact of the proposed rulemaking. Two region wide spatial data sets were used in the Region III analysis, National Hydrography Data (NHD) and National Wetland Inventory (NWI) data. NHD is digital stream reach data (digital stream and river maps) available across the nation. The scale of the data set is 1:100,000 and was used as the region wide stream data. Digital NWI maps were used as the region wide wetland data. The scale of the NWI digital maps is 1:24,000. These two data sets represent the aquatic resources potentially impacted by the proposed rulemaking.

Purpose:

The analysis presented in this report is intended to complement the Region III GIS Team study by developing and analyzing site-specific data at four relatively small study areas in Region III. The analysis utilized both GIS and aerial photography interpretation (API).

The purpose of this analysis is two fold:

1) To compare the data used by the Region III GIS Team in its region wide analysis with wetlands and streams interpreted from aerial photography.

2) To evaluate the potential impacts of the proposed rulemaking on the

four study areas in Region III.

2) To evaluate the potential impacts of the proposed rulemaking on the four study areas in Region III using both region wide data sets (NWI and NHD) used by the Region GIS Team and data interpretable from aerial photography.

Numerous studies have shown that both the stream and wetlands mapping available on a regional or national basis underestimate the extent of both stream and wetland resources. Aerial photography interpretation (API) was used as a tool in this analysis to more accurately determine the potential effects of the proposed rulemaking.

The methodology used in this analysis is located in the methods section of this report.

The Study Areas:

Four study areas were established around wetland field sites investigated by Region III. Each study area was based on the stereo viewing area of the acquired aerial photography. The average size of the study areas is 30 square miles (19,200 acres), the total area analyzed was 123 square miles (78,720 acres). The study areas are: French Creek State Park and vicinity in Chester County, PA, the middle reaches of White Clay Creek in New Castle County, DE, an area around Millington, MD and an area around Church View, VA. Two of the study areas are in the eastern piedmont physiographic province and two are on the eastern coastal plain physiographic province.

The French Creek State Park study area is a hilly headwater setting in the Pennsylvania piedmont, the White Clay Creek Study area includes a fourth order stream in the Delaware piedmont. The Millington, MD study area is a headwater coastal plain setting that includes many hydrologically isolated wetlands known as Delmarva Bays. The Church View study area is centered around a section of a fourth order coastal plain stream.

Conclusions:

By using aerial photography interpretation, the potential impact of changes in jurisdiction was greater than shown by the regional GIS analysis. The regional analysis indicated that between 12% and 36% of wetlands could be impacted by changes in jurisdiction. However, when the region wide data was applied to the field sites, between 3,478 - 5,704 acres (51% - 84%) of total NWI wetlands would be affected depending on the interpretation of the ANPRM. Total NWI wetlands in the four study areas is 6,744 acres. The API data set indicated that between 2,579-6,074 acres (34% - 80%) of API wetlands would be affected depending on the interpretation of the ANPRM. Total API wetlands in the four study areas is 7,638 acres.

The potential impact of the proposed rulemaking on streams is also significant. Between 70%- 77% of all stream resources in the study areas were potentially impacted under the intermediate interpretation and up to 88%-92% of all stream resources were potentially impacted by the broad interpretation. Up to 100% of stream resources could be impacted in small, localized watersheds.

The potential impact of the intermediate and broad interpretations of the ANPRM on wetlands and all interpretations on streams will likely be greater in the field than was shown by this study. Because both the regional data set and the API data set underestimate stream and wetland resources, additional acres of wetlands and miles of streams that actually exist in the field were not covered by this study.

In this study, no study area showed less than a 33% potential wetland impact with the intermediate interpretation and up to 100% potential impact was seen with the broad interpretation.

The impact was greater in the study areas that were located in headwater settings. Up to 100% potential impact to wetlands can be expected in small first and second order watersheds using the intermediate and broad interpretations.

The API data set reduced the wetland impacts under the narrow interpretation as compared to the regional data set (2579 acres compared to 3478 acres). This suggests the higher resolution of the stream data, the lower the potential impact would be to wetlands under the narrow interpretation.

The higher the resolution of the wetlands data, the greater will be the potential impact of the proposed rulemaking. The total acreage of wetlands potentially impacted by the intermediate and broad interpretations is greater using the API data set as compared to the region wide data set (5219- 6074 acres compared to 5134-5705 acres). The percentage of wetlands potentially impacted by intermediate and broad interpretations the ANPRM using the API data set was less than that of the regional data set (34%-80% compared to 51%-84%). However, the greater potential overall acreage impact to wetlands using the API data set indicates the higher the resolution of the wetlands data, the greater will be the potential impact of changes in jurisdiction.

The higher the resolution of the stream data, the greater the potential impacts to stream miles under the intermediate and broad interpretations. The API data set, with its large number of first and second order streams, increased the potential impact of the proposed rulemaking on stream resources relative to the regional data set.

The regional data set underestimated stream and wetland resources as compared to the API data set.

Discussion:

Using the spatial analysis tools of the ArcView GIS, the three interpretations of the ANPRM were applied to both the regional stream and wetland data sets and to the results of stream and wetland mapping derived from the interpretation of aerial photography at the four study areas identified above. This was done to compare the results of the aerial photography interpretation to the region wide data sets and to determine the geographic extent of the three interpretations on the four study areas using both data sets.

Selected maps that graphically depict some of the results of this analysis are attached to this report. Not every conclusion discussed in this report is reflected in a graphic figure. However, all of the data that supports the conclusions can be found in the results table at the end of the report.

Study Area Impacts:

In this study, the potential impact of the proposed rulemaking was greater than shown by the region wide GIS analysis. This is due to the small size of the study areas, which results in study area specific variations in the spatial distribution of wetlands and streams.

For example, the French Creek Study area was 38 square miles and contained a predominance of first and second order streams. This analysis of the study area showed that 763 acres of NWI wetlands (98% of total NWI) using the regional data set and 980 acres of API wetlands (89% of total API wetlands) using the API data set would potentially be impacted as the result of the broad interpretation of the ANPRM. (See Figures 1 and 2) The regional analysis indicated that 38.7% of wetlands in Pennsylvania would be potentially impacted by the broad interpretation of the ANPRM.

A more dramatic potential impact of the proposed rulemaking was found at the 30 square mile Millington, MD study area. (Figures 3 and 4) This is the area of the regionally rare Delmarva Bay wetlands. Due to the relative lack of streams in this area, the broad interpretation resulted in

3933 acres of impact to NWI wetlands (100% of total NWI) and 3793 acres of impact to API wetlands (94% of total API wetlands). The region wide GIS analysis indicated that 29.6% of wetlands in Maryland would be potentially impacted by the broad interpretation of the ANPRM. In the Millington study area, the smallest potential impact of the proposed rulemaking was 2073 acres of API wetlands (51%). The region wide GIS analysis indicated that under the narrow interpretation 12% of Maryland's wetlands would be potentially impacted by the proposed rulemaking.

Contrasting to the above example, the 30 square mile, Church View, VA study area showed less potential impact; 124 -1110 acres (6%-50% of total) depending on the data set and interpretation of the ANPRM. (See Figures 5 and 6) This is due to the large wetland area associated with Dragon Run, a fourth order stream. The wetlands associated with Dragon Run represented a significant proportion of the wetlands in the study area. These wetlands were not included in the analysis of the potential impact of the proposed rulemaking, lowering the overall impact. In this study area the impact was closer to the region wide GIS analysis, which indicated that between 9.5% and 36.6% of wetlands in Virginia would potentially be impacted by the proposed rulemaking depending on the interpretation.

Total NWI wetlands in the four study areas is 6771 acres; of this between 3478 and 5705 could potentially be affected by the proposed rulemaking, depending on the interpretation.

The total API wetlands in the four study areas is 7638 acres; of this between 2579 and 6074 acres could be affected by the proposed rulemaking, depending on the interpretation.

<u>The three interpretations</u>:

Figures 8-10 show the impact of the three interpretations on the Millington, MD study area.

Narrow Interpretation:
The average potential impact on wetlands resources of the narrow interpretation of the ANPRM in the four study areas is between 2579 acres (34% API data set) and 3478 acres (51% regional data set). The lowest potential study area impact was 124 acres (6% API data set) of all wetlands in the Church View study area. The highest potential impact of the proposed rulemaking was 3069 acres (78% regional data set) in the Millington, MD study area. The API data lowered the overall impact of the narrow interpretation.

Intermediate Interpretation:
The potential impacts of the proposed rulemaking jumped significantly with the intermediate interpretation (47% increase over the narrow interpretation with the regional data set and a 102% increase with the API data set). This is the result of numerous first order streams in both data sets. First order streams are the data layer used to select wetland resources potentially impacted by the proposed rulemaking . The average potential impact on wetland resources of the

intermediate interpretation of the ANPRM is between 5219 acres (68 % API data set) and 5134 acres (76% regional data set). The lowest potential study area impact was 731 acres (33% aerial photography data set) of all wetlands in the Church View study area, the highest potential impact of the proposed rulemaking was 3665 acres (93% regional data set) in the Millington, MD study area.

Broad Interpretation:
The potential impacts of the proposed rulemaking increased less significantly with the broad interpretation (11% increase over the intermediate interpretation with the regional data set and a 16% increase with the API data set). This is due to the relatively fewer second order streams in both data sets as compared to the number of first order streams. The average potential impact on wetland resources of the broad interpretation of the ANPRM is between 6074 acres (80% aerial photography data set) and 5705 acres (85% regional data set). The lowest potential study area impact was 1110 acres (50% aerial photography data set) of all wetlands in the Church View study area, the highest potential impact of the proposed rulemaking was 3933 acres (100% regional data set) in the Millington, MD study area.

Potential Impacts to first and second order streams:

If the intermediate and broad interpretations of the ANPRM include first and second order streams to be at risk from loss of jurisdiction under the CWA, the potential impacts are significant. According to the region wide data applied to the field sites, 133.4 miles of streams are located in the four study areas. Of that, 92.3 miles (69%) are first order streams and 24.6 (18%) miles are second order streams. A total of 117.9 miles of first and second order streams (88% of total) are potentially impacted by the proposed rulemaking using the regional data set.

Looking at the API data set, a total of 343.2 miles of streams were mapped in the four study areas. Of this 265.5 miles (77%) are first order streams and 49.3 miles (14%) are second order streams. A total of 314.8 miles of first and second order streams (92% of total) are potentially impacted by the proposed rulemaking using the API data set.

Figure 7 illustrates the potential impact to first and second order streams in the vicinity of French Creek State Park.

Regional Data Sets Compared to Aerial Photography Data Sets:

A comparison of the data sets used in the region wide analysis to that derived from API showed that the NHD stream maps underestimated the stream network in the study areas from 118% to 286%. The average underestimation was 157% which indicates that on average, over two and one half times more stream length is visible on aerial photography as compared to the 1:100,000 scale NHD data. The NWI data underestimated (as compared to API) the acreage of wetlands in the study areas from 3% to 41%. The average was a 13% underestimation of the area of wetlands as compared to that interpretable from aerial photography.

Notwithstanding the differences outlined above, the trends in the potential impact of the proposed rulemaking on wetland resources using the two data sets were similar. Averaging the four study areas, the region wide data indicated that between 51% and 84% (51% narrow, 76% intermediate, 84% broad) of wetlands could be affected depending on the interpretation of the ANPRM. The API data set indicated that on average between 34% and 80% (34% narrow, 68% intermediate, 80% broad) of wetlands could be affected depending on the interpretation of the ANPRM.

The narrow interpretation resulted in the least amount of impact and the broad interpretation resulted in the greatest impact in both data sets.

The range of data at all four sites was also similar between the two data sets, 8% to 100% potential impact using the regional data set and 6% to 94% with the API data set.

The narrow interpretation showed the greatest difference in results between the two data sets with 51% of all wetlands potentially impacted using the regional data set and only 34% using the API data set. The smaller potential of impact when using the API data set is a result of the larger number of streams in the API data set as compared to the regional data set. This resulted in less wetland acreage located greater than 100 feet from a stream. Since the narrow interpretation considers the wetlands located greater than 100 feet from any stream to be potentially impacted by the proposed rulemaking, the overall impact of the narrow interpretation was less when using the API data sets.

Two observations are relevant to the differences between the data sets for the intermediate and broad interpretations. First, a narrowing of the percentage differences between the two data sets was observed for these interpretations relative to the narrow interpretation. This is explained by the fact that the study area watershed boundaries are the same for each data set and that both the intermediate and broad interpretations select all the wetlands in the first and second order watersheds regardless of the number of first or second order streams or wetlands in the data set. This tended to narrow the percentage differences between the data sets. However, as reported in the conclusions the *acreage* of potential impact of the intermediate and broad interpretations was greater for the API data set than the regional data set.

Secondly, the difference in the percentage of potential impact that does exist between the two data sets is due to differences in stream order in the data sets. The intermediate and broad interpretations did show a small reduction of potential impact on a percentage basis using the API data set as compared to the regional data set. With the intermediate interpretation, 76% of wetlands were potentially impacted using the regional data set compared to 68% for the API data set. The difference in the percentage of potential impact in the API data set is the result of some of the first order streams in the regional data set being classified as second order streams in the

API data set. The intermediate interpretation selects only wetlands associated with first order streams as a potential impact, not those associated with second order streams, so the reclassification of some first order streams to second order streams resulted in fewer wetlands being considered a potential impact of the intermediate interpretation using the API data set. With the broad interpretation, 84% of wetlands were potentially impacted using the regional data set as compared 80% using the API data set. The broad interpretation selects wetlands associated with first and second order streams as a potential impact, not those associated with third order streams, so the reclassification of some second order streams to third order streams resulted in fewer wetlands being considered a potential impact of the intermediate interpretation using the API data set.

As described above, the difference in the potential impact of the proposed rulemaking that is apparent between the data sets under the intermediate and broad interpretations is the result of a larger stream orders in the API data set as compared to the region wide data sets. A discussion of the stream ordering process can be found in the methods section

An example of the effect of stream ordering on the results of the GIS analysis can be found in the Millington, MD study area. Due the presence of only first and second order streams in this study area in the regional data set, the broad interpretation using the regional data set resulted in 100% of all wetlands potentially impacted by the proposed rulemaking. However due to the increased resolution of the API data, a second order stream segment contained in the region wide data was considered to be a third order stream in the API data set. The wetlands along this third order stream were not selected as a potential impact of the proposed rulemaking, thus the overall impact was slightly less with the API data set than the region wide data set. The aerial photography data set resulted in 94% of all wetlands potentially impacted by the proposed rulemaking. The relatively small percentage difference is the result of the stream ordering process.

However, the potential impacts to wetlands of the proposed rulemaking are significant even when using the higher resolution data interpreted from the aerial photography. Using the API data set, the results of this GIS analysis showed the potential impacts of the proposed changes was a 34%-80% reduction of wetlands under CWA jurisdiction, depending on the interpretation. This amounted to between 2579 and 6074 acres of a total of 7638 acres of wetlands potentially impacted by the proposed rulemaking. Moreover, although the percentage of the total wetlands in the API data set was less that that of the regional data set, because of the greater overall acreage of wetlands in the API data set, the acreage of wetland potentially impacted by the intermediate and broad interpretations is actually greater using the API data set.

Disclaimer:

All of the results described above must be qualified considering the inherent issues associated with wetland identification and stream mapping from small scale region wide data bases and the interpretation of aerial photography (time of year, scale, film type). This study and other studies have shown that the region wide data underestimate stream and wetland resources. Although API can improve the region wide mapping, API cannot locate and map all wetland areas and stream segments visible in the field. In addition, false positive identifications exist. The API was not ground truthed over the vast majority of the study areas.

The results of the API can be considered a step closer to actual field conditions when compared to the regional data, but without ground truth , it should not be considered as representing actual field conditions. If the three interpretations of the ANPRM were applied on a case-by-case basis in the field, the results would differ from this study

Methods

Photo Interpretation:

Stereo pairs of vertical aerial photography were obtained and examined through the use of a standard light table and stereoscope. This process enables three-dimensional viewing of the study area. Three-dimensional viewing enhances the identification of objects, drainage patterns, topography, landform and landscape position.

The analysis of the aerial photography was performed under various magnifications allowing the interpreter to zoom in on an area and examine the area from a distance. This technique facilitates a thorough analysis of conditions and features appearing on the aerial photography.

Wetlands are a landscape feature that can be identified from aerial photography based on their shape, size, texture, landscape position, vegetative cover, and evidence of water or high soil moisture. The combination of landscape position (depressions, low gradient drainage areas, flood plains, adjacency to lakes, estuaries or other water features), with characteristic vegetation cover (emergent, shrub or forested vegetation) and indications of water (standing water, wetland drainage patterns, persistent ground moisture conditions and dark photographic tones) form an identifiable "signature" of a wetland area on aerial photography.

Drainage patterns are observable on aerial photography as curvilinear features that form branching patterns on the landscape. Individual reaches are identified by characteristic curving or straight lines, associated vegetation patterns, photographic tones, landscape position and in some cases visible water. Drainage pattern mapping is aided with stereoscopic viewing.

The aerial photography was interpreted for two main purposes:

> To map streams interpretable from aerial photography and to compare these the streams mapped by the US Geological Survey (USGS) 100,000 scale hydrology data. The USGS 100,000 scale

(100K) stream data was a major input in the regional GIS analysis of the effects of the proposed rulemaking.

Additional drainage paths visible on the aerial photography were added to the USGS 1:24,000 stream maps (the 1:24,000 scale data was chosen because it more closely resembled the drainage patterns observable on the aerial photography as compared to the 1:100,000 scale stream data). Other edits to the 1:24,000 stream maps (better fit to visible streams) were made and saved as photo interpreted drainage layer.

The drainage interpreted from the aerial photography does not include every possible ephemeral channel visible. Instead an attempt was made to map only distinct drainage paths with watershed areas greater that 15-20 acres.

2) To create a map of wetlands interpretable from aerial photography and to compare these to that of the National Wetland Inventory (NWI). NWI is available region wide and was used a major input in the regional wide analysis of the effects of the proposed rulemaking.

From the interpretation of the aerial photography additional wetland areas were added to NWI where visible, and other edits to NWI wetland shape and size were made and saved as the photo interpreted wetlands layer.

The wetlands interpreted from the aerial photography are potential wetlands. They have not been field verified except at the Region 3 field sites. The wetlands interpreted from aerial photography do not represent a complete inventory. It is likely that numerous small seeps that form the headwaters of many drainages, small toe of slope wetlands, and other small wetlands scattered across the study areas were missed. In addition, false positives may exist. The wetland data should be qualified considering the above and the inherent issues associated with wetland identification from the interpretation of aerial photography (time of year, scale, film type).

GIS Analysis:

ArcView GIS software spatial analysis tools were used to perform the same GIS analysis as was done on the region wide data sets. This GIS effort included both the wetland and stream data derived from the regional data sets and the data derived from aerial photography interpretation. The GIS analysis evaluation has several purposes. First, to compare the region wide data with that of a more focused site-specific analysis. This was done to compare the regional data on wetland acreage and stream length with that obtained from aerial photography interpretation. Second, using regional data sets and the same protocols. GIS analyses were run on the four small study areas to provide a site specific base line to compare the results of the aerial photography interpretation. Then, the more detailed results from the aerial photography interpretation (more detailed drainage pattern and wetland mapping) were used as inputs for the same GIS analysis to get a more realistic, site specific evaluation of the potential effects of the proposed rulemaking.

The following analysis was run on both the regional data sets (NWI and NHD 100K Data) and photo interpreted wetlands and streams.

1) Narrow interpretation of the ANPRM: Activate the wetland theme, use the select by theme tool to select all wetlands located within 100 feet from the stream theme (stream order is not used as a selection criteria). Open the wetland theme attribute table and switch selection to select all the wetlands located over 100 feet from a stream of any order. Save the selected wetlands as shape file, narrow interpretation theme.

2) Intermediate interpretation: Activate the stream theme that is attributed with stream order. Using the query function select the set of streams that equal first order. Save as a shape file, first order streams. Activate the wetland theme and use the select by theme tool to select all wetlands located within 100 feet of the first order stream theme. Save the selected wetlands as a shape file (temp directory). Merge this theme with the narrow interpretation theme. Save the merged data as the intermediate interpretation theme. The merged data set represents all wetlands in first order stream watersheds and those over 100 feet from a stream of any order.

3) Broad interpretation: Activate the stream theme that is attributed with stream order. Using the query function select the set of streams that equal first and second order. Save as a shape file, first and second order streams. Activate the wetland theme and use the select by theme tool to select all wetlands located within 100 feet of the first and second order stream theme. Save the selected

wetlands as a shape file (temp directory). Merge this theme with the narrow interpretation theme. Save the merged data as the broad interpretation theme. The merged data set represents all wetlands in first and second order stream watersheds and those over 100 feet from a stream of any order.

The GIS analysis steps selected all wetlands meeting the above criteria. In some instances with the intermediate and broad interpretations, the GIS selected wetlands adjacent to third and fourth order streams due of the presence of first or second order streams intersecting the larger stream order. This is inconsistent with the premise of the interpretations, that only wetlands associated with first and second order streams would be affected by the proposed rulemaking. Therefore wetlands clearly associated with third and fourth order streams were manually deselected from the GIS selected data set before saving the selected data set as either the intermediate or broad interpretation theme.

Data Used:

Aerial Photography

USGS National Aerial Photography Program (NAPP)
Scale: 1:40,000

11378:18-20	Date: 4-13-99	B&W
11380:226-228	Date: 4-13-99	CIR
9:18-20,115-117	Date: 4-17-88	CIR
7684:27,28	Date: 3-12-94	CIR
7686:70,71	Date: 3:17-94	CIR
7691:12-14,26-28	Date: 3-11-95	CIR
5512: 42-44	Date: 4-6-92	B&W

Digital Data

Digital Ortho Quads (DOQ):
Elverson, PA, Millington MD, Newark West DE and Church View VA:
Projection UTM NAD 83

Hydrography Data:
100,000 Scale National Hydrography data (NHD) from USGS Site:
Projection, Digital Degree NAD 83
24,000 Scale Hydrography data from GIS Data Depot: Projection, UTM NAD 27
24,000 Scale Hypsography data from GIS Data Depot: projection, UTM NAD 83

National Wetland Inventory (NWI):
National Wetland Inventory Data from NWI Site: Projection UTM NAD 27

Soils Data:
SSURGO County Soil Survey Data from NRCS for King and Queen and Middlesex Counties, VA: Projection. Digital Degree NAD 83

Field Site Location:
GPS data from Region 3: Projection Digital Degree NAD 83

Data Handling:

DOQ's:
The DOQ's are directly viewable in ArcView and formed the map base for each study area. ArcView projection utility was used to convert all shapefiles to UTM Zone 18N NAD 83 so they could be overlayed on the DOQ map base.

NHD:
The 100,000 HHD Data was downloaded from the USGS site. The Digital Degree (DD) data was readable by ArcView but had to be converted to the ArcView shape file format for further processing. The NHD DD shape files were converted to NAD 83 using the ArcView projection utility.

1:24,000 data:
The 24,000 scale Hydrography and Hypsography data (SDTS Format) were downloaded from the GIS Data Depot site and converted to AutoCad Drawing format using a SDTS DOS utility.The AutoCad drawing is viewable in ArcView. The AutoCad drawing was converted to the ArcView shape file format for further processing (datum conversion). The 24K hydrology and hypsography data was then converted to NAD 83 using the ArcView projection utility. The hypsography data was used to enhance the on screen digitizing of API streams.

All data was clipped to the study area boundary for ease in processing. Clipped 24 K hydrography data was "cleaned"; (deleted ponds, deleted double lines, deleted quadrangle border). The purpose of the data cleaning was to get a more accurate estimate of the linear feet of drainage within the study area. Ponds and the quadrangle outline were deleted because they are not streams yet had a linear outline which would contribute erroneously to the total linear footage of streams. Double lines along both sides of large streams were eliminated to create one single line representing the stream

The cleaned 24K hydrography data and the NWI data were converted to new shapefiles, which formed the base data to be modified by photo interpretation. The cleaned 24 K hydrography was not further processed and the NWI was not processed after clipping.

Stream Ordering:
The 100,000 scale NHD data and the aerial photography interpreted drainage were manually attributed with stream order classifiers so that the intermediate and broad interpretations of the ANPRM could be applied in a GIS environment. When ordering the streams in the API data set the stream orders interpretable from the 1:24,000 scale stream data set and the 1:100,000 scale stream data set was factored in the process in order to be as consistent as possible with the stream orders interpretable from these data sets. For example, second order streams were not created at every intersection of two small and likely intermittent first order streams. Instead, the location of first and second order streams observable in the 1:24,000 and 1:100,000 stream data set was used as a guide when assigning stream order to the API data set. Even so, due the higher number and greater density of streams in the API data as compared to the 1:24,000 and 1:100,000 scale data, the stream ordering of the API data assigned higher orders to some stream segments.

The API tended to move the larger order streams higher in the watersheds than the regional data set because more stream segments and stream intersections were visible. The stream ordering process looks at streams segments and intersections and when two first order streams combine the stream segment below is classified as a second order stream. Two second order streams combining create a third order stream and so on. Since more stream segments are visible in the API data set the formation of second order streams tended to somewhat higher in the watershed as compared to the regional data.

NWI:
The NWI Data was downloaded from the NWI site as ArcInfo files and imported to ArcView using the ArcView Import function. The NWI data was converted to NAD 83 using the ArcView projection utility.

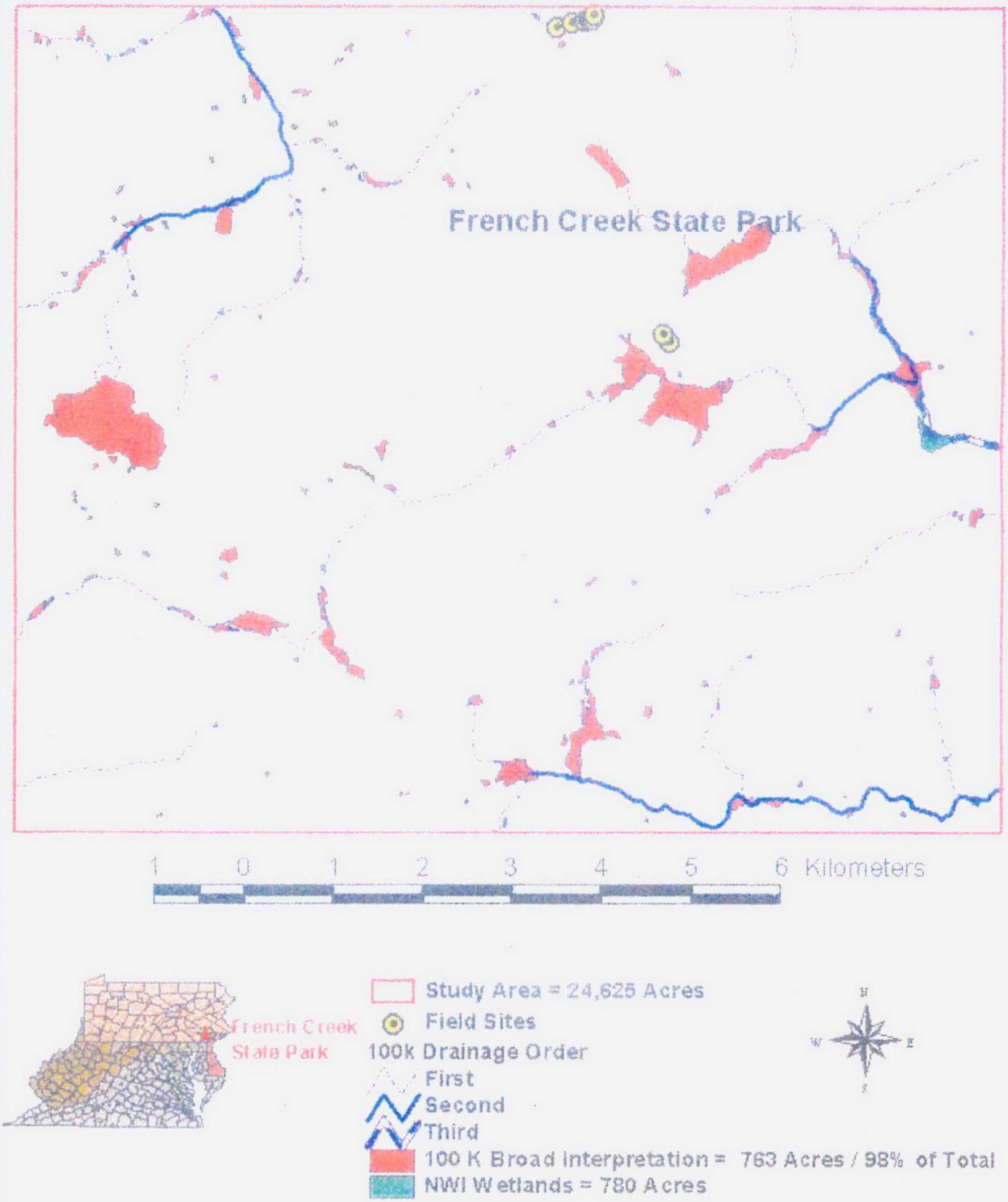
Field Data:
Field Sites location GPS data was in shape file format. The field site data was converted to NAD 83 using the ArcView projection utility

Results Table: the following table summarizes the data obtained from the API and GIS analysis.

Results Table: the following table summarizes the data obtained from the API and GIS analysis.

Study Area	French Creek	Church View	Millington	White Clay Creek	Total	Average
Size sq/mi	38	30	30	25	123	30
Total 100K stream miles	33.9m	46 9m	20.0m	32.6m	133.4m	33.35
First order	24.5m	31 8m	15.2m	20.8m	92.3m/69%	23m
Second order	8.5m	6.0m	4 8m	5.3m	24 6m/18%	6.1m
Third order	0.9m	9 2m	------	0.9m	11.0m/8%	2.75m
Fourth Order	------	------	------	5.6m	5.6m/4%	1 4m
24 k stream miles	52.0m	76.0m	41 4m	47.6m	217m	54.25
Delta 24K/100K	53%	62%	107%	46%	-----	63%
Total API stream miles	86.2m	108.6m	77.3m	71.1m	343 2m	85.8m
First order	64.7m	78.2m	64.8m	57.8m	265.5m/77%	66.4m
Second order	18.0m	16.9m	7.5m	6.9m	49.3m/14%	12.3m
Third Order	3.6m	4.6m	5.0m	0.9m	14.1m/4%	3 5m
Fourth Order	-------	8 9m	-------	5.6m	14.5m/4%	3.6m
Delta API/24k	66%	43%	87%	49%	------	58%
Delta API/100k	154%	132%	286%	118%	------	157%
100K Narrow/% of Total	193a/25%	153a/8%	3069a/78%	63a/29%	3478a/52%	869a
100K Intermediate/% of Total	662a/85%	687a/38%	3665a/93%	120a/56%	5134a/76%	1284a
100 K Broad/% of Total	763a/98%	856 a/47%	3933a/100%	153a/71%	5705a/85%	1426a
NWI Acres	780a	1817a	3933a	214a	6744a	1686a
NWI acres/sq mi	20a	61a	131a	8.6a	------	55a
API Wetland Acres	1097a	2221a	4056a	264a	7638a	1910a
Delta API/NWI	41%	22%	3%	23%	------	13%
API wet acres/sq mi	29a	74a	135a	11a	------	62a
API Narrow/% of Total	341a/ 31%	124 a/ 6%	2073a/ 51%	41a/15%	2579a/34%	675a
PI Intermediate/% of Total	737 a/ 67%	731a/ 33%	3589 a/ 88%	162a/61%	5219a/68%	1305a
PI Broad/% of Total	980a /89%	1110a/50%	3793 a/ 94%	191a/72%	6074a/80%	1519a

Wetlands in the Vicinity of French Creek State Park, Elverson, PA (Broad Interpretation using 100K Hydrology Data and NWI)

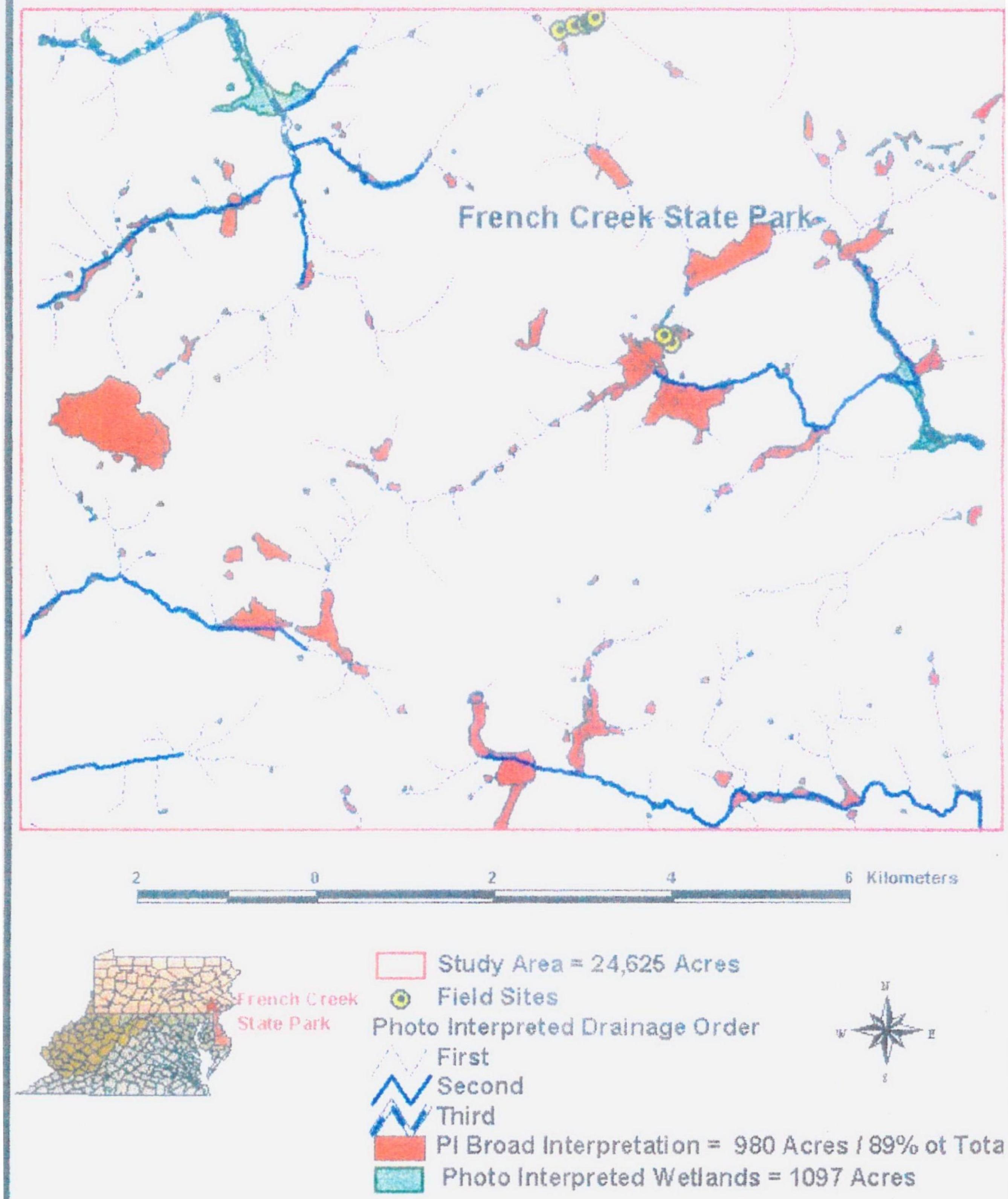


Source Data:
USGS National Hydrography Data
National Wetland Inventory (NWI)
Map Prepared by Peter Stokely
EPA Region 3 703-648-4292

Broad Interpretation of ANPRM:
NWI wetlands located over
100 feet from the
100 K USGS Hydrology Data
plus all NWI wetlands associated
with first and second order streams

Figure 1

Wetlands in the vicinity of French Creek State Park, Elverson, PA
(Broad Interpretation using Aerial Photo Interpreted Wetlands and Drainage)

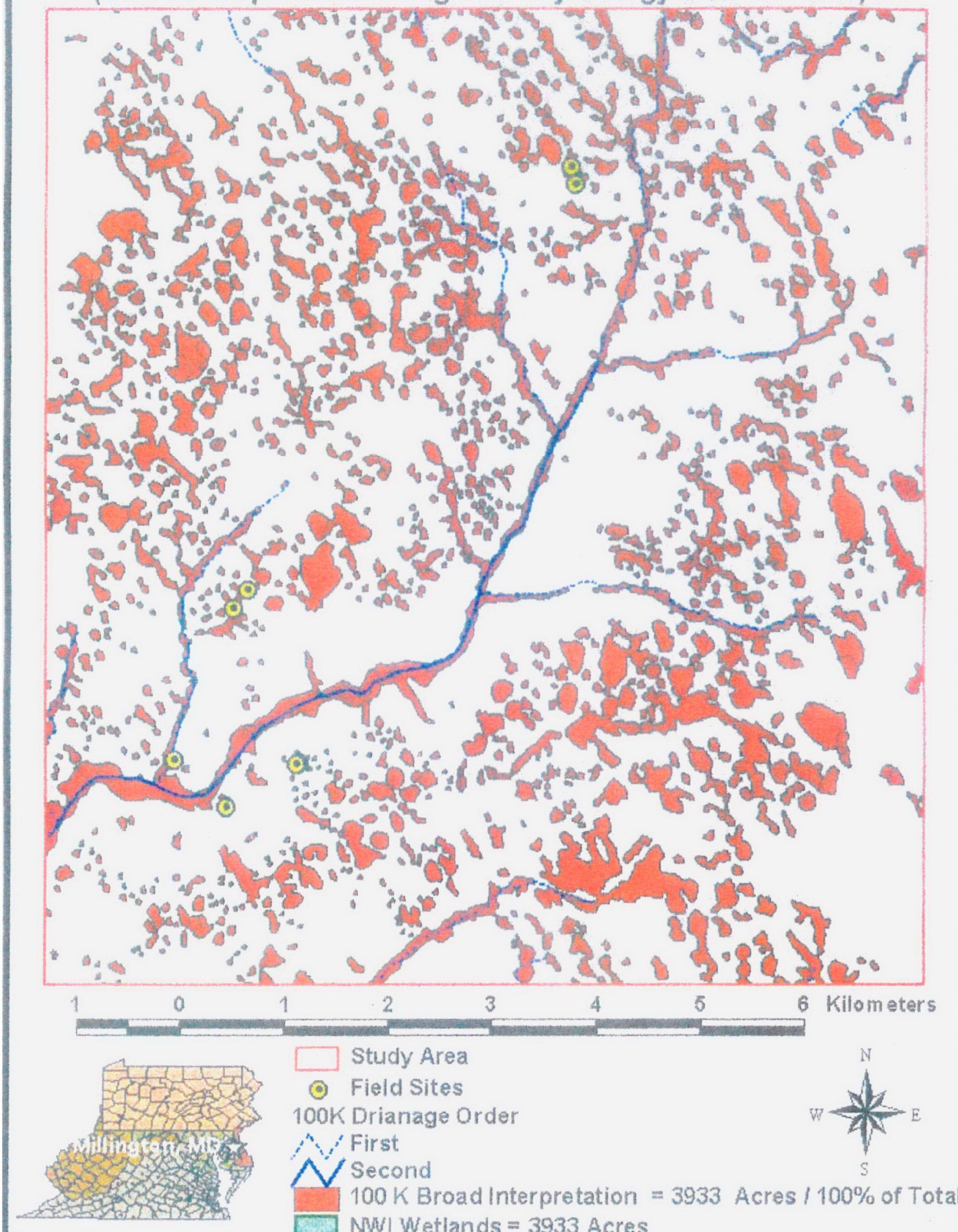


Source Data:
B&W NAPP Aerial Photography 4-13-99
USGS Hydrography
NWI
Map Prepared by Peter Stokely
EPA Region 3 703-648-4292

Broad Interpretation of ANPRM:
API mapped wetlands located over
100 feet from API mapped drianage
plus all wetlands associated
with with first and
second order streams

Figure 2

Wetlands in the Vicinity of Millington, MD
(Broad Interpretation using 100K Hydrology Data and NWI)

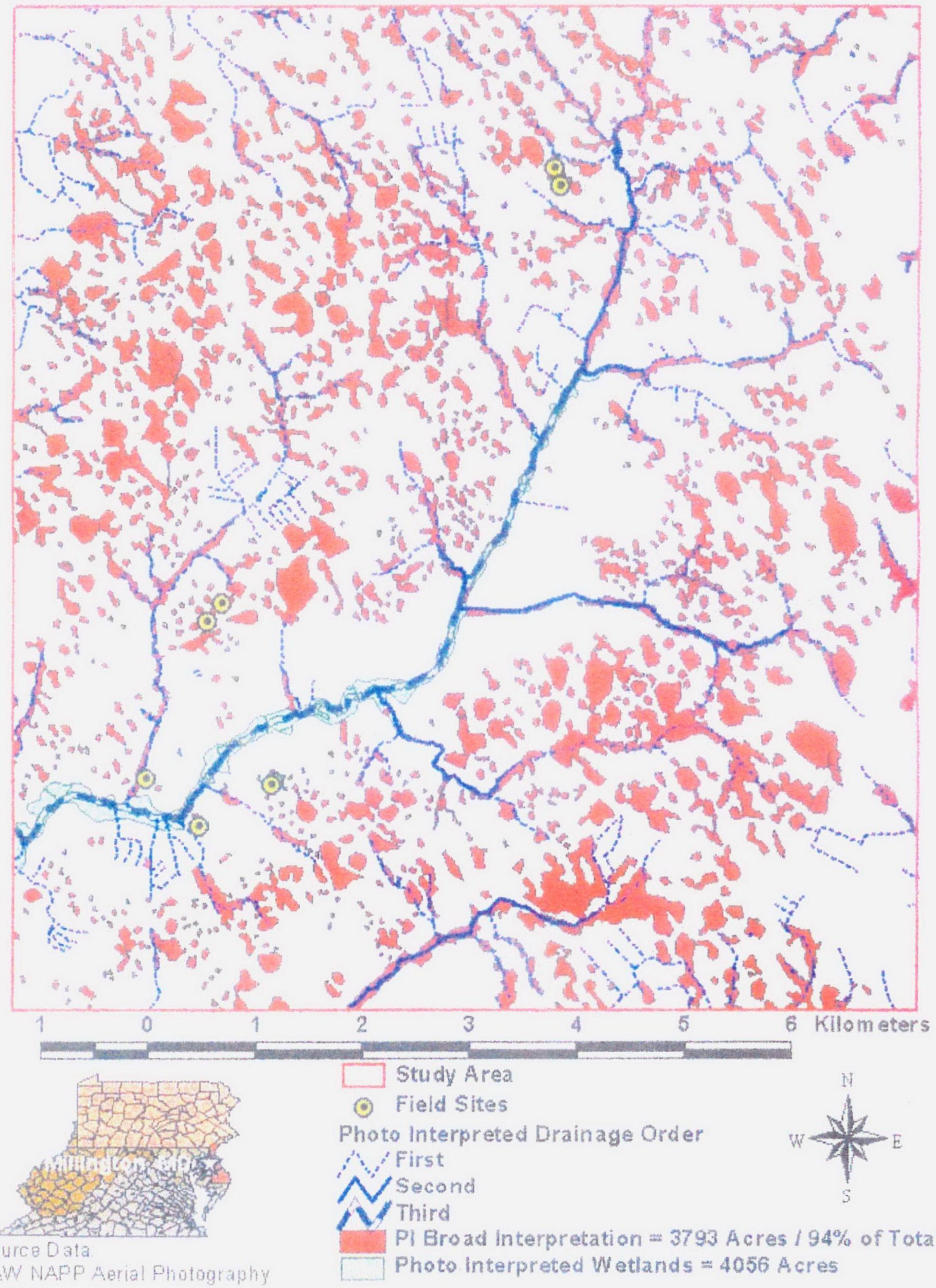


Source Data:
USGS National Hydrography Data
National Wetland Inventory (NWI)
Map Prepared by Peter Stokely
EPA Region 3 703-648-4292

Broad Interpretation of ANPRM: all NWI wetlands located over 100 feet from the 100 K USGS Hydrology Data plus all NWI wetlands associated with first and second order streams

Figure 3

Wetlands in the Vicinty of Millington, MD
(Broad Interpretation using Aerial Photo Interpreted Wetlands and Drainage)

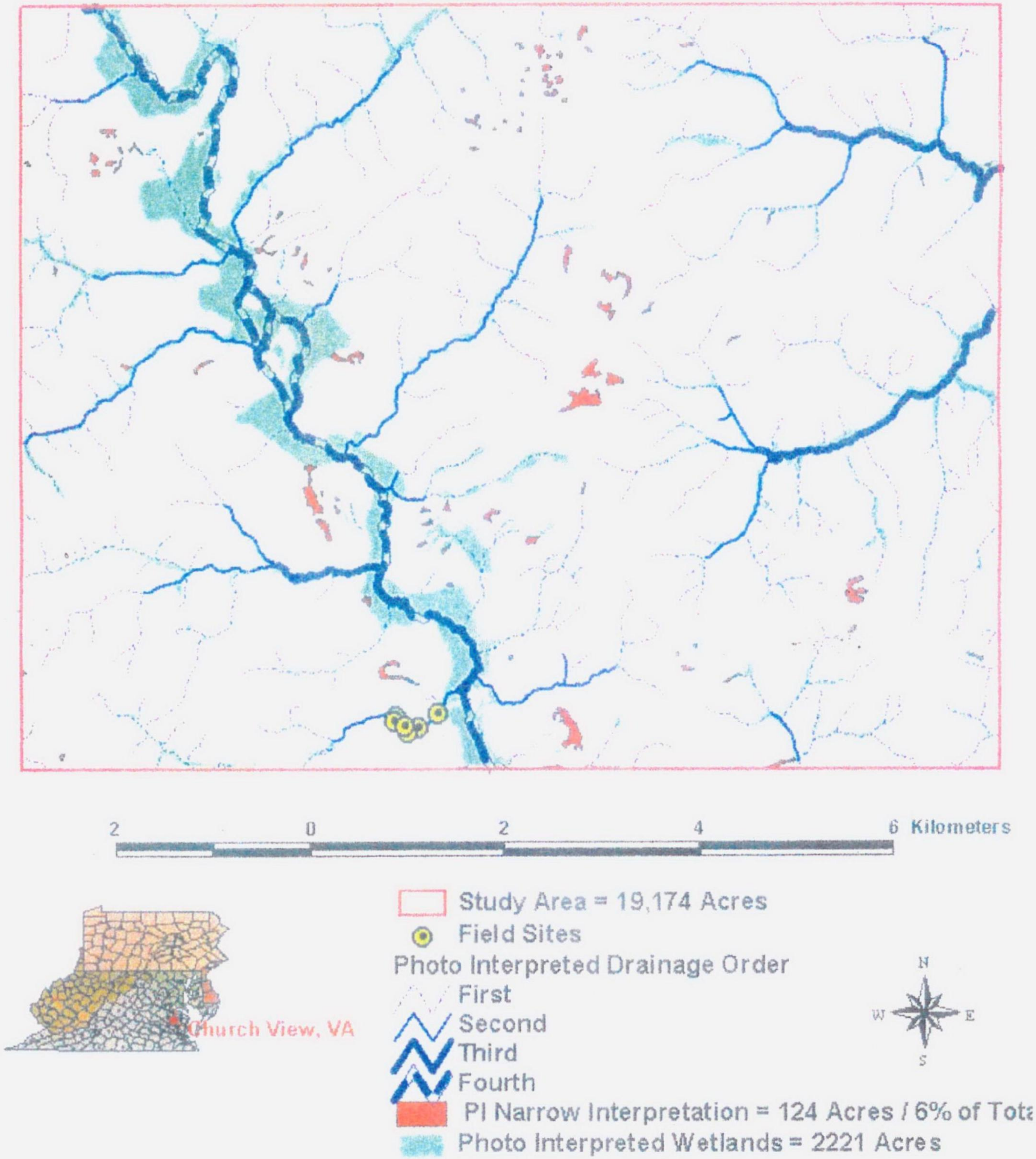


Source Data
B&W NAPP Aerial Photography
4-17-88
USGS Hydrography
National Wetland Inventory NWI
Map Prepared by Peter Stokely
EPA Region 3 703-648-4292

Broad Interpretation of ANPRM: PI mapped wetlands located over 100 feet from PI mapped drainage plus all wetlands associated with first and second order streams

Figure 4

Wetlands in the Vicinity of Church View, VA (Narrow Interpretation using Aerial Photo Interpreted Wetlands and Drainage)

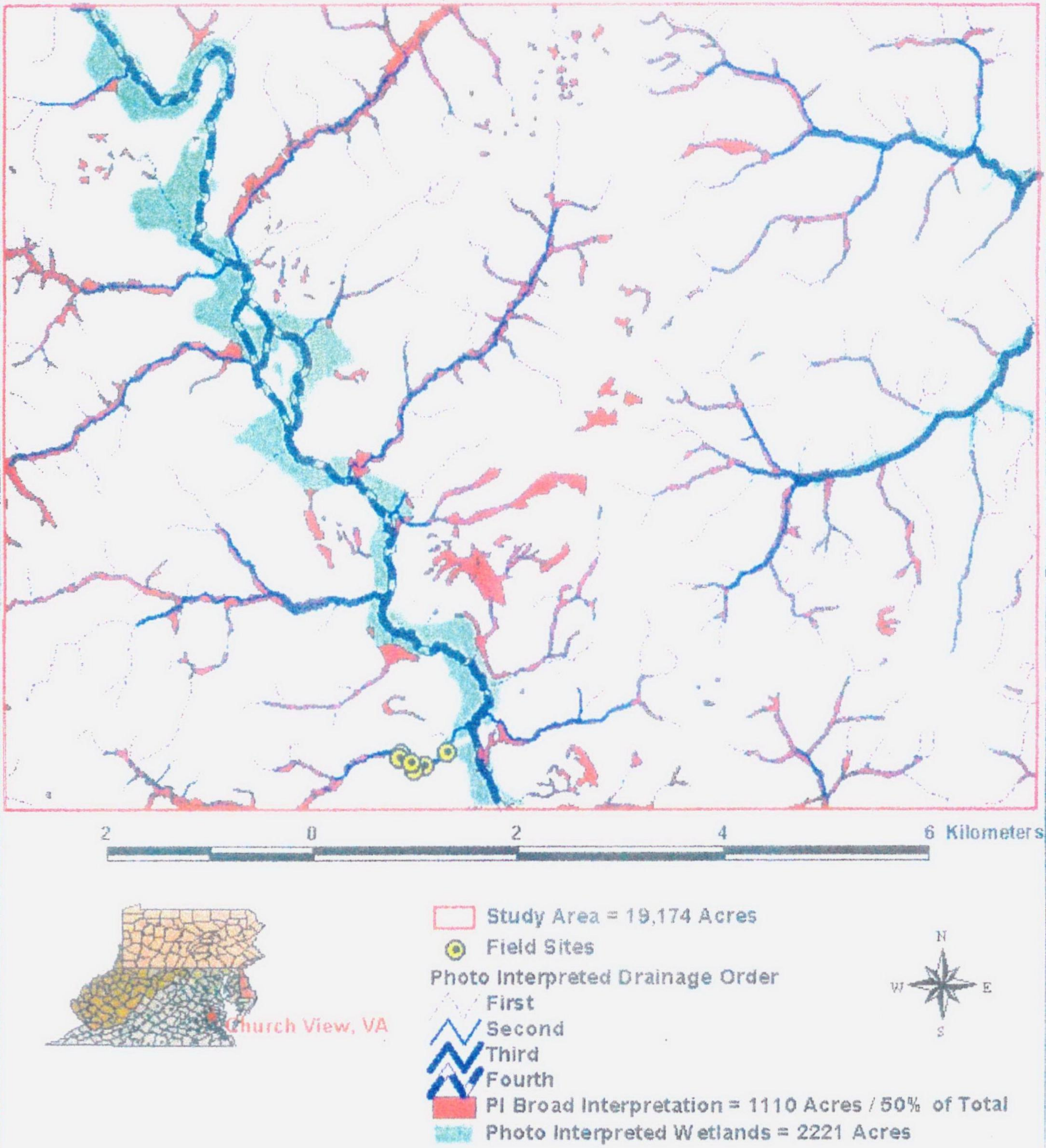


Source Data:
CIR NAPP Aerial Photography 3-11-95
USGS Hydrography Data
National Wetland Inventory (NWI)
Map Prepared by Peter Stokely
EPA Region 3 703-648-4292

Narrow Interpretation of ANPRM: PI mapped wetlands located over 100 feet from PI mapped drianage

Figure 5

Wetlands in the Vicinity of Church View, VA (Broad Interpretation using Aerial Photo Interpreted Wetlands and Drainage)



Source Data:
CIR NAPP Aerial Photography 3-11-95
USGS Hydrography Data
National Wetland Inventory (NWI)
Map Prepared by Peter Stokely
EPA Region 3 703-648-4292

Broad Interpretation of ANPRM: PI mapped wetlands located over 100 feet from PI mapped drianage plus all wetlands associated with with first and second order stream watershds

Figure 6

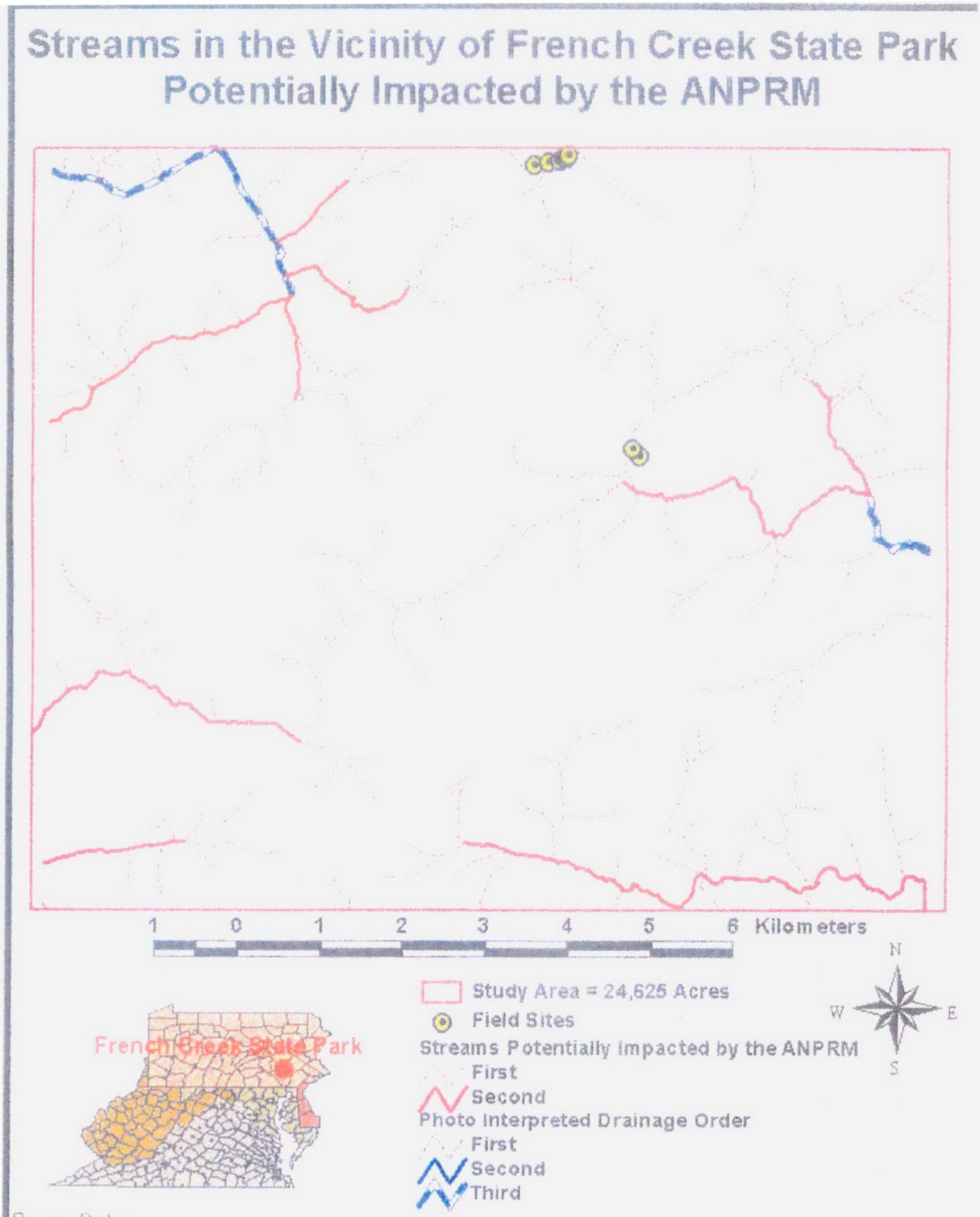
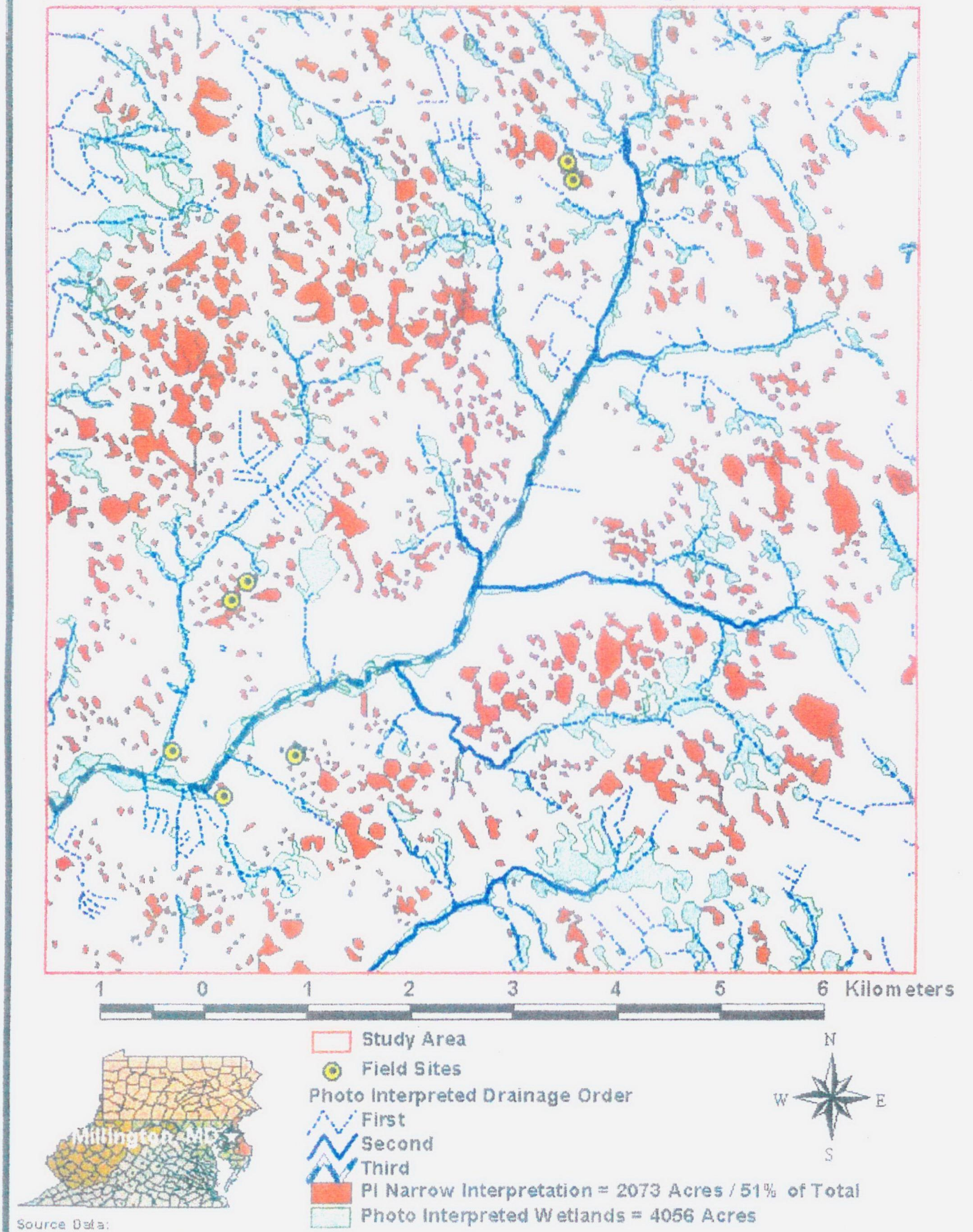

Streams in the Vicinity of French Creek State Park Potentially Impacted by the ANPRM
1 0 1 2 3 4 5 6 Kilometers
N
W
E
S
Study Area = 24,625 Acres
Field Sites
Streams Potentially Impacted by the ANPRM
First
Second
Photo Interpreted Drainage Order
First
Second
Third
French Creek State Park
Source Data:
B&W NAPP Aerial Photography 4-13-99
USGS Hydrography
NWI
Map Prepared by Peter Stokely
EPA Region 3 703-648-4292

Figure 7

Wetlands in the Vicinty of Millington, MD (Narrow Interpretation using Aerial Photo Interpreted Wetlands and Drainage)

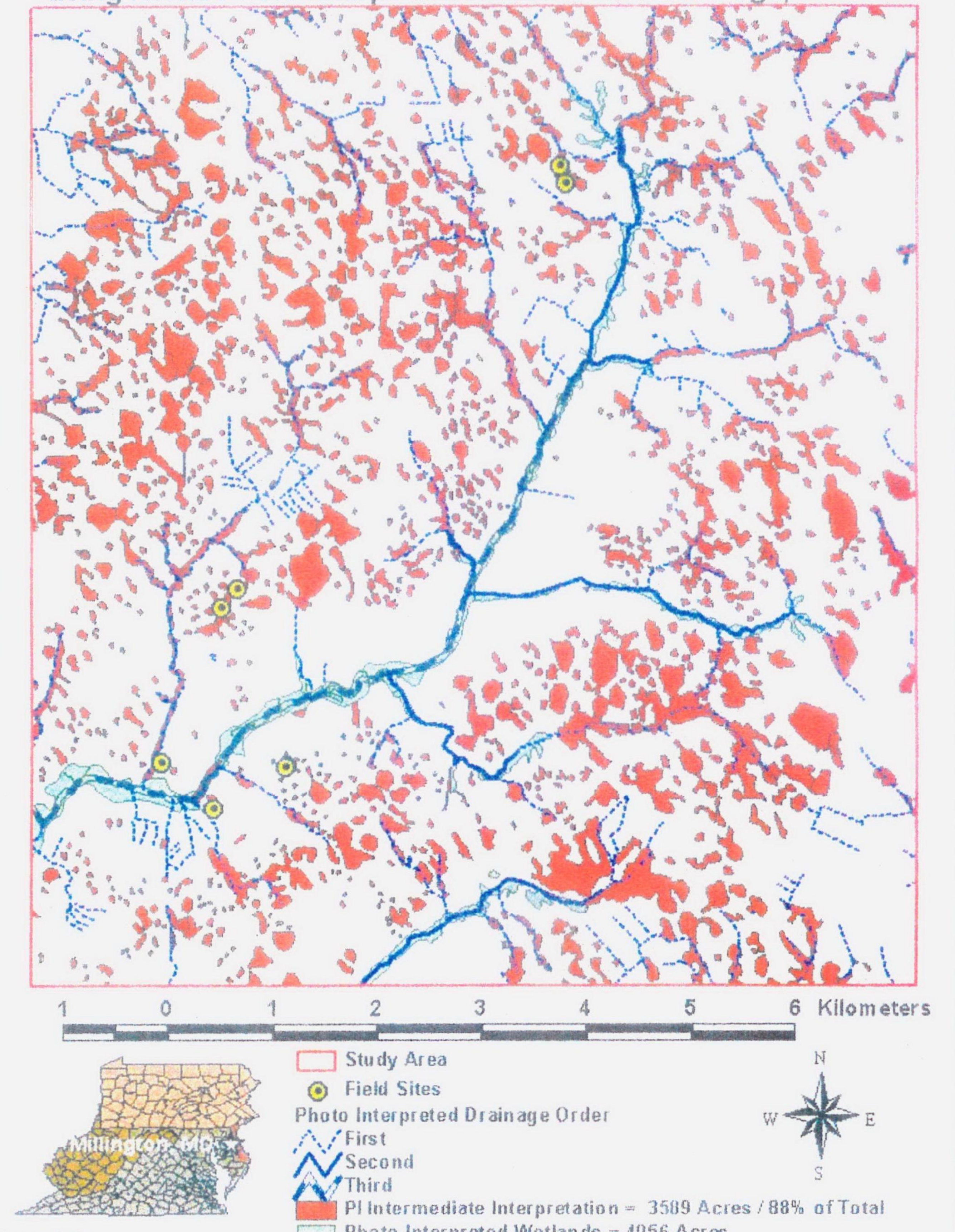


Source Data:
B&W NAPP Aerial Photography 4-17-88
USGS Hydrography
National Wetland Inventory (NWI)
Map prepared by Peter Stokely
EPA Region 3 703-648-4292

Narrow interpretation of ANPRM: PI mapped wetlands located over 100 feet from PI mapped drainage

Figure 8

Wetlands in the Vicinty of Millington, MD (Intermediate Interpretation using Aerial Photo Interpreted Wetlands and Drainage)



Source Data:
B&W MAPP Aerial Photography 4-17-88
USGS Hydrography Data
National Wetlands Inventory (NWI)
Map made by Peter Stokely
EPA Region 3 703-648-4292

Intermediate Interpretation of ANPRM: PI mapped wetlands located over 100 feet from PI mapped drainage plus all wetlands associated with first order streams

Figure 9

Wetlands in the Vicinty of Millington, MD (Broad Interpretation using Aerial Photo Interpreted Wetlands and Drainage)

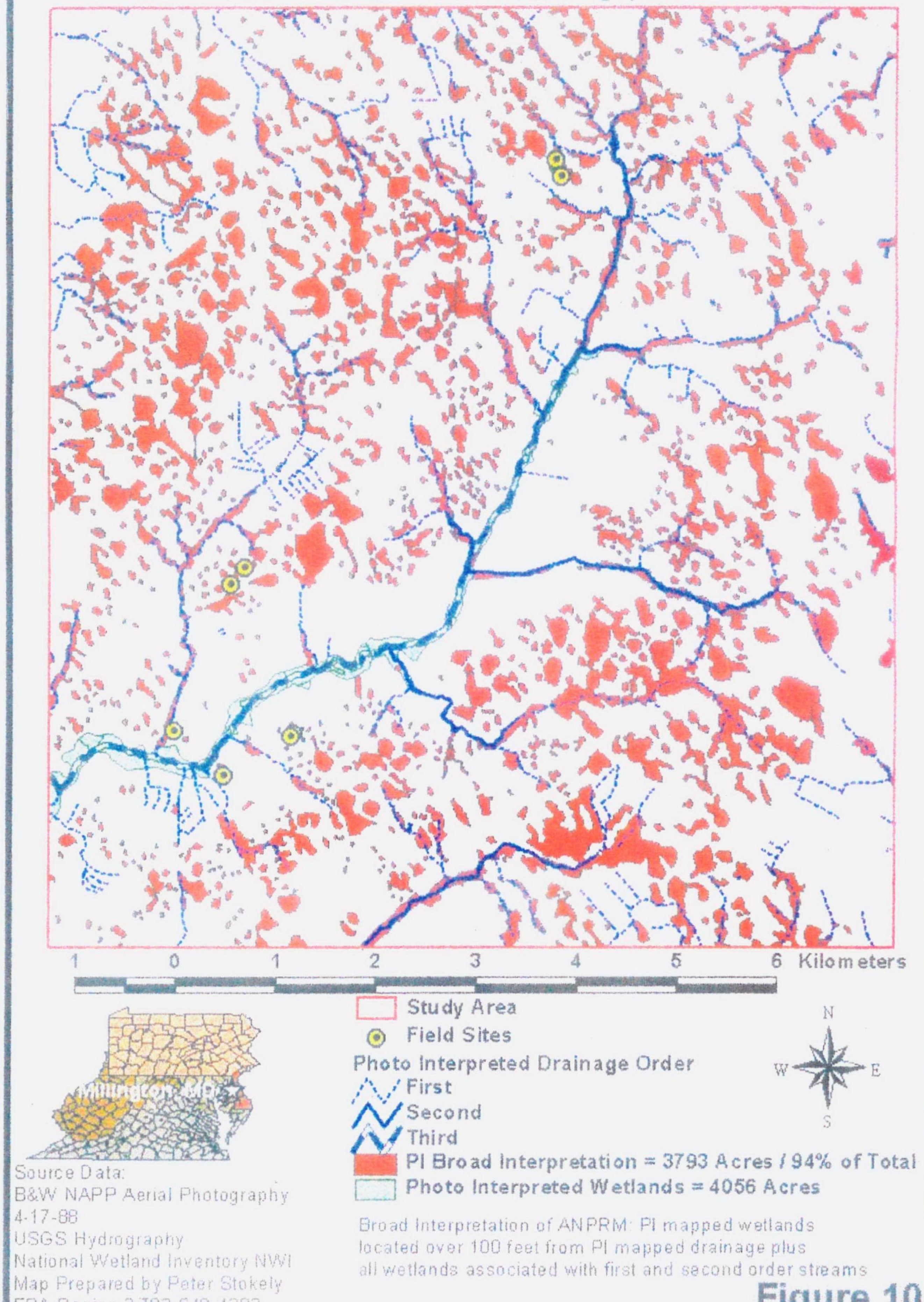


Figure 10

Appendix C
Available Upon Request

APPENDIX D

Literature Review
Character and Function of "Isolated" Wetlands

USEPA, PHILADELPHIA, PA

Charles A. Rhodes Jr.

1. Definition and discussion of "isolated" wetlands in the literature

In a review of the scientific literature concerning wetlands, the term "isolated wetland" is used in a variety of circumstances. Frequently the term refers to the space and time relationship of the subject wetland to other wetland or aquatic systems. The term connotes a physical or hydrological (often surficial) separation, indicating that the wetlands are discrete units in the landscape. Usually, however, there is the acknowledgment that the separation may be temporary or that the wetland is integrated within a larger network via other pathways (e.g., groundwater, intermittent or ephemeral connections, movement of fauna, etc.). In the scientific literature the term "isolated"[1] is a descriptive term, limited in scope and commonly has no bearing in a regulatory context.

A wide ranging variety of significant wetland types (e.g., coastal plain interfluvial flats. wooded wetlands in glaciated landscapes. slope and montane wetlands) may be characterized as wetlands with non-traditional linkages. For the sake of brevity, the term "non-traditional linkages" refers to wetlands that are hydrologically connected to other waters by non-perennial surface and/or groundwater flows. Wetlands with non-traditional linkages do not exhibit a perennial surface water connection yet they are closely integrated to the larger watershed network via groundwater and non-perennial surface connections. Thus, most wetlands that do not exhibit a perennial surface connection are not truly "isolated" in the ecological and hydrological sense.

There are many categories of wetlands that by their nature are primarily unconnected by surface waters. A partial list would include a number of continentally or regionally significant categories of wetlands such as:

Peat Wetlands of the Glaciated Region
Slope Wetlands
Bogs
Pocosins
Carolina Bays (Delmarva Bays)
Potholes
Playas
Wetlands of the Nebraska Sandhill Region

Cypress Domes
Vernal pools of the Mediterranean climates of the Pacific Coast
Vernal pools of the temperate eastern United States

In descriptions of the general characteristics of several of these wetland categories, the authors clearly point out the aspects of the wetland ecology, which relate to their existence as separate, distinct units.

One of the most extreme examples of such wetlands is the vernal pool community type. Keeley and Zedler (1998) describe vernal pools as seasonal wetlands that form in shallow basins and alternate on an annual basis between a stage of standing water and extreme drying conditions. Although this definition is applicable to the vernal pools characteristic of California (that actually range in distribution from eastern Washington to the northern Baja Peninsula) it is recognized that other locations subject to a Mediterranean climate (Chile, South Africa, Australia, the Mediterranean basin) may have similar communities. They recognize that vernal pools in other locations exhibit comparable conditions (e.g., continental climate granite outcrops and tropical alpine seasonal pools). They also contrast other seasonal pools as not exhibiting classic vernal pool characteristics. Such communities would include desert playas, Great Plains buffalo wallows or prairie playas, and potholes.

Colburn (2001) notes that temporary ponds occur worldwide and vary widely in character but share common strategies for dealing with seasonal drying. In eastern North America the term "vernal pool" has gained wider acceptance and is currently used generically to refer to shallow, fishless water bodies that dry periodically and are dominated by species intolerant of fish predation.

A significant number of wetland community types with non-traditional linkages were formed by climatic and geologic phenomena that date to the last glacial period. Systems, such as prairie potholes, bogs of the glaciated region, Atlantic white cedar swamps and bogs, and pocosins are spatially distinct landscape features because of the forces that formed them.

For example pocosin [Algonquin: meaning "swamp-on-a-hill" (Richardson et al. 1981, Williams and Askew 1988)] communities began to develop after the Wisconsin Ice Age and pollen data supports the assumption that pocosin wetlands developed between 10,000 and 12,000 years ago (Otte 1981). Sharitz and Gibbons (1982) define pocosins as freshwater wetland ecosystems characterized by broadleaved evergreen shrubs, or low trees commonly including pond pine (Pinus serotina), and commonly growing on highly organic soils that have developed in areas of poor drainage. Williams and Askew (1988) describe them as flat, poorly drained sites located along the center of broad, interstream divides. Their present range of occurrence is the Atlantic Coastal Plain from southern Virginia to northern Florida.

Sharitz and Gibbons (1982) categorize four different types of geologic situations that are considered to support pocosin communities in the southeastern Coastal Plain:

1. Flat areas associated with blocked stream drainage on the lower terraces.
2. Carolina bays.
3. Areas of ridge and swale topography between relict beaches and dune ridges (Woodwell 1956).
4. Springs and springheads of the upper Coastal Plain (Christensen et al. 1981).

Sharitz and Gibbons (1982) define Carolina bay ecosystems as elliptical depressions of the southeastern Coastal Plain which are consistently oriented in a northwest-southeast direction and many of which contain shrub bog communities. They occur abundantly in a broad geographic band that closely parallels that of pocosins. They characteristically have no tributary systems, are not spring-fed and rely on direct precipitation and run-off to maintain water volume.

Carolina bays are restricted to the southeastern Coastal Plain and lower Piedmont, and occur predominantly in the coastal areas of South Carolina and in southeastern North Carolina. A recent report by Bliley and Pettry (1979) identified more that 150 bays on the Eastern Shore of Virginia and Melton (1938) stated that examples could be found in Maryland and Delaware. About 400,000, or 80% of the total number estimated by Prouty (1952) are found in the Carolinas.

Scientists or laymen universally accept no single theory concerning the origin of Carolina bay depressions. The range of cited theories includes solution pits, wind and/or wave action, or an ancient meteor shower. Wind and wave theories rely on analogous formations in Alaska, Chile and Texas (Kaczorowski 1977). Their estimated time of formation also ranges widely from 10,000 to 100,000 years ago.

Ecosystems similar to Carolina bays include the pine barrens of New Jersey (characterized by stunted pine canopy overtopping a low shrub community) and bay forests of Florida (dominated by evergreen tree and shrub species).

Certain landforms that were created during the close of the last glacial epoch 10,000 years ago promoted the formation of wetland communities as widely divergent as prairie potholes and bog communities. Pielou (1998) remarks that wetlands are particularly abundant in regions having an immature drainage system, that is, where the drainage system is incompletely developed. This is true of the land that was covered by thick ice sheets during the last ice age. Since the ice melted (c. 10,000 years ago) there has not been enough time for streams and rivers to erode a continuous linked system of channels draining all the once-glaciated ground to the seas.

Creation of moraines (e.g. ground, washboard, thrust, dead ice and terminal) and meltwater (e.g., glacial outwash plain, collapsed glacial outwash, glacial lake plains) landforms promoted the formation of potholes (Kantrud et al. 1989). Comparable glacial phenomena, combined with the topographic heterogeneity of the northeast promoted the formation of northeastern bog communities. Damman and French (1987) define bogs as nutrient poor, acid peatlands with vegetation in which peat mosses (Sphagnum spp.), ericaceous shrubs, and sedges (Cyperaceae) play a prominent role, although conifers are often present. Bogs include both ombrotrophic (nutrients derived from rainwater) and minerotrophic (nutrients derived from surface or groundwater) wetlands.

Wetlands with non-traditional linkages are an important and integral part of stream/river networks. Several authors propose consideration of the terrestrial-aquatic systems as a single continuum. As wetlands are interposed between these systems they serve as critical zones in this transition. Pielou (1998) notes that the majority of rivers begin at an indeterminate point in a slight depression in the ground where groundwater is discharged as a seep or spring. She also notes that slow seeps are more common than vigorous springs and are usually unnoticed. In other situations groups of seeps may be aligned along a contour across sloping ground forming a spring-line. Such a depression (or network of depressions) also serves as a collector of overland flow although when a stream originates, groundwater seepage is usually far more important than overland flow in bringing it into being. In general Pielou notes that only one-fifth of the water that reaches the surface as rain collects in streams and rivers.

Overland flow begins as sheet flow, but irregularities in the ground surface soon split it into rills (i.e. miniature gullies formed by a single rainfall event). Eventually seepage in the bottom of the depression, augmented by the water entering in rills, accumulates to erode a self-sustaining, permanent channel through which the water drains away—the origin of a stream.

Vannote et al. (1980), in the development of the river continuum concept, note that from headwaters to mouth, the physical variables with a river system present a continuous gradient of physical conditions. This gradient should stimulate a series of responses within the constituent populations that result in a continuum of biotic adjustments and consistent patterns of loading, transport, utilization, and storage of organic matter along the length of a river. Moreover from the headwaters to the downstream extent, the physical variables within a stream system present a continuous gradient of conditions including width, depth, velocity, flow volume, temperature, and entropy gain.

Many headwater streams are influenced strongly by the riparian vegetation that reduces autotrophic production by shading and contributes large amounts of allochthonous detritus. As stream size increases, the reduced importance of terrestrial organic input coincides with enhanced significance of autochthonous primary production and organic transport from upstream. This transition from headwaters, dependent on terrestrial inputs, to medium-sized rivers, relying on algal or rooted vascular plant production, is thought to be generally reflected by a change in the ratio of gross primary productivity to community respiration (P/R).

Headwater streams, riparian zones and the wetlands associated with them represent the maximum interface with the landscape and are therefore predominantly accumulators, processors, and transporters of materials from the terrestrial system. Among these inputs are heterogeneous assemblages of labile and refractory dissolved compounds, comprised of short- and long-chain organics. Heterotrophic use and physical absorption of labile organic compounds is rapid, leaving the more refractory and relatively high molecular weight compounds for export downstream. The relative importance of large particle detritus to energy flow in the system is expected to follow a curve similar to that of the diversity of soluble organic compounds; however its importance may extend farther downstream.

On an evolutionary time scale, the spatial shift has two vectors: a downstream one involving most of the aquatic insects and an upstream one involving most of the aquatic mollusks and crustaceans. The insects are believed to have evolved terrestrially and to be secondarily aquatic. Since the maximum terrestrial-aquatic interface occurs in the headwaters, it is likely that the transition from land to water first occurred here with the aquatic forms then moving progressively downstream. The mollusks and crayfish are thought to have developed in a marine environment and to have moved through estuaries into rivers and thence upstream. The convergence of the two vectors may explain why maximum species diversity occurs in the midreaches of rivers.

Despite the continua described above, it has been generally assumed that southeastern bottomland hardwood swamps are tightly linked to their river systems, thereby forming "classic" navigable systems. However, some floodplains in the southeast apparently were also affected by the climatic changes associated with continental glaciation (Wharton et al. 1982).

One striking feature reflecting these past climatic regimes is the dramatic discrepancy between the size of the floodplain and the size of the present day river. Today many streams are too small (in terms of discharge volume and meander dimensions) to have produced such wide floodplains. Such streams are described as "underfitted" (Dury 1977). Dury calculated from ratios of former to present channel bed-widths and meander wavelengths, that discharge 12,000 years ago was 18 times greater that at present and the sediment delivery rates were 3 times those of today.

The term floodbasin specifically applies to vast underfitted floodplains where channel meanders may occupy only a portion or belt of the floodplain width. Along southeastern rivers that are not markedly underfitted, the floodplain between the natural levees and high valley wall is generally called ambiguously a "backswamp" or more succinctly a "flat" where elevational relief is limited to shallow depression basins and almost imperceptible rises. The term backswamp may also be applied specifically to peat-forming environments occupying relict channels along the outer rim of the floodplain. (Note: Here again, adjacency issues and what is or is not "isolated" may be relevant questions.)

Aeolian dunes form when strong winds blow exposed sand from point bars or other sources onto the floodplain. Aeolian dunes and those associated with the relict braided stream channels were probably formed by gale-force Pleistocene winds blowing across the unvegetated part of the floodplain from the southwest. (Note: The resultant ridge and swale topography may also complicate adjacency issues—particularly with wetlands that are adjacent to already "adjacent" wetlands.)

Scour channels, hummocks and mini-basins are additional southeastern bottomland microtopographic features that produce only slight elevational and drainage changes. However their effect on plant species distribution and ecological communities is often marked.

Climatic changes, coupled with the more subtle influences of change in gradient brought about by lowered sea levels or tectonic rebound of the land, formed another characteristic of southeastern floodplains—the floodplain terrace. Increased flow volume or, in some cases, an increased gradient, changed the hydrologic regime and created a new floodplain surface, often lower than the old one. Step like terraces resulted, many of them that are remnants of prehistoric surfaces.

The origin of Atlantic white cedar (Chamaecyparis thyoides) wetlands is also closely related to the advance and wasting of the glaciers, which greatly influenced the topography of the land both under the glaciers and over the entire continent's coastal area, due to factors such as direct glacial action (e.g., migration to southern refugia and reestablishment during glacial retreat), and major variations in sea level.

Laderman (1989) noted that Atlantic white cedar (and associated species) are geographically restricted to freshwater wetlands in a narrow band along the eastern coast of the United States ranging from Maine to Mississippi. Distinctive biotic assemblages dominated by Atlantic white cedar grow under conditions too extreme for the majority of temperate dwelling organisms. The character and distribution of the community varies geographically. Cedar dominated wetlands in the glaciated northeast, New Jersey Pine Barrens, the Delmarva Peninsula, the Dismal Swamp, Carolinas and juniper swamps of the southeast all have distinct community "types". Cedar swamps are generally situated shoreward of lakes, river or stream channels, or estuaries; on river floodplains; in isolated catchments; or on slopes.

Slightly elevated hummocks dominated by cedar are often interspersed with water filled hollows in a repeating pattern that forms a readily identified functionally interrelated landscape. This phenomenon of dominant trees established on hummocks amidst a matrix of water filled depressions is also typical of Eastern hemlock (Tsuga canadensis) swamp forests of the northeast (e.g. Pocono region) and upper Midwest, as well as southeastern bottomland hardwoods (Wharton et al. 1982) and red maple swamps of the glaciated northeast (Golet et al. 1993).

Additionally significant portions of wetland communities in geographic regions exhibit spatial separation by virtue of their topographic location. Wetlands associated with mountainous terrain are excellent examples. Windell et al. (1986) described the two major settings for Rocky wetlands as mountain valleys and intermountain basins. Mountain valleys are relatively young topographical forms shaped by the erosional forces of running water and, at higher elevations, by glacial movements. Mountain wetlands are located in a wide range of sites from cliff faces to gentle slopes to flat valley floors. A high water table is maintained by accumulation from melting snow and frequent summer storms which interacts with variable depth of bedrock and permeable materials such as moraines and other glacial till, that contain either surface or subsurface water.

Intermountain basins were formed by ancient tectonic and volcanic events contemporary with the mountain building process. Erosion of neighboring mountain ranges has contributed deep strata of alluvial material that are gradually filling large topographic depressions. Rivers have inscribed channels across the flat "parks" and have changed course or been impounded by tectonic or volcanic alterations in basin geomorphology. Wetlands also are associated with river meander patterns, impounded waters, and high water tables maintained by underlying aquifers, annual flooding, or impermeable substrates.

Diehl and Behling (1982) in discussing the origins of wetlands in the unglaciated sections of West Virginia recognized three primary natural geologic phenomena (as opposed to artificial, human induced wetlands) that promote wetland formation in that region:

1. In maturely developed stream valleys that are blanketed by a veneer of poorly permeable alluvial material. The stream gradient is generally very low and meanders are often present.
2. The majority of wetlands in their study are situated atop dipping strata ranging from gentle folds to those of larger amplitude. Associated with these fold belts are dipping strata that intersect streambeds at an acute angle. When a resistant stratum crops out in a streambed, a knickpoint occurs which generally gives rise to an increase in gradient downstream from that point. A wetland forms above the knickpoint due to ponding, the settling out of sediments and the diversion of stream energy from channel deepening to lateral erosion.
3. In cases where flat or nearly flat-lying resistant strata cap a highland area that has been dissected by major streams. While headward erosion is continually encroaching upstream towards the heads of the small tributaries on which the wetlands occur, the resistance of the cap rock will determine the rate of weathering.

Stone and Stone (1994) recognized an even wider range of geologic formative processes (e.g. faults, fractures, shallow bedrock or glacial till), which enable wetlands (many of which are spatially separated) to be expressed on the landscape via expressions of groundwater on the surface. They continue by noting that groundwater is a major component in both the creation of wetlands and their integration into a much larger and complex hydrologic unit.

Discussions of broad categories of wetlands such as northeastern red maple swamps (Golet et al. 1993) or bottomland hardwoods (Wharton et al. 1982) also acknowledge that a significant number of sites within the respective communities are formed as discrete, separate locations, particularly in headwaters associated with first or second order streams.

In summary, a large portion of the national wetland resource is represented by wetlands that are spatially discrete landforms. That however does not ignore the fact that these wetlands are linked biologically, chemically and physically into a much larger hydrological network. The phenomena that form these linkages may be perennial, intermittent, ephemeral or episodic but are ecologically significant nevertheless.

2. Extent of "isolated" wetlands

The difficulty in determining the extent of "isolated" wetlands is that this term is not generally used in the wetland inventory nomenclature. The most prevalent wetland classification nomenclature currently in use is that of Cowardin et al. (1979) which is based on a hierarchical format that integrates plant community structure, water regime and landscape position. The fact that wetlands may or may not be separated physically is not relevant to the classification system. One may develop a crude estimate by focusing on those parts of a wetland inventory that may contain a significant portion of "isolated" wetlands in them.

For example, Tiner and Burke (1995) indicate that of the 598,388 acres of wetlands inventoried in Maryland [1981-1982 National Wetland Inventory (NWI) data], palustrine wetlands composed 342,626 (57%) of the total wetland resource. Furthermore, of the palustrine wetlands, the three water regimes toward the dry end of the hydrological spectrum (temporarily flooded, saturated, intermittently flooded) comprised 189,410 acres—55% of the palustrine total. Comparable areal relationships are found in other northeastern states (Tiner 1985, 1989).

One of the difficulties in using inventory data is that the limits of the remote sensing technology tend to underestimate the extent of wetlands. This is particularly problematic in headwater areas of watersheds and in physiographic provinces landward of the coastal plain. For example field inspections in the ridge and valley region of central Pennsylvania demonstrate that National Wetland Inventory maps generally underestimate the extent of wetlands (Table 1).

Table 1. Comparison of National Wetland Inventory (NWI) Coverage with Additional Wetland Inventory Methods during the Upper Juniata Watershed Wetland Condition Assessment (Wardrop, D. H., personal communication)

Wetland Type	Avg. NWI	Additional	% Of Total in	Number

	(ha)*	Inventory (ha)*	NWI	of Points
Riparian Depression	<0.01	0.17	4%	15
Ridge side slope	0.05	0.07	43%	3
Headwater area	0.32	0.88	26%	20
Mainstem floodplain	0.70	1.70	31%	74
* Wetland acreage found in randomly selected sample rectangles in locations with a "high probability" of wetland occurrence based on hydrogeomorphic selection criteria.				

Stolt and Baker (1975) acknowledge that NWI maps are not designed to identify jurisdictional wetlands. Unfortunately they are frequently the only widely available wetland inventory data set. They found that in two study areas in the Blue Ridge Highlands, 91.8 and 109.3 hectares of jurisdictional wetlands were found in the field while the NWI maps indicated only 2.5 and 17.4 hectares of wetlands respectively. Their conclusion is that because of the small scale that photointerpreters must work with and the number of wetlands located in dense woodlands; the NWI maps may not adequately inventory wetlands in the Blue Ridge. (Note: This is precisely the geographic location where many "isolated" wetlands or wetlands with non-traditional linkages are situated. They go on to note that ground-truths based on extensive field reconnaissance efforts are the only means to verify the interpretations and estimations made from remotely sensed data.

For wetland communities that are predominantly discrete landforms (e.g., prairie potholes, pocosins, playas) the majority of the wetland inventory would most likely be of the type with non-traditional linkages. For example it is estimated that pocosin ecosystems once covered more than 3 million acres. In 1962 nearly 70% of all the existing pocosins (2,243,500 acres) occurred in North Carolina. They were rapidly developed and by 1979 only 31% of this ecosystem remained in its natural state (Richardson, 1982). Nevertheless they still comprise more that 50% of North Carolina's wetlands (Richardson et al. 1981).

The Southwest Florida Water Management District inventoried wetlands within several areas of its jurisdiction. Of the total wetland acreage sampled, 68.6% consisted of isolated wetlands. Additionally 79% of the total wetland acreage sampled consisted of wetland of 2 hectares or less in area (Hart and Newman 1995).

Underestimation of wetland area in headwaters compounds a problem of natural resource management as headwater systems provide the most extensive and intimate interaction with adjacent terrestrial systems. Headwater hydrology is predominantly via riparian transport (i.e., movement of water from the upland to the floodplain by nonchannelized overland flow and by shallow groundwater), which tends to be episodic rather than perennial, at least on the surface. Moreover the "wetted edge" where initial ecological function is performed is most profound at the headwaters. Brinson (1993) demonstrates this by comparing the range of stream order and remarking that although the floodplain surface area approximately doubles from higher order to lower order streams, the total length increases by orders of magnitude (Table 2).

Table 2. Relationship between stream order and other dimensions of stream configuration. First four columns are from Leopold et al. (1964) (from Brinson 1993)

Stream Order	Number	Average Length (km)	Total Length (km)	Estimated Floodplain Width (m)	Floodplain Surface Area (km^2)
1	1.570.000	1.6	2,526.130	3	7.578
2	350,000	3.7	1,295.245	6	7.771
3	80,000	8.5	682,216	12	8.187
4	18.000	19.3	347,544	24	8,341
5	4.200	45.1	189.218	48	9.082
6	950	103.0	97,827	96	9.391
7	200	236.5	47,305	192	9.082
8	41	543.8	22.298	384	8,562
9	8	1,250.2	10,002	768	7.681
10	1	2,896.2	2.896	1,536	4.449

3. Ecosystem Functions

Earlier debates concerning wetland regulation concerned the notion that wetland function and value was linked to, and correlated with, the water regime. In other words it was frequently the contention that "wetter was better." As the science of wetland ecology has demonstrated over the past two decades that contention is not true (Roelle et al. 1984, Environmental Defense Fund and World Wildlife Fund 1992). Although the literature is extensive with regard to the ecological function of a wide variety of wetlands, discussions of specifically identified "isolated" wetlands is more limited.

a. Flood water storage

In a literature review of the wetland floodwater storage/desynchronization function Adamus et al. (1991) acknowledge that although the literature is mixed, some studies have supported the importance of wetlands (or wetlands plus lakes) for altering flood flows. Some of these studies have indicated that the consequences of wetland loss are most severe if wetland filling occurs where other wetlands/lakes comprise less than about 10 percent of the watershed areas above the point of flooding. In most instances, wetlands are more effective that developed environments for flood storage and desynchronization (Novitzki 1979). Comparisons of watersheds before and after wetland drainage (Brun et al. 1981) and region-wide studies of multiple watersheds with drained versus undrained wetland acreage (Moore and Larson 1979) both strongly suggest the importance of wetlands for desynchronization of peak flows.

The problem still remains with regard to distinguishing the function of "isolated" or headwater wetlands (where many "isolated" wetlands and wetlands with non-traditional linkages are located) from that of other wetland communities.

If wetlands located "high" in the watershed have been drained, detention of floodwaters by wetlands along the mainstem "low" in the watershed might, at least theoretically, aggravate flooding by helping synchronize local run-off with surface flows arriving from higher in the watershed. A cited simulation of a hypothetical 10-square mile watershed indicated that detention basin networks are more effective if located in the upper 40-80% of a watershed than in areas farther downstream (Flores et al. 1981).

However wetlands along streams low in the watershed (fifth-order streams) were found by Ogawa and Male's (1983) simulation studies to reduce flooding over a greater downstream area (exceeding 8 miles) than wetlands associated with first- through third-order streams, which reduced downstream flooding only significantly over an approximately 2-mile reach. Further, wetlands low in the watershed were important regardless of the total amount of other storage available in the watershed, while individual wetlands high in the watershed (stream order 1 and 2) ceased to play a major role in floodflow attenuation as soon as the acreage of other wetlands above them exceeded 7 percent of the total (Ogawa and Male 1983).

The diminished flood retention function of one, or several wetlands may be difficult to quantify, but the cumulative impacts of diminished flood retention function may have very significant regional impacts. Miller and Nudds (1996) studied prairie landscape change over several decades and the flooding in the Mississippi River Valley and determined that the cumulative losses of wetlands had a significant impact on flooding events. While flood magnitudes along the Mississippi River have increased (e.g., summer of 1993, spring of 1995) at least three major hypotheses, (which are not mutually exclusive) have been proposed to explain trends in flood magnitude:

1. Belt (1975) attributed increased flood stages in the middle Mississippi River to greater channel confinement.
2. Knox (1988) concluded that climate change, specifically variation in winter snowfall and early summer rainfall, was largely responsible for trends in flood magnitudes in the upper Mississippi Valley, primarily Wisconsin.
3. Widespread landscape change, including wetland drainage and removal of native vegetation has been implicated in recent flooding in the Mississippi River Valley.

Although wetland loss has occurred throughout the prairie-parkland region, average wetland density is nonetheless 3.1 times greater in Canadian areas (16.3 wetlands/km^2) than in the U.S. portions of the survey region (5.2 wetlands/km^2). Furthermore, although agricultural expansion into marginally productive soils in prairie Canada has reduced native upland vegetation since at least the 1940s, that process appears to be significantly more advanced in the U.S. Moreover, in Canada, precipitation currently determines the population sizes of breeding waterfowl through its effects on the numbers of wetlands of all types whereas in the U.S. more ephemeral wetlands have been drained, such that duck numbers are now largely constrained by residual, more permanent wetlands. regardless of how much precipitation falls.

The hypothesis of the study was that precipitation that once filled wetland basins in the U.S. prairies, or was otherwise retained in organic soils and by native vegetation, now increasingly drains at faster rates into nearby rivers, creating the potential for greater floods downstream. This hypothesis predicts that, while controlling for temporal variation in precipitation, annual flow rates of unregulated rivers should have increased over time more in the U.S. than in Canada (where habitat alteration has been less extensive). Alternatively, the climate change hypothesis predicts similar trends in both precipitation and annual river flows in each country. By restricting the study to unregulated rivers the confounding influence of channel confinement was removed.

The study selected five unregulated rivers with watersheds located entirely in the U.S. that flow to the Gulf of Mexico and seven unregulated rivers with watersheds located entirely in Canada that flow to Hudson Bay. The results demonstrated that river flows had increased significantly in more U.S. rivers (4 of 5) than Canadian rivers (0 of 7).. The results are consistent with the hypothesis that landscape alteration, rather than change in precipitation, has produced greater runoff into rivers that drain the Mississippi River Valley. Because only unregulated and predominantly undyked rivers were studied, artificial channel confinement cannot be the cause of the increased annual flow rates although channel confinement may augment flow rates in very large rivers (Belt 1975).

The conclusion is that although the Canadian prairies have been altered by agriculture, the number of wetlands and extent of untilled vegetation appears to be sufficient yet to maintain flow rates of Canadian rivers at historic levels. Interestingly, the one U.S. river for which no change in flow rates was detected was the Little Missouri River. These headwaters are near Devil's Tower National Monument in Wyoming and flow through the Badlands of North Dakota. These areas are not noted for extensive crop production.

Miller and Nudds (1996) noted that flood control efforts typically have involved the construction of expensive dams and levees. yet as witnessed by the 1993 and 1995 floods, these structures can and do fail to contain high river flows. Such large floods can cause widespread property damage, pollution and loss of life. All the while wetland drainage and other landscape changes continue upriver, creating the potential for even greater flooding in the future. As precipitation runoff is lower in meadows than either cropland. or all but the most thoroughly contoured and terraced rangeland. and both native vegetation and wetlands are believed to provide natural flood control. wetland conservation and restoration could prove less expensive and more reliable in the long term than conventional flood control methods while at the same time benefiting waterfowl and other wetland and riverine species.

Gilliam and Skaggs (1981) noted that at that time the latest period of increased development activity in the pocosin region of North Carolina began about 1973, a time period that coincided with the large algal bloom problems in the Chowan River. To study the effects of drainage and agricultural development upon drainage waters they used three pairs of sites (developed and undeveloped land) to span the different soils that are likely to be developed in the Blackland area of North Carolina. They found that peak runoff rates occurred earlier (on occasion 24 hours earlier) and were three to four times higher from developed sites than from similar undeveloped sites. From a cumulative environmental impact standpoint such effects, translated downstream to estuarine waters, were identified as having potentially significant negative impacts to downstream estuarine communities including shrimp, shellfish, commercial and recreational fisheries (Copeland et al. 1983, 1984).

b. Nutrient Dynamics

As noted by Brinson (1993) and others, wetland and riparian communities generally are the first natural contact between cultural sources of nutrients and receiving water bodies. Peterjohn and Correll (1984) studied the role of a Maryland riparian forest in transforming the nutrients received from an agricultural watershed. Nutrient (C, N and P) concentration changes were measured in surface runoff and shallow groundwater as they moved through the watershed. Some of the results are as follows:

From March 1981- March 1982 dramatic changes in waterborne nutrient loads occurred in the riparian forest of the watershed. From surface waters that had transited approximately 50 m of riparian forest an estimated 4.1 Mg of particulates, 11 kg of particulate organic-N, .83 kg of ammonium-N, 2.7 kg of nitrate-N and 3.0 kg of total particulate-P per hectare of riparian forest were removed during the study year. In addition an estimated removal of 45 kg ha^{-1} yr^{-1} of nitrate-N occurred in <u>subsurface flow</u> as it moved through the riparian zone.

Although mean annual particulate concentrations of P, C and organic-N in surface runoff decreased after moving through the riparian zone, the concentrations of these nutrients per unit of sediment increased. These results indicated that the particulates leaving the forest were more organic in composition and had a greater exchange capacity.

Of the estimated total nitrogen exports from cropland 64% was in harvested crop, 9.2% in surface runoff and 26% in groundwater flow. Groundwater appears to be the dominant pathway of total nitrogen flux between the cropland and riparian forest. Nitrogen retention for the cropland was found to be low (8%) which is consistent with ideas about disturbed ecosystems.

For the riparian forest, 17% of the estimated total-N inputs came in bulk precipitation, 61% in groundwater, and 22% in surface runoff. Of the estimated total-N losses from the riparian forest, 75% was lost in groundwater flow. Thus it appears that the major pathway of nitrogen loss from the riparian forest was in subsurface flow. The calculated nitrogen retention by the riparian forest was 89%--much higher than the retention in the cropland (8%).

Of the estimated total phosphorus exports from the cropland, 84% was in the harvested crop, 16% in surface runoff and <1% in groundwater flow. Surface runoff is thus the dominant pathway of phosphorus flux between cropland and riparian forest. The calculated phosphorus retention was 41% for the cropland and 80% for the riparian forest. For the riparian forest 3.8% of the estimated total phosphorus input was from bulk precipitation, 94% in surface runoff, and 2.5 in groundwater flow. Phosphorus export was nearly evenly divided between surface runoff (59%) and groundwater flow (41%).

Losses of groundwater nitrate concentrations are probably due to two possibilities: uptake by vegetation or denitrification. As only 33% of the removal is attributable to incremental growth it seem that considerable denitrification is plausible.

Reductions in sediment loads and their associated nutrients in surface runoff should be a fairly universal effect of riparian forests because of the physical nature of the processes involved. A few studies present evidence that riparian zones reduce sediment and phosphorus loads in adjacent streams (McColl 1978, Schlosser and Karr 1981a, 1981b). Similar results were found in a similar study in Georgia (Lowrance et al. 1984a, 1984b). Nutrient losses from diffuse sources are generally understood as a threat to most bodies of water. Therefore the removal of particulates, nitrogen, and phosphorus is potentially an extremely important ecological function.

Puckett et al. (1993) found that large quantities of sediment and associated trace metals were retained in the wetlands of the upper Chickahominy River basin—the upper reaches of which drain approximately 155 km^2 of dense commercial, industrial and urban development in and around Richmond, Virginia. As the Chickahominy River currently supplies 46% of the raw water of Newport News (and other nearby communities) disturbance of these wetlands could be problematic.

c. Habitat

Colburn (2001) discussed the ecological role of vernal pools in the glaciated Northeast as tremendous reservoirs of biodiversity, important for the survival of a variety of species of frogs, salamanders and crustaceans. These pools are located in woodlands and dry at least occasionally. Sometimes a mere 30 feet across, they can be easily overlooked. Generally vernal pools are largest and deepest in the spring, attaining maximum depths of about 1 meter. Their most defining quality is their impermanence. Their periodic dryness prevents fish from surviving and limits the distribution of other vertebrate and invertebrate predators. This is a requirement for species such as wood frogs, mole salamanders (genus Ambystoma including marbled, spotted, blue-spotted, Jefferson's, small-mouthed, and tiger salamanders), fairy shrimp, clam shrimp, and certain flatworms, caddisflies and water beetles.

Although all pools dry out at some point. as a group vernal pools span a wide hydrological continuum, ranging from short-lived waters that flood in spring and dry by early summer, through basins that fill in late fall and retain water until late summer, to semipermanent ponds that remain flooded for several years at a time. Colburn (2001) cites one study in Massachusetts' Cape Cod that followed 14 vernal pools monthly for two years and used the results and pre-existing groundwater monitoring data to model the history of the pools' hydrology. From 1982-1997, the pools fluctuated in size and depth with some pools drying up in most years and others drying only occasionally.

For wildlife that live in vernal pools, the ability to complete their life cycles in an ephemeral environment varies. which means that the presence of most species is tied to the flooding regime. For example, species such as wood frogs, which breed in short-duration ponds, must complete development in on the 2-3 months. Wood frogs deposit their eggs in early spring; the eggs hatch within three weeks and the tadpoles grow quickly into young frogs before the pool dries out. Wood frogs do well in pools that dry too rapidly for salamanders, which take longer to complete their embryonic and larval phases, and require pools that remain flooded longer.

Both the duration of flooding and the length of the dry period winnow down the number and type of species that are able to survive in an individual pool. Depending where each falls along the hydrologic continuum. vernal pools support different communities of aquatic organisms. Because relatively few animals can grow rapidly and also tolerate extended desiccation, short-duration pools have fewer species—and different ones—that pools that remain flooded longer. Some species are restricted to annually drying pools because of their intolerance of predators living in semi-permanent pools. Drought intolerant aquatic animals such as bullfrogs, green frogs, predaceous water bugs, and large dragonflies found in semi-permanent wetlands may prey on or compete with vernal pool-dependent amphibian and invertebrates. Pool hydrology therefore affects animals' distributions directly, through their ability to develop during the flooded period and survive the dry period, and indirectly through their interactions with other species.

The biological community also varies within a given pool from year to year, as the pool's hydrology changes with annual fluctuations in precipitation and temperature. For instance, small semi-permanent ponds commonly support spotted salamanders and fairy shrimp, but fairy shrimp often appear only when the ponds refill after a drying episode. The presence of vernal pool species in some permanent and semi-permanent ponds may indicate that these ponds were once annually drying ponds that have been altered by dredging or impoundment.

During their life cycles, many vernal pool-dependent species use a complex of uplands and wetlands. of which vernal pools are critical—but not the sole—components. For example, feeding in vernal pools is important for some populations of spotted and Blanding's turtles. They spend the winter in vernal pools in other wetlands, and use uplands for aestivation (summer dormancy) and nesting. Some water beetles and water bugs breed in vernal pools but overwinter in permanent water bodies. Amphibians, whose populations depend on vernal pools, spend most of their lives in uplands woods, and some travel far from the pool from which they hatched or will return to breed. For example, mole salamanders often travel 100-300 meters from the pools, and wood frogs typically travel 400-800 meters. About 10-20% of wood frogs disperse to new pools when they are first ready to breed, traveling an average of 1,000 meters from their natal ponds. Because of these animals' large ranges, the use of vernal pools by breeding amphibians is highly correlated with contiguous woodland and the proximity of other pools.

Northeastern vernal pools, unlike temporary pools in prairies or the desert southwest, are located in woodlands. These woodlands maintain pool hydrology, temperature, and water chemistry and they contribute leaves and other detritus to the pond food web. The forest context structures the vernal pool food web, which in turn affects pool wildlife. The contributions by forest trees of an abundant supply of leaves and other dead plant material, coupled with the cyclical drying regime, contributes to high food quality in vernal pools. Colburn cites Bärlocher et al. (1978) who noted that the air-dependent fungi and bacteria that break down this detritus during the dry cycle contribute more nutrients and protein than decomposers that are active in water.

Semlitsch (2000) discussed why small wetlands are extremely valuable for maintaining the biodiversity of a number of plant and animal species. He noted additionally that healthy populations of many species depend on not just a single wetland but also a landscape densely covered by a variety of wetlands.

Ecologists describe the value of small isolated wetlands by their aggregate role in protecting small wetland-dependent species through source-sink dynamics. More variable than larger wetlands, each small wetland in an area may fluctuate in the number of individuals of a species it contains; at times a wetland may act as a sink when the population of a species dies out locally from that wetland or it may be a source that produces surplus individuals, which can colonize a nearby sink wetland. Such populations of a species that are spread over a number of locations are referred as metapopulations and this source-sink dynamic is crucial to the regional survival of a species. A metapopulation of a wetland-dependent species depends on the abundance and proximity of wetlands, rather than a critical size threshold.

The loss of critical wetlands from an area could result in the loss of ecological connections and potentially collapse the metapopulations of wetland-dependent species, thereby causing local extinctions. This is particularly detrimental to species groups such as amphibians, many of which are suffering dramatic global population declines. For example, Semlitsch (2000)cites a study of 371 Carolina bays in the southeastern Atlantic Coastal Plain of South Carolina, where it was found that the wetlands were close together and generally small. They were distributed at a density of .476/km^2 and ranged in size from .2 to 78.2 hectares. In that population of wetands, 46.4% of all of the bays were 1.2 hectares or smaller and 87.3% were 4.0 hectares or smaller.

Another 16-year monitoring study of a half-hectare area called Rainbow Bay documented the presence of 27 species of frogs, toads, and salamanders—one of the highest species diversities known for amphibians in that region.

The suggestion is that as the distance between wetlands increases the potential for migration and recolonization by amphibians decreases and consequently the chance of recolonization by source populations from nearby wetlands also decreases. Furthermore many pond-breeding salamanders, and possibly many frogs and toads, are faithful to the ponds from which they are hatched and do not emigrate long distances. For example the maximum dispersal distance for wood frogs, measured by gene flow over multiple generations is approximately 1,126 meters (Berven and Grudzien 1990). Because of the limited dispersal ability of these animals, any increase in distances between wetlands through wetland destruction impedes their colonization. In Carolina bays, if all wetlands smaller that 1.2 hectares were removed the nearest- wetland distance would increase from 471 to 666 meters. Removal of all wetlands 4.0 hectares or smaller would increase the distance to 1,633 meters (beyond the maximum dispersal distance of wood frogs). In this case the direct loss of habitat is compounded by the indirect effect of reduced recolonization opportunities. The biodiversity value of such wetlands is therefore intimately linked to its position in the landscape with respect to other wetlands.

Moler and Franz (1987) note that isolated wetlands are of unique biological importance and many species are totally dependent on them, in large part because of their isolation. Isolated wetlands, by virtue of their separation from larger wetland systems, contribute to local landscape diversity. Because they are scattered widely across the landscape, they provide an important local source of drinking water to many forms of terrestrial life. They further note that at least 29 native species of anurans occur in the southeastern Coastal Plain. Ten of these species breed primarily or exclusively in small, isolated, often ephemeral wetlands and at least 10 others utilize such habitats opportunistically. The bullfrog group (major competitors and predators) typically spends their first year as aquatic larvae and are, thus, unsuited for reproduction in ephemeral wetlands. In addition to anurans, 5 species of southeastern salamanders breed more or less exclusively in small, isolated wetland habitats free of predatory fish and at least 7 other species use these habitats as well as more permanent sites.

Extensive, permanent, freshwater marshes are widespread in the lower Coastal Plain, yet only 4 species of anurans breed in numbers in such habitats and one other breeds along the margins. Often, those species which are able to reproduce in larger, permanent wetland habitats are characterized by unpalatable or toxic eggs or tadpoles, have eggs which are physically more resistant to predation or display behavioral or phenotypic patters which reduce vulnerability to predation. As stated elsewhere, it is important to recognize that, for many species of anurans, the use of small isolated wetlands is obligative. Their eggs and larvae are simply not adapted to withstand the levels of predation encountered in more permanent wetlands. They cite Wilbur (1980) who pointed out that: ".... the limit on the permanent end of the continuum is probably set by the species' susceptibility to predation. The more nearly permanent a pond is, the greater the range of predators it supports and the greater the likelihood that it contains fish. The flush of primary productivity following flooding permits rapid growth and high population densities. The drying of the pond eliminates fish and other large predators so that when the pond fills tadpoles have an initial size advantage over invertebrate predators."

Amphibians serve as a cornerstone of the vertebrate food chain. In addition to the importance of larvae and aquatic forms as prey for wading birds, many terrestrial predators feed to varying degrees on amphibians. Wassersug (1975) commented, "The amphibious life cycle of anurans constitutes one of the few biotic mechanisms for transport of excessive nutrients out of eutrophic bodies of water and back into terrestrial ecosystems."

A variety of snakes feed heavily on frogs. Moreover, because small wetlands tend to be scattered widely over the landscape, they are an important source of prey for these and other predators; the loss of such wetlands can impact wildlife populations to a considerable distance from the pond. Using a 2 km dispersal distance away from a pond, then the production would be scattered over a distance of some 1300 ha (actual dispersal distances will vary with species).

Moler and Franz (1987) cite the work of Burton and Likens (1975) and Gosz et al. (1978) in New Hampshire who suggest an important role for amphibians in energy cycling. Burton and Likens (1975) found that the biomass of salamanders was about double that of birds during the peak birding season and about equal to the biomass of small mammals. Gosz et al. (1978) found that salamanders and shrews were the most important vertebrates preying on the invertebrates of the forest floor. They estimated that birds consumed 6.5 times and shrews 4.7 times the amount of food energy consumed by the salamander community. However, because the warm-blooded birds and shrews expended 98% of their energy intake on maintenance compared to only 40% for the salamanders, salamanders contribute 4.6 (shrews) and 6.3 (birds) times as much biomass to the available prey base.

Murdock (1994) notes that at least one third of the threatened and endangered species of the United States live in wetlands. Southern Appalachian bogs and fens, in particular support a wealth of rare and unique life forms, many of which are found in no other habitat type. In North Carolina alone, nonalluvial mountain wetlands provide habitat for nearly 90 species of plants and animals that are considered rare, threatened or endangered. These species include the bog turtle (Clemmys muhlenbergii), the Baltimore butterfly (Euphydryas phaeton), mountain sweet pitcher plant (Sarracenia rubra ssp. jonesii), green pitcher plant (Sarracenia oreophila), swamp pink (Helonias bullata), bunched arrowhead (Sagittaria fasciculata), and Gray's lily (Lilium grayi). Remaining bog turtle habitats are becoming increasingly isolated as more wetlands are destroyed. Although this turtle is capable of moving along streams and other wetland corridors in search of suitable habitat, threats to it increase as the distance between wetlands increases.

Mountain wetlands are one of the most important habitats for rare species in the southeast. Until recently they have received little attention because of their usual small size (<10 acres) and difficulty in mapping. Almost one-fifth of the 722 rare plant species monitored by the North Carolina Natural Heritage Program occur in nonalluvial mountain wetlands. and most of them are limited to these habitat types (Murdock 1994).

Floodplain pools in the mountains are an extremely important wetland habitat and are even more rare than bogs. A higher percentage of this habitat type has probably been lost that other mountain wetland. Floodplain pools are the primary breeding habitat for a number of amphibians including the four-toed salamander (Hemidactylium scutatum) and the mole salamander (Ambystoma talpoideum). Other amphibians that are rare or declining in the mountains and use floodplain pools include the mountain chorus frog (Pseudacris brachyphona), the seepage salamander (Desmognathus aeneus), the longtail salamander (Eurycea longicauda), and the mud salamander (Pseudotriton montanus) (Murdock 1994).

The greatest threats to the rare species of mountain wetlands are habitat destruction and degradation. Channelization of adjacent streams can result in destruction of hydrological integrity even if the bog itself is not directly targeted. The deepening and widening of the stream channel often causes a lowering of the local water table, which results in drying of the bog habitat and acceleration of shrub succession. In view of the fact that some of the bogs are thousands of years old, the question arises as to why many of them are now succumbing relatively quickly to encroachment by woody species. There are few unaltered mountain wetlands left and relatively minor alterations such as clearing the surrounding uplands or channelizing an adjacent stream can substantially dry these habitats. Once shrubs and trees are established they consume a tremendous amount of water, further drying the habitat and accelerating the process of succession. Restoration of mountain wetlands has met with very limited success—often once drastically altered they are almost impossible to repair (Murdock 1994).

Hart and Newman (1995) discussed the importance of isolated wetlands to fish and wildlife in Florida. Identified isolated wetland communities included (all or part): freshwater marshes, wet prairies, flatwoods ponds, stonewort (Chara spp.) ponds. sinkhole ponds, hammock ponds, pitcher plant bogs, cutthroat seeps, cypress swamps, cypress domes, scrub cypress communities, bayheads, shrub bogs, and mixed evergreen and deciduous hardwood swamps.

They noted that amphibians that must breed and spend their larval stages in temporary waters represent the most obligate users of isolated wetlands (Moler and Franz 1987). However there are other obligate requirements of a species population for isolated wetlands under certain circumstances. This need is illustrated by wading birds that require a threshold concentration of prey in order to forage and by snail kites

(Rostrhamus sociabilis plumbeus) whose sole food source is the apple snail (Pomacea paludosa).

The authors list 25 species of amphibians, reptiles, birds and mammals that are obligate users of isolated wetlands in Florida as well as 117species of amphibians, reptiles, fish, birds and mammals that are facultative users of isolated wetlands in Florida. For at least 12 federally and state listed endangered or threatened species or species of special concern (amphibians, reptiles, birds, mammals) isolated wetlands are obligate habitats for certain periods of their life cycle. An additional 6 listed species (reptiles, birds, mammals) are facultative users of isolated wetlands and 62 additional listed plant species occur in isolated wetlands.

Hart and Newman (1995) noted that in 1986, excessive rains in Florida (during a season when waters are usually receding) resulted in a dramatically reduced concentration of wading birds. They cited biologists who believed that the birds scattered throughout the region seeking small isolated wetlands that had the desired concentrations of food items. Takekawa and Beissinger (1989) demonstrated how regional isolated wetlands with standing water were critical to the snail kite during droughts that dried the marshes where they normally forage on apple snails.

Cycles of periodic drying and reflooding of isolated wetlands favor rapid nutrient recycling and high rates of primary and secondary production (Kahl 1964). Predation increases in drying wetlands, and fish kills result from low oxygen levels and desiccation. Crowding under conditions of low oxygen can cause higher mortality than predation during drydowns. Kushlan (1976) observed that fish mortality was 99.4% in a drying pond where birds were not present to forage. In contrast, fish subject to predation by wading birds under similar conditions has only 77% mortality, and survivors represented all of the fish species that were in the pond before drydown.

Hatchling alligators are more likely to escape predation in isolated wetlands near the nest site than in lakes that contain cannibalistic adult alligators and other potential predators. After the first few months, however they begin to use larger and deeper water areas to escape heat, disease and restricted food supply (Woodward et al. 1987). In south Florida, alligators lengthen the hydroperiod of the wetlands they inhabit by digging alligator holes to collect the water remaining during the dry season (Kushlan and Hunt 1979).

In discussions of Atlantic white cedar wetlands Laderman (1989) provides an interim list of 89 cedar-associated plant species and sub-taxa that are considered regionally rare, threatened or endangered.

The ecology of waterfowl species are widely acknowledged as being closely linked with wetland ecological conditions. Behavioral spacing of breeding pairs and the availability of energy resources have been proposed as major factors that regulate duck populations. Patterson (1976) studied a heterogeneous system of beaver ponds west of Ottawa, Ontario in order to compare the relative importance and interaction of the two mechanisms. The number of breeding pairs of ducks was found to be dependent only on the amount of surface water available, indicating that the major population regulatory mechanism was behavioral spacing. Fledged ducks on the other hand, selected fertile wetlands regardless of pond size, indicating that populations were regulated by the availability of energy resources. Habitat requirements of broods were intermediate, because behavioral escape cover and food availability were both important. It was hypothesized that the different environmental requirements of the three life history stages are an evolutionary adaptation to a temporarily unpredictable environment. The adaptations allow duck populations to maintain equilibrium in a temporarily unpredictable environment and to attain high population size in a spatially heterogeneous environment.

The population of prairie pothole wetlands, with a wide diversity of sizes, hydrology and spatial relationships (that vary over annual and long term cycles), also present such an evolutionary challenge to waterfowl (Drewien and Springer 1969, Dzubin 1969, Stoudt 1969). Such adapted species face difficulties when the wetland mosaic is altered significantly.

In addition to the critical reproductive habitat dynamics describe above, "isolated" wetlands are critical for other aspects of waterfowl life history. For example, the remaining wetlands of the rainwater basin area in south-central Nebraska are particularly important as a spring staging area for millions of waterfowl. However, since the mid-1970's thousands of waterfowl have died in the area from avian cholera. Smith and Higgins (1990) studied the temporal changes in wetland numbers and densities in Nebraska's Rainwater Basin area and related the data to outbreaks of avian cholera (Pasteurella multocida) .

Naturally occurring palustrine wetlands of temporary, seasonal or temporary water regimes (Cowardin et al. 1979) were surveyed with 1981 data and compared with data from 1965. Because water regimes are determined at the deepest portion of the wetland basins, a large portion of the semipermanently flooded wetlands basin may actually function as a seasonally flooded wetland. In order to be consistent with the 1965 data set, wetlands that had been created by excavation or impoundment were not included. While many surveyed wetlands contained drainage ditches (that may have reduced the original size of the wetland area, as well as altered the original classification) a wetland was only considered lost if it was totally altered and dewatered.

A total of 445 palustrine wetlands occupying 11,436 ha were found on 1981 National Wetland Inventory maps. Of this total, 117 (26%) were of the temporary water regime, 202 (46%) were seasonal, and 126 (28%) were semipermanent. Drainage ditches affected 362 (81%) of the 445 wetlands, leaving only 83 (19%) in a natural condition occupying 1,926 ha. Wetland basins known to commonly experience avian cholera epizootics had significantly fewer semipermanent wetlands within 3.2 km (the limit of P. multocida movement via surface water flowage) that did semipermanent wetland basins not experiencing epizootics. Thus avian cholera epizootics were inversely related to semipermanent wetland basin densities.

Drainage of Nebraska's wetland habitat possibly contributes to the incidence of avian cholera epizootics by decreasing the density of available waterfowl staging areas. Apparently, where semipermanent wetland densities are high, waterfowl are less concentrated on individual wetlands. Conversely, lower wetland density may force birds together in higher concentrations. Friend (1981) was cited who suggested that the high concentration of birds might cause more stress, lessen water quality, and increase disease susceptibility.

Although wetland drainage in Nebraska's rainwater basin area has resulted in drastic reductions of wetland habitat, this drainage is the direct cause of avian cholera, as the origin, retention, and transfer mechanism of avian cholera are not yet known.

RESPONSE TO ANPRM: WETLAND LITERATURE REFERENCES

Adamus, P. R., L. T., Stockwell, E. J. Clairain, Jr., M. E. Morrow, L. P. Rozas, and R. D. Smith. 1991. Wetland Evaluation Technique (WET); Volume I: Literature Review and Evaluation Rationale. Tech. Rpt. WRP-DE-2. US Army Corps of Engineers, Washington, DC. 297 pp.

Ash, A. N., C. B. McDonald, E. S. Kane, and C. A. Pories. 1983. Natural and modified pocosins: literature synthesis and management options. US Fish Wildl. Serv., Washington, DC. FWS/OBS-83/04. 156 pp.

Babbitt, K. J. and G. W. Tanner. 2000. Use of temporary wetlands by anurans in a hydrologically modified landscape. Wetlands 20(2): 313-322.

Bärlocher, R. J., R. J. MacKay, and G. B. Wiggins. 1978. Detritus processing in a temporary vernal pool in southern Ontario. Archiv. Hydrobiology 81: 269-295.

Bayley, S. E., R. S. Behr, and C. A. Kelly. 1986. Retention and release of S from a freshwater wetland. Water, air and soil Pollution 31: 104-114.

Bedford, B. L. 1996. The need to define hydrologic equivalence at the landscape scale for freshwater wetland mitigation. Ecol. Applications 6(1): 57-68.

Bellrose, F. C. and N. M. Trudeau. 1988. Wetlands and their relationship to migrating and wintering populations of waterfowl. Pages 183-194. In D. D. Hook, W. H. McKee, Jr., H. K. Smith, J. Gregory, V. G. Burrell, Jr., M. R. DeVoe, R. E. Sojka, S. Gilbert, R. Banks, L. H. Stolzy, C. Brooks, T. D. Matthews, and T. H. Shear (eds.). The ecology and management of wetlands, Volume 1: Ecology of wetlands. Timber Press, Portland, OR. 592 pp.

Belt, C. B., Jr. 1975. The 1973 flood and man's constriction of the Mississippi River. Science 189: 681-684.

Bennett, D. H. 1972. Notes on the terrestrial wintering of mud turtles (Kinosternon subrubrum). Herpetologica 28: 245-247.

Bennett, D. H., J. W. Gibbons, and J. C. Franson. 1970. Terrestrial activity in aquatic turtles. Ecology 51: 738-740.

Bennett, S. H., J. W. Gibbons, and J. Glanville. 1979. Terrestrial activity, abundance and diversity of amphibians in differently managed forest types. Am. Midl. Nat. 103: 412-416.

Berven, K. A. and T. A. Grudzien. 1990. Dispersal in the wood frog (Rana sylvatica): implications for genetic population structure. Evolution 44(8): 2047-2056.

Beschta, R. L. and W. S. Platts. 1986. Morphological features of small streams: significance and function. Water Res. Bull. 22(3): 369-379.

Bliley, D. J. and D. E. Pettry. 1979. Carolina bays on the eastern shore of Virginia. Soil Sci. Soc. Am. J. 43: 558-564.

Burton, T. M. and G. E. Likens. 1975. Salamander populations and biomass in the Hubbard Brook Experimental; Forest, New Hampshire. Copeia 1975: 541-546.

Brinson, M. M. 1977. Decomposition and nutrient exchange of litter in an alluvial swamp forest. Ecology 58 (3): 602-609.

Brinson, M. M. 1988. Strategies for assessing the cumulative effects of wetland alteration on water quality. Environ. Manage. 12: 655-662.

Brinson, M. M. 1991. Landscape properties of pocosins and associated wetlands. Wetlands 11, Special Issue: 441-466.

Brinson, M. M. 1993. Changes in the functioning of wetlands along environmental gradients. Wetlands 13(2), Special Issue: 65-74.

Brown, K. W. 1980. An analysis of herpetofaunal species diversity along a temporal gradient of loblolly pine stands in South Carolina. Master's Thesis. Texas Christian University. Fort Worth, TX.

Brown, M. T. and M. F. Sullivan. 1988. The value of wetlands in low relief landscapes. Pages 133-145. In D. D. Hook, W. H. McKee, Jr., H. K. Smith, J. Gregory, V. G. Burrell, Jr., M. R. DeVoe, R. E. Sojka, S. Gilbert, R. Banks, L. H. Stolzy, C. Brooks, T. D. Matthews, and T. H. Shear (eds.). The ecology and management of wetlands, Volume 1: Ecology of wetlands. Timber Press, Portland, OR. 592 pp.

Brown, R. G. 1985. Effects of wetlands on quality of runoff entering lakes in the twin cities metropolitan area. Minnesota Water Resources Investig. Rept. 85-4170. US Geological Survey, Reston, VA 32 pp.

Brown, R. G. 1988a. Effects of precipitation and land use on storm runoff. Water Resour. Bull. 24: 421-426.

Brown, R. G. 1988b. Effects of wetland channelization on runoff and loading. Wetlands 8: 123-133.

Brown, R. G., J. R. Stark, and G. L. Patterson. 1988. Ground-water and surface-water interactions in Minnesota and Wisconsin wetlands. Pages 176-180. In D. D. Hook, W. H. McKee, Jr., H. K. Smith, J. Gregory, V. G. Burrell, Jr., M. R. DeVoe, R. E. Sojka, S. Gilbert, R. Banks, L. H. Stolzy, C. Brooks, T. D. Matthews, and T. H. Shear (eds.). The ecology and management of wetlands, Volume 1: Ecology of wetlands. Timber Press, Portland, OR. 592 pp.

Brown, S. 1984. The role of wetlands in the Green Swamp. Pages 405-415 In K. C. Ewel and H. T. Odum (eds.), cypress Swamps. University Presses of Florida, Gainesville, FL.

Brun, L. J., J. L. Richardson, J. W. Enz, and J. K. Larsen. 1981. Stream flow changes in the southern Red River Valley of North Dakota. North Dakota Farm Res. 38(5): 11-14.

Burke, V. J. and J. W. Gibbons. 1995. Terrestrial buffer zones and wetland conservation: A case study of freshwater turtles in a Carolina bay. Conservation Biology 9(6): 1365-1369.

Carter, V. and R. P. Novitzki. 1988. Some comments on the relation between ground water and wetlands. Pages 68-86. In D. D. Hook, W. H. McKee, Jr., H. K. Smith, J. Gregory, V. G. Burrell, Jr., M. R. DeVoe, R. E. Sojka, S. Gilbert, R. Banks, L. H. Stolzy, C. Brooks, T. D. Matthews, and T. H. Shear (eds.). The ecology and management of wetlands, Volume 1: Ecology of wetlands. Timber Press, Portland, OR. 592 pp.

Christensen, N. L., R. B. Burchell, A. Liggett, and E. L. Simms. 1981. The structure and development of pocosin vegetation. Pages 43-61 In C. J. Richardson, (ed.) Pocosin wetlands: an integrated analysis of coastal plain bogs in North Carolina. Hutchinson Ross Publishing Co., Stroudsburg, PA. 364 pp.

Colburn, B. A. 2001. Small pools close up: examining vernal pools of the northeast. National Wetlands Newsletter 23(1): 7-8, 17-18.

Cooper, D. J. 1990. Ecology of wetlands in Big Meadows, Rocky Mountain National Park, Colorado. US Fish Wildl. Serv. Biol. Rep. 90(15). Washington, DC. 45 pp.

Cooper, J. R. and J. W. Gilliam. 1987. Phosphorus redistribution for cultivated field into riparian areas. Soil Sci. Am. J. 51: 1600-1604.

Cooper, J. R., J. W. Gilliam. R. B. Daniels, and W. P Robarge. 1987. Riparian areas as filters for agricultural sediment. Soil Sci. Soc. Am. J. 51: 416-420.

Cooper, J. R.. J. W. Gilliam. and T. C. Jacobs. 1986. Riparian areas as a control of nonpoint pollutants. Pages 166-192 in D. L. Correll (ed.) Watershed Research Perspectives. Smithsonian Institution Press, Washington, DC.

Copeland, B. J., R. G. Hodson, and S. R. Riggs. 1984. The ecology of the Pamlico River, North Carolina: an estuarine profile. US Fish Wildl. Serv. Washington, DC. FWS/OBS-82/06. 83 pp.

Copeland, B. J., R. G. Hodson, S. R. Riggs, and J. E. Easley, Jr. 1983. The ecology of Albemarle Sound. North Carolina: an estuarine profile. US Fish Wildl. Serv. Washington, DC. FWS/OBS-83/01. 68 pp.

Cowardin, L. M., V. Carter, F, C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U. S. Fish Wildl. Serv. Office of biological Services, Washington, DC. FWS/OBS-79-31. 131 pp.

Craft, C. B. and W. P. Casey. 2000. Sediment and nutrient accumulation in floodplain and depressional freshwater wetlands of Georgia, USA. Wetlands 20(2): 323-332.

Crisp, D. T. 1966. Input and output of minerals for an area of Pennine moorland: The importance of precipitation, drainage, peat erosion and animals. J. of Applied Ecology 3: 327-348.

Damman, A. W. H. and T. W. French. 1987. The ecology of peat bogs of the glaciated Northeastern United States: a community profile. US Fish Wildl. Serv. Biol. Rep. 85(7.16). 100 pp.

Daniel, C. C., III. 1981. Hydrology, geology and soils of pocosins: a comparison of natural and altered systems. Pages 69-108. In C. J. Richardson, (ed.) Pocosin wetlands: an integrated analysis of coastal plain bogs in North Carolina. Hutchinson Ross Publishing Co., Stroudsburg, PA. 364 pp.

Davis, C. B., J.L. Baker. A. G. van der Valk, and C. E. Beer. 1981. Prairie pothole marshes as traps for nitrogen and phosphorus in agricultural runoff. Pages 153-163 In B. Richardson (ed.). Selected proceedings of the Midwest conference on wetland values and management, June 17-19, 1981. St. Paul. MN. The Freshwater Society. St. Paul, MN. 660 pp.

Day, F. P., Jr. and J. P. Megonigal. 1993. The relationship between variable hydroperiod. production allocation. and belowground organic turnover in forested wetlands. Wetlands 13(2). Special Issue: 115-121.

Demissie, M. and A. Khan. 1993. Influence of wetlands on streamflow in Illinois. Contract Rept. 561 prepared for the Illinois Dept. of Conservation. Illinois Dept. of Energy and Natural Resources. Champaign. IL. 47 pp.

Diamond. J. 1975. The island dilemma: Lessons of modern biogeographical studies for design of natural preserves. Biol. Conservation 7: 129-146.

Diamond, J. M. 1976. Island biogeography and conservation: strategy and limitations. Science 193: 1027-1029.

Diehl, J. W. and R. E. Behling. 1982. Geologic factors affecting formation and presence of wetlands in the North Central section of the Appalachian Plateaus province of West Virginia. Pages 3-9 In B. R. MacDonald (ed.). Proceedings of the symposium on wetlands of the unglaciated Appalachian Region. West Virginia University, Morgantown, WV. 253 pp.

Dodd, C. K., Jr. 1995. Reptiles and amphibians in the endangered longleaf pine ecosystem. In: LaRoe, E. T., G. T. Ferris, C.E. Pucket, P. Doran, (Eds.) Our Living Resources: A report to the nation on the distribution, abundance, and health of plants, animals and ecosystems. National Biological Service, Washington, DC.

Dodd, C. K. and B. G. Charest. 1988. The herpetofaunal community of temporary ponds in north Florida sandhills: species composition, temporal use, and management implications. Pages 87-97 In Szaro, R. C., K. R. Severson, and D. R. Patton (eds.). Management of Amphibians, Reptiles, and Small Mammals in North America. USDA Forest Service Gen. Tech. Report RM-166. Ft. Collins, CO. 458 pp.

Drewien, R. C. and P. F. Springer. 1969. Ecological relationships of breeding blue-winged teal to prairie potholes. Pages 102-115. In: Saskatoon wetlands seminar. Can. Wildl. Serv. Rep. Series No. 6. The Queen's Printer, Ottawa, Ontario. 262 pp.

Dury, G. H. 1977. Underfit streams: retrospect, perspect, and prospect. Pages 281-293. In K. J. Gregory (ed.). River channel changes. John Wiley and Sons, New York, NY. 448 pp.

Dzubin, A. 1969. Comments on carrying capacity of small ponds for ducks and possible effects of density on mallard production. Pages 138-160. In: Saskatoon wetlands seminar. Can. Wildl. Serv. Rep. Series No. 6. The Queen's Printer, Ottawa, Ontario. 262 pp.

Elder, J. 1985. Nitrogen and phosphorus speciation and flux in a large Florida river wetland ecosystem. Water Res. Res. 21: 724-732.

Environmental Defense Fund and World Wildlife Fund. 1992. How Wet is a Wetland? New York, NY. 175 pp.

Euliss, N. H., Jr., and D. M. Mushet. 1996. Water-level fluctuation in wetlands s a function of landscape condition in the prairie pothole region. Wetlands 16(4): 587-593.

Fetter, C. W., Jr., W. E. Sloey, and F. L. Spangler. 1978. Use of a natural marsh for wastewater polishing. J. Water Pollut. Cont. Fed. 50: 290-307.

Flores, A. C., P. B. Bedient, and L. W. Mays. 1981. Method for optimizing size and locations of urban detention storage. Pages 357-365 in Proc. of the International symposium on Urban Hydrology, Hydraulics and Sediment control. ASCE, New York, NY.

Friend, M. 1981. Waterfowl management and waterfowl disease: independent or cause and effect relationship? Trans. N. Am. Wildl. Nat. Res. Conf. 46: 94-103.

Fritzell, E. K. 1988. Mammals and wetlands. Pages 213-226. In D. D. Hook, W. H. McKee, Jr., H. K. Smith, J. Gregory, V. G. Burrell, Jr., M. R. DeVoe, R. E. Sojka, S. Gilbert, R. Banks, L. H. Stolzy, C. Brooks, T. D. Matthews, and T. H. Shear (eds.). The ecology and management of wetlands. Volume 1: Ecology of wetlands. Timber Press, Portland, OR. 592 pp.

Gallagher, J. L. and H. V. Kibby. 1980. Marsh plants as vectors in trace metal transport in Oregon tidal marshes. Am. J. Bot. 67: 1069-1074.

Gibbs, J. P. 1993. Importance of small wetlands for the persistence of local populations of wetland-associated animals. Wetlands 13(1): 25-31.

Gilliam, J. W. 1991. Wet soils in the North Carolina coastal plain. Wetlands 11, Special Issue: 391-399.

Gilliam, J. W. and R. W. Skaggs. 1981. Drainage and agricultural development: effects on drainage waters. Pages 109-124 In C. J. Richardson, (ed.) Pocosin wetlands: an integrated analysis of coastal plain bogs in North Carolina. Hutchinson Ross Publishing Co., Stroudsburg, PA. 364 pp.

Gillion, R. J. 1985. Pesticides in rivers of the United States. Pages 85-92 in Water Supply Paper 2275. US Geological Survey, Reston, VA.

Golet, F. C., A. J. K. Calhoun, W. RE. DeRagon, D. J. Lowry, and A. J. Gold. 1993. Ecology of red maple swamps in the glaciated northeast: a community profile. US Fish Wildl. Serv., Biol. Rep. 12. Washington, DC. 151 pp.

Gosz, J. R., R. T. Holmes, G. E. Likens, and F. H. Bormann. 1978. The flow of energy in a forest ecosystem. Sci. Amer. 238(3): 100-111.

Greenwood, R. J., A. B. Sargeant, D. H. Johnson, L. M. Cowardin, and T. L. Shaffer. 1995. Factors associated with duck nest success in the prairie pothole region of Canada. Wildl. Monographs 128. 54 pp.

Guenzi, W. D. and W. E. Beard. 1968. Anaerobic conversion of DDT to DDD and aerobic stability of DDT in soil. Proc. Soil Sci. Soc. Am. 32: 5220524.

Guenzi, W. D., W. E. Beard, and F. G. Viets, Jr. 1971. Influence of soil treatment on persistence of six chlorinated hydrocarbon insecticides in the field. Proc. Soil Sci. Soc. Am. 35: 910-913.

Gwin, S. E., M. E. Kentula, and P. W. Shaffer. 1999. Evaluating the effects of wetland regulation through hydrogeomorphic classification and landscape profiles. Wetlands 19(3): 477-489.

Hanski, I. and O. Ovaskainen. 2000. The metapopulation capacity of a fragmented landscape. Nature 404: 755-758.

Harden, J. W., E. T. Sundquist, R. F. Stallard, and R. K. Mark. 1992. Dynamics of soil carbon during deglaciation of the Laurentide Ice Sheet. Science 258: 1921-1924.

Hart, R., and J. R. Newman. 1995. The importance of isolated wetlands to fish and wildlife in Florida. Fla. Game and Fresh Water Fish Comm. Nongame Wildl. Program Project Rep., Tallahassee, FL. 145 pp.

Hecnar, S. J. and R.T. M'Closkey. 1996. Regional dynamics and the status of amphibians. Ecology 77(7): 2091-2097.

Hershner, C., K. Havens, D. Schatt, and T. Rudnicky. 2000. Headwater and floodplain wetlands in Virginia. Virginia Inst. of Marine Science Special Report No. 00-2.8 pp.

Hey, D. L. and N. s. Philippi. 1995. Flood reduction through wetland restoration: the upper Mississippi River basin as a case history. Restoration Ecology 3(1): 4-17.

Hickok, E. A., M. C. Hannaman, and N. C. Wenck. 1977. Urban runoff treatment methods: Vol. I. Nonstructural wetlands treatment. EPA-600/1-77-217. US Environmental Protection Agency, Washington, DC. 131 pp.

Hill, A. R. and K. J. Devito. 1997. Hydrological-chemical interactions in headwater forested wetlands. 1997. Pages 213-230 In C. C. Trettin, M. F. Jurgensen. D. F. Grigal, M. R. Gale. and J K. Jeglum (eds.) Northern Forested Wetlands: Ecology and Management. Lewis Publ., Boca Raton, FL. 486 pp.

Hindall. S. M. 1975. Measurement and prediction of sediment yields in Wisconsin streams. Water Resour. Invest. 54-75. US Geological Survey, Reston. VA. 27 pp.

Hossner, L. R. and W. H. Baker. 1988. Phosphorus in flooded soils. Pages 293-306. In D. D. Hook, W. H. McKee, Jr., H. K. Smith, J. Gregory, V. G. Burrell, Jr., M. R. DeVoe, R. E. Sojka, S. Gilbert. R. Banks, L. H. Stolzy, C. Brooks, T. D. Matthews, and T. H. Shear (eds.). The ecology and management of wetlands, Volume 1: Ecology of wetlands. Timber Press, Portland, OR. 592 pp.

Hubbard, D. E. 1988. Glaciated prairie wetland functions and values: a synthesis of the literature. U. S. Fish Wildl. Serv. Biol. Rep. 88(43). Ft. Collins, CO. 50 pp.

Hubbard, D. E. and R. L. Linder. 1986. Spring runoff retention in prairie pothole wetlands. J. Soil and Water Conservation 41: 122-125.

Hupp, C. R. and A. Simon. 1991. Bank accretion and the development of vegetated depositional surfaces along modified alluvial channels. Geomorphology 4: 111-124.

Hupp, C. R., M. D. Woodside. and T. M. Yanosky. 1993. Sediment and tract element trapping in a forested wetland, Chickahominy River, Virginia. Wetlands 13(2), Special Issue: 95-104.

Ingram, H. A. P. 1967. Problems of hydrology and plant distribution in mires. J. of Ecology 55: 711-724.

Jacobs, T. C. and J. W. Gilliam. 1983. Nitrate loss from agricultural drainage waters: Implications for non-point source control. Report No. 209. Water Resources Institute of the Univ. of North Carolina, Raleigh, NC.

Johnston, C. A. 1994. Cumulative impacts to wetlands. Wetlands 14(1): 49-55.

Kaczorowski, R. T. 1976. Origin of the Carolina bays. Pages II.16-II.36. In M.O. Hayes et al. Terrigenous clastic depositioinal environments. Univ. south Carolina Coastal Res. Div. Tech. Rept. No. 11.

Kahl, P. M., Jr. 1964. Food ecology of the wood stork (Mycteria americana) in Florida. Ecol. Monographs 34(1): 97-117.

Kantrud, H. A., G. L. Krapu, and G. A. Swanson. 1989. Prairie basin wetlands of the Dakotas: a community profile. US Fish Wildl. Serv. Biol. Rep. 85(7.28). Washington, DC. 111 pp.

Karickhoff, W. W., D. S. Brown. and T. A. Scott. 1979. Sorption of hydrophobic pollutants on natural sediments. Water Res. 13: 241-248.

Keeley, J. E. and P. H. Zedler. 1998. Characterization and global distribution of vernal pools. Pages 1-14 In C. W. Witham, E. T. Bauder, D. Belk, W. R. Ferren Jr., and R. Ornduff (eds.) Ecology, Conservation and Management of Vernal Pool Ecosystems—Proceedings from a 1996 Conference. California Native Plant Society, Sacramento, CA. 285 pp.

Kirkman, L. K., M. B. Drew, L. T. West, and E. R. Blood. 1998. Ecotone characterization between upland longleaf pine/wiregrass stands and seasonally-ponded isolated wetlands. Wetlands 18(3): 346-364.

Kirkman, L. K., S. W. Golladay, L. Laclaire, and R. Sutter. 1999. Biodiversity in southeastern, seasonally ponded, isolated wetlands: management and policy perspectives for research and conservation. J. N. Am. Benthol. Soc. 18(4): 553-562.

Kirkman, L. K., R. F. Lide, G. Wein, and R. R. Sharitz. 1996. Vegetation changes and land-use legacies of depression wetlands of the western coastal plain of South Carolina: 1951-1992. Wetlands 16(4): 564-576.

Kirkman, L. K., P. C. Goebel, L. West, M. B. Drew, and B. J. Palik. 2000. Depressional wetland vegetation types: a question of plant community development. Wetlands 20(2): 373-385.

Kittelson, J. M. 1988. Analysis of flood peak moderation by depressional wetland sites. Pages 98-111. In D. D. Hook, W. H. McKee, Jr., H. K. Smith, J. Gregory, V. G. Burrell, Jr., M. R. DeVoe, R. E. Sojka, S. Gilbert, R. Banks, L. H. Stolzy, C. Brooks, T. D. Matthews, and T. H. Shear (eds.). The ecology and management of wetlands, Volume 1: Ecology of wetlands. Timber Press, Portland, OR. 592 pp.

Knight, R. L., J. S. Bays, and F. R. Richardson. 1989. Floral composition, soil relations, and hydrology of a Carolina bay in South Carolina. Pages 219-234 in R. R. Sharitz and J. W. Gibbons (eds.). Freshwater Wetlands and Wildlife, March 24-27, 1986. Charleston, SC, US Office of Health and Environ. Research, Off. Sci. and Tech. Information. Washington, DC. 1265 pp.

Knox, J. C. 1988. Climatic influence on Upper Mississippi Valley floods. Pages 279-300. In V. R. Baker, R. C. Kochel, and P. C. Patton (eds.). Flood geomorphology. John Wiley and Sons, New York, NY.

Ko, W. H., and J. L. Lockwood. 1968. Conversion of DDT to DDD in soil and the effect of these compounds on soil organisms. Can. J. Microbiol. 14: 1069-1073.

Kudray, G. M. and M. R. Gale. 1997. Relationships between groundwater characteristics, vegetation, and peatland type in the Hiawatha National Forest, Michigan. Pages 89-96 In C. C. Trettin, M. F. Jurgensen, D. F. Grigal, M. R. Gale, and J K. Jeglum (eds.) Northern Forested Wetlands: Ecology and Management. Lewis Publ., Boca Raton, FL. 486 pp.

Kushlan, J. A. 1976. Wading bird predation in a seasonally fluctuating pond. The Auk 93(3): 464-476.

Kushlan, J. A. and B. P. Hunt. 1979. Limnology of an alligator pond in south Florida. Florida Scientist 42: 65-84.

LaBaugh, J.W., T. C. Winter, and D. O. Rosenberry. 1998. Hydrologic functions of prairie wetlands. Great Plains Research 8: 17-37.

Laderman, A. D. 1989. The ecology of the Atlantic white cedar wetlands: a community profile. US Fish Wild. Serv. Biol. Rep. 85(7.21). 114 pp.

Laney, R. W. 1988. The elimination of isolated and limited-flow wetlands in North Carolina. Pages 243-253 In W. L. Lyke and T. J. Hoban (eds.) Proc. of the Symposium on Coastal Water Resources. Am. Water Resources Assoc., Bethesda, MD.

Laxen, D. P. H., and R. M. Harrison. 1977. The highway as a source of water pollution: an appraisal with the heavy metal lead. Water Res. 11: 1-11.

Leopold, L. B., M. G. Wolman, and J. P. Miller. 1964. Fluvial Processes in Geomorphology. W. H. Freeman and Co., San Francisco, CA.

Lehtinen, R. M., S. M., Galatowitsch, and J. R. Turner. 1999. Consequences of habitat loss and fragmentation for wetland amphibian assemblages. Wetlands 19(1): 1-12.

Lide, R. F. and V. G. Meentemeyer. 1995. Hydrology of a Carolina bay located on the upper coastal plain of western South Carolina. Wetlands 15(1): 47-57.

Lowrance, R. R., R. L. Todd, and L. E. Asmussen. 1984a. Nutrient cycling in an agricultural watershed: Phreatic movement. J. Environm. Qual. 13: 22-27.

Lowrance, R. R., R. L. Todd, J. Flail, O. Hendrickson, R. Leonard, and L. E. Asmussen. 1984b. Riparian forests as nutrient filters in agricultural watersheds. Bioscience 34: 374-377.

Lowrance, R., L. S. Altier, J. Denis Newbold, R. S. Schnabel, P. M. Groffman, J. M. Denver, D. L. Correll, J. W. Gilliam, J. L. Robinson, R. B. Brinsfield, K. W. Staver, W. Lucas, and A. H. Todd. 1997. Water quality functions of riparian forest buffers in Chesapeake Bay watersheds. Environmental Management 21(5): 687-712.

Ludden, A. P., D. L. Frink, and D. H. Johnson. 1983. Water storage capacity of natural wetland depressions in the Devils Lake basin of North Dakota. J. Soil and Water Conservation 38: 45-48.

Maser, C. and J. R. Sedell. 1994. From the Forest to the Sea: The ecology of wood in streams, rivers, estuaries and oceans. St. Lucie Press, Delray Beach, FL. 200 pp.

McColl, R. H. S. 1978. Chemical runoff from pastures: the influence of fertilizer and riparian zones. New Zealand Journal of Marine and Freshwater Research 12: 371-380.

Melton, F. A. 1938. Possible late Cretaceous origin of the Carolina "bays." Geol. Soc. Am. Bull. 49: 1954.

Mitsch, W. J. and J. G. Gosselink. 1986. Wetlands. Van Nostrand Reinhold, New York, NY. 539 pp.

Miller, M. W., and T. D. Nudds. 1996. Prairie landscape change and flooding in the Mississippi River valley. Conservation Biology 10(3): 847-853.

Moler, P. E. and R. Franz. 1987. Wildlife values of small, isolated wetlands in the southeastern coastal plain. Pages 234-241 In: Proceedings of the Third southeastern Nongame and Endangered Wildlife Symposium, August 8-10, 1987, Athens GA.

Molinas, A., G. T. Auble, C. A. Segelquist, and L. S. Ischinger (eds.). 1988. Assessment of the role of bottomland hardwoods in sediment and erosion control. NERC-88/11. US Fish and Wildlife Service, National Ecology Research Center, Ft. Collins, CO. 116 pp.

Moore, I. D. and D. L. Larson. 1979. Effects of drainage projects on surface runoff from small depressional watersheds in the north-central region. Univ. Minn. Water Resources Res. Center Bull. 99. 225 pp.

Moorhead, K. K. 1992. Wetland resources of coastal North Carolina. Wetlands 12(3): 184-191.

Mortellare, S., S. Krupa, L. Fink, and J. VanArman. 1995. Literature review on the effects of groundwater drawdowns on isolated wetlands. South Florida Water Management District Technical Publication 96-01. West Palm Beach, FL. 44 pp.

Mulholland, P. J. 1992. Regulation of nutrient concentrations in a temperate forest stream: Roles of upland, riparian and instream processes. Limnol. Oceanog. 37: 1512-1526.

Mulholland, P. J., L. A. Yarbro, R. P. Sniffen, and E. J. Kuenzler. 1981. Effects of floods on nutrient and metal concentrations in a coastal plain stream. Water Res. Res. 17: 758-764. 1992.

Mulholland, P. J. and E. J. Kuenzler. 1979. Organic carbon export from upland and forested wetland watersheds. Limnol. Oceanog. 24: 960-966.

Murdock, N. A. 1994. Rare and endangered plants and animals of southern Appalachian wetlands. Water, Air and Soil Pollution 77: 385-405.

Nichols, D. S. 1983. Capacity of natural wetlands to remove nutrients from wastewater. J. Water Poll. Cont. Fed. 55: 495-505.

Niering, W. A. 1988. Endangered, threatened and rare wetland plants and animals of the continental United States. Pages 227-238. In D. D. Hook, W. H. McKee, Jr., H. K. Smith, J. Gregory, V. G. Burrell, Jr., M. R. DeVoe, R. E. Sojka, S. Gilbert, R. Banks, L. H. Stolzy, C. Brooks, T. D. Matthews, and T. H. Shear (eds.). The ecology and management of wetlands, Volume 1: Ecology of wetlands. Timber Press, Portland, OR. 592 pp.

Novitzki, R. P. 1978. Hydrology of the Nevin wetland near Madison, Wisconsin. US Geol. Surv. Water Resour Invest. 78-43. 25 pp.

Novitzki, R. P. 1979. The hydrological characteristics of Wisconsin wetlands and their influence on floods, streamflow, and sediment. Pages 377-388 in P. E. Greeson, J. R. Clark, and J. E. Clark (eds.), Wetland functions and values: the state of our understanding. Am Water Resources Assoc. Minneapolis, MN. 674 pp.

Oberts, G. L. 1981. Impacts of wetlands on watershed water quality. Pages 213-227 in B. Richardson (ed.). Selected proceedings of the Midwest conference on wetland values and management. Freshwater Soc., Navarre, MN.

Odum W. E., and J. E. Drifmeyer. 1978. Sorption of pollutants by plant detritus: a review. Environ. Health Perspect. 27: 133-37.

Ogawa, H., and J. W. Male. 1983. The flood mitigation potential of inland wetlands. Univ. Ma. Water Resources Research Center, Amherst, MA. 164 pp.

Otte, L. J. 1981. Origin, development and maintenance of pocosin wetlands of Northe Carolina. Unpublished report to the North Carolina Natural Heritage Program. North Carolina Dept. of Natural Resources and Community Development. Raleigh, NC. 51 pp.

Parr, J. F., and S. Smith. 1976. Degradation of toxaphene in selected anaerobic soil environments. Soil Sci. 121: 52-57.

Patrick, W. J., Jr. and R. A. Khalid. 1974. Phosphate release and sorption by soil and sediments: Effect of aerobic and anaerobic conditions. Science 186: 53-55.

Patterson, J. H. 1976. The role of environmental heterogeneity in the regulation of duck populations. J. Wildl. Manage. 40(1): 22-32.

Pearson, S. M. 1994. Landscape-level processes and wetland conservation in the southern Appalachian Mountains. Water, Air and Soil Pollution 77: 321-332.

Peterjohn, W. T. and D. L. Correll. 1984. Nutrient dynamics in an agricultural watershed: Observations on the role of a riparian forest. Ecology 65(5): 1466-1475.

Phillips, P. J. and R. J. Shedlock. 1993. Hydrology and chemistry of groundwater and seasonal ponds in the Atlantic Coastal Plain in Delaware, USA. J. Hydrology 141: 157-178.

Phillips, P. J., J. M. Denver, R. J. Shedlock, and P. A. Hamilton. 1993. Effect of forested wetlands on nitrate concentrations in ground water and surface water on the Delmarva Peninsula. Wetlands 13(2), Special Issue: 75-83.

Pielou, E. C. 1998. Fresh water. Univ. Chicago Press, Chicago, IL. 275 pp.

Pionke, H. B. and G. Chesters. 1973. Pesticide-sediment-water interactions. J. Environ. Qual. 2: 29-45.

Porcher, R. D. 1981. The vascular flora of the Francis Beidler forest in four Holes Swamp, Berkeley and Dorchester Counties, South Carolina. Castanea 46: 248-280.

Postel, S.L. 1981. The economic benefits of pocosin preservation. Pages 283-302. In C. J. Richardson, (ed.) Pocosin wetlands: an integrated analysis of coastal plain bogs in North Carolina. Hutchinson Ross Publishing Co., Stroudsburg, PA. 364 pp.

Prouty, W. F. 1952. Carolina bays and their origin. Bull. Geol. Soc. Am. 63: 167-224.

Puckett, L. J., M. D. Woodside, B. Libby, and M. R. Schening. 1993. Sinks for trace metals, nutrients, and sediments in wetlands of the Chickahominy River near Richmond, Virginia. Wetlands 13(2), Special Issue: 105-114.

Rannie, W. F. 1980. The Red River flood control system and recent flood events. Water Res. Bull. 16: 207-214.

Reddy, K. R. and D. A. Graetz. 1988. Carbon and nitrogen dynamics in wetland soils. Pages 307-318. In D. D. Hook, W. H. McKee, Jr., H. K. Smith, J. Gregory, V. G. Burrell, Jr., M. R. DeVoe, R. E. Sojka, S. Gilbert, R. Banks, L. H. Stolzy, C. Brooks, T. D. Matthews, and T. H. Shear (eds.). The ecology and management of wetlands, Volume 1: Ecology of wetlands. Timber Press, Portland, OR. 592 pp.

Rheinhardt, R. D., M. C. Rheinhardt, M. M. Brinson, and K. Faser. 1998. Forested wetlands of low order streams in the inner coastal plain of North Carolina, USA. Wetlands 18(3): 365-378.

Richardson, C. J. 1981. Pocosins: ecosystem processes and the influence of Man on system response. Pages 135-151. In C. J. Richardson, (ed.) Pocosin wetlands: an integrated analysis of coastal plain bogs in North Carolina. Hutchinson Ross Publishing Co., Stroudsburg, PA. 364 pp.

Richardson, C. J. 1991. Pocosins: an ecological perspective. Wetlands 11, Special Issue: 335-354.

Richardson, C. J., R. Evans, and D. Carr. 1981. Pocosins: an ecosystem in transition. Pages 3-19. In C. J. Richardson, (ed.) Pocosin wetlands: an integrated analysis of coastal plain bogs in North Carolina. Hutchinson Ross Publishing Co., Stroudsburg, PA. 364 pp.

Richardson, E. M. and E. Epstein. 1971. Retention of three insecticides on different size soil particles suspended in water. Soil Sci. Soc. Am. Proc. 35: 884-887.

Richardson, J. L. and J. L. Arndt. 1989. What use prairie potholes? J. Soil and Water Conservation 44: 196-198.

Richter, K. O. and A. L. Azous. 1995. Amphibian occurrence and wetland characteristics in the Puget Sound basin. Wetlands 15(3): 305-312.

Roelle, J. E., G. T. Auble, D. B. Hamilton, R. L. Johnson, and C. A. Segelquist, eds. 1987. Results of a workshop concerning ecological zonation in bottomland hardwoods. U.S. Fish Wildl. Serv., National Ecology Center, Ft. Collins, CO. NEC-87/14. 141 pp.

Roulet, N. T. 1990. Hydrology of a headwater basin wetland: Groundwater discharge and wetland maintenance. Hydrological Processes 4: 387-400.

Russell, K. R. and H. G. Hanlin. 1999. Aspects of the ecology of worm snakes (Carphophis amoenus) associated with small isolated wetlands in South Carolina J. Herpetology 33(2): 339-344.

Schafale, M. P. 1999. Nonriverine wet hardwood forests in North Carolina Status and Trends. North Carolina Heritage Program. 12 pp.

Semlitsch, R. D. 2000. Size does matter: the value of small isolated wetlands. National Wetlands Newsletter 22(1): 5-6, 13.

Semlitsch, R. D. and J. R. Bodie. 1998. Are small, isolated wetlands expendable? Conservation Biology 12(5): 1129-1133.

Shaffer, P. W., M. E. Kentula, and S. E. Gwin. 1999. Characterization of wetland hydrology using hydrogeomorphic classification. Wetlands 19(3): 490-504.

Sharitz, R. R. and J. W. Gibbons. 1982. The ecology of southeastern shrub bogs (pocosins) and Carolina bays: a community profile. US Fish Wildl. Serv., Washington, DC. FWS/OBS-82/04. 93 pp.

Sharom, M. S., J. R. W. Miles, C. R. Harsis, and F. L. McEwen. 1980. Behavior of 12 insecticides in soil and aqueous suspensions of soil and sediment. Water Res. 14(8): 1095-1100.

Skaggs, R. W., J. W. Gilliam, and R. O. Evans. 1991. A computer simulation study of pocosin hydrology. Wetlands 11, Special Issue: 399-416.

Smith. A. G. 1969. Waterfowl-habitat relationships on the Lousana, Alberta Waterfowl Study Area.. Pages 116-122. In: Saskatoon wetlands seminar. Can. Wildl. Serv. Rep. Series No. 6. The Queen's Printer. Ottawa. Ontario. 262 pp.

Smith. B. J. and K. F. Higgins. 1990. Avian cholera and temporal changes in wetland numbers and densities in Nebraska's Rainwater Basin area. Wetlands 10(1): 1-5.

Snodgrass, J. W., A L. Bryan, Jr., R. F. Lide, and G. M. smith. 1996. Factors affecting the occurrence and structure of fish assemblages in isolated wetlands of the upper coastal plain, U.S.A. Can. J. Fish. Aquat. Sci. 53: 443-454.

Spencer, W. F., M. M. Cliath, W. J. Farmer, and R. A. Shepard. 1974. Volatility of DDT residues in soil as affected by flooding and organic matter applications. J. Environ. Qual. 3: 126-129.

Stolt, M. H. and J. C. Baker. 1995. Evaluation of National Wetland Inventory maps to inventory wetlands in the southern Blue Ridge of Virginia. Wetlands 15(4): 346-353.

Stolt. M. H. and M. C. Rabenhorst. 1987. Carolina Bays on the eastern shore of Maryland: I. Soil characterization and classification. Soil Sci. Soc. Am. J. 51: 394-405.

Stone, A. W., and A. J. L. Stone. 1994. Wetlands and groundwater in the United States. Amer. Ground Water Trust. Dublin, OH. 100 pp.

Stoudt. J. H. 1969. Relationships between waterfowl and water area on the Redvers Waterfowl Study Area. Pages 123-131. In: Saskatoon wetlands seminar. Can. Wildl. Serv. Rep. Series No. 6. The Queen's Printer, Ottawa, Ontario. 262 pp.

Striegel, R. G. 1987. Suspended sediment and metals removal from urban runoff by a small lake. Water Resour. Bull. 23(6): 985-996.

Takekawa, J. E. and S. R. Beissinger. 1989. Cyclic drought, dispersal, and the conservation of the snail kite in Florida: lessons in critical habitat. J. Range Manage. 3: 254-258.

Tang, Z. C. and T. T. Kozlowski. 1984. Ethylene production and morphological adaptation of woody plants to folding. Can. J. Botany 62: 1659-1664.

Thomas. D. M., and M. A. Benson. 1970. Generalization of streamflow characteristics from drainage basin characteristics. Water-Supply Paper 1975. US Geological Survey, Washington. DC.

Tiner, R. W. 1984. Wetlands of the United States: Current Status and Recent Trends. U. S. Fish Wildl. Serv., Newton Corner, MA. 59 pp.

Tiner, R. W. 1985. Wetlands of New Jersey. U. S. Fish Wildl. Serv., National Wetland Inventory, Newton Corner, MA. 117 pp.

Tiner, R. W. 1987. Mid-Atlantic Wetlands: A Disappearing Natural Treasure. U. S. Fish Wildl. Serv., National Wetland Inventory, Newton Corner, MA and U. S. Environmental Protection Agency, Philadelphia, PA. Cooperative Publication. 28 pp.

Tiner, R. W. 1989. Wetlands of Rhode Island. U. S. Fish Wildl. Serv., National Wetland Inventory, Newton Corner, MA. 71 pp.

Tiner, R. W. and D. G. Burke. 1995. Wetlands of Maryland. U. S. Fish Wildl. Serv., Ecological Services, Hadley MA and Maryland Dept. of Natural Resources, Annapolis, MD. Cooperative Publication. 193 pp.

Tiner, R. W., H. C. Bergquist, G. P. DeAlessio, and M J. Starr. 2002. Geographically Isolated Wetlands: A Preliminary Assessment of their Characteristics and Status in Selected Areas of the United States. U.S. Dept. Interior, Fish and Wildlife Service, Hadley, MA.

Tompkins, T. M., W. W. Whipps, L. J. Manor, M. J. Wiley, C. W. Radcliffe, and D. M. Majewski. 1997. Wetland effects on hydrological and water quality characteristics of a mid-Michigan river system. Pages 273-285 In C. C. Trettin, M. F. Jurgensen, D. F. Grigal, M. R. Gale, and J K. Jeglum (eds.) Northern Forested Wetlands: Ecology and Management. Lewis Publ., Boca Raton, FL. 486 pp.

Van Hassel, J. H., J. J. Ney, and D. L. Garling, Jr. 1980. Heavy metals in a stream ecosystem at sites near highways. Trans. Am. Fisheries Soc. 109: 636-643.

Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell, and C. E. Cushing.. 1980. The river continuum concept. Can. J. Fish. Aquatic Sci. 37: 130-137.

Verry, E. S., and D. H. Bolter. 1979. Peatland Hydrology. Pages 389-402 in P. E. Greeson, J. R. Clark, and J. E. Clark (eds.), Wetland functions and values: the state of our understanding. Am. Water Resources Assoc. Minneapolis, MN. 674 pp.

Vince, S. W., S. R. Humphrey, and R. W. Simons. 1989. The ecology of hydric hammocks: a community profile. US Fish Wildl. Serv. Biol. Rep. 85(7.26). 81 pp.

Walbridge, M. R., and C. J. Richardson. 1991. Water quality of pocosins and associated wetlands of the Carolina coastal plain. Wetlands 11, Special Issue: 417-440.

Wassersug, R. J. 1975. The adaptive significance of the tadpole stage with comments on the maintenance of complex life cycles in anurans. Am. Zool. 15: 405-417.

Weakley, A. S., and M. P. Schafale. 1991. Classification of Pocosins of the Carolina coastal plain. Wetlands 11, Special Issue: 355-376.

Wharton, C. H., W. M. Kitchens, E. C. Pendleton, and T. W. Sipe. 1982. The ecology of bottomland hardwood swamps of the southeast: a community profile. US Fish Wildl. Serv. Washington, DC. FWS/OBS-81/37. 133 pp.

Whigham, D., R. F. C. Chitterling, and B. Palmer. 1988. Impacts of freshwater wetlands on water quality: A landscape perspective. Environ. Management 12: 663-671.

Wieder, R. K. and G. E. Lang. 1982. Modification of acid mine drainage in a freshwater wetland. Pages 43-53 In B. R. MacDonald (ed.). Proceedings of the symposium on wetlands of the unglaciated Appalachian Region. West Virginia University, Morgantown, WV. 253 pp.

Wilbur, H. M. 1980. Complex life cycles. Ann. Rev. Ecol. Syst. 11: 67-93.

Williams, G. P. and M. G. Wolman. 1984. Downstream effects of dams on alluvial rivers. U. S. Geological Survey Prof. Paper 1286. U. S. Govt. Printing Office, Washington, DC.

Williams, T. M. and G. R. Askew. 1988. Impact of drainage and site conversion of pocosin lands on water quality Pages 213-218. In D. D. Hook, W. H. McKee, Jr., H. K. Smith, J. Gregory, V. G. Burrell, Jr., M. R. DeVoe, R. E. Sojka, S. Gilbert, R. Banks, L. H. Stolzy, C. Brooks, T. D. Matthews, and T. H. Shear (eds.). The ecology and management of wetlands, Volume 2: Management, use and value of wetlands. Timber Press, Portland, OR. 394 pp.

Williams, T. M. and G. R. Askew. 1990. Man-caused and natural variations in Pocosin water quality. Pages 79-87 In R. R. Sharitz and J. W. Gibbons (eds.) Freshwater wetlands and wildlife. U S. Dept. of Energy, Office of Scientific and Technical Information, Oak Ridge, TN. 1265 pp.

Windell, J. T., B. E. Willard. D. J. Cooper. S. Q. Goster, C. F. Knud-Hansen. L. P. Rink, and G. N. Kiladis. 1986. An ecological characterization of Rocky Mountain montane and subalpine wetlands. US Fish Wild. Serv. Biol. Rep. 86(11). Washington, DC. 298 pp.

Winter, T. C. 1988. A conceptual framework for assessing cumulative impacts on the hydrology of nontidal wetlands. Environ. Management 12: 605-620.

Winter, T. C. and D. O. Rosenberry. 1995. The interaction of ground water with prairie pothole wetlands in the Cottonwood Lake area, east-central North Dakota, 1979-1990. Wetlands 15(3): 193-211.

Woodward, A. R., T. C. Hines, C. L. Abercrombie, and J. D. Nichols. 1987. Survival of young American alligators on a Florida lake. J. Wildlife Manage. 51: 931-931.

Woodwell, G. M. 1956. Phytosociology of coastal plain wetlands in the Carolinas. M. S. Thesis. Duke University, Durham, NC. 50 pp.

Wycoff, R. L., and D. G. Pyne. 1975. Urban water management and coastal wetland protection in Collier County, Florida. Water Res. Bull. 2: 455-469.

Zampella, R. A. and R. G. Lathrop. 1997. Landscape changes in Atlantic white cedar (Chamaecyparis thyoides) wetlands of the New Jersey Pinelands. Landscape Ecology 12: 397-408.

Appendix E
Literature Review
Extent and Function of Headwater Streams

USEPA, WHEELING, WV
February 2003

M.Passmore
L.Reynolds
F. Borsuk

1. Definitions of Perennial, Intermittent and Ephemeral Headwater Streams

The hydrologic definitions of perennial, intermittent and ephemeral stream types depend on normal flow durations which are difficult to measure and verify. Flow duration and the points of origin of ephemeral, intermittent or perennial flow in streams vary temporally as the local water tables vary. There is a lot of confusion within regulatory agencies and in the peer reviewed literature concerning definitions of perennial, intermittent and ephemeral streams. At first glance, it would seem that perennial and ephemeral channels are more easily and more clearly defined than are intermittent streams, based on hydrology alone. Perennial channels have contiguous surface flow all year. Ephemeral channels have surface flow only following intense rainfall or snowmelt.

Intermittent streams are often generally described as streams which are below the local water table for at least some part of the year, and obtain their flow from both surface and ground water sources. The term "intermittent" has been used to describe streams with a wide gradient of flow permanence. This term has been used to describe streams with only a few months of contiguous surface flow a year as well as streams that have contiguous surface flow for all but a few days or weeks a year. Many streams have perennial, spring-fed reaches in the headwaters, with intermittent reaches further downstream, where the flow hits the alluvial deposits of the valley floor and becomes subsurface flow. Even further downstream the streams are once again perennial. In these cases, the intermittent reach is positioned between two perennial reaches. Some seemingly intermittent streams that do not have continuous surface flow maintain contiguous longitudinal hydrological connections through interstitial or subsurface flow. So, the term intermittent has traditionally been used to describe a wide gradient of hydrological conditions, and it is a poor term for classifying streams according to their ability to support aquatic life or their habitat functions. As one researcher put it, "No single hydrological or climatological parameter will suffice to classify the intermittency, at least to the satisfaction of biologists" (Clifford 1966).

Many states and agencies have attempted to classify or further define headwater streams. For example, the Ohio EPA developed a headwater stream assessment method and they are conducting studies in order to document the biological and physical features associated with various types of headwater habitats in Ohio (Ohio EPA 2002). Ohio EPA defined primary headwater habitat streams (PHWH) as surface drainage ways that have a defined stream bed and bank and a watershed area less than 1 mi^2 and maximum depth of water of 40 cm or less. Ohio EPA proposed a classification system which describes 3 classes of headwater streams. Class III-PHWH headwater streams have the potential to support cool or cold-water adapted vertebrate (headwater fish populations and/or amphibians) and benthic macroinvertebrate communities. The water flow in these streams is continuous at the surface or in the subsurface. The second type of headwater stream habitat provides an environment which can support a warm water adapted community of aquatic benthic macroinvertebrate, fish and amphibians (Class II-PHWH). The Class II streams may or may not become intermittent or summer dry. Ohio EPA describes a third type of headwater habitat as streams which do not provide a significant aquatic life function, but which do have important water quality functions (Class I - PHWH). These streams are essentially ephemeral streams. In other words, Ohio EPA found that presence or absence of continuous perennial surface flow was not a good predictor of aquatic life potential in headwater streams.

Ohio EPA also struggled with the hydrological definitions and classifications of headwater streams, to the point where they suggested new terms to fully describe the different hydrological regimes. They summarized two major hydrologic regimes of headwater streams as those with continuous (perennial) flow and those with periodical flow. They further subcategorized two types of perennial flowing streams, and two types with periodical flow. Ohio EPA defined continuous flow streams as those that have 1) suprafacial flow, or flow always visible in the stream channel - this is a new term coined by Ohio EPA, or 2) interstitial flow, or flow that is seasonally interrupted on the surface of the channel by dry sections with isolated pools in between. An important characteristic of interstitial flow is that flowing groundwater connects the isolated pools. Periodical flow includes streams that have 1) intermittent flow, or flow that is seasonally interrupted with dry sections and isolated pools without groundwater flow connecting the pools, or 2) ephemeral flow, or flow that only occurs during or immediately after precipitation events.

In some Region 3 state water quality standards, intermittent streams are also defined by the presence or types of aquatic life inhabiting the streams, although these definitions are much more general than Ohio EPA's classification system. For example, West Virginia defines intermittent streams in its water quality standards as streams which have no flow during sustained periods of no precipitation and which do not support aquatic life whose life history requires residence in flowing waters for a continuous period of at least six months. In Pennsylvania, perennial streams are defined as "a body of water flowing in a channel or bed composed of substrates associated with flowing waters and is capable, in the absence of pollution or other manmade stream disturbances, of supporting a benthic macroinvertebrate community which is composed of 2 or more recognizable taxonomic groups of organisms which are large enough to be seen by the unaided eye and can be retained by a United States Standard No. 30 sieve, and live at least part of their life cycles within or upon available substrates in a body of water of water transport system". In other words, if a stream supports two aquatic macroinvertebrate taxa, it is defined as a perennial stream in Pennsylvania - continuous surface flow is not required.

After reviewing the literature, it is clear that an attempt to classify headwater stream types (perennial, intermittent or ephemeral) needs to be based on the biological assemblages that inhabit these streams. Since the biota live in the stream, they are the best integrators of all the localized abiotic conditions as well as the hydrologic conditions year round. Regulatory agencies should not try to characterize or classify headwater streams by general hydrological parameters or surface flow duration. Normal surface flow duration is difficult to measure or verify since it varies in time and space. Furthermore, perennial streams should be defined as having continuous surface or subsurface flow. Regulatory agencies should use the biota that inhabit the stream as a more reliable measure of hydrological character and flow duration.

2. Extent of Ephemeral, Intermittent and Perennial Headwater Streams

It is well known that the number and length of streams is inversely related to their order or position in the watershed - the length and number of headwater or first-order streams is far greater than the length or number of larger streams and rivers (Gordon et al 1992). For example, based on estimates from the 1:100,000 scale National Hydrology Dataset (NHD), there are over 200,000 miles of streams in USEPA Region 3. We know this to be an underestimate of the length of the resource. due to the coarse scale of the mapping. However, the estimate can be used to illustrate the importance of headwaters streams as a proportion of the total resource. Based on the NHD estimates, first-order streams make up over 50% of the total resource. Unfortunately, although regional and national stream coverages are sometimes attributed as to the perennial or intermittent nature of streams. the accuracy and bias of these attributes are not known, so it is difficult to accurately estimate the regional extent of the resource by flow characteristics. However, we know from our years of field experience that many of the first order streams could have intermittent periods during dry years, or even in a normal water year, given certain topography and geomorphology. In some areas of the country, the length of summer-dry streams may well exceed the length of permanent streams and the intermittent stream resource provides critical habitat to aquatic life and other wildlife (Clifford 1966, Zale et al 1989).

The Pennsylvania Department of Environmental Protection (PADEP) addressed the scale issue when they updated their stream spatial coverage . Based on 1:100,000 scale topographic maps, PADEP estimated they had approximately 54,000 miles of streams statewide. Using 1:24,000 scale USGS topographic maps as the base, they estimated they had approximately 83,160 miles of streams statewide - an increase of 54%. USGS is now working to adjust the estimate of stream miles using a more intensive mapping exercise and PADEP estimates the total stream miles will increase by another 30% (personal communication with R. Kime, PADEP). The PADEP estimates that 56% of the total stream miles based on the 1:24,000 scale maps are first order streams. Pennsylvania has not tried to estimate the extent of perennial, intermittent or ephemeral streams.

Ohio EPA provides estimates of the total length of streams in Ohio, including headwater streams. A summary of estimates of the length of these waterbody types is given in Table 1. Clearly, the headwater habitats make up a large proportion of the stream resource in Ohio. According to Ohio EPA's headwater classification, the Class II-PHWH streams may or may not become intermittent or summer dry (30.7% of the total resource). The Class I-PHWH streams are ephemeral (21.8% of the total resource).

Table 1. Summary of estimated miles of flowing waters in Ohio (Ohio EPA 2002)

Waterbody Type	Length in Miles	Proportion of Total
Named Streams		
(ODNR, USGS Blue Lines)	21,048	12.61%
Unnamed Streams *		
Class I - PHWH	36,405	21.80%
Class II - PHWH	51,250	30.69%
Class III - PHWH	27,551	16.51%
Unnamed Waterways		
Nonstream waterways **	30,708	18.39%
Total of all types (mean)	166,962	100% (rounded)
95% Upper Confidence Interval of Mean	250, 636	

* A random site selection statistical approach was used to estimate the total length of "unnamed stream" miles. This value would include intermittent blue lines on USGS topographic 7.5 minute map series.

** Nonstream waterways do not have a well defined bed-bank, thus they do not meet Ohio EPA's concept of a "primary headwater stream", however, they do meet the definitions of "waters of the state" in Ohio Revised Code. Section 6111.

Hansen (2001) explored the scale issue and tried to categorize stream types when he surveyed streams within the Chattanooga River watershed in the Blue Ridge Mountains of Georgia, South Carolina and North Carolina. Streams indicated on a 1:100,000 scale map identified about 650 km of "blue line" streams in the 728 km^2 watershed, while the 1:24,000 scale map indicated 970 km of "blue line" streams, or a 49% increase (similar to what PADEP found). "Blue line" streams are considered perennial streams on USGS topographic maps. A computer based mapping exercise that used contour crenulations with field verification estimated 1300 km of perennial streams. Of the 1300 km identified, the topographic maps indicated only 50-75 % of the total perennial length, depending on scale. Approximately 59% of the total stream length was made up of first-order streams. Hansen defined the stream lengths as perennial, intermittent or ephemeral based on a combination of physical and biological indicators (see table 2). Of the total 4666 km of total streams identified, only 28% were considered perennial based on the presence of a defined channel and certain indicator macroinvertebrate taxa. The remainder of the stream length was intermittent (17%) or ephemeral (55%).

Table 2. Field criteria used for determining stream type in the Chattanooga River watershed (Hansen, 2001)

Criteria	Stream Type		
	Perennial	**Intermittent**	**Ephemeral***
Channel	Defined	Defined	Not defined
Flow Duration (estimated)	Almost always	Extended, but interrupted	Stormflow only
Bed water level	Above channel	Near channel surface	Below channel
Aquatic Insects	Present	Few if any	None
Material movement	Present	Present, less obvious	Lacking or limited
Channel materials	Scoured, flow sorted No organic buildup	Scoured or flow sorted lacks organic buildup	Mostly soil materials Organic buildup
Proportion of total stream network	28%	17%	55%

* Healed gully channels were classed as ephemerals when there were no recent signs of flow or scour. When forested, there is evidence of organic accumulations and decomposition.

Childers and Passmore (2003) estimated the extent of intermittent and perennial stream lengths in the primary region of mountaintop/valley fill coal mining in southern West Virginia using GIS techniques to generate a stream network and compared the designations and results to field surveys. The USGS documented the flow origin, drainage areas and hydrologic characteristics of perennial and intermittent streams in this region in 2000 and 2001 (Paybins 2003). Results indicated that the median drainage area upstream of the origin of intermittent flow was 14.5 acres. The median drainage area upstream of the origin of perennial flow was 40.8 acres. Childers used these median drainage areas to delineate the watersheds and used a flow accumulation model to estimate the stream lengths associated with intermittent flow and perennial flow in this region. The results of this study are shown in table 3. Thirty-four percent (34%) of the total stream resource was designated as intermittent by the GIS modeling. Thirty-one percent (31%) of the total stream resource was designated as 1st order perennial. The results of the computer modeling were compared to independent field data which were collected to verify perennial and intermittent stream lengths for a proposed mining permit. The intermittent and perennial definitions used in the field effort was based on a combination of hydrological and biological characteristics (Green and Passmore 1999b). The field survey indicated 12 headwater sites were perennial streams. The GIS modeling indicated 11 of these 12 sites were perennial (an agreement of 92%).

Table 3. Estimates of perennial and intermittent stream lengths in the mountaintop valley fill coal mining region of southern West Virginia (Childers 2003)

Stream Type	Length in km	Length in Miles	Proportion of Total
Intermittent	8780	5456	34%
1st order perennial	8126	5049	31%
Intermittent + 1st order perennial	16906	10505	65%

Note that the total stream length is 25,900 km (16,094 miles) and was based on an upstream watershed acre cutoff of 14.5 acres. This threshold is the median watershed acreage upstream of the origin of intermittent flow (Paybins 2003).

Headwater streams make up the majority of our stream resource. Although it is difficult to get reliable estimates of perennial, intermittent and ephemeral stream lengths, the case studies that are available indicate the proportion of the total stream length that could be intermittent, even in more humid regions, is significant (a range of 17 to 34%). The extent of ephemeral headwater streams is even larger (a range of 22 to 55%) . We should be very wary of any attempt to downgrade the value or importance of headwater streams, especially as they relate to the aquatic life use in these streams and the role these headwater streams play in the overall stream network. Doing so would put the majority of our freshwater aquatic stream resource at risk, as well as severely limiting our ability to protect downstream waters.

3. Ecosystem Functions and Headwater Streams

Headwater streams are where the watershed begins. As a beginning of a watershed, headwaters function in many ways that are critical to the ecosystem. In a Symposium on Aquatic Ecosystem Enhancement at Mountain Top Mining Sites, Wallace (2000) describes headwater steam aspects:

- Have maximum interface with the terrestrial environment with large inputs of organic matter from the surrounding landscape
- Serve as storage and retention sites for nutrients, organic matter and sediments
- Are sites for transformation of nutrients and organic matter to fine particulate and dissolved organic matter
- Are the main conduit for export of water, nutrients, and organic matter to downstream areas.

The major functions of headwater streams can be summarized into two categories, physical and biological (Wallace 2000):

Physical Functions

- Headwater streams tend to moderate the hydrograph, or flow rate, downstream
- They serve as a major area of nutrient transformation and retention
- They provide a moderate thermal regime compared to downstream waters- cooler in summer and warmer in winter
- They provide for physical retention of organic material as observed by the short "spiraling length"

Biological Functions

- Biota in headwater streams influence the storage, transportation and export of organic matter
- Biota convert organic matter to fine particulate and dissolved organic matter
- They enhance downstream transport of organic matter
- They promote less accumulation of large and woody organic matter in headwater streams
- They enhance sediment transport downstream by breaking down the leaf material
- They also enhance nutrient uptake and transformation

The River Continuum Concept, developed by Vannote and others (1980) describes a river system in terms of energy patterns and biotic responses along a continuum from the headwaters to the mouth. Headwaters are areas where energy is derived from terrestrial inputs, also termed allochthonous sources, in the form of leaf litter and other organic matter. It is generally recognized, though, that in some ecosystem headwater streams (eg., desert regions) primary production by autotrophs, or autochthonous production, are important sources of energy (Minshall et. al. 1985). The biology of headwaters have evolved to take advantage of these energy sources and, in general, are characterized by shredding and collecting macroinvertebrates. Energy is thereby transferred and transported downstream.

The headwater stream is the origin for energy processing within the river ecosystem. Headwater streams in the Appalachian highlands are generally located in forested areas and are characterized by a heavy leaf canopy and low photosynthetic production. Sources of energy for headwater streams are allochthonous in origin or derived from the terrestrial environment. The vast majority of this allochthonous material arrives in the streams in the form of Coarse Particulate Organic Matter or CPOM (> 1 mm in size). Smaller amounts of other allochthonous material that is transported to the stream includes Fine Particulate Organic Matter (FPOM, 50 um – 1 mm in size) and Dissolved Organic Matter (DOM) traveling from surface and groundwater flow. Microbes and specialized macroinvertebrates living in headwater streams, called shredders, feed on the DOM and CPOM, converting it into FPOM and DOM. The FPOM and DOM are carried downstream to mid-sized streams.

Riparian zones, terrestrial areas adjacent to the stream, interact and influence headwaters a great deal (Vannote et. al, 1981) and can be defined as "three dimensional zones of direct interaction between the aquatic and terrestrial ecosystems" (Gregory et. al, 1991). Interactions include microclimate, nutrient and organic matter inputs, and retention of these inputs. Given this intricate link between the aquatic and terrestrial ecosystem, headwater channels cannot be considered apart from their associated riparian zones.

Valley landform, or geomorphology, plays a major role in determining the function of streams in general (Frissell et. al, 1986). Ecosystem functions such as riparian inputs and detrital storage are greatly influenced by geomorphic features (Minshall et. al, 1985). For example, high gradient headwater streams with steep valleys will store less detrital material than low gradient braided headwaters. The ecosystem functions of headwater streams are defined within a context of physical geomorphology.

Nutrients are generally thought of as cycling but in stream ecosystems nutrients are also transported downstream and are more appropriately described as spiraling (Allan 1995). This concept of nutrient spiraling is important when considering headwaters because nutrient spiraling length is the sum of the distance an atom of a particular nutrient travels in the inorganic state and the distance traveled as a part of the biota. Headwaters do not merely move nutrients downstream like a pipe, but use them and process them as they move. Meyer and Wallace (2001) note that headwater streams play an important role in carbon mineralization, phosphorous and nitrogen uptake, and soluble reactive phosphorous removal. It has been demonstrated that frequently more than 50% of inorganic nitrogen inputs to headwater streams are retained and transformed (Peterson et. al, 2001).

Clearly, headwaters play an important and crucial role in ecosystem function. Despite this importance, headwaters are increasingly vulnerable to anthropogenic disturbance and elimination due to agriculture, mining, and urbanization (Meyer and Wallace, 2001). Meyer and Wallace (2001) hypothesize the consequences of alterations to ecosystem function due to headwater stream loss (Table 4, Meyer and Wallace, 2001).

Table 4. Ecological consequences of the alterations caused by loss of headwater streams (Table 14.1 in Meyer and Wallace, 2001).

Alteration	Consequence
Loss of hydrologic retention capacity	Increased frequency and intensity of flooding downstream and lower base flows
Increased downstream channel erosion	Increased sediment transport and reduced habitat quality
Reduced retention of sediments	Excess sediments downstream
Reduced retention and transformation of nutrients and contaminants	Increased nutrient and contaminant loading to downstream ecosystems
Reduced retention and mineralization of organic matter	Increased loading downstream
Reduced processing of allochthonous inputs	Reduced supply of fine particulate organic matter to downstream food webs
Reduced secondary production in headwaters	Less drift supplied to food webs downstream and less emergence production subsidizing riparian food webs.
Loss of unique habitats	Increased extinction vulnerability of aquatic species (invertebrates, amphibians, fishes)
Altered thermal regimes	Altered growth and reproduction in aquatic insects and fishes
Loss of thermal refuges and nursery areas	Increased mortality of fishes

4. Aquatic Ecological Value of Headwater and Intermittent Streams

4.1 Macroinvertebrate Assemblages in Headwater and Intermittent Streams

The peer-reviewed and grey literature clearly support the idea that headwater streams in general, and intermittent streams in particular, can support diverse and abundant macroinvertebrate assemblages. This review is limited to more mesic climates in the United States, because we believe these citations to be more representative of Region 3 headwater streams. Literature from arid climates was not reviewed.

The peer reviewed literature indicates a significant overlap of taxa between intermittent and perennial streams. Generally, fewer taxa are found to be unique to either perennial or intermittent streams. Several factors may explain the lack of difference in invertebrate community structure between intermittent and perennial streams. Generalized adaptations of stream invertebrates, including spring emergence as winged adults, the ability to recolonize through flight or drift, drought-resistant eggs (as reviewed in Williams 1996), asynchronous development that spreads life stages over time (Dieterich and Anderson, 1995), short univoltine life cycles (Delucchi and Peckarsky 1989) and the ability of some taxa to take refuge in the hyporheic zone (Clifford 1966) help explain why many taxa are found at both perennial and intermittent sites. Few taxa seem to have specialized adaptations to surviving drought. In addition, it is often difficult to determine whether the "intermittent" streams studied in the peer reviewed literature are truly intermittent (residual pools are not connected by surface or subsurface flow) or if they might have continuous flow connected in the subsurface. Clearly, streams that have subsurface flow should provide habitat more similar to the traditional perennial streams (those with continuous surface flow).

Although the literature generally indicates large faunal overlap between intermittent and perennial streams, many researchers have found that intermittent streams, springbrooks and seepage areas contain some unique aquatic species. Dieterich and Anderson (2000) found 202 aquatic and semi-aquatic invertebrate species, including at least 13 previously undescribed taxa. Morse et al (1997) have reported that many rare invertebrate species in the southeast are known from only one of a few locations with pea-sized gravel or in springbrooks and seepage areas. Kirchner (F. Kirchner pers. comm. 2000 and Kirchner and Kondratieff 2000) reports 60 species of stoneflies from eastern North America are found only in first and second order streams, including seeps and springs. 50% of these species have been described as new to science in last 25-30 years. So, although many studies have found significant faunal overlap, we should not ignore the fact that they also contain some unique species.

Resistance during the drying phase, and the ability of assemblages to recover (resiliency) depends on many abiotic variables. These include whether the stream goes completely dry, the length of the dry period, the distance to nearby refugia (e.g. residual pools) both upstream and downstream, the area of refugia habitat, whether there is high predation in the refugia (e.g. fish), the existence of interstitial spaces and a wet hyporheic zone, the existence of contiguous subsurface flow, and the presence of cover over the stream bed. Refugia can include residual pools; moist microhabitat beneath stones, stumps, mats of dried algae or leaf matter, and in rotting wood; the hyporheos and crayfish burrows (Boulton 1989, Williams and Hynes 1977, Williams 1987).

Streams that are shaded by a riparian canopy should have a more prolonged drying phase and more moisture retention than streams with no canopy cover (Dietrich and Anderson 2000). Streams with canopy cover should also maintain cooler stream bed temperatures. Streams with have larger substrates, which promote numerous and relatively large interstitial spaces and which have wet hyporheic zones should provide better refugia for invertebrates during dry periods

(Clifford 1966 and Delucchi 1987). The distance to perennial reaches both upstream and downstream is important as these refugia are sources of invertebrates for recolonization. Many streams have perennial segments upstream from intermittent reaches due to the presence of springs and seeps. These upstream perennial reaches provide colonization through drift once flow resumes (Fritz and Dodd, unpublished). Interstitial flow between residual pools can increase the area of refugia and the connectivity between residual pools, resulting in better habitat and greater invertebrate diversity (Ohio EPA 2002).

4.1.1 Reference Annotations

Williams (1996) identified and described those factors which are common to the majority of temporary fresh waters and which most strongly influence their insect faunas. This review included all types of temporary fresh waters, and was not limited to streams. Aquatic insects counter intermittent dry periods by physiological tolerance, migration and life history modification. Adaptations allow them to avoid or survive the dry periods. For example, mayflies survive drought as eggs, beetles survive as adults, and stoneflies survive as diapausing early instars. Some insects emerge as winged adults before the dry period in summer.

Williams found that there is evidence that temporary water communities are somewhat less diverse that those of permanent water bodies and the physiochemical environment is more harsh. However, he concluded that virtually all of the aquatic insect orders contain at least some species capable of living in temporary waters and that a wide variety of adaptations across a broad phylogenetic background has resulted in over two-thirds of these orders being well represented in temporary waters. This researcher stated that "perhaps the concept of temporary waters constraining their faunas is based more on human perception than on fact".

Zane et al (1989) reviewed the literature on intermittent streams to understand their importance for Great Plains ecosystems. Their review included summaries of physiochemical characteristics, community production and respiration, plants, invertebrates, fish, and wildlife associated with intermittent streams. They concluded that a wide diversity of invertebrates reside in intermittent streams, and that diversity, species richness, and density of invertebrates tends to increase with increases in habitat complexity, stream size and permanence of flow. They found that species with life cycles of 2 years or more, or species that require a growth period in summer followed by emergence in fall were generally absent. They found several taxa that were absent from perennial waters were present in intermittent streams.

Dietrich and Anderson (2000) studied seven streams in western Oregon. The seven streams varied in flow permanence and cover. Temporary streams were defined as streams which have continuous flow for at least 4 months. They found that taxa richness of invertebrates (>125 species) in temporary forest streams actually exceeded that in a permanent headwater stream (100 species). Species richness was intermediate in seep areas and a temporary meadow stream. Species richness was lowest at the ephemeral sites. Dietrich and Anderson found that only 8%

of the species in the total collection were only found in the permanent headwater. 25% were restricted to the summer-dry streams and 67% were in both permanent and summer-dry streams. The authors found that both flow duration and exposure (meadow vs. forest) were decisive factors in shaping the macroinvertebrate communities. These researchers concluded that the potential of summer-dry streams with respect to habitat function is still widely underestimated.

Delucchi (1988) studied four streams in the same watershed in New York to determine whether benthic invertebrate structure varied among streams with different temporal flow regimes. The author described the riffle sites as permanent (flows all year), intermittent (flows for > 9 months), or dry (flows for less than 9 months). The riffle sites were categorized as large, medium, small or very small using discharge. The large riffle sites were categorized as having June discharge greater than 0.01 m^3/s or 0.27 cfs. Kick samples were taken from 13 riffles and 4 pools once a month from June to November 1982. This study found that differences between adjacent pools and riffles were greater than that between temporary and permanent riffles. Stream size, seasonal changes in taxa, how recently the riffle had dried, and the length of the dry period contributed to differences in community structure among riffles. Although invertebrate community structure differed immediately following the period of drying and rewetting, all stream invertebrate communities were similar just before the dry season in June (after streams have been flowing for a maximum amount of time). The author concluded that "differences in community structure between permanent and temporary riffles are minimized by generalized adaptations of stream benthos, such as high rates of migration, drought-resistant eggs, and the tendency to take refuge in the hyporheic zone".

Delucchi and Peckarsky (1989) studied an intermittent and perennial stream in New York to determine whether life history patterns of intermittent stream species allowed them to avoid drought, while the life history patterns of permanent stream species were more variable. They found that although intermittent specialist species had life history patterns allowing them to survive the drought (e.g. drought-resistant eggs), these patterns were not unique to the intermittent stream fauna. The intermittent stream did not have a unique fauna and seven of the eight species studied occurred in both the perennial and intermittent stream. Drought specialist species in the intermittent stream that emerged earlier were more abundant than species that emerged later.

Feminella (1996) studied several northern Alabama streams of varying flow permanence, including two streams that were normally intermittent (riffles ceased flowing in normal rain years) in summer, one that was rarely intermittent, and three streams that were occasionally intermittent (riffles ceased flowing during dry years). He found only slight differences in the invertebrate assemblages. Presence-absence data revealed that 75% of the taxa (171 total taxa, predominantly aquatic insects), were ubiquitous across the 6 streams or displayed no pattern with respect to permanence and 7% of the species were found exclusively in the normally intermittent streams. The benthic invertebrate assemblages showed subtle relationships with stream permanence. The previous year's hydrology (e.g. a wet year that followed a dry year) was associated with riffle permanence and seemed to affect the structure of the assemblages.

Pond and McMurray (2002) developed a Macroinvertebrate Bioassessment Index (MBI) for headwater streams in the Southwestern Appalachians, Central Appalachians, and the Western Allegheny Plateau ecoregions of eastern Kentucky. The authors described headwater streams as those draining less than 5 square miles. The index was based on sites ranging in size from 0.18 to 3.1 square miles. Macroinvertebrates were collected with both semi-quantitative and multi-habitat qualitative techniques; approximately 30,000 specimens representing over 320 taxa from 75 families were collected from all sites combined. Clearly, these small headwater streams support a rich and diverse assemblage of aquatic macroinvertebrates. Most of the organisms were sensitive Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), indicating healthy ecological conditions. The authors found rich and diverse assemblages in streams that were known to be intermittent, despite the fact that the region endured one of the worst droughts on record in 1999.

Pond (2000) found similar results in an earlier survey of two first order intermittent streams in Letcher County, Kentucky. The two streams had watershed areas of 0.21 and 0.32 square miles and the author stated the streams may have periods of intermittency in late summer and early fall of dry years, but may remain perennial during wet summers. A total of 118 macroinvertebrate taxa representing 14 orders and 45 families was collected in both streams combined during 4 seasonal sampling events. The invertebrate fauna in both streams consisted mainly of insect larvae typically associated with clean, high gradient streams in that region.

Ohio EPA (Ohio EPA 2002a) sampled 247 primary habitat streams from 1999 to 2000. Ohio EPA defined primary headwater habitat streams (PHWH) as surface drainage ways that have a defined stream bed and bank and a watershed area less than 1 mi^2 and maximum depth of water of 40 cm or less.. Macroinvertebrate voucher samples from selected streams were identified to the lowest practical taxonomic level. Ohio EPA identified 384 macroinvertebrate taxa from streams with a drainage area less than or equal to 1 mi^2 in Ohio. Macroinvertebrates were collected in all streams with standing or flowing water. In general, three types of assemblages were identified in primary streams in Ohio: 1) a surface water community with reproducing populations of three or more native coolwater adapted taxa (Class III-PHWH), 2) a surface water community with native populations dominated by warmwater adapted taxa with less than three taxa of coolwater adapted taxa (Class II-PHWH), and 3) a surface water community with reproducing populations of native short-lived primarily springtime macroinvertebrate assemblages (Class I - PHWH). A defining characteristic of Class III streams was that they were associated with cool groundwater with continuous flow (either "suprafacial", defined as continuous flow on the surface, or interstitial flow) all year round. Class II streams ranged from permanent flow to intermittent flow (without interstitial flow to connect pools) and were derived from overland flow and shallow subsurface flow rather than deeper groundwater. Class I streams were normally dry and only flowed during or after precipitation events (ephemeral).

Rosario and Resh (2000) sampled two streams in Marin County, in coastal California, to compare the invertebrate fauna of an intermittent and perennial stream. The intermittent stream dried completely during the summer. They examined if the stream surface and/or hyporheic assemblages in the 2 streams differed in terms of taxon densities, richness, and diversity. 20,701 individuals representing 60 taxa, including 35 insect families and 8 noninsect invertebrate taxa were collected from the 46 surface samples. The intermittent and perennial streams had similar faunal composition, consistent with the several other studies that have found large faunal overlap in perennial and intermittent streams. The intermittent stream had lower total densities, taxon richness, and diversity than the perennial stream.

Clifford (1966) studied an intermittent stream in south-central Indiana. This stream regularly dried every summer, and was contiguous with a downstream perennial stream for only 46 days during the year's study period. For most of the study period , the stream was a series of widely scattered shallow pools, but water still persisted below the stream bed. The stream was dominated by two crustaceans throughout the year. The other aquatic animals in the stream were characterized as a late summer/early autumn group, consisting mainly of short lived species and adult beetles, and a late spring group including mayflies, stoneflies and caddisflies. The spring fauna had one generation per year (univoltine), exhibited little growth in the summer, and completed their life cycles in one year. Clifford discussed temporal flow characteristics (the length of the dry phase) but also emphasized the importance of local features such as the nature of the substrate, local water table characteristics, the existence and quality of the hyporheic zone, and canopy cover to the survival of the aquatic fauna. Clifford also emphasized that the fauna of a stream are a better indicator of the intermittent nature of a stream than are a few described parameters relating to its flowing or non-flowing period.

Rabeni and Wallace (1998) studied 15 sites in a single drainage basin in southwestern Missouri over a two year period to relate stream flow to community structure and to evaluate the possibility of biomonitoring low flow streams. Streams were classified as perennial, intermediate and intermittent based on late summer mean discharge and water depth in riffles. Details on this classification were not given. They found that each stream class had a characteristic community structure, although the differences among classes were more in relative abundance than in presence or absence of taxa. Indices of community structure indicated that total richness and richness in sensitive orders were positively related to flow permanence.. The intermittent and intermediate fauna were a subset of the perennial stream fauna and were more tolerant, based on an index that measured overall pollution tolerance.

Fritz and Dodds (unpublished) studied 7 sites of varying flow permanence within the Kings Creek watershed in the Konza Prairie Biological Station in eastern Kansas. The 4 intermittent sites in the study were considered to belong to the harsh intermittent stream type, with the average number of zero discharge days varying from 190 days to 340 days. The authors evaluated the relationship between a "harshness" index and annual macroinvertebrate characteristics over two years. They found that total macroinvertebrate abundance was significantly related to harshness values in both years, whereas taxonomic richness and species diversity were significantly related to harshness index values only for the year with lower flood frequency. Evenness was not related to harshness. In general, there was high taxonomic overlap among the streams, such that 77% of the taxa were collected from intermittent and perennial sites. This study indicates that a moderately diverse invertebrate assemblage can be maintained even in stream habitats that appear quite harsh.

USEPA Region 3 conducted field surveys to confirm the extent of perennial and intermittent stream reaches that would be buried by mountaintop mining valley fills proposed in specific permits. This field work indicated that the 1:24,000 USGS topographic maps underestimate both the perennial and intermittent stream resources (Green and Passmore 1999a, Green and Passmore, 1999b). These field surveys indicated that all of the sites that were classified as intermittent based on flow supported aquatic life very similar to the sites classified as perennial based on flow. These surveys indicated that lack of permanent surface flow is a poor indicator of the abundance and diversity of invertebrate life supported by a stream.

USEPA Region 3 also described stream conditions in southern West Virginia for the Mountaintop Mining/Valley Fill Environmental Impact Statement (EIS). This study found that intermittent streams supported diverse, healthy and balanced invertebrate populations preceding and following a severe drought in the summer of 1999 (Green et al 2000). During the summer and fall 1999 index periods, many of the reference streams in this study were flow limited, with only trickles of water in their channels, and some of these streams went completely dry. In the spring 1999 index period, preceding the drought, and in the winter 2000 index period, following the drought, all of the intermittent streams could be sampled, and all of the intermittent reference streams were in good or very good condition with diverse and balanced benthic invertebrate assemblages. Clearly these streams, though lacking perennial surface flow, supported diverse and balanced aquatic life.

Other field work done in support of the Mountaintop Mining/Valley Fill EIS assessed the potential limits of viable aquatic communities in small headwater streams in southern West Virginia (Kirchner et al 2000). Similar to our field work, this effort found that most of the small streams sampled were not indicated on existing 1:24,000 scale USGS topographic maps. Furthermore, the study found that a number of taxa that were found in the extreme headwaters had multi-year life cycles suggesting that sufficient water s present for long-lived taxa to complete their juvenile development prior to reaching the aerial adult stage. Although only contiguous flow areas were considered for this study, the field work took place in the winter and based on our field experience, it is probable these extreme headwaters are subject to annual drying.

4.2 Amphibian Assemblages in Headwater Streams

Stream salamanders are the top predators in fishless first-order streams. These headwater streams provide environments for nesting, larval development, foraging, and refuge for many species of aquatic salamanders (Pauley et al. 2000). Stream salamanders prey on a variety of winged and non-winged insects and, conversely, provide a high percentage of protein to terrestrial predators such as reptiles, birds and mammals. Salamanders are excellent bioindicators of subtle as well as obvious alterations in stream habitats because they are sensitive to changes in water temperature and water chemistry (such as pH). This sensitivity is a result of the permeable skin, gilled larvae. and gelatinous eggs of salamanders (Dunson et al. 1992). Changes of salamander populations in headwater streams could alter trophic levels throughout a forest. Therefore, amphibians are an appropriate vertebrate biological indicator for small headwater streams that cannot support fish.

Amphibians are ectothermic and are sensitive to changes in temperature that result from habitat alterations such as clearcutting and overgrazing. In addition, they have glandular skins which makes them sensitive to habitat perturbations that result in loss of soil moisture, loss of aquatic habitats, low pH of soil and water. and toxic substances. Their sensitivity to changes in temperature and moisture make them good indicators of changes in the environment. Dunson et al. (1992) suggested that amphibians are excellent indicators of environmental changes because (1) some species have complex life cycles with aquatic and terrestrial stages which expose them to pollutants in both environments; (2) some species show keen competition for vital resources which can quickly show how different species react to pollutants; (3) they have permeable skin, gills, and eggs that are susceptible to pollutants in the environment; (4) ectothermy makes them vulnerable to environmental fluctuations; (5) many species hibernate or estivate in soils that may expose them to toxic conditions; and (6) they are important in terrestrial and aquatic food webs. Amphibians are among the first animals to emerge in the spring and, as a result, provide food for predators when food sources are less available. Predatory salamander larvae are important in determining abundance of zooplankton and aquatic insects (Dodson, 1970; Dodson and Dodson, 1971), and tadpoles are important in determining types and amounts of phytoplankton, magnitude of nutrient cycling, and levels of primary production (Seale, 1980).

Reptiles have epidermal scales and are somewhat less sensitive to moisture loss and toxic materials in the substrate than amphibians but their metabolism remains dependent on ambient temperatures. In eastern North America. riparian zones support more species of amphibians and reptiles than any other single ecosystem. The rich diversity of species in riparian habitats is due to environmental conditions such as microclimate conditions conducive to ectothermic species, and presence of breeding habitats, cover habitats, and foraging sites. Riparian habitats such as pools and streams allow different life history stages of amphibians to exist in a small area. Amphibians and reptiles in these systems are major players in food web dynamics and energy flow.

Terrestrial ecosystems and the aquatic ecosystems they border are intricately interconnected by physical, chemical, and biological processes. Terrestrial systems influence aquatic systems with nutrients and energy, and aquatic systems can influence terrestrial systems in the riparian zone because soils frequently are saturated and inundated. Interactions between terrestrial and aquatic components influence the biotic character of riparian areas and the waterways draining them (Bilby 1988). Temperature of water entering a forest stream system will be similar to the subsoil temperatures of the watershed (Beschta et al. 1987). Headwater stream amphibians are therefore sensitive to perturbations of the riparian zone as well as the stream.

State programs in and around EPA Region 3 are using salamanders as part of a monitoring program for headwater streams. Dr. Tom Pauley of Marshall University in West Virginia is working in first order streams of the state to examine the impacts of various land uses and water quality on salamander populations (T. Pauley, personal communication). There are 11 species of salamanders in West Virginia that inhabit headwater streams (first and second order streams) as larvae, subadults and adults (Green and Pauley 1987).

The Ohio EPA has developed a primary headwater habitat assessment manual and has conducted studies in order to document the biological and physical features associated with various types of headwater habitats in Ohio (OhioEPA 2002b). Ohio EPA has identified three different salamander assemblages that are found in three classes of primary headwater habitat (PHWH) streams (Ohio EPA 2002b). The class III-PHWH assemblage is represented by obligate aquatic species that have a larval stage requiring annual flow. These salamanders are all classified within the Tribe Hemidactyliini, Subfamily Plethodontinae, of the Family Plethodontidae. This type of salamander assemblage is also associated with coldwater macroinvertebrate assemblages in Ohio (Ohio EPA 2002b). Class II-PHWH assemblages are composed of species that do not require flowing water on an annual basis. The third type of assemblage, Class I - PHWH, do not have an aquatic larval stage and are adapted to the terrestrial environment. Ohio's program is unique in that it recognizes different types of headwater streams and the salamander assemblages associated with them.

Plethodontid salamanders were also used as headwater stream indicators in Pennsylvania (Rocco and Brooks 2000). Stream plethodontids responded to gradients of environmental variables (landscape, physical, and chemical) in streams. The salamander response variables included abundance, lifestage, biomass, species composition, and assemblage attributes. Metrics were proposed that may be used to develop an index of biotic integrity for headwater streams using salamanders.

4.3 Fish Assemblages in Headwater Streams

Headwaters is a generic term which includes a great variety of stream habitats. From the headwaters to the mouth of the stream, energy flow and the biological communities that inhabit them change from one dependant on terrestrial inputs to one based on autochthonous production (Vannote et al. 1980). Stream fish assemblages exhibit longitudinal patterns from headwaters to lower reaches suggesting adaptation of particular assemblages to zones within drainage basins. (Schlosser 1991). These zones can be described as: the erosional zone, intermediate zone, and a depositional zone (Moyle and Cech 1996). Headwaters are included in the erosional zone in temperate forest ecosystems and are dominated by trout (Moyle and Cech 1996). However, in lower gradient warm water systems, more species rich assemblages can occur in headwaters (eg., Paller 1994).

Factors that influence fish assemblages in headwater streams include factors such as energy flow at the aquatic terrestrial boundary or ecotone, landscape-scale habitat patchiness, and the existence and distribution of refugia from the harsh conditions that exist seasonally (Schlosser 1992). Fish inhabit headwaters as permanent residents or as seasonal transients (Pezold et al., 1997), and can provide thermal refugia for fishes in both winter and summer (eg. Power et al. 1999, Curry et al. 1997). Intermittency can trigger the movement of fish adapted to this type of stream environment (eg. *Nocomis leptocephalus*, Albanese, 2001). Intermittency should not be used to determine if a stream should be jurisdictional because intermittency can be a natural and important condition that fishes have adapted to and evolved with.

Nationwide, headwaters are important habitats for fish. The Arkansas darter (Etheostoma cragini), a federally threatened species, can be found in headwater tributaries of the Arkansas River (Labbe and Fausch 2000). Ohio EPA found nineteen different species of fish in 67 headwater streams (Ohio EPA 2002b). Ten of those nineteen species preferred headwater stream habitat and were used as primary headwater habitat indicators. A total of twenty-six species of fish are imperiled in the springs and headwaters of the Southeastern United States (Etnier 1997). Headwaters of the Southeastern United States are also an important component of regional biodiversity (Paller 1994). Preservation of headwater habitats is necessary to preserve the species that depend upon them.

Headwater stream fish assemblages in high elevation streams can include sculpins, dace, brown trout and brook trout (DiLauro and Bennet, 2001). Brook trout, in particular, are important residents in headwater streams in Appalachia and have been designated as Heritage Trout in Pennsylvania (Epifano and Fosburgh 1998). Headwater stream habitats are already imperiled by acid precipitation (eg., Carline et al., 1992) and multiple anthropogenic stressors can affect brook trout populations (Marschall and Crowder 1996). Brown trout and rainbow trout present in lower stream reaches can competitively exclude brook trout (Fausch and White 1981, Dewald and Wilzbach 1992) making headwaters an essential, unique habitat for the preservation of brook trout.

The stock concept is a tool that fisheries scientists have developed to manage salmonid populations based on genetic composition (Ricker 1972). Headwaters by their nature isolate populations through physical (eg., dams, waterfalls, temperature) or ecological (eg., competitive exclusion) barriers. This isolation may promote the establishment of genetically distinct stocks (eg., Mitchell et al. 2002). Headwater stream assemblages thereby increase the genetic diversity of watersheds and ecoregions and are important sources for recolonization or for artificial propagation of endangered or imperiled stocks.

References:

Definitions and Extent of Perennial, Intermittent and Ephemeral Streams References

Childers. H. and M. Passmore. 2003. Using GIS Hydrologic Modeling Tools and Field Survey Data to Estimate the Lengths of Intermittent and Perennial Headwater Streams in the Mountaintop Mining Region of Southern West Virginia. Veridian Corporation and USEPA, Wheeling, WV.

Clifford, H.M. 1966. The ecology of invertebrates in an intermittent stream. 1966. Invest. Indiana Lakes and Streams. Vol. VII, No. 2:57-98.

Hansen, W.F. 2001. Identifying stream types and management implications. Forest Ecology and Management. 143:39-46.

Gordon, N.D., T.A. McMahon and B.L. Finlayson. 1992. Stream Hydrology: An Introduction for Ecologists. John Wiley and Sons, Ltd. West Sussex, England.

Green, J. and M. Passmore. 1999b. Field Survey Report: An Estimate of Perennial Stream Miles in the Area of the 1997 Proposed Hobet Mining Spruce No. 1. Mine (West Virginia Surface Mine Application #5013-97). July 1999. USEPA, Wheeling, WV.

Paybins, K.S. 2003. Flow origin, drainage area, and hydrologic characteristics for headwater streams in the mountaintop coal-mining region of southern West Virginia. Water Resources Investigation Report 02-4300. USGS, Charleston, WV.

Ohio EPA. 2002. Field evaluation manual for Ohio's primary headwater habitat streams. Final version 1.0. Division of Surface Water, Columbus, Ohio.

Zale, A.V., D.M. Leslie, W.L.Fisher, and S.G. Merrifield. 1989. The Physiochemistry, Flora, and Fauna of Intermittent Prairie Streams: A Review of the Literature. USFWS Biological Report 89(5).

Ecosystem Function References

Allan, J.D. 1996. Stream Ecology Structure and Function of Running Waters. Chapman and Hall. New York. 388pp.

Frissell, C.A., W.J. Liss, C.E. Warren, and M.D. Hurley. 1986. A hierarchical framework for stream habitat classification: viewing streams in a watershed context. Environ. Manag. 10(2): 199-214.

Gregory, S.V., F.J. Swanson, W.A. McKee, and K.W. Cummins. 1991. An ecosystem perspective of riparian zones. Bioscience 41(8): 540-550.

Meyer. J.L. and J.B. Wallace. Lost linkages and lotic ecology: rediscovering small streams. Pp. 295-317 in Press. M.C., J.J. Huntly, and S. Levin, eds. Ecology: Achievement and Challenge The 41'st Symposium of the British Ecological Society. Blackwell Science. Oxford.

Minshall, G.W., K.W. Cummins, R.C. Petersen, C.E. Cushing, D.A. Bruns. J.R. Sedell, and R.L. Vannote. 1985. Developments in stream ecosystem theory. Can. J. Fish. Aquat. Sci. 42:1045-1055.

Peterson, B.J., and 14 coauthors. 2001. Control of nitrogen export from watersheds by headwater streams. Science 292:86-90.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing. 1980. The river continuum concept. Can. J. Fish. Aquat. Sci. 37: 130-137.

Wallace, J.B. 2000. Symposium on Aquatic Ecosystem Enhancement at Mountain Top Mining Sites.

Macroinvertebrate References

Boulton, A.J. 1989. Over-summering refugees of aquatic macroinvertebrates in two intermittent streams in Central Victoria. Trans. R. Soc. S. Aust. 113:23-34.

Clifford, H.M. 1966. The ecology of invertebrates in an intermittent stream. 1966. Invest. Indiana Lakes and Streams. Vol. VII, No. 2:57-98.

Delucchi, C.M. 1988. Comparison of community structure among streams with different temporal flow regimes. Can. J. Zool. Vol. 66:779-586.

Delucchi. C.M. and Peckarsky, B.L. 1989. Life history patterns of insects in an intermittent and a permanent stream. J. N. Am. Benthol. Soc. 8(4):308-321.

Dieterich, M. and N.H. Anderson. 1995. Life cycles and food habits of mayflies and stoneflies from temporary streams in western Oregon. Freshwater Biology. 34:47-60.

Dieterich. M. and N.H. Anderson. 2000. The invertebrate fauna of summer-dry streams in western Oregon. Arch. Hydrobiologie. 147:273-295.

Feminella. J.W. 1996. Comparison of benthic macroinvertebrate assemblages in small streams along a gradient of permanence. J. N. Amer. Benthol. Soc. 15(4):651-669.

Fritz. K.M. and W. K. Dodds. (Unpublished 2003). Harshness: characterization of intermittent stream habitat over time and space. USEPA. Cincinnati, OH and Division of Biology. Kansas State University, KS.

Green, J., M. Passmore, and H. Childers. 2000. A Survey of the Condition of Streams in the Primary Region of Mountaintop Mining/Valley Fill Coal Mining (in final draft). USEPA. Wheeling, WV.

Green, J. and M. Passmore. 1999a. Field Survey Report: An Estimate of Perennial Stream Miles in the Area of the Proposed Independence Mining Company, Constitution Mine. February 1999. USEPA, Wheeling, WV.

Green, J. and M. Passmore. 1999b. Field Survey Report: An Estimate of Perennial Stream Miles in the Area of the 1997 Proposed Hobet Mining Spruce No. 1. Mine (West Virginia Surface Mine Application #5013-97). July 1999. USEPA, Wheeling, WV.

Kirchner, R.F. US Army Corps of Engineers, Apple Grove, WV. Personal Communication on 10/19/2000 via telephone and on 10/ 30/2000 via email.

Kirchner, R.F. and B.C. Kondratieff. 2000. Plecoptera of Eastern North America Found Only in First and Second Order Streams, Including Seeps and Springs. US Army Corps of Engineers, Apple Gove, WV. Colorado State University, Fort Collins, CO.

Kirchner, R.F., B. Stout and B. Wallace. 2000. A Survey of Eight Major Aquatic Insect Orders Associated with Small Headwater Streams Subject to Valley Fills from Mountaintop Mining (in draft). US Army Corps of Engineers. Apple Gove, WV. Jesuit University, Wheeling, WV University of Georgia, Athens, GA.

Morse. J.C., B.P. Stark, W.P. McCafferty and K.J. Tennessen. 1997. Southern Appalachia and other southeastern streams at risk: implications for mayflies, dragonflies, stoneflies and caddisflies. Pp 17-42, in: G.W. Benz and D.E. Collins (eds.) Aquatic Fauna in Peril: The Southeastern Perspective. Special Publication 1, Southeastern Aquatic Research Institute. Lenz Design and Communications, Decatur. GA. 554 p.

Ohio EPA. 2002. Field evaluation manual for Ohio's primary headwater habitat streams. Final version 1.0. Division of Surface Water. Columbus, Ohio.

Ohio EPA. 2002a. Technical Report: Ohio's Primary Headwater Streams - Macroinvertebrate Assemblages. September 2002. Division of Surface Water, Columbus, Ohio.

Pond, G.J., S.E. McMurray. 2002 A Macroinvertebrate Bioassessment Index for Headwater Streams of the Eastern Coalfield Region. Kentucky. Kentucky Department of Environmental Protection, Division of Water. Frankfort. KY.

Pond. G.J. 2000. Comparison of macroinvertebrate communities of two intermittent streams with different disturbance histories in Letcher County, KY. J. Ky. Acad. Sci. 61(1):10-22.

Rabeni, C.F. and G.S. Wallace. 1998. The influence of flow variation on the ability to evaluate the biological health of headwater streams. In Hydrology, Water Resources and Ecology in Headwaters (Proceedings of the Headwater '98 Conference held at MeranMerano Italy, April 1998). IAHS Publ. No. 248: 411-417.

Williams, D.D. 1996. Environmental constraints in temporary fresh waters and their consequences for the insect fauna. J.N. Amer. Benthol. Soc. 15(4):634-650.

Williams, D.D. 1987. The Ecology of Temporary Waters. The Blackburn Press, Caldwell, New Jersey.

Williams, D.D. and H.B. Hynes. 1977. The ecology of temporary streams: II.General remarks on temporary streams. Int. Revue ges. Hydrobiol. 62(1):53-61.

Zale, A.V., D.M. Leslie, W.L.Fisher, and S.G. Merrifield. 1989. The Physiochemistry, Flora, and Fauna of Intermittent Prairie Streams: A Review of the Literature. USFWS Biological Report 89(5).

Amphibian References

Beschta, R. L., R. E. Bilby, G. W. Brown, L. B. Holtby, and T. D. Hofstra. 1987. Stream temperature and aquatic habitat: fisheries and forestry interactions. Pages 191-232 *in* E. O. Salo and T. W. Cundy, editors. Streamside management: forestry and fishery interactions. Contribution No. 57. College of Forest Resources, University of Washington, Seattle.

Bilby, R. E. 1988. Interactions between aquatic and terrestrial systems. Pages 13-29 in K. J. Raedeke, editor. Streamside management: riparian wildlife and forestry interactions. College of Forest Resources, University of Washington.

Dodson, S.I. 1970. Complementary feeding niches sustained by size-selective predation. Limnology and Oceanography 15:131-137.

Dodson. S.I. and V.E. Dodson. 1971. The diet of Ambystoma tigrinum larvae from western Colorado. Copeia 1971:641-624.

Dunson. W.A., R.L. Wyman, and E.S. Corbett. 1992. A symposium on amphibian declines and habitat acidification. Journal of Herpetology 26:349-352.

Ohio EPA. 2002. Field evaluation manual for Ohio's primary headwater habitat streams. Final version 1.0. Division of Surface Water. Columbus, Ohio.

Ohio EPA. 2002b. Technical Report. Ohio's Primary Headwater Habitat Streams. Fish and Amphibian Assemblages. September 2002. Division of Surface Water, Columbus, Ohio.

Green, N.B. and T.K. Pauley. 1987. Amphibians and Reptiles in West Virginia. University of Pittsburgh Press, Pittsburgh, PA.

Pauley, T. K., J.C. Mitchell, R.R. Buech, and J.J. Moriarty. 2000. Ecology and management of riparian habitats for amphibians and reptiles (Chapter 10, pages 169-192). *In.* Riparian Management in Forests of the Continental Eastern United States. E.S. Verry, J.W. Hornbeck, and C.A. Dolloff, editors. CRC Press (Lewis Publishers).

Rocco, G.L. and R.P. Brooks. 2000. Abundance and Distribution of Stream Plethodeontid Salamander Assemblages in 14 Ecologically Dissimilar Watersheds in the Pennsylvania Central Appalachians. Report No. 2000-4. Penn State Cooperative Wetlands Center, Pennsylvania State University, University Park, PA.

Seale, D.B. 1980. Influence of amphibian larvae on primary production, nutrient flux, and competition in a pond ecosystem. Ecology 61:1531-1550.

Fish References

Albanese, Brett. 2001. Movement of fishes in a network of streams and implications for persistence. Doctoral dissertation, Virginia Polytechnic Institute and State University. Blacksburg, Virginia.

Carline, R.F., W.E. Sharpe, and C.J. Gagen. 1992. Changes in fish communities and trout management in response to acidification of streams in Pennsylvania. Fisheries 17(1) 33-38.

Curry, R.A., C. Brady, D.L.G. Noakes, and R.G. Danzmann. 1997. Use of small streams by young brook trout spawned in a lake. Trans. Amer. Fish. Soc. 126: 77-83.

DeWald. L. and M.A. Wilzbach. 1992. Interactions between native brook trout and hatchery brown trout: effects on habitat use, feeding, and growth. Trans. Amer. Fish. Soc. 121:287-296.

DiLauro, M.N., and R.M. Bennett. 2001. Fish species composition in two second-order headwater streams in the North Central Appalachians ecoregion. J. Freshwat. Ecol. 16(1)35-43.

Etnier, D.A. 1997. Jeopardized southeastern freshwater fishes: a search for causes. pp. 87-104. *In*: Aquatic Fauna in Peril: The Southeastern Perspective. Benz, G.W., and D.E. Collins, eds. Special Publication 1, Southeastern Aquatic Research Institute. Lenz Design and Communications, Decatur , Georgia.

Epifanio, J., and W. Fosburgh. 1998. A status report of coldwater fishery management in the

U.S. - An overview of state programs. Trout Unlimited Technical Report.

Fausch, K. D., and R. J. White. 1981. Competition between brook trout (Salvelinus fontinalis) and brown trout (Salmo trutta) for positions in a Michigan stream. Can. J. Fish. Aquat. Sci. 38(10): 1220-1227.

Labbe, T.R., and K.D. Fausch. 2000. Dynamics of intermittent stream habitat regulate persistence of a threatened fish at multiple scales. Ecol. App. 10(6): 1774-1791.

Marschall. E. A. and L. B. Crowder. 1996. Assessing population responses to multiple anthropogenic effects: A case study with brook trout. Ecol.App. 6(1): 152-167.

Mitchell, R. M., R.L. Johnson, and G.L. Harp. 2002. Population Structure of an Endemic Species of Yellowcheek Darter, Etheostoma moorei (Raney and Suttkus), of the Upper Little Red River, Arkansas. Am. Midl. Nat. 148(1)129-137.

Moyle, P.B., and J.J. Cech Jr. 1996. Fishes: an introduction to ichthyology. Prentice-Hall, Inc. Simon and Schuster. Upper Saddle River, NJ.

Paller, M.H. 1994. Relationships between fish assemblage structure and stream order in South Carolina coastal plain streams. Trans. Amer. Fish. Soc. 123:150-161.

Pezold, F.A., B. Crump, and W. Flaherty. 1997. Seasonal patterns of fish abundance in two mountain creeks of the Little Missouri River drainage, Arkansas. J. Fresh. Ecol. 12: 51-60.

Power, G., R.S. Brown, and J.G. Imhof. 1999. Groundwater and fish - insights from northern North America. Hydrol. Processes 13: 401-422.

Ricker, W. E. 1972. Hereditary and environmental factors affecting certain salmonid populations. *In* R. C. Simon and P. A. Larkin (eds.), The Stock Concept in Pacific Salmon, p. 27-160. University of British Columbia, Vancouver, B. C.

Schlosser, I.J., 1991. Stream fish ecology. a landscape perspective. Bioscience 41(10)704-712.

Schlosser, I.J. 1995. Critical landscape attributes that influence fish population dynamics in headwater streams. Hydrobiologia 303:71-81.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing. 1980. The river continuum concept. Can. J. Fish. Aquat. Sci. 37: 130-137.

F

Appendix G
Total Maximum Daily Loads of Nutrients and Dissolved Oxygen Under Low-Flow Conditions in the Christina River Basin Pennsylvania, Delaware, and Maryland

Total Maximum Daily Loads of Nutrients and Dissolved Oxygen Under Low-Flow Conditions in the Christina River Basin, Pennsylvania, Delaware, and Maryland

United States Environmental Protection Agency
Region III

in cooperation with the
Delaware Department of Natural Resources and Environmental Control
Pennsylvania Department of Environmental Protection
Maryland Department of the Environment
and
Delaware River Basin Commission

January 19, 2001
(revised October 2002)

Approved by:

Jon M. Capacasa, Acting Director
Water Protection Division

10-8-02
Date

Executive Summary

Total Maximum Daily Loads of Nutrients and Dissolved Oxygen Under Low-Flow Conditions in the Christina River Basin, Pennsylvania, Delaware, and Maryland

Introduction

The Environmental Protection Agency Region III (EPA) establishes these Total Maximum Daily Loads (TMDLs) for nutrients and other oxygen demanding pollutants in order to attain and maintain the applicable Water Quality Standards (WQS) for dissolved oxygen (DO) in the Christina River Basin under low-flow conditions (equivalent to the minimum seven-day low flow expected to occur every 10 years - conditions used to establish National Pollution Discharge Elimination System (NPDES) permits). EPA has established these TMDLs in cooperation with the Pennsylvania Department of Environmental Protection (DEP), Delaware Department of Natural Resources and Environmental Control (DNREC), Maryland Department of the Environment (MDE) and the Delaware River Basin Commission (DRBC). As part of these TMDLs, EPA has allocated specific amounts of nutrients and other oxygen demanding pollutants to certain point and nonpoint sources necessary to restore and maintain the applicable WQS.. These TMDLs recommend that eight facilities, seven in Pennsylvania and one in Maryland, have their NPDES permits modified when next reissued to reduce the amounts of pollutants that may be discharged.

During permit reviews for several of the facilities covered by January 19, 2001 TMDLs, it was discovered that flow rates used in the original TMDL calculations were in error. As a result, model runs using updated flow figures for these facilities were performed and revisions to the TMDL recommendations for the Brandywine Creek portion of the Christina River Basin were made.

A related, but separate, effort is underway to establish TMDLs for nutrients, DO and other pollutants causing water quality problems under high-flow conditions. EPA expects these high-flow TMDLs to be completed by December 2004.

Summary of TMDL Development and Public Participation

In 1991, at the request of DNREC and DEP, DRBC agreed to coordinate water management issues in the "interstate" Christina River Basin. The issues included monitoring, modeling, and pollution controls; balancing the conflicting demands for potable water while maintaining necessary minimum requirements to sustain aquatic life; protection of vulnerable, high quality scenic and recreational areas; restoration of wetlands and other critical habitats; and implementation of Delaware's Exceptional Recreational or Ecological Significance (ERES) objectives. DRBC facilitated a series of meetings with DNREC, DEP, EPA, Chester County Water Resources Authority (CCWA) and the United States Geological Survey (USGS). The two states, DRBC, EPA and other government agencies reached agreement in late 1993 to initiate a cooperative and coordinated monitoring and modeling approach to develop and establish TMDLs to address water quality problems occurring at low-flow conditions by late 1999.

Both Pennsylvania and Delaware have identified multiple segments and pollutants in the Christina River Basin on their respective lists of impaired waters still requiring the development of a TMDL. Based on available information, Pennsylvania identified 24 stream segments on its 1998 303(d) lists while Delaware identified 15 stream segments on its 1998 303(d) list as not meeting WQS for nutrients and low DO within the Christina River Basin.

Concurrent with the water quality improvement activities taking place within the Christina River Basin, EPA settled two civil lawsuits regarding EPA's oversight of the TMDL programs of Pennsylvania and Delaware. Both suits alleged violations of the Clean Water Act (CWA), the Endangered Species Act (ESA) and the Administrative Procedures Act (APA). The settlement of the Pennsylvania matter, American Littoral Society and the Public Interest Research Group v. EPA, Civil No. 96-489 (E.D. Pa), was entered on April 9, 1997. The Pennsylvania TMDL settlement requires certain numbers of TMDLs by certain dates but gives discretion to Pennsylvania and EPA as to which TMDLs must be completed. The settlement of the Delaware lawsuit, American Littoral Society and Sierra Club v. EPA Civil Action No. 96-591 (SLR) (D.De), was entered on August 9, 1997. The Delaware TMDL settlement sets forth specific deadlines for EPA relating to specific waters and TMDLs in the Christina River Basin. Under the schedule set forth the settlement, Delaware was to establish low-flow TMDLs for all water quality limited segments (except for those impaired by bacteria), including Brandywine Creek, Christina River, Red Clay Creek and White Clay Creek, by December 31, 1999. The Delaware settlement also expects Delaware to establish the high-flow TMDL by December 31, 2004. Pursuant to the Delaware agreement, EPA is required to establish TMDLs within one year should Delaware fail to do so.

Despite best efforts by DRBC, EPA, Delaware and other participants, including the use of expert contractors from Tetra Tech and Widener University, the low-flow TMDLs for the Christina River Basin were not completed by December 1999. EPA thereafter assumed the lead to establish these TMDLs.

EPA held two public information meetings on preliminary draft Christina River Basin TMDLs on July 18-19, 2000 in West Chester, PA and Wilmington, DE respectively. After making appropriate changes, EPA opened the formal public comment period on the proposed TMDLs with two public hearings on August 29-30, 2000, again in West Chester, PA and Wilmington, DE respectively. As advertised in local papers, EPA held the comment period for the draft TMDLs open through October 15, 2000. EPA received numerous comments from both the public hearings and during the public comment period. EPA reviewed and considered those comments in making its final decision for these TMDLs. EPA has prepared a public comment responsiveness summary which accompanies the final TMDL Decision Rationale document.

For the revised TMDLs, EPA issued a public notice of the proposed revisions on March 1, 2002 for a 30-day public comment period. The notice was published in the Chester County Community Newspaper Group and the Wilmington News-Journal. Copies of the notice were also mailed to each affected point source discharger in the Christina River Basin. One set of comments were received and EPA has prepared a response to those comments which accompanies this revised TMDL Decision Rationale document. Because of the limited changes being made to the TMDLs and the few comments received, EPA determined that the proposed TMDL revisions could proceed without the need for a public hearing.

Applicable Water Quality Standards for TMDLs

The CWA requires States to adopt WQS to define the water goals for a waterbody by designating the use or uses to be made of the water, by setting criteria necessary to protect the uses and by protecting water quality through antidegradation provisions. These WQS serve dual purposes: they establish water quality goals for a specific waterbody, and they serve as the regulatory basis for establishing water quality-based controls and strategies beyond the technology-based levels of treatment required by sections 301(b) and 306 of the CWA.

Within the Christina River Basin, there are four regulatory agencies which have adopted applicable WQS. DEP, DNREC and MDE each have WQS which apply to the stream segments of the Christina River Basin in the respective state. DRBC is an interstate agency which has the authority to establish WQS and regulate pollution activities within the Delaware River Basin including the Christina River Basin, one of the Delaware River's tributary basins.

Once EPA identifies the applicable use designation and water quality criteria, EPA determines the numeric water quality target or goal for the TMDL. These targets represent a number where the applicable water quality is achieved and maintained. In these TMDLs, the target is to attain and maintain the applicable DO water quality criteria at low-flow conditions. EPA has set forth specific targets for DO in the Tables and Figures provided in the TMDL Decision Rationale applicable to each segment. The table below identifies the general numeric water quality targets or endpoints for the Christina River Basin TMDLs.

Summary of TMDL Endpoints*

Parameter [illegible]	[illegible]	[illegible]
Daily Average [illegible]	5.0 mg/L	Pennsylvania Water Quality Standards
Daily Average DO [illegible]	5.5 mg/L	Delaware Water Quality Standards
DO at any time, freshwater, Maryland	5.0 mg/L	Maryland Water Quality Standards
Minimum DO [illegible]	4.0 mg/L	Pennsylvania and Delaware Water Quality Standards

* - the state of Maryland adopted the EPA water quality criteria for ammonia nitrogen in January 2001 (effective April 2001 - Title 26 Maryland Department of the Environment Subtitle 08 Water Pollution Chapter 02 Water Quality). This was approved by EPA in June 2001.

In addition to the TMDL DO endpoints summarized in the above table, there are higher DO WQS for certain Christina River Basin segments during the critical conditions time periods considered in these low-flow TMDLs. Generally, these segments were either not listed on 303(d) lists for point source impacts or found not to be impacted by point source discharges in the TMDL evaluations. The results of the TMDL model runs, incorporating the proposed TMDL reductions, indicate that these higher DO WQS will also be protected.

These TMDLs have also identified the pollutants and sources of pollutants that cause or contribute to the impairment of the DO criteria and allocate appropriate loadings to the various sources. Given our scientific knowledge regarding the interrelationship of nutrients, Biochemical Oxygen Demand (BOD), Sediment Oxygen Demand (SOD) and their impact on DO, EPA determined it necessary and appropriate to establish numeric targets for total nitrogen and total phosphorus based on applicable state narrative criteria (or numeric criteria in the case of Maryland) to support the attainment of the numeric DO criterion. Likewise, to maintain adequate instream levels of DO at low-flow conditions, EPA found it necessary and appropriate to develop as part of these TMDLs waste load allocations for total phosphorus, total nitrogen, ammonia-nitrogen, Carbonaceous Biochemical Oxygen Demand (CBOD) and DO for point sources. Establishing numeric water quality endpoints or goals also provides the ability to measure the progress toward attainment of the WQS and to identify the amount or degree of deviation from the allowable pollutant load.

Christina River Basin Water Quality and TMDL Development

As noted above, Pennsylvania identified 24 stream segments on its 1998 303(d) list while Delaware identified 15 stream segments on its 1998 303(d) list as not meeting WQS for nutrients and low DO within the Christina River Basin. The listed stream segments identified various causes of impairment including excessive nutrients, organic enrichment and low DO. Data appendices prepared for and considered in this report describe in detail the existing water quality during low-flow. These appendices can be viewed at the EPA Region III Christina River Basin TMDL web site (www.epa.gov/reg3wapd/christina).

These TMDLs also address loadings of pollutants from waterbodies or segments which have not been listed as impaired on the states' 303(d) lists. The CWA requires for interstate waters that the water from the upstream state meet the WQS of the downstream state at or before the state line. In this case, these interstate TMDLs not only address the segments listed respectively by Pennsylvania (the upstream state) and Delaware (the downstream state), but also address other water quality problems associated with discharges from non-listed waters necessary to protect the water quality of downstream waters of Delaware during low-flow conditions. In a few cases, including certain segments of the East Branch of the Brandywine River, the TMDL modeling also revealed problems in previously unlisted waters where none had been identified before. In some cases where a segment may not have been previously identified as impaired, these TMDLs allocate pollutant loads that are causing or contributing to the impairment of that water and/or downstream waters. EPA established such waste load allocations in order to attain and maintain the applicable WQS of both upstream and downstream waters consistent with our authority to establish these TMDLs.

As indicated in the data assessment (appendices found at the web site), the nutrient concentrations of the tidal Christina River are heavily influenced by tributary loads from the Brandywine Creek, Red and White Clay Creeks and nontidal Christina River. The data analysis also indicates that DO concentrations within the tidal Christina River violate both the minimum and daily average WQS during low-flow critical conditions. In addition to the influential nutrients loads from tributaries, spatial data analysis indicates that high levels of plant biomass are likely the result of transport from inland tributaries. In any case, the nutrient and biomass loadings from inland tributaries potentially contribute to the DO WQS violations within the tidal Christina River. This further justifies the need to consider sources of pollutants and tributaries on a watershed basis, regardless of whether that waterbody is explicitly listed on the states' 303(d) lists.

TMDL Model

In establishing these TMDLs, EPA utilized the EFDC water quality model, a public domain surface water modeling system incorporating fully integrated hydrodynamic, water quality and sediment-contaminant simulation capabilities, to evaluate the linkage between the applicable water quality criteria and the identified sources and to establish the cause-and-effect relationships. The EFDC model has been applied in similar studies including the Peconic Estuary, the Indian River Lagoon/Turkey Creek, and the Chesapeake Bay system and has been used to develop TMDLs in Oklahoma and Georgia.

Summary of TMDL Allocations

The TMDL waste load and load allocations for specific segments are provided in tables at the end of this Executive Summary. The Level 1 allocations result from the evaluation of each individual discharger. For Level 2, the resultant Level 1 allocations were added one at a time in a cumulative assessment of WLA impacts. The Level 2 allocations are the proposed WLAs for the affected dischargers. Tables are also provided that display the total discharge load reductions proposed by the TMDLs to ensure that the DO WQS are met under low-flow conditions in the Christina Basin.

Federal regulations at 40 CFR 122.44(d)(1)(vii)(B) require that, for an NPDES permit for an individual point source, the effluent limitations must be consistent with the assumptions and requirements of any available WLA for the discharger prepared by the state and approved by EPA or established directly by EPA. To ensure consistency with these TMDLs, as NPDES permits are issued for the point sources that discharge the pollutants of concern to the Christina Basin, any deviation from the WLAs described herein for the particular point source must be documented in the permit Fact Sheet and made available for public review along with the proposed draft permit and the Notice of Tentative Decision. The documentation should: (1) demonstrate that the loading change is consistent with the goals of these TMDLs and will implement the applicable WQS, (2) demonstrate that the changes embrace the assumptions and methodology of these TMDLs, and (3) describe that portion of the total allowable loading determined in the TMDL report that remains for other point sources (and future growth where included in the original TMDL) not yet issued a permit under the TMDL.

Discussion of Regulatory Conditions

Federal regulations at 40 CFR Section 130 require that TMDLs must meet the following eight regulatory conditions:

1) The TMDLs are designed to implement applicable water quality standards.
2) The TMDLs include a total allowable load as well as individual waste load allocations and load allocations.
3) The TMDLs consider the impacts of background pollutant contributions.
4) The TMDLs consider critical environmental conditions.
5) The TMDLs consider seasonal environmental variations.
6) The TMDLs include a margin of safety.
7) The TMDLs have been subject to public participation.
8) There is reasonable assurance that the TMDLs can be met.

The TMDL Decision Rationale document discusses how these TMDLs satisfy each of these regulatory conditions in Section VII. The Christina River Basin TMDLs for nutrients and DO under low-flow conditions have fulfilled the 40 CFR Section 130 regulatory conditions.

Total Maximum Daily Load of Nutrients and Dissolved Oxygen Under Low-Flow Conditions in the Christina River Basin, Pennsylvania, Delaware, and Maryland

TMDL Summary by Subwatershed for the Christina River Basin

Sum of Individual Waste Load Allocations					
Subwatershed	CBOD5 lb/day	NH3-N lb/day	[illegible]	[illegible]	[illegible]
Brandywine Creek main stem	79.72	16.82	43.04	9.00	26.74
Brandywine Creek East Branch	1,022.79	157.30	3,562.99	118.76	523.97
Brandywine Creek West Branch	600.16	124.15	1,218.68	69.48	257.01
[illegible]	7.55	0.79	1.91	0.61	1.53
Brandywine Creek Watershed	**1,710.22**	**299.06**	**4,826.62**	**197.85**	**809.25**
Christina River West Branch	75.57	13.57	125.33	6.26	37.56
Little Mill Creek	0.00	0.00	0.00	0.00	0.00
Christina River main stem	0.00	0.00	0.00	0.00	0.00
Christina River Watershed	**75.57**	**13.57**	**125.33**	**6.26**	**37.56**
Burroughs Run	0.04	0.01	0.02	0.01	0.03
Red Clay Creek West Branch	162.32	19.44	46.94	12.83	71.36
Red Clay Creek main stem	108.96	4.81	11.61	75.52	112.11
Red Clay Creek Watershed	**271.32**	**24.26**	**58.57**	**88.36**	**183.50**
White Clay Cr. Middle Branch	53.83	10.52	25.46	4.51	11.27
White Clay Cr. East Branch	88.78	8.69	149.67	11.23	16.17
Muddy Run	0.00	0.00	0.00	0.00	0.00
Pike Creek	0.00	0.00	0.00	0.00	0.00
Mill Creek	0.00	0.00	0.00	0.00	0.00
White Clay Cr. main stem	0.75	0.03	0.06	0.03	1.25
White Clay Creek Watershed	**143.36**	**19.24**	**175.19**	**15.77**	**28.69**
Total Waste Load Allocation for Point Sources in Christina River Basin	**2,200.47**	**356.13**	**5,185.71**	**308.24**	**1,059.00**

TMDL Summary by Subwatershed for the Christina River Basin

Sum of Load Allocations					
Subwatershed	CBOD5 (lb/day)	NH3-N (lb/day)	TN (lb/day)	TP (lb/day)	DO (lb/day)
Brandywine Creek main stem	52.01	1.78	137.30	1.50	497.95
Brandywine Creek East Branch	162.33	3.85	248.01	3.35	1,333.95
Brandywine Creek West Branch	99.18	3.08	262.94	2.77	958.41
Buck Run	34.72	0.96	92.45	0.94	338.75
Brandywine Creek Watershed	**348.24**	**9.67**	**740.69**	**8.55**	**3,129.05**
Christina River West Branch	1.17	0.02	0.82	0.02	5.94
Little Mill Creek	36.27	0.52	25.38	0.51	186.02
Christina River main stem	34.99	1.65	26.85	0.86	163.08
Christina River Watershed	**72.43**	**2.19**	**53.05**	**1.38**	**355.05**
Burroughs Run	4.60	0.10	9.10	0.21	33.65
Red Clay Creek West Branch	20.05	0.42	39.68	0.90	146.87
Red Clay Creek main stem	40.10	0.91	79.24	1.83	292.00
Red Clay Creek Watershed	**64.75**	**1.43**	**128.02**	**2.94**	**472.52**
White Clay Cr. Middle Branch	20.80	0.67	58.11	0.66	237.96
White Clay Cr. East Branch	23.44	0.77	65.42	0.74	267.66
Muddy Run	3.23	0.11	9.00	0.10	36.80
Pike Creek	5.57	0.19	15.52	0.18	63.40
Mill Creek	7.64	0.26	21.31	0.24	87.06
White Clay Cr. main stem	17.96	0.68	49.76	0.59	201.98
White Clay Creek Watershed	**78.64**	**2.68**	**219.12**	**2.51**	**894.86**
Total for LA Christina River Basin	**564.06**	**15.97**	**1,140.88**	**15.38**	**4,851.48**
Margin of Safety	Implicit through conservative assumptions				
TMDL for Christina River Basin	**2,764.53**	**372.10**	**6,326.59**	**323.62**	**5,910.47**

Note: Totals subject to rounding variations.

Total Maximum Daily Load of Nutrients and Dissolved Oxygen Under Low-Flow Conditions in the Christina River Basin, Pennsylvania, Delaware, and Maryland

Level 1 Baseline Allocations

NPDES Facility	Flow (mgd)	Existing Permit Limits			Level 1 Allocation Limits			Level 1 [illegible]		
		CBOD5 (mg/L)	NH3-N (mg/L)	TP (mg/L)	CBOD5 (mg/L)	NH3-N (mg/L)	TP (mg/L)	CBOD5 [illegible]	[illegible]	[illegible]
East Branch Brandywine Creek										
PA0026531	7.134	10	2.0	2.0	8.9	1.78	1.78	11%	11%	11%
West Branch Brandywine Creek										
PA0026859***	3.85	15	2.0	2.0	12.3	2.0	1.64	18%	0%	18%
West Branch Red Clay Creek										
PA0024058	1.1	25	3.0	7.5*	17.5	2.1	1.35	30%	30%	82%
West Branch Christina River										
MD0022641	0.7	22**	6.45*	1.0	22**	2.0	1.0	0%	69%	0%

Note: WLAs/ permit limits for critical conditions period; applicable to seasonal permit periods (e.g., May 1 -October 31 - DEP)

* no permit limits, values shown are based on monitoring data.
** value shown is BOD5. MDE permits list BOD5 instead of CBOD5; equivalent CBOD5 value is 12.22 mg/l.

PA0026531 - Downingtown Area Reg. Auth.
PA0024058 - Kennett Square
*** - formerly Coatesville City Authority

PA0026859 - PA American Water Co.***
MD0022641 - Meadowview Utilities, Inc.

Total Maximum Daily Load of Nutrients and Dissolved Oxygen Under Low-Flow Conditions in the Christina River Basin, Pennsylvania, Delaware, and Maryland

Level 2 Allocations

NPDES Facility	Flow (mgd)	Existing Permit Limits			Level 2 Allocation Limits			Level 1 and 2 Percent Reduction		
		CBOD5 (mg/L)	NH3-N (mg/L)	TP (mg/L)	CBOD5 (mg/L)	NH3-N (mg/L)	TP (mg/L)	CBOD5	NH3-N	TP
East Branch Brandywme Creek										
PA0043982	0.4	25·	2.0*	2.0	22.95	2.00	1.88	8%	0%	6%
PA0012815	1.028	34	6.0	1.0	24.41	4.31	0.72	28%	28%	28%
PA0026531	7.134	10	2.0	2.0	6.38	1.28	1.28	36%	36%	36%
West Branch Brandywine Creek										
PA0026859	3.85	15	2.0	2.0	11.07	2.00	1.48	28%	0%	28%
PA0044776	0.6	15	3.0	2.0	13.50	2.70	1.80	10%	10%	10%
West Branch Red Clay Creek										
PA0024058	1.1	25	3.0	7.5*	16.63	2.00	1.28	34%	34%	83%
PA0057720-001	0.05	10	2.0	2.0*	9.50	1.90	1.90	5%	5%	5%
West Branch Christina River										
MD0022641**	0.7	22***	6.45*	1.0	22***	2.0	1.0	0%	69%	0%

Note: WLAs/permit limits for critical conditions period: applicable to seasonal permit periods (e.g:. May 1 - October 31 - DEP)

* no permit limits. values shown are based on typical characteristics or monitoring data.
**allocation did not change from Level 1 allocation.
***value shown is BOD5. MDE permits list BOD5 instead of CBOD5; equivalent CBOD5 value is 12.22 mg/l.

PA0026531 - Downingtown Area Reg. Auth.
PA0024058 - Kennett Square
PA0043982 - Broad Run Sew. Co.
PA0057720-001 - Sunny Dell Foods, Inc.
**** - formerly Coatesville City Authority

PA0026859 - PA American Water Co.****
MD0022641 - Meadowview Utilities, Inc.
PA0012815 - Sonoco Products
PA0044776 - NW Chester Co. Mun. Auth.

Total Maximum Daily Load of Nutrients and Dissolved Oxygen Under Low-Flow Conditions in the Christina River Basin, Pennsylvania, Delaware, and Maryland

I. Introduction

The Environmental Protection Agency Region III (EPA) establishes these Total Maximum Daily Loads (TMDLs) for nutrients and other oxygen demanding pollutants in order to attain and maintain the applicable Water Quality Standards (WQS) for dissolved oxygen (DO) in the Christina River Basin under low-flow conditions (equivalent to the minimum seven-day low flow expected to occur every 10 years - conditions used to establish National Pollution Discharge Elimination System (NPDES) permits). EPA has established these TMDLs in cooperation with the Pennsylvania Department of Environmental Protection (DEP), Delaware Department of Natural Resources and Environmental Control (DNREC), Maryland Department of the Environment (MDE) and the Delaware River Basin Commission (DRBC). As part of these TMDLs, EPA has allocated specific amounts of nutrients and other oxygen demanding pollutants to certain point and nonpoint sources necessary to restore and maintain the applicable WQS. These TMDLs recommend that eight facilities, seven in Pennsylvania and one in Maryland, have their NPDES permits modified when next reissued to reduce the amounts of pollutants that may be discharged.

During permit reviews for several of the facilities covered by the January 19, 2001 TMDLs, it was found that some flow rates used in the original TMDL calculations were in error. As a result, model runs using updated flows were performed and revisions to the TMDL recommendations for the Brandywine Creek portion of the Christina River Basin were made.

A related, but separate, effort is underway to establish TMDLs for nutrients, DO and other pollutants causing water quality problems under high-flow conditions. EPA expects these high-flow TMDLs to be completed by December 2004.

II. Historical Perspective

In 1991, at the request of DNREC and DEP, DRBC agreed to mediate water management issues in the "interstate" Christina River Basin. The issues included interstate and intrastate coordination of monitoring, modeling, and pollution controls; balancing the conflicting demands for potable water while maintaining necessary minimum pass-by requirements to sustain aquatic life; protection of vulnerable, high quality scenic and recreational areas; restoration of wetlands and other critical habitats; and implementation of Delaware's Exceptional Recreational or Ecological Significance (ERES) objectives. A comprehensive basin approach was needed.

The DRBC facilitated a series of meetings with DNREC, DEP, EPA, Chester County Water Resources Authority (CCWA) and the United States Geological Survey (USGS). EPA funded a study by Scientific Applications International Corporation (SAIC) for completion of an initial data assessment and problem identification study for the non-tidal portion of Brandywine Creek. The findings of this study, *Preliminary Study of the Brandywine Creek Sub-basin, Final Report, September 30, 1993*, provided a framework for use in a multi-step TMDL study for the entire Christina River Basin. The two states, DRBC and EPA reached agreement in late 1993 to initiate a cooperative and coordinated monitoring and modeling approach to produce Christina River Basin TMDLs for low-flow conditions by late 1999.

Even as the parties reached agreement on how best to address the impacts of pollutants during low-flow conditions, they recognized that additional efforts would be necessary to address the distinct water quality problems resulting from primarily nonpoint sources of pollutants during high-flow conditions. In 1993, EPA recommended that DRBC expand the effort to consider high-flow conditions. As a result, the Christina Basin Water Quality Management Committee (CBWQMC) was created with the purpose of addressing the applicable water quality problems and management policies on a watershed scale. The CBWQMC represents a variety of stakeholders and interested parties including the Brandywine Valley Association/Red Clay Valley Association (BVA/RCVA), Chester County Conservation District (CCCD), Chester County Health Department (CCHD), Chester County Planning Commission (CCPC), CCWA, DNREC, Delaware Nature Society (DNS), DRBC, New Castle County Conservation District (NCCD), DEP, EPA Region III, USGS, United States Natural Resources Conservation Service (USDA-NRCS) and the Water Resources Agency for New Castle County (WRANCC).

The CBWQMC developed a unified, multi-phased, 5-year Water Quality Management Strategy (WQMS) that firsts, addresses the water quality problems through voluntary watershed/water quality planning and management activities and second, establishes appropriate TMDLs. The reason for separating the development of TMDLs to address water quality problems between low-flow and high-flow TMDLs is that each scenario has different and distinct pollutants and problems at different flow regimes.

Since 1995, the CBWQMC has been conducting activities set forth in the WQMS designed to implement programs aimed at protecting and improving water quality. These activities include Geographic Information System (GIS) watershed inventory, water quality assessment, watershed pollutant potential and prioritization, stormwater monitoring, Best Management Practices (BMP) Implementation projects and public education/outreach. A summary of these activities can be found in *Phase I and II Report, Christina River Basin Water Quality Management Strategy, May 1998* and *Phase III Report, Christina Basin Water Quality Management Strategy, August 5, 1999*. These reports describe ongoing efforts to provide pollution control and restore water quality within the Christina River Basin.

Both Pennsylvania and Delaware have identified multiple segments and pollutants in the Christina River Basin on their respective lists of impaired waters still requiring the development of a TMDL. Based on available information, Pennsylvania identified 24 stream segments on its 1998 303(d) list while Delaware identified 15 stream segments on its 1998 303(d) list as not meeting WQS for nutrients and low DO within the Christina River Basin. The Clean Water Act

(CWA) requires that upstream waters must meet the applicable WQS of the downstream state at or before the state line. In other words, any TMDL to achieve the WQS in the Christina River Basin in Delaware requires Pennsylvania waters to meet WQS at the Delaware state line.

Concurrent with the water quality improvement activities taking place within the Christina River Basin, EPA settled two civil lawsuits regarding EPA's oversight of the TMDL programs of Pennsylvania and Delaware. Both suits alleged violations of the CWA, the Endangered Species Act (ESA) and the Administrative Procedures Act (APA). The settlement of the Pennsylvania matter, American Littoral Society and the Public Interest Research Group v. EPA, Civil No. 96-489 (E.D. Pa), was entered on April 9, 1997. The Pennsylvania TMDL settlement requires certain numbers of TMDLs by certain dates but gives discretion to Pennsylvania and EPA as to which TMDLs must be completed. The settlement of the Delaware lawsuit, American Littoral Society and Sierra Club v. EPA Civil Action No. 96-591 (SLR) (D.De), was entered on August 9, 1997. The Delaware TMDL settlement sets forth specific deadlines for EPA relating to specific waters and TMDLs in the Christina Rivern Basin. Under the schedule set forth the settlement, Delaware was to establish low-flow TMDLs for all water quality limited segments (except for those impaired by bacteria), including Brandywine Creek, Christina River, Red Clay Creek and White Clay Creek, by December 31, 1999. The Delaware settlement also expects Delaware to establish high-flow TMDLs by December 31, 2004. Pursuant to the Delaware agreement, EPA is required to establish TMDLs within one year should Delaware fail to do so.

In response to the requirement to establish TMDLs, Delaware, in cooperation with the CBWQMC, identified the need for a scientific modeling tool to investigate water quality impairments related to the development of TMDLs in the Christina River Basin. Tetra Tech, already under contract to EPA (Contract No. 68-C7-0018), was asked to provide regional TMDL watershed analysis and support within the Christina River Basin. The original work plan was approved August 28, 1997 to provide a calibrated water quality model for nutrients and DO for the Christina River Basin to be used by DNREC and DEP in establishing TMDLs. The model would be calibrated for critical, low-flow summer period, use all available information and include both point and nonpoint sources. The WASP5[1] model was originally envisioned as the analytical tool, however, EPA ultimately decided to use the EFDC[2] model after considering the complexity of the Christina River Basin and the need to link this model with the HSPF[3] model

---

[1] Ambrose, R.B., T.A. Wool, and J.L. Martin. 1993. The water quality analysis and simulation program, WASP5 version 5.10. Part A: Model documentation. U.S. Environmental Protection Agency, Office of Research and Development, Environmental Research Laboratory, Athens, GA.

[2] Hamrick, J.M. 1992. A three-dimensional environmental fluid dynamics computer code: theoretical and computational aspects. SRAMSOE #317, The College of William and Mary, Gloucester Point, VA.

[3] Bicknell, B.R., J.C. Imhoff, J.L. Kittle, A.S. Donigan, and R.C. Johanson. 1993. Hydrological Simulation Program-FORTRAN (HSPF): User's manual for release 10.0. EPA 600/3-84-066. Environmental Research Laboratory, U.S. Environmental Protection Agency, Athens, GA.

being developed by the USGS to characterize high-flow conditions. The work plan was further expanded on April 20, 1999 to include additional reaches in Delaware and allow for further validation of the model.

Following DNREC's request for scientific modeling support, a model/technical group was formed to develop the scientific modeling tool within the Christina River Basin. Members who participated in this effort include representatives from DNREC, DEP, EPA, DRBC, USGS and Tetra Tech. Although the Cecil County, Maryland Department of Public Works and MDE were not originally included, once it was discovered that these TMDLs would impact point sources in Maryland, these organizations were contacted and have participated in the development of the TMDLs since May 2000.

After Tetra Tech began providing TMDL watershed analysis and support in 1998, the model/technical group met on a consistent basis in order to develop the modeling tool in support of the requirement to establish TMDLs for low-flow conditions by December 31, 1999. In September 1998, when it became apparent that the model development was behind schedule, and at the request of DNREC and DEP, DRBC agreed, by resolution, to hire Widener University to further assist in the development of TMDLs once the model was completed. Despite best efforts by DRBC, EPA, the states and other participants on the CBWQMC, the low- flow TMDLs for the Christina were not completed by December 1999, EPA thereafter assumed the lead to establish these TMDLs.

III. Christina River Basin Water Quality Perspectives

In addition to the legal, statutory and regulatory requirements of identifying water quality limited segments and establishing TMDLs, there are several compelling reasons why establishing these TMDLs is good public policy to address the water quality of the Christina River Basin: (1) protect water quality uses, (2) protect sources of drinking water, and (3) promote appropriate growth. One goal of the CWA, and other similar legislation, is to restore and maintain the chemical, physical and biological integrity of the Nation's waters. These critical, but often delicate natural resources, can be easily degraded by anthropogenic and other sources of pollution. Polluted waters can affect the quality of life, health and vitality of citizens in the Christina River Basin. Consistent with the goals of the CWA, it is in the public interest to sustain the diverse human, ecological, aesthetic and recreational resources of the watershed.

While it is often difficult to attach a precise economic value to natural resources such as the Nation's waters, the CWA recognizes the benefits gained by restoring and maintaining the Nation's waters. Actions such as these become even more critical where the waterbody serves as the primary source of drinking water for 75% of the residents in New Castle County, Delaware. Many of the water supply withdrawals in Chester County, Pennsylvania originate in waters from the Christina River Basin. Development will continue to occur in the Christina River Basin along with the consequential impacts on water quality. Establishing protective and appropriate water quality targets will allow progress while ensuring water quality integrity.

EPA characterizes the past and current condition of water quality in the Christina River Basin, and assesses available data, as part of the basis for these TMDLs. Data appendices prepared for this report describe in detail the existing water quality during low flow. The data assessment developed by Dr. John Davis of Widener University, in draft form for the DRBC TMDL determination, has been included verbatim from the "*Preliminary Draft TMDL Document 5/27/99*" provided to DRBC on June 7, 1999. EPA used this data in developing these TMDLs. These appendices can be viewed at the EPA Region III Christina River Basin TMDL web site (www.epa.gov/reg3wapd/christina).

IV. Basin Summary and Source Assessment

The Christina River Basin (Hydrologic Unit Code 02040205) covers an area of 564.06 square miles and is located in Chester County, Pennsylvania, New Castle County, Delaware and Cecil County, Maryland (Figure 1). Major streams include the Christina River (tidal and nontidal), Brandywine Creek (tidal and nontidal), Red Clay Creek and White Clay Creek (tidal and nontidal). These streams are used as habitat for aquatic life, for municipal and industrial water supplies and for recreational purposes. The Christina River Basin drains to the tidal Delaware River at Wilmington, Delaware. The portions included in the model appear as thick or outlined segments of the streams in Figure 1.

The Christina River Basin is composed of diverse land uses including urban, rural and agricultural areas. Urban areas in the watershed include greater Wilmington and Newark, Delaware, and the Pennsylvania towns of West Chester, Downingtown, Kennett Square, Coatesville, Parkesburg, Honey Brook, Avondale and West Grove. The land use distribution within the basin is summarized in Table 1 below.

Table 1. Land Use Summary (square miles)

Land Use	[illegible]	[illegible]	[illegible]	[illegible]
Urban/Suburban	87	108	195	34
Agricultural	18	160	178	31
Open Space or Protected Lands	21	5	26	5
Wooded	37	123	160	28
Water/other	3	3	6	2
Total	166	399	565	100

Source: Phase I/II Report Christina River Basin Water Quality Management Strategy (CBWQMC - May 1998)

There are 122 NPDES dischargers included in the Christina River Basin TMDL analysis (see Table 2 and Figure 2). The discharges range from single resident discharges (about 500 gallons per day (gpd)) to large industrial and municipal wastewater treatment plants with effluent

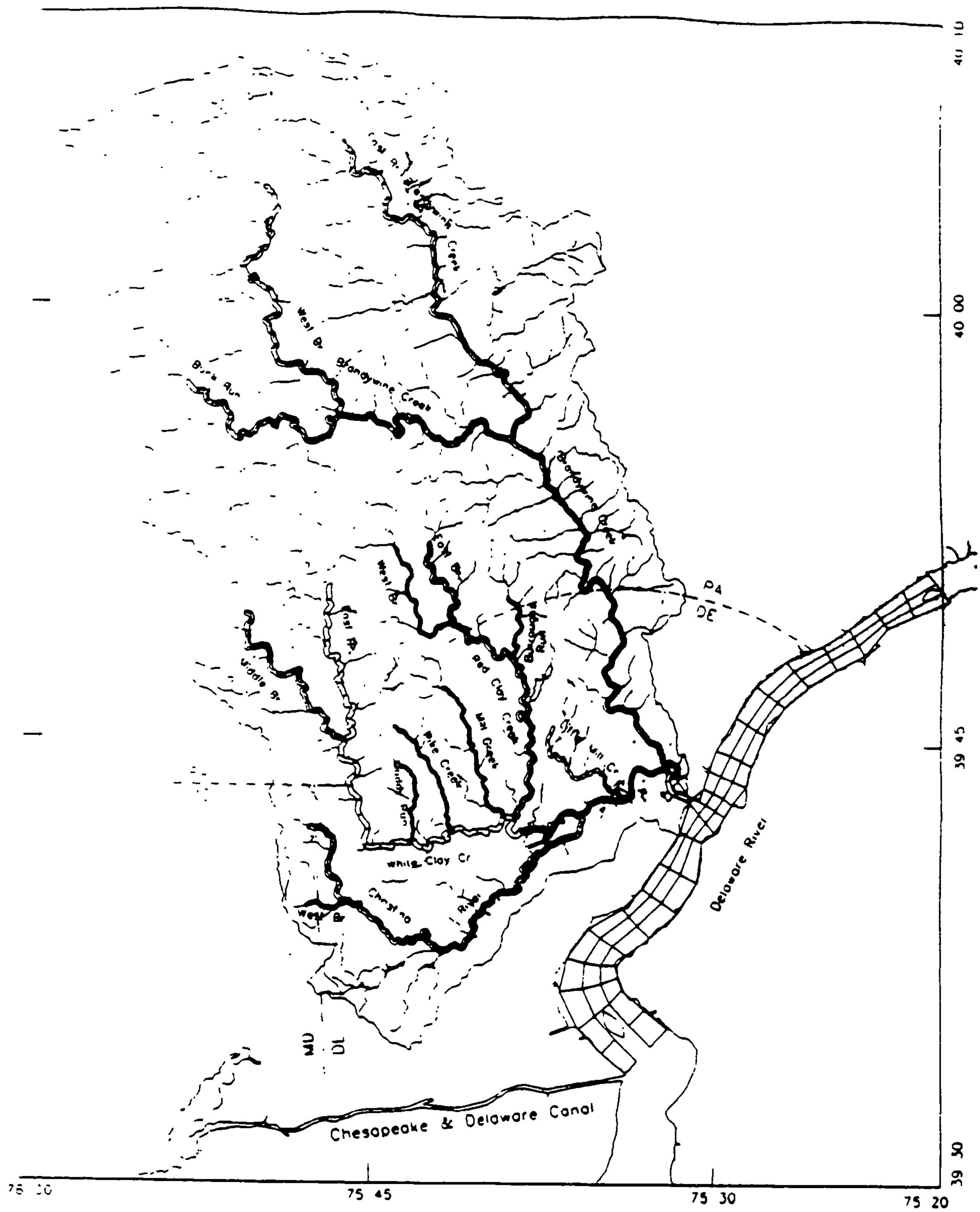


Figure 1. Christina River Basin Study Area

Table 2. Locations of NPDES point source discharges included in the model.

RIVER MILE	CELL I, J	NPDES NUMBER	FLOWLIM MGD	CODE	OWNER	STREAM	TYPE	DESCRIPTION
Brandywine Creek (main stem)								
76 610	54,15	DE0050962	0 0000	SWR	AMTRAK	TB Brandywine Creek	Industrial	Stormwater
83.554	54,27	DE0021768	0.0250	STP	Winterthur Museum	Clenney Run	Municipal	Small STP
88.644	54,37	PA0053082	0 0206	STP	Mendenhall Inn	TB Brandywine Creek	Commercial	Small STP
89.917	54,38	PA0052663	0.0900	STP	Knight's Bridge Co/Villages at Painters	Harvey Run	Commercial	Small STP
89 917	54,38	PA0055476	0.0400	STP	Birmingham TSA/Ridings at Chadds Ford	TB Harvey Creek	Municipal	Small STP
89 917	54,38	PA0055085	0.0005	SRD	Winslow Nancy Ms.	TB Brandywine Creek	Municipal	Single Residence STP
89.917	54,38	PA0055484	0 0005	SRD	Keating Herbert & Elizabeth	TB Brandywine Creek	Municipal	Single Residence STP
89 917	54,38	PA0047252	0.0700	STP	Pantos Corp/Painters Crossing	Harvey Run		
90.553	54,39	PA0030848	0.0063	STP	Unionville - Chadds Ford Elem. School	Ring Run	Municipal	Small STP
93.098	54,42	PA0056120	0.0005	SRD	Schindler	Pocopson Creek	Municipal	Single Residence STP
92 462	54,43	PA0031097	0.0170	STP	Radley Run C.C.	Radley Run	Municipal	Small STP
92 462	54,43	PA0053449	0.1500	STP	Birmingham Twp. STP	Radley Run	Municipal	Small STP
93 735	54,43	PA0057011	0.0773	STP	Thornbury Twp./Bridlewood Farms STP	Radley Run		
92 462	54,44	PA0036200	0.0320	STP	Radley Run Mews	Plum Run	Municipal	Small STP
94 371	54,44	PA0056171	0.0005	SRD	McGlaughlin Jeffrey	Plum Run	Municipal	Single Residence STP
94.371	54,44	PA0050005	0.1400	GWC	Sun Company	TB Brandywine Creek	GWCleanup	New permit 03/27/98
94 371	54,44	PA0051497	0 0300	NCW	Lenape Forge	Brandywine Creek	Industrial	Cooling Water
Brandywine Creek East Branch								
98 647	54,52	PA0026018	1.8000	MUN	West Chester Borough MUA/Taylor Run	Taylor Run	Municipal	Large STP
98 647	54,52	PA0054747	0.0000	SWR	Trans-Materials, Inc	Taylor Run	Industrial	Stormwater
98.647	54,52	PA0057282	0 0005	SRD	Jonathan & Susan Pope	TB Valley Creek	Municipal	Single Residence STP
99 276	54,53	PA0051365	0.3690	WFP	West Chester Area Mun. Auth.	EB Brandywine Creek	Municipal	Ingram's Mill Backwash
100 535	54,55	PA0053937	0 0005	SRD	Johnson Ralph & Gayla	Broad Creek	Municipal	Single Residence STP
100 535	54,55	PA0056324	0 0440	GWC	Mobil SS#16-GPB	TB-WB Valley Run	Commercial	DP
100 535	54,55	PA0056618	0.0005	SRD	O'Cornwell David & Jeanette	Broad Run	Municipal	Single Residence STP
100 535	54,55	PA0054305	0 0000	IND	Sun Co, Inc (R&M)	TB Valley Creek	Industrial	
100 535	54,55	PA0053561	0 0360	GWC	Johnson Matthey	Valley Creek	GWCleanup	Permitted 03/12/96
101 794	54,57	PA0043982	0.4000	ATP2	Broad Run Sew Co.	EB Brandywine Creek	Municipal	Large STP
103.682	54,60	PA0012815	1.0280	IND	Sunoco Products	EB Brandywine Creek	Industrial	Paper Company - Mill Raceway
103 682	54,60	PA0026531	7.1340	ATP2	Downingtown Area Regional Authority	EB Brandywine Creek	Municipal	Large STP
104.312	54,61	PA0051918	0.1440	NCW	Pepperidge Farms	Parke Run Creek	Industrial	Cooling Water
103 682	54,61	PA0055531	0.0007	STP	Khalife Paul	TB Valley Run	Commercial	Small STP
104 312	54,61	PA0057126	0.0000	IND	Hess Oil - SS #38291	Valley Run	Commercial	DP
104 312	54,61	PA0030228	0.0225	STP	Downingtown I&A School	Beaver Creek	Municipal	No flow since Feb 1994
104 312	54,61	PA0053678	0.0000	IND	Lambert Earl R.	EB Brandywine Creek	Industrial	DP
104.312	54,61	PA0053660	0.0000	IND	Mobil Oil Company #016	EB Brandywine Creek	Commercial	Air stripper at Service Sta
106.830	54,65	PA0054917	0.4750	STP	Uwchlan Twp. Municipal Authority	Shamona Creek	Municipal	Eagleview CC STP
107.459	54,66	PA0057045	0.0000	SWR	Shyrock Brothers, Inc.	EB Brandywine Creek	Commercial	Stormwater
108.088	54,67	PA0027987	0.0500	STP	Pennsylvania Tpk./Caruiel Service Plaza	Marsh Creek	Commercial	Small STP
108.088	54,67	PA0036374	0.0150	STP	Eaglepoint Dev. Assoc.	TB Marsh Creek	Municipal	Small STP
108.088	54,67	PA0052949	0.0000	IND	Phila. Suburban Water Co.	Marsh Creek	Industrial	Uwchlan DP
108.088	54,67	PA0057274	0.0005	SRD	Michael & Antionette Hughes	TB Marsh Creek	Municipal	Single Residence STP
109.977	54,70	PA0050458	0.0531	STP	Little Washington Drainage Co	Culbertson Run	Municipal	Small STP
112.495	54,74	PA0050229	0.0005	SRD	unknown	Indian Run	Municipal	Single Residence STP
112.495	54,74	PA0050547	0.0375	STP	Indian Run Village MHP	Indian Run	Municipal	Small STP
112.495	54,74	PA0055492	0.0005	SRD	Topp John & Jane	Indian Run	Municipal	Single Residence STP
113 753	54,76	PA0054691	0.0005	SRD	Stoltzfus Ben Z.	TB Brandywine Creek	Municipal	Single Residence STP

Table 2. Locations of NPDES point source discharges included in the model (continued).

RIVER MILE	CELL I, J	NPDES NUMBER	FLOWLIM MGD	CODE	OWNER	STREAM	TYPE	DESCRIPTION
Brandywine Creek West Branch								
97 976	46, 79	PA0056561	0.0000	SWR	Richard M Armstrong Co	Broad Run	Commercial	Stormwater
101 708	40, 79	PA0029912	0.1000	STP	Embreeville Hospital	WB Brandywine Creek	Municipal	Large STP
102 330	39, 79	PA0053996	0 0005	SRD	Redmond Michael	TB-WB Brandywine Creek	Municipal	Single Residence STP
107.306	29, 79	PA0053228	0.0005	SRD	Gramm Jeffery	WB Brandywine Creek	Municipal	Single Residence STP
107.306	29, 79	PA0053236	0.0005	SRD	Woodward Raymond Sr STP	WB Brandywine Creek	Municipal	Single Residence STP
110.416	24, 79	PA0036897	0 3900	ATP1	South Coatesville Borough	WB Brandywine Creek	Municipal	Large STP
111 038	23, 79	PA0026859	3 8500	ATP1	Coatesville City Authority	WB Brandywine Creek	Municipal	Large STP
111 038	23, 79	PA0011568-001	0.5000	IND	Lukens Steel Co	Sucker Run	Industrial	Large STP
111.038	23, 79	PA0011568-016	0.5000	IND	Lukens Steel Co	Sucker Run	Industrial	Large STP
111 038	23, 79	PA0053821	0.0000	SWR	Chester County Aviation Inc.	Sucker Run	Commercial	Stormwater
112.282	20, 79	PA0012416	0.1400	WFP	Coatesville Water Plant	Rock Run	Industrial	Water Filtration Backwash
112.282	20, 79	PA0052990	0.0005	SRD	Mitchell Rodney	Rock Run	Municipal	Single Residence STP
112.282	20, 79	PA0056073	0.0005	SRD	Vreeland Russell Dr	TB Rock Run	Municipal	Single Residence STP
113 526	18, 79	PA0052728	0.0004	STP	Farmland Industries Inc /Turkey Hill	WB Brandywine Creek	Industrial	Small STP
114 770	16, 79	PA0055697	0 0490	STP	Spring Run Estates	WB Brandywine Creek	Commercial	Small STP
120.368	06, 79	PA0036412	0 0550	STP	Tel Hai Retirement Community	TB-WB Brandywine Creek	Municipal	Small STP
120.368	06, 79	PA0044776	0 6000	STP	NW Chester Co Municipal Authority	WB Brandywine Creek	Municipal	Large STP
120 368	06, 79	PA0057339	0 0005	SRD	Brian & Cheryl Davidson	TB-WB Brandywine Creek	Municipal	Single Residence STP
Buck Run								
117.041	33, 61	PA0024473	0 7000	STP	Parkersburg Borough Authority WWTP	TB-Buck Run	Municipal	Small STP eliminated 06/1[illegible]/97
117 041	33, 61	PA0036161	0 0360	STP	Lincoln Crest MHP STP	Buck Run	Municipal	Small STP
117 041	33, 61	PA0057231	0.0005	SRD	Archie & Cloria Shearer	TB-Buck Run	Municipal	Single Residence STP
Christina River (tidal)								
82 274	45, 13	DE0000400-001	0.0000	NCW	Ciba-Geigy Corp.	Christina River	Industrial	Cooling Water
83 561	43, 09	DE0051004	0.0000	SWR	Boeing	Nonesuch Creek	Industrial	Stormwater
Christina River West Branch								
99.587	16, 09	MD0065145	0.0500	STP	Highlands WWTP	WB Christina River	Municipal	Small STP
100 209	14, 09	MD0022641	0.4500	STP	Meadowview Utilities, Inc	WB Christina River	Municipal	Small STP
Red Clay Creek								
89.828	43, 26	DE0000221-001	0 0060	NCW	HAVEG/AMTEK (eliminated July 1996)	Red Clay Creek	Industrial	Cooling Water
89.828	43, 26	DE0000221-003	0.0040	NCW	HAVEG/AMTEK (eliminated July 1996)	Red Clay Creek	Industrial	Cooling Water
91.746	43, 29	DE0000230-001	0 3500	NCW	Hercules Inc.	Red Clay Creek	Industrial	Cooling Water
95.583	43, 35	DE0021709-001	0.0150	STP	Greenville Country Club	TB-Red Clay Creek	Municipal	Small STP
96 861	43, 37	PA0055425	0.0005	SRD	D'Ambro Anthony Jr -Lot #22	TB-EB Red Clay Creek	Municipal	Single Residence STP
98.780	43, 40	DE0050067	0.0015	STP	Center for Creative Arts	TB-Red Clay Creek	Municipal	Small STP
98.780	43, 40	DE0000451-002	2.1700	NCW	NVF Yorklyn	Red Clay Creek	Industrial	Stormwater/Cooling Water
101 337	43, 44	PA0055107	0 1500	STP	East Marlborough Township STP	TB-EB Red Clay Creek	Municipal	Large STP
103 [illegible]	43, 47	PA0054755	0.0000	SWR	Trans-Materials Inc.	EB Red Clay Creek	Industrial	Stormwater
Red Clay Creek West Branch								
10[illegible] [illegible]	[illegible] 43	PA0053554	0.0000	SWR	Earthgro Inc.	WB Red Clay Creek	Industrial	Stormwater
10[illegible] 950	30, 43	PA0024058	1.1000	STP	Kennett Square Boro. WWTP	WB Red Clay Creek	Municipal	Large STP
104 268	29, 43	PA0050679	0.2500	NCW	National Vulcanized Fiber (NVF)	TB-WB Red Clay Creek	Industrial	Cooling Water
104.579	28, 43	PA0057720-001	0 0500	STP	Sunny Dell Foods, Inc	WB-Red Clay Creek	Industrial	Mushroom Can/Process Wate[r]
104.579	28, 43	PA0057720-003	0.0900	NCW	Sunny Dell Foods, Inc	WB-Red Clay Creek	Industrial	Mushroom Can/Cooling Wate[r]
White Clay Creek								
93.090	32, 18	DE0000191-001	0.0300	NCW	FMC Corp.	Cool Run	Industrial	Stormwater/Cooling Water
102 824	15, 18	PA0053783	0.0200	STP	Avon Grove School Dist	TB-WB White Clay Creek	Commercial	Small STP
108.696	06, 18	PA0024066	0.2500	STP	West Grove Borough Authority STP	WB White Clay Creek	Municipal	Large STP

Table 2. Locations of NPDES point source discharges included in the model (continued).

RIVER MILE	CELL I, J	NPDES NUMBER	FLOWLIM MGD	CODE	OWNER	STREAM	TYPE	DESCRIPTION
White Clay Creek East Branch								
102.750	19, 24	PA0052451	0 0012	STP	Frances L. Hamilton Oates STP	EB White Clay Creek	Municipal	Small STP
104.020	19, 26	PA0057029	0 1440	GWC	Hewlett Packard Co	Egypt Run	GWCleanup	Groundwater Cleanup
106.560	19, 30	PA0025488	0 3000	ATP2	Avondale Borough Sewer Authority	Indian Run	Municipal	Large STP
106.560	19, 30	PA0052019	0 0075	STP	Avon Grove Trailer Court	EB White Clay Creek	Municipal	Small STP
106 560	19, 30	PA0056898	0 0650	IND	To-Jo Mushrooms Inc	Trout Run	Industrial	Small STP-online Jan 98
107 195	19, 31	PA0056952	0 0029	IND	Sun Company Inc	EB White Clay Creek	GWCleanup	Groundwater Cleanup
107 830	19, 32	PA0029343	0 0270	STP	Chatham Acres	TB-EB White Clay Creek	Municipal	Small STP
107.830	19, 32	PA0040436	0 0090	STP	Chadds Ford Investment Co /Red Fox GC	TB-EB White Clay Creek	Municipal	Small STP
107 830	19, 32	PA0040665	0.0100	STP	Stone Barn Restuarantand Apt Cplx	EB White Clay Creek	Commercial	Small STP
Little Mill Creek								
82 441	41, 55	DE0000523-001	0.0000	SWR	General Motors Assembly	Little Mill Creek	Industrial	Stormwater
83 373	38, 55	DE0000566	0.0000	SWR	DuPont Chestnut Run	Little Mill Creek	Industrial	Stormwater/Cooling Water
Delaware River								
63 839	57, 04	DE0021555 001	0 5500	MUN	Delaware City STP	Delaware River	Municipal	
65 272	57, 05	DE0000256 601	13.0000	IND	Star Enterprises	Delaware River	Industrial	
65 272	57, 05	DE0000612 001	0.8000	IND	Formosa Plastics Corp	Delaware River	Industrial	
65 272	57, 05	DE0020001 001	0 6800	MUN	Standard Chlorine	Delaware River	Municipal	
65 272	57, 05	DE0050911 001	0 3000	MUN	Occidental Chemical Corp.	Delaware River	Municipal	
75 237	57, 15	DE0020320-001	134 0000	MUN	City of Wilmington	Delaware River	Municipal	
77 162	57 17	DE0000051 001	5.2000	IND	Dupont-Edgemoor	Delaware River	Industrial	
77 162	57, 17	DE0000051 002	3 0000	IND	Dupont-Edgemoor	Delaware River	Industrial	
77 162	57, 17	DE0000051-003	6 0000	IND	Dupont-Edgemoor	Delaware River	Industrial	
81 307	57, 20	DE0000655 001	33 3000	IND	General Chemical Corporation	Delaware River	Industrial	
83 907	57, 22	PA0012637-002	52 3500	IND	Bayway Manufacturing	Delaware River	Industrial	SEE NOTE 1
83 907	57, 22	PA0012637-101	69.8000	IND	Bayway Manufacturing	Delaware River	Industrial	SEE NOTE 1
83 907	57, 22	PA0012637-201	3 3400	IND	Bayway Manufacturing	Delaware River	Industrial	SEE NOTE 1
85 199	57, 23	PA0027103-001	44.0000	MUN	Delcora	Delaware River	Municipal	
82.639	58, 21	NJ0005045-001	1 2700	IND	Solutia (formerly Monsanto)	Delaware River	Industrial	SEE NOTE 2
63 839	59, 04	NJ0024856-001	1.4450	MUN	City of Salem	Delaware River	Municipal	SEE NOTE 1
69 534	59, 09	NJ0021598-001	2.4650	MUN	Pennsville Sewage Authority	Delaware River	Municipal	SEE NOTE 1
73 339	59, 12	NJ0005100-661	22.9000	IND	Dupont-Chambers Works	Delaware River	Industrial	SEE NOTE 1
75.237	59, 15	NJ0021601-001	1 7290	MUN	Carneys Pt. Sewage Authority	Delaware River	Municipal	SEE NOTE 1
76 045	59, 16	NJ0024023-001	0 9500	MUN	Penns Grove Sewage Authority	Delaware River	Municipal	SEE NOTE 1
77.162	59, 17	NJ0024635-001	0 0366	MUN	Fort Dix/Pedricktown Facility	Delaware River	Municipal	SEE NOTE 1
79 919	59, 19	NJ0004286-001	2 1000	IND	Geon	Delaware River	Industrial	
82 639	59, 21	NJ0027545-001	0.9860	MUN	Logan Township MUA	Delaware River	Municipal	SEE NOTE 1

NOTES.

(1) No flow limit available in PCS data base; flow limit shown is maximum reported flow during 01/01/95 to 12/31/98

(2) No flow limit or reported flow available in PCS data base, flow limit is based on value used to calculate CBOD5 load in permit

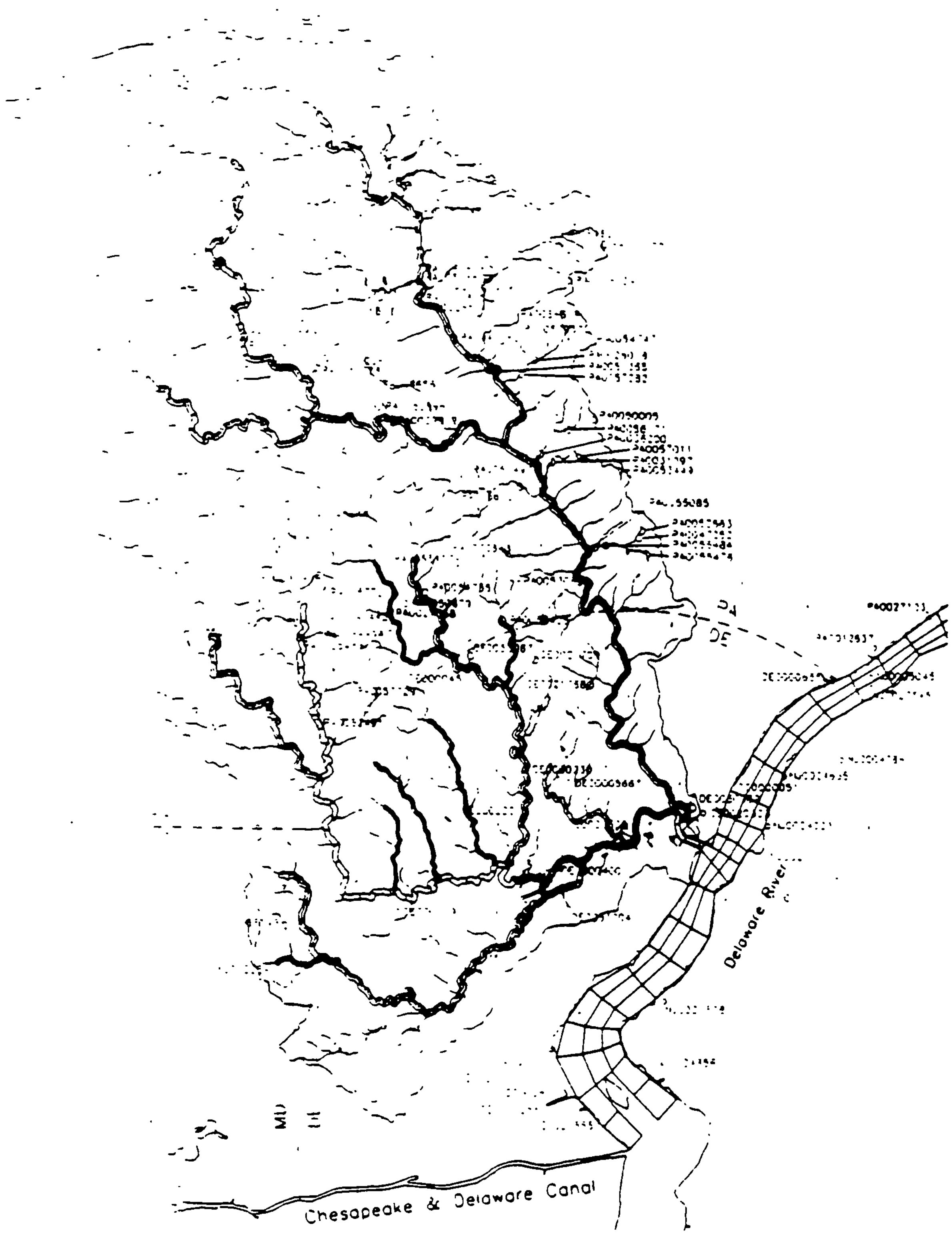


Figure 2. Locations of NPDES discharges in the Christina River Basin

flow rates in the range of 1 to 7 million gallons per day (mgd). The largest NPDES facilities in the Christina River Basin are Downingtown (permitted flow of 7.134 mgd), Sonoco (1.028 mgd), West Chester Taylor Run (1.50 mgd), Lukens Steel (1.00 mgd), PA American Water Co. (formerly Coatesville - 3.85 mgd), South Coatesville (0.39 mgd), Kennett Square (1.10 mgd) and Avondale (0.30 mgd). There are seven NPDES facilities with flows above 10 mgd that discharge to the tidal Delaware River portion of the model, the largest being the City of Wilmington (now rated at 134 mgd).

V. Problem Identification and Understanding

In response to the requirements of Section 303(d) of the CWA, DEP and DNREC listed multiple Christina River Basin waterbodies on their 1996 and 1998 303(d) lists of impaired waterbodies based on available information. As noted earlier, Pennsylvania identified 24 stream segments on its 1998 303(d) list (Table 3) while Delaware identified 15 stream segments on its 1998 303(d) list (Table 4) as not meeting WQS for nutrients and low DO within the Christina River Basin. Pursuant to the TMDL Consent Decree in Delaware, those 15 stream segments were given high priority. Likewise, Pennsylvania identified 23 of the 24 listed segments as high priority. A number of monitoring stations are located throughout the Christina River Basin within the listed waters (Figures 3 and 4). Data from these stations were used to determine the impairment and inclusion on the 303(d) lists based on the number of values exceeding WQS for DO. Excessive nutrients, organic enrichment and low DO are specified as the causes of impairment in the various listed stream segments. The pollutant sources are varied and include industrial and municipal point sources, agriculture, Superfund sites and hydromodification. As noted above, this extensive data assessment is provided in the appendices at the web site (www.epa.gov/reg3wapd/christina).

These TMDLs also address loadings of pollutants from waterbodies or segments which have not been listed as impaired on the states' 303(d) lists. The CWA requires for interstate waters that the water from the upstream state meet the WQS of the down stream state at or before the state line. In this case, these interstate TMDLs not only address the segments listed respectively by Pennsylvania (the upstream state) and Delaware (the downstream state), but also address other water quality problems associated with discharges from non-listed waters necessary to protect the water quality of downstream waters of Delaware during low-flow conditions. In a few cases, including certain segments of the East Branch of the Brandywine River, the TMDL modeling also revealed problems in previously unlisted waters where none had been identified before. In some cases where a segment may not have been previously identified as impaired, these TMDLs allocate pollutant loads that are causing or contributing to the impairment of that water and/or downstream waters. EPA established such wasteload allocations in order to attain and maintain the applicable WQS of both upstream and downstream waters consistent with our authority to establish these TMDLs.

Table 3. Christina River Basin Stream Reaches on the PA 1998 303(d) List

Watershed	Stream ID	Segment ID	Miles	[illegible]	[illegible]
Brandywine Creek	00004	27	1.28	other	nutrients
Buck Run	00131	50	1.77	municipal point source	nutrients, low DO
Sucker Run	00202	970930-1437-GLW	6.78	agriculture	nutrients
W.Br. Brandywine Creek	00085	970618-1118-GLW 970618-1340-GLW 970619-1222-GLW 970619-1345-GLW	2.98 3.57 5.51 3.99	agriculture	nutrients
Broad Run	00434	971209-1445-ACW	4.10	hydromodification, agriculture	organic enrichment, low DO, nutrients
E.Br. [illegible] Creek	00413	971023-1050-MRB 971204-1400-ACW	6.53 5.09	agriculture	organic enrichment, low DO
E.Br. [illegible] Creek	00432	970409-1130-MRB 970506-1320-MRB 970508-1430-ACE 971113-1335-GLW 971119-1116-GLW 971120-1331-GLW	6.07 8.61 2.44 3.10 1.21 8.12	agriculture	nutrients nutrients organic enrichment, low DO organic enrichment, low DO nutrients nutrients
Egypt Run	00440	970508-1245-ACE	3.66	agriculture	organic enrichment, low DO
Indian Run	00475	115	1.09	agriculture, municipal point source	nutrients
Middle Br. White Clay	00462	115	17.33	agriculture, municipal point source	nutrients
Red Clay Creek	00374	971203-1400-ACW	0.76	agriculture	organic enrichment, low DO
Trout Run	00402	970506-1425-MRB	2.74	agriculture	nutrients
Walnut Run	00435	971209-1445-ACW	1.39	agriculture, hydromodification	organic enrichment, low DO, nutrients
W.Br. Red Clay Creek	00391	971023-1145-MRB	4.58	agriculture	organic enrichment, low DO
White Clay Creek	00373	971216-1230-GLW	1.13	agriculture	nutrients

Source: Excerpt PADEP Final 1998 Section 303(d) List, Submitted August 7, 1998 and Approved by EPA on August 27, 1998

Table 4. Christina River Basin Stream Reaches on the DE 1998 303(d) List

Waterbody ID	Watershed Name	Segment	Miles	Pollutant/Stressor	Probable Sources
DE040-001	Brandywine Creek	Lower Brandywine	3.8	nutrients	PS, NPS, SF
DE040-002	Brandywine Creek	Upper Brandywine	9.3	nutrients	PS, NPS, SF
DE260-001	Red Clay Creek	Main Stem	12.8	nutrients	PS, NPS, SF
DE260-002	Red Clay Creek	Burroughs Run	4.5	nutrients	NPS
DE320-001	White Clay Creek	Main Stem	18.2	nutrients	PS,,NPS
DE320-002	White Clay Creek	Mill Creek	16.6	nutrients	NPS
DE320-003	White Clay Creek	Pike Creek	9.4	nutrients	NPS
DE320-004	White Clay Creek	Muddy Run	5.8	nutrients	NPS
DE120-001	Christina River	Lower Christina	1.5	nutrients, DO	NPS, SF
DE120-002	Christina River	Middle Christina River	7.5	nutrients	NPS, SF
DE120-003[illegible]	Christina River	Upper Christina River	6.3	nutrients	NPS, SF
DE120-003-02	Christina River	Lower Christina Creek	8.4	nutrients	NPS
DE120-005-01	Christina River	West Branch	5.3	nutrients	NPS
DE120-006	Christina River	Upper Christina Creek	8.3	nutrients	NPS
DE120-007-01	Christina River	Little Mill Creek	12.8	nutrients, DO	NPS, SF

PS= point source; NPS = nonpoint source; SF=superfund site

Source: Excerpt DNREC Final 1998 Section 303(d) List, Submitted July 7, 1998 and Approved by EPA on July 17, 1998

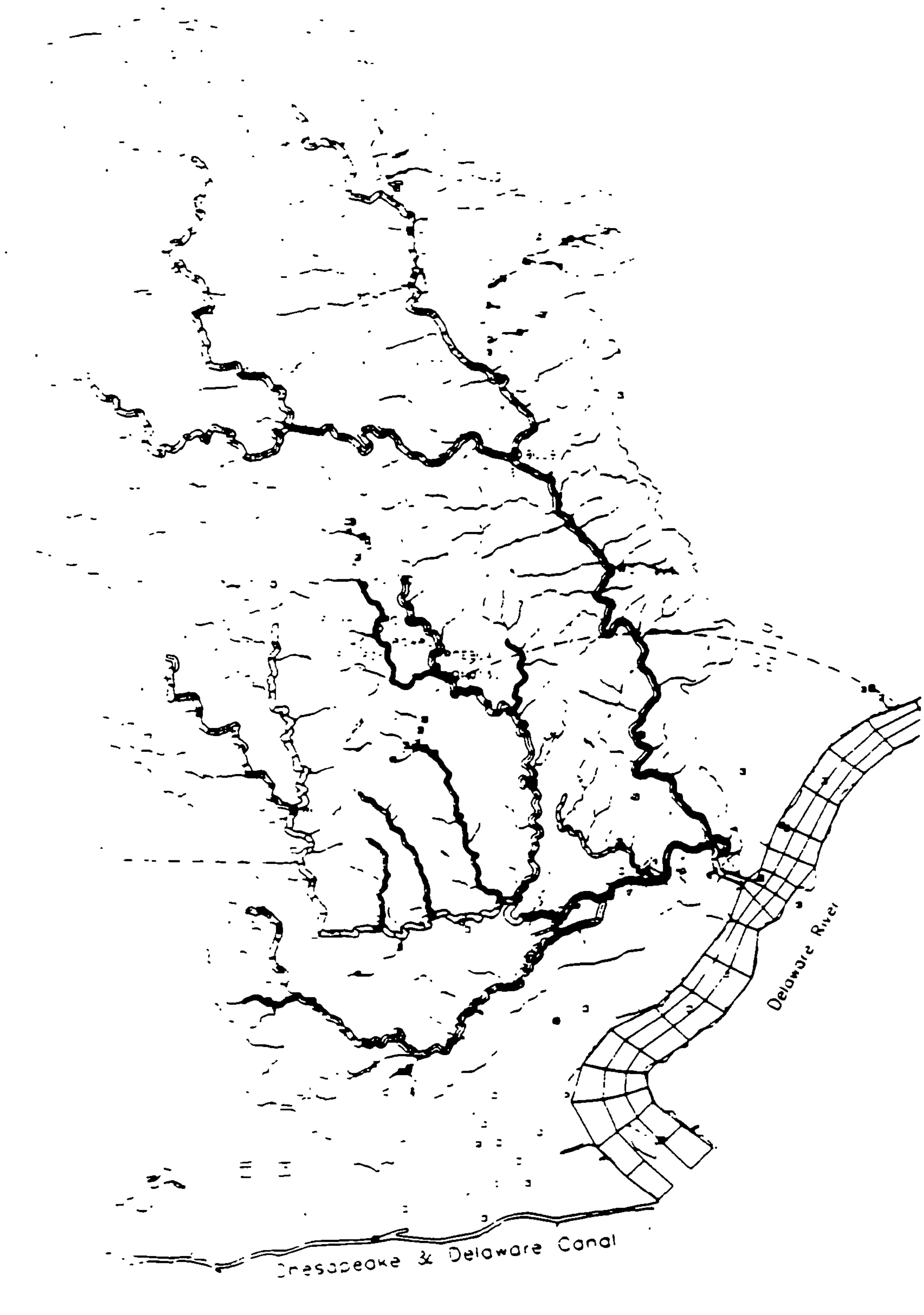


Figure 3 Locations of water quality monitoring stations in the Christina River Basin

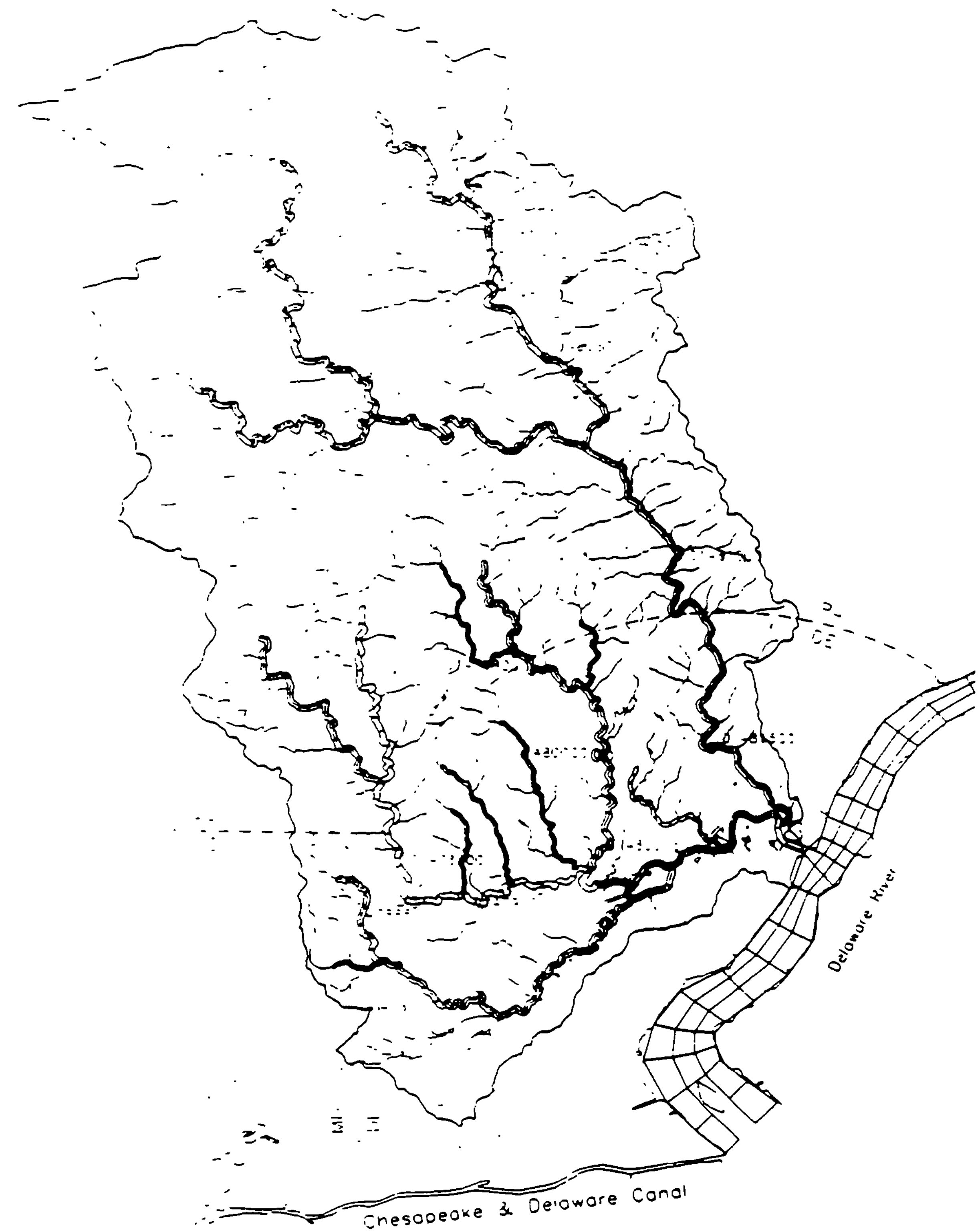


Figure 4 Locations of USGS stream gages in the Christina River Basin

EPA developed these TMDLs using the underlying principles of the Watershed Protection Approach. EPA's Watershed Protection Approach is governed by the principle that many water quality and ecosystem problems are best solved at the larger watershed levels rather than on the smaller, individual waterbody or discharger level. The Watershed Protection Approach increases the ability to identify and target priority problems, promotes broader stakeholder involvement, integrates solutions which use all available expertise and provides a better measure of success through the use of data and monitoring. Managing water resources on a watershed basis makes sense environmentally, financially and socially.

As indicated in the data assessment found in the appendices at the Christina TMDL web site, the nutrient concentrations of the tidal Christina River are heavily influenced by tributary loads from the Brandywine Creek, Red and White Clay Creeks and nontidal Christina River. The data analysis also indicates that DO concentrations within the tidal Christina River violate both the minimum and daily average WQS during critical conditions. In addition to the influential nutrients loads from tributaries, spatial data analysis indicates that high levels of phytoplankton biomass are likely the result of transport from inland tributaries. In any case, the nutrient and biomass loadings from inland tributaries contribute to the DO WQS violations within the tidal Christina River. This further justifies the need to consider sources of pollutants and tributaries on a watershed basis, regardless of whether that waterbody is explicitly listed on a state's 303(d) list.

Excess nutrients in a waterbody can have many detrimental effects on designated or existing uses, including drinking water supply, recreational use, aquatic life use and fishery use[4] Eutrophication, a term usually associated with the natural aging process experienced by lakes, describes the excessive nutrient enrichment of streams and rivers which can experience an undesirable abundance of plant growth, particularly phytoplankton (photosynthetic microscopic organisms (algae)), periphyton (attached benthic algae) and macrophytes (large vascular rooted plants). Photosynthesis and respiration of these plants as well as the microbial breakdown of dead plant matter contribute to wide fluctuations in the DO levels in streams. The impact of low DO concentrations or of anaerobic conditions is reflected in an unbalanced ecosystem, fish mortality, odors and other aesthetic nuisances[5]. These types of impairments interfere with the designated uses of waterbodies by disrupting the aesthetics of the river, causing harm to inhabited aquatic communities and causing violations of applicable water quality criteria. Figure 5 below shows the interrelationship of the major processes which affect DO.

---

[4] U.S. Environmental Protection Agency. 1999. Protocol for Developing Nutrient TMDLs. Pg 2-1. EPA 841-B-99-007. Office of Water (4503F). U.S. EPA, Washington D.C. 135pp.

[5] Thomann, R.V., J.A. Mueller. 1987 Principles of Surface Water Quality Modeling. HarperCollins Publishers, Inc. Section 6.1.

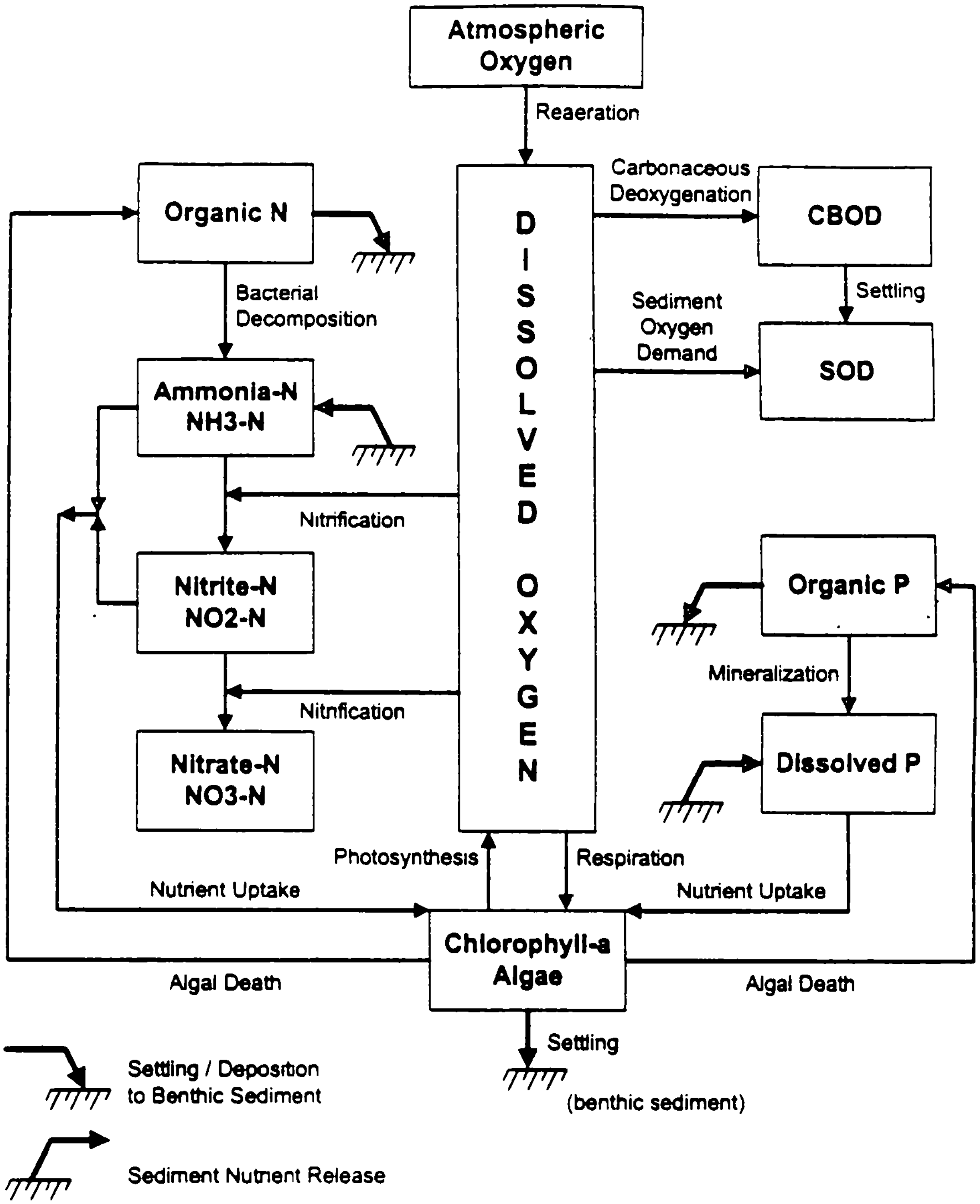


Figure 5. Interrelationship of major kinetic processes for BOD, DO, and nutrients as represented by water quality models (adapted from EPA 823-B-97-002).

The presence of aquatic plants in a waterbody can have a profound effect on the DO resources and the variability of the DO throughout a day or from day to day[6]. Growing plants provide a net addition of DO to the stream on an average daily basis through photosynthesis, yet respiration can cause low DO levels at night that can affect the survival of less tolerant fish and aquatic life species. This is due to the photosynthetic and respiration processes of aquatic plants which can cause large diurnal variations in DO that are harmful to fish and aquatic life. Photosynthesis is the process by which plants utilize solar energy to convert simple inorganic nutrients into more complex organic molecules[7]. Due to the need for solar energy, photosynthesis only occurs during daylight hours and is represented by the following simplified equation (proceeds from left to right):

$$\underset{\text{(Carbon Dioxide)}}{6CO_2} + \underset{\text{(Water)}}{6H_20} \longleftarrow\!\!\!-\!\!-\!\!-\!\!\longrightarrow \underset{\text{(Sugar)}}{C_6H_{12}0_6} + \underset{\text{(Oxygen)}}{60_2}$$

In this reaction, photosynthesis is the conversion of carbon dioxide and water into sugar and oxygen such that there is a net gain of DO in the waterbody. Conversely, respiration and decomposition operate the process in reverse and convert sugar and oxygen into carbon dioxide and water resulting in a net loss of DO in the waterbody. Respiration and decomposition occur at all times and are not dependent on solar energy. Also, if environmental conditions cause a die-off of either microscopic or macroscopic plants, the decay of biomass can cause severe oxygen depressions. Waterbodies exhibiting typical diurnal variations of DO experience the daily maximum in mid-afternoon during which photosynthesis is the dominant mechanism and the daily minimum in the predawn hours during which respiration and decomposition have the greatest effect on DO and photosynthesis is not occurring. Therefore, excessive plant growth, as a result of excessive nutrients, can affect a streams ability to meet both average daily and instantaneous DO standards[8].

Sediment oxygen demand (SOD) is due to the oxidation of organic matter in bottom sediments[9]. The organic matter originates from various sources including wastewater treatment facilities, leaf litter, organic-rich soil or photosynthetically produced plant matter which settles and accumulates. In some instances, SOD can be significant portion of total oxygen demand, particularly in small streams where the effects may be more pronounced during low-flow or high

---

[6] Supra, footnote 5. (Thomann, Mueller) Section 6.3.3.

[7] Chapra, S.C. 1997. Surface Water-Quality Modeling. WCB/McGraw-Hill. Section 19.1.

[8] U.S. Environmental Protection Agency. 1997. Technical Guidance Manual for Developing Total Maximum Daily Loads, Book 2: Streams and Rivers, Part 1: Biochemical Oxygen Demand/Dissolved Oxygen and Nutrients/Eutrophication. Office of Water(4305). EPA 823-B-97-002. Section 4.2.1.2.

[9] Supra, footnote 7. (Chapra) Section 25

temperature conditions[10].

Biochemical Oxygen Demand (BOD) is a measure of the amount of oxygen required to stabilize organic matter in wastewater[11]. It is typically determined from a standardized test measuring the amount of oxygen available after incubation of the sample at 20°C for a specific length of time, usually five days. Conceptually, BOD requires a distinction between the oxygen demand of the carbonaceous material in waste effluents and the nitrogenous oxygen demanding component of an effluent[12]. Carbonaceous biochemical oxygen demand (CBOD) involves the breakdown of organic carbon compounds while nitrogenous biochemical oxygen demand (NBOD) involves the oxidation of ammonia to nitrate, referred to as the nitrification process[13].

VI. Christina River Basin Water Quality Model

Thomann and Mueller[14] define a model as "a theoretical construct, together with assignment of numerical values to model parameters, incorporating some prior observations drawn from field and laboratory data, and relating external inputs or forcing functions to system variable responses." In order to evaluate the linkage between the applicable water quality criteria numbers (endpoints) and the identified sources and establish the cause-and-effect relationships, EPA is utilizing the EFDC water quality model. EFDC is a public domain surface water modeling system incorporating fully integrated hydrodynamic, water quality and sediment-contaminant simulation capabilities.

EFDC is extremely versatile and can be applied in 1,2, or 3 dimensional simulation of rivers, lakes and estuaries with coupled salinity and temperature transport. Further capabilities of the model include a directly coupled water quality-eutrophication and toxic contaminated sediment transport and fate models, integrated near-field mixing zone model, as well as pre- and post-processing for input file creation, analysis and visualization. The eutrophication component of EFDC can simulate the transport and transformation of 22 state variables including cyanobacteria, diatom algae, green algae, refractory particulate organic carbon, labile particulate organic carbon, dissolved carbon, refractory particulate organic phosphorus, labile particulate organic phosphorus, dissolved organic phosphorus, total phosphate, refractory particulate organic nitrogen, labile particulate organic nitrogen, dissolved organic nitrogen, ammonia nitrogen, nitrate nitrogen, particulate biogenic silica, dissolved available silica, chemical oxygen demand, dissolved oxygen, total active metal, fecal coliform bacteria and macroalgae. The EFDC model

---

[10] Supra, footnote 8. (EPA Guidance Manual for Developing TMDLs) Section 2.3.4.4.

[11] Supra, footnote 8. (EPA Guidance Manual for Developing TMDLs) Section 2.3.4.

[12] Supra, footnote 5. (Thomann, Mueller) Section 6.3.1.

[13] Supra, footnote 7. (Chapra) Section 19.4.

[14] Supra, footnote 5. (Thomann, Mueller) Section 1.2.1.

has been used in similar water quality studies including the Peconic Estuary, the Indian River Lagoon/Turkey Creek and the Chesapeake Bay system and the EFDC model was used to develop TMDLs for waterbodies in Oklahoma and Georgia, including Wister Lake, OK (2000), and the St. Mary's and Suwanee Watersheds, GA (2000).

In order to ensure that the EFDC model is adequately representing the hydrodynamic and water quality processes of the Christina River Basin, separate calibration and validation of the model was performed to establish model robustness[15]. Calibration involves adjusting kinetic parameters within the model to achieve a specified level of performance in comparison to actual observed hydrodynamic and water quality data from a basin. Data from a site-specific field study (Davis 1998) were used to establish certain kinetic parameters, e.g., the phosphorus half-saturation constant for periphyton. The model calibration was executed over a period of 143 days from May 1 to September 21, 1997. EPA also validated the Christina River Basin model to confirm and provide additional confidence that the model can be used as an effective prediction tool for a range of conditions other than those in the original calibration. During validation, the kinetic parameters which were adjusted during calibration remain fixed to evaluate the model accuracy in representing the Christina River Basin. The model validation was executed over a period of 143 days from May 1 to September 21, 1995. Point source loads during calibration and validation are representative of actual discharged loads as listed on Discharge Monitoring Reports (DMRs) during the calibration or validation periods. Nonpoint source loads are based on STORET data, USGS water quality data, baseflow sampling, and data from interstate monitoring efforts during the calibration or validation periods. These loads represent contributions from nonpoint sources and form the basis of the load allocations.

EPA also provides an assessment of the calibration and validation quality. There are two general approaches for assessing the quality of a calibration: subjective and objective[16]. The subjective assessment typically involves visual comparison of the simulation with the data, as in time series plots for state variables, while the objective assessment utilizes quantitative measures of quality such as statistical measures of error. EPA included both types of assessment and compared the Christina River Basin model error statistics with those from other similar studies. The Christina River Basin model compares very favorably as discussed in Section 11 of the *Hydrodynamic and Water Quality Model of Christina River Basin Final Report, May 31, 2000.* A complete and more-detailed technical discussion of the EFDC model is available in this report.

The calibrated and validated water quality model was used to confirm that the model was able to simulate the locations of the impaired stream segments on the 303(d) lists. The model results from the 1997 calibration run were plotted on a map view of the Christina River Basin and those model grid cells not meeting the daily average and minimum DO water quality criteria were highlighted (see Figures 6 and 7). The 1997 calibration results indicate that the daily average DO criteria were not met in portions of the tidal Christina River, tidal Brandywine

---

[15] Supra, footnote 7. (Chapra) Section 18.1.5.

[16] Supra, footnote 7. (Chapra) Section 18.3

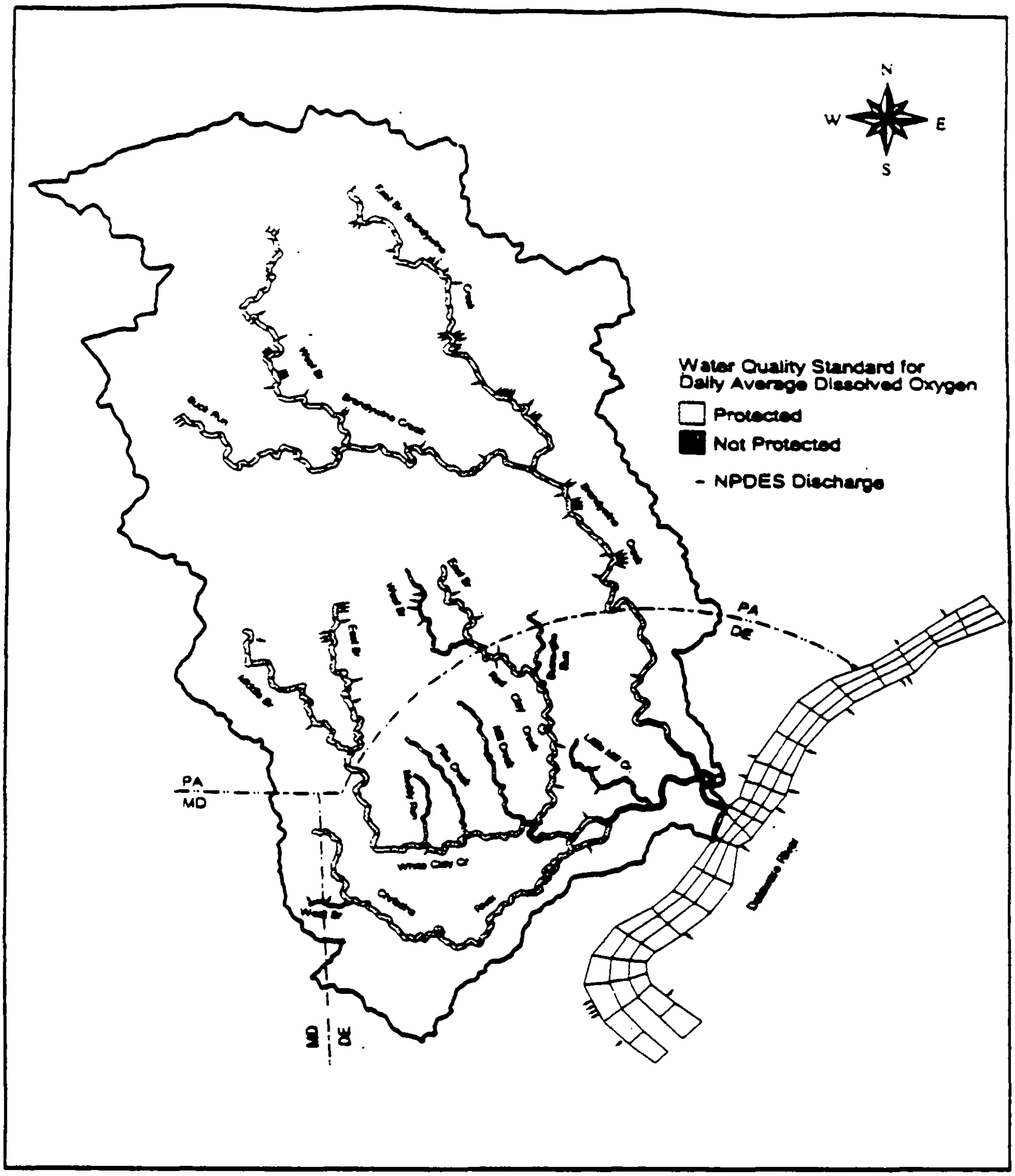


Figure 6 Modeled stream segments violating daily average dissolved oxygen water quality criteria based on the EFDC model using 1997 calibration data.

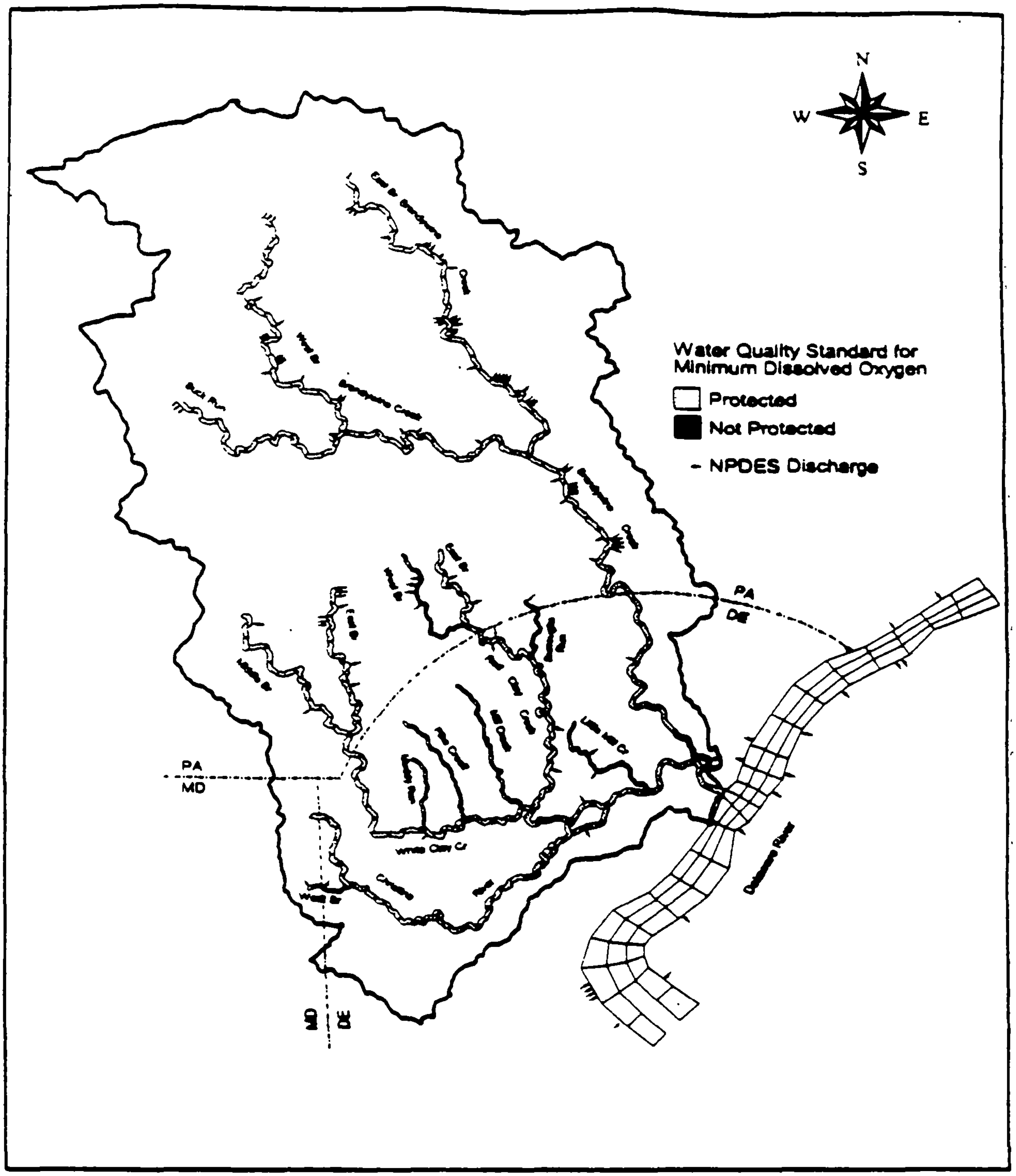


Figure 7 Modeled stream segments violating minimum dissolved oxygen water quality criteria based on the EFDC model using 1997 calibration data.

Creek, tidal White Clay Creek, West Branch Red Clay Creek and Little Mill Creek (Figure 6). The 1997 results also indicate that the minimum DO criteria were not protected in portions of the West Branch Red Clay Creek, Little Mill Creek and tidal Brandywine Creek (Figure 7).

A separate analysis was performed to investigate potential WQS violations during critical conditions. During this scenario, the NPDES point source discharges were set to their maximum permitted flows and concentrations and the model was run under 7Q10 (minimum 7-day flow expected to occur every 10 years) stream flow conditions. Nonpoint source pollutant loads, as computed by multiple data sets, were developed to represent expected conditions and pollutant contributions during critical periods. The use of actual site-specific data to characterize nonpoint sources is appropriate and would essentially act to integrate past pollutant loading events. While the process of calibrating and validating the water quality model was dynamic, the critical condition analysis is representative of steady-state conditions. Tidal elevations at the north and south boundaries on the Delaware River were set using tidal harmonic constants derived from NOAA subordinate tide stations at Chester, Pennsylvania, and Reedy Point, Delaware. Map-view graphics were created to highlight problem areas (see Figures 8 and 9).

The model results for the period August 1 through August 31 when critical stream flows are most likely to occur (while August was used, it is possible for the critical conditions to occur at other times) indicate that the daily average DO criteria will not be satisfied in portions of the West Branch Brandywine Creek, West Branch Red Clay Creek, West Branch Christina River and tidal Christina River (Figure 8). The model results also indicate that the minimum DO criteria will not be achieved in portions of the West Branch Brandywine Creek, East Branch Brandywine Creek below Downingtown and West Branch Red Clay Creek (Figure 9).

The tidal estuary portion of the EFDC model is used to characterize the Delaware River Estuary and consider potential impacts to water quality within the Christina River Basin from pollutant loads to the estuary. Of the 122 NPDES dischargers evaluated in this TMDL assessment, 23 are point sources discharging to the Delaware River which were considered in the linkage analysis. In considering which dischargers to include, the spatial range was limited to about 10 miles above and below the confluence of the Christina River and the Delaware River due to the tidal excursion, which is approximately eight miles.

While this TMDL analysis and subsequent allocation scenarios are designed to address low-flow conditions and the contributions from the primary sources (point sources), the analysis includes land-based nonpoint sources. As discussed further below, because at low-flow conditions there are no significant nonpoint source contributions, the nonpoint source allocation is included as part of the background loading. Addressing this critical condition establishes the baseline condition which point sources within the Christina River Basin must comply with in order to achieve WQS (for example, DEP uses the 7Q10 analysis as the basis for assuring that WQS will be met 99% of the time).

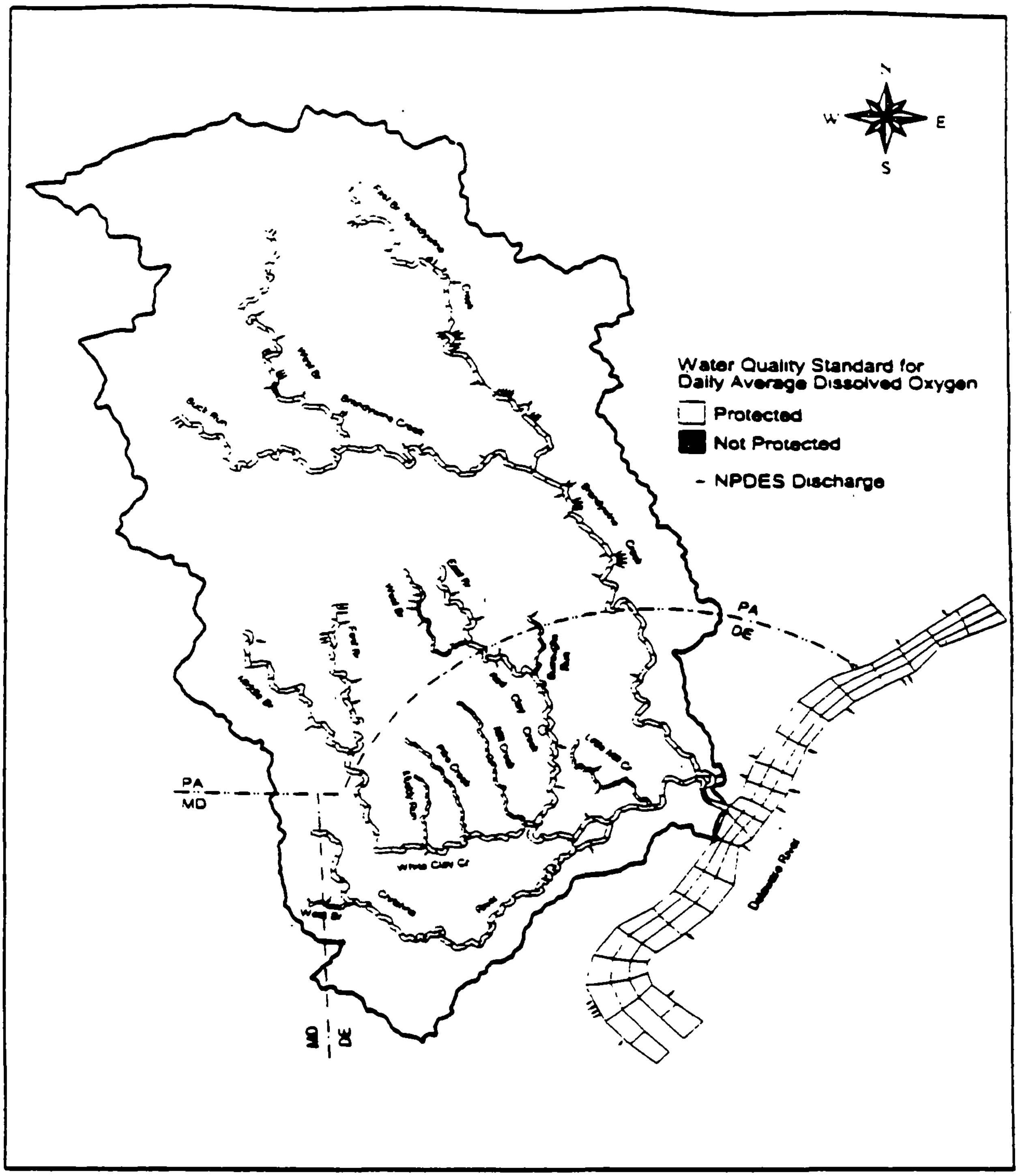


Figure 8 Modeled stream segments violating daily average dissolved oxygen water quality criteria based on the EFDC model during critical conditions.

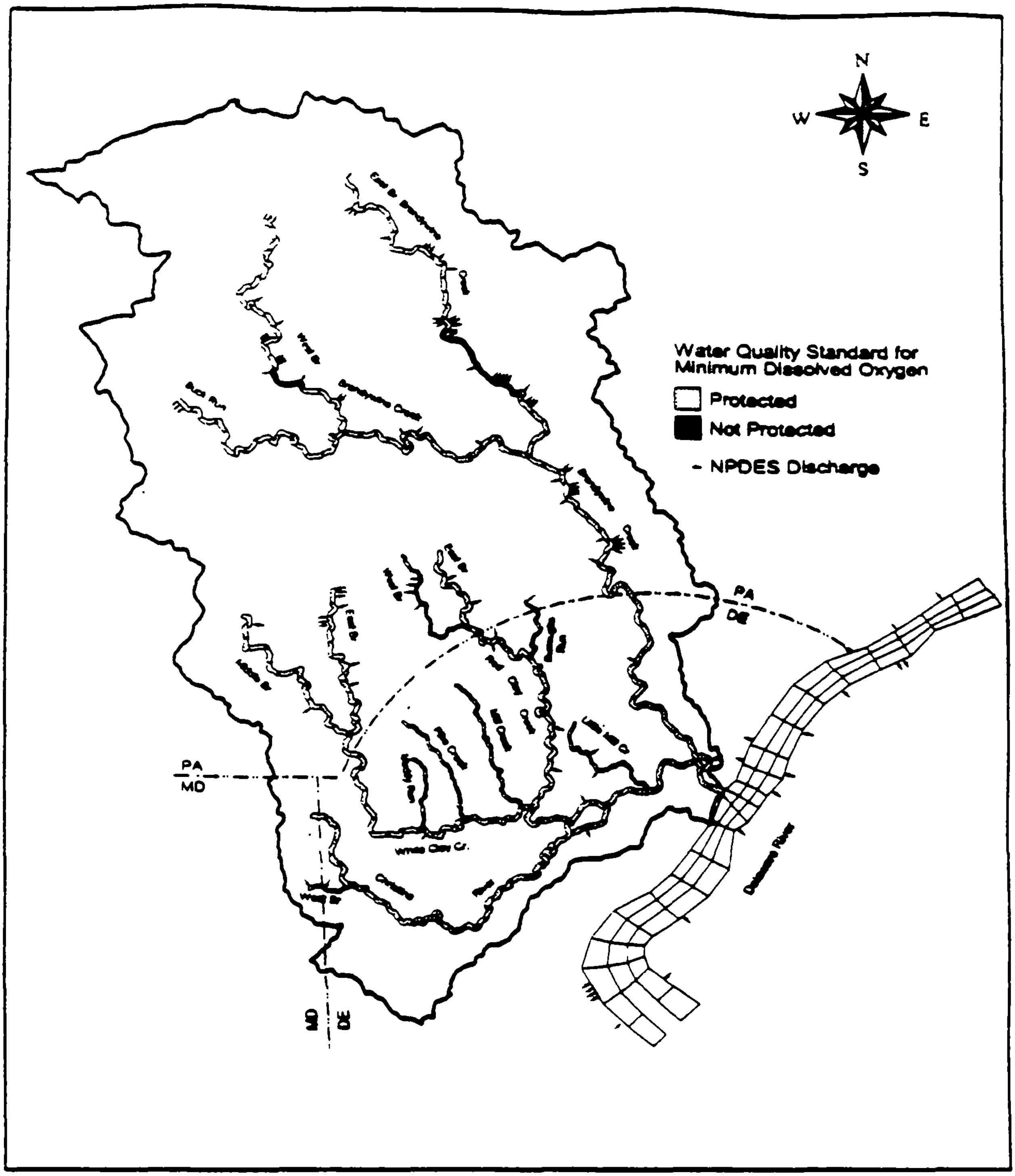


Figure 9 Modeled stream segments violating minimum dissolved oxygen water quality criteria based on the EFDC model during critical conditions.

The stream reaches identified by the model as not meeting DO criteria are in general agreement with those on the 303(d) lists. EPA believes that the Christina River Basin model is an appropriate tool for understanding the current water quality problems in the Christina River Basin, evaluating the linkage between cause-and-effect and allocating pollutant loads to identified sources.

VII. Discussion of Regulatory Conditions

Federal regulations at 40 CFR Section 130 require that TMDLs must meet the following eight regulatory conditions:

1) The TMDLs are designed to implement applicable water quality standards.
2) The TMDLs include a total allowable load as well as individual waste load allocations and load allocations.
3) The TMDLs consider the impacts of background pollutant contributions.
4) The TMDLs consider critical environmental conditions.
5) The TMDLs consider seasonal environmental variations.
6) The TMDLs include a margin of safety.
7) The TMDLs have been subject to public participation.
8) There is reasonable assurance that the TMDLs can be met.

EPA provides the following information to demonstrate how the Christina River Basin TMDLs meet these eight regulatory requirements.

1) The TMDLs are designed to implement applicable water quality standards.

Target Analysis

The CWA requires states to adopt WQS to define the water goals for a waterbody by designating the use or uses to be made of the water, by setting criteria necessary to protect the uses and by protecting water quality through antidegradation provisions. These standards serve dual purposes: they establish water quality goals for a specific waterbody, and they serve as the regulatory basis for establishing water quality-based controls and strategies beyond the technology-based levels of treatment required by sections 301(b) and 306 of the CWA[17].

Within the Christina River Basin, there are four regulatory agencies which have applicable WQS. The DEP, DNREC, and MDE have WQS which apply to those stream segments of the Christina River Basin located in the respective state. The DRBC[18] is an

[17] U.S. Environmental Protection Agency. 1994. Water Quality Standards Handbook: Second Edition. Office of Water(4305). EPA 823-B-94-005a. Section 2.1.

[18] The DRBC was created by compact among Pennsylvania, New Jersey, New York, Delaware and the federal government in 1961.

interstate agency which has the authority to establish WQS and regulate pollution activities within the Delaware River Basin including the Christina River Basin, one of the Delaware River's tributary basins. Tables 5 and 6 below summarizes the applicable WQS relating to DO and nutrients.

Table 5. Summary of Applicable Use Designations and DO Criteria

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Warm water fish (WWF)	5.0	4.0	
	Cold water fish (CWF)	6.0	5.0	
	Trout stocking fishery (TSF)	6.0	5.0	Feb 15 - Jul 31
		5.0	4.0	Aug 01 - Feb 14
	High Quality CWF		7.0	Special Protection Waters
	High Quality TSF	6.0	5.0	Special Protection Waters
	Exceptional value			Special Protection Waters
[illegible]	Fresh waters	5.5*	4.0	*Average for June-September period shall not be less than 5.5 mg/L
	Cold water fish	6.5	5.0	Seasonal
	Marine waters	5.0	4.0	Salinity greater than 5.0 ppt
	Exceptional recreation or ecological significance			Existing or natural water quality
[illegible]	Fresh waters	5.0	5.0	Use I waters, DO must not be less than 5.0 mg/L at any time
[illegible]	Resident game fish	5.0	4.0	
	Trout	6.0	5.0	
			7.0	During spawning season
	Tidal: resident or anadromous fish	4.5		6.5 mg/L seasonal average during Apr 01 - Jun 15 and Sep 16 - Dec 31

Table 6. Summary of Nutrient Criteria

Parameter Agency	Comments
Ammonia-Nitrogen*	
DEP	1-day and 30-day average ambient criteria are a function of pH and temperature for toxicity; Implementation Guidance document for Ammonia allocations for NBOD and Toxicity.
DNREC	No specific numeric criteria; Narrative statement for prevention of toxicity.
DRBC	NPDES effluents limited to a 30-day average of 20 mg/L as N.
Nitrate-Nitrogen	
DEP	Ambient criteria is maximum of 10 mg/L as N applied at the point of water supply intake, not at the point of an effluent discharge. For the case of an interstate stream, the state line shall be considered a point of water supply intake.
DNREC	Ambient nitrate criteria is maximum of 10 mg/L as N; provision for site-specific nutrient controls. The DNREC 303(d) rationale document cites 3.0 mg/L total nitrogen as guidance for determining impairment.
DRBC	No specific numeric criteria.
Phosphorus	
DEP	No specific numeric criteria are specified in the Pennsylvania Code, Title 25, Chapter 93 (Water Quality Standards). According to Chapter 95 (Wastewater Treatment Requirements), phosphorus effluent limits are set to a maximum of 2 mg/L whenever the Department determines that instream phosphorus alone or in combination with other pollutants contributes to impairment of designated stream uses.
DNREC	No specific numeric criteria; provision for site specific controls. The 303(d) rationale document cites 0.1 mg/L total phosphorus as guidance for use impairment.
DRBC	No specific numerical criteria.

*** - the state of Maryland adopted the EPA water quality criteria for ammonia nitrogen in January 2001 (effective April 2001 - Title 26 Maryland Department of the Environment Subtitle 08 Water Pollution Chapter 02 Water Quality). This was approved by EPA in June 2001.**

Once EPA identifies the applicable use designation and water quality criteria, EPA determines the numeric water quality target or goal for the TMDL. These targets represent a number where the applicable water quality is achieved and maintained. In these TMDLs, the target is to attain and maintain the applicable DO water quality criteria at low-flow conditions. Figure 10 below shows the applicable use designations for stream segments included in the Christina River Basin TMDL. Using Tables 5 and 6 and Figure 10, the numeric water quality targets for DO can be identified for each segment. Table 7 below identifies the general water quality targets or endpoints for the Christina River Basin TMDLs.

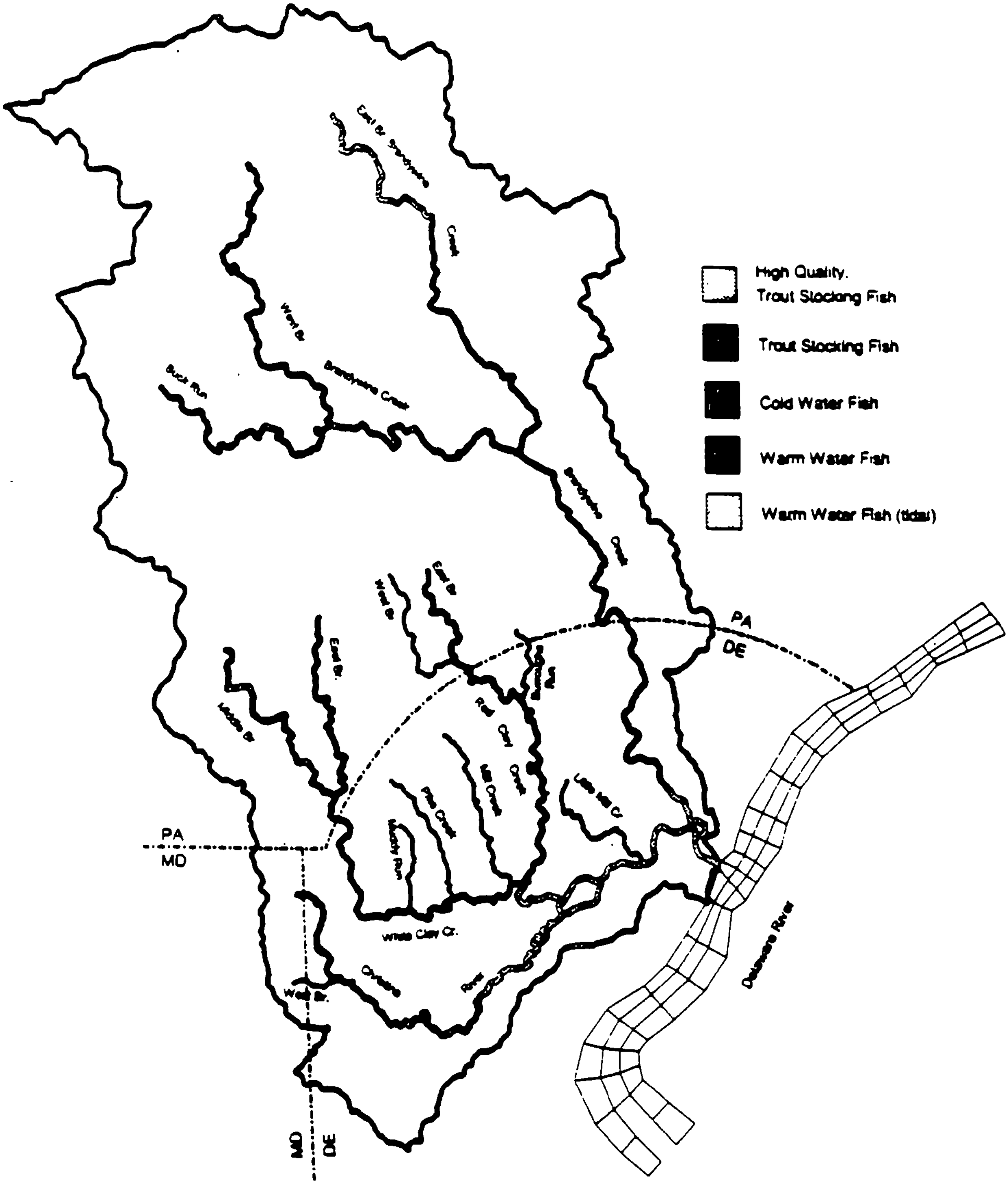


Figure 10 Applicable use designations for stream segments in the Christina River Basin

Table 7. Summary of TMDL Endpoints

Parameter	Target/Limit	Reference
Daily Average DO, freshwater, Pennsylvania	5.0 mg/L	Pennsylvania Water Quality Standards
Daily Average DO, freshwater, Delaware	5.5 mg/L	Delaware Water Quality Standards
Daily Average DO, tidal waters, Delaware	5.5 mg/L	Delaware Water Quality Standards
DO at any time, freshwater, Maryland	5 0 mg/L	Maryland Water Quality Standards
Minimum DO	4.0 mg/L	Pennsylvania and Delaware Water Quality Standards

In addition to the TMDL DO endpoints summarized in Table 7, there are higher DO WQS for certain Christina River Basin segments during the critical conditions time periods considered in these low-flow TMDLs. Generally, these segments were either not listed on 303(d) lists for point source impacts or found not to be impacted by point source discharges in the TMDL evaluations. The results of the TMDL model runs, incorporating the proposed TMDL reductions, indicate that these higher DO WQS will be protected. This information is summarized in a series of data plots showing DO levels and WQS for the major segments in the Christina River Basin found in Appendix A1 of this document.

These TMDLs have also identified the pollutants and sources of pollutants that cause or contribute to the impairment of the DO criteria and allocate appropriate loadings to the various sources. Given our scientific knowledge regarding the interrelationship of nutrients, BOD, SOD and their impact on DO, EPA determined it necessary and appropriate to establish numeric targets for total nitrogen and total phosphorus based on applicable state narrative criteria to support the attainment of the numeric DO criterion. Likewise, to maintain adequate instream levels of DO at low-flow conditions, EPA found it necessary and appropriate to develop as part of these TMDLs waste load allocations (WLAs) for total phosphorus, total nitrogen, ammonia-nitrogen, CBOD, and DO for point sources. Establishing numeric water quality endpoints or goals also provides the ability to measure the progress toward attainment of the WQS and to identify the amount or degree of deviation from the allowable pollutant load.

One Christina River Basin segment, the East Branch White Clay Creek, has been designated as Exceptional Value waters by Pennsylvania. In addition to TMDL results showing the DO WQS for this segment will be protected, the East Branch White Clay Creek is afforded additional protection of water quality conditions through the regulatory provisions of the Pennsylvania antidegradation program (25 PA Code Chapter 93.4 (c)) and 40 CFR 131.32.

While the ultimate endpoint for this TMDL analysis is to ensure that the WQS for DO are maintained throughout the Christina River Basin, it is necessary to determine if other applicable water quality criteria are met and maintained. Specifically, this applies to the Pennsylvania WQS for nitrate-nitrogen of 10 mg/l and ammonia-nitrogen which is based on temperature and pH and the Maryland WQS for ammonia-nitrogen. As a result of the pollutant load reductions necessary to maintain the water quality criteria for DO, the WQS for nitrate-nitrogen and ammonia-nitrogen of Pennsylvania and Maryland were also evaluated. The ammonia-nitrogen standard is met throughout the Pennsylvania portion of the Christina River Basin. The only instances where the 10 mg/l nitrate nitrogen value is exceeded are small distances on the East Branch Brandywine Creek and West Branch Brandywine Creek. As there are no drinking water withdrawals at these locations, the standard is not applicable and additional reduction is not necessary. The ammonia-nitrogen WQS in Maryland was not met during the initial point source evaluation and required treatment reductions at one facility in the West Branch Christina River.

Delaware WQS also set a numeric water quality criteria of 10 mg/l for nitrate-nitrogen. The WQS for nitrate-nitrogen of Delaware are met throughout the Delaware portion of the Christina River Basin. Delaware does not have numeric water quality criteria for ammonia-nitrogen, however, the analysis indicates that ammonia-nitrogen levels throughout the Delaware portion of the Christina River Basin are consistent with the recommended EPA water quality criterion from Section 304(a) of the CWA.

Achieving these in-stream numeric water quality targets will ensure that the designated uses (aquatic life and human health uses) of waters in Pennsylvania, Delaware, and Maryland are supported during critical conditions.

2) The TMDLs include a total allowable load as well as individual waste load allocations and load allocations.

Total Allowable Load

The total allowable load for each portion of the Christina River Basin, as determined by the EFDC model, was calculated based on the segmentation of the model in order to better correspond with the 303(d) listing, ensure the integrity of each stream segment and to allow pollution trading alternatives (for this low-flow TMDL, trading options may be limited to alternate WLA scenarios among affected point source dischargers. See the discussion under Allocation Scenarios on Pages 48-49.) Table 8 below identifies the total allowable load as well as the WLAs, load allocations and margin of safety (MOS) for each of the 16 stream segments of the model.

Table 8
TMDL Summary by Subwatershed for the Christina River Basin

Sum of Individual Waste Load Allocations					
Subwatershed	CBOD5 lb/day	NH3-N lb/day	[illegible]	[illegible]	[illegible]
Brandywine Creek main stem	79.72	16.82	43.04	9.00	26.74
Brandywine Creek East Branch	1,022.79	157.30	3,562.99	118.76	523.97
Brandywine Creek West Branch	600.16	124.15	1,218.68	69 48	.257.01
Buck Run	7.55	0.79	1.91	0.61	1.53
Brandywine Creek Watershed	**1,710.22**	**299.06**	**4,826.62**	**197.85**	**809.25**
Christina River West Branch	75.57	13.57	125.33	6.26	37.56
Little Mill Creek	0.00	0.00	0.00	0.00	0.00
Christina River main stem	0.00	0.00	0.00	0.00	0.00
Christina River Watershed	**75.57**	**13.57**	**125.33**	**6.26**	**37.56**
Burroughs Run	0.04	0.01	0.02	0.01	0.03
Red Clay Creek West Branch	162.32	19.44	46.94	12.83	71.36
Red Clay Creek main stem	108.96	4.81	11.61	75.52	112.11
Red Clay Creek Watershed	**271.32**	**24.26**	**58.57**	**88.36**	**183.50**
White Clay Cr. Middle Branch	53.83	10.52	25.46	4.51	11.27
White Clay Cr. East Branch	88.78	8.69	149.67	11.23	16.17
Muddy Run	0.00	0.00	0.00	0.00	0.00
Pike Creek	0.00	0.00	0.00	0.00	0.00
Mill Creek	0.00	0.00	0.00	0.00	0.00
White Clay Cr. main stem	0.75	0.03	0.06	0.03	1.25
White Clay Creek Watershed	**143.36**	**19.24**	**175.19**	**15.77**	**28.69**
Total Waste Load Allocation for Point Sources in Christina River Basin	**2,200.47**	**356.13**	**5,185.71**	**308.24**	**1,059.00**

Table 8 (continued)
TMDL Summary by Subwatershed for the Christina River Basin

Sum of Load Allocations					
Subwatershed	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Brandywine Creek main stem	52.01	1.78	137.30	1.50	497.95
Brandywine Creek East Branch	162.33	3.85	248.01	3.35	1,333.95
Brandywine Creek West Branch	99.18	3.08	262.94	2.77	958.41
Buck Run	34.72	0.96	92.45	0.94	338.75
Brandywine Creek Watershed	**348.24**	**9.67**	**740.69**	**8.55**	**3,129.05**
Christina River West Branch	1.17	0.02	0.82	0.02	5.94
Little Mill Creek	36.27	0.52	25.38	0.51	186.02
Christina River main stem	34.99	1.65	26.85	0.86	163.08
Christina River Watershed	**72.43**	**2.19**	**53.05**	**1.38**	**355.05**
Burroughs Run	4.60	0.10	9.10	0.21	33.65
Red Clay Creek West Branch	20.05	0.42	39.68	0.90	146.87
Red Clay Creek main stem	40.10	0.91	79.24	1.83	292.00
Red Clay Creek Watershed	**64.75**	**1.43**	**128.02**	**2.94**	**472.52**
White Clay Cr Middle Branch	20.80	0.67	58.11	0.66	237.96
White Clay Cr East Branch	23.44	0.77	65.42	0.74	267.66
Muddy Run	3.23	0.11	9.00	0.10	36.80
Pike Creek	5.57	0.19	15.52	0.18	63.40
Mill Creek	7.64	0.26	21.31	0.24	87.06
White Clay Cr main stem	17.96	0.68	49.76	0.59	201.98
White Clay Creek Watershed	**78.64**	**2.68**	**219.12**	**2.51**	**894.86**
Total for LA Christina River Basin	**564.06**	**15.97**	**1,140.88**	**15.38**	**4,851.48**
Margin of Safety	Implicit through conservative assumptions				
TMDL for Christina River Basin	2,764.53	372.10	6,326.59	323.62	5,910.47

Note: Totals subject to rounding variations.

Deposition from atmospheric sources is also considered in the Christina River Basin water quality model. While atmospheric deposition may not be as important in the narrow stream channels, it could become more important in the open estuary waterbodies in the lower Christina and Delaware rivers. Atmospheric loads are typically divided into wet and dry deposition. Wet deposition is associated with dissolved substances in rainfall. The settling of particulates during non-rainfall events contributes to dry deposition. Observations of concentrations in rainwater are frequently available and dry deposition is usually estimated as a fraction of the wet deposition. The atmospheric deposition rates reported in the Long Island Sound Study (HydroQual 1991) and the Chesapeake Bay Model Study (Cerco and Cole 1994) as well as information provided by DNREC for Lewes, Delaware, were used to develop both dry and wet deposition loads for the EFDC model of the Christina River Basin. Atmospheric deposition loads are included in Tables 12-28 as well as in the summary watershed calculations provided in Table 8.

Size-Based Equal Marginal Percent Removal Allocation Strategy

The general theory of WLAs, and more specifically the size-based equal marginal percent removal (EMPR) allocation strategy that is used for these TMDLs, is discussed in this section. While a complete and detailed understanding of the concepts discussed below is not essential to using the Christina River Basin water quality model, a general appreciation of underlying principles will aid the user in applying the model and interpreting the results. The strategy presented in this section is based largely upon the document *Implementation Guidance for the Water Quality Analysis Model 6.3* (Pennsylvania DEP 1986). While EPA has many ways of allocating pollutant loads, based on this discussion EPA determined the EMPR strategy to be sound, fair and consistent with the goals of the CWA.

The term "waste load allocation" refers to a specific set of circumstances in which two or more point source discharges are in sufficiently close proximity to one another to influence the level of treatment each must provide to comply with WQS. This definition is technically correct since without discharge interaction there is no need to share (i.e., to allocate) the assimilation capacity of the receiving water body. In a single discharge situation, all that needs to be done is to determine the level of treatment that must be provided to comply with WQS. The size-based EMPR analysis does this as a first step: (1) to determine if a WLA situation exists; and if it does, (2) to assign WLAs to each of the discharges that is contributing to the water quality violation. A WLA should have three major objectives: (1) to assure compliance with the applicable WQS; (2) to minimize, within institutional and legal constraints, the overall cost of compliance; and (3) to provide maximum equity (or fairness) among competing discharges.

The first objective, is fundamental to water quality and public health protection. It is an ethical statement that assumes the social, economic and environmental benefits of water pollution control outweigh the associated costs. This is consistent with the goals and requirements of the CWA.

The second objective is a statement of the desirability of economic efficiency. Resources devoted to one purpose are not available for another use. This holds true whether the resources are of a public or a private nature. It therefore behooves a water quality management program to achieve water quality management goals with maximum economic efficiency (i.e., at least cost). It can be shown that maximum efficiency is achieved when the marginal cost of pollution abatement is the same for all participants. The marginal cost of wastewater treatment is related to the marginal rate of removal. If it is assumed that the marginal cost per unit of removal is the same for all discharges, then maximum economic efficiency is achieved when the marginal rate of removal for all discharges is the same. Institutional and legal constraints may prevent water quality programs from achieving optimal economic efficiency. Nevertheless, maximum efficiency within existing institutional and legal constraints should be pursued.

The third objective is a social statement that goes hand in hand with the second objective. Maximizing economic efficiency would by definition, provide for maximum equity. The desirability of equity, especially in a regulatory program, among individual (and potentially competing) members of society is a reasonably well accepted concept. The specific definition of when (or how) equity is to be achieved is, however, open to debate and interpretation. The WLA strategy employed in this TMDL is that of EMPR. It is based on the premise that all dischargers, whether or not they are part of a WLA scenario, should provide sufficient treatment to comply with WQS, and that some dischargers, because they are part of an allocation scenario, must provide additional treatment, due to the cumulative impact that they and nearby dischargers have on the receiving stream.

The strategy is similar in most respects to more traditional uniform treatment approaches, where all dischargers provide the same degree of treatment. The major difference is in the selection of the baseline condition for the WLA process. In most traditional uniform treatment approaches all dischargers that are believed to be part of the WLA start at the same treatment level. The traditional approach introduces economic inefficiencies and inequities into the WLA process because it fails to consider the individual impact that each discharger has on the receiving stream. This individual impact is a function of the discharge size and location. The practical result of failing to take these factors into consideration is to impose unnecessarily stringent treatment requirements on smaller dischargers, solely because they happen to be in the vicinity of a larger discharger. This imposes higher than necessary costs on these smaller dischargers, and in effect, causes them to subsidize dischargers that have a greater impact on water quality. At the same time, uniform treatment does not significantly improve overall water quality.

In the size-based EMPR strategy, the baseline condition for each discharger is the level of treatment the discharge must provide if it is the only discharger to the receiving stream. This level of treatment is water quality based for this TMDL. It is a function of the discharge size and location. In selecting this baseline condition, there are no assumptions made as to whether a discharger is or is not part of an allocation scenario.

Once the baseline condition for each discharger is established, a determination is made of whether additional treatment is needed because of the cumulative impact of multiple discharges. The dischargers are added back into the model one at a time, based on the size of their load (i.e., kg/day of CBOD). The model is then run again. If additional treatment is necessary, then all dischargers contributing to the WQS violations are reduced by equal percentages, starting from their individual levels of treatment at the end of the previous model run. Thus, the marginal rate of removal for all affected dischargers is the same in any given model run, while the overall rate of removal for each may be different.

Another difference between the traditional uniform treatment approach and the size-based EMPR strategy is in the determination of which dischargers are part of the WLA scenario. In the uniform treatment approach, it is commonly assumed that the WLA segment starts at the first discharger that adversely affects in-stream conditions, and extends downstream to the point where the stream returns to background conditions. It is not entirely clear whether this assumption is absolutely required, or is merely a matter of convenience. In either case, the specification of a return to background stream quality tends to extend the allocation segment to include dischargers that may not be part of the allocation at all. This further increases the economic inefficiency and inequity of uniform treatment solutions.

The size-based EMPR WLA does not require any assumptions with regard to a return to background stream conditions. The strategy determines the downstream limit of the allocation problem based on compliance with WQS. These features, combined with the different baseline condition, makes size-based EMPR a more cost-efficient and equitable WLA strategy than the traditional methods.

Christina River Basin Allocation Process

The first consideration is to determine what time period to use for the allocation scenarios. Only the results from the model period August 1-31 were analyzed to determine the daily average DO and minimum DO for comparison to WQS and to direct the allocation scenarios. This time period was selected as most representative of when critical conditions are expected to occur within the system. The model was run for a sufficient period to allow for: (1) the nutrient loads to transport their way through system; (2) the predictive sediment diagenesis model to attain dynamic equilibrium; and (3) the algae to react to the availability of nutrients.

The size-based EMPR allocation process relies on three levels of analysis for the Christina River Basin. Level 1 involves analyzing each NPDES point source individually to determine the baseline levels of treatment necessary to achieve WQS for daily average and minimum DO. The point sources not being considered individually and the tributaries are set to the baseline conditions listed in Table 9 below. This allows the in-stream flow to remain at 7Q10 levels and provides no net impact on water quality from the point sources not being considered individually. Level 2 involves multiple model runs in which the NPDES dischargers are added to the model one at a time based on the size of their CBOD load to determine the WLAs necessary to achieve WQS. If necessary, Level 3 involves analyzing the NPDES dischargers outside the Christina Basin (i.e., those discharging to the tidal Delaware River) in order to meet WQS in the tidal Christina River.

The ultimate endpoints of these low-flow TMDLs are the daily average and the minimum DO criteria for the various stream segments in the study area. DO concentrations vary throughout the course of a 24-hour day and tend to follow a general sinusoidal pattern with the lowest point occurring just before sunrise and the highest value occurring in the afternoon. In general, controlling CBOD has a greater impact on the daily average DO than on the diel (24-hour period) DO range. Depending on whether a system is nitrogen or phosphorus limited, the available nitrogen or phosphorus influences the diel DO range due to the impact on algae and periphyton growth kinetics. The model calibration and validation indicated that phosphorus is the limiting nutrient in the freshwater streams in the Christina River Basin (*Hydrodynamic and Water Quality Model of Christina River Basin Final Report, May 31, 2000)*. In Section 9.6 of the Model Report, it is noted that there was an abundance of nitrogen available and that phosphorous is the more limiting of the two nutrients based on data at five locations. The five locations were in West Branch Brandywine Creek, East Branch Brandywine Creek, Brandywine Creek (at Chadds Ford), Christina River and West Branch Red Clay Creek. Time-series plots at each location are found in Figures 9-12 through 9-16 in the Model Report.

The allocation process proceeds by reducing the CBOD, nitrogen, and phosphorus loads from the NPDES point sources in equal percentages until the daily average DO criteria are satisfied. After this is accomplished, if the minimum DO criteria have not been met, then the phosphorus loads will be further controlled until the diel DO range is reduced sufficiently to satisfy the minimum DO criteria.

Since these TMDLs deals with low-flow conditions only, by definition very little nonpoint source load from land-based sources will be entering the system during drought conditions. The nonpoint source flows from peripheral tributaries and groundwater sources are considered to be at baseline (i.e., background) conditions. The baseline concentrations for the various water quality parameters were determined from all data in the STORET database for the period 1988 to 1998. The 10th percentile concentration values were assumed to be indicative of the nonpoint source contributions during the 7Q10 low-flow period. The concentrations were within the range of expected values for watersheds in the eastern United States according to Omernik (1977). The baseline concentrations for total nitrogen and total phosphorus are presented in Table 9.

Table 9. Baseline Concentrations of Nitrogen and Phosphorus for Christina Basin TMDL

Subwatershed	Total Nitrogen (mg/l)		[illegible] Phosphorus (mg/l)	
	Baseline	Omernik (1977) (67% range)	[illegible]	[illegible]
Main Stem and East Branch Brandywine Creek	1.56	0.33 - 6.64	0.01	0.008 - 0.251
West Branch Brandywine Creek	2.44	0.33 - 6.64	0.03	0.008 - 0.251
Red Clay Creek	2.65	0.33 - 6.64	0.05	0.008 - 0.251
White Clay Creek	2.31	0.33 - 6.64	0.02	0.008 - 0.251
Christina River	1.08	0.33 - 6.64	0.02	0.008 - 0.251

Source: STORET data 1988-1998 and Nonpoint Source Stream Nutrient Level Relationships (Omernik, 1977)

Level 1 Allocation Results - Baseline Allocations

The first level of the size-based EMPR allocation involved considering each NPDES discharger individually to determine if WQS for DO were met. Those dischargers not considered individually were set to the baseline conditions in Table 9. This allowed the in-stream flow to remain at 7Q10 levels and created no net impact on water quality from the point sources not being considered individually. If WQS were not met, then CBOD, nitrogen and phosphorus for the individual point source were reduced in 5% increments until standards were achieved. Of the 99 NPDES point sources located in the Christina River Basin, 87 of them are small, with flow rates of 0.25 mgd or less. In order to avoid making 87 individual model runs to determine whether a Level 1 allocation was needed, all the small NPDES discharges were grouped into a single model run. The model results for this run indicated that the WQS for daily average DO and minimum DO were protected at all locations in the Christina River Basin. Thus, if as a group there were no violations of the DO standard for the small dischargers, then individually there would be no violations.

Next, the remaining 12 large NPDES dischargers were analyzed individually. Of these 12, only three indicated violations of the DO standards: (1) PA0026531 (Downingtown) on the East Branch Brandywine Creek (minimum DO standard only), (2) PA0026859 (PA American Water Co. - formerly Coatesville City) on the West Branch Brandywine Creek (daily average and minimum DO standards), and (3) PA0024058 (Kennett Square) on West Branch Red Clay Creek (daily average and minimum DO standards). These violations are shown on Figures 11 and 12. Analysis for a fourth facility, MD0022641 - Meadowview Utilities on West Branch Christina River, indicated the EPA water quality criteria for ammonia nitrogen (US EPA 1998; subsequently adopted by the state of Maryland) was not being protected and was, therefore, also included in the Level 1 allocations. The Level 1 load reductions necessary to achieve compliance with the WQS for these facilities are shown in Table 10.

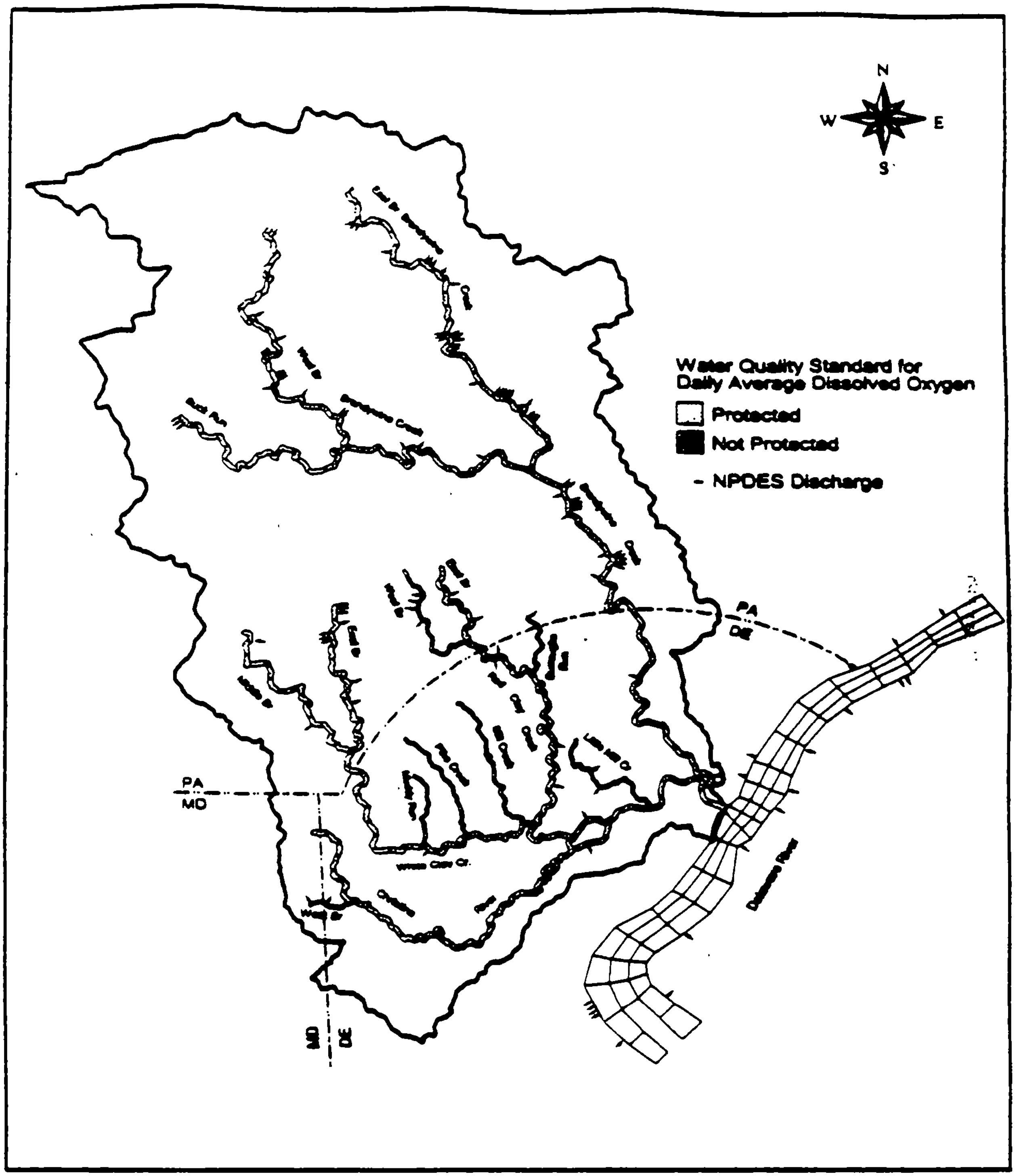


Figure 11. Modeled stream segments which violate daily average dissolved oxygen water quality criteria based on the Level 1 allocation analysis.

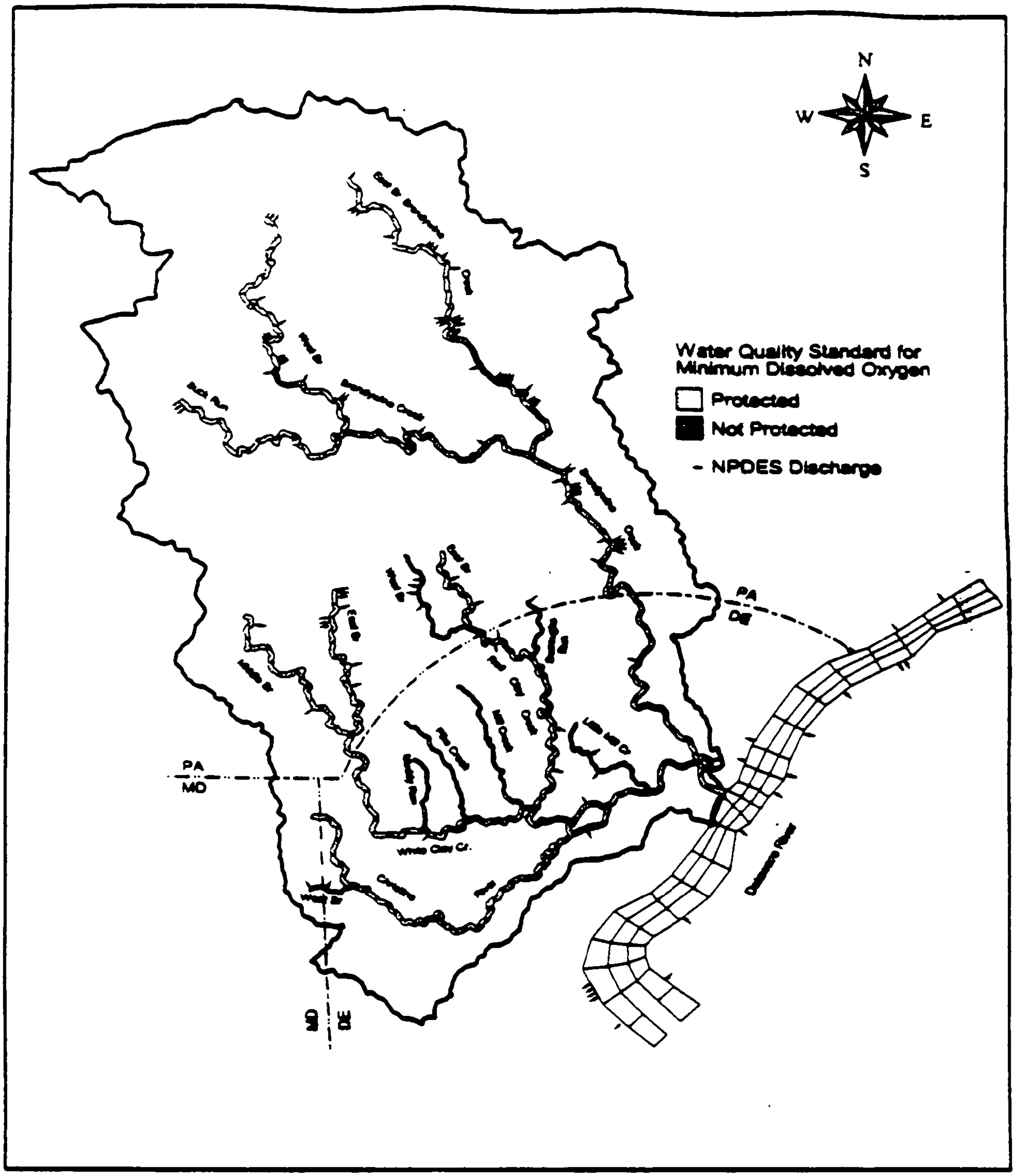


Figure 12 Modeled stream segments which violate minimum dissolved oxygen water quality criteria based on Level 1 allocation analysis.

Table 10. Level 1 Baseline Allocations

NPDES Facility	Flow (mgd)	Existing Permit Limits			Level 1 Allocation Limits			Level 1 Percent Reduction		
		CBOD5 (mg/L)	NH3-N (mg/L)	TP (mg/L)	CBOD5 (mg/L)	NH3-N (mg/L)	TP (mg/L)	CBOD5	NH3-N	TP
East Branch Brandywine Creek										
PA0026531	7.134	10	2.0	2.0	8.9	1.78	1.78	11%	11%	11%
West Branch Brandywine Creek										
PA0026859	3 85	15	2.0	2.0	12.3	2.0	1.64	18%	0%	18%
West Branch Red Clay Creek										
PA0024058	1.1	25	3 0	7.5*	17.5	2.1	1.35	30%	30%	82%
West Branch Christina River										
MD0022641	0.7	22**	6.45*	1.0	22**	2.0	1.0	0%	69%	0%

Note- WLAs/permit limits for critical conditions period, applicable to seasonal permit periods (e.g., May 1 -October 31 - DEP)
* no permit limits, values shown are based on monitoring data.
** value shown is BOD5 MDE permits list BOD5 instead of CBOD5; equivalent CBOD5 value is 12.22 mg/l.

PA0026531 - Downingtown Area Reg. Auth.
PA0024058 - Kennett Square
*** formerly Coatesville City Authority

PA0026859 - PA American Water Co.***
MD0022641- Meadowview Utilities, Inc.

Level 2 Allocation Results

The second level of the size-based EMPR allocation strategy involved adding the dischargers one at a time based on the size of Level 1 baseline CBOD allocations (kg/day) and performing waste load allocations to those stream segments indicating violations of the DO WQS. The daily average and minimum DO results of the initial Level 2 run are shown in Figures 13 and 14. It is apparent that the DO WQS are not being met in the East Branch Brandywine Creek, West Branch Brandywine Creek, West Branch Red Clay Creek and the tidal portion of the Christina River with the two largest dischargers added to each of these stream reaches. The allocation proceeded by running the water quality model in an iterative fashion by reducing CBOD, NH3-N, and TP in 5% intervals for all NPDES dischargers upstream of the farthest downstream model grid cell indicating a DO violation. Once WQS were achieved at the 5% increment level, the allocations were fine tuned in 1% increments. After the allocations were fine tuned, the next largest discharger was added to the stream reach and the process was repeated until all dischargers were included in the analysis.

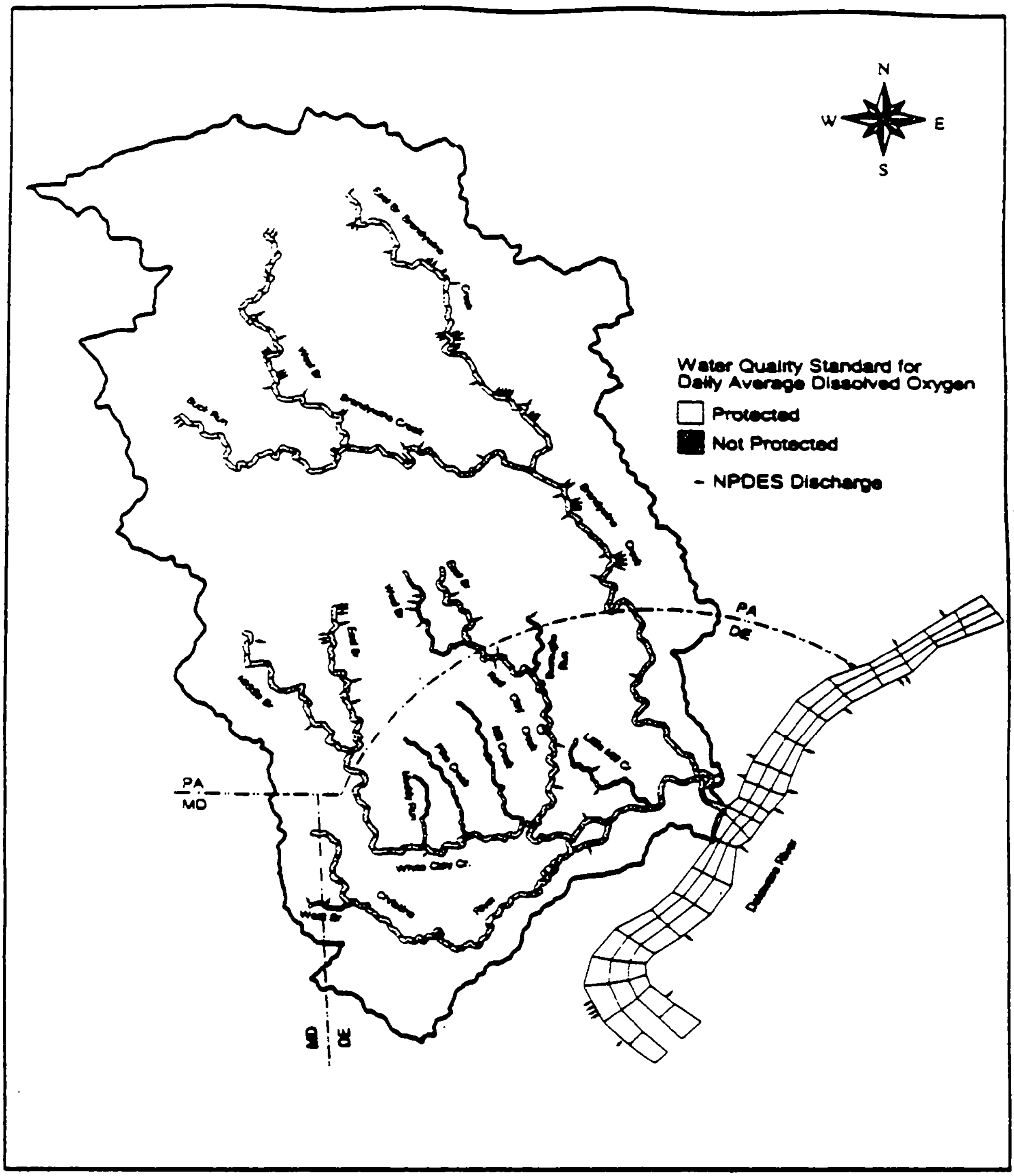


Figure 13 Modeled stream segments which violate daily average dissolved oxygen water quality criteria based on Level 2 allocation analysis.

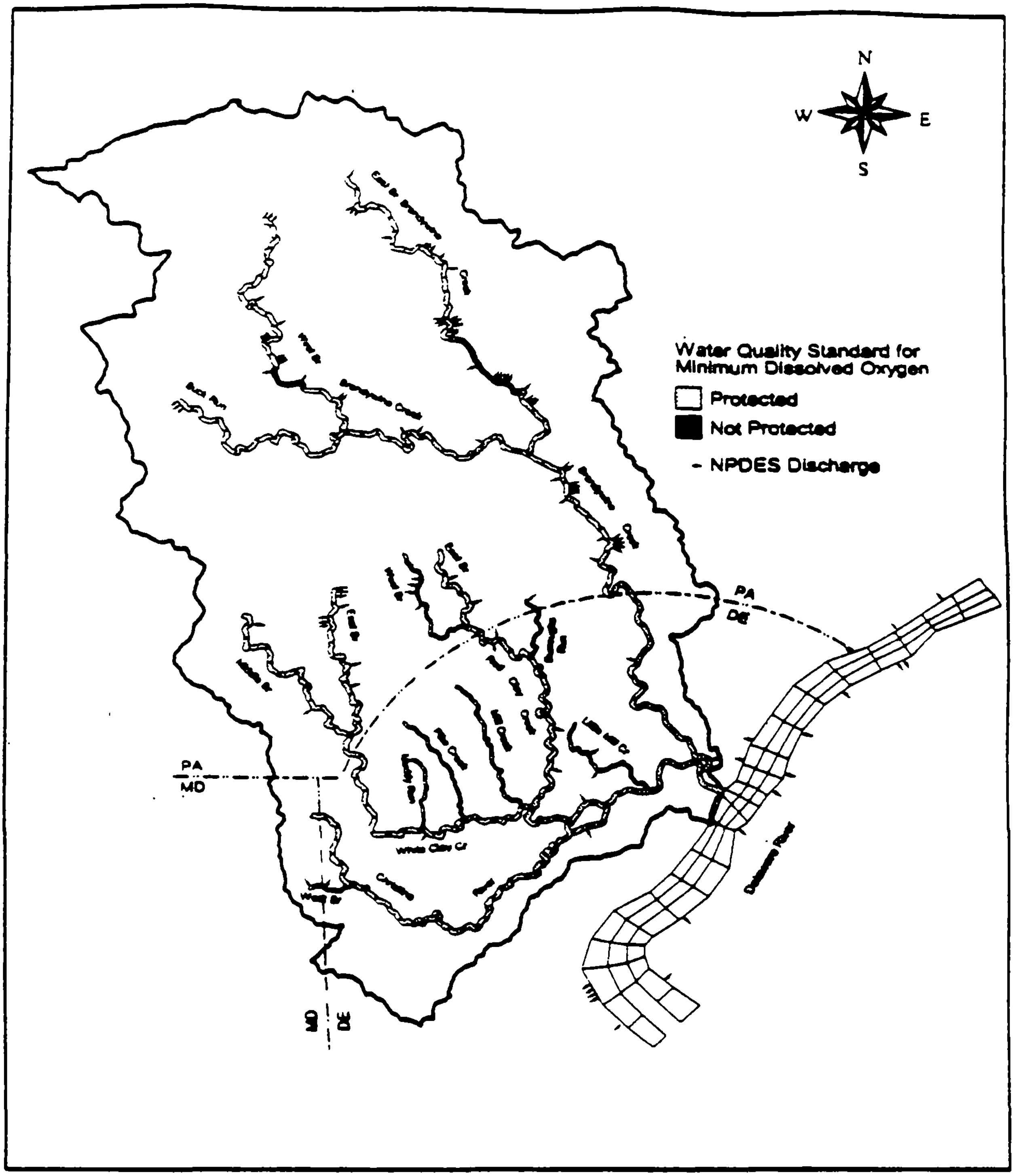


Figure 14 Modeled stream segments which violate minimum dissolved oxygen water quality criteria based on Level 2 allocation analysis.

No allocations were made to point sources on the main stem Brandywine Creek until the stream segments on the East and West Branches were first in compliance with WQS. The small residence dischargers (0.0005 mgd), groundwater cleanup dischargers, and water filtration plant backwash facilities were not included in the allocation analysis since, as noted before, a model run covering all small dischargers indicated that the WQS for daily average DO and minimum DO were protected at all locations in the Christina River Basin. Furthermore, filtration backwash facilities only discharge as needed and not on a continual basis. The Level 2 allocation results are presented in Table 11 and are shown in Figures 15 and 16 (the Level 2 allocation limits will be applicable to seasonal periods (e.g., May 1 to October 31 in Pennsylvania) covering the design critical conditions time used in the TMDL evaluations). It can be seen that there are no violations of the daily average DO or minimum DO criteria at any point inside the Christina River Basin. Thus, a Level 3 allocation will not be necessary for the tidal Christina River.

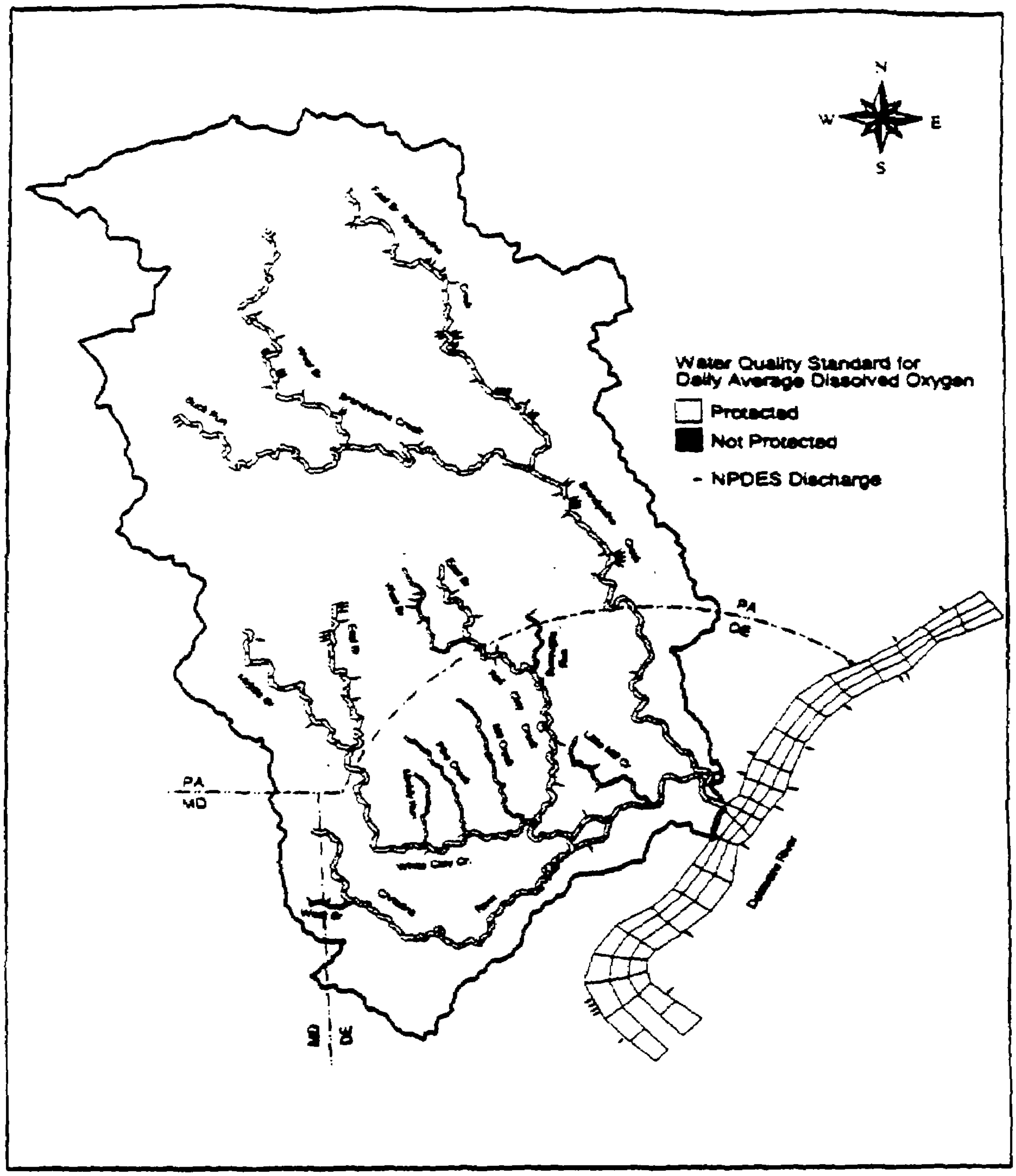


Figure 15 Final Level 2 allocation analysis results which indicate no violations of daily average dissolved oxygen water quality criteria in modeled stream segments.

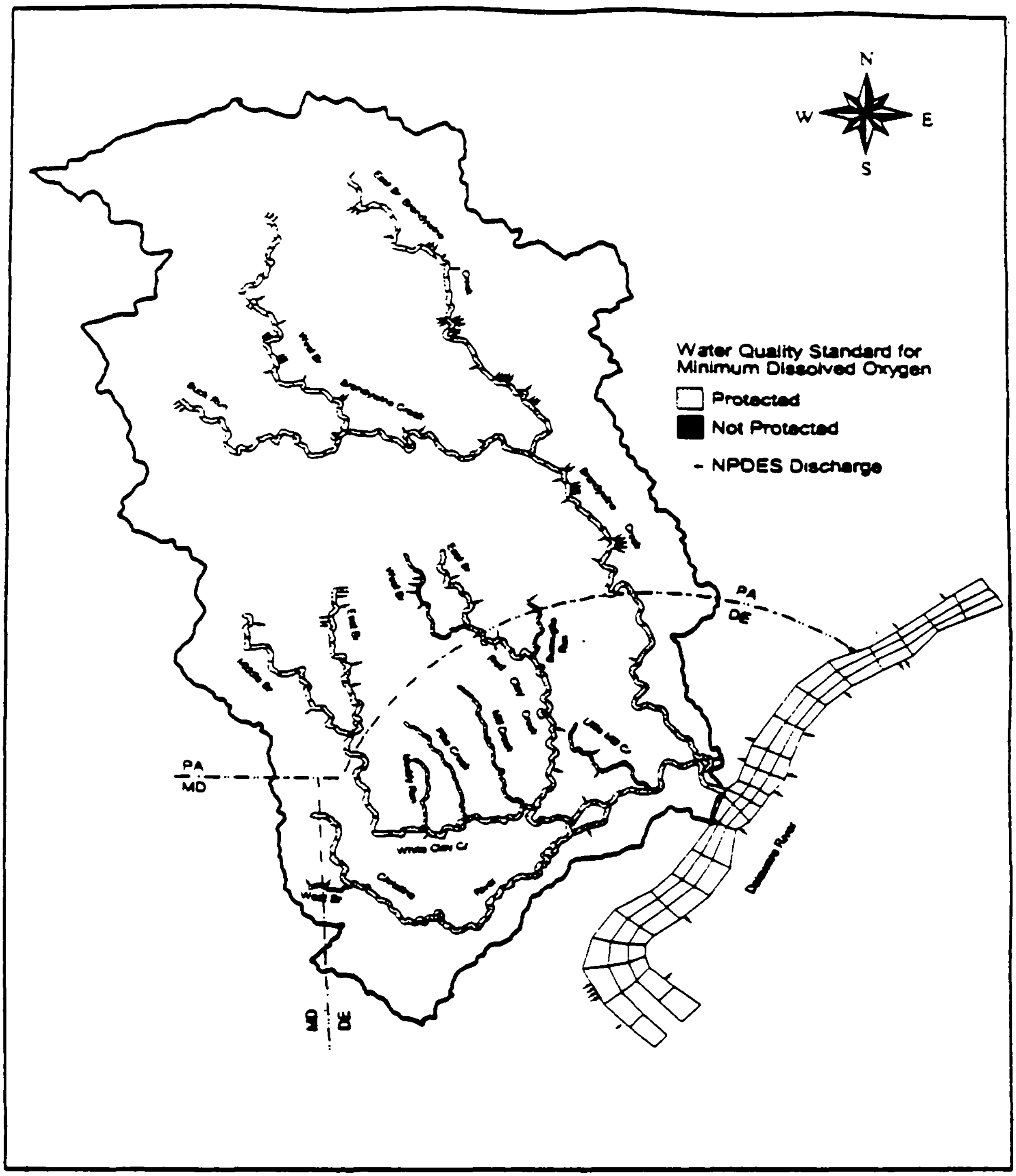


Figure 16 Final Level 2 allocation analysis results which indicate no violations of minimum dissolved oxygen water quality criteria in modeled stream segments.

Table 11. Level 2 Allocations

NPDES/Facility[1]	Flow (mgd)	Existing Permit Limits			Level 2 Allocation Limits			Level 1 and 2 Percent Reduction		
		CBOD5 (mg/l)	NH3-N (mg/l)	TP (mg/l)	CBOD5 (mg/l)	NH3-N (mg/l)	TP (mg/l)	CBOD5	NH3-N	TP
East Branch Brandywine Creek										
PA0043982	0 4	25	2.0*	2.0	22.95	2.00	1.88	8%	0%	6%
PA0012815	1.028	34	6.0	1.0	24.41	4.31	0.72	28%	28%	28%
PA0026531	7 134	10	2.0	2.0	6.38	1.28	1.28	36%	36%	36%
West Branch Brandywine Creek										
PA0026859	3.85	15	2.0	2.0	11.07	2.00	1.48	28%	0%	28%
PA0044776	0.6	15	3.0	2.0	13.50	2.70	1.80	10%	10%	10%
West Branch Red Clay Creek										
PA0024058	1.1	25	3.0	7.5*	16.63	2.00	1.28	34%	34%	83%
PA0057720-001	0.05	10	2.0	2.0*	9.50	1.90	1.90	5%	5%	5%
West Branch Christina River										
MD0022641**	0.7	22***	6.45*	1.0	22***	2.0	1.0	0%	69%	0%

Note: WLAs/permit limits for critical conditions period; applicable to seasonal permit periods (e.g., May 1 -October 31 -DEP)
* no permit limits, values shown are based on typical characteristics or monitoring data.
**allocation did not change from Level 1 allocation.
***value shown is BOD5. MDE permits list BOD5 instead of CBOD5; equivalent CBOD5 value is 12.22 mg/l.

PA0026531 - Downingtown Area Reg. Auth.
PA0024058 - Kennett Square
PA0043982 - Broad Run Sew. Co.
PA0057720-001 - Sunny Dell Foods, Inc.
**** - formerly Coatesville City Authority
PA0026859 - PA American Water Co.****
MD0022641 - Meadowview Utilities, Inc.
PA0012815 - Sonoco Products
PA0044776 - NW Chester Co. Mun. Auth.

In Appendix A1 of this document, data plots are presented showing the DO water quality standards, the impacts of existing NPDES permitted loads, and the TMDL model results for the proposed TMDL waste load reductions for each major Christina River Basin stream segment..

Performance data for the year 2000 for the three largest facilities (Downingtown, Coatesville, and Sonoco Products) indicate that these facilities are already achieving generally consistent performance near or below the proposed level 2 reductions. The main exception is the phosphorous discharges at Downingtown and Coatesville. Additional information on performance of major Christina River Basin dischargers is available in the Model Report (Table 7-3, 1997 data used in model calibration) and recent performance information can be obtained from the appropriate state agencies.

Waste Load Allocations (WLAs)

Federal regulations at 40 CFR 130.7 require TMDLs to include individual WLAs for each point source. Tables 12-27 outline the individual WLAs for those dischargers in the Christina River Basin. Of the 122 NPDES facilities considered, only those eight dischargers considered during the Level 1 and Level 2 EMPR analysis require reductions to their NPDES permit limits for those pollutants listed above.

Load Allocations

According to Federal regulation at 40 CFR 130.2(g), load allocations are best estimates of the nonpoint or background loading. These allocations may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished.

Nonpoint source loads within the Christina River Basin model are based on monitoring data from STORET, USGS water quality data, baseflow samples taken in 1997, and interstate monitoring data collection efforts. The loads represent expected low-flow contributions from subwatersheds according to the delineation of the 39 subwatersheds in the HSPF model currently being developed by USGS. This will allow the HSPF model to be directly linked to the EFDC model to investigate seasonality and address high flow situations. Those data sets were used to develop characteristic loads of parameters of concern (carbon, nitrogen, phosphorus, DO and algae) for each of the 39 subwatershed as delineated by the HSPF model. Load allocations were based on actual site-specific data and are broken down by subwatershed in Tables 12-27 below.

Allocations Scenarios

EPA realizes that its determination of the total loads below for carbonaceous biochemical oxygen demand (5-day), ammonia nitrogen, total nitrogen, total phosphorus and DO to the point sources and nonpoint sources is one allocation scenario. As implementation of the established TMDLs proceed, the states and DRBC may find that other combinations of point and nonpoint source allocations are more feasible and/or cost effective. However, any subsequent changes in the TMDLs must conform to gross WLAs and load allocations for each segment and must ensure that the biological, chemical, and physical integrity of the waterbody is preserved.

Federal regulations at 40 CFR 122.44(d)(1)(vii)(B) require that, for an NPDES permit for an individual point source, the effluent limitations must be consistent with the assumptions and requirements of any available WLA for the discharger prepared by the state and approved by EPA or established directly by EPA. EPA has authority to object to the issuance of an NPDES permit that is inconsistent with WLAs established for that point source. To ensure consistency with these TMDLs, as NPDES permits are issued for the point sources that discharge the pollutants of concern to the Christina Basin, any deviation from the WLAs described herein for the particular point source must be documented in the permit Fact Sheet and made available for public review along with the proposed draft permit and the Notice of Tentative Decision. The documentation should: (1) demonstrate that the loading change is consistent with the goals of these TMDLs and will implement the applicable WQS, (2) demonstrate that the changes embrace the assumptions and methodology of these TMDLs, and (3) describe that portion of the total allowable loading determined in the TMDL report that remains for other point sources (and future growth where included in the original TMDL) not yet issued a permit under the TMDL.

It is also expected that the states will provide this Fact Sheet, for review and comment, to each point source included in the TMDL analysis as well as any local and state agency with jurisdiction over land uses for which load allocation changes may be impacted. EPA believes that this gives flexibility to the state agencies to address point source trading within the NPDES permitting process. However, should these trading activities result in changes to the total loading by basin or subwatershed segment, then EPA would expect that TMDL revisions would be necessary and the states or DRBC would need to follow the formal TMDL review and approval process.

In addition, EPA regulations and program guidance provide for effluent trading. Federal regulations at 40 CFR 130.2 (i) state: "If Best Management Practices (BMPs) or other nonpoint source pollution controls make more stringent load allocations practicable, then WLAs may be made less stringent. Thus, the TMDL process provides for nonpoint source control tradeoffs." The states may trade between point sources and nonpoint sources identified in these TMDLs as long as three general conditions are met: (1) the total allowable load to the waterbody is not exceeded, (2) the trading of loads from one source to another continues to properly implement the applicable WQS and embraces the assumptions and methodology of these TMDLs, and (3) the trading results in enforceable controls for each source. Final control plans and loads should be identified in a publicly available planning document, such as the state's water quality management plan (see 40 CFR 130.6 and 130.7(d)(2)). These final plans must be consistent with the goals of the approved TMDLs. While the design conditions of the low-flow TMDL restrict trading between point and nonpoint sources at the present time, EPA expects that this option will be available when the Christina River Basin high-flow TMDLs are developed.

Table 12

TMDL Summary for Buck Run

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
PA0036161	0.0360	25.00	2 60	6 29	2.00	5.00	7.512	0.781	1.890	0.601	1 502	0 0%	0 0%	0.0%
PA0057231	0.0005	10 00	1.50	3 63	2.00	6.00	0.042	0.006	0 015	0.008	0.025	0 0%	0.0%	0 0%
	Total Waste Load Allocation						7.553	0.787	1.905	0.609	1.527			
Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	[illegible]	[illegible]	mg/L	[illegible]	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
B05	4.70	0.75	0.02	2.00	0.02	7.34	19.010	0.507	50.693	0.507	186.044	0.0%	0.0%	0.0%
B06	3.86	0.75	0.02	2.00	0.02	7.34	15.603	0.416	41.609	0.416	152.705	0.0%	0.0%	0 0%
Atm Deposition							0.103	0.038	0 148	0.013				
	Total Load Allocation [illegible]						34.716	0.961	92.450	0.936	338.748			

Table 13

TMDL Summary for Brandywine Creek West Branch

Waste Load Allocations														
NPDES	[illegible]	CBOD [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	DO [illegible]	TMDL Percent Reduction		
												CBOD5	NH [illegible]	[illegible]
PA00[illegible]	0.0000	15.00	1.50	3.63	2.00	5.00	0.000	0.000	0.000	0.000	0.000	0 0%	0.0%	0.0%
PA00[illegible]	0.1000	25.00	20.00	48.40	2.00	3.00	20.866	16.693	40.396	1.669	2.504	0.0%	0.0%	0.0%
PA00[illegible]	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
PA00[illegible]	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0 0%
PA00[illegible]	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
PA00[illegible]	0.3900	25.00	7.00	30.00	2.00	2.00	81.377	22.785	97.652	6.510	6.510	0.0%	0.0%	-0.0%
PA00[illegible]	3.8500	11.07	2.00	30.00	1.48	5.00	355.716	64.267	964.001	47.557	160.667	26.2%	0.0%	26.2%
PA00[illegible]	0.6400	5.00	0.50	5.30	0.30	5.00	26.708	2.671	28.311	1.602	26.708	0.0%	0.0%	0.0%
PA00[illegible]	0.5045	5.00	0.50	12.00	0.30	5.00	21.054	2.105	50.529	1.263	21.054	0.0%	0.0%	0.0%
PA00[illegible]	0.0000	15.00	1.50	3.63	2.00	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
PA00[illegible]	0.0005	10.00	1.50	3.63	2.00	6 00	0 042	0.006	0.015	0.008	0.025	0 0%	0.0%	0.0%

PA0012416	0.1400	10.00	0.10	0.24	0.10	5.00	11.685	0.117	0.280	0.117	5.842	0.0%	0.0%	0.0%
PA0052990	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
PA0052728	0.0004	25.00	1.50	3.63	2.00	2.00	0.083	0.005	0.012	0.007	0.007	0.0%	0.0%	0.0%
PA00[illegible]	0.0490	25.00	1.50	3.63	2.00	3.00	10.224	0.613	1.485	0.818	1.227	0.0%	0.0%	0.0%
PA0036412	0.0550	10.00	2.90	7.02	1.90	5.00	4.590	1.331	3.223	0.872	2.295	0.0%	0.0%	0.0%
PA00[illegible]	0.6000	13.50	2.70	6.53	1.80	6.00	67.605	13.521	32.701	9.014	30.047	10.0%	10.0%	10.0%
PA00[illegible]	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
	Total Wasteload Allocation [illegible]						600.160	[illegible]	[illegible]	[illegible]	[illegible]			
Load Allocations														
Subwatershed	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] DO	TMDL Percent Reductions [illegible]	[illegible]	[illegible]
B01 [illegible]	6.17	0.75	0.020	2.00	0.020	7.34	24.945	0.665	66.521	0.665	244.133	0.0%	0.0%	0.0%
B02 [illegible]	9.06	0.75	0.020	2.00	0.020	7.34	36.659	0.978	97.758	0.978	358.771	0.0%	0.0%	0.0%
B03 [illegible]	4.96	0.75	0.020	2.00	0.020	7.34	20.059	0.535	53.489	0.535	196.306	0.0%	0.0%	0.0%
B04 [illegible]	2.92	0.75	0.020	2.00	0.020	7.34	11.817	0.315	31.511	0.315	115.644	0.0%	0.0%	0.0%
B07 [illegible]	1.10	0.75	0.020	2.00	0.020	7.34	4.450	0.119	11.868	0.119	43.554	0.0%	0.0%	0.0%
Atm. Deposition							1.249	0.467	1.790	0.159				
	Total Load Allocation [illegible]						[illegible]	[illegible]	[illegible]	2.770	958.409			

Table 14
TMDL Summary for Brandywine Creek East Branch

	Waste Load Allocations													
NPDES	Flow mgd	CBOD5 mg/L	NH3-N mg/L	TKN mg/L	TP mg/L	DO mg/L	CBOD5 lb/day	NH3-N lb/day	TKN lb/day	TP lb/day	DO lb/day	TMDL Percent Reduction CBOD5	NH3-N	TP
PA0056171	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
PA0026018	1.5000	25.00	2.50	6.05	2.00	5.00	312.987	31.299	75.743	25.039	62.597	0.0%	0.0%	0.0%
PA0054747	0.0000	15.00	1.50	3.63	2.00	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
PA0057282	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
PA0051365	0.3690	2.00	0.10	0.24	0.10	5.00	6.160	0.308	0.739	0.308	15.399	0.0%	0.0%	0.0%
PA0053937	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
PA0056324	0.0440	2.00	0.04	2.10	0.11	5.00	0.734	0.015	0.771	0.040	1.836	0.0%	0.0%	0.0%
PA0056818	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
PA0054305	0.0000	30.00	0.50	4.65	0.30	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
PA0053561	0.0360	2.00	0.04	2.10	0.11	5.00	0.601	0.012	0.631	0.033	1.502	0.0%	0.0%	0.0%
PA0043982	0.4000	22.95	2.00	45.00	1.88	2.00	76.619	6.677	150.234	6.276	6.677	8.2%	0.0%	6.2%
PA0012815	1.0280	24.41	4.31	40.06	0.72	5.00	209.438	36.980	343.716	6.178	42.900	28.2%	28.2%	28.2%
PA0026531	7.1340	6.38	1.28	50.00	1.28	6.00	379.883	76.215	2977.136	76.215	357.256	36.2%	36.2%	36.2%
PA0030228	0.0225	7.00	1.00	2.42	3.00	5.00	1.315	0.188	0.454	0.563	0.939	0.0%	0.0%	0.0%
PA0051918	0.1440	2.00	0.10	0.24	0.10	5.00	2.404	0.120	0.288	0.120	6.009	0.0%	0.0%	0.0%
PA0053678	0.0000	30.00	0.50	4.65	0.30	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
PA0053660	0.0000	30.00	0.50	4.65	0.30	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
PA0055531	0.0007	25.00	1.50	3.63	2.00	3.00	0.146	0.009	0.021	0.012	0.018	0.0%	0.0%	0.0%
PA0057126	0.0000	30.00	0.50	4.65	0.30	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
PA0054917	0.4750	5.89	0.78	1.89	0.78	6.00	23.351	3.092	7.493	3.092	23.787	0.0%	0.0%	0.0%
PA00570[illegible]	0.0000	15.00	1.50	3.63	2.00	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
PA0036374	0.0150	10.00	0.50	1.21	0.50	5.00	1.252	0.063	0.151	0.063	0.626	0.0%	0.0%	0.0%
PA0052949	0.0000	30.00	0.50	4.65	0.30	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
[illegible]	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
[illegible]	0.0531	10.00	3.00	7.26	1.00	6.00	4.432	1.330	3.218	0.443	2.659	0.0%	0.0%	0.0%
[illegible]	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
[illegible]	0.0375	10.00	3.00	7.26	1.00	5.00	3.130	0.939	2.272	0.313	1.565	0.0%	0.0%	0.0%
[illegible]	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
[illegible]	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%

Load Allocations														
Subwatershed	Flow cfs	CBOD5 mg/L	NH3-N mg/L	TN mg/L	TP mg/L	DO mg/L	CBOD5 lb/day	NH3-N lb/day	TN lb/day	TP lb/day	DO lb/day	TMDL Percent Reduction CBOD5	NH3-N	TP
B08	12.43	0.89	0.020	1.36	0.018	7.34	59.686	1.341	91.205	1.207	492.241	0.0%	0.0%	0.0%
B09	3.02	0.89	0.020	1.36	0.018	7.34	14.504	0.326	22.163	0.293	119.616	0.0%	0.0%	0.0%
B10	3.99	0.89	0.020	1.36	0.018	7.34	19.172	0.431	29.297	0.388	158.117	0.0%	0.0%	0.0%
B11	5.62	0.89	0.020	1.36	0.018	7.34	27.003	0.607	41.263	0.546	222.696	0.0%	0.0%	0.0%
B12	5.09	0.89	0.020	1.36	0.018	7.34	24.448	0.549	37.359	0.494	201.628	0.0%	0.0%	0.0%
B13	3.53	0.89	0.020	1.36	0.018	7.34	16.933	0.381	25.875	0.342	139.650	0.0%	0.0%	0.0%
Atm Deposition							0.589	0.220	0.843	0.075				
	[illegible]						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			

Table 15
TMDL Summary for Brandywine Creek Main Stem

Waste Load Allocations														
NPDES [illegible]	Flow mgd	CBOD5 [illegible]	[illegible]	[illegible]	[illegible]	DO [illegible]	CBOD5 [illegible]	[illegible]	[illegible]	[illegible]	DO lb/day	[illegible] CBOD5	[illegible]	[illegible]
DE0050962	0.0000	15.00	1.50	3.63	2.00	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
DE0021768	0.0250	15.00	1.50	3.63	2.00	5.00	3.130	0.313	0.757	0.417	1.043	0.0%	0.0%	0.0%
PA0053082	0.0206	10.00	3.00	7.26	2.00	5.00	1.719	0.516	1.248	0.344	0.860	0.0%	0.0%	0.0%
PA00526[illegible]	0.0900	10.00	1.00	2.42	2.00	5.00	7.512	0.751	1.818	1.502	3.756	0.0%	0.0%	0.0%
[illegible]	0.0400	10.00	3.00	7.26	2.00	3.00	3.339	1.002	2.424	0.668	1.002	0.0%	0.0%	0.0%
[illegible]	0.0700	25.00	3.00	7.26	2.00	3.00	14.606	1.753	4.242	1.168	1.753	0.0%	0.0%	0.0%
[illegible]	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
[illegible]	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
[illegible]	0.0063	25.00	1.50	3.63	2.00	3.00	1.315	0.079	0.191	0.105	0.158	0.0%	0.0%	0.0%
[illegible]	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
[illegible]	0.0170	25.00	20.00	48.40	2.00	5.00	3.547	2.838	6.867	0.284	0.709	0.0%	0.0%	0.0%
[illegible]	0.1500	15.00	1.50	3.63	2.00	5.00	18.779	1.878	4.545	2.504	6.260	0.0%	0.0%	0.0%
[illegible]	0.0773	25.00	3.50	8.47	2.00	5.00	16.129	2.258	5.465	1.290	3.226	0.0%	0.0%	0.0%
[illegible]	0.0320	25.00	20.00	48.40	2.00	3.00	6.677	5.342	12.927	0.534	0.801	0.0%	0.0%	0.0%
[illegible]	0.1400	2.00	0.04	2.10	0.11	5.00	2.337	0.047	2.454	0.129	5.842	0.0%	0.0%	0.0%
[illegible]	0.0300	2.00	0.10	0.24	0.10	5.00	0.501	0.025	0.060	0.025	1.252	0.0%	0.0%	0.0%
	[illegible]													

Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
B14	2.92	0.75	0.020	2.00	0.020	7.34	11.817	0.315	31.511	0.315	115.644	0.0%	0.0%	0.0%
B15	4.70	0.75	0.020	2.00	0.020	7.34	19.010	0.507	50.693	0.507	186.044	0.0%	0.0%	0.0%
B16	3.86	0.75	0.020	2.00	0.020	7.34	15.603	0.416	41.609	0.416	152.705	0.0%	0.0%	0.0%
B17	1.10	0.75	0.020	2.00	0.020	7.34	4.450	0.119	11.868	0.119	43.554	0.0%	0.0%	0.0%
Atm. Deposition							1.131	0.422	1.620	0.144				
	Total Load Allocation						[illegible].011	[illegible]	[illegible]	1.601	497.947			

Table 16
TMDL Summary for Burroughs Run

Waste Load Allocations														
NPDES	Flow mgd	CBOD5 mg/L	NH3-N mg/L	TN mg/L	TP mg/L	DO mg/L	CBOD5 lb/day	NH3-N lb/day	TN lb/day	TP lb/day	DO lb/day	TMDL Percent Reduction CBOD5	NH3-N	TP
PA0055425	0.0005	10.00	1.50	3.63	2.00	6.00	0.042	0.006	0.015	0.008	0.025	0.0%	0.0%	0.0%
	Total Waste Load Allocation						0.042	0.006	0.016	[illegible]	0.025			
Load Allocations														
Subwatershed	[illegible]	[illegible]	NH3-N	TN	TP	DO mg/L	CBOD5 lb/day	NH3-N lb/day	TN lb/day	TP lb/day	DO lb/day	TMDL Percent Reduction CBOD5	NH3-N	TP
R03	0.85	1.00	0.02	1.98	0.05	7.34	4.585	0.092	9.078	0.206	33.652	0.0%	0.0%	0.0%
Atm. Deposition							0.013	0.005	0.018	0.002				
	[illegible]						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			

Table 17
TMDL Summary for Red Clay Creek West Branch

Waste Load Allocations														
NPDES	Flow mgd	CBOD5 mg/L	[illegible]	[illegible]	[illegible]	DO	[illegible]	[illegible]	[illegible]	[illegible]	DO lb/day	TMDL Percent Reduction CBOD5	[illegible]	[illegible]
PA0053554	0.0000	15.00	1.50	3.63	2.00	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
[illegible]	1.1000	16.63	2.00	4.83	1.28	6.00	152.679	18.362	44.344	11.752	55.086	33.5%	33.5%	82.9%
[illegible]	0.2500	2.00	0.10	0.24	0.10	5.00	4.173	0.209	0.501	0.209	10.433	0.0%	0.0%	0.0%
[illegible]	0.0500	9.50	1.90	4.60	1.90	5.00	3.965	0.793	1.920	0.793	2.087	5.0%	5.0%	5.0%
[illegible]	0.0900	2.00	0.10	0.24	0.10	5.00	1.502	0.075	0.180	0.075	3.756	0.0%	0.0%	0.0%
	[illegible]										[illegible]			
Load Allocations														
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	3.71	1.00	0.020	1.98	0.045	7.34	20.009	0.400	39.618	0.900	146.869	0.0%	0.0%	0.0%
Atm. Deposition							0.044	0.016	0.063	0.006				
	[illegible]										[illegible]			

Table 18
TMDL Summary for Red Clay Creek Mainstem and East Branch

Waste Load Allocations														
NPDES	Flow mgd	CBOD5 mg/L	NH3-N mg/L	TN mg/L	[illegible]	DO mg/L	CBOD5 [illegible]	[illegible]	TN lb/day	TP lb/day	DO lb/day	TMDL Percent Reduction CBOD5	NH3-N	[illegible]
DE0000230	0.3500	7.00	0.10	0.24	0.10	5.00	20.449	0.292	0.701	0.292	14.606	0.0%	0.0%	0.0%
DE0021709	0.0150	20.00	1.50	3.63	2.00	5.00	2.504	0 188	0.454	0.250	0.626	0.0%	0.0%	0.0%
DE0050067	0.0015	30.00	1.50	3.63	2.00	5.00	0.376	0.019	0.045	0.025	0.063	0.0%	0.0%	0.0%
DE0000451	2.1700	3.00	0.10	0.24	4.00	5.00	54.335	1.811	4.347	72.446	90.558	0.0%	0.0%	0.0%
PA0035107	0.1500	25.00	2.00	4.84	2.00	5.00	31.299	2.504	6.059	2.504	6.260	0.0%	0.0%	0 0%
PA0054755	0.0000	15.00	1.50	3.63	2.00	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0 0%
	[illegible]						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			

Load Allocations														
Subwatershed	Flow [illegible]	CBOD5 [illegible]	[illegible]	[illegible]	[illegible]	DO [illegible]	CBOD5 [illegible]	[illegible]	TN [illegible]	TP [illegible]	DO lb/day	TMDL Percent Reduction CBOD5	NH3-N	TP
R02	1.39	1.00	0.020	1.98	0.045	7.34	7.500	0.150	14.851	0.338	55 052	0.0%	0.0%	0.0%
R04	1.37	1.00	0.020	1.98	0.045	7.34	7.387	0.148	14.626	0.332	54.221	0 0%	0 0%	0.0%
R05	3.62	1.00	0.020	1.98	0.045	7.34	19.530	0.391	38.669	0.879	143.349	0 0%	0.0%	0 0%
HOOPES	1.00	1.00	0.020	1.98	0.045	7.30	5.394	0.108	10.681	0.243	39.379	0.0%	0.0%	0.0%
Atm. Deposition							0.291	0.109	0.417	0.037				
	[illegible]						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			

Table 19

TMDL Summary for the White Clay Creek Middle Branch

Waste Load Allocations														
NPDES	Flow mgd	CBOD5 mg/L	NH3-N mg/L	TN mg/L	TP mg/L	DO mg/L	CBOD5 lb/day	NH3-N lb/day	TN lb/day	TP lb/day	DO lb/day	TMDL Percent Reduction CBOD5	NH3-N	TP
PA0053783	0.0200	10.00	3.00	7.26	2.00	5.00	1.669	0.501	1.212	0.334	0 835	0 0%	0 0%	0 0%
PA0024066	0.2500	25.00	4.80	11.62	2.00	5.00	52.165	10.016	24.246	4.173	10.433	0 0%	0.0%	0.0%
	[illegible] Load Allocation						53.834	10.516	25.458	4.507	11.268			
Load Allocations														
Subwatershed	Flow [illegible]	CBOD5 [illegible]	[illegible]	TN [illegible]	TP [illegible]	DO [illegible]	CBOD5 lb/day	NH3-N lb/day	TN lb/day	TP lb/day	DO lb/day	TMDL Percent Reduction CBOD5	NH3-N	TP
W01	2.35	0.64	0.02	1.79	0.02	7.34	8.114	0.254	22.694	0.254	93.059	0 0%	0 0%	0.0%
W02	3.66	0.64	0.02	1.79	0.02	7.34	12.634	0.395	35.337	0.395	144.901	0.0%	0.0%	0.0%
Atm. Deposition							0.054	0.020	0.078	0.007				
	[illegible]						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			

Table 20

TMDL Summary for the White Clay Creek East Branch

Waste Load Allocations														
NPDES	Flow [illegible]	CBOD5 [illegible]	[illegible]	[illegible]	[illegible]	DO [illegible]	[illegible]	[illegible]	TN [illegible]	TP [illegible]	DO [illegible]	TMDL Percent Reduction [illegible]	[illegible]	[illegible]
[illegible]	0.0012	25.00	20.00	48.40	2.00	2.00	0.250	0.200	0.485	0.020	0.020	0.0%	0.0%	0.0%
[illegible]	0.1440	2.00	0.04	2.10	0.11	5.00	2.404	0.048	2.524	0.132	6.009	0.0%	0.0%	0 0%
[illegible]	0.3000	25.00	2.00	50.00	4.00	2.00	62.597	5.008	125.195	10.016	5.008	0.0%	0.0%	0.0%
[illegible]	0.0075	25.00	6.00	14.52	2.00	6.00	1.565	0.376	0.909	0.125	0.376	0.0%	0 0%	0.0%
[illegible]	0.0650	25.00	3.50	32.55	0.30	5.00	13.563	1.899	17.659	0.163	2.713	0.0%	0 0%	0 0%
[illegible]	0.0029	30.00	0.50	4.65	0.30	5.00	0.726	0.012	0.113	0.007	0.121	0.0%	0.0%	0.0%
[illegible]	0.0270	20.00	3.00	7.26	2.00	5.00	4.507	0.676	1.636	0.451	1.127	0.0%	0.0%	0.0%
[illegible]	0.0090	20.00	3.00	7.26	2.00	5.00	1.502	0.225	0.545	0.150	0.376	0.0%	0 0%	0 0%
[illegible]	0.0100	20.00	3.00	7.26	2.00	5.00	1.669	0.250	0.606	0.167	0.417	0.0%	0.0%	0.0%
	[illegible]													
Load Allocations														
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	4.32	0.64	0.020	1.79	0.020	7.34	14.913	0.466	41.710	0.466	171 033	0.0%	0.0%	0.0%

W04	2.44	0.64	0.020	1.79	0.020	7.34	8.425	0.263	23.564	0.263	96 627	0.0%	0 0%	0 0%
Atm Deposition							0.099	0.037	0.141	0.013				
	Total Load Allocation						23.437	0.766	65.415	0.742	267.660			

Table 21
TMDL Summary of Muddy Run

Load Allocations														
Subwatershed	Flow mgd	CBOD5 mg/L	NH3-N mg/L	TN mg/L	TP mg/L	DO mg/L	CBOD5 lb/day	NH3-N lb/day	TN lb/day	TP lb/day	DO lb/day	TMDL Percent Reduction CBOD5	NH3-N	TP
W07	0.93	0.64	0.02	1.79	0.02	7.34	3.208	0.100	8.973	0.100	36.795	0 0%	0.0%	0.0%
Atm. Deposition							0.017	0.006	0.024	0.002				
	Total Load Allocation						3.225	0.106	8.997	0.102	36.795			

Table 22
TMDL Summary of Pike Creek

Load Allocations														
Subwatershed	Flow mgd	CBOD5 mg/L	NH3-N mg/L	TN mg/L	TP mg/L	DO mg/L	CBOD5 lb/day	NH3-N lb/day	TN lb/day	TP lb/day	DO lb/day	TMDL Percent Reduction CBOD5	NH3-N	TP
W06	1.60	0.64	0.02	1.79	0.02	7.34	5.528	0.173	15.462	0.173	63.403	0.0%	0.0%	0.0%
Atm. Deposition							0.039	0.015	0.056	0.005				
	[illegible]						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			

Table 23
TMDL Summary of Mill Creek

Load Allocations														
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
W0[illegible]	2.20	0.64	0.02	1.79	0.02	7.34	7.591	0.237	21.232	0.237	87.065	0.0%	0.0%	0.0%
Atm. Deposition							0.051	0.019	0.073	0.007				
	[illegible]						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			

Table 24
TMDL Summary of White Clay Creek Mainstem

Waste Load Allocations														
NPDES	Flow [illegible]	CBOD5 [illegible]	NH3-N mg/L	TN mg/L	TP mg/L	DO mg/L	CBOD5 [illegible]	NH3-N [illegible]	TN lb/day	TP lb/day	DO lb/day	TMDL Percent Reduction CBOD5	NH3-N	TP
DE0000191 [illegible]	0.0300	3.00	0.10	0.24	0.10	5.00	0.751	0.025	0.060	0.025	1.252	0.0%	0.0%	0.0%
	Total Waste Load Allocation [illegible]						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
Load Allocations														
Subwatershed [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] lb/day	TP lb/day	DO lb/day	TMDL Percent Reduction CBOD5	NH3-N	TP
W08	1.72	0.64	0.02	1.79	0.02	7.34	5.938	0.186	16.609	0.186	68.107	0.0%	0.0%	0.0%
W09 [illegible]	2.17	0.64	0.02	1.79	0.02	7.34	7.495	0.234	20.964	0.234	85.964	0.0%	0.0%	0.0%
W10 [illegible]	1.21	0.64	0.02	1.79	0.02	7.34	4.177	0.131	11.684	0.131	47.910	0.0%	0.0%	0.0%
Atm. Deposition							0.348	0.13	0.499	0.044				
	[illegible]						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			

Table 25
TMDL Summary for the Christina River West Branch

Waste Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
MD0022641*	0.7000	12.22	2.00	20.00	1.00	6.00	71.395	11.685	117.0	5.842	35.055	0.0%	69.0%	0.0%
MD0065145*	0.0500	10.00	4.52	20.00	1.00	6.00	4.173	1.886	8.33	0.417	2.504	0.0%	0.0%	0.0%
	Total Waste Load Allocation						75.568	13.571	125.33	6.260	37.558			
Load Allocations														
	Flow	CBOD5	NH3-N	TN	TP	DO	CBOD5	NH3-N	TN	TP	DO	TMDL Percent Reduction		
Subwatershed	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
C01WB	0.15	1.43	0.02	1.00	0.02	7.34	1.158	0.016	0.810	0.016	5.943	0.0%	0.0%	0.0%
Atm. Deposition							0.008	0.003	0.011	0.001				
	Total Load Allocation						1.166	0.019	0.821	0.017	5.943			

* - the equivalent BOD5 values are: MD0022641 - 128.4 lbs/day and MD0065145 - 6.3 lbs/day; total BOD5 waste load allocation of 134.7 l.bs/day. There are no BOD5 reductions at these facilities recommended by this TMDL.

Table 26
TMDL Summary for Little Mill Creek

Waste Load Allocations														
[illegible]	Flow	CBOD5	[illegible]	[illegible]	[illegible]	DO	[illegible]	[illegible]	TN	TP	DO	TMDL Percent Reduction		
NPDES	mgd	mg/L	[illegible]	[illegible]	[illegible]	mg/L	[illegible]	[illegible]	lb/day	lb/day	lb/day	CBOD5	NH3-N	TP
DE0000[illegible]	0.0000	20.00	1.50	3.63	2.00	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
DE0000[illegible]	0.0000	20.00	1.50	3.63	2.00	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%	0.0%
	[illegible]						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
Load Allocations														
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	DO	TMDL Percent Reduction		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	lb/day	CBOD5	[illegible]	TP
[illegible]	4.70	1.43	0.02	1.00	0.02	7.34	36.241	0.507	25.343	0.507	186.020	0.0%	0.0%	0.0%
Atm. Deposition							0.028	0.011	0.041	0.004				
	[illegible]						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			

Table 27

TMDL Summary of the Christina River Main Stem

Waste Load Allocations														
NPDES	Flow (mgd)	CBOD5 mg/L	[illegible]	[illegible] TN	[illegible]	[illegible] DO	CBOD5 [illegible]	[illegible]	[illegible]	[illegible]	[illegible] DO lb/day	TMDL Percent Reduction		
												CBOD5	[illegible]	[illegible]
DE0000400	0.0000	2.00	0.10	0.24	0.10	5.00	0.000	0.000	0.000	0.000	0.000	0.0%	0 0%	0.0%
DE0051004	0.0000	15.00	1.50	3.63	2.00	5.00	0.000	0.000	0.000	0.000	0 000	0.0%	0 0%	0.0%
	[illegible]						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
Load Allocations														
Subwatershed [illegible]	[illegible]	CBOD5 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	CBOD5 [illegible]	[illegible]	[illegible]	[illegible] TP	[illegible] DO	TMDL Percent Reduction		
												CBOD5	NH3-N	[illegible] TP
C01 [illegible]	0.60	1.43	0.02	1.00	0.02	7.34	4.625	0.065	3.234	0.065	23.741	0.0%	0.0%	0 0%
C02 [illegible]	0.65	1.43	0.02	1.00	0.02	7.34	5.016	0.070	3.508	0.070	25.748	0.0%	0.0%	0.0%
[illegible]	0.48	1.43	0.02	1.00	0.02	7.34	3.700	0.052	2.588	0.052	18.994	0.0%	0.0%	0.0%
C05 [illegible]	0.80	1.43	0.02	1.00	0.02	7.34	6.165	0.086	4 311	0.086	31 644	0.0%	0.0%	0 0%
C06 [illegible]	1.59	1 43	0.02	1.00	0.02	7 34	12.265	0.172	8.577	0.172	62 956	0 0%	0 0%	0 0%
Atm Deposition							3.222	1.207	4.630	0 412				
	[illegible]						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			

Table 28
Point and Nonpoint Source Contributions to the Delaware River Estuary

Waste Load Allocations														
NPDES	Flow mgd	CBOD5 mg/L	NH_3-N mg/L	TN mg/L	TP mg/L	DO mg/L	CBOD5 lb/day	NH_3-N lb/day	TN lb/day	TP lb/day	DO lb/day	TMDL Percent Reduction CBOD5	NH_3-N	TP
DE0021555-001	0 5500	12 00	1.50	3.63	2.00	5.00	55.09	6.89	16.66	9.18	22.95	0.0%	0.0%	0.0%
DE0000256-601	13.0000	25.00	12 00	50.00	0.30	5.00	2712.53	1302.02	5425.07	32 55	542.51	0.0%	0.0%	0.0%
DE0000612-001	0.8000	18.00	0.50	4.65	0.30	5.00	120.19	3.34	31.05	2.00	33.39	0 0%	0 0%	0.0%
DE0020001-001	0.6800	14.00	1.50	3.63	2.00	5.00	79.46	8.51	20.60	11.35	28.38	0 0%	0.0%	0.0%
DE0050911-001	0.3000	13.21	1.50	3.63	2.00	5.00	33.08	3.76	9.09	5.01	12 52	0.0%	0.0%	0.0%
DE0020320-001	134.0000	17.00	1.50	3.63	2.00	5.00	19012.77	1677.60	4059.79	2236.80	5591 99	0.0%	0.0%	0.0%
DE0000051-001	5.2000	30.00	0.50	4.65	0.30	5.00	1302.02	21.70	201.81	13.02	217.00	0.0%	0.0%	0.0%
DE0000051-002	3.0000	8.00	0.50	4.65	0.30	5.00	200.31	12.52	116.43	7.51	125.19	0.0%	0.0%	0 0%
DE0000051-003	6 0000	8.00	0.50	4.65	0.30	5.00	400.62	25.04	232 86	15.02	250.39	0.0%	0.0%	0.0%
DE0000655-001	33.3000	17.00	1.20	11.16	0.30	5 00	4724.82	333.52	3101.70	83.38	1389 65	0.0%	0.0%	0.0%
PA0012637-002	52.3500	30 00	0.50	4.65	0.30	5.00	13107.79	218.46	2031.71	131.08	2184.63	0 0%	0 0%	0 0%
PA0012637-101	69.8000	30.00	0.50	4.65	0.30	5.00	17477.06	291.28	2708.94	174 77	2912.84	0 0%	0.0%	0.0%
PA0012637-201	3.3400	52.00	29.00	50.00	0.30	5 00	1449.58	808.42	1393 82	8 36	139 38	0 0%	0 0%	0 0%
PA0027103-001	44.0000	30 00	30.00	50.00	0.30	5.00	11017.06	11017.06	18361 76	110.17	1836.18	0 0%	0.0%	0.0%
NJ0005405-001	1.2700	45.00	35.00	50.00	0.30	5.00	476.99	370.99	529.99	3.18	53.00	0.0%	0.0%	0 0%
NJ0024856-001	1.4450	30.00	1.50	3.63	2.00	5.00	361.81	18 09	43.78	24.12	60 30	0.0%	0.0%	0 0%
NJ0021598-001	2.4650	30.00	35.00	65.00	2.00	5.00	617.21	720.07	1337.28	41.15	102.87	0 0%	0.0%	0.0%
NJ0005100-661	22.9000	30.00	0.50	4.65	0.30	5.00	5733.88	95.56	888.75	57.34	955.65	0.0%	0.0%	0.0%
NJ0021601-001	1.7290	30.00	1.50	3.63	2.00	5.00	432.92	21.65	52.38	28 86	72.15	0.0%	0 0%	0 0%
NJ0024023-001	0.9500	40.00	1.50	3.63	2.00	5.00	317.16	11.89	28.78	15.86	39.64	0.0%	0 0%	0.0%
NJ0024635-001	0.0366	15 00	1.50	3.63	2.00	5.00	4.58	0.46	1.11	0.61	1.53	0.0%	0.0%	0.0%
NJ0004286-001	2.1000	30.00	0.50	4.65	0.30	5.00	525.81	8.76	81.50	5.26	87.64	0.0%	0.0%	0.0%
NJ0027[illegible]-001	0.9860	30.00	1.50	3.63	2.00	5.00	246.88	12.34	29.87	16.46	41.15	0 0%	0.0%	0.0%
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			

Load Allocations														
Subwatershed	Flow cfs	CBOD5 mg/L	NH3-N mg/L	TN mg/L	TP mg/L	DO mg/L	CBOD5 lb/day	[illegible] lb/day	TN lb/day	TP lb/day	DO lb/day	TMDL Percent Reduction CBOD5	NH3-N	TP
none														
Atm. Deposition							117.83	44.01	168.84	15.01				
	Total Load Allocation						117.83	[illegible]	[illegible]	15.01				

3) The TMDLs consider the impacts of background pollutant contributions.

Background pollutant contributions are the result of non-anthropogenic sources such as from stream erosion, wild animal wastes, leaf fall, and other natural or background processes[19] During low-flow, summer conditions baseflow contributions to the river are considered most influential and are representative of background contributions.

In terms of the low flow TMDL analysis, EPA used monitoring data from STORET, USGS water-quality data from monitoring stations, baseflow samples collected in 1997 (Senior, 1999), and data from a field study conducted by Dr. John Davis of Widener University (Davis, 1998). Furthermore, atmospheric loads from both dry and wet deposition are considered. EPA believes that use of actual instream monitoring data and atmospheric data will effectively account for background pollutant contributions.

As previously mentioned, the Christina River Basin drains to the Delaware River Estuary, which is affected by tidal influences. Furthermore, the Christina River, Brandywine Creek and White Clay Creek also experience similar tidal effects. The tides are the movement of water above and below a datum plane, usually sea level, which causes tidal currents[20]. Tides are the result of the gravitational forces of the sun and moon on the earth.

Of particular importance when considering tidal influences is the net estuarine flow which is the flow that flushes material out of the estuary over some period of time. Estuaries typically have complicated flow patterns from tidal motion impacts resulting in vertical stratification where freshwater inflow rides over saline ocean water. In essence then, any discharge of pollutants to the Delaware River above and below the confluence of the Christina River and the Delaware River, within a certain distance, could potentially impact water quality within the tidally influenced portions of the Christina River Basin.

It is important to recognize that these pollutant loads are discharged outside the Christina River Basin. However, increased pollutant loads from these sources could negatively impact water quality within the tidally influenced segments of the Christina River Basin causing violations of WQS. Therefore, EPA included the point source loads for those dischargers on the Delaware River in Table 28 above and EPA considers them as background conditions for the estuary. While sensitivity analyses to determine the exact nature and magnitude of impacts to water quality in the tidal portions of the Christina River Basin from increased or decreased pollutant loads from the Delaware Estuary have not been performed, any changes to pollutant loads from these sources should strive to be consistent with the existing pollutant loads in the estuary.

---

[19] Supra, footnote 4. (EPA 1999 Protocol for Developing Nutrient TMDLs) Pg 5-5.

[20] Supra, footnote 5. (Thomann, Mueller) Section 3.

4) The TMDLs consider critical environmental conditions.

Federal regulations at 40 CFR 130.7(c)(1) require TMDLs to take into account critical conditions for streamflow, loading and water quality parameters. The intent of this requirement is to ensure that the water quality of all waterbodies of the Christina River Basin are protected during times when it most vulnerable.

Critical conditions are important because they describe the factors that combine to cause a violation of WQS and will help in identifying the actions that may have to be undertaken to meet WQS.[21] Critical conditions are the combination of environmental factors (e.g., flow, temperature, etc.) that result in attaining and maintaining the water quality criterion and have an acceptably low frequency of occurrence. In specifying critical conditions in the waterbody, an attempt is made to use a reasonable "worst-case" scenario condition. For example, stream analysis often uses a low flow (7Q10) design condition as critical because the ability of the waterbody to assimilate pollutants without exhibiting adverse impacts is at a minimum. Additionally, the *Technical Support Document for Water Quality-based Toxics Control (EPA 505-2-90-001)* recommends the 1Q10 flow (minimum 1-day flow expected to occur every 10 years) or 7Q10 as the critical design periods when performing water quality modeling analysis. Historically, these so-called "design" flows were selected for the purposes of WLA analyses that focused on instream DO concentrations and protection of aquatic life[22]. Pennsylvania, Delaware and Maryland specify 7Q10 as the design or critical conditions for the application of water quality criteria in their WQS.

The Christina River Basin TMDLs adequately addresses critical conditions for flow through the use of 7Q10 flows during the model period from August 1 to August 31. The 7Q10 values are based on data from 17 USGS stream gages in the Christina River Basin. Table 29 below presents flow statistics from USGS gages in the basin.

---

[21] EPA Memorandum regarding EPA Actions to Support High Quality TMDLs from Robert H. Wayland III, Director, Office of Wetlands, Oceans, and Watersheds to the Regional Water Management Division Directors, August 9, 1999.

[22] Supra, footnote 17. (EPA 1994 Water Quality Standards Handbook) Section 5.2.

Table 29. Summary of Flow Statistics from USGS Gages in the Christina River Basin

USGS Gage ID	Drainage Area (mi^2)	Years of Record	Average Flow	Harmonic Mean	7Q10 Flow	[illegible] Flow	[illegible]	[illegible]
01478000	20.5	1944-94	28.21	8.31	1.53	0.54	3.79	1.83
01478500	66.7	1952-79	85.91	47.10	11.00	10.15	24.05	22.38
01478650		1994		38.66				
01479000	89.1	1932-94	114.65	62.19	15.60	14.04	31.23	28.45
01479820		1989-96		24.69				
01480000	47.0	1944-94	63.39	36.51	10.25	8.91	18.38	16.37
01480015		1990-94		41.08				
01480300	18.7	1961-96	26.25	12.83	3.40	3.01	6.62	6.19
01480500	45.8	1944-96	66.33	34.64	8.24	7.34	15.41	14.21
01480617	55.0	1970-96	91.31	52.79	19.02	15.54	24.84	21.63
0148065[illegible]	6.2	1967-68	6.00	3.51				
01480665	33.4	1967-68	36.36	23.45				
01480700	60.6	1966-96	93.46	50.53	13.86	12.17	21.84	19.87
01480800	81.6	1959-68	86.63	44.81	12.56	11.86	20.57	18.81
01480870	89.9	1972-96	153.43	87.17	28.44	23.62	37.66	34.63
01481000	287.0	1912-96	395.13	234.13	70.63	65.04	117.01	107.14
01481500	314.0	1947-94	477.01	266.73	78.13	71.96	123.45	113.32

Source: USGS

In terms of pollutant loading, the critical conditions for point source loads occur during times when maximum flow and concentrations are being discharged. The maximum flows and loads are based on the NPDES permits for each facility. These conditions for point sources are used in the critical condition analysis and allocation scenarios.

Nonpoint source loads were based on monitoring data from STORET as well as data collected by USGS, baseflow samples collected in 1997 and data collected by DEP and DNREC and are representative of background contributions as well as expected land-based, nonpoint sources during low-flow conditions. During these conditions, land-based nonpoint sources are expected to contribute very little pollutant loadings to the waterbody. Furthermore, the ability of the waterbody to assimilate pollutant loads during these low-flow conditions is at a minimum. Consideration of nonpoint source loads would simply remove assimilative capacity and cause further reductions to point sources in order to achieve WQS. As can be seen from Table 8, in most watersheds point sources are the dominant contributors of pollutant loadings in low-flow conditions. The data sets were used to develop characteristic loads of parameters of concern (carbon, nitrogen, phosphorus, DO and algae) for each of the 39 subwatersheds as delineated by the HSPF model.

Use of these loads in the model provides the ability to integrate past pollutant loading events. It is recognized that delayed impacts on DO levels from wet-weather events during critical summertime periods may occur. However, Thomann and Mueller observed that "for some rivers and estuaries, the deposition of solids proceeds only during the low flow summer and fall months when velocities are low. High spring flows the following year may scour the bottom clean and reduce the problem until velocities decrease again. Intermediate cases are common where high flows may scour only a portion of the deposit, oxidize a portion, and then redeposit the material in another location."[23] It is likely that the use of site-specific data to characterize nonpoint source loads during critical conditions would consider those sporadic summertime loading events. In addition, both wet and dry deposition of atmospheric loads are included in the EFDC model.

The water quality parameters of concern are DO and nutrients throughout the system. However, as previously discussed, DO can be affected by BOD, SOD, algae and reaeration. These parameters, in addition to nitrogen and phosphorus, are addressed within the linkage analysis to ensure that the pollutant allocation scenario will ensure that WQS are met and maintained throughout the system.

5) The TMDLs consider seasonal environmental variations.

Addressing seasonal variation, similar to critical conditions, is necessary to ensure that WQS are met during all seasons of the year. Seasonal variations involve changes in streamflow as a result of hydrologic and climatological patterns. In the continental United States, seasonal high flow normally occurs during the colder period of winter and in early spring from snowmelt and spring rain, while seasonal low flow typically occurs during the warmer summer and early fall drought periods[24]. Other seasonal variations include reduced assimilative capacity from changes in flow and temperature as well as sensitive periods for aquatic biota. Seasonal fluctuations in both point and nonpoint source loads must also be considered.

In terms of the point source loads, the values used in the model are representative of those loads expected during the summer season based on DMRs, NPDES permit limits or characteristic concentrations. Likewise, the use of data from STORET, USGS and baseflow sampling to characterize expected nonpoint source loads during the summer will effectively consider seasonality.

[23] Supra, footnote 5. (Thomann, Mueller) Section 6.3.4.

[24] Supra, footnote 8. (EPA 1997 Technical Guidance for Developing TMDLs) Section 2.3.3.

EPA expects that seasonal variations will continue to be addressed through the development of the HSPF model in conjunction with the TMDLs for high-flow conditions. Once this model is linked with EFDC, this will provide EPA with a powerful tool to investigate seasonality, critical conditions and alternate allocation strategies on a larger temporal and spatial scale. However, use of the EFDC model to represent critical low-flow summer conditions prior to development of the HSPF model in no way downgrades the scientific validity or defensibility of the current TMDL analysis and allocation scenario. Regardless, use of the fully integrated and linked model would still require consideration of critical conditions and seasonality. It is reasonable to expect that the allocation scenario from this integrated analysis would reflect the same critical condition and seasonality components in the current low-low analysis and result in similar pollutant loading allocations.

6) The TMDLs include a margin of safety.

This requirement is intended to add a level of safety to the modeling process to account for any uncertainty or lack of knowledge. MOSs may be implicit, built into the modeling process, or explicit, taken as a percentage of the WLA, load allocation, or TMDL.

In consideration of the sheer quality and quantity of data, and the development of the HSPF watershed loading model which will be linked to this EFDC model, EPA is utilizing an implicit MOS through the use of conservative assumptions within the model application. An example of a conservative assumption used in this model is the discharge of point sources located on tributaries directly into the model without consideration of attenuation in the tributary water. The effect is conservative in terms of the main stem river segment since modeling directly to the main stem will not consider potential attenuation between the point of discharge into the tributary and confluence with the downstream main stem segment. This could potentially affect the pollutant allocation scenario. The exact nature of the effect is not known and could be positive or negative. The reverse, however, is not conservative when considering the tributary since negative water quality impacts could be occurring. The ability to model these water quality effects is extremely limited due to lack of resources, time and data and use of this conservative assumption is valid.

Additional factors in the MOS for the TMDLs for the Christina River Basin include:

- All point sources were set to their maximum permitted loads for the TMDL allocations.
- Streamflows were set to critical 7Q10 conditions for the TMDL allocations.
- No shading of the stream due to vegetation canopy was incorporated into the model, therefore, full sunlight conditions reach the stream during daylight hours resulting in maximum photosynthetic activity. Also, no cloud cover was incorporated into the model TMDL allocation runs resulting in maximum solar radiation reaching the stream.

- Stream water temperatures were set to critical high values based on historical data at USGS monitoring stations.

- Finally, all of the above items occur simultaneously resulting in very conservative conditions for the TMDL allocations.

It should be pointed out that this modeling effort relies on data which could be easily characterized as extensive and high-quality. The number of USGS stations and water quality stations, period of record, multiple sources of data, site-specific studies, and comprehensive review and analysis of the model application and techniques all contribute to the confidence EPA has in this TMDL analysis.

7) The TMDLs have been subject to public participation.

Public participation is a requirement of the TMDL process and is vital to its success. At a minimum, the public must be allowed at least 30 days to review and comment prior to establishing a TMDL. In addition, EPA must provide a summary of all public comments and the response to those comments to indicate how the comments were considered in the final decision.

For several years, the CBWQMC and the CBWQMC Policy Committee have served as valuable forums to discuss Christina River Basin issues including the low-flow TMDL study. During the past two years as the work on the TMDLs has accelerated and reached completion, updates on the status of the TMDLs have been presented at the following meetings. These meetings, while not explicitly inviting the general public, were nonetheless open to the public:

- CBWQMC Meetings: March 12, 1999, April 22, 1999, August 5, 1999, January 28, 2000, March 30, 2000 and October 12, 2000.

- CBWQMC Policy Committee Meetings: October 29, 1999, May 31, 2000, July 7, 2000, November 3, 2000 and November 30, 2000.

In addition to the above meetings, a Public Outreach Task Force of the CBWQMC, led by Bob Struble of the Brandywine Valley/Red Clay Creek Valley Association, has held regular meetings to discuss Christina River Basin issues, including these TMDLs.

A special meeting of Public Outreach Task Force was held on May 24, 2000. Invitations to the major dischargers in the Christina River Basin were distributed for this meeting and representatives from Northwestern Chester Municipal Authority, Downingtown Area Regional Authority, City of Coatesville Authority, Bethlehem Steel Corporation, West Chester/Taylor Run STP and the Cecil County, MD Department of Public Works were in attendance. Also attending were representatives of Delaware and Maryland and engineers representing facilities in the Christina River Basin. During this meeting, the draft modeling results and allocations from the Christina River Basin TMDL model were presented and discussed. The model results and allocations were also discussed at a May 31, 2000 Public Outreach Task Force meeting and the May 31, 2000 Policy Committee meeting as well. Additional discharger representatives from Sonoco, Inc. and Kennett Square were present at the May 31 meetings. During the December 1, 2000 Public Outreach Task Force meeting, EPA provided a status report on the Christina River Basin TMDLs.

The CBWQMC has published annual reports summarizing activities and ongoing work for the past several years. The Phase III report, which included a summary of the work completed to date on the Christina River Basin TMDLs and planned future work, was published on August 5, 1999.

A public meeting sponsored by the Delaware Nature Society on the Christina River Basin was held at the Ashland Nature Center in Delaware on June 17, 1999. A presentation on the Christina River Basin TMDLs was included on the agenda.

The proposed Christina River Basin low-flow TMDLs were the subject of two public information meetings on July 18-19, 2000 in West Chester, PA and Wilmington, DE. As result of information received at these meetings, changes were made to the proposed TMDLs and revised draft TMDLs were presented at two formal public hearings on August 29-30, 2000 in West Chester, PA and Wilmington, DE. The public meetings and hearings were the subject of a July 12, 2000 EPA press release and the meetings were advertized in the Wilmington News-Journal, West Chester Local News and the Chester County Papers consortium. EPA held the comment period for the draft TMDLs open through October 15, 2000. As a result of comments received at the public hearings, and during the public comment period, additional changes were made to the Christina River Basin low-flow TMDLs. Comments submitted at the public hearings and prior to the close of the public comment period were reviewed and a public comment responsiveness summary prepared which accompanied the January 19, 2001 TMDL Decision Rationale document.

For the revised TMDLs, EPA issued a public notice of the proposed revisions on March 1, 2002 for a 30-day public comment period. The notice was published in the Chester County Community Newspaper Group and the Wilmington News-Journal. Copies of the notice were also mailed to each affected point source discharger in the Christina River Basin. One set of comments were received and EPA has prepared a response to those comments which accompanies this revised TMDL Decision Rationale document. Because of the limited changes being made to the TMDLs and the few comments received, EPA determined that the proposed TMDL revisions could proceed without the need for a public hearing.

As noted before, EPA Region III established a web site for the Christina River Basin TMDLs to serve as an information clearinghouse for these TMDls. Information related to the proposed TMDLS was posted on this site and included meeting announcements, summaries of presentations and draft TMDL documents. The web site also provided a means for the public to submit comments on the proposed TMDLs

8) There is reasonable assurance that the TMDLs can be met.

There is a high degree of reasonable assurance that each WLA and load allocation for these TMDLs will be implemented. EPA expects the states to implement these TMDLs by ensuring that NPDES permit limits are consistent with the WLAs described herein. The treatment recommendations made by these TMDLs are achievable. According to 40 CFR 122.44(d)(1)(vii)(B), the effluent limitations for an NPDES permit must be consistent with the assumptions and requirements of any available WLA for the discharge prepared by the state and approved by EPA. Furthermore, EPA has authority to object to issuance of an NPDES permit that is inconsistent with WLAs established for that point source. Additionally, according to 40 CFR 130.7(d)(2), approved TMDL loadings shall be incorporated into the states' current water quality management plans. These plans are used to direct implementation and draw upon the water quality assessments to identify priority point and nonpoint water quality problems, consider alternative solutions and recommend control measures. This provides further assurance that the pollutant allocations of the TMDLs will be implemented.

In terms of the nonpoint sources, the load allocations are representative of expected pollutant loads during critical conditions from baseflow, atmospheric, and traditional land-based sources. Reasonable assurance that the current load allocations will be met is based on the extensive data set used to characterize the current nonpoint source pollutant loadings. These loadings are not expected to vary significantly. Therefore, reductions from the current load allocations are unnecessary to meet WQS under low-flow conditions.

VIII. References

Davis, Dr. John 1998. Measurement of Community Photosynthetic and Respiration Rates for Selected Reaches of the Christina Watershed. Report for the Pennsylvania Department of Environmental Protection and Delaware Department of Natural Resources and Environmental Control. March 1998

Omernik, J.M. 1977. Nonpoint Source Stream Nutrient Level Relationships: A Nationwide Study. Corvallis ERL, ORD, US EPA, Corvallis, OR. 151 pp. EPA-600/3-77-105.

Senior, L.A. 1999. Background concentrations for Christina River Model. U.S. Geological Survey, Malvern, PA. Memorandum to M.R. Morton, Tetra Tech, Inc., dated August 6, 1999.

PA DEP. 1986. Implementation Guidance for the Water Quality Analysis Model 6.3. Pennsylvania Department of Environmental Protection. Document ID 391-2000-007. June 1986.

U.S. EPA. 1985a. Ambient Water Quality Criteria for Ammonia-1984. EPA 440/5-85-001. U.S. Environmental Protection Agency, Office of Water, Washington D.C.

U.S. EPA. 1985b. Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling (Second Edition). EPA 600/3-85-040. Office of Research and Development, Athens, GA.

U.S. EPA. 1986 Quality Criteria for Water. EPA 440/015-86-001. U.S. Environmental Protection Agency, Washington, D.C.

U.S. EPA. 1991. Guidance for Water Quality-based Decisions: The TMDL Process. EPA 440/4-91-001. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

U.S. EPA. 1998. 1998 Update of Ambient Water Quality Criteria for Ammonia. EPA 822-R-98-006. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

Total Maximum Daily Load of Nutrients and Dissolved Oxygen Under Low-Flow Conditions in the Christina River Basin, Pennsylvania, Delaware, and Maryland

Appendix A1

Presented in this appendix are longitudinal transect graphs showing the daily average and minimum dissolved oxygen for each of the following 12 stream reaches:

1. Brandywine Creek main stem
2. Brandywine Creek East Branch
3. Brandywine Creek West Branch
4. Buck Run
5. Christina River (tidal reach downstream of Smalleys Pond)
6. Christina River (non-tidal reach upstream of Smalleys Pond)
7. Christina River West Branch
8. Red Clay Creek main stem and East Branch
9. Red Clay Creek West Branch
10. White Clay Creek main stem and Middle Branch
11. White Clay Creek East Branch
12. Delaware River (from Reedy Point, DE to Chester, PA)

Each longitudinal graph shows the following:

- DO average or minimum Water Quality Standard (i.e., TMDL endpoint)
- Model results for NPDES discharges at their existing permit loads
- Model results for NPDES discharges at their final TMDL allocation loads
- Stream flow is in the downstream direction, i.e., from higher to lower river mile

(This page intentionally blank)

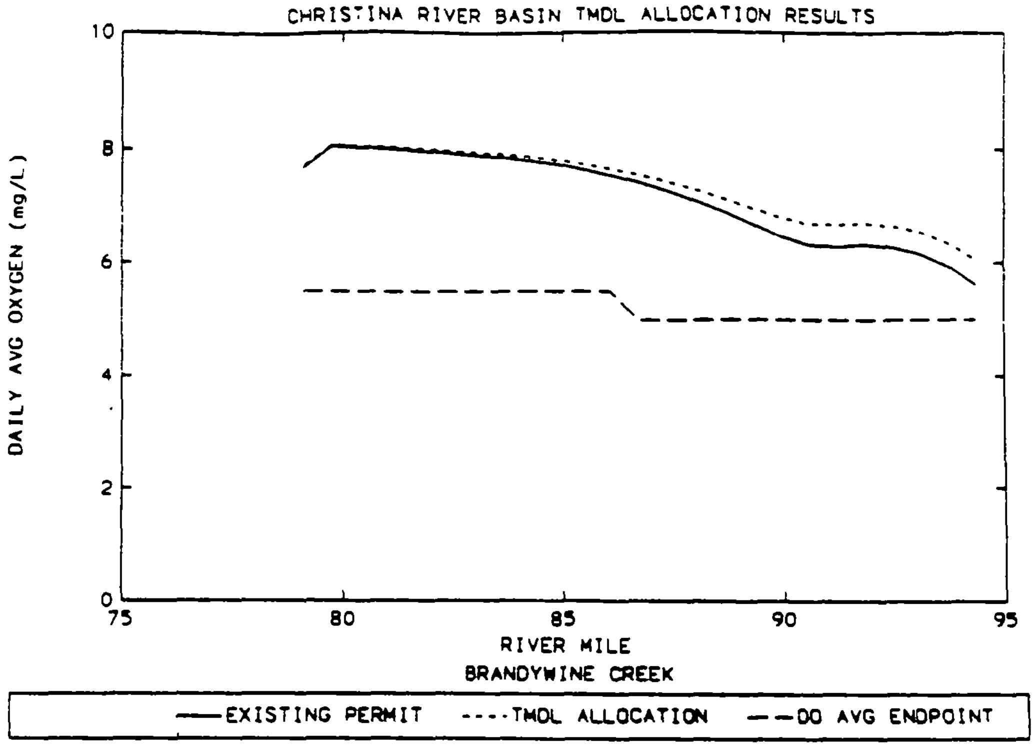


Figure A-1. Brandywine Creek main stem, daily average DO.

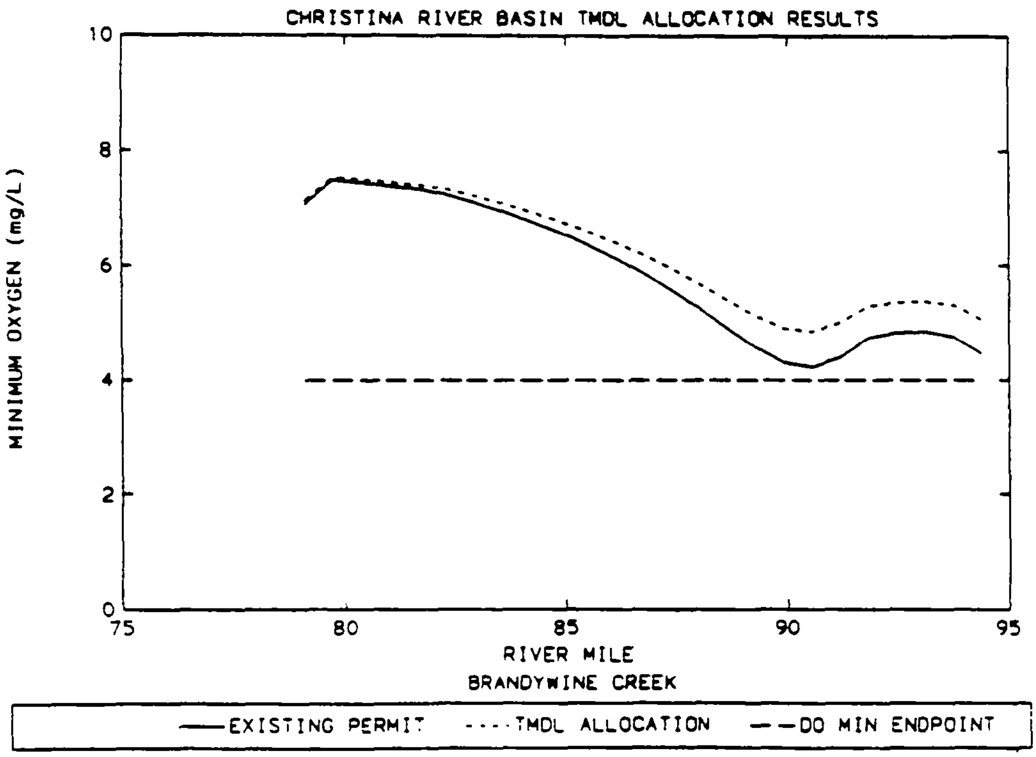


Figure A-2. Brandywine Creek main stem, minimum DO.

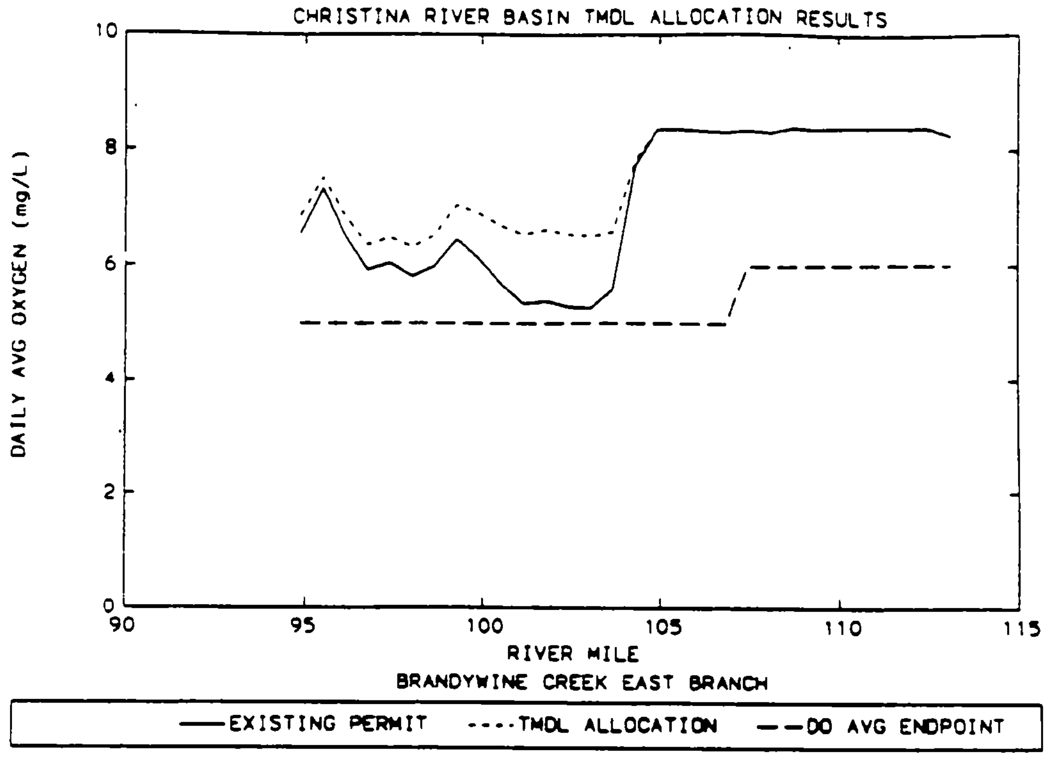


Figure A-3. Brandywine Creek East Branch, daily average DO.

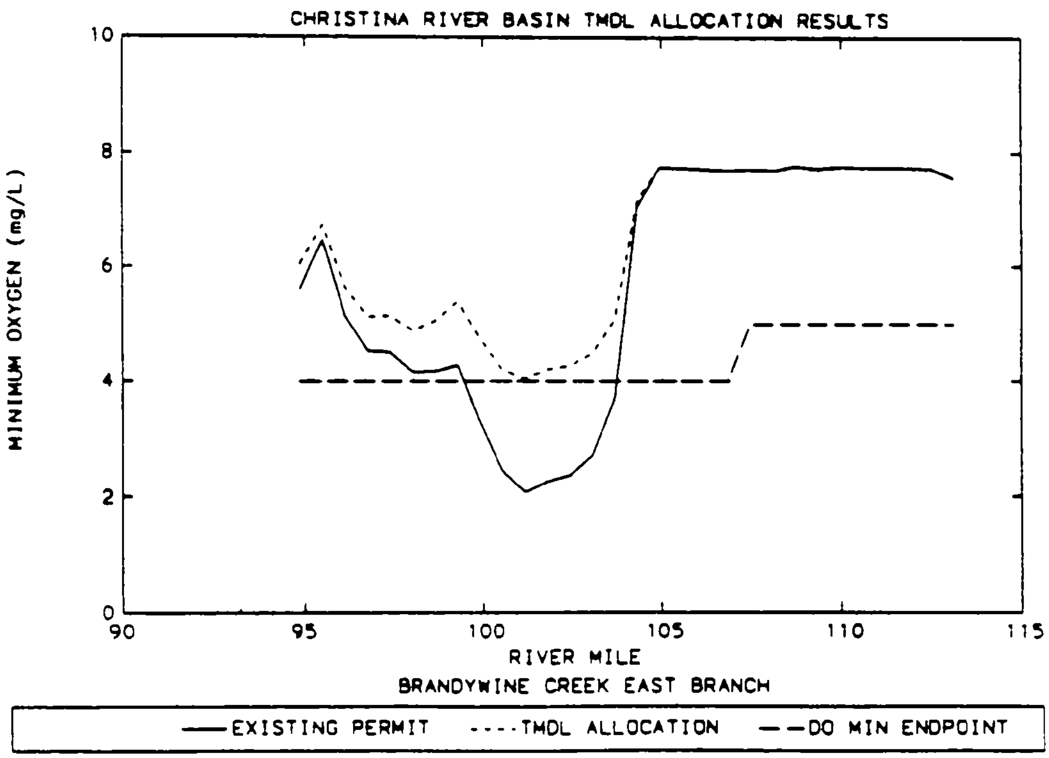


Figure A-4. Brandywine Creek East Branch, minimum DO.

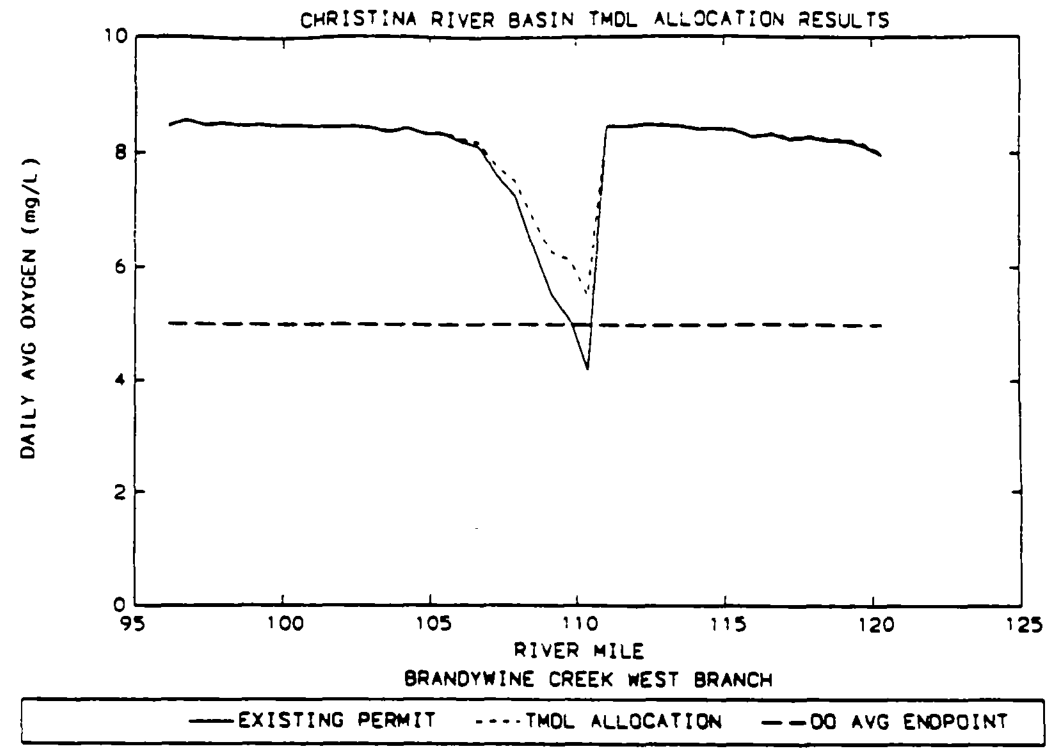


Figure A-5. Brandywine Creek West Branch, daily average DO.

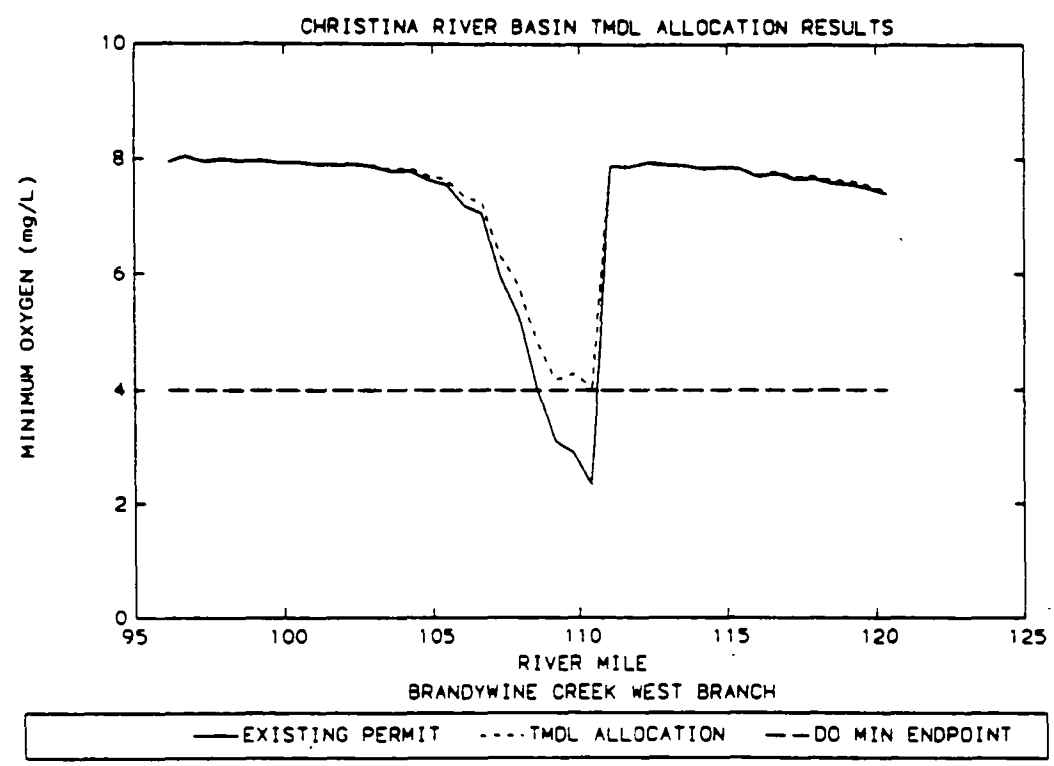


Figure A-6. Brandywine Creek West Branch, minimum DO.

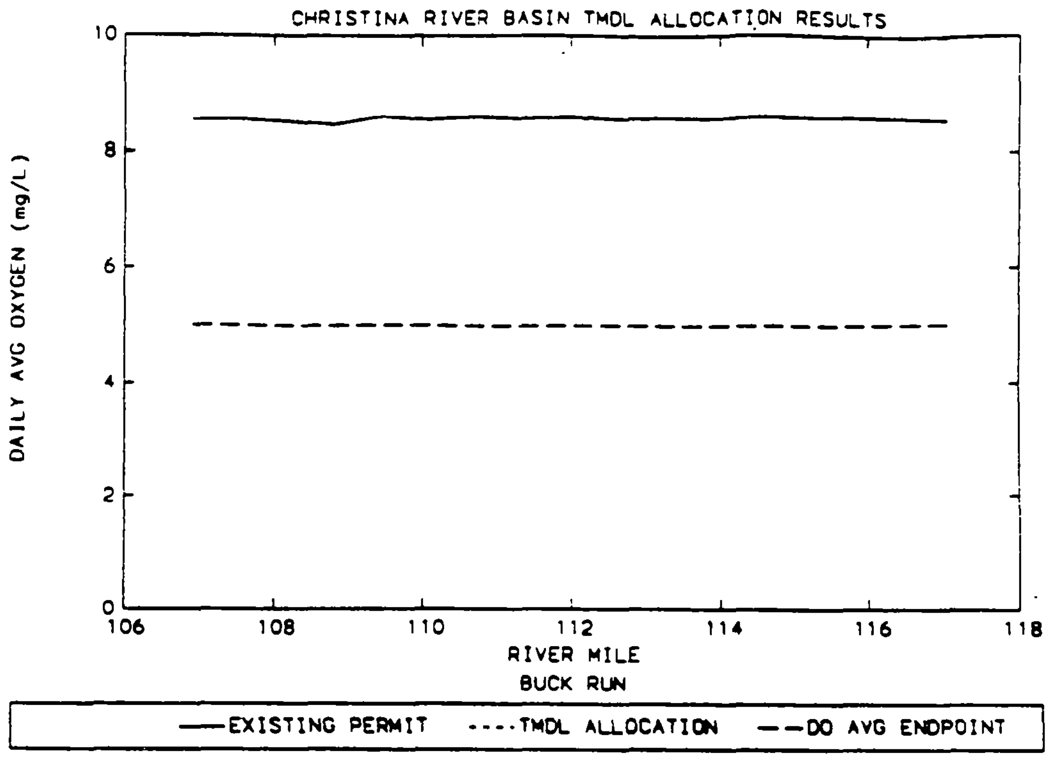


Figure A-7. Buck Run, daily average DO.

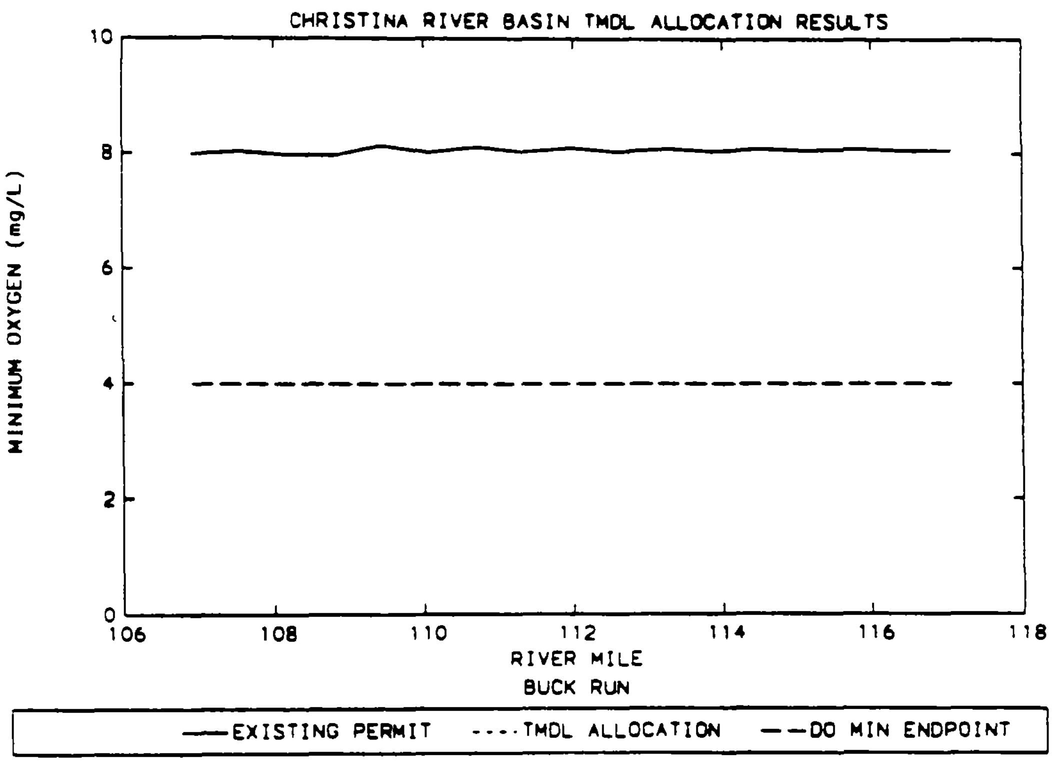


Figure A-8. Buck Run, minimum DO.

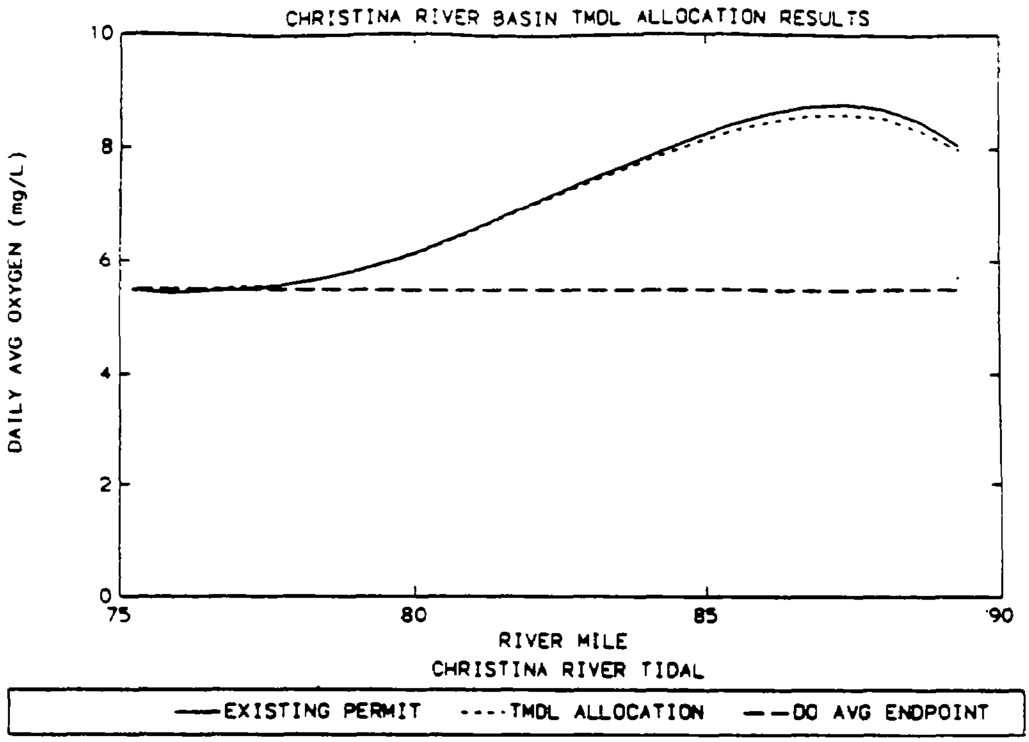


Figure A-9. Christina River (tidal), daily average DO.

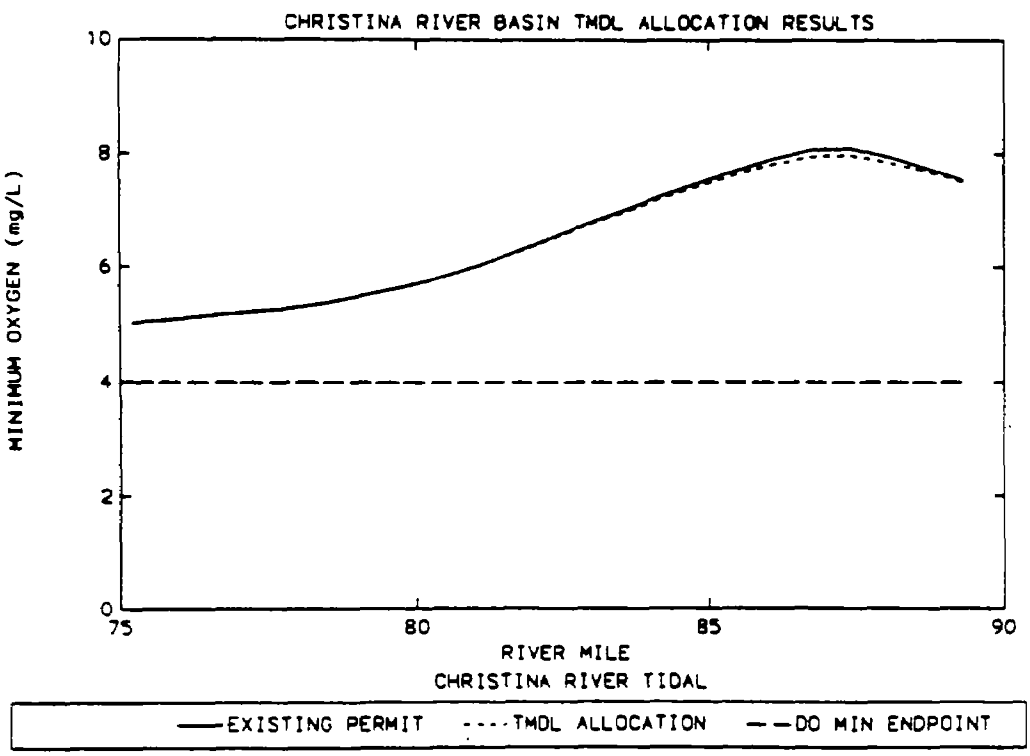


Figure A-10. Christina River (tidal), minimum DO.

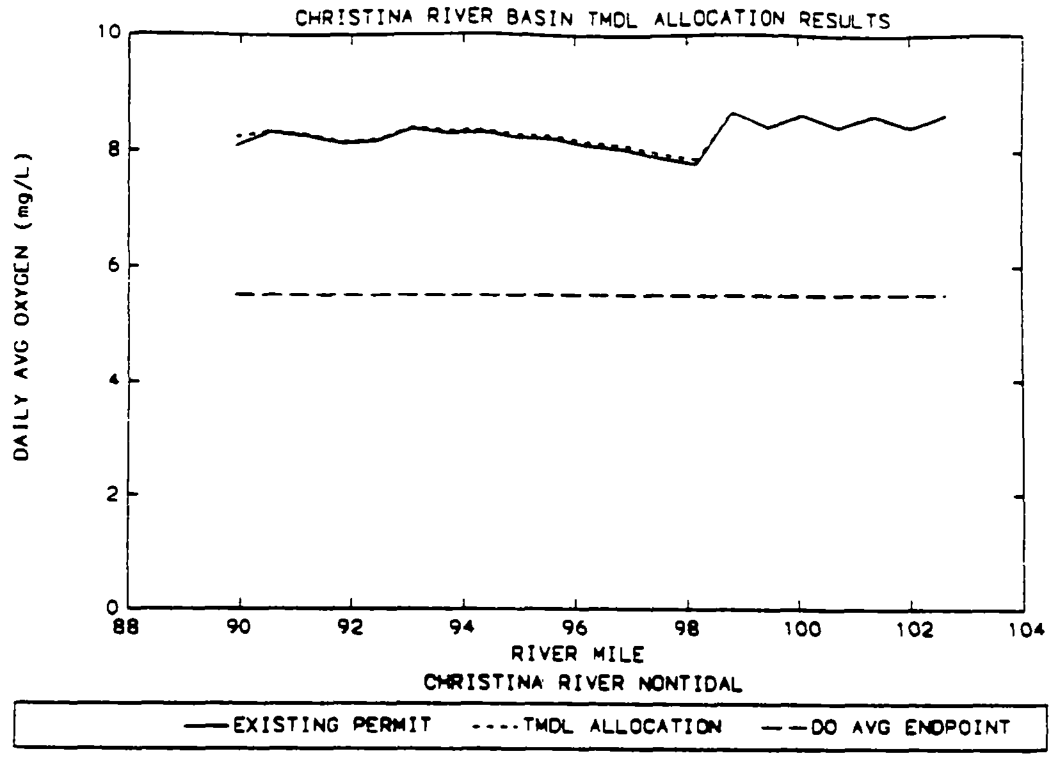


Figure A-11. Christina River (non-tidal), daily average DO.

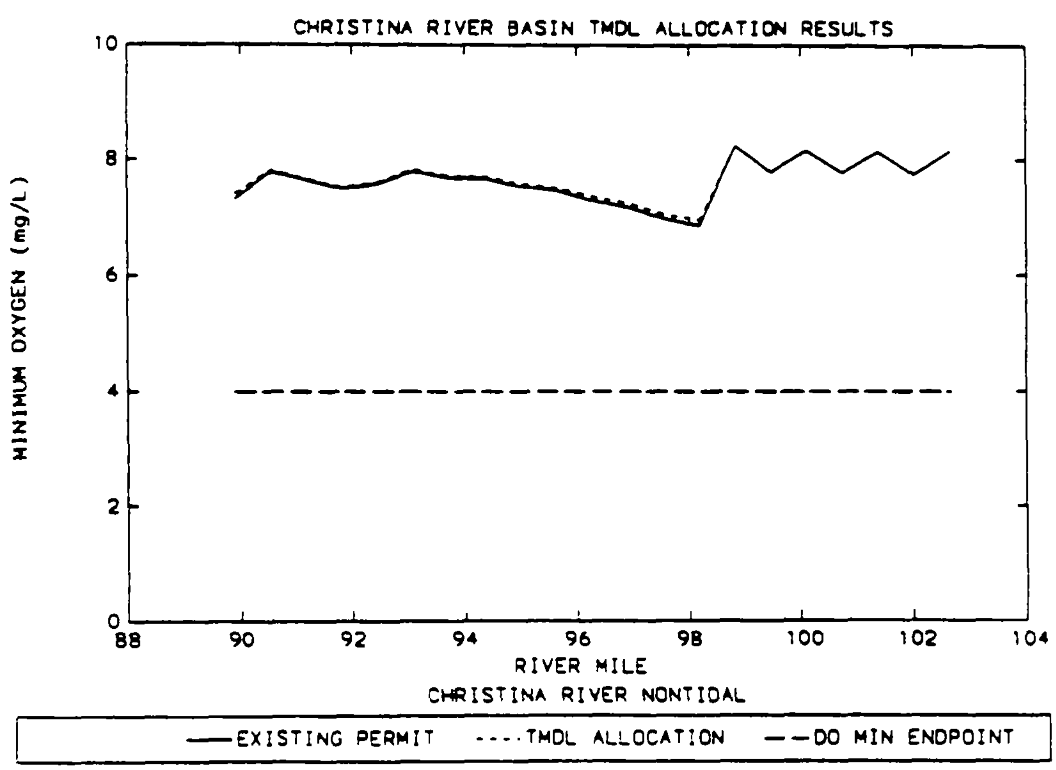


Figure A-12. Christina River (non-tidal), minimum DO.

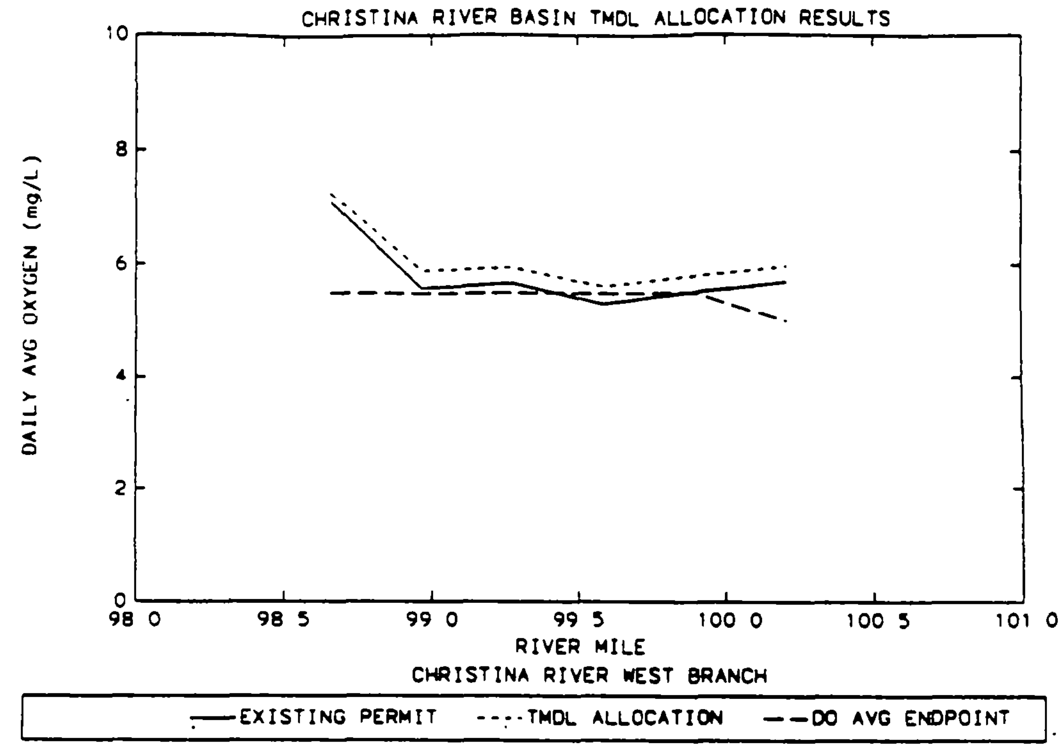


Figure A-13. Christina River West Branch, daily average DO.

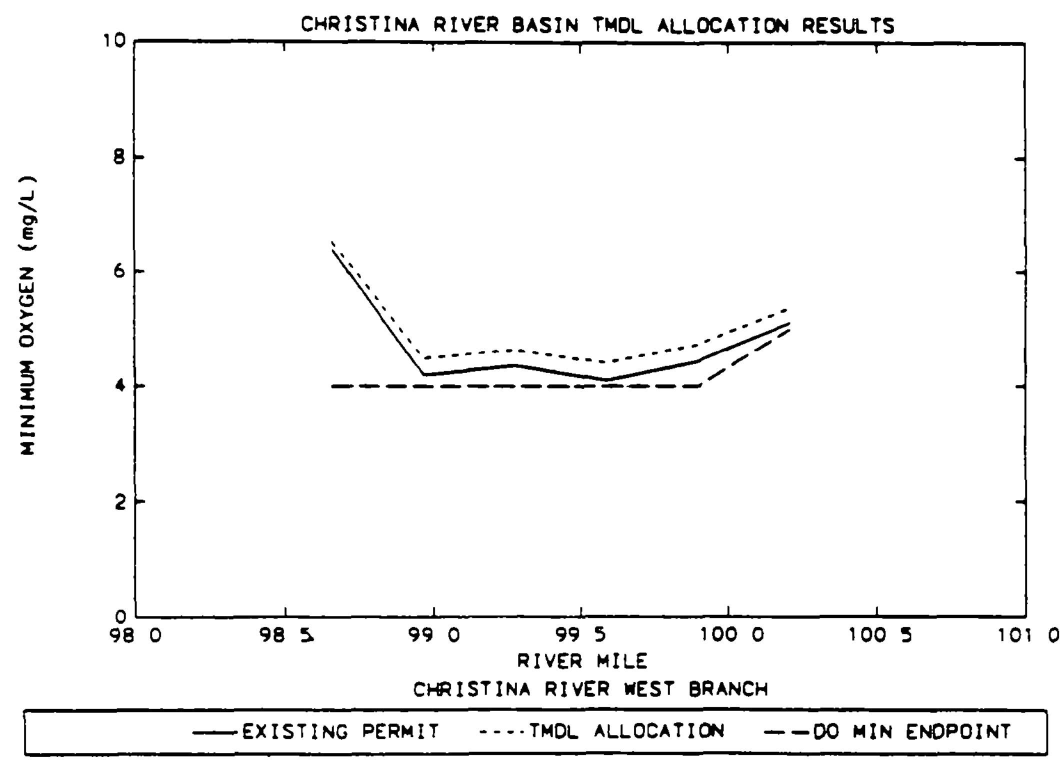


Figure A-14. Christina River West Branch, minimum DO.

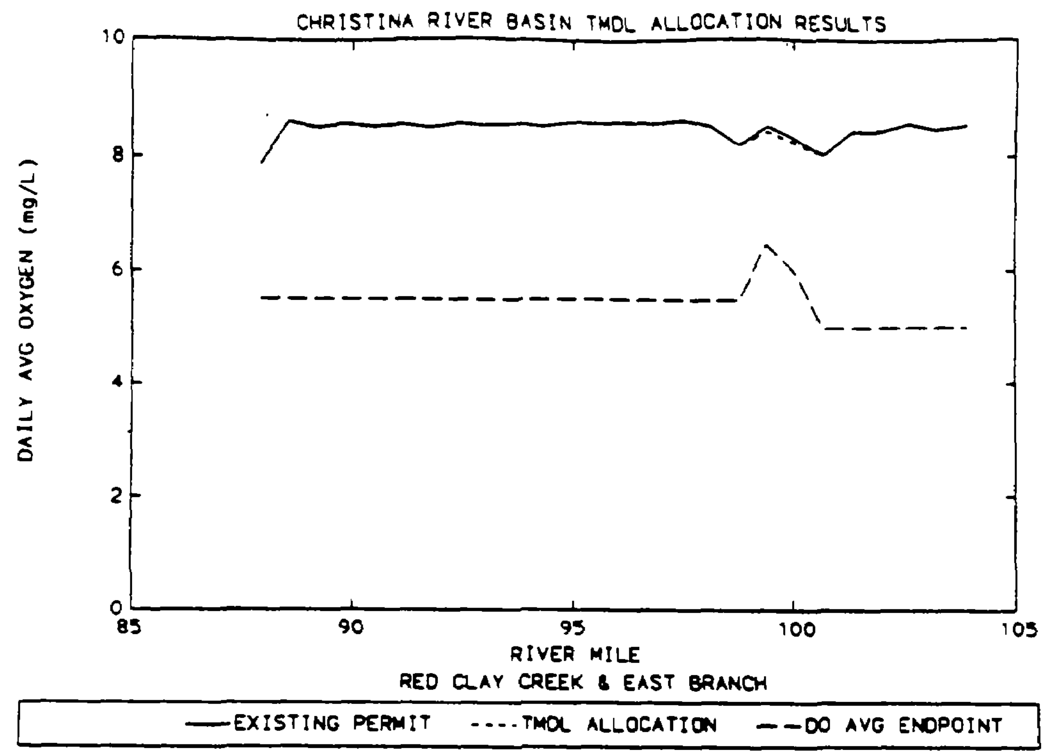


Figure A-15. Red Clay Creek main stem and East Branch, daily average DO.

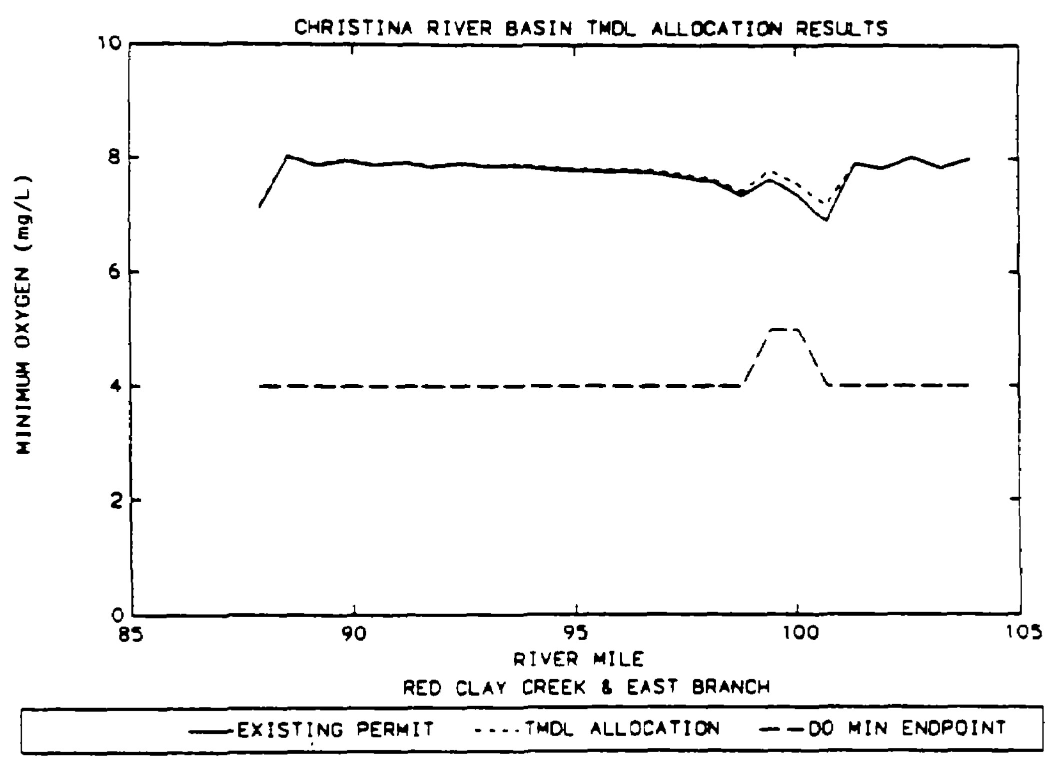


Figure A-16. Red Clay Creek main stem and East Branch, minimum DO.

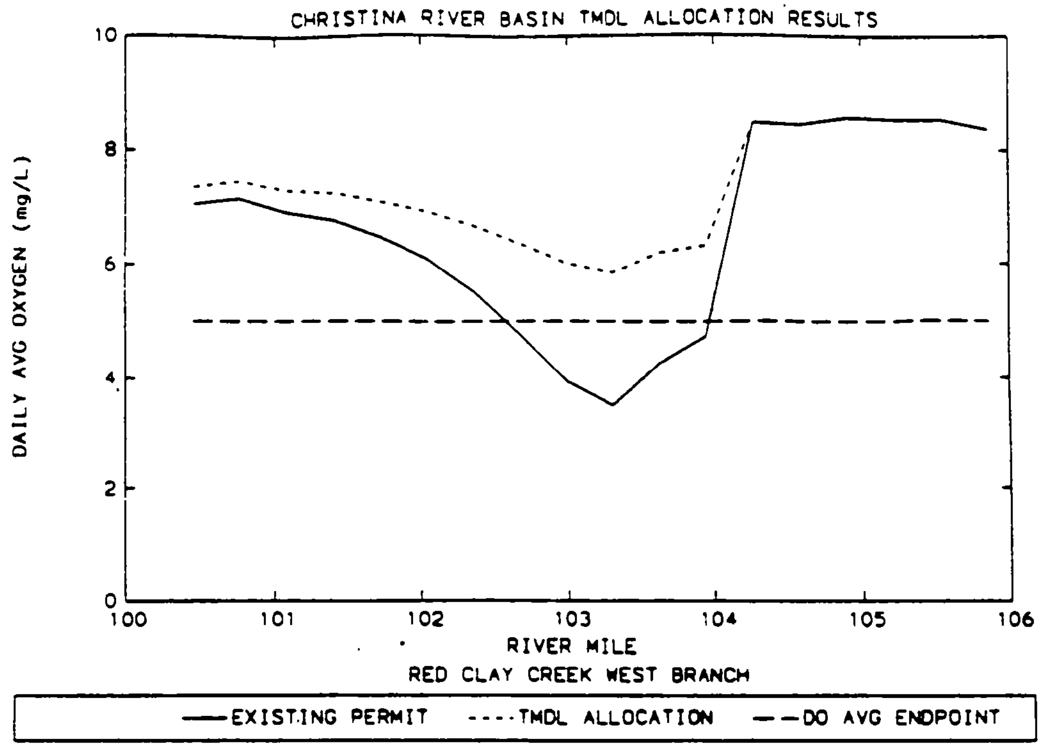


Figure A-17. Red Clay Creek West Branch, daily average DO.

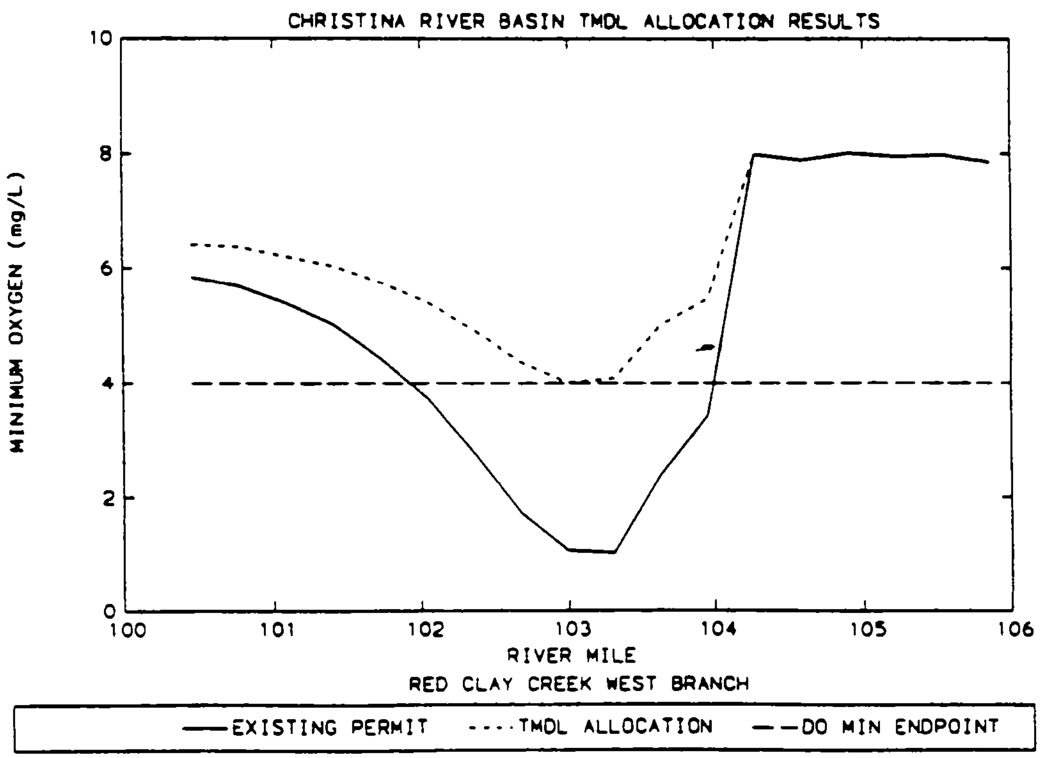


Figure A-18. Red Clay Creek West Branch, minimum DO.

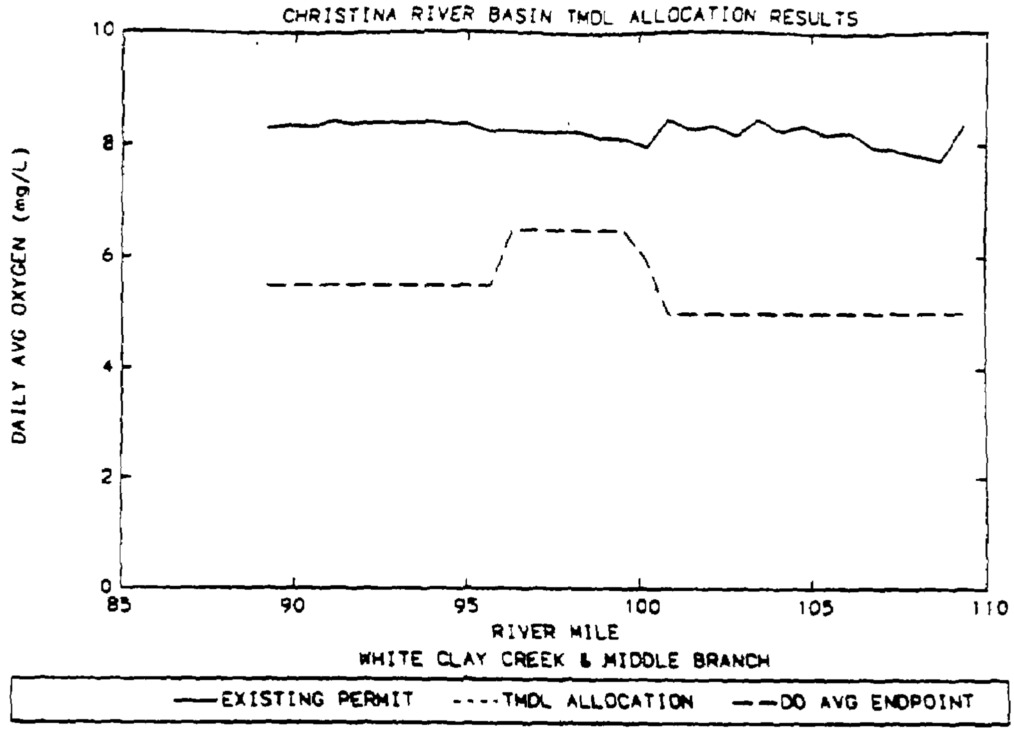


Figure A-19. White Clay Creek main stem and Middle Branch, daily average DO.

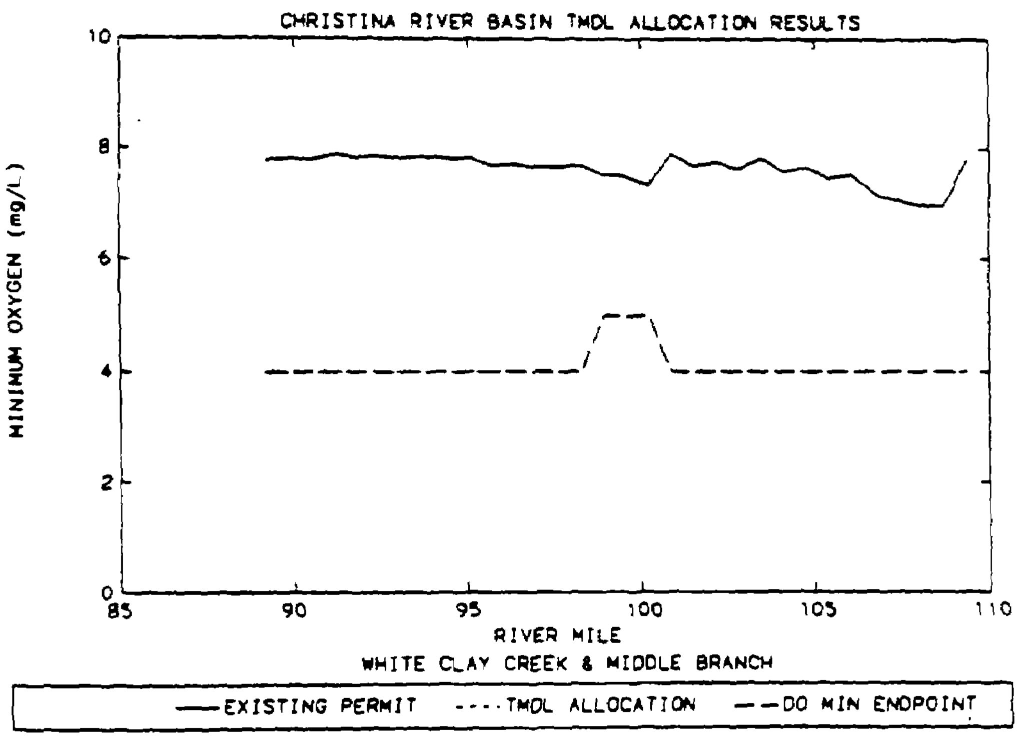


Figure A-20. White Clay Creek main stem and Middle Branch, minimum DO.

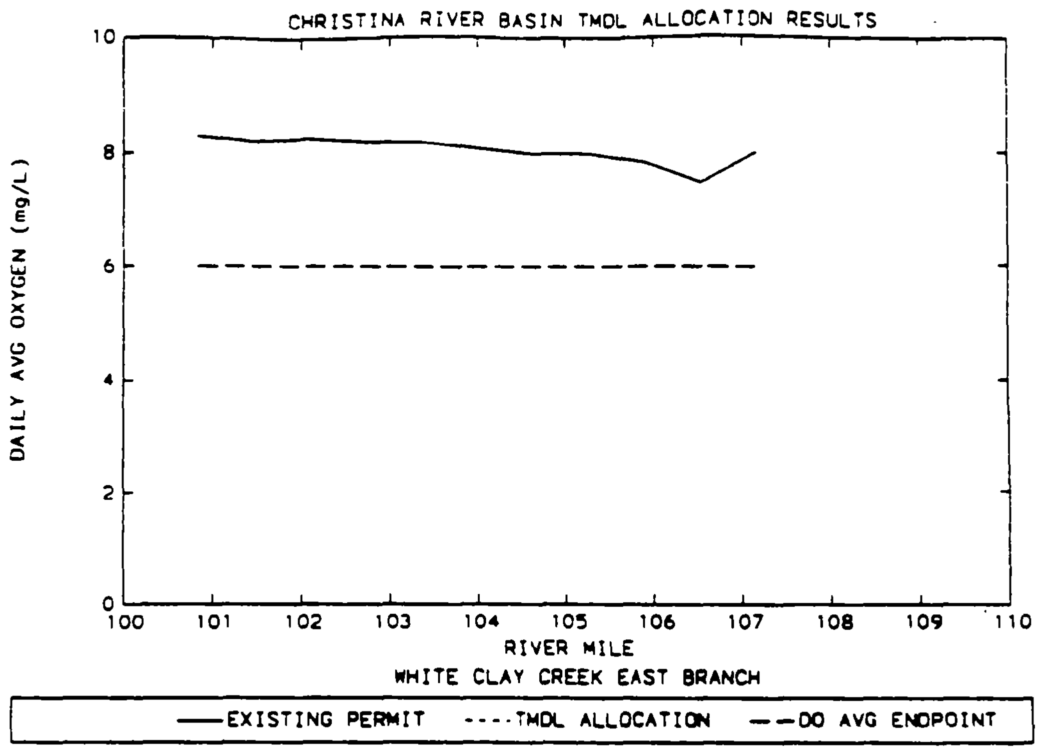


Figure A-21. White Clay Creek East Branch, daily average DO.

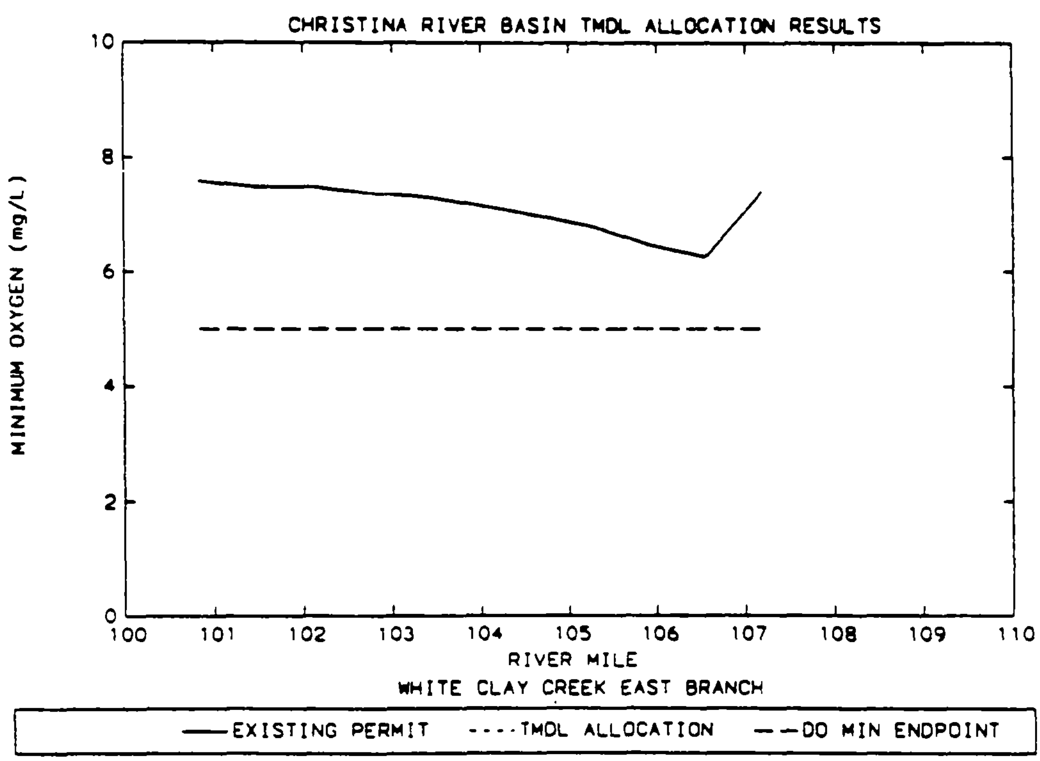


Figure A-22. White Clay Creek East Branch, minimum DO.

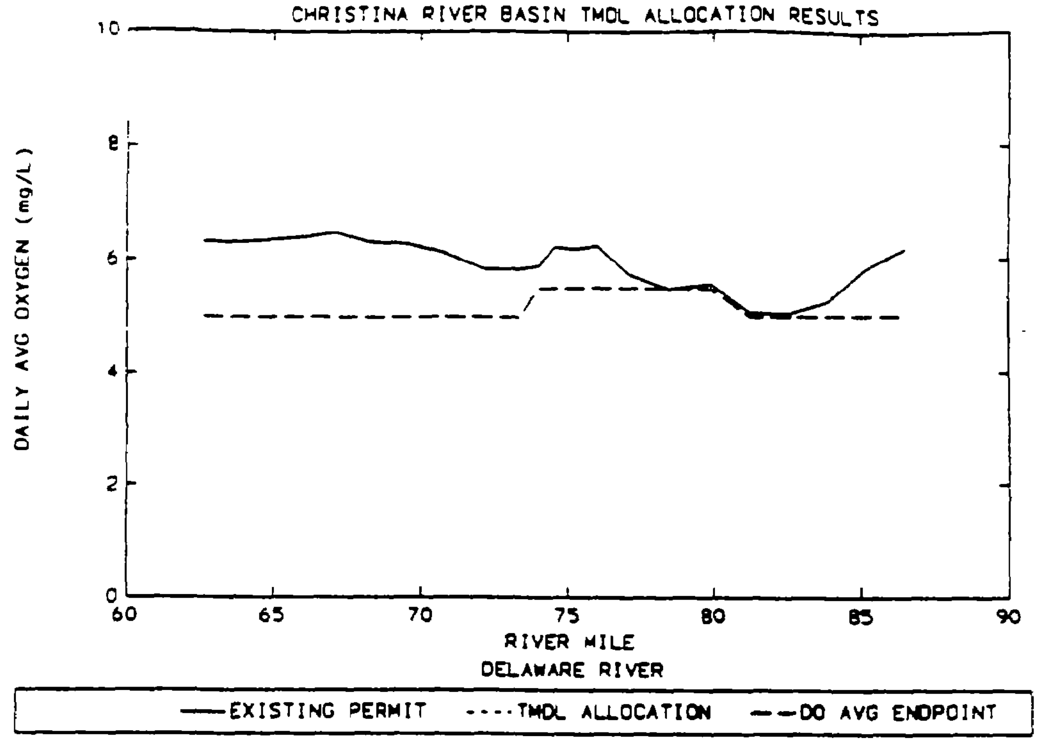


Figure A-23. Delaware River (Reedy Point to Chester), daily average DO.

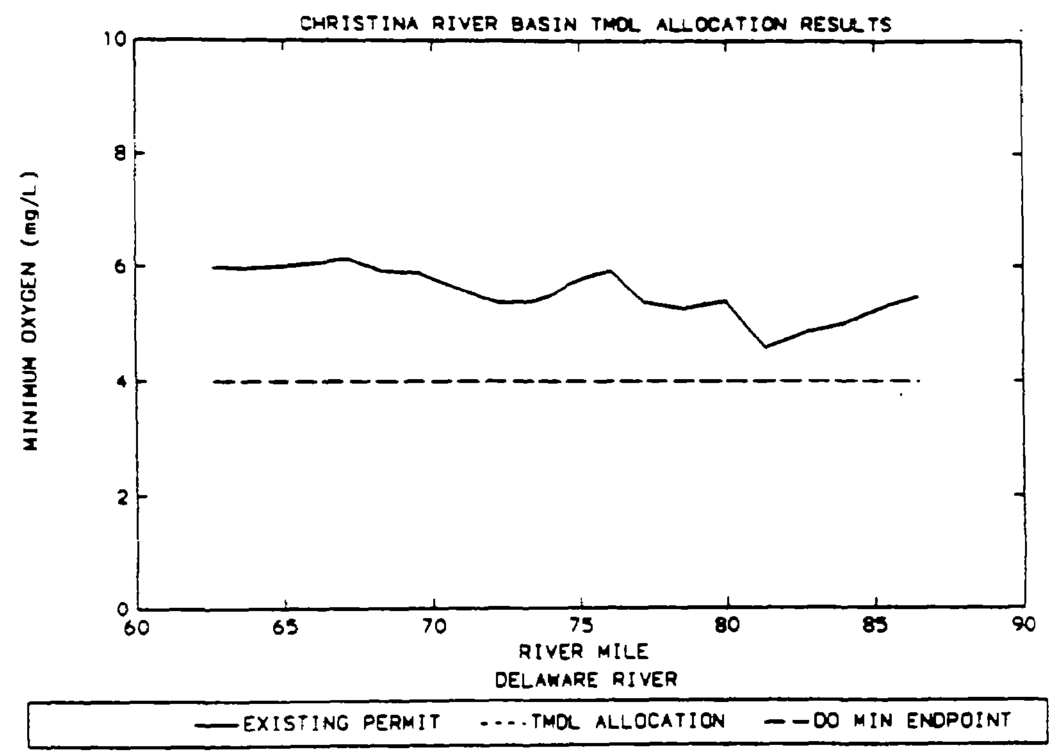


Figure A-24. Delaware River (Reedy Point to Chester), minimum DO.

Response to Comments - Proposed Christina Low-Flow TMDLs Revision

On March 1, 2002, EPA Region III issued a public notice for a proposed revision of the Christina River Basin Total Maximum Daily Loads (TMDLs) under Low-Flow Conditions. The proposed revisions to the TMDLs established by EPA on January 19, 2001 were announced in newspapers in Wilmington, DE and Chester County, PA. Copies of the proposed revisions were mailed to affected wastewater treatment dischargers in the Christina River Basin.

In the public notice, EPA stated that a decision on whether to hold a public hearing on the proposed TMDL revisions would be based on comments submitted on the revisions. Comments by letter dated March 28, 2002 were received from just a single party, Hall & Associates, representing the Downingtown Area Regional Authority. EPA has reviewed these comments and 1) prepared the attached response, and 2) made a determination that the comments do not constitute a need to schedule a public hearing on the proposed revisions. EPA's response to comments follows the order in which the comments were made.

Response to Hall & Associates March 28, 2002 Comments - Proposed Christina Low-Flow TMDLs Revision (March 1, 2002)

A. <u>**Periphyton Model Fundamentally Flawed**</u>

The comments in this section raise issues on periphyton growth projections and how they were used in the Christina River Basin TMDL water quality model in assessing minimum dissolved oxygen values in the watershed, notably the East Branch of Brandywine Creek.

In response to these comments, EPA's contractor for the development of the Christina River Basin TMDL Environmental Fluid Dynamics Code water quality model provided a detailed review of the issues raised. EPA provides this review as its response to these comments as an attachment to this document.

B. <u>**Modeling Assumptions Do Not Reflect Relevant Conditions**</u>

The comments in this section include three points: 1) assumptions used in the revised TMDLs will occur less frequently than one percent of the time and PADEP regulations (25 PA Code 96.3) set a compliance goal of 99 percent to achieve WQS; 2) the revised flow figure of 7.134 mgd used for the Downingtown facility incorporates wet weather flows and would not be appropriate for the conditions used to set the revised TMDLs and 3) the design conditions, particularly the permitted limits for each parameter, used as the basis for the TMDL are inappropriate for the critical conditions analysis used to develop the revised TMDLs.

EPA Response:

Several of these points and related issues were made in comments submitted on the Christina River Basin Low-Flow TMDL issued by EPA on January 19, 2001. In the Responsiveness Summary prepared for the public hearing and open comment period, comments (and responses) 01-A-03, 02-B-02, 07-G-02 and 10-J-05 are pertinent to some of the issues raised by these comments and are hereby incorporated here by reference.

On the question of the PADEP 99% compliance goal, PADEP interprets this goal in the context of setting NPDES effluent limitations as equivalent to a 7Q10 (7-day average flow occuring once in 10 years) low-flow analysis. Limits set on this basis are considered to ensure that WQS are maintained 99% of the time. As EPA used a 7Q10 analysis in calculating the TMDLs, the recommended limits do not impose a greater WQS compliance requirement than employed in PADEP regulations.

The revised flow figure for the Downingtown Area Regional Authority of 7.134 mgd (one of the flow figures that was found in error in the original TMDL calculation - 7.0 mgd was previously used) is the permitted flow value used in establishing NPDES permit limits for the Downingtown facility. EPA used maximum permitted flow values in calculating the TMDLs. As was explained in comments on the original Christina TMDL, this is standard EPA practice and is a consideration in establishing a reasonable Margin of Safety in the TMDL calculations.

Regardless of how the flow would be comprised. Downingtown is permitted to discharge 7.134 mgd and this figure must be used in the TMDL calculations.

The design conditions and critical conditions analysis used in the TMDL calculations are standard EPA practice. The use of the 7Q10 flow condition has been previously discussed above. The maximum permitted flow figures are appropriate when used in steady-state conditions as employed in the Christina River Basin TMDL calculations The combination of these factors is designed to produce a 'worst-case' but possible scenario to ensure that WQS will be met and helps provide a reasonable Margin of Safety as noted above

C. **EPA's Approach is More Restrictive Than Necessary to Achieve Standards**

The comments in this section suggest that the revised TMDLs should only be used to set permit limitations during the month of August when critical flow and temperature conditions are expected to occur simultaneously.

EPA Response:

Both TMDL calculation procedures and NPDES permitting processes employed a critical conditions analysis to determine appropriate limitations. While low flow information and model calibrations may be limited to a period as short as one month (e.g, August) or less, comparable low flow conditions can occur at other times during the year. PADEP procedures for seasonal applications of NPDES permit limits employ a May 1 to October 31 period. The revised Christina River Basin low-flow TMDL and the specific TMDL reductions have been clarified in the revised TMDL document to indicate that the TMDL Waste load allocations are applicable during the May 1 to October 31 period used in PADEP permitting decisions. EPA believes this is an appropriate seasonal approach to ensure adequate protection of WQS and provide a reasonable Margin of Safety.

TETRA TECH, INC.
10306 Eaton Place, Suite 340
Fairfax, VA 22030
Telephone (703) 385-6000
FAX (703) 385-6007
Email MortoMi@tetratech-ffx.com

MEMORANDUM

DATE: June 28, 2002
TO: Tom Henry and Larry Merrill, U.S. EPA Region III
FROM: Mike Morton, Tetra Tech, Inc.
SUBJECT: *Response to DARA Comments on Revised Christina River TMDL*

Attached are my responses to the issues raised by Hall & Associates (March 28, 2002 letter to EPA Region III) regarding the Revised Christina River Basin TMDL and the impacts on the Downingtown Area Regional Authority (DARA) wastewater treatment plant.

Response to DARA comments on Revised Christina River TMDL

U.S. Environmental Protection Agency
Region III

June 7, 2002

It appears the primary point of contention revolves around the water quality model's ability to simulate periphyton biomass and the associated daily range of dissolved oxygen (DO) due to photosynthesis and respiration. More specifically, the comments from Gallagher and Knorr focused primarily on the phosphorus half-saturation constant (KHPm) used in the model. It appears that neither Gallagher or Knorr was aware of the 1997 field study (Davis 1998) in which a laboratory algal assay determined a value for KHPm of 0.132 mg/L. This site-specific phosphorus half-saturation constant was used as the basis for formulating the periphyton kinetics in the water quality model. A literature search indicates that the algal phosphorus half-saturation constant can range from 0.001 to 1.520 mg/L (see Table 1 below).

Table 1. Literature values for phosphorus half-saturation constant.

Algal Species	Half-saturation Constant (mg/L)	Reference
Asterionella formosa	0.002	Holm & Armstrong, 1981
Asterionella japonica	0.014	Thomas & Dodson, 1968
Biddulphia sinensis	0.016	Quasim et al., 1973
Ceratualina bergonii	0.003	Finenko & Krupatkina, 1974
Chaetoceros curvisetus	0.074 - 0.105	Finenko & Krupatkina, 1974
Chaetoceros socialis	0.001	Finenko & Krupatkina, 1974
Chlorella pyrenoidosa	0.380 - 0.475	Jeanjean, 1969
Cyclotella nana	0.055	Fuhs et al., 1972
Cyclotella nana	0.001	Fogg, 1973
Dinobryon cylindricum	0.076	Lehman (unpublished)
Dinobryon sociale	0.047	Lehman (unpublished)
Euglena gracilis	1.520	Dlum, 1966
Microcystis aeruginosa	0.006	Holm & Armstrong, 1981
Nitzschia actinastreoides	0.095	Von Muller, 1972
Pediastrum duplex	0 105	Lehman (unpublished)
Pithophora oedogonia	0.980	Spenser & Lembi, 1981
Scenedesmus obliquus	0.002	Fogg, 1973
Scenedesmus sp.	0.002 - 0.050	Rhee, 1973
Thalossiosira fluviatilis	0.163	Fogg, 1973

As a part of his review, Knorr performed a statistical analysis of the model periphyton biomass data presented in Table 9-5 of the model report and concluded that the biomass projected by the model was significantly different from the biomass measured in 1985. Unfortunately, the model periphyton biomass values reported in Table 9-5 were from an early draft calibration report, not the final calibration. The ranges of model periphyton biomass from the final model calibration (during the period 8/1/1997 - 8/31/1997) are presented in the corrected table below:

Table 9-5. Comparison of model periphyton with 1985 measurements (Knorr and Fairchild 1987).

Site ID	River Mile	1985 Periphyton Biomass (ug chlorophyll-a · cm⁻²)	EFDC Grid Cell	Model Periphyton (ug chlorophyll-a · L)	Water Depth (m)	Model Periphyton Biomass (ug chlorophyll-a · cm⁻²)
1	109.3	6.2 - 10.2	54.69	74 - 97	0.30	1.6 - 2.0
2	NA	8.0 - 16.5	NA	NA	NA	NA
3	106.2	8.5 - 13.0	54.64	59 - 72	0.33	1.3 - 1.7
4	102.4	9.0 - 17.0	54.58	351 - 601	0.36	8.2 - 14.0
5	101.2	11.5 - 21.0	54.56	396 - 662	0.37	9.1 - 15.2
6	96.1	8.0 - 14.3	54.50	93 - 169	0.35	3.6 - 6.5

The purpose of citing the Knorr and Fairchild periphyton biomass was to demonstrate that the model predictions were in the ballpark with historical information. One cannot reasonably expect that the model, which was developed using 1997 conditions, to exactly agree with field measurements made 12 years earlier in 1985. It is also important to understand a statement from the Knorr and Fairchild (1987) paper:

> *"High current velocities, however, may have caused erosion of accumulated algal cells, reducing standing crop below levels otherwise sustainable by ambient light and nutrient supply. Storm events on 16 and 27 July, and on 1 August during the 23 day incubation period, monitored by fluctuating discharge at USGS gaging station 01480870 located at site 5, provide additional evidence of probable scouring of the pots during the study."*

This statement implies that the periphyton biomass measured in 1985 may have been substantially lowered by three storm events. This confounds attempts to directly compare the 1997 model periphyton predictions with the 1985 observations. The time to establish maximum periphyton biomass following a scouring storm event typically ranges from 20 to 120 days (Biggs 2000). Knorr's use of the Crystal Ball Monte Carlo analysis was interesting, however, the exercise was moot due to the different hydraulic and nutrient loading conditions in 1985 and 1997.

Our responses to individual comments are presented below.

Comments

A. Periphyton Model Fundamentally Flawed

The model developed by EPA to evaluate compliance with dissolved oxygen standards in the Christina River Basin predicts periphyton growth as the primary factor affecting minimum DO levels in the receiving water. This projection of minimum DO was used to mandate more restrictive TP, CBOD, and ammonia limits. DARA has already notified the Agency that periphyton projections made to compare the TMDL loading with other allocation scenarios are fundamentally flawed for the following reasons:

- *No periphyton measurements were made to calibrate the model or to verify calibration of the periphyton growth subroutine, thus the model results are sheer guesswork.*

Response: Direct instream measurements of periphyton biomass were not made during the recent (1995-1997) field studies in the Christina River Basin. However, as part of the August 1997 field study (Davis 1998), a laboratory algal assay analysis was conducted which estimated periphyton biomass productivity at eight locations in the Christina River Basin, including two stations on East Branch Brandywine Creek. This algal assay analysis indicated an algal biomass of 12 ug/L (dry weight) at the station upstream of DARA and 187 ug/L (dry weight) downstream of DARA. In addition, diel DO measurements from August 1997 show the diel DO swing downstream of DARA is about 6 to 7 mg/L, and the diel DO swing upstream of DARA is about 2 mg/L. The water quality model projects these diel DO swings very well (see Figure 9-17 in the model report). This is clear evidence based on field observations that increased nutrients from the DARA discharge are stimulating periphyton growth and the diel DO swing. The fact that the model projects this diel DO swing indicates that the periphyton kinetics formulated in the model are scientifically credible.

- *Site-specific periphyton data for the East Branch of Brandywine Creek from Knorr and Fairchild (1987), cited in the model documentation as the basis for periphyton biomass projections, demonstrate that the model does not accurately represent periphyton growth in the East Branch of Brandywine Creek. The model greatly under-predicts periphyton biomass upstream of the DARA outfall and over-predicts periphyton biomass downstream of the outfall.*

Response: The model documentation does not claim that the Knorr and Fairchild (1987) study was used as the basis for periphyton biomass projections. The Knorr and Fairchild periphyton biomass, measured in 1985, represented the only in-situ measurements available for comparison to the model periphyton biomass predictions. The Knorr and Fairchild data were not used to develop any coefficients in the model. The purpose of citing the Knorr and Fairchild periphyton biomass was to show that the model predictions were in the ballpark with historical information. One cannot reasonably expect that the model, which was developed using 1997 conditions, to exactly agree with field measurements made 12 years earlier in 1985.

- *Available data do not indicate that periphyton data will change significantly due to higher loadings from DARA. In fact, the projected TP levels under permitted loadings are lower than the conditions observed by Knorr and Fairchild, which confirmed periphyton levels did not increase significantly below DARA.*

Response: The field study conducted by Davis (1998) indicates that periphyton growth in the East Branch Brandywine Creek in the vicinity of DARA is phosphorus limited. The model kinetics were developed based on the Davis (1998) study which confirmed that periphyton levels do, indeed, increase downstream of DARA. As part of the August 1997 field study (Davis 1998), a laboratory algal assay analysis was conducted which estimated periphyton biomass at eight locations in the Christina River Basin, including two stations on East Branch Brandywine Creek. This algal assay analysis indicated an algal biomass of 12 mg/L (dry weight) at the station upstream of DARA and 187 ug/L (dry weight) downstream of DARA.

- *Knorr and Fairchild, the only periphyton data cited in the final report, concluded that phosphorus did not limit growth of periphyton in the East Branch of Brandywine Creek at ambient concentrations significantly less than the TMDL level. Consequently, increases in phosphorus concentration above the TMDL level would have little, if any, effect on periphyton biomass, contrary to the model's prediction*

Response: As part of the Davis (1998) field study, a laboratory algal productivity analysis was conducted by PA DEP. The study concluded that the limiting nutrient for periphyton growth in all reaches was phosphorus. Also, the Davis study concluded that contributions of phosphorus from wastewater dischargers in the study reaches had a significant impact on downstream phosphorus concentrations and periphyton biomass. The water quality model was formulated based on the Davis (1998) study and supports the conclusions of that study.

1. Findings of Thomas W. Gallagher

(a) *Literature and field studies indicate that limiting nutrient levels for periphyton growth due to phosphorus range from 5 to 50 ug/L, far lower than ambient TP levels found during various studies used to develop the TMDL.*

Response: No reference was provided for this statement. Site-specific field studies in the Christina River Basin (Davis 1998) indicate that limiting phosphorus levels for periphyton growth are greater than 0 100 mg/L.

(b) *The periphyton predictions in the model are not credible. Given the level of phosphorus in the TMDL and alternative scenarios, there should be no significant effect on periphyton biomass under low flows or increased loadings.*

Response: Given the fact that the site-specific phosphorus half-saturation constant was estimated as 0 132 mg/L, the increased phosphorus loadings from DARA cause a predictable increase in periphyton biomass and diel DO range downstream of DARA.

(c) *The predicted changes in DO associated with phosphorus loading for the TMDL and alternative scenarios are unrealistic, inconsistent with the literature, and inconsistent with site-specific analysis of the East Branch Brandywine Creek.*

Response: Site-specific diel DO measurements were made during the 1997 field study (Davis 1998) These DO measurements are shown in Figure 9-17 in the model report. The measured DO swing downstream of DARA is about 6 to 7 mg/L, and the diel DO swing upstream of DARA is about 2 mg/L. As one can see from Figure 9-17, the water quality model provides a reasonable projection of these diel DO swings. The site-specific data collected in 1997 provides evidence that increased nutrients from the DARA discharge are stimulating periphyton growth and the diel DO swing. The fact that the model projects this diel DO swing indicates that the periphyton kinetics formulated in the model are realistic.

(d) *The model used a phosphorus Michaelis constant for periphyton of 132 ug/L, over 100 times greater than that for suspended algae (without any scientifically defensible justification), and compensated for this by modifying the carbon chlorophyll ratio to match the diurnal variation during the calibration period The same data fit could have been obtained using more realistic model coefficients and would not have had unrealistic periphyton growth projections*

Response The Michaelis constant (i.e., phosphorus half-saturation constant) of 0.132 ug/L was derived from a field study conducted during August 1997 (Davis 1998). The commentor may not understand the use of the carbon-to-chlorophyll ratio in the water quality model. Algal biomass is computed in the model in units of carbon The carbon-to-chlorophyll ratio has absolutely no bearing on any internal computations of algal growth or dissolved oxygen levels. The purpose of the carbon-to-chlorophyll ratio is to convert the algal biomass in carbon units to chlorophyll units for model output

(e) *The model was developed without sufficient data to link nutrients, periphyton, and dissolved oxygen..*

Response: The model was developed based on a field data collected primarily from 1995 to 1998. In addition, a special field study conducted in 1997 (Davis 1998) to measure community photosynthetic and respiration rates in selected reaches of East Branch Brandywine Creek, West Branch Brandywine Creek, West Branch Red Clay Creek, and White Clay Creek. As part of the Davis (1998) field study, a laboratory algal productivity analysis was conducted by PA DEP. The study concluded that the limiting nutrient for periphyton growth in all reaches was phosphorus. Also, the study concluded that contributions of phosphorus from wastewater dischargers in the study reaches had a significant impact on downstream phosphorus concentrations and photosynthesis rates. The study recommended that pollution control strategies directed toward maintaining dissolved oxygen concentrations in these stream reaches should address the impact of phosphorus loads from wastewater discharges on the photosynthesis and respiration processes of instream periphyton.

2. Findings of Don Knorr

(a) *EPA's use of the information contained in Knorr and Fairchild (1987) is biased and incorrect.*

Response: The algal biomass from the 1985 field study by Knorr and Fairchild (1987) was included in Table 9-5 of the Christina Model Report to show that the predicted model periphyton was in the ball park of historical measurements.

(b) *The TMDL model predictions in the calibration report are significantly different than the data contained in Knorr and Fairchild (1987) and demonstrate that the model is inadequate for predicting periphyton biomass.*

Response: The information contained in Knorr and Fairchild (1987) was not used for calibrating the model. The information was presented as a simple side-by-side comparison of the predicted model periphyton biomass and biomass measured in the field to demonstrate that the model was computing biomass in a ballpark range consistent with historical field observations. In fact, the conditions during the 1985 field survey and the 1997 calibration periods were significantly different, so one would not expect the model biomass to exactly replicate the measurements made in 1985.

(c) *Knorr and Fairchild determined that phosphorus was not limiting to periphyton growth. This finding contradicts the TMDL model, which assumed that phosphorus was limiting periphyton at all sites.*

Response: The more recent field study conducted in August 1997 (Davis 1998) concluded that phosphorus was the limiting nutrient. Information from the 1997 field survey was used as the basis for developing periphyton kinetics in the water quality model.

(d) *The calculation error is likely due to the use of an invalid phosphorus half-saturation constant for periphyton growth. The study results suggest a half-saturation constant of 1.5 ug/L. The value used in the model is 132 ug/L, nearly 100 times higher.*

Response. The phosphorus half-saturation constant of 0.132 mg/L was derived from a site-specific laboratory algal assay study conducted in August 1997 (Davis 1998).

References

Biggs, B.J F. 2000. New Zealand Periphyton Guideline: Detecting, Monitoring, and Managing Enrichment of Streams. Prepared for the Ministry for the Environment. 122 p June 2000.

Davis, J F 1998. Measurement of Community Photosynthetic and Respiration Rates for Selected Reaches of the Christina Watershed. Prepared for Pennsylvania Department of Environmental Protection and Delaware Department of Natural Resources and Environmental Control. March 1998.

Knorr, D F. and G.W. Fairchild. 1987 Periphyton, benthic invertebrates and fishes as biological indicators of water quality in the East Branch Brandywine Creek. *Proceedings of the Pennsylvania Academy of Science*, 61(1):61-66.

Appendix H
CWA Jurisdictional Waters ANPRM
Tygart River Case Study
Water Quality Standards and TMDLs

M. Passmore
USEPA Wheeling, WV
February 2003

The Tygart River is located in northeastern West Virginia and covers an area of approximately 1362 square miles. The Tygart River joins the West Fork River in Fairmont to form the Monongahela River. The Tygart River watershed is an excellent example of how sources of pollution in small headwater streams can cumulatively impact the ability to attain water quality standards in downstream waters of the United States.

From 1995 to 1999, WVDEP assessed 136 streams, representing approximately 700 miles of stream length in the Tygart River Valley watershed. Of the 682 miles assessed for support of the aquatic life, 35% of the streams fully supported the aquatic life use, 30% were supporting but threatened, 19% were partially supporting, and 17% did not support the aquatic life use. The principle causes of the impairment were siltation, habitat alteration, metals, and pH. The principle sources of the pollution were abandoned mine drainage, acid mine drainage and unknown sources (WVDEP 2000).

The mainstem Tygart Valley River, Buckhannon River, Ten Mile Creek and Middle Fork River, together with 54 smaller water bodies within the watershed were placed on the West Virginia 1996 303(d) list because of iron, manganese, aluminum, and/or pH violations caused by abandoned coal mine discharges.

In 2001, the EPA developed a TMDL for the Tygart River watershed for pH and metals (USEPA 2001). Two of the major tributary streams had TMDLs developed for them separately. (Buckhannon and Ten Mile Creek). The supporting documentation for the TMDL clearly indicates the impact that the small headwater stream loadings have on the condition of the downstream waters. The report states, "A top down methodology was followed to develop the TMDLs and to allocate loads to sources. Impaired headwaters were first analyzed, because their impact frequently had a **profound effect** on downstream water quality" (bold emphasis added). The modeling effort indicated that load reductions in both impaired and not impaired headwaters streams were necessary to attain water quality standards in downstream waters. In other words, load allocation reductions in the downstream reaches alone were not enough to attain water quality standards in downstream waters.

The TMDL was developed without allocations for future growth. The TMDL document makes clear that in order for additional new point sources to be located in headwaters reaches, and still attain water quality standards downstream. they would have to attain water quality standards at the end of the effluent pipes. The report states: " A new facility could be permitted anywhere in the watershed, provided that the effluent limitations are based upon the achievement of water quality standards end-of-pipe for the pollutants of concern in the TMDL". Clearly, if new mining activity were to discharge to small headwater streams without a permit, and without meeting water quality standards end-of-pipe, the TMDL for the whole watershed would be affected.

References

USEPA. 2001. Metal and pH TMDLs for the Tygart Valley River Watershed, West Virginia. USEPA, Region 3, Philadelphia, PA.

WVDEP. 2000. West Virginia Water Quality Status Assessment 2000 305(b) Report. West Virginia Department of Environmental Protection.

Appendix I
Threatened and Endangered Species

Headwater streams and headwater and isolated wetlands provide crucial habitat for a diverse array of animal and plant species, including migratory birds, mammals, amphibians, reptiles, invertebrates, and many threatened and endangered species. Region III has many different types of habitats that could potentially be considered isolated waters. These include bogs, fens, Delmarva Bays, eastern vernal pools, and pocosins.

Threatened and endangered species face many challenges, including habitat loss, pollution, and other factors. Many of these species have very specific life requirements, where wetlands and headwater streams play a major role. By protecting these habitats some of these species may be able to recover and eventually be removed from the federal endangered species list, while other species that are on the verge of being listed may also recover.

The following are threatened and endangered species that are found in Region III and could be impacted by any change in regulations regarding isolated waters. There are many other species that are not yet listed as threatened or endangered that could also be impacted that are not discussed here. Many amphibian species are dependant on headwater and wetland environments for at least part of their life cycle. Amphibian populations have been declining in recent years.

Bog Turtle (*Clemmys muhlenbergii*), Threatened

The bog turtle has a discontinuous range, living in widely separated habitats from western Connecticut, eastern New York, Pennsylvania, New Jersey, and South Carolina.

Bog Turtles live in damp, grassy fields and meadows with slow-moving streams and boggy areas fed by springs. The bog turtle needs a mosaic of microhabitats for foraging, nesting, basking, hibernating, and shelter (USFWS 1997).

Presently many wetlands occupied by bog turtles are in agricultural areas that are subject to livestock grazing, which meets the open canopy habitat that bog turtles seem to require. The discovery of bog turtles in calcareous fen habitats is important to their conservation in New Jersey and Pennsylvania. Fens are primarily shrub and herb communities formed in low lying areas where groundwater percolates over limestone bedrock. The alkaline seepage water most likely retard the growth of canopy closing trees. (USFWS, 1997)

Habitat loss is a major factor fo the past and present decline of bog turtles throughout much of their range. Wetland habitats have been drained and filled for development, agriculture, road construction, and impoundments. These activities have also severely fragmented the remaining habitat and have created physical barriers to movement; thus isolating existing bog turtle populations from other such sites. Development and agriculture continue to cause indirect hydrological alterations of adjacent wetland habitats by changing the surface water flow into or out of occupied wetland habitats. Development and agriculture adjacent to bog turtle habitat can result in soil disturbance and increases in sediment and nutrient load, thus allowing invasion of exotic species.

Untimely mowing, burning and the use of herbicides and pesticides on adjacent agricultural fields also degrade bog turtle habitat. While light grazing impedes plant succession, heavy grazing destroys vegetation that is necessary for nesting, basking , foraging, and cover. (USFWS 1997)

Eastern Massasauga (*Sistrurus catenatus catenatus*), Federal Candidate, PA State Endangered

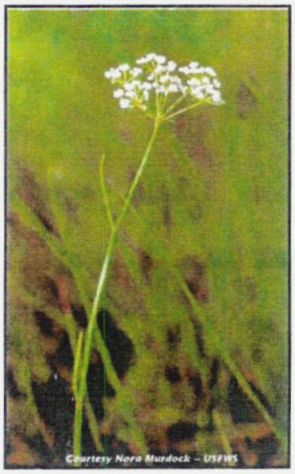
This snake is known as the swamp rattler, and ranges from western Pennsylvania and southern Ontario west through Ohio, Michigan, and several Midwest states. (Fergus, 2000). Massasaugas live in sphagnum bogs, fens, swamps, marshes, shrub-dominated peatlands, wet meadows, and floodplains to dry woodland. They prefer seasonal wetlands with a mixture of open grass-sedge areas and short closed canopy (edge situations). (Nature serve, 2003)

Loss of wetlands and associated grassland habitats put massasauga populations at risk. (Ohio CNR, 2003)

Eastern Massasauga PADCNR

Canby's Dropwort (*Oxypolis canbyi*), Endangered

This plant is found in the Coastal Plain province of Delaware (extirpated), Maryland, North Carolina, South Carolina, and Georgia. Habitat includes cypress ponds, grass-sedge dominated Carolina bays, wet pine savannahs, shallow pineland ponds, and cypress-pine swamps. (Nature serve, 2003)



Canby's Dropwort FWS

The most significant threat to this species is the direct loss or alternation of its wetland habitats. Ditching and draining of lowland areas, primarily for agricultural purposes has altered the groundwater table and changed the vegetative composition in many areas of the mid-Atlantic coastal plain where this species has historically occurred. In addition to changing soil moisture levels, lowering of the water table enables other plants to become established, modifies vegetative succession, and makes sites less conducive overall to the plat's growth and reproduction. (USFWS, 2003)

Virginia Sneezeweed (*Helenium virginicum*), Federally Threatened, Virginia Endangered

Virginia Sneezeweed is a wetland plant restricted to shallow, seasonally inundated ponds, in or near sinkholes. The ponds are located in Virginia and usually flooded from January to July. In general, the ponds supporting Virginia Sneezeweed are poorly drained, acidic, and silty loam soils. (Nature serve, 2003)

Virginia Sneezeweed

Virginia Sneezeweed has adapted to survive the water level fluctuations of the seasonal ponds, giving it a competitive advantage in this habitat. From year to year, Virginia Sneezeweed populations may greatly vary. (VADCR, 2003)

Habitat modification from residential development, incompatible agricultural practices, filling and ditching of wetland habitats, groundwater withdrawal, and other disruptions of hydrology are the principal threats to the species.(Federal Register, 1998)

Eastern Prairie White-Fringed Orchid (Platanthera leucophaea), Threatened

This species is found in mesic to wet prairies and wet sedge meadows. This species occupies calcareous wetlands, including open portions of fens, sedge meadows, marshes, and bogs. Peripheral habitat includes sedge-sphagnum bog mats around kettle lakes and fallow fields. It is also found in wet ditches and railroad right of ways. It is found in New York, Ohio, Pennsylvania, Virginia, and Wisconsin. (Federal Register, 1988).

This species is extirpated in much of its historic range and is very rare throughout its current range. Most of its habitat has been destroyed due to drainage or conversion to agriculture, fire suppression, and intensive mowing. The mostly small populations that remain are only infrequently visited by appropriate pollinators. (Nature serve, 2003)

Northeastern Bulrush (*Scirpus ancistrochaetus*), Endangered

This species is found in the Appalachians in Vermont, New Hampshire, Massachusetts, New York, Maryland West Virginia, and Virginia, with most occurrences in Pennsylvania. Throughout its range, Northeastern bulrush is found in open, tall-herb dominated wetlands, where it often grows at the waters edge. At the southern end of its range, it is often found in sinkhole ponds, where water levels vary seasonally. It the northern end of its range, beaver influenced wetlands provide suitable habitat. (Federal Register, 1990). It is usually found in wetlands of one acre or less, where the water level is high in the spring and drops through the summer. Threats to this species include drainage, development, agricultural runoff and developments that alter local hydrology.(PADCNR, 3/11/2003)

Harperella (*Ptilimnium nodosum*), Endangered

This species typically occurs in either rocky or gravelly shoals of clear swift-flowing streams or at the edges of pineland ponds or low, wet savannah meadows on the Coastal Plain. It has also been found in a granite outcrop seep.(USFWS, 2003). It is found in Alabama, Arkansas, Georgia, Maryland, North Carolina, South Carolina, and West Virginia. Since it is dependant on narrow hydrologic conditions, this species is vulnerable to upstream development and water change (nature serve, 2003).

Knieskern's Beaked-Rush (*Rhynchospora knieskernii*), Threatened

This species is an obligate wetland plant that occurs in groundwater-influenced, constantly fluctuating, successional habitats. This species is intolerant of competition. Recent records indicate that this species occurs in early successional wet habitats created by human disturbances. (USFWS, 2003).

Small Anthered-Bittercress (*Cardamine micranthera*), Threatened

This species is found in Virginia and North Carolina. The 1991 FWS Recovery Plan indicates that this species is found in seepages, wet rock crevices, and wet woods along small streams. (USFWS, 1991). This species is threatened by continued conversion of habitat, encroachment of exotic species, runoff, and livestock-related erosion and trampling. In several of the surviving populations, the original seep habitats no longer exist and the plants are found only in streambeds, where they are highly vulnerable to periodic floods. (Nature serve, 2003)

(Virginia Spiraea *Spiraea virginiana*), Threatened

This species is found in West Virginia, Virginia, Tennessee, North Carolina, Kentucky, and Georgia. Virginia Spirea occurs along rocky, flood scoured stream and riverbanks in gorges or canyons. One population in West Virginia was found in a disturbed wetland near a road. (USFWS, 03)

Virginia Spirea

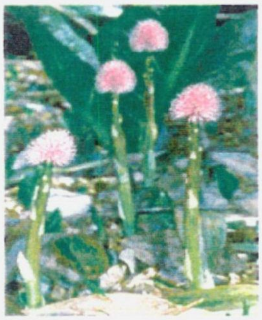
Sensitive Joint-Vetch (*Aeschynomene virginica*), Threatened

This species is found in Maryland, New Jersey, North Carolina, and Virginia. The species seems to prefer marsh edges near the upper limit of tidal fluctuation. It is frequently found in the estuarine meander zone of tidal rivers where sediments transported from upriver settle out and extensive marshes are formed.

This species has been impacted by habitat destruction, sedimentation, competition from exotic plant species, recreational activities, agriculture, mining, commercial and residential development, impoundments, water withdrawal projects, and introduced insect pests. (USFWS, 2003)

Swamp Pink (*Hielonias bullata*), Threatened

This species is found in New Jersey, Delaware, Maryland, Virginia, North Carolina, South Carolina, and Georgia. Swamp Pink occurs in a variety of wetland habitats. These include Atlantic white cedar swamps, Blue Ridge swamps, swampy forested wetlands which border small streams, meadows, and spring seepage areas. This species requires a saturated habitat, but not flooded.(Nature serve, 2003)



Swamp Pink

Loss of wetlands to urban and agricultural development and timbering operations resulted in this species status. (USFWS, 2003)

Hay's Spring Amphipod (*Stygobromus hayi*), Endangered

This species is only known to inhabit five springs along Rock Creek in the District of Columbia. It is believed that the amphipod may spend its life in a shallow groundwater zone, moving in water that percolates among sand grains and gravel unless large volumes of water flush it up and out of and exit as a spring. These species are difficult to monitor since they appear seasonally and sporadically in seeps and springs. (Pavek, 2002)

Eastern Mud Salamander (*Pseudotriton montanus montanus*), PA Endangered

Mud salamanders burrow into the muck and mud around spring seeps and along the banks of streams. The species range from New Jersey southward to the Coastal Plain and Piedmont regions. (Fergus, 2000)

Eastern Mud Salamander

Literature References

Canby's Dropwort, 3/10/2003. www.natureserve.org

Eastern Massasauga Rattlesnake, www.natureserver.org

Eastern Prarie White -Fringed Orchid, 3/10/2003 www.natureserve.org

Federal Register/ Vol. 53, No. 196 /Tuesday, October 11, 1988/ Proposed Rule, Endangered and Threatened Wildlife and Plants; Proposal to Determine Platanthera leucophaea (Eastern Prarie Fringed Orchid) to be Threatened Species

Federal Register/Vol. 55, No. 217/Thursday, November 8, 1990/ Proposed Rules, Endangered and Threatened Wildlife and Plants Proposed Endangered Status for Northeastern Bulrush.

Federal Register/Vol 63, No. 212/ Tuesday, November 3, 1998/ Rules and Regulations, Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for Virginia Sneezeweed (Helenium virginicum).

Fergus Charles. Wildlife of Pennsylvania and the Northeast. Mechanicsburg: Stackpole Books, 2000.

Harperella, 3/11/2003, http://endangered.fws.gov/i/q/saq58.html

Harperella, 3/10/2003, www.natureserve.org

Knieskern's Beaked Rush, 3/11/2003, http://endangered.fws.gov/i/q/saq6q.htm

Ohio Division of Wildlife Life History Notes Eastern Massasauga Rattlesnake, 2/26/2003. www.dnr.state.oh.us/wildlife/resources/wildnotes/pub374.htm

PA CNR, WRCF Northeastern Bulrush 3/10/2003, http://www.dcnr.state.pa.us/wrcf/bulrush.htm

Pavek, Diane Endangered Species Bulletin, January/February 2002, Volume XXVII NO. 1, Endemic Amphipods in Our Nation's Capitol.

Sensitive Joint-Vetch, 3/11/2003, http://endangered.fws.gov/i/q/saq95.html

Sensitive Joint-vetch, www.natureserve.org

Shaffer, Larry L. Pennsylvania Amphibians and Reptiles. Harrisburg: PFBC, 1995.

Small Anthered Bittercress, www.natureserve.org

Swamp Pink, 3/12/2003, http://endangered.fws.gov/i/q/saq54.html

Swamp Pink, 3/10/2003, www.natureserve.org

USFWS, Cabby's Dropwort, 3/12/2003. http://endangered.fws.gov/i/q/saq3a.html

USFWS, Cabby's Dropwort in North Carolina, http://nc-es/fws.gov/plant/canbydrop.html

USFWS, Small Anthered Bittercress Recovery Plan, July 10, 1991.

USFWS, 50CFR Part 17 RIN 1018-AD05, Endangered and Threatened Wildlife and Plants; Proposed Rule to List the Northern Population of the Bog Turtle as Threatened and the Southern Population as Threatened Due to Similarity of Appearance , 1997

Virginia Natural Heritage Program Sneezeweed Fact Sheet, 3/11/2003. http://www.dcr.state.va.us/dnh/helenium.htm

Virginia Natural Heritage Program Swamp Pink Fact Sheet, 3/12/2003 http://www.dcr.state.va.us/dnh/whelon.htm

Virginia Sneezeweed, 3/10/2003. www.natureserve.org

Virginia Spirea, 3/11/2003, http://endangered.fws.gov/i/q/saq64.html

Virginia Spirea, www.natureserve.org

Appendix J
NPDES Permit Program Overview

Water pollution degrades surface waters making them unsafe for drinking, fishing, swimming, and other activities. As authorized by the Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. Point sources are discrete conveyances such as pipes or man-made ditches. Concentrated animal feeding operations (CAFOs) are also defined by the CWA as point sources.

The NPDES permit program is delegated to all Region 3 states with the exception of the District of Columbia. Total NPDES permits issued in Region 3 as of December 2002: 744 majors and 13,389 minors (including facilities covered by General Permits). Major facilities include publicly owned treatment works (POTWs) discharging at least 1.0 million gallons per day of wastewater and industrial facilities that meet a certain ranking based on several factors including type of discharge and receiving water.

Considering the number of point source dischargers in Region 3, there would be currently regulated dischargers that would no longer be regulated under the NPDES program if the receiving stream no longer is considered a water of the US. In those cases, we would be relying on State laws, such as Pennsylvania's Clean Streams Law, to regulate those discharges and EPA would have no enforcement jurisdiction. For our delegated states, State regulations are established to implement the federal NPDES program requirements. Amendments to these state regulations would be required in order to permit facilities that are no longer regulated under NPDES.

Table 1 shows selected current NPDES permits in Pennsylvania that could potentially be eliminated from the NPDES program if the receiving streams are removed from the definition of waters of the US. Wastewater from these facilities discharge to streams having a low flow of less than 1.0 cfs. NPDES permits are written to provide water quality protection during low stream flow conditions. These facilities were chosen as examples because Pennsylvania applies the designated use of water supply to all surface waters and NPDES permits developed by Pennsylvania take into consideration potential drinking water use. As shown in Table 1, the NPDES permit for Lansdale limits the amount of Nitrite/Nitrate, a major concern for drinking water supply. The receiving stream of this discharge is within a 303(d) listed watershed. Eliminating this discharge from permit obligations could result in not meeting the stream's designated use of water supply and could affect the waste load allocations (WLAs) that a TMDL would establish for this impaired watershed.

Program Emphasis

The NPDES permitting program has recently been placing emphasis on CAFOs, combined sewer overflows (CSOs), sanitary sewer overflows (SSOs), and storm water. New programs/rules such as the CAFO rule, signed on December 15, 2002, could be affected by a change in the definition of waters of the US. For example, the requirement of a regulated facility to have a 100 ft setback from a surface water body for land application of manure would not apply to those farms located near ditches, intermittent streams, etc. if these waters are removed from the definition. A major concern of land applying manure is the potential release of excess nutrients (nitrogen and phosphorus) that could run off the land and impact surface waters. Table 1 also shows a potentially affected CAFO NPDES permit. Note that this CAFO is also located in a 303(d) listed watershed.

Permit holders, regulatory authorities and communities are actively using a watershed approach to develop innovative and flexible methods to improve environmental quality. Protection of headwaters / 1st order streams is a concern for many watershed organizations and in the development of TMDLs. The NPDES program is a key element of a TMDL by implementing in NPDES permits the WLAs of TMDLs. How do you assign WLAs to facilities discharging to streams that are not waters of the US?

TABLE 1 - Sample of Current NPDES Permits on Small Streams					
NPDES Permit No.	**Facility Name**	**Discharge Flow (cfs)**	**Receiving Water**	**Streamflow $Q_{7\text{-}10}$ (cfs)**	**Examples of Current Permit Limitations (Ave Monthly)**
PA0045021	PreFinish Metals	0.05	Unnamed Tributary to Biles Creek	0.07	Total Dissolved Solids 698 lbs/day Cyanide, Total 0.076 lbs/day
PA0080195	Supply Sales (Grinnell Corp)	0.23	Unnamed Tributary to Shawnee Run	0.13	Total Suspended Solids 31 mg/l Total Cadmium 0.004 mg/l
PA0026182	Boro of Lansdale	6.96	Unnamed Tributary to West Branch Neshaminy Creek (WB Neshaminy Creek listed on PA's 1998 303d list due to Nutrients from Municipal Point Sources)	0.11	NO_2-N / NO_3-N 356 lbs/day Total Suspended Solids 1,126 lbs/day

TABLE 1 - Sample of Current NPDES Permits on Small Streams					
PA0088285	Kreider Dairy Farm (CAFO)	CAFOs receive a no discharge permit	Unnamed Tributary to Chickies Creek (Chickies Creek watershed listed on PA's 1998 303d list due to Agriculture)	0.41	Maintain proper freeboard in manure storage impoundment 100ft setback from stream for land application of manure

Appendix K
Analysis of State Programs

According to the Association of State Wetland Managers, two thirds of the United States currently lack regulatory programs that comprehensively address wetlands and isolated wetlands in particular. The Middle Atlantic States (EPA Region III) paint a similar picture. Currently three states out of five in Region III have some type of wetlands protection program that provides regulation for isolated, non-tidal wetlands. Those states are Pennsylvania, Maryland and Virginia. Both Delaware and West Virginia lack comprehensive wetland programs. Delaware and West Virginia would not be able to provide any sort of state regulation should the scope of federal jurisdiction for section 404 of the CWA program be revised to exclude isolated wetlands and wetlands adjacent to non-navigable streams. Virginia may not be able to provide state regulation of certain waters, as the geographic jurisdiction of its program has been held by one court to be coextensive with federal jurisdiction. United States v. Newdunn, 195 F. Supp. 2d 751, 768-69 (E.D. Va. 2002).

Furthermore, the federal wetland program has provided an important complement to state programs, often sharing the burden of assessment, permitting and enforcement. The result of narrowing the CWA definition of "waters of the United States" will shift more of the economic burden for regulating wetlands and headwater streams to states and local governments. No Region III state has been authorized, pursuant to Section 33 U.S.C. 1344(g), to assume the Section 404 program.

The effect of narrowing the jurisdictional scope of waters of the United States will also impact the areas and activities subject to Clean Water Act Section 401 programs which require State approval for federally permitted activities. These changes will also limit the areas and activities addressed by State Programmatic General Permits. These changes will be felt most acutely in Delaware and West Virginia which rely on their 401 certification program to ensure that water quality standards are met for wetlands. Moreover, reliance on the 401 water quality program to protect wetland resources is further complicated by the fact that most of the states in Region III do not have specific water quality standards for wetlands. Additional state programs could be required to "recapture" isolated waters and wetland areas in Delaware and West Virginia.

The following tables identify states in Region III and the programs available within each state to regulate wetlands and other waters of those states.

ANPRM Issues	Delaware
Provide protection for waters affected by SWANCC	No, state program protects tidal wetlands only.(Tidal Wetlands Act).
If so, what is the state mechanism	N/A
Wetlands specifically defined as waters of the state	Yes
Definition	See #1 below
Unique WQS for wetlands	No
Other laws or authorities to control point source discharges	Delaware's Subaqueous Lands Act(7 Del. C. Chapter 72), see #2
	Delaware's Environmental Protection Act(7 Del. C. Chapter 60), see # 3
Clause in any laws that limits state ability to have stricter regulation that the federal laws or regulations	No

1. Definition of state waters, Delaware - All surface waters of the State including but not limited to:(a) Waters which are subject to the ebb and flow of the tide, including but not limited to estuaries, bays, and the Atlantic Ocean; (b) All interstate waters, including interstate wetlands; (c) All other waters of the State, such as lakes, rivers, streams (including intermittent and ephemeral streams), drainage ditches, tax ditches, creeks, mudflats, sandflats, wetlands, sloughs, or natural or impounded ponds; (d) All impoundments of waters otherwise defined as waters of the State under this definition; (e) Wetlands adjacent to waters (other than waters that are themselves wetlands) identified in (a)-(d); (2) Waste and stormwater treatment systems, including but not limited to treatment ponds or lagoons designed to meet the requirements of the Clean Water Act (other than cooling ponds which otherwise meet the requirements of subsection (l) of this definition) are not waters of the State.

2. Delaware's Subaqueous Lands Act(7 Del. C. Chapter 72) covers submerged lands which are defined as, "lands lying below the plane of the ordinary high water mark of non-tidal rivers, streams lakes, ponds, bays and inlets within the boundaries of the State as established by law". These waterways do not have to be "navigable". DE does not regulate ephemeral streams.

3. Delaware's Environmental Protection Act(7 Del. C. Chapter 60) requires a permit for an activity that, "may cause or contribute to discharge of a pollutant into any surface or groundwater." A "pollutant" is defined as, "dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, hydrocarbons, oil and product chemicals, and industrial, municipal and agricultural wastes discharged into water."

Pending Regulations under this statute would add "fill material" to this definition. A state discharge permit would be needed for those waters that would fall out of 402 requirements as a result of new rulemaking.

ANPRM Issues	Virginia
Provide protection for waters affected by SWANCC	Yes
If so, what is the state mechanism	VA Water Protection Permit see #1
Wetlands specifically defined as waters of the state	Yes
Definition	"All water, on the surface and under the ground, wholly or partially within or bordering the Commonwealth or within its jurisdiction, including wetlands"
Unique WQS for wetlands	No
Other laws or authorities to control point source discharges	Virginia State Water Control Law Title 62.1 Chapter 3.1 of the Code of Virginia, see #2
Clause in any laws that limits state ability to have stricter regulation that the federal laws or regulations	General Assembly has to approve, see #3

1. Since 1992, the Virginia Water Protection Permit Program has served as the Commonwealth's Section 401 Certification process for both tidal and nontidal impacts permitted under Section 404 of the Clean Water Act. In 2000, the General Assembly removed the dependence of the State nontidal wetlands program on the issuance of a Federal permit, thus enabling DEQ to use the Virginia Water Protection Permit Program to regulate activities in wetlands. Such activities as certain types of excavation in wetlands and fill in isolated wetlands (which may not be under Federal jurisdiction) were added to the activities already regulated through the Section 401 Certification process. DEQ can provide Section 401 Certification through issuing a Virginia Water Protection individual or general permit or by certifying U.S. Army Corps of Engineers nationwide or regional permits. Some U.S. Army Corps of Engineers permit Certifications contain conditions which must be met in order for the Certification to apply. Some U.S. Army Corps of Engineers permits are not §401-Certified at all, and thus, impacts under these U.S. Army Corps of Engineers permits will also require a Virginia Water Protection permit to ensure State natural resources are protected.

2. Virginia State Water Control Law Title 62.1 Chapter 3.1 of the Code of Virginia provides that the Commonwealth shall prohibit waste discharges or other quality alterations of state waters except as authorized by permit (see Section 62.1-44.5 of the Code of Virginia) It is also part of the powers and duties of the State Water Control Board to set water quality standards, issue VWP, VPDES and VPA permits

3. Under Section 62.1-44.15 of the Code of Virginia, Power and Duties of the Board, it says "To adopt such regulations as it deems necessary to enforce the general water quality management program of the Board in all or part of the Commonwealth, except that a description of provisions of any proposed regulation which are more restrictive than applicable federal requirements, together with the reason why the more restrictive provisions are needed, shall be provided to the standing committee of each house of the General Assembly to which matters relating to the content of the regulation are most properly referable."

ANPRM Issues	Pennsylvania
Provide protection for waters affected by SWANCC	Yes
If so, what is the state mechanism	Dam Safety and Encroachments Act of 1978, see # 1
Wetlands specifically defined as waters of the state	Yes. Chapter 93.1 and Chapter 105.1
Definition	Rivers, streams, creeks, rivulets, impoundments, ditches, watercourses, storm sewers, lakes, dammed water, wetlands, ponds, springs and other bodies or channels of conveyance of surface and underground water, or parts thereof, whether natural or artificial, within or on the boundaries of this Commonwealth, see #2.
Unique WQS for wetlands	Yes. Narrative criteria and designated uses are found at 105.1 and 105.17 respectively.
Other laws or authorities to control point source discharges	Clean Streams Law, see #3.
	302 of the Flood Plain Management Act
Clause in any laws that limits state ability to have stricter regulation that the federal laws or regulations	No

1.Regulations promulgated under the Act are found at Title 25 Chapter 105 and are entitled Dam Safety and Waterway Management last amended 10/26/91. Water obstructions and encroachments into wetlands and watercourses require a permit. The evaluation of permit applications includes the review of an environmental assessment that details the quality and quantity of wetlands and streams impacted and of the wetlands and streams located around the impact area. A permit review also includes analysis of mitigation and an aquatic resource compensation plan.

2. Also includes surface waters—Perennial and **intermittent** streams, rivers, lakes, reservoirs, ponds, **wetlands**, springs, natural seeps and estuaries, excluding water at facilities approved for wastewater treatment such as wastewater treatment impoundments, cooling water ponds and constructed wetlands used as part of a wastewater treatment process.

3. Clean Streams Law § 691- The discharge of sewage or industrial waste or any substance into the waters of this Commonwealth, which causes or contributes to pollution as herein defined or creates a danger of such pollution is hereby declared not to be a reasonable or natural use of such waters, to be against public policy and to be a public nuisance.

ANPRM Issues	West Virginia
Provide protection for waters affected by SWANCC	Only CWA Section 401
If so, what is the state mechanism	Water Resources [West Virginia code (22-11-3)]
Wetlands specifically defined as waters of the state	Unclear (see #1)
Definition	See # 1
Unique WQS for wetlands	No
Other laws or authorities to control point source discharges	State Water Pollution Control Act (22-11), Groundwater Protection Act (22-12), State Water Quality Standards (46csr1) and Rules For Individual State Certification of Activities Requiring a Federal Permit (47csr5A) - CWA 401
Clause in any laws that limits state ability to have stricter regulation that the federal laws or regulations	Water Quality programs appear to be tied to the federal CWA. (See # 2)

1. **§47-5A-1** - Defines Aquatic resources include but are not limited to wildlife, fish, recreational uses, critical habitats, **wetlands**, and other natural resources under the Secretary's jurisdiction.

2. 46csr1 - These rules establish requirements governing the discharge or deposit of sewage, industrial wastes and other wastes into the waters of the state and establish water quality standards for the waters of the State standing or flowing over the surface of the State. These rules establish general Water Use Categories and Water Quality Standards for the waters of the State. Unless otherwise designated by these rules, at a minimum all waters of the State are designated for the Propagation and Maintenance of Fish and Other Aquatic Life (Category B) and for Water Contact Recreation (Category C) **consistent with Federal Act goals**.

ANPRM Issues	Maryland
Provide protection for waters affected by SWANCC	Yes
If so, what is the state mechanism	Nontidal Wetlands and Waterways Permits.(See #1)
Wetlands specifically defined as waters of the state	Yes
Definition	See # 2
Unique WQS for wetlands	No
Other laws or authorities to control point source discharges	See # 3
Clause in any laws that limits state ability to have stricter regulation that the federal laws or regulations	Unless there is another state law that regulates discharges, it appears that the state law is tied to the federal NPDES Program..

1. COMAR 26.23. - A permit is required for any activity that alters a nontidal wetland or its 25-foot buffer.

2. Waters of this State" includes: Both surface and underground waters within the boundaries of this State subject to its jurisdiction, including that part of the Atlantic Ocean within the boundaries of this State, the Chesapeake Bay and its tributaries, and all ponds, lake, rivers, streams, tidal and nontidal wetlands, public ditches, tax ditches, and public drainage systems within this State, other those designed and used to collect, convey, or dispose of sanitary sewage.

3. COMAR 26.08.01 through 26.08.04 and COMAR 26.08.08 - The surface water discharge permit is a combined state and federal permit under the National Pollutant Discharge Elimination System (NPDES). This permit is issued for discharge to State surface waters. The permit is designed to meet federal effluent guidelines when applicable and also ensure the discharge satisfies State water quality standards.