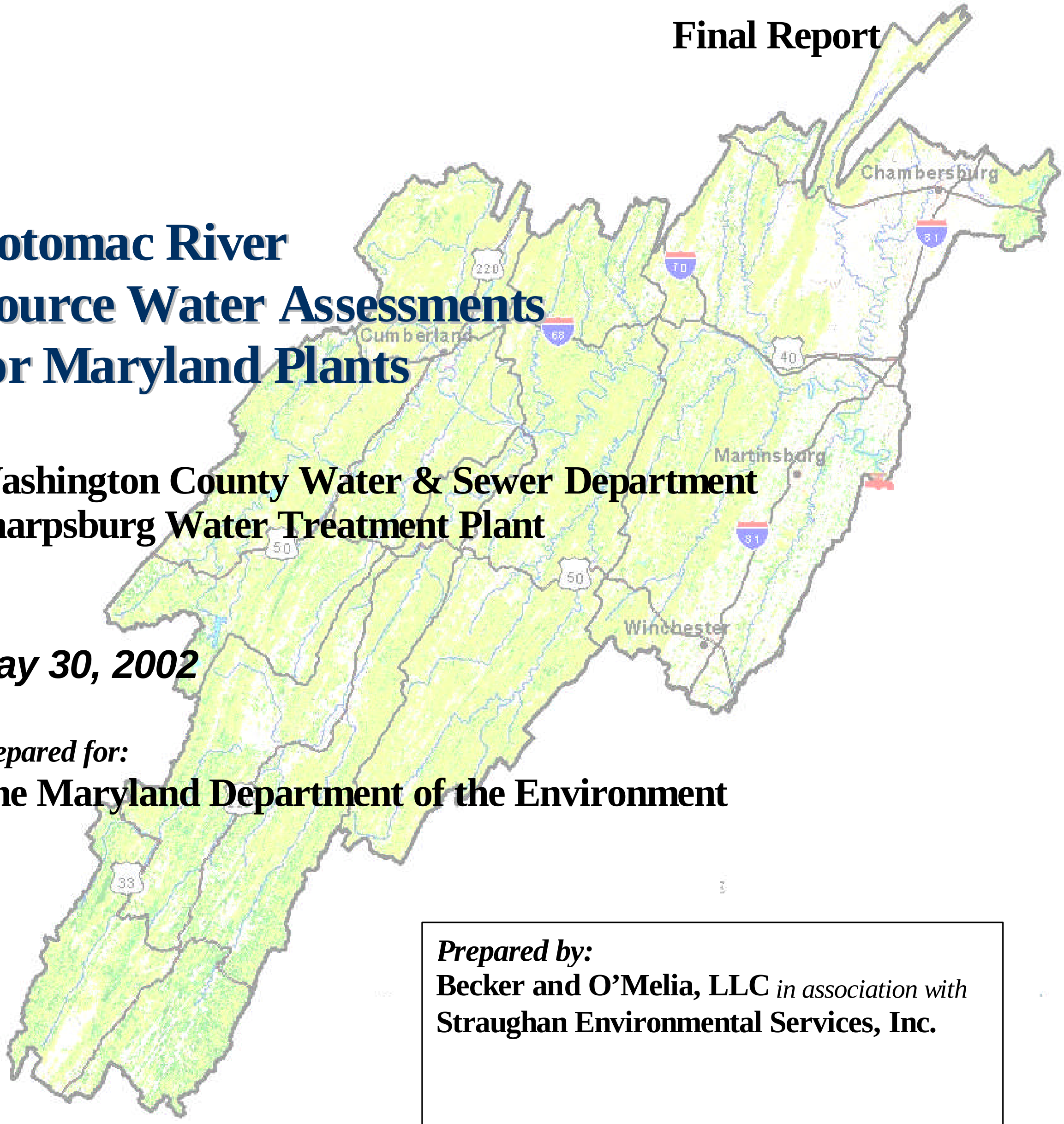

Final Report

Potomac River Source Water Assessments for Maryland Plants

Washington County Water & Sewer Department
Sharpsburg Water Treatment Plant

May 30, 2002

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The Maryland Department of the Environment

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APPENDICES AND SOURCE MAPPING ON ATTACHED COMPACT DISC

EXECUTIVE SUMMARY

OVERVIEW

The safety of drinking water is one of the most important public health issues in any society. In the past, efforts to achieve safety and to meet drinking water quality regulations have tended to focus on the treatment works within a system. It was felt that with reliable treatment, deterioration in source water quality could be overcome. Unfortunately, this approach fails to take into account that the treatment "barrier" against contamination may fail at times (*e.g.*, the treatment plant may have an upset). Also, some customers, such as those who are immuno-deficient, may need additional protection. Additionally, some as-yet unknown contaminants, which may exist in trace amounts, may pass through the treatment plant. Thus a need for source water quality protection as an additional "barrier" to contamination and an enhancement to water quality is now well recognized as an important part of the "multiple barrier" approach. Source water protection also may result in cost savings in plant operations.

Efforts to clean the nation's surface waters started several decades ago, but have largely focused on improving the ecological quality of streams, rivers, lakes, and estuaries for protection of wildlife and the environment rather than potable water supply. Although wildlife and human health needs are often similar, "safe" raw water is not necessarily the same as "clean" natural water. Protection and restoration of water bodies as an additional barrier for providing high quality drinking water requires somewhat different management practices. A first step toward achieving this is provided by the 1996 Safe Drinking Water Act Amendments, which requires each State to conduct a Source Water Assessment (SWA) for each drinking water intake in the State.

This SWA for Maryland Water Plants on the main stem of the Potomac River was conducted to meet the above requirement and was undertaken by the Maryland Department of the Environment (MDE) with the Becker & O'Melia, LLC team (including the Center for Watershed Protection) serving as the consultant to perform the assessment. The purpose of this report is to document the methodology and procedures, findings, and recommendations of the SWA, and to provide a framework for developing a Source Water Protection Plan (SWPP).

The focus of the SWA is primarily on the Potomac River Watershed and does not review in detail other key components of Washington County's system such as the treatment and distribution facilities. As such, the SWA only addresses the raw water quality and does not address the quality of the finished (*i.e.*, tap) water. The safety requirements for finished water are achieved by meeting the United States Environmental Protection Agency prescribed limits, known as Maximum Contaminant Levels (MCL), for the contaminants which are known or suspected to pose a significant health risk. It should be noted that numerous long-standing efforts to improve water quality in the Potomac River exist. The SWA and its protective outcomes are thus an additional, proactive, and conservative effort toward achieving higher quality drinking water and creating an additional barrier against contaminants which are or may be present in the raw water.

The following summarizes the main tasks of the SWA for Maryland Water Plants on the Main Stem of the Potomac River:

- delineating the boundaries of the watershed,
- identifying potential contaminants of concern,
- locating potential sources of those contaminants,
- analyzing the threats posed by these sources and the likelihood of the delivery of these contaminants to the intake,
- developing recommendations for a Source Water Protection Plan, and
- coordinating project efforts and communicating results with local stakeholders.

The key findings of the SWA include:

- The dynamic nature of the Potomac River's water quality at the existing intake is a major challenges to providing safe drinking water and need to be better understood and managed.
- The watershed is primarily forested with significant agricultural and some urban land uses.
- Contaminants causing major challenges and of particular concern include: natural organic matter (NOM) and disinfection by-product (DBP) precursors, *Cryptosporidium* oocysts & *Giardia* cysts, taste and odor causing compounds, sediment/turbidity, algae, and fecal coliforms.
- Future conditions are expected to show a small deterioration in source water quality at the intake without implementation of increased management practices. The amount of contaminants reaching the river and its tributaries can be reduced noticeably by implementing "aggressive" management practices. However, levels reaching the plant intake are expected to show a much smaller reduction for certain contaminants for many years. This is due to natural processes in the river from the point of receiving the contaminants to the plant intake. Furthermore, "aggressive" management in the upper watershed will result rather quickly in reductions in phosphorus at the "edge-of-stream" locations, but will not result in significant phosphorus reductions in the intake water due to storage of phosphorus in the streambed and field sediment. However, when the phosphorus concentrations in the streambed sediment reach equilibrium with the reduced phosphorus loadings from the watershed, the impacts of the "aggressive" management practices will be reflected in a proportional improvement in the intake water quality. Therefore, these practices can be considered as an effective method of limiting phosphorus and algae at the intake in the long-term.
- The WTP is vulnerable to spills from a variety of sources in the watershed, and needs a proactive spill management and response plan.

The recommendations of the SWA include:

- A watershed protection group representing stakeholders should be formed to explore and advocate "safe" water issues in concert with other SWAs for plants served by the Potomac River and with ongoing and future "clean" water activities.
- The watershed protection group should consider the following key issues and concerns:
    - identification of goals, steps toward achieving those goals, and measures of success;

- involvement of local stakeholders in defining and pursuing the necessary studies and steps before development of a source water protection plan;
- direct public awareness, outreach, and education efforts; and
- aggressive involvement in agricultural and animal farming BMP implementation plans to address nutrient, bacteria, and pathogen loads..
- As *Cryptosporidium* in raw water poses a threat, appropriate source evaluation and management practices for fecal contamination should be considered to improve public health protection.
- Phosphorus control should be pursued. This is expected to eventually have modest positive impacts on raw water NOM concentrations due to reduced algae production, but the impacts of nutrient control may be delayed significantly due to nutrient storage in the fields and streambeds.
- Phosphorus control will have little or no impact on terrestrial NOM & DBP precursors which are likely significant due to the extent of forested land in the watershed. Further study on the relative contribution and fate of DBP precursors from terrestrial sources compared to in-river sources (*i.e.*, algae) is warranted to focus management practice implementation.
- A proactive spill management and response plan, in coordination with other stakeholders should be developed

Potential Benefits of a Source Water Protection Plan

This source water assessment indicates that implementation of a source water protection program can be expected to improve the Potomac River water quality at the intake. These opportunities for improvements include:

- reducing the solids loading to the plant,
- reducing the magnitude and frequency of high pH, high NOM events which result from algal, phytoplankton, and macrophyte activities in the Potomac and its tributaries, and
- improved protection from pathogens including *Cryptosporidium* and *Giardia*.

The primary improvement that management activities would accomplish is the provision of an additional barrier in the protection of the health of Washington County's customers. Environmental improvements would also be achieved through improved watershed management. The following improvements relevant to the WTP can also be expected:

- a reduction in the amount of treatment chemicals, (including coagulant, chlorine, and acid) required to treat water,
- a reduction in the amount of residuals which must be processed and disposed of, and
- a lengthening in filter runs and thus reduction in the amount of backwash water used at the WTP.

Source Water Assessment Methodology

This assessment project provides a technical framework upon which a Source Water Protection Plan can be developed and implemented for the WTP. The following summarizes the main tasks of the SWA:

- delineating of the boundaries of the watershed,
- identifying potential contaminants of concern,

- locating potential sources of those contaminants,
- analyzing the threats posed by these sources and the likelihood of the delivery of these contaminants to the intake,
- developing recommendations for a Source Water Protection Plan, and
- coordinating project efforts and communicating findings to local stakeholders, including briefings and public meetings.

The project approach reflects MDE's commitment to develop an effective basis and approach for protecting the Potomac River for use as a regional water supply source. This approach is consistent with MDE's Source Water Assessment Plan that was approved by the US EPA.

Delineation of Boundaries of the Watershed

The watershed boundaries were established based on preliminary delineation maps, which were prepared by MDE. These maps were refined in the area of the intake based on local geography. The Potomac watershed is very large and includes parts of four states. Coordination of protection efforts among many stakeholders is another challenge and is needed for a successful SWPP.

Inventory of Potential Contaminants of Concern

Contaminants of concern were selected based on the actual challenges that the WTP faces and on the criteria provided by the Maryland Source Water Assessment Plan (MD-SWAP). This was achieved by collecting water quality data from a variety of sources and determining the level and frequency of their historical occurrences (see Section 5 and Appendix B of the main report).

Location of Potential Sources of Contaminants

Potential sources of contaminants were compiled using a variety of data sources (see Section 6 of the main report). These potential sources were organized according to source type and shown on GIS maps. The maps include land uses, point and nonpoint source locations as well as potential spill sources. These mapped sources served as the basis for management options which were developed by the project team. The options must be discussed and coordinated with the stakeholders and be used as the basis for developing a protection plan.

Analysis of Threats Posed by Sources and the Likelihood of the Delivery of Contaminants to the Water Supply

The threats to the water supply for various scenarios were assessed. Based on potential sources within each subbasin, appropriate management practices were selected for evaluation. These management practices were evaluated using the Center for Watershed Protection's Watershed Treatment Model (WTM) which estimates the "edge-of-stream" contaminant loading. Changes in contaminant concentration as they travel from the "edge-of-stream" toward the plant intake were evaluated using the Chesapeake Bay Program Model. Scenarios evaluated include:

- current conditions,
- future (year 2020) conditions reflecting growth and projected changes in land use with little change in current management practices,
- future conditions with moderate improvements in management practices, and
- future conditions with aggressive improvement in management practices.
- The Bay Program model was modified and calibrated at the point of the WSSC Potomac WFP intake. The results of this modeling were evaluated in the area of the Sharpsburg intake.

A time of travel model was run by the Interstate Commission for the Potomac River Basin to group the potential contaminant sources according to the flow time from the edge of the stream to the intake under several flow conditions.

Key Findings

The tasks in the methodology described above resulted in information about:

- contaminants of particular concern at the WTP,
- the sources of these contaminants of concern, and
- the threats posed by these sources on the WTP.

Based on evaluation of this information, key findings regarding the WTP and its watershed are described below.

Inventory of Potential Contaminants of Concern

Identified contaminants of concern to the Sharpsburg WTP therefore include:

- *Cryptosporidium* and *Giardia*
- Fecal coliforms
- Sediment
- Natural Organic Matter and disinfection by-product precursors
- Algae, and their limiting nutrient, phosphorus
- Tastes and odor causing compounds

To facilitate the assessment of the extent that these contaminants may reach the Sharpsburg intake, these contaminants have been classified into three groups:

Group 1 – *Cryptosporidium*, *Giardia*, fecal coliforms, and sediment. *Cryptosporidium* and *Giardia* are human pathogens that are resistant to chlorine disinfection and are one of the most significant challenges for a water treatment plant. Fecal coliforms are indicators of fecal contamination and the presence of other human pathogens. Sediment can shield pathogens from disinfection and increases treatment costs. These contaminants have been grouped together because they are all generally associated with sediment and solids in the River and watershed and their presence in the raw water also significantly impacts treatment plant operations. Because of their association with solids, they are generally transported to and removed in a treatment plant by similar mechanisms and with somewhat comparable efficiencies, and they can therefore be modeled to some extent through the use of sediment as a surrogate.

Group 2 – Natural organic matter, disinfection byproduct precursors, and algae and its nutrients nitrogen and phosphorus. Natural organic matter, which can be represented by total organic carbon, includes disinfection by-product precursors and increases coagulant demand. Algae may increase disinfection by-product levels, increase coagulant demand, and interfere with filter operations. The growth and activity of algae is largely dependent upon the availability of the nutrients nitrogen and phosphorus. These contaminants are grouped together because they are similar in terms of their impact on chemical and physical treatment processes in the plant as well as on the formation of disinfection byproducts following chlorination.

Group 3 - taste and odor causing compounds. Taste and odor causing compounds are numerous and can affect consumer confidence in their drinking water. Algae can also produce noxious tastes and odor compounds, and while listed in Group 2, algae levels may affect taste and odors.

Location of Potential Sources of Contaminants

Watershed sources of contaminants in the Potomac River are categorized as potential spill sources, point sources, or nonpoint sources. Maps were created showing land use types and the following contaminant themes:

- Watershed and subwatershed delineation
- Land use
- Hazardous and toxic waste sources
- Potential petroleum sources
- Facilities with NPDES permits
- Potential sewage problem areas

Air deposition is reflected in land runoff and was not separately analyzed. Maps showing sources are included in the report body and appendices.

Potential Spill Sources

The WTP may be vulnerable to a variety of contaminants due to spills. A time-of-travel model was used to analyze the potential spill sources which could impact the water quality at the plant intake. The significant potential sources were grouped by their time of travel to the plant under various flow conditions in the River and have been summarized and documented.

Point Sources

Municipal wastewater treatment plants (WWTPs) contribute *Cryptosporidium* oocysts, *Giardia* cysts, fecal coliforms, natural organic matter, and nutrients which stimulate algae. Other compounds found in municipal discharges, such as pharmaceutical chemicals and hormones were not studied as part of this project. WWTP design and operating parameters are key factors in reducing the impact on and risk to drinking water supplies. Plant upsets including flood flows (whether caused by combined systems (CSOs) or inflow and infiltration in sanitary systems (SSOs)) and process failures result in violations and adverse impacts on receiving water quality. In the Potomac watershed, sewerage failures result in significant untreated discharges. The maps in the attached CD specifically identify these WWTP and other point sources.

Nonpoint Sources

Nonpoint sources are significant sources of *Cryptosporidium* oocysts, *Giardia* cysts, fecal coliforms, sediment, dieldrin, natural organic matter, nutrients which stimulate algae, and taste and odor causing compounds. Impacts of nonpoint sources are quantified based on aggregate land uses in the subwatersheds of the basin.

Evaluation of current land uses in the watershed indicates:

- the headwaters are predominantly forested and include the bulk of the area under silviculture as well as substantial pastured areas;
- the Upper Great Valley, is dominated by agricultural land uses including cropland and pastures with a significant forested area, although very little of these forested areas are under silviculture;

These landuses are shown on maps in the appendices (on the attached CD). The large livestock population in the watershed is a major challenge and is likely to be as significant a source of pollution as the human population. Detailed future land uses were developed for the year 2020, and changes in land use were projected. The findings indicate the following:

- Agricultural, silvicultural and mining land uses are expected to remain unchanged throughout the watershed.
- Some forested areas throughout the watershed are expected to urbanize and this will result in increased residential development, commercial/industrial development, and roadways, with similarly decreased forested areas.
- Projections include reductions in active construction in the headwaters.
- Active construction is expected to increase in the lower parts of the watershed.

Analysis of Threats Posed by Contaminant Sources and the Likelihood of the Delivery of Contaminants to the Water Supply

The modeling approach described above was utilized to analyze the susceptibility of the water supply to contamination from the identified contaminants of concern. The results of the modeling are discussed below and organized by contaminant group. It is important to remember that the quantitative predictions from the modeling are subject to the limitations presented by the assumptions and the surrogates utilized as well as the relatively gross scale and level of detail in the models. Results are presented primarily to provide relative comparisons of overall management options.

<u>Susceptibility to Group 1 Contaminants of Concern (sediment/turbidity, *Cryptosporidium*, *Giardia*, and fecal coliform)</u>

Group 1 contaminants are at their highest concentrations at the plant following rainfall and increased river flow. While it is typical that high sediment levels in water correlate with elevated *Cryptosporidium*, *Giardia* and fecal coliform, management of these sources can be separate and distinct from sediment control. In addition while sediment stored in the tributaries and river system will continue to impact the water plant into the future, the elimination or reduction of sources of fecal contamination will produce immediate benefits due to limitations concerning the survival time of pathogens in the environment.

Unlike sediment particles, *Cryptosporidium* and *Giardia* enter the environment through fecal contamination. Appropriate oocyst and cyst management practices include those that prevent fecal contamination (e.g. animal waste management, stream fencing, wastewater treatment filtration, CSO/SSO control). Where contamination is not prevented, oocysts and cysts survive for up to 18 months in the environment. They are transported through the environment in much the same way that sediment particles are transported. Appropriate management practices therefore also include those that control particle runoff to and particle transport within streams (e.g. buffer strips, structural treatment practices, erosion and sediment control).

- The effectiveness of appropriate management practices in preventing fecal contamination is highly dependent on local conditions but is well demonstrated. Unfortunately, insufficient data is available to allow appropriate modeling of these practices (especially regarding *Cryptosporidium* and *Giardia*). Recommendations for prevention of fecal contamination therefore remain qualitative. Because oocysts and cysts persist in the environment, sediment particles are considered an appropriate surrogate for their transport in the environment. Sediment control management practices applied in areas which are susceptible to fecal contamination (i.e. pastures, urban areas, dairy farms) are therefore expected to control oocysts and cysts in roughly the same way they control sediment.

The only contaminant in Group 1 which was explicitly modeled under the modeling approach was sediment/turbidity.

Susceptibility to Group 2 Contaminants of Concern (natural organic matter, disinfection byproduct precursors, and algae and its nutrients)

- Group 2 contaminants generally present their greatest challenges to the treatment plant during low flow, warmer months. The contaminants in Group 2 were modeled using explicit and surrogate measures. Total organic carbon was modeled and served as a surrogate for natural organic matter and disinfection byproduct precursors. Chlorophyll-a, which is a constituent of algal cells, was modeled as a surrogate for algae, while total nitrogen and total phosphorus were modeled explicitly.

Susceptibility to Group 3 Contaminants of Concern (taste and odor producing compounds)

None of the Group 3 contaminants were modeled explicitly due to limitations of the models and the unknown nature of the taste and odor producing compounds. Taste and odor causing compounds would generally be a concern during summer months when algal blooms occur in stagnant areas of the Potomac River.

Recommendations

Source Water Protection Planning Recommendations

Based on the finding of this SWA a series of recommendations were developed to be used as the starting point for developing a SWPP. These recommendations are summarized in the overview part of this Executive Summary and presented in detail in the report, separately for each group of contaminants of concern.

Public Outreach Program for this Source Water Assessment

Participation from others outside of the project team has been a key element of this Source Water Assessment. Ultimately the success of source water protection efforts will be dependent on a wide range of participants including local jurisdictions, Potomac Basin States, water utilities, watershed residents, agricultural producers, the federal government and the public. The project team has coordinated closely with teams performing other SWAs in the Potomac Watershed and the assistance of these dedicated professionals has been key to performing the assessment. The project team also visited each of the Maryland Water Treatment Plants on the main stem of the Potomac and engaged plant staff and utility management in carrying out the assessment. MDE has held public meetings discussing the project goals approach and results of the assessment. Important input has been received through these meetings. News articles have published the availability of the project summary through MDE and discussed some of the key findings. The complete report will be supplied to the county environmental agencies and the General Assembly in accordance with the Potomac River

Protection Act. Further coordination and public discussion of the significance of these findings along with the findings of source water assessments of other water suppliers using the Potomac River is anticipated.

SECTION 1 - INTRODUCTION

1.1 - New Water Supply Challenges

The 1996 Safe Drinking Water Act Amendments required that an SWA be conducted for all public water systems, with the overall purpose to enhance public health protection by assessing sources from the drinking water perspective. This perspective is somewhat different from the “fishable and swimable” goal of the Clean Water Act. For example, a river that meets all typical environmental water quality criteria for aquatic life and recreation may have high organic content that forms unacceptable levels of disinfection by-products upon adding chlorine during water treatment.

Efforts to clean the nation’s surface waters started several decades ago, but have largely focused on improving the quality of streams, rivers, lakes, and estuaries for protection of wildlife and the environment rather than potable water supplies. Efforts to provide safe drinking water have historically included finding the best available source, using appropriate treatment and, more recently, improving the distribution and storage of treated water. Although wildlife and human health needs are often similar, “safe” raw water is not necessarily the same as “clean” natural water and protection and restoration of water bodies for drinking water supply require somewhat different management practices, and thus the need has been identified for source water assessments (SWAs).

The Washington County Water & Sewer Department (WCW&SD), Maryland Department of the Environment (MDE) and other water utilities and regulators now perform their critical work in an environment of increasingly stringent regulations and with a public that is more educated on water quality issues than ever before. In response to new and proposed regulations, the Partnership for Safe Water, and public concern, the Sharpsburg Water Treatment Plant (WTP) and other treatment facilities are being optimized to meet ever more demanding goals for pathogens, disinfection by-products (DBPs), turbidity and particle counts.

1.2 - Challenges at the Sharpsburg WTP

Raw water quality at the Sharpsburg WTP presents a major treatment challenge and needs to be better understood and managed to assure continued and improved protection of the health of WCW&SD's customers. Although WCW&SD's Sharpsburg WTP consistently produces water with filtered water that meets of does better than EPA's drinking water standards, its operators face many challenges due to less than ideal raw water quality.

1.3 - Overall Strategy for Meeting These New Challenges

1.3.1 - A Multi-Barrier Approach

In the US, multiple barriers are employed to protect the public from waterborne illness. These barriers include: collection and treatment of contaminated domestic and industrial wastes; mitigation within rivers, reservoirs and aquifers, drinking water treatment and distribution, and management of our water supplies to prevent or mitigate contamination.

The extent to which WCW&SD's customers are protected from waterborne disease depends on the number and efficiency of barriers to infection. Consistent improvements in farming practices, the collection and treatment of wastewater in the watershed, and the treatment and distribution of safe drinking water by WCW&SD have consistently improved the quality of water supplied to WCW&SD's customers. The 1996 Safe Drinking Water Act (SDWA) amendments establish, within the regulatory framework, ongoing efforts to extend and improve the multiple-barrier approach by placing a strong emphasis on preventing contamination through source water protection and enhanced water system management. These SWAs serve as the latest step in a process of evaluating and improving watershed activities for the protection of public health.

Although there has been significant progress, source water quality problems persist in the Potomac River. Recent sampling and evaluation efforts indicate that significant fractions of its tributaries are at least partially impaired. Point sources contribute significant amounts of contaminants that must attenuate within the river system or be removed in the treatment works at the Sharpsburg WTP. Although somewhat less well documented and quantified, the effects of non-point sources of pollution are known to be significant in the entire Potomac River Watershed . Nonpoint sources include urban and suburban run off, crop and livestock operations, forest activities, and other watershed activities.

According to EPA "*Source water protection is a common sense approach to guarding public health by protecting drinking water supplies. In the past, water suppliers have used most of their resources to treat water from rivers, lakes, and underground sources before supplying it to the public as drinking water. Source water protection means preventing contamination and reducing the need for treatment of drinking water supplies. Source water protection also means taking positive steps to manage potential sources of contaminants and contingency planning for the future by determining alternate sources of drinking water. Protecting source water is an active step towards safe drinking water; a source water protection program (along with treatment, if necessary) is important for a community's drinking water supply. A community may decide to develop a source water protection program based on the results of a source water assessment*".[1]

1.4 - Framework of the Study

In August of 1997, EPA presented the "Source Water Assessment and Source Water Protection Program (SWPP) Guidance for States" to use while implementing the source water

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[1] USEPA (1999).

provisions of the 1996 SDWA Amendments. The SWA program is designed to provide information that will lead to a SWPP that improves public health protection.

EPA guidance on SWAs addresses the 1996 SDWA Amendments' requirement that States identify the areas that are sources of public drinking water, assess water systems' susceptibility to contamination, and inform the public of the results of this assessment. Based on this guidance, MDE has developed the Maryland Source Water Assessment Program under which this project has been executed.

Because of the historical emphasis on ecological issues, there is a great deal of existing information regarding the effects of watershed activities on the quality of natural surface waters, particularly for parameters which affect the biological health of these waters. Due to the SDWA, Information Collection Rule (ICR), the Source Water Assessment Program (SWAP), the Clean Water Action Plan (CWAP), and other programs, there is also a great deal of data regarding raw water quality, pathogen occurrence and treatability, and the occurrence and impacts of best management practices (BMPs). This project has made use of this historical record and has built upon and expanded this body of knowledge with an emphasis on public health and drinking water issues.

Conclusions regarding general approaches to protecting the Potomac River as a water supply can be drawn from this and previous work, but specific plans depend on local needs, opportunities, and restrictions. The implementation of management practices and the development on specific watershed protection programs requires input and contributions from a wide variety of stakeholders. Water utilities; federal, state and local governments; watershed councils; and grassroots organizations are among the active players in watershed management and must share information effectively, whether through formal or informal partnerships. These stakeholders have a range of missions, jurisdictions, and authorities and may be better able to fulfill each mission with close partnerships.[2]

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[2] USEPA 1999

SECTION 2 - BACKGROUND

Much of this current concern for watershed protection and for particle removal efficiency stems from the cryptosporidiosis outbreak that occurred in Milwaukee, Wisconsin in the spring of 1993, which infected approximately 400,000 people, hospitalized 4,000 people and resulted in the death of more than 100 immunocompromised individuals.

Regarding the Milwaukee outbreak, the New England Journal of Medicine[3] states “This massive outbreak … was caused by *Cryptosporidium* oocysts that passed through the filtration system of one of the city’s water treatment plants. Water quality standards … were not adequate to detect this outbreak.” It is important to note that the Milwaukee facility was meeting the turbidity removal regulations in place during the outbreak and that although lowered turbidity standards may help avoid another similar outbreak, this episode makes it clear that pathogenic particles can pass through a treatment works. Turbidity standards have since been reduced. This event highlights the importance of source water protection to provide an additional barrier for public health protection.

2.1 - Legislation

The Safe Drinking Water Act Amendments of 1996 initiated a new era in drinking water regulations by providing for prevention of source water contamination. In addition to drinking water treatment and monitoring regulations, the new EPA requirements call for the implementation of Source Water Assessments (SWAs) and imply the need for Source Water Protection Plans (SWPPs). Source water assessment and watershed protection are a logical extension of the traditional multi-barrier approach to public health protection and a reasonable

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[3] M^{c}Kenzie et al. (1994)

response to threats posed by pathogens such as *Cryptosporidium* oocysts and *Giardia* cysts, disinfection by-products, pesticides, and other drinking water contaminants.

Maryland has more than 3,800 public water supplies, approximately 50 of which use surface water sources. The Maryland Department of the Environment (MDE) submitted the Maryland Source Water Assessment Plan (MD-SWAP) to EPA in February of 1999. EPA approved the MD-SWAP in November of 1999. Under these federal regulatory requirements, MDE has until May 2003 to complete these SWAs. The Potomac River Protection Act, signed into law by Governor Glendening in May of 2000, sets an accelerated schedule in calling for completion of the Potomac River SWAs by July 1, 2002.

Since 1996, the Potomac River has been designated as an American Heritage River. In order to maintain this designation, the local community must achieve "measurable results" toward achieving "natural resource and environmental protection, economic revitalization, and historic and cultural preservation" of the Potomac.

2.2 - Source Water Assessment Approach

The assessment project was performed to gather, analyze and interpret water quality information and to establish the science upon which a Source Water Protection Plan can be developed and implemented. The SWA for the Sharpsburg WTP included:

- delineation of the boundaries of the watershed,
- inventory of potential contaminants of concern,
- location of potential sources of those contaminants,
- analysis of threats posed by these sources and the likelihood of the delivery of these contaminants to the water supply,
- development of recommendations for a Source Water Protection Plan, and

- coordination of project efforts and communication of findings with local stakeholders, including regular briefings and public meetings.

This project approach reflects MDE commitment to an in-depth analysis of the Potomac River Watershed and its desire to develop an effective approach for protecting the Potomac River for its use as a regional water supply source. These tasks are described in more detail below.

2.2.1 - Delineation of Boundaries of the Watershed

The watershed boundaries were established based on preliminary delineation maps, which were prepared by MDE. These maps were refined in the area of the intake based on local hydrology. These boundaries are shown on the Watershed Delineation Map included in the appendices (on attached compact disc).

2.2.2 - Inventory of Potential Contaminants of Concern

A list of potential contaminants of concern was developed based on the MD-SWAP and on conditions particular to the Sharpsburg WTP. Water quality data were collected from a variety of sources and evaluated to determine the level and frequency of historical occurrences at the Sharpsburg Intake and in finished water from the plant. This allowed selection of a list of contaminants that were considered of particular concern. These evaluations are described in detail in Appendix A and summarized below in this report under the Section 5.1, “Review of Water Sampling Data”

In addition to past raw water quality monitoring, reports on historical water quality conditions throughout the entire Potomac River Watershed were reviewed. Historical data for some particular contaminants (including TOC, and dieldrin) were collected and evaluated to determine historical trends. These evaluations are described in detail in Appendix B and summarized in this report under Section 5.2, “Review of Historical Ambient Water Quality Data and Reports”.

2.2.3 - *Location of Potential Sources of Contaminants*

Potential sources of contaminants were compiled using a variety of data sources. These potential sources were organized according to source type and pinpointed on maps, which are attached (on the attached compact disc). Sources include point and nonpoint sources as well as potential spill sources. These mapped sources served as the basis for management plans which the project team developed. Based on potential sources within each subbasin, appropriate management practices were selected to reduce the edge-of-stream loading of contaminants. These management practices were evaluated under the Center for Watershed Protection's Watershed Treatment Modeling (WTM) task using the detailed data in these maps aggregated according to subwatershed. Scenarios evaluated include:

- Current conditions,
- Future conditions reflecting growth and projected changes in land use with no change in current management practices,
- Future conditions with moderate improvements in management practices, and
- Future conditions with aggressive improvement in management practices.

The development of these management plans and evaluations using the WTM are described in this report under Section 7, "Susceptibility Analysis".

2.2.4 -*Analysis of Threats Posed by Sources and the Likelihood of the Delivery of Contaminants to the Water Supply*

Contaminants that flow into the Potomac River and its tributaries undergo natural processes, which may significantly affect the amount that reaches the intake. Some contaminants (including natural organic matter, algae, and taste and odor causing compounds) may be produced within the waterbody rather than produced on, or applied to, the land. A few contaminants undergo no change in the waterbody and are delivered to the intake at the same rate that they reach the edge of the stream. In order to evaluate the contaminant load at the intake, rather than at the edge of the streams, the Chesapeake Bay Program Office's Chesapeake Bay Model was applied as a watershed and fate and transport model. The Bay Program Model was modified to evaluate only the subsheds up to and including the Sharpsburg WTP intake. Using this model, the same scenarios described above were run to evaluate the same management practice programs evaluated with the WTM.

The Bay Program Model cannot directly model future conditions or management practices. The WTM was therefore used to predict changes in the edge-of-stream loading, and these changes to the edge-of-stream loading were entered into the Bay Program model for each scenario. Running the Bay Program Model with these modified edge-of-stream loading allowed evaluation of the impacts of these changed loadings (and the management practices which cause them) on the raw water quality at the Sharpsburg WTP intake. This modeling effort is described in detail in this report under the subsection titled "Susceptibility Analysis".

2.2.5 – Development of Recommendations for a Source Water Protection Plan

Based on the previous analyses, recommendations for the source water protection program were made. There are a very large number and variety of people involved in management of the watershed and implementation of a source water protection plan will necessarily involve coordination with a variety of officials, commercial entities, landowners, and private citizens. Recommendations therefore include coordination with key stakeholders and ongoing management activities. Specific management practices and the appropriate land use for their implementation were recommended as a starting point for development of a source water protection program. Based on the susceptibility analysis and experience with management practices, the project team determined and described potential benefits of a management program that includes these recommended practices. These recommendations are described in the "Recommendations for Source Water Protection Program" subsection of this report.

SECTION 3 - GENERAL SOURCE WATER INFORMATION

3.1 - Description of Sharpsburg WTP Watershed

The Potomac River is a water supply critical to many communities and provides other benefits to the public. It has historically been used for navigation, fishing, and commerce and currently provides unique recreational and aesthetic benefits. The watershed is an interjurisdictional, multistate watershed encompassing approximately 5,950 square miles with thousands of potential sources of contamination.

The watershed includes areas of Maryland, Virginia, Pennsylvania and West Virginia. The headwaters include the North and South Branches of the Potomac, which drain Appalachian areas of Maryland and West Virginia. These areas include the urban areas of Frostburg, Cumberland, Keyser, Romney and Petersburg. Mining activities continue in the upper parts of the watershed.

The Upper Great Valley region includes a great deal of agricultural areas as well as the urban areas of Winchester, Hagerstown, and Chambersburg.

3.2 - Description of Sharpsburg WTP

The Sharpsburg WTP is a 0.3 MGD conventional package WTP employing raw water intake and pumping, flash mixing of treatment chemicals, upflow solids contact clarification, filtration, disinfection and finished water storage and pumping. Current treatment facilities include one clarifier, two mono-media (anthracite) filters and filter-to waste capabilities. A single 23,500 gallon clearwell provides contact time for chlorine disinfection and storage for on-site finished water pumping. Backwash water and sludge from the clarifier is treated in two on-site sludge lagoons.

Treatment chemicals applied at the plant include aluminum sulfate as a primary coagulant, cationic and nonionic polymers, soda ash for pH and corrosion control, hydroflousilicic acid, and chlorine for disinfection. The plant operates 8 to 10 hours each day, for seven days each week

The intake structure was upgraded in October of 1998 and is located, approximately 1/3 mile from the treatment works and is accessible via the C&O Canal Tow Path. The intake structure includes two submerged cylindrical wedge-wire screens located approximately 20-feet from the shore. Raw water flows through two 50-foot long, 8-inch diameter pipes, past two sluice gates into a two separate wet wells. Two submerged pumps in the wet well pump through two 6-inch pipes approximately 1,600-feet to the treatment works. A manual compressed air system at the intake facility periodically blasts debris from the screens. The compressed air system and the power supply equipment for the intake structure are located on an elevated platform adjacent to the below grade pumping station.

Aside from the remote intake facilities, very little of the plant is automated and treatment and finished water pumping operations require significant manual control.

3.3 - Results of Site Visit

The previous intake and raw water pumping facilities were prone to siltation and caused occasional disruptions to production as sediment was manually removed. The new intake facilities (constructed in 1998) have reportedly solved these problems and no forced reductions in production have occurred due to the new intake facilities. Operators report that there are no problems with ice or leaves clogging the screens or intake. The site visit occurred during a period of very low flows when the screens were submerged less than 1-foot. The new intake facilities reportedly include stainless steel wedgewire screens and air blasting facilities to keep the screens clear of debris.

Operators report occasional earthy-musty odors in the raw and finished water, which they attribute to algal activity in the river. Also as a result of algal activity, pH rises seasonally as high as 8.5 and demonstrates a significant diurnal fluctuation. Aside form these issues, the operators consider the water quality to be consistent and report few other episodes of difficult treatment. During occasional high turbidity events the coagulant dose is increased as high as 70 mg/L from the more typical 25 mg/L. Filter runs are generally 50 to 75 hours long, except during high turbidity periods (greater than approximately 100NTU) and cold water periods when runs are reduced to approximately half that time.

There is a generator at the plant site that, in the event of a power failure, can reportedly run all essential treatment and finished water pumping facilities including the remote raw water pumping facilities.

The Sharpsburg WTP reportedly practiced prechlorination until 1988 when the pre-chlorine facilities were removed.

The treatment facilities are generally redundant, with the exception of the chemical feed facilities. Spare parts are not available for some older chemical feed equipment that is not backed up. Where possible, spare feed pumps are kept available. The raw water pipeline travels “cross country” to the treatment facilities and no routine maintenance of the pipeline is reported. Consideration should be given to periodic cleaning and maintenance of this line.

SECTION 4 - WATERSHED CHARACTERIZATION

The Bay Program watersheds include 5 Potomac River subsheds that lie upstream of the Sharpsburg WTP intake. These subsheds generally comprise the areas described on Table 1.

Table 1 – Counties Within CBPO Subwatersheds

CBPO Subshed Designation	General Description	Maryland Counties	Virginia Counties	Pennsylvania Counties	West Virginia Counties
160	North Branch Potomac	Garrett, Allegany		Bedford, Somerset	Grant, Hampshire, Mineral
170	South Branch Potomac		Highland		Grant, Hampshire, Pendleton
175	Cacapon-Town & Conococheague-Opequon	Allegany		Bedford, Fulton	Morgan, Hampshire
730	Conococheague-Opequon	Washington*		Franklin, Adams*	
740	Conococheague-Opequon	Washington	Clarke, Frederick	Franklin, Fulton	Morgan, Jefferson, Berkeley

* subwatershed contains a very small portion of this county

4.1 - Current Land Use, Livestock and Population

Detailed land use is shown on maps included in the appendices (on attached CD). Approximate current (1997) land use distribution in the watershed is shown on Figure 1 and in Table 2.

Evaluations of this land use data indicate:

- the headwaters (subsheds 160, 170, and 175) are predominantly forested and include the bulk of the area under silviculture as well as substantial pastured areas;
- the Upper Great Valley, (subsheds 730 and 740) is dominated by agricultural land uses including cropland and pastures with a significant forested area, although very little of these forested areas are under silviculture;

Current estimates of livestock throughout the watershed are shown on Table 3. Pollutants from beef cattle are accounted for in pasture landuse categories and are thus not included in these totals. As the watershed includes a large amount of pastureland, the number of beef cattle is high and represent a significant source of contaminants.

There are currently 155 wastewater treatment plants in the watershed, more than 118 of which are considered minor based on treatment capacity.

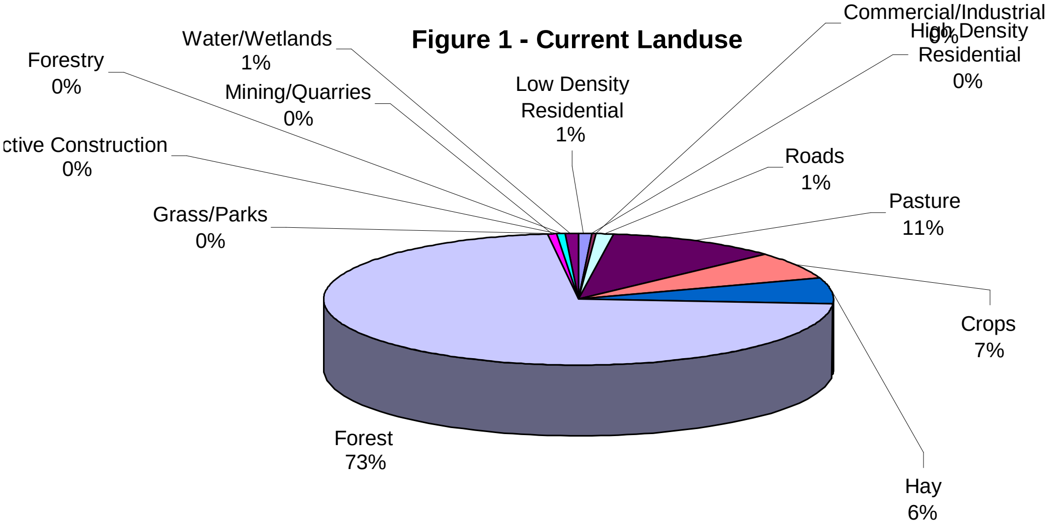

Figure 1 - Current Landuse

Table 2. Land Use in the R.C Willson WTP Watershed-1997 (acres)

Chesapeake Bay Program Subwatershed	160	170	175	730	740(*)	Total(*)
	North Branch Potomac	South Branch Potomac	Cacapon-Town & Conoc. - Opequon	Conoc. - Opequon	Conoc. - Opequon	
Low Density Residential	9,628	2,129	2,743	5,733	15,641	35,874
High Density Residential	555	96	35	781	839	2,36
Commercial/ Industrial	1,373	280	341	1,762	2,413	6,169
Roads	11,462	7,833	7,705	4,915	14,512	46,427
Pasture	62,192	131,577	56,042	30,179	126,859	406,849
Crops	18,052	5,992	20,000	102,968	100,384	247,396
Hay	28,639	24,736	32,288	48,401	107,687	241,751
Forest	695,189	762,657	671,775	113,755	488,291	2,731,667
Grass/Parks	-	-	-	146	341	487
Mining/Quarries	14,977	204	295	179	1,501	17,156
Active Construction	1,017	678	381	372	1,878	4,326
Forestry	3,645	4,792	5,719	789	-	14,945
Water/Wetlands	9,542	5,120	5,348	5,157	10,247	35,411
Total Area (acres)	856,270	946,095	802,672	315,135	870,593	3,790,765

* The Sharpsburg WTP is located within subshed 740, and some portion of these landuse totals are actually downstream of the intake.

Table 3. Number of Animals by Watershed Segment.

Segment	SWINE	DAIRY(**)	LAYERS	BROILERS	TURKEYS
160	2,760	7,416	28,030	214,028	5,628
170	1,466	149	59,305	628,195	137,038
175	4,466	5,055	17,480	88,105	1,158
730	65,184	27,673	156,846	36,443	49,229
740 (*)	22,055	15,933	31,631	2,697	15,781

* The Sharpsburg WTP is located within subshed 740, and some portion of these animal populations are actually downstream of the intake.

** Pollutants from beef cattle are accounted for in pasture landuse categories and are thus not included in these totals.

4.2 - Population Projections

Population distribution by 8-digit hydrologic unit code (HUC-8) and the changes in population from 1992 to 2000 are shown on Table 4. Population within the watershed is concentrated in the Conococheague watershed, relatively close to the intake. Projected population, organized according to Chesapeake Bay Program Office (CBPO) subwatershed, is shown on Table 5. Population growth within the basin is projected in areas with significant current population.

Table 4 Population By HUC – 8 Watershed

	Population by HUC - 8		
HUC - 8 name	**1992**	**1995**	**2000**
CACAPON-TOWN	29,328	30,344	30,998
CONOCOCHEAGUE (*)	366,394	379,768	400,108
NORTH BRANCH POTOMAC	114,423	114,490	116,427
SOUTH BRANCH POTOMAC	29,181	30,156	29,659
Total	539,326	554,758	577,192

* The Sharpsburg WTP is located within subshed 740, and some portion of these landuse totals is actually downstream of the intake.

Table 5 – Projected Population by Watershed Segment

CBPO Subshed	**Distribution among HUC 8s**	**1997 population**	**2020 population**	**Population Increase**
160	North Branch Potomac	115,265	117,145	1,880
170	South Branch Potomac	29,957	31,582	1,625
175	Cacapon-Town 2% of Conococheague	30,667	35,149	4,482
730	Conococheague-Opequon	83,868	89,597	5,729
740(*)	Conococheague-Opequon	204,981	265,489	60,508
Total		464,738	538,962	74,224

* The Sharpsburg WTP is located within subshed 740, and some portion of these landuse totals is actually downstream of the intake.

4.3 - Land Use Projections

Projected future (year 2020) land uses within the watershed, summarized according to the Bay Program subwatersheds, are shown on Table 6 and described in detail in Appendix C. Evaluation of these projections indicates:

- Agricultural, silvicultural and mining land uses are expected to remain unchanged throughout the watershed.
- Some forested areas throughout the watershed are expected to urbanize and this will result in increased residential development, commercial/industrial development, and roadways, with similarly decreased forested areas.
- Projections include reductions in active construction in the headwaters.
- Active construction is expected to increase in the lower parts of the watershed.

Table 6. Land Use in the Sharpsburg WTP Watershed-2020 (acres)

Chesapeake Bay Program Subwatershed	160	170	175	730	740 (*)	Total (*)
	North Branch Potomac	South Branch Potomac	Cacapon -Town & Conoc. - Opequon	Conoc. - Opequon	Conoc. - Opequon	
Low Density Residential	12,794	3,103	3,868	7,291	33,373	60,429
High Density Residential	738	140	50	993	1,791	3,712
Commercial/ Industrial	1,824	408	481	2,240	5,150	10,103
Roads	15,231	11,419	10,865	6,251	30,963	74,729
Pasture	62,192	131,577	56,042	30,179	126,859	406,849
Crops	18,052	5,992	20,000	102,968	100,384	247,396
Hay	28,639	24,736	32,288	48,401	107,687	241,751
Forest	688,143	758,293	667,426	110,308	449,828	2,673,998
Grass/Parks	-	-	-	146	341	487
Mining/Quarries	14,977	204	295	179	1,501	17,156
Active Construction	494	309	290	234	2,470	3,797
Forestry	3,645	4,792	5,719	789	-	14,945
Water/Wetlands	9,542	5,120	5,348	5,157	10,247	35,414
Total Area (acres)	856,271	946,093	802,672	315,136	870,594	3,790,766

* The Sharpsburg WTP is located within subshed 740, and some portion of these landuse totals is actually downstream of the intake.

SECTION 5 - WATER QUALITY DATA

In order to determine the historical occurrence of contaminants in the raw water at the Sharpsburg WTP, sampling data were collected and evaluated. These evaluations are described in detail in Appendix A and are summarized below.

5.1 - Review of Water Sampling Data

Monitoring of raw, finished and tap water quality is an important step in reliably providing safe water and assuring protection of the public health. Under the Safe Drinking Water Act, EPA requires monitoring of regulated contaminants. WCW&SD and MDE regularly monitor for these and other water quality parameters. These data are an important resource for evaluation of the Potomac River as a drinking water supply. A review of these data, data from other WTPs on the Potomac, and other ambient water quality monitoring data has established contaminants that are of concern at the Sharpsburg WTP. The project team has reviewed historical water quality reports, and data stored in the EPA's STORET and ICR databases, and MDE's Public Drinking Water Information System Database, as well as Monthly Operating Reports submitted to MDE by WCW&SD and other Potomac River WTPs.

This review resulted in the identification of the following contaminants as being of particular concern at the Sharpsburg WTP:

- Natural Organic Matter
- *Giardia*
- *Cryptosporidium*
- Tastes and odors
- Sediment
- Algae (and their limiting nutrient, phosphorus)
- Disinfection Bu-Product Precursors
- Fecal Coliforms

5.1.1 - *Method of Evaluations*

Evaluations were based on an extensive list of potential contaminants of concern, which was developed using criteria established in the Maryland Source Water Assessment Plan and experience at Potomac River treatment facilities. Contaminants listed in Appendix 2.1 of Maryland's Source Water Assessment Plan (MD-SWAP), and other compounds that affect the water quality were considered.

In addition to all regulated contaminants with established maximum contaminant levels (MCLs), contaminants that have a negative impact on plant operations and raw water treatability were considered for evaluation. Natural organic matter, which is traditionally measured by surrogates including total organic carbon (TOC), was included because it can have a controlling impact on coagulation, exerts a chlorine demand, and because it includes disinfection by-product precursors. Sediment [measured as turbidity or total suspended solids (TSS)] was included because of the cost and operational difficulties of removing and disposing of sediment and because many other contaminants enter the treatment works associated with sediment. Contaminants that threaten the natural steady state condition and long-term sustainability of the Potomac River were also identified. Phosphorus (the limiting nutrient in the Potomac River), pH, and ammonia were also considered. Consideration was also given to contaminants for which regulations are expected soon. Finally, contaminants listed on the EPA Candidate Contaminant List (CCL) and under the EPA secondary standards were also considered. MDE, and B&O'M collected readily available data for the list of potential contaminants of concern in Appendix A.

5.1.2 - *Results of Evaluations*

The evaluations were carried out to determine which potential contaminants were to be considered "contaminants of concern" according to established selection criteria. Because the list of potential contaminants was more extensive than that established by the SWAP, some additional selection criteria were developed. These criteria are described below, as are the results of the evaluations.

5.1.2.1 - Regulated Contaminants

According to the SWAP, contaminants for which there is an MCL will not be listed as contaminants of concern if existing raw water data indicate that measured concentrations do not exceed 50% of the current MCL more than 10% of the time (the “50/10” criterion). Where raw water data are not available, finished water data was evaluated and the 50% exceedance was applied to the maximum detection. (If any finished water sample had a concentration exceeding 50% of the MCL, the contaminant was considered of particular concern.) Evaluation of the data (as described in detail in Appendix A) revealed that none of the regulated contaminants (for which an MCL has been established) meets this criterion and none are considered contaminants of concern at the Sharpsburg WTP.

Details of evaluations for inorganic compounds are presented in Appendix A. Of the 11 listed inorganic compounds for which data were available, 9 had no positive samples (above the detection limit) for the contaminant. Of those that include positive samples, (nitrate and nitrite) none had been detected at concentrations exceeding 50% of the MCL. None of these inorganic contaminants will be considered a contaminant of concern at WCW&SD’s Potomac River WTP.

Details of evaluations for organic compounds are also presented in Appendix A. Of the 42 contaminants for which data were available, 38 had no positive samples (above the detection limit) for the contaminant. Of the 4 organic contaminants which include positive samples, atrazine had one positive sample and dalapon, di(2-ethylhexyl)adipate, and di(2-ethylhexyl)phthalate results included more than one positive sample. Only di(2-ethylhexyl)phthalate has been detected at concentrations exceeding 50% of the MCL. Details on positive dalapon, di(2-ethylhexyl)adipate, and di(2-ethylhexyl)phthalate samples are presented in

Appendix A. Di(2-ethylhexyl)adipate and di(2-ethylhexyl)phthalate were also found in laboratory blank samples and therefore are not believed to represent the actual water quality of the river. Similar unusually high concentrations of di(2-ethylhexyl)phthalate were found in results of evaluations performed at the same lab on the same day for samples collected at other facilities. Because of the history of false positive samples and the coincidental occurrences reported at other facilities di(2-ethylhexyl)phthalate will not be listed as a contaminant of concern based solely on the results of the May 15, 1995 sample and evaluation. It is therefore not considered a contaminant of concern at the WCW&SD Potomac WTP.

Details of evaluations for radionuclides are presented in Appendix A. One sample each for beta particles & photon emitters and for gross alpha particle activity were available. There were no positive samples (above the detection limit) for either radionuclide and therefore, no radionuclide is considered a contaminant of concern at the WCW&SD Potomac River WTP.

Several contaminants are regulated (under the Total Coliform Rule, Surface Water Treatment Rule, and Interim Enhanced Surface Water Treatment Rule) by requiring a particular treatment technique rather than establishment of a MCL. These include total coliforms, fecal coliforms, e. coli, turbidity, *Giardia*, *Cryptosporidium*, enteric viruses, legionella and heterotrophic plate counts. The Sharpsburg WTP meets or exceeds all relevant treatment technique requirements. Microbiological contaminants are discussed in Section 5.1.2.4 below. As discussed later, turbidity and *Cryptosporidium* are contaminants of concern.

5.1.2.2 - Contaminants with Established Health Advisories

Part of EPA’s regulation setting process includes evaluation of health affects data to determine at what concentration a particular contaminant is expected to cause a significant health affect. Once these health affects have been established under this process, EPA may issue a series of “health advisories” for that contaminant. It is important to note that except for arsenic (for which there is a recent reduction in the MCL), these are unregulated contaminants. In this assessment, the health advisory that correlates to the lowest drinking water concentration was used to establish the criterion for selection of contaminants of concern from this category. Because the risk assessment for establishment of health advisories is similar to that for establishing MCLs, the 50/10 criterion was applied to these parameters.

Details of evaluations for contaminants with established health advisories are presented in Appendix A. Data were available for 7 such contaminants. There were no positive samples (above the detection limit) for any of these contaminants. Therefore none of these contaminants are considered contaminants of concern at the WCW&SD Potomac River WTP.

5.1.2.3 - Contaminants Which Affect Sharpsburg WTP Operations

Some contaminants in natural waters significantly affect WTP operations although they may otherwise pose little or no public health threat. Sampling data for these contaminants were evaluated, but operational criteria were applied rather than health affects or established MCL limits. Under these criteria, evaluations (as described in detail in Appendix A) were performed for alkalinity, pH, TOC and sediment (using turbidity as a surrogate).

Monthly operating reports from January 1999 to January of 2002 were evaluated to determine the occurrence, in the raw water, of contaminants that affect the operations of the treatment works. Results of these evaluations are presented in Appendix A. Alkalinity has varied from 11 mg/L to 147 mg/L with an average of 86 mg/L. Within this range, high alkalinity is a boon to treatment. Low alkalinity can inhibit coagulation, making treatment more difficult. The 10% exceedance (alkalinity which 10% of the samples have exceeded) is therefore not relevant.

pH has varied from 6.7 to 8.6 with an average of 7.8 and a 10% exceedance of 8.1. High pH causes problems with coagulation when metal salts (like aluminum sulfate) are employed. In response to coagulation difficulties during periods of elevated pH, Sharpsburg is considering switching from aluminum sulfate to polyaluminum chloride (PACl) as the primary coagulant. Although PACl does not suppress pH to the extent that metal salt coagulants do, it may be a more effective coagulant at elevated pHs.

Raw water turbidity has varied from 1.9 NTU to 233.1 NTU with an average of 10.1 NTU. Turbidity has exceeded 17.5 NTU on 10% of the days over the time period evaluated. Elevated turbidity increases the solids loading on the facility, generally increasing the demand for treatment chemicals; reducing filter run length; and increasing the amount of sludge that must be processed.

Based on current and future regulations, review of Potomac River water quality data, previously prepared water quality summary reports, and evaluations performed in other Potomac River Source Water Assessments, organic carbon is considered to be of concern and is included in this SWA. Insufficient raw water organic carbon data were available for a thorough evaluation. Organic carbon can have a controlling impact on coagulation and is an indicator of disinfection by-product precursors.

5.1.2.4 - Disinfection and Disinfection By-Products

5.1.2.4.1 - Disinfection By-Products

At the Sharpsburg WTP, which disinfects with free chlorine, disinfection by-products of concern include trihalomethanes (THMs) and haloacetic acids (HAAs). These DBPs are formed when some naturally occurring organic compounds (referred to in this role as DBP precursors) react with chlorine. DBPs themselves are not expected in the raw water of the Sharpsburg WTP, because DBPs are generally formed within the treatment works and distribution and storage system after application of free chlorine. Raw water DBP formation potential data, which would typically be evaluated to determine the watershed impacts on DBP formation, are not available. Because of the current importance of DBPs in the water supply industry and the role of watershed activities in controlling DBPs, DBP precursors are considered a contaminant of concern at the Sharpsburg WTP.

5.1.2.4.2 - Cryptosporidium and Giardia

Cryptosporidium (Greek for "hidden spore") is a waterborne, parasitic pathogen that has been implicated in several waterborne disease outbreaks in the US. Indications of cryptosporidiosis include severe dehydration and diarrhea that is self-limiting in healthy patients (typically lasting 10 to 14 days[4]) but can be chronic and life threatening in immunocompromised individuals (including AIDS, transplant, and cancer patients; infants; and the elderly)[5]. 132 oocysts has been proposed as the dose which will infect 50% of those exposed (the so called ID_{50}), but doses as low as 30 oocysts may cause infection in healthy people. It is thought that a single oocyst can cause infection in immunocompromised people[6].

Cryptosporidium and *Giardia* enter the environment through fecal contamination from infected humans and animals. Previous research has indicated that *Cryptosporidium* and *Giardia* are present in source waters for most US surface water treatment plants.[7] In cyst and oocyst form they are resistant to many environmental conditions and disinfectants. *Giardia* cysts can be reliably removed and inactivated in conventional water treatment.

Cryptosporidium data recently collected by MDE and evaluated by a new method seem to indicate consistent and somewhat high concentrations.

Requirements of the Long Term 2, Enhanced Surface Water Treatment Rule (LT2ESWTR) will impose *Cryptosporidium* inactivation requirements [similar to those of the Interim Enhanced Surface Water Treatment Rule (IESWTR)] on small systems based on the results of future required monitoring with newer protocols. In September of 2000 the Federal

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[4] Holman (1993)
[5] Graczyk et al. (2000)
[6] DuPont et al., (1995)

Advisory Committee (FACA) for the LTESWTR finalized an Agreement in Principle, which is expected to serve as a foundation for the LT2ESWTR. The requirements of the LT2ESWTR have not been finalized but are expected to require additional *Cryptosporidium* inactivation (beyond that required by the IESWTR) depending on additional required water quality monitoring. The regulatory definition of "inactivation" is expected to include a "toolbox" of practices which may be utilized including inactivation (employing UV irradiation, ozone, or chlorine dioxide), physical oocyst removal, and watershed practices. For instance, utilities are expected to get 0.5 log credit for watershed protection programs and 0.5 log credit for maintaining filtered water turbidity below 0.15 NTU.

Because of the presence of wastewater discharges, sewer overflows, and livestock in the Potomac Watershed, *Cryptosporidium* is considered a significant public health issue at the Sharpsburg WTP. Historical sampling in the watershed (carried out under the Information Collection Rule) indicates the occasional presence of oocysts, but because of deficiencies in analytical technology it is difficult to gauge the degree of contamination and the infectivity of the oocysts that are present. MDE has initiated a project to further assess the presence and infectivity of oocysts in the Potomac River and in wastewater effluents discharged to the river. Preliminary results of this study indicate occasional but inconsistent presence of oocysts in relatively low concentrations during non-storm events. However, storm samples consistently had detectable and significant levels of oocysts. A significant fraction of the oocysts detected were determined to be viable and infective.

Wastewater and cattle are major sources of *Cryptosporidium* oocysts and *Giardia* cysts[8]. High concentrations of *Cryptosporidium* oocysts are present in livestock and wildlife manure[9].

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[7] LeChevallier, et al (1991)

[8] Jurenak et al (1995)

[9] Fayer, et al. (1997)

Feces from newborn calves (up to 2 weeks) have demonstrated the highest concentration of oocysts[10,11]. Land application of manure is widespread in the Potomac Basin and may be another important source of contamination.[12]

Several researchers have reported oocyst concentrations in municipal sewage ranging from 10 to 100 oocysts/L [13]. States et al. (1997) measured oocysts in combined sewers, finding a geometric mean of 20,130 oocysts/L.[14] MDE's ongoing study indicates high oocyst concentrations in most WWTP effluents and implicates municipal WWTPs as a significant source. The MDE data and other research do indicate that wastewater filtration is an important technology in reducing oocyst concentrations in wastewater effluent. New York City is funding microfiltration membrane processes at wastewater treatment plants in their watershed to remove oocysts.

Giardia and *Cryptosporidium* are considered contaminants of concern because of uncertainty in previous sampling results, recent significant recovery of oocysts in the Potomac basin by MDE, and the importance of watershed management in the multiple barrier approach to minimizing pathogen threats.

5.1.2.4.3 - Viruses and Coliform Bacteria

MDE presumes a public health hazard if the log mean of fecal coliform samples exceeds 200 MPN/100 mL. Although fecal coliforms are removed and inactivated in conventional treatment like that practiced at the Sharpsburg WTP, they are an indication of fecal contamination and may indicate contamination with other fecal pathogens. Details of evaluations for microorganisms are presented in Appendix A.

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[10] Walker et al (1999)
[11] Xia et al. (1993)
[12] Holman (1993)
[13] Walker, et al (1999)
[14] States et al. (1997)

Data were available for fecal coliforms including samples with more than 80 MPN/100 ml and others with 110 MPN/100 mL. The test methodology applied occasionally does not allow determination of the most probable number if it exceeds 80 MPN/100 ml. 13 of 45 samples included concentrations above the limit that could be enumerated. Treating these samples as if the concentration equaled the maximum that could be enumerated, the log mean concentration equals 18.5 MPN/100 ml. 10% of the samples had fecal coliform counts above 80 MPN/100 ml. Available data indicate fecal coliform concentrations in excess of 50% of the MDE standard and the MPN in some samples could be significantly higher than that. Fecal coliforms are therefore considered a contaminant of concern at the WCW&SD Potomac River WTP.

5.1.2.5 - Contaminants Which Affect the Aesthetic Quality of the Water

Appendix A includes details of evaluations of parameters that affect the aesthetic quality of drinking water (those for which a secondary standard has been established). Of these contaminants, only sulfate data were available. 5 sulfate samples were collected from May 1995 to May 1999. Results indicate sample concentrations ranging from 36 to 85 mg/L. All reported concentrations are therefore well below the secondary standard of 250 mg/L and no contaminants will be considered contaminants of concern based on the secondary standards.

5.1.3 - Summary of Water Quality Sampling Data Evaluations

These evaluations (as described in detail in Appendix A) resulted in the identification of contaminants of concern for the project. The subsequent work on the project focused on these contaminants:

- NOM
- *Giardia*
- *Cryptosporidium*
- Tastes and odors
- Sediment

- Algae (and their limiting nutrient, phosphorus)
- Disinfection By-Product Precursors
- Fecal Coliforms

5.2 - Review of Historical Ambient Water Quality Data and Reports

In order to better understand and define the current water quality conditions and historical trends in the basin, historical reports of water quality conditions in the basin were evaluated, as were selected historical water quality data.

Despite significant population growth and development in the basin, there have been significant improvements in the general water quality of the Potomac Watershed, notably since the passage of the Clean Water Act of 1972. Improvements to and expansion of wastewater treatment facilities have caused reductions in failing septic systems and significant water quality improvements in most areas of the basin, particularly reducing bacterial contamination.

5.2.1 - Pesticides

The United States Geological Survey (USGS) has found pesticides to be present in nearly all of the nation's surface waters. More than half of the waters in urban and agricultural areas have one or more pesticides greater than the guideline set for protection of aquatic life, although annual average concentrations are almost always below drinking water standards and guidelines. National trends indicate reductions in occurrence and concentrations of organochlorine insecticides in fish tissues, although these chemicals remain persistent in fish tissue and sediment at urban and agricultural areas[15].

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[15] USGS 1999

5.2.1.1 - Dieldrin

Although dieldrin was not identified as a contaminant of concern for the project, an evaluation of dieldrin occurrence data indicates that dieldrin occurs throughout the entire Potomac River Watershed . As shown on figures in Appendix B, high peaks characterize these dieldrin data. These data do not reveal a significant trend over time and neither support nor refute reported improvements in the watershed. Data were available and reviewed for dieldrin in the water column, in the tissue of fish taken from the water bodies, and in riverbed sediment samples. All subwatersheds with available data indicated the presence of dieldrin in the water column. Dieldrin was present in some bed sediment samples from each subbasin for which data are available. Fish tissue sampling suggests more significant contamination of the North Branch Potomac, and Conococheague-Opequon than in other subsheds, although sediment and water sampling do not necessarily support these trends. The fish tissue data also demonstrate some very high peaks, which significantly affect the arithmetic mean concentration, which are in some cases above the USFDA limit for consumption.

Occurrences in the water column are most likely due to historical contamination of the streambed sediment, as dieldrin was banned in the 1970s. Because the sources of this toxic contaminant are generally controlled at this time, improvements over some time frame are reasonably expected, although insufficient data are available to estimate a time frame for these improvements.

5.2.2 - Nutrients

National trends for total nitrogen are stable and this is generally the case throughout the Potomac Basin. USGS has noted a national change in the nitrogen speciation toward higher concentration of nitrate and reduced ammonia concentrations.

Phosphorus is the limiting nutrient for algal growth in nontidal reaches of the Potomac River, and nitrate concentrations are consistently well below the MCL, so nitrate control is not considered particularly important to the Sharpsburg WTP.

Phosphorus loadings and concentrations have been reduced and, although total nitrogen loads and concentrations have remained steady, seasonal blue-green algal blooms seem to have been reduced significantly. pH fluctuations, due to algal photosynthesis, and low dissolved oxygen conditions, which can be caused by algal blooms, have been reduced.

Since the 1970s, phosphorus and sediment loading to the entire Potomac River Watershed have decreased significantly while nitrogen loading has remained roughly constant [16,17]. Nonpoint sources account for approximately 60%-70% of nutrient load from the Potomac watershed with a majority of this from agricultural sources.

In 1989 –1991, water quality in the river was dominated by nonpoint source pollutants with 70% to 97% of the annual nutrient and sediment load due to storm events. The Potomac River estuary receives significant loads of sediment, nitrogen and phosphorus from nonpoint sources. These represent a nutrient load significantly higher than that imposed by wastewater treatment plants in the watershed.[18]

In 1995, 900 of 12,000 miles of streams in the Potomac Basin were thought to be impaired by nutrients. At the time, the leading source of nutrients was agricultural activities; with urban sources the second leading cause.[19]

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[16] CB&WMA, 1993

[17] Tawil, May 1997

[18] CB&WMA, 1993

[19] ICPRB, 1995

5.2.3 - pH, PCBs and Metals

Acid water conditions in the headwaters persist due to active and abandoned mining operations, although there have been notable improvements (pH has increased since the 1970s, which represents an improvement). Monitoring from the early 1970s through the mid-1980s indicates increasing lead and chromium and decreasing trends for mercury [20]. PCBs, metals and other toxics are detected in some specific areas, although these are generally thought to be the result of historical contamination and sources of these pollutants have been significantly reduced.

5.2.4 - Fecal Contamination

LaVale, Frostburg, Westernport and Cumberland, Maryland and other jurisdictions in the watershed are operating their wastewater collection systems under a consent order related to combined sewer overflows (CSOs). Although the persistence of fecal coliforms downstream of these contamination events depends on many factors (including temperature, pH, ultraviolet light conditions, and flow conditions) these CSO events are clear cases of fecal contamination and are sure to contain untreated human pathogens. A review of wastewater effluent sampling data makes it clear that *Cryptosporidium* oocysts and *Giardia* cysts are commonly present in combined and sanitary sewer overflows and that these pathogens very likely persist well downstream of these overflow locations.

5.2.5 - Cryptosporidium

Because of deficiencies in available sampling and testing techniques, little reliable data on *Cryptosporidium* oocyst concentration is currently available for the Potomac River or any other waterbody. The ongoing study by MDE is employing relatively new sampling and testing protocols and is expected to yield significant relevant information

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[20] ICPRB, 1987

on the occurrence and concentrations of *Cryptosporidium* in the watershed. Preliminary results of this study suggest *Cryptosporidium* is present throughout much of the basin, with consistent detection of oocysts downstream of urban areas, livestock, and wastewater effluent. In more pristine, forested areas, detections are generally limited to storm events and detected concentrations are significantly lower.

The vulnerability of the Potomac River to contamination with land applied contaminants is somewhat reduced by the Karst geology common in the Great Valley where much of the agricultural activities take place in the basin. These geological conditions cause increased infiltration (and increased groundwater contamination) in these areas, relative to areas with less pervious geology.

SECTION 6 - SIGNIFICANT SOURCES OF CONTAMINATION

Watershed sources of contaminants in the Potomac River can be categorized as either point or nonpoint sources and include agricultural cropping practices, urbanization, lawn and pavement run off, municipal treatment plants, septic systems, and destruction of shoreline vegetation. Detailed data on contaminant sources are attached in the maps included on the attached CD. Mapping themes include:

- Watershed and subwatershed delineation
- Land use
- Hazardous and toxic waste sources
- Potential petroleum sources
- Facilities with NPDES permits
- Potential sewage problem areas

6.1 - Point Sources

Point sources of pollution are shown on the maps in the appendices (on attached CD). Wastewater treatment plants (and septic systems) contribute solids, nutrients, natural organic matter, fecal coliforms, *Giardia* cysts, *Cryptosporidium* oocysts, taste and odor causing compounds, bacteria, viruses, parasites, and organic chemical contaminants. WWTP design and operating parameters are key factors in reducing the impact on and risk to drinking water supplies. Plant upsets including flood flows (whether caused by combined systems or inflow and infiltration in sanitary systems) and process failures result in violations and adverse impacts on receiving water quality. Sewerage failures result in significant untreated discharges within the basin.

6.2 - Nonpoint Sources

6.2.1 - Urban

Urban and suburban areas within the watershed (shown on the landuse maps in attached compact disc) contribute nutrients, sediment, NOM, taste and odor causing compounds, *Giardia*, *Cryptosporidium*, fecal coliform and other bacteria, and heavy metals to the Potomac River. Lawn and pavement run off also increases instream flow and stream bed erosion. Until the streambed downstream of urbanized areas reaches a steady state with new streamflow patterns caused by increased impervious cover, which can take 60 years or longer, this effectively represents a sediment load to the Sharpsburg WTP. Among other particulate and adsorbed contaminants, this sediment from the streambed may include NOM, *Giardia*, *Cryptosporidium*, and dieldrin. Urban lands have also been reported to produce more nitrogen and phosphorus run off (per unit area) than agricultural lands.[21]

6.2.2 - Forest

Erosion and increases in peak flow from forest road construction and maintenance, logging, and forestry site preparation affect the water quality in the Potomac River in areas downstream of silviculture activities (shown on the landuse maps in attached compact disc). Changes in nutrient uptake and decomposition caused by slash disposal and forest cutting may affect water quality. Roadways and skid trails are a likely source of sediment and surface erosion and mass movement of soil and organic debris pose a water quality threat in forested areas of the watershed. Research indicates that surface erosion is the dominant erosion mechanism in forested areas and the amount of sediment transported to the surface water is generally proportional to the amount of bare soil in the watershed.

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[21] EPA 1999

6.2.3 - Agricultural

Agricultural land uses that contribute to Potomac River contamination (shown on the landuse maps in attached compact disc) include cropland, livestock feeding facilities, and grazing on pastureland. Contaminants from these land uses include sediment, nutrients, NOM, *Cryptosporidium*, *Giardia*, and fecal coliform and other bacteria.

6.2.4 - Mining

Mining activities in the Sharpsburg WTP Watershed are generally well upstream of the intake. Active mine sites (shown on the landuse maps in attached compact disc) are considered point sources and are regulated under NPDES permits, though abandoned mines are generally considered nonpoint sources and have fewer controls. Mining operations in the watershed are concentrated in the headwaters. Many of these water quality impacts are therefore mitigated by natural attenuation before reaching the intake and affecting the WTP. Lime dosers maintained by MDE and the Jennings Randolph Dam also mitigate the impacts of mining operations on the Sharpsburg WTP. Contaminants from mining operations can include acid drainage, leaching and run off of heavy metals and sediment.

6.2.5 - Other Activities

Destruction of streamside vegetation due to recreation, livestock and construction activities contributes sediment, nutrients, and NOM and also increases export of other terrestrial contaminants to the Potomac River and its tributaries.

SECTION 7 - SUSCEPTIBILITY ANALYSIS

7.1 –Modeling Approach

Using the information collected in previous tasks, the following tasks were performed:

- Computer Modeling Simulations (described below), which included:
    - ◊ Fate and Transport Modeling
    - ◊ Future Scenario Modeling
    - ◊ Treatment Scenario Modeling and
    - ◊ Time of Travel Modeling for Spill Source Evaluations

The susceptibility analysis was performed to evaluate the potential future watershed conditions and the impact of these watershed conditions on the raw water quality and treatability at the Sharpsburg WTP. To effect these evaluations, four scenarios were developed and modeled. These scenarios were:

- Current conditions (defined as the year 1997 due to lack of more current data),
- Future (year 2020) no management conditions (i.e., without increased management over current and planned future practices), and
- Future management conditions (with implementation of increased management practices), including
    - moderate management conditions [with intermediate (between no management and aggressive management scenarios) implementation of increased management practices]
    - aggressive management conditions (with aggressive implementation of increased management practices)

Current and future land use, livestock, point sources, and population are described above in the "Watershed Characterization" section, described in detail in Appendix C, and current data is shown in detail on maps included in the appendices (attached compact disc). Watershed management programs for each of these scenarios were developed based on data evaluation, and project team experience with watershed management practices both within and outside of the watershed. It is important to note that the level of detail in these evaluations may not be sufficient to make firm watershed management planning decisions and these decisions are highly dependent on local conditions and the input of other stakeholders. The details of each management scenario (as summarized below) represent the project team's recommendations regarding management practices. The management program for each scenario is described below.

7.1.1 – Inputs to the Model for Current Scenario and Future No Management Scenario

The change in future land use is projected as an increase in urban land. For the "future no management" scenario, the controls on future development are set based on existing programs in place within the watershed segment. Overall, it was assumed that lawn care education, erosion and sediment control, and street sweeping practices remain the same. However, management of storm water is explicitly treated differently for new development versus existing development. This difference is reflected in the fraction of development regulated for water quality and the fraction of new development where flow control is implemented.

Based on the estimations presented in Table 7, the management of storm water for future development was characterized based on the fraction of a segment in each state. The management practices are categorized as:

- Agricultural,

- Urban Structural,
- Urban Nonstructural

TABLE 7. CONTROLS ON NEW DEVELOPMENT BY STATE		
State	**Flow Control (%)**	**Water Quality Control (%)**
Maryland	45	90
Pennsylvania	0	70
Virginia	0	70
West Virginia	0	25

7.1.1.1 - Current Agricultural Practices

Agricultural practices were applied with the following assumptions:

- In general, efficiencies are equivalent to those reported by the Chesapeake Bay Program
- Practices are applied in series, so each successive practice can treat only the remaining load after previous practices have been applied. For example, a practice that is 50% efficient is effectively 10% efficient if it follows a practice with an 80% efficiency.

In addition, two discount factors are applied to agricultural practices. The first is an implementation factor that accounts for the level of implementation on targeted farms. The second is a discount factor applied to practices in series, which reduces efficiencies by 50% when applied as the second, third or fourth in a series.

Approximate efficiencies for these practices are provided in Table 8. Two practices are reflected not by efficiency but by a shift in land use. These are tree planting and retirement of highly erodible land. Tree planting is reflected by shifting any current land use where this practice is to be applied to forest. Highly erodible land is characterized as having four times the load of cropland. This load is subtracted from the total load for the land use where this practice is applied.

TABLE 8. EFFICIENCIES FOR AGRICULTURAL PRACTICES

Practice	Efficiency (%)			Notes
	TN	TP	TSS	
Conservation Tillage	40	70	75	Source: Palace, et al. (1998)
Nutrient Management	40	40	0	See Text
Water Quality Plan (Cropland)	10	40	40	Source: Palace, et al. (1998)
Water Quality Plan (Pasture)	40	14	14	Source: Palace, et al. (1998)
Water Quality Plan (Hay)	4	8	8	Source: Palace, et al. (1998)
Cover Crop	43	15	15	Source: Palace, et al. (1998)
Buffer	50	70	70	Source: Palace, et al. (1998); forest buffer
Grazing Land Protection	50	25	25	Source: Palace, et al. (1998)
Animal Waste Management (Swine and Dairy)	80	80	0	Source: Palace, et al. (1998)
Animal Waste Management (Poultry)	15	15	0	Source: Palace, et al. (1998)
Stream Fencing	75	75	75	Source: Palace, et al. (1998)
Highly Erodible Land Retirement	See Text			
Tree Planting	See Text			

7.1.1.2 - Current Urban Practices

7.1.1.2.1 - Structural Treatment Practices

Very little information is available to determine the extent to which structural practices have been employed in the watershed over time. However, based on general knowledge of the area, and the state of storm water practices throughout the region, it was estimated that dry ponds serve 5% of all development, and that another 2.5% is served by wet ponds.

7.1.1.2.1.1 - Structural Practice Efficiencies

Ideal efficiencies (before the application of discount factors) for these practices are derived from Winer (2000) are shown on Table 9:

TABLE 9. POLLUTANT REMOVAL FOR STRUCTURAL PRACTICES

	TN	TP	TSS
Dry Ponds	25%	19%	47%
Wet Ponds	33%	51%	80%
Wetlands	30%	49%	76%

7.1.1.2.1.2 - Discount Factors for Structural Treatment Practices

Three discount factors are applied to these ideal efficiencies:

- a capture discount to account for the fraction of annual rainfall captured by the practices,
- a design discount to reflect the design standards in place at the time that the practices were built, and
- a maintenance discount to reflect upkeep of the practice over time.

A uniform set of discount factors was used to characterize practices. These include:

- 0.9 for the “capture discount” (assumes 90% capture of annual runoff)
- 1.0 for the “design discount” (assumes typical design standards)
- 0.6 for the “maintenance discount” (assumes that relatively little maintenance occurs over time)

7.1.1.2.2 - Nonstructural Urban Practices

7.1.1.2.2.1 - Erosion and Sediment Control

Ideal efficiency of erosion and sediment control is reduced by:

- a "treatability" discount factor to reflect the fraction of development required to implement sediment control measures,
- a "compliance" discount to reflect the fraction of practices installed, and
- an "implementation/maintenance" discount to reflect the fraction of practices that are installed and maintained properly.

A uniform set of estimates was used to characterize erosion and sediment control practices, including:

- Practice Efficiency of 70%
- Treatability Factor of 0.8
- Compliance Discount of 0.7
- Installation/Maintenance Discount of 0.6

7.1.1.2.2.2 - Lawn Care Education

It is assumed that some level of lawn care education exists throughout the watershed. The WTM makes several default assumptions about reductions achieved through lawn care education. These include:

- 78% of the population fertilizes their lawns
- 65% of these people over-fertilize
- Over-fertilizers apply approximately 150 lb/acre-year of N and 15 lb/acre-year of P
- Successful lawn care education will cause people to reduce fertilizer application by 50%

- 25% of N and 5% of P applied to lawns is “lost” to the environment, either as surface runoff or as infiltration.
- Of the people who receive and remember information about lawn care practices, 70% are willing to change their behavior.

The remaining input parameter to characterize lawn care education is the fraction of the population that receives, understands and remembers information about more environmentally sensitive lawn care practices. It is assumed that 20% of the population matches this description.

7.1.1.2.2.3 - Street Sweeping

Street sweeping reductions are applied to loads from roadways. The only discount factor applied to the ideal street sweeping efficiency is a “technique discount” which represents the fraction of the road that is actually swept (e.g., parked cars do not interfere, etc.). It is estimated that 30% of all non-residential streets are swept on a monthly basis using a mechanical sweeper, with a technique discount of 0.8.

7.1.1.2.2.4 - Riparian Buffers

The WTM reflects stream buffers as the length of stream channel covered by buffers times the typical buffer width. This practice is treated separately from agricultural buffers because buffers in agricultural areas have different efficiencies, and also are not applied to urban sources. It was assumed that 5% of the urban stream channel was treated by stream buffers. Urban stream length was estimated as 4 miles of urban stream channel per square mile of urban drainage. A fifty foot buffer width was assumed.

7.1.2 – Inputs to the Model for Future (year 2020) Moderate and Aggressive Management Scenario

7.1.2.1 - Point Sources

The Chesapeake Bay Program database of loads and flows[22] were used to develop management scenario point source loads using revised average effluent concentrations based on improved treatment practices. For the "moderate management" scenario, concentrations of 8.0 mg/L TN and 0.5 mg/L TP were used. These concentrations represent BNR nitrogen removal and fairly aggressive phosphorus control. In the "aggressive management" scenario, Limit of Technology (LOT) concentrations were used to characterize outflow concentrations (3.0 mg/L for TN and 0.075 mg/L for TP). Resulting loads for each subshed are reported in Table 10.

TABLE 10. POINT SOURCE LOADS

Segment	Flow (MGD)	Load (Improved) (lb/year)		Load (Aggressive) (lb/year)	
		TN	TP	TN	TP
160	35.46	630,781*	55,449	332,695	8,317
170	0.42	10,508	657	3,941	99
175	0.07	1,751	109	657	16
730	8.38	209,662	13,104	78,623	1,966
740 (**)	9.94	248,693	15,543	93,260	2,331

* Same as existing load without controls.
** The Sharpsburg WTP is located within subshed 740, and some portion of these landuse totals is actually downstream of the intake.

7.1.2.2 - Urban Management Practices

Reasonable urban management practices include a change in the management of new development (including reducing impervious cover and providing better and more widespread storm water management), and improved erosion and sediment control. "Better Site Design" techniques include reducing the impervious cover associated with certain land use classes. The efficiency estimates for this analysis included for both the

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[22] Wiedemen and Cosgrove, 1998

“moderate management” and “aggressive management” scenarios are based on Schueler and Caraco, 2001 and include:

- 25% of new development occurs with better site design
- Impervious cover for low density residential uses can be reduced by 30%
- Impervious cover for high density residential uses can be reduced by 15%
- Impervious cover for industrial/commercial uses can be reduced by 15%

In addition, the improved management scenarios assume a higher level of storm water management on new development, reflected by higher discount factors and a greater fraction of development regulated and employing flow control measures. In the moderate management scenario, it is assumed that 80% of new development requires water quality control (or at least as much as in the existing scenario), and that 50% requires channel protection flow control. For the aggressive management scenario, these values are increased to 90% and 75%, respectively. The maintenance discount factor is increased to 0.9 (from the current 0.7) for both scenarios.

Improved erosion and sediment control was reflected as an increase in the fraction of sites controlled, and higher discount factors. For both the moderate and aggressive management scenarios, it was assumed that 90% of sites are regulated, with compliance and maintenance discount factors of 0.9.

7.1.2.3 - Agricultural Management Practices

For the “moderate management” scenario, agricultural practices were characterized by a reduction that is the average of the current management scenario and the “aggressive management” scenario. Rather than applying a separate suite of practices for this scenario, this set of reduction values was used.

In the “aggressive management” scenario, the following assumptions were made:

- 80% of all cropland and hay land will include nutrient management or farm plans
- 75% of all cropland will be in conservation tillage
- Buffers will be increased, based on statewide commitments of buffer restoration by Chesapeake Bay states.
- 90% of animal waste load can be treated by animal waste management systems.
- The total land treated by a particular practice is not reduced in any segment.

Implementation of the buffer assumption includes distributing the miles of stream committed to be restored in a state among each model segment, based on the total area. This is accomplished by multiplying the total miles to be restored within the state by the fraction of the state's Chesapeake Bay Drainage within that segment. This gives the miles of buffer within each state. It is then estimated that buffers can treat 1,000 feet of agricultural land. These buffers were then divided among the agricultural land uses in the watershed based on the fraction of each use in the watershed. For example, if 75% of the agricultural land is in cropland, 75% of the buffer is applied to cropland. For pasture, the buffer is reflected as stream fencing.

7.2 - Fate Transport and Treatment Evaluations of Contaminants of Concern

7.2.1 - General Fate and Transport and Treatment Characteristics of Contaminants of Concern

Pollutants that flow into the Potomac River upstream of the intake may be removed, produced or significantly altered by processes within the river. In evaluating the susceptibility of the Sharpsburg WTP intake to contamination from sources in the watershed, it is important to account for the attenuation, which will take place in the watershed. Specific processes related to contaminants of concern are discussed below.

To facilitate the assessment of the extent that the identified contaminants may reach the Sharpsburg WTP intake, these contaminants have been classified into three groups, which are discussed below and include:

- Group 1 – *Cryptosporidium*, *Giardia*, Fecal Coliforms, and Sediment;
- Group 2 – Natural Organic Matter, Disinfection By-Product Precursors, and Algae; and
- Group 3 - Taste and Odor Causing Compounds

7.2.1.1 –Group 1 – Cryptosporidium, Giardia, Fecal Coliforms, and Sediment

Cryptosporidium and *Giardia* are human pathogens that are resistant to chlorine disinfection and are one of the most significant challenges for a water treatment plant. Fecal coliforms are indicators of fecal contamination and the presence of other human pathogens. Sediment can shield pathogens from disinfection and increases treatment costs. These contaminants have been grouped together because they are all generally associated with sediment and solids in the River and watershed and their presence in the raw water also significantly impacts treatment plant operations. Because of their association with solids, they are generally transported to and removed in a treatment plant by similar mechanisms and with somewhat comparable efficiencies, and they can therefore be modeled to some extent through the use of sediment as a surrogate.

7.2.1.2 - Group 2 – Natural Organic Matter, Disinfection By-Product Precursors, and Algae

Natural organic matter, which can be represented by total organic carbon, includes disinfection by-product precursors and increases coagulant demand. Algae may increase disinfection by-product levels, increase coagulant demand, and interfere with filter operations. The growth and activity of algae in the Potomac Watershed is largely dependent upon the availability of the nutrient phosphorus. These contaminants are grouped together because they are similar in terms of their impact on chemical and physical treatment processes in the plant as well as on the formation of disinfection byproducts following chlorination.

7.2.1.3 - Group 3 - Taste and Odor Causing Compounds.

Taste and odor causing compounds are numerous and can affect consumer confidence in their drinking water. Algae can produce noxious tastes and odor compounds, and while listed in Group 2, algae levels may affect taste and odors.

7.2.2 – Detailed Fate, Transport, and Treatment Characteristics of Specific Contaminants

7.2.2.1 -Natural Organic Matter, THMs and HAAs

Natural organic matter (NOM) exerts coagulant and chlorine demands and results in increased treatment residuals, which must be treated and disposed of. Researchers have reported alum demand exerted by NOM ranging from 5.3 to 9 mg alum/mg TOC[23,24]. Thus, source water NOM concentration has a significant affect on the operations and cost of drinking water treatment. However, the most important problem associated with NOM is that it includes precursors to disinfection by-product formation. NOM is a mixture of organic chemical compounds present in natural waters including the Potomac River. Because NOM is a complex mixture of many chemicals, direct measurement is impractical and surrogate measurements are typically made to evaluate NOM levels. Total organic carbon (TOC) is a common surrogate for NOM.

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[23] Owen et al. 1993

[24] AWWARF 2000

NOM may be derived from excretions from and deterioration of algae, phytoplankton and macrophytes (weeds and aquatic vegetation) within the Potomac and its tributaries or it may be derived from terrestrial activities and transported to the river through storm run off or groundwater infiltration. NOM is classified (according to its adsorbability on special resins) as humic or non-humic. Humic substances include humic and fulvic acids while the non-humic fraction of NOM includes carbohydrates, hydrophilic acids, proteins and amino acids. NOM produced by terrestrial activities are generally more aromatic than NOM produced by algae, phytoplankton and macrophytes within the waterbody[25]. These aromatic organic chemicals are somewhat more likely to be chlorine disinfection by-product precursors (organic chemicals which, when they react with chlorine form THMs and HAAs) than in non-aromatic organic matter. NOM from terrestrial activities may therefore be somewhat more likely to produce DBPs than NOM produced within the waterbody.

Terrestrial sources of NOM are primarily the result of natural decomposition of biomass, which can affect important water quality parameters and results in fulvic acids, humic acids and other DBP-causing compounds. However, as a protective cover, vegetation can significantly affect raindrop impact, soil infiltration characteristics, surface run off filtering, and biological uptake of nutrients and other contaminants.[26]

NOM production within the Potomac River is caused by algal and macrophytic activities and can be controlled by reducing phosphorus loading to the river and its tributaries. Practices which control phosphorus do so by reducing land applications,

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[25] Bouwer et al., 1995

[26] AWWARF- 1991

modifying hydrologic flow paths, or modifying the adsorptive capacity of the land, either by soil conditioning or, more typically, by maintaining plantings which take up nutrients.

A large part of the Potomac Watershed is forested and most likely produces NOM loads as fallen leaves and dead plants degrade. There is also a great deal of agricultural cropland in the watershed, which also produces NOM. It is therefore likely that the terrestrial sources contribute a significant amount of NOM to the Potomac. The Potomac River has a history of significant seasonal algal blooms in stagnant areas. Due to significant historical nutrient loading; algae, phytoplankton and macrophytes most likely contribute significant seasonal NOM loads at the intake.

Historical raw water quality data from samples taken near the Sharpsburg WTP indicate relatively high TOC levels for a run of the river intake and suggest relatively high NOM and DBP precursors. NOM control measures therefore have the potential to lower treatment costs and sludge production.

7.2.2.2 - Giardia and Cryptosporidium

Giardia and *Cryptosporidium* are persistent in the environment in their cyst and oocyst stages. In these stages, they are thought to behave in the environment like other particles of similar size and density. *Giardia* cysts are approximately 8-10 μm in diameter and have a density somewhat less than average sediment particles. *Cryptosporidium* oocysts are smaller (4 – 6 μm) and also less dense than average sediment particles. As they are denser than water, cysts and oocysts may settle to the bed of the waterway. Depending on physical and chemical conditions and previous contacts with other particles, cysts and oocysts may be associated with other particles, in which case the settling velocity, and likelihood of sedimentation, is likely higher than individual cysts and oocysts. Oocysts from any part of the watershed may arrive at the Sharpsburg

WTP intake if flow conditions maintain them in suspension or if they are resuspended and carried to the intake while they remain viable. They may also settle to the streambed and become buried by streambed processes or become nonviable before resuspension.

Giardia cysts can be reliably removed and inactivated in conventional water treatment like that practiced at the Sharpsburg WTP. *Cryptosporidium* oocysts are extremely resistant to chlorination and difficult to inactivate, but can be removed by coagulation, sedimentation, and filtration in water treatment facilities. Ultraviolet (UV) radiation has been shown to render oocysts nonviable and is a promising treatment technique. EPA has estimated that conventional drinking water treatment, like that practiced at the Sharpsburg WTP, can remove 99% of oocysts. However, significant numbers of oocysts may pass through with inadequate dosages of coagulant, during ripening at the beginning of a filter run and particle breakthrough at the end of a filter run, and during hydraulic surges which occur during normal operations.

7.2.2.3 - Algae

Under appropriate environmental conditions, algae are formed in natural waters. In the Potomac River, seasonal algal blooms have historically formed when sufficient phosphorus is available in quiescent areas of the river. Since phosphorus is the so-called “limiting nutrient” in the river upstream of WCW&SD’s intake, control of algae is generally dependent on control of phosphorus. Algae cells are low-density particles and once they form in the river, they are efficiently transported. They are sensitive to low light and low nutrient conditions and are generally not expected in significant concentrations far from blooms in quiescent zones. Photosynthetic activities and cell mortality can have a significant affect on pH, oxygen concentration, NOM concentrations and nutrient levels in downstream reaches of the river. The Bay Program Model simulates chlorophyll a ($C_{55}H_{72}MgN_4O_5$), which is a constituent of algal cells and a suitable modeling surrogate for algal growth. The Bay Program Model also simulates TOC concentrations, which are a suitable surrogate for NOM. However, the TOC simulation in the Bay Program model has not been calibrated.

Algae cells are somewhat more difficult to remove than other particles and may cause increased particle counts in filtered water, but disinfection processes effectively oxidize any algae that pass through the filters.

7.2.2.4 - Sediment

Sedimentary particles which runoff into the Potomac River and its tributaries may settle to the stream bed depending on flow conditions, particle size and particle density. Sediment particles may also agglomerate depending on a wide variety of particle characteristics and water quality and flow conditions. Most particles which runoff into the streams of the Potomac Watershed will settle to the streambed, to be reentrained by subsequent storm flow. The fate and transport of sediment and other particles is therefore dependent on processes within the streambed. Relevant processes include physical processes (sedimentation, scour, etc.), chemical processes (organic and inorganic reactions within the pore water and at the streambed surface), and biological processes (bacterial, macrophytic, and bioturbation from benthic macrofauna). Streambeds therefore function as sediment sources, sinks and storage sites. [27] The Bay Program Model models TSS explicitly.

Sedimentary particles are removed efficiently in conventional treatment like that practiced at the Sharpsburg Plant.

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[27] DiToro, D.M., 2001

7.2.2.5 - Tastes and Odors

A wide range of compounds including by-products of algal activities can cause tastes and odors in drinking water. These compounds may be dissolved and are therefore transported with water flow. Geosmin and methylisoborneol (MIB) are two common by-products of algal activities that enter water plants as dissolved constituents and cause earthy-musty tastes and odors.

7.3 - Modeling Results for Watershed Segments

Three primary modeling tools were combined to estimate the susceptibility of the Sharpsburg WTP to contamination from watershed activities. These are watershed modeling, contaminant fate and transport modeling, and time of travel modeling (for potential spill evaluations). The watershed models were used to examine contaminant loads to the river under current and projected land use patterns as well as under various BMP implementation scenarios.

Contaminant loads from the watershed models were used to adjust edge-of-stream contaminant inputs (*i.e.*, loadings to the main stem or some major tributaries of the Potomac River) in the in-river contaminant fate and transport model. Contaminant fate and transport models were then used to assess the potential for contaminant attenuation from the points of entry to the river up to the intake location.

Previous modeling studies have generally been concerned with the ecological health of the Potomac River and have evaluated water quality throughout the river (rather than at a single point) and have focused on different contaminants. The susceptibility analysis modeling for this project focused on the Sharpsburg WTP intake water quality.

Two computer modeling packages were used including the Center for Watershed Protection’s Watershed Treatment Model (WTM), and the Chesapeake Bay Watershed

Model (CBWM). Because of constraints imposed by the project approach, which coordinated this SWA with 6 others on the Potomac River, the entire CBWM subshed was modeled, including the portion downstream of the intake.

7.3.1 – Watershed Simulation

Current annual loads for the major subbasins were estimated using the WTM. These WTM loads were used only as a basis to compare current conditions with future scenarios and management scenarios. The WTM is a simple method model designed to evaluate changes in annual load, which result from simulated changes in land use and management practices. Running the WTM under current conditions established the baseline for determining changes in the edge-of-stream loadings due to proposed future changes in land use and watershed management. A model of the watershed, from the headwaters to the discharge point of subshed 740, was developed based on EPA's Chesapeake Bay Watershed Model (CBWM). This model was designated as the Potomac Watershed Model (PWS Model) and run for current conditions to establish the hourly loadings of each modeled parameter at the edge of the stream from each of the major subbasins designated by EPA's Chesapeake Bay Program Office (CBPO) in the CBWM.

Scenarios that represent future land use and management scenarios were developed based on predicted future conditions and modeled using the WTM. Modeling of these scenarios yielded estimated annual loads of each modeled parameter, from each major subbasin. Comparison of these results and the baseline loadings from the current conditions run gave estimates of the change in the edge-of-stream loadings under the modeled scenario. This change in loading was then applied to the PWS Model by modifying the hourly edge-of-stream loading from each major subbasin based on the annual load changes predicted by the WTM. The PWS Model was then employed to model the fate and transport of contaminants from the point of run-off to the discharge point of subshed 740.

Table 11 –Watershed Loads From WTM

Segment		Total Nitrogen	Total Phosphorus	Total Suspended Solids
160		% of Current Load		
	Future-scenario 1	102%	104%	103%
	Future-scenario 2	101%	86%	100%
	Future-scenario 3	92%	73%	99%
170				
	Future-scenario 1	102%	103%	102%
	Future-scenario 2	99%	96%	99%
	Future-scenario 3	96%	91%	98%
175				
	Future-scenario 1	102%	103%	104%
	Future-scenario 2	98%	94%	100%
	Future-scenario 3	95%	87%	98%
	Future-scenario 1	105%	104%	101%
	Future-scenario 2	103%	97%	96%
	Future-scenario 3	100%	91%	90%
730				
	Future-scenario 1	102%	102%	103%
	Future-scenario 2	78%	65%	94%
	Future-scenario 3	61%	50%	86%
740 (*)				
	Future-scenario 1	110%	110%	112%
	Future-scenario 2	97%	87%	102%
	Future-scenario 3	88%	75%	95%
	Future-scenario 1	103%	102%	104%
	Future-scenario 2	100%	90%	91%
	Future-scenario 3	82%	66%	79%

* The Sharpsburg WTP is located within subshed 740, and some portion of these landuse totals is actually downstream of the intake.

WTM results showed moderate to good changes in edge-of stream loads from the watershed under the future managed scenarios. Expected changes are smaller for sediment. Management practices were able to reduce sediment loads slightly and phosphorus loads somewhat more. Table 11 summarizes these results as percentages of existing loads. Overall, point source nutrient loads could be changed significantly under the very aggressive treatment scenario, but urban loads typically increased, even with treatment. However, this increase in urban load did not typically increase the overall load from a segment significantly, because of the small amount of urban land. As urban areas increase in the watershed, especially beyond the planning period of this study, control of these impacts will become more important.

The WTM modeling indicates that management practices are expected to reduce edge-of-stream contaminant loadings to the Potomac River and its tributaries. However, fate and transport modeling suggests that the impact these changes have on the WTP raw water are significantly delayed due to natural processes within the river. The Potomac River bed serves as a signficant source of solids, nutrients, *Cryptosporidium*, *Giardia*, and contaminants which sorb to sediment including NOM.

When left undisturbed, the streambed reaches a steady state with flow conditions such that contaminant inputs and exports are roughly equivalent. When this steady state is altered by changes in flow pattern (due to changes in impervious cover, storm water practices, or climatological trends) or by changes in contaminant loading (due to agricultural activities, urbanization, or implementation of management practices) the streambed will undergo geomorphological processes which eventually bring it back into a new steady state condition. The timescale for this return to steady state depends on many local factors but is grossly estimated at more than 60 years in this case assuming the disturbances cease. Most disturbances in the watershed have been in place for some time, and relatively small changes are expected over the planning period of this project. Therefore, reductions in loading should not be expected to immediately affect the downstream water quality. Reduction in the loading of sediment and nutrients would therefore be expected to have little affect on the downstream water quality in the short term.

Contaminants which have run off into the Potomac in the past and are stored in the sediment of the upper watershed will continue to be transported to the WTP intake whether management practices are applied or not. The modeling results reflect this process. The reduction in edge-of-stream nutrient loading does not cause a similar reduction in algal activity (as indicated by simulated chloraphyll a and TOC concentrations).

Regardless of these modeling results, simple mass balance considerations indicate that application of these practices will eventually have beneficial impacts roughly equivalent to the impacts on edge-of-stream loading (for example, a 10% reduction in phosphorus loading should eventually reduce algal activity by approximately 10%), but for contaminants associated with sediment (including nutrients, and turbidity) this impact may lag years behind the implementation of the practices.

Regardless of loading, the streambeds of the watershed will serve as sources of nutrients for some time and algal activity will likely persist. Contaminants associated with the nutirent cycle and algal activities will likely also persist. These contaminants include NOM, DBP precursors, algal cells, and taste and odor causing compounds.

Cryptosporidium oocycts are thought to persist in the environment for a period of approximately 18 months, but not for periods on the timescale studied[28]. *Giardia* cysts are similarly persistent but not on the timescale of the planning period of this project. Reductions in oocyst and cyst loadings from the upper parts of the watershed would therefore be expected to reduce raw water oocyst concentrations rather quickly. Fecal bacteria, viruses, and other pathogenic organisms are even less persistent in the environment and management practices which yield reductions in edge-of-stream loading will have essentially immediate reductions in loadings at the Sharpsburg WTP.

7.3.1.1 – Simulation Modeling Results

As described above, the modeling activities of this project involved adjusting the edge-of-stream loading of suspended solids and nutrients in the PWS Model (the CBPO model of the Potomac Watershed). These edge-of-stream loadings were adjusted according to the WTM modeling task also described above. Future conditions without new management practices are characterized my small increases in TOC and moderate increases in TSS. The in-River fate and transport was then modeled with the PWS. Because nutrients and solids are stored in the Potomac streambed and because algal activities are concentrated in quiescent zones, little change in the in-River concentrations at the intake was noted for chloraphyll a under "no management", "moderate management" and "aggressive management" scenarios. Under improved management conditions, moderate reductions in projected TOC were noted, especially in peak levels (10% exceedance). This suggests that algal blooms would be reduced in the upper part of

Table 12 – Potomac River Watershed - TSS

	% Change From Current			
	2020 No Change in Management	2020 Moderate Manage.	2020 Aggressive Manage	Net Affect of Agg. Manag.
Average	105%	98%	94%	- 11%
Median	102%	99%	97%	- 5%
10% Exceedance	107%	98%	93%	- 14%

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[28] Rose, J.B., 1997

the watershed and instream production of TOC, NOM and DBP precursors would also be reduced. Increased management would also be expected to demonstrate a significant improvement in TSS conditions.

Table 13 – Potomac River Watershed - TOC				
	% Change From Current			
	2020 No Change in Management	2020 Moderate Manage.	2020 Aggressive Manage	Net Affect of Agg. Manag.
Average	102%	95%	90%	- 7%
Median	101%	98%	95%	- 6%
10% Exceedance	102%	94%	89%	- 13%

7.4 Modeling Results for Contaminants Groups

The modeling approach described previously in Chapter 2 and described in detail later in this chapter was utilized to analyze the susceptibility of the Sharpsburg WTP water supply to contamination from the identified contaminants of concern. The results of the modeling are discussed below and organized by contaminant group. It is important to remember that the quantitative predictions from the modeling are subject to the limitations presented by the assumptions and the surrogates utilized as well as the relatively gross scale and level of detail in the models. Results are presented primarily to provide relative comparisons of overall management options.

7.4.1 - Susceptibility to Group 1 Contaminants of Concern (sediment/turbidity, Cryptosporidium*,* Giardia*, and fecal coliform)*

Group 1 contaminants are at their highest concentrations at the plant following rainfall and increased river flow. While it is typical that high sediment levels in water correlate with elevated *Cryptosporidium, Giardia* and fecal coliform, management of these sources can be separate and distinct from sediment control. In addition while sediment stored in the tributaries and river system will continue to impact the water plant into the future, the elimination or reduction of sources of fecal contamination will produce benefits soon after their reduction due to the relatively short survival time of many pathogens in the environment.

Unlike sediment particles, *Cryptosporidium* and *Giardia* enter the environment through fecal contamination. Appropriate oocyst and cyst management practices include those that prevent fecal contamination (e.g. animal waste management, stream fencing, wastewater treatment filtration, CSO/SSO control). Where contamination is not prevented, oocysts and cysts survive for up to 18 months in the environment. They are transported through the environment in much the same way that sediment particles are transported. Appropriate management practices therefore also include those that control particle runoff to and particle transport within streams (e.g. buffer strips, structural treatment practices, erosion and sediment control).

The effectiveness of appropriate management practices in preventing fecal contamination is highly dependent on local conditions but is well demonstrated. Unfortunately, insufficient data is available to allow appropriate modeling of these practices (especially regarding *Cryptosporidium* and *Giardia*). Recommendations for prevention of fecal contamination therefore remain qualitative. Because oocysts and cysts persist in the environment, sediment particles are considered an appropriate surrogate for their transport in the environment. Sediment control management practices applied in areas which are susceptible to fecal contamination (i.e. pastures, urban areas, dairy farms) are therefore expected to control oocysts and cysts in roughly the same way they control sediment.

The only contaminant in Group 1 which was explicitly modeled under the modeling approach was sediment/turbidity.

7.4.2 - Susceptibility to Group 2 Contaminants of Concern (natural organic matter, disinfection byproduct precursors, and algae and its nutrients)

Group 2 contaminants generally present their greatest challenges to the treatment plant during low flow, warmer months. The contaminants in Group 2 were modeled using explicit and surrogate measures. Total organic carbon was modeled and served as a surrogate for natural organic matter and disinfection byproduct precursors. Chlorophyll-a, which is a constituent of algal cells, was modeled as a surrogate for algae, while total nitrogen and total phosphorus were modeled explicitly.

7.4.3 - Susceptibility to Group 3 Contaminants of Concern (taste and odor producing compounds)

None of the Group 3 contaminants were modeled explicitly due to limitations of the models and the unknown nature of the taste and odor producing compounds. Based on plant operating experience, any taste and odor producing compounds present in the raw water seem to be removed efficiently in the Sharpsburg WTP, and therefore further analysis of this contaminant of concern was not conducted.

7.5 - Spill Source Evaluations

The Sharpsburg WFP may be vulnerable to a variety of contaminants due to spills. The time-of-travel model was used to analyze the potential spill sources which could impact the water quality at the plant intake. The significant potential sources were grouped by their time of travel to the plant under various flow conditions in the River and have been summarized and documented. Due to security considerations, this documentation is not included as part of this report.

SECTION 8 - RECOMMENDATIONS FOR SOURCE WATER PROTECTION PLAN

8.1 - Coordination with Ongoing Source Water Protection Activities

A key aspect of the source water protection plan that is developed should be successful engagement in the ongoing watershed protection efforts within the basin. It is extremely important that prospective management practices are considered in the context of all impacts, rather than only those impacts on the Sharpsburg WTP. For example, management practices which may not seem cost effective when considering only the impacts on the Sharpsburg WTP may have significant aesthetic, environmental, and recreational benefits.

Key ongoing efforts include:

- Other source water assessment programs including Fairfax County Water Authority, the Washington Aqueduct Division of the Army Corps of Engineers for the District of Columbia and other Maryland water suppliers on the Potomac River.
- Floodplain preservation in Maryland
- Chesapeake Resource Protection Areas in Virginia, which limits building near streams and promotes stream buffers.
- Implementation of improved storm water management criteria in Maryland.
- Virginia’s recently adopted storm water manual.
- Efforts of regional planning agencies including ICPRB, COG, EPA-CBPO, Agricultural Extension Offices.
- Ongoing NPDES permitting and compliance programs in the watershed.
- The pollution impaired waterbody listing process (i.e. 303d or TMDL).

- The Chesapeake 2000 Agreement.
- The Upper Potomac and Middle Potomac tributary teams of the Maryland Tributary Strategies Program.

8.2 - Recommended Management Practices

Noting the need to coordinate with local stakeholders, some specific practices are recommended for consideration in the source water protection program. These are described in Table 14. Other recommendations for the program include:

1. Formation of a watershed protection group representing stakeholders and empowered with sufficient authority to explore and advocate “safe” water issues in concert with ongoing and future “clean” water activities. Specific recommendations for the watershed protection group include:
    - identification of goals, steps toward achieving those goals, and measures of success;
    - active involvement of local stakeholders to define and pursue the necessary studies and steps before development of a source water protection plan; and
    - public awareness, outreach and education efforts;
2. aggressive involvement in agricultural BMP implementation plans to address nutrient, bacteria, and pathogen loads from urban lands.
3. Further studies and monitoring including:
    - additional monitoring for significant contaminants including *Cryptosporidium*, and NOM surrogates (UV-254, TOC, DOC, and/or SUVA); and

TABLE 14. MANAGEMENT PRACTICES RECOMMENDED FOR CONSIDERATION

AGRICULTURAL PRACTICES

Practice	Applied To	For Control of
Conservation Tillage	Cropland	NOM, DBPs, Algae, Sediment
Nutrient Management	Cropland, Hayland	NOM, DBPs, Algae, Sediment
Water Quality Plan	Cropland, Hayland, Pasture	NOM, DBPs, Algae, Sediment
Cover Crop	Cropland	NOM, DBPs, Algae, Sediment
Tree Planting	Cropland, Hayland, Pasture	NOM, DBPs, Algae, Fecal Coliforms, *Cryptosporidium*, *Giardia*, Sediment
Buffer	Cropland, Hayland	NOM, DBPs, Algae, Fecal Coliforms, *Cryptosporidium*, *Giardia*, Sediment
Highly Erodible Land Retirement	Cropland, Hayland	NOM, DBPs, Algae, Sediment
Grazing Land Protection	Pasture	NOM, DBPs, Algae, Fecal Coliforms, *Cryptosporidium*, *Giardia*, Sediment
Animal Waste Management	Animal Waste	NOM, DBPs, Algae, Fecal Coliforms, *Cryptosporidium*, *Giardia*,
Stream Fencing	Pasture	Fecal Coliforms, *Cryptosporidium*, *Giardia*, Sediment

URBAN PRACTICES

Practice	Applied To	For Control of
CSO/SSO Control	Locations of Previous Sewage Overflows	Fecal Coliforms, *Cryptosporidium*, *Giardia*,
Wastewater Filtration	WWTPs	Fecal Coliforms, *Cryptosporidium*, *Giardia*,
Structural Treatment Practices	All Urban Land	NOM, DBPs, Algae, Fecal Coliforms, *Cryptosporidium*, *Giardia*, Sediment
Erosion and Sediment Control	Active Construction	NOM, DBPs, Algae, Fecal Coliforms, *Cryptosporidium*, *Giardia*, Sediment
Lawn Care Education	All Lawns (Institutional, Residential, Commercial)	NOM, DBPs, Algae, Sediment
Pet Waste Education	All Urban Land	NOM, DBPs, Algae, Fecal Coliforms, *Cryptosporidium*, *Giardia*,
Street Sweeping	Streets, Roads and Highways	Sediment
Impervious Cover Disconnection	Commercial and Residential Roofs	Sediment
Riparian Buffers	All Urban Land	NOM, DBPs, Algae, Fecal Coliforms, *Cryptosporidium*, *Giardia*, Sediment

- detailed evaluations of fecal contamination to identify the most significant sources of fecal contamination to target;

4. Implementation of a source water protection plan that is fully engaged with the ongoing watershed protection efforts within the basin. This plan may include:

- evaluation (by MDE or a watershed protection group) of an acceleration to the ongoing enhancement of combined sewer overflow (CSO) management in Western Maryland;
- support of stream buffer implementation throughout the watershed; and
- management practices as described in Table 14 below.

8.3 - Planning Level Cost Information

Appendix D presents preliminary planning level cost data for specific urban and agricultural management practices. These data can be used by the source water protection group in the development of the source water protection plan to help prioritize practices and identify funding needs for preferred practices.

General preliminary planning level cost information is presented for urban practices including structural stormwater treatment practices, stormwater control programs, and program costs for urban programs. These data are presented as annualized costs, as well as broken down into separate construction and maintenance costs for each practice.

Planning level cost information is also presented for agricultural practices. Agricultural environments are generally more diverse than urban areas and thus implementation of agricultural management practices varies widely. An important factor to consider when using any of the data on agricultural practices is the particular milieu in which a particular cost is to be incurred. Some sources report total cost savings for practices, which include savings to the farmer for materials such as fertilizer, for example. Other costs represent program costs incurred, and do not account for cost savings or production impacts. In addition, costs vary significantly depending on the region of the country in which the data were developed.

8.4 - Potential Benefits of Recommended Management Practices

When making decisions regarding watershed management, it is important to consider all of the impacts of a particular practice under consideration. While watershed management practices add additional barriers that increase public health protection, when they are applied in lieu of additional treatment, the reliability of the practice is an important consideration. Watershed management may reduce treatment costs and add to the multiple barriers of protection, but the reliability of these practices is different than the reliability of treatment facilities. It is a mistake to consider one as a substitute for the other. It is also important that stakeholders in the Potomac River Watershed, including water suppliers; consumers; landowners; and federal, state and local authorities, view source water protection as the first barrier in a multi-barrier approach to the supply of safe drinking water. This source water assessment, as well as previous work carried out by the project team and others, indicates that opportunities exist to improve the Potomac River water quality at the Sharpsburg WTP intake. These opportunities for improvements include:

- reducing the solids loading to the plant,
- reducing the NOM concentrations which result from algal, phytoplankton and macrophyte activities in the Potomac and its tributaries, and
- improved protection from pathogens including *Cryptosporidium* and *Giardia*.

8.5 - Potential Benefits to the Sharpsburg WTP

The primary improvement management activities would accomplish would be the provision of an additional barrier in the protection of the health of WCW&SD's

customers. Significant environmental improvements would also be achieved through improved management. The following improvements relevant to the Sharpsburg WTP can also be expected:

- a reduction in the amount of treatment chemicals, (including coagulant, and chlorine) required to treat water at the Sharpsburg WTP,
- a reduction in the amount of residuals which must be processed and disposed of, and
- a lengthening in filter runs and thus reduction in the amount of backwash water used at the WTP.

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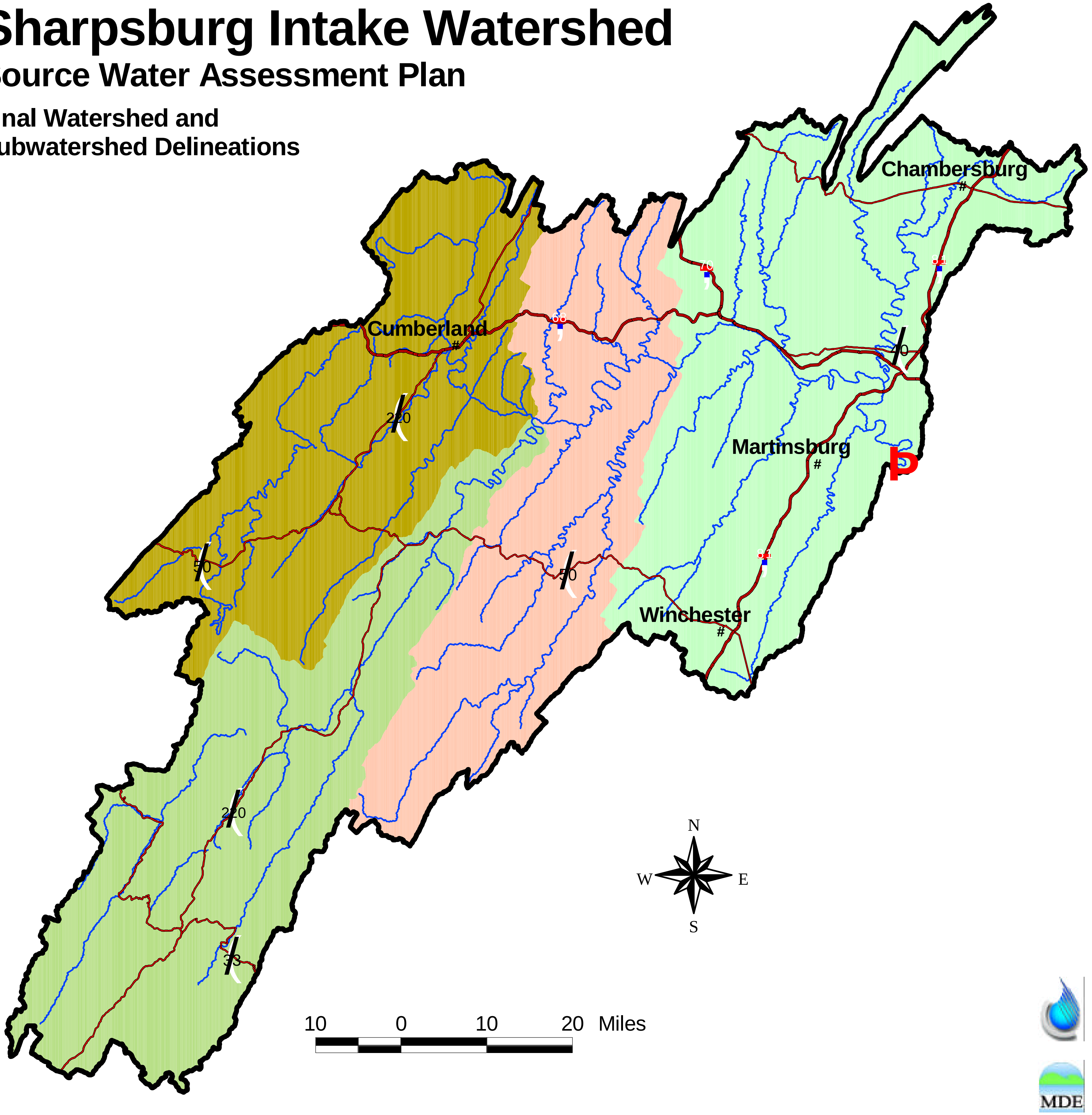
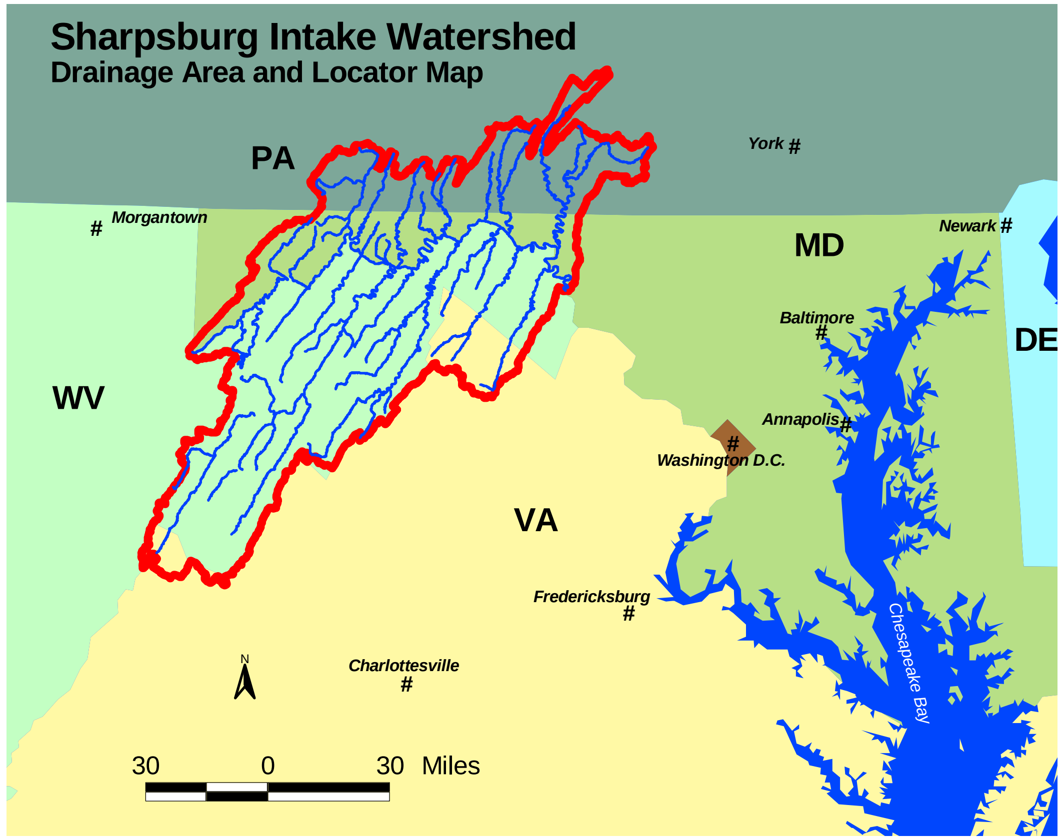
Sharpsburg Intake Watershed

Source Water Assessment Plan

Final Watershed and
Subwatershed Delineations





Sharpsburg Intake Watershed
Drainage Area and Locator Map

Legend

- Sharpsburg Intake
- Watershed Boundary
- Hydrology
- # Major Cities
- Interstate Highways
- Interstate Route Numbers

Huc 8 Subwatersheds

- Cacapon-Town
- Conococheague-Opequon
- North Branch Potomac
- South Branch Potomac
- U.S. Highways
- / U.S. Route Numbers

Data Sources: Watershed, subwatershed and political boundaries from U.S. EPA Office of Water, Office of Science and Technology, Washington, D.C. Major roads and cities from Environmental Systems Research Institute, Redlands, CA. Hydrology from Maryland Department of the Environment.

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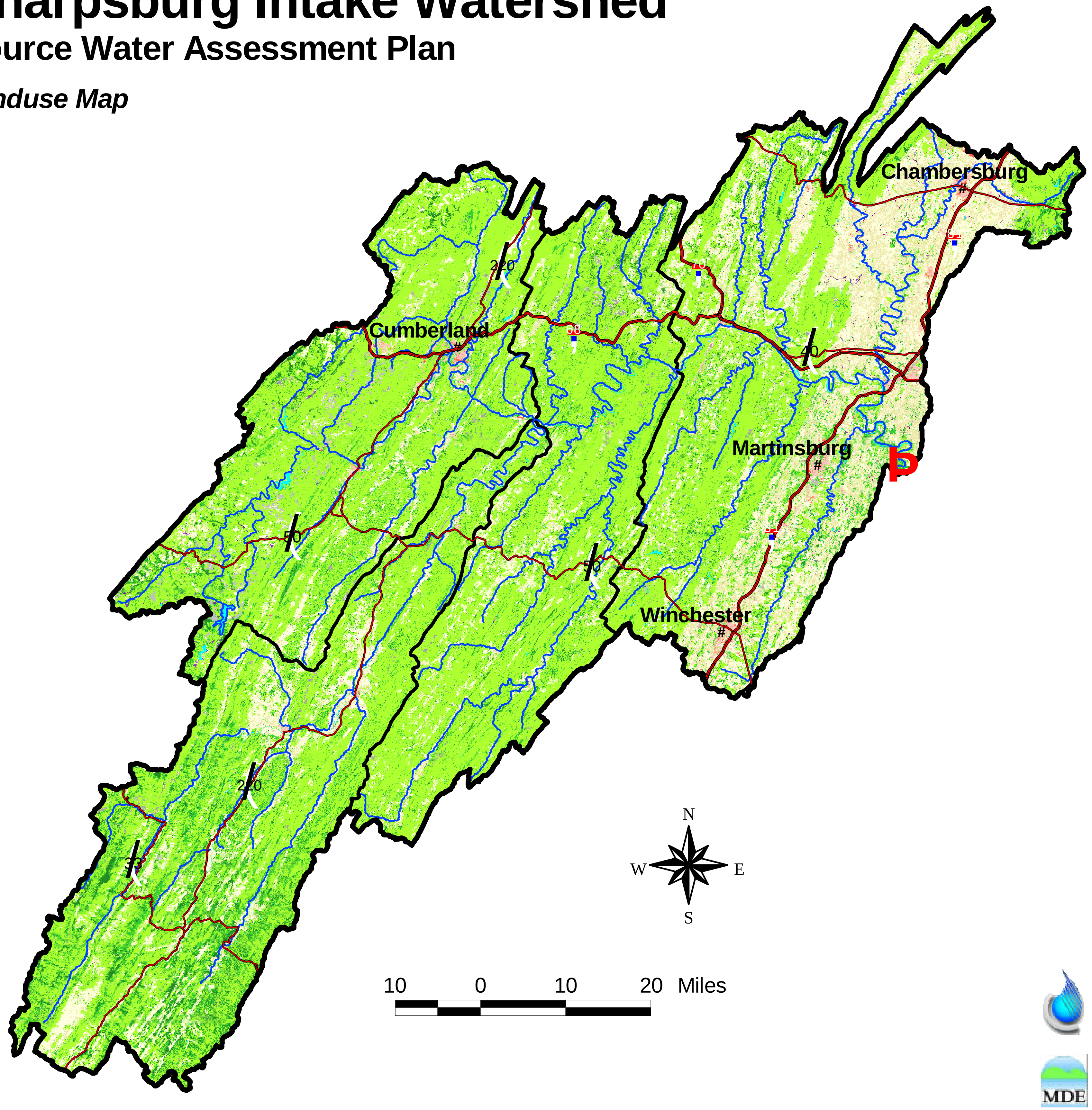
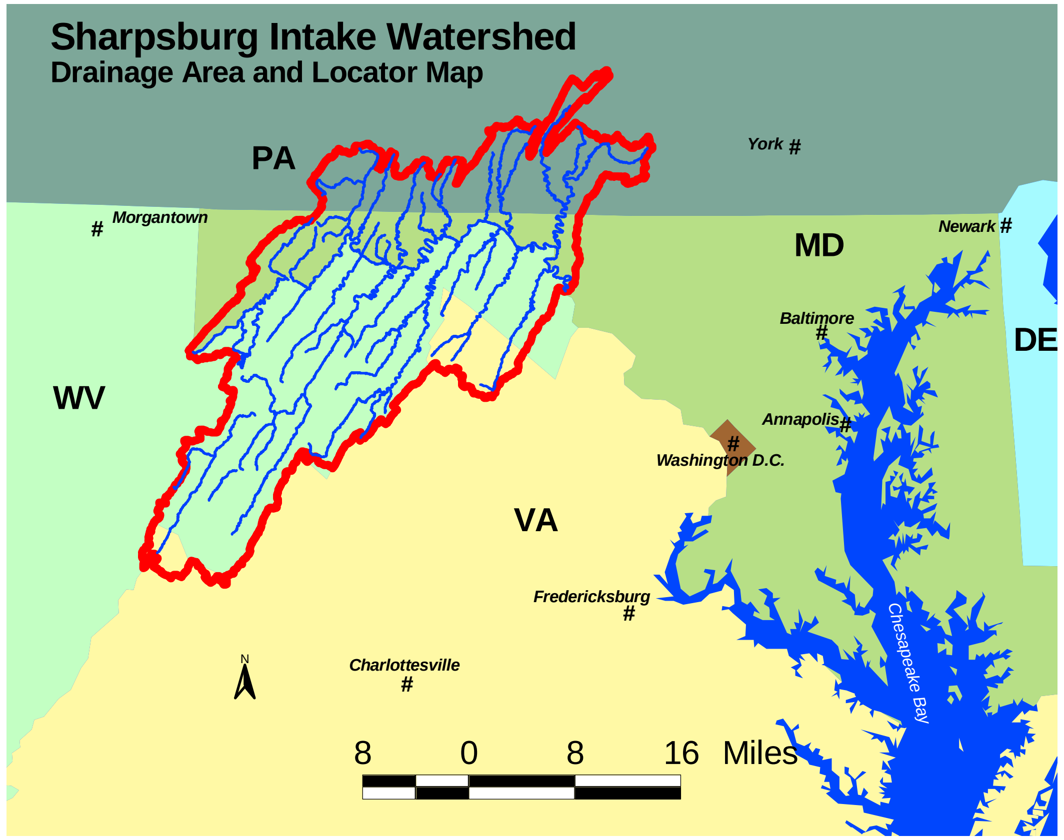
Sharpsburg Intake Watershed

Source Water Assessment Plan

Landuse Map





Sharpsburg Intake Watershed
Drainage Area and Locator Map

Legend

▭ Watershed Boundary
▭ Huc 8 Subwatersheds
— Hydrology
Sharpsburg Intake
\# Major Cities
— Interstate Highways
Interstate Route Numbers
— U.S. Highways
/ U.S. Route Numbers

Landuse

- 🟦 Water
- 🟥 Low Intensity Residential
- 🟧 High Intensity Residential
- 🟥 High Intensity Commerical/Industrial
- 🟨 Hay/Pasture
- 🟨 Row Crops
- 🟨 Other Grass/Parks
- 🟩 Conifer Forest
- 🟩 Mixed Forest
- 🟩 Deciduous Forest
- 🟪 Woody Wetlands
- 🟪 Emergent Wetlands
- ⬜ Quarries/Mining
- ⬜ Rock/Sand
- ⬜ Transitional
- ⬜ No Data

Data Sources: Watershed, subwatershed and political boundaries from U.S. EPA Office of Water, Office of Science and Technology, Washington, D.C. Major roads and cities from Environmental Systems Research Institute, Redlands, CA. Hydrology from Maryland Department of the Environment. Landuse from Multi-Resolution Land Characteristics Consortium (MRLC).

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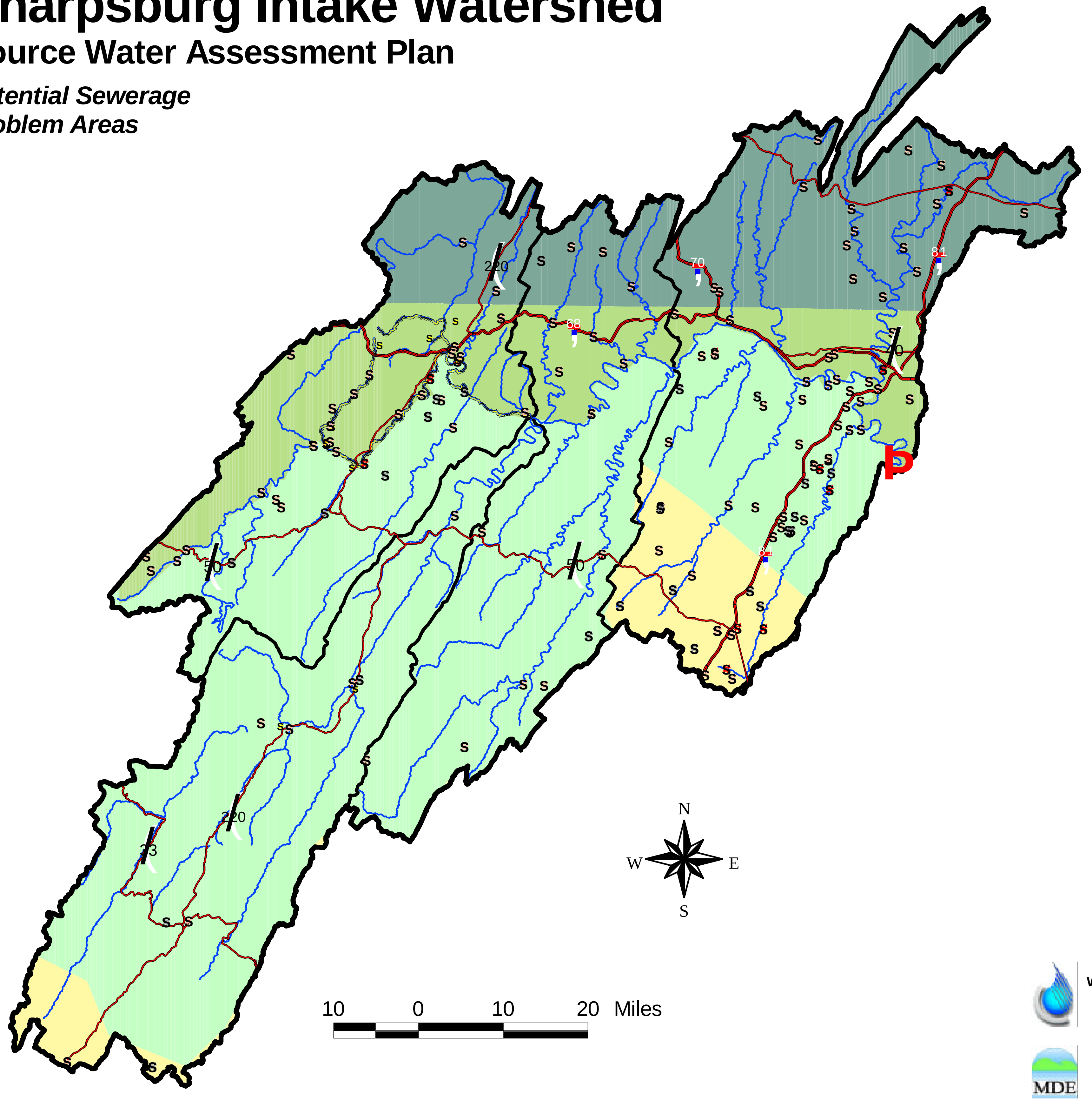
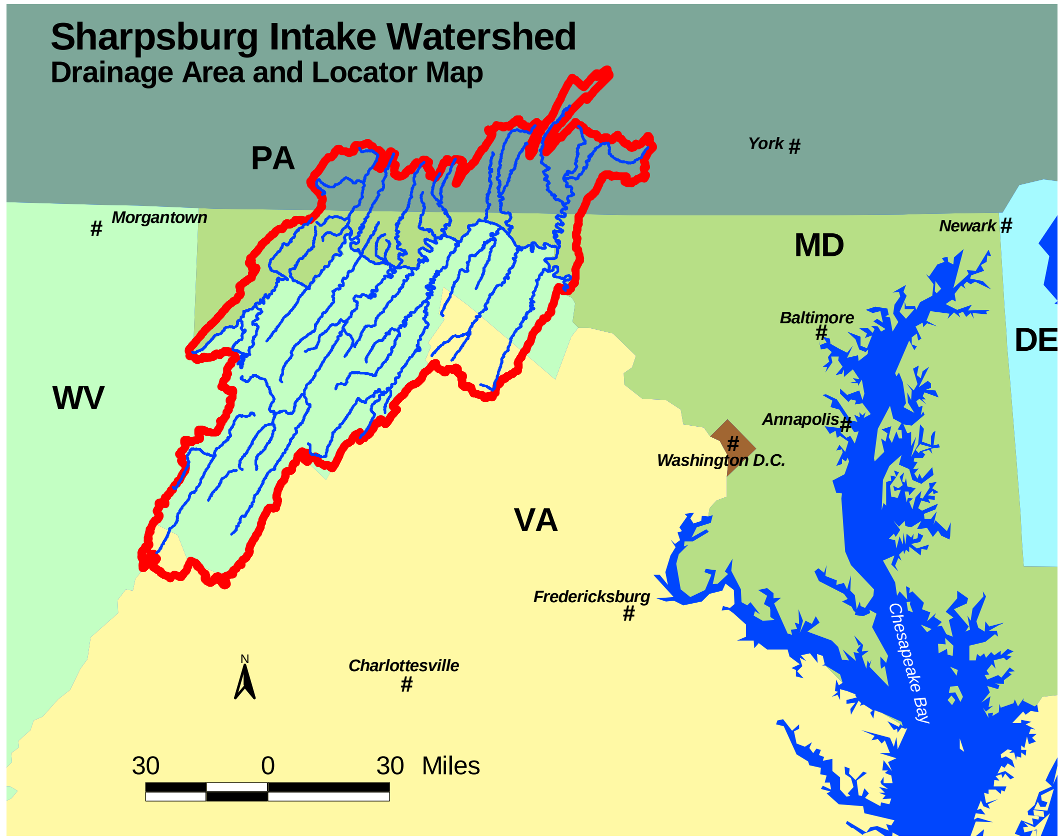
Sharpsburg Intake Watershed

Source Water Assessment Plan

Potential Sewerage Problem Areas




Sharpsburg Intake Watershed
Drainage Area and Locator Map

Legend

- Sharpsburg Intake
- ▭ Watershed Boundary
- ▭ Huc 8 Subwatersheds
- — Hydrology
- — Interstate Highways
- — U.S. Highways
- Interstate Route Numbers
- / U.S. Route Numbers
- s Major Wastewater/Sewage Treatment Plants*
- s Minor Wastewater/Sewage Treatment Plants*
- s Wastewater/Sewage Treatment Plants, Size Unknown
- s Existing CSO Locations
- — Reaches Susceptible to CSOs

*Major and minor designation determined by State agencies or BASINS database. Generally, major facilities are > 1 MGD.

Data Sources: Watershed, subwatershed and political boundaries from U.S. EPA Office of Water, Office of Science and Technology, Washington, D.C. Major roads and cities from Environmental Systems Research Institute, Redlands, CA. Hydrology from Maryland Department of the Environment. Wastewater and sewage treatment plants from EPA BASINS, MDE, and Virginia Department of Environmental Quality. CSO data from EPA and MDE.

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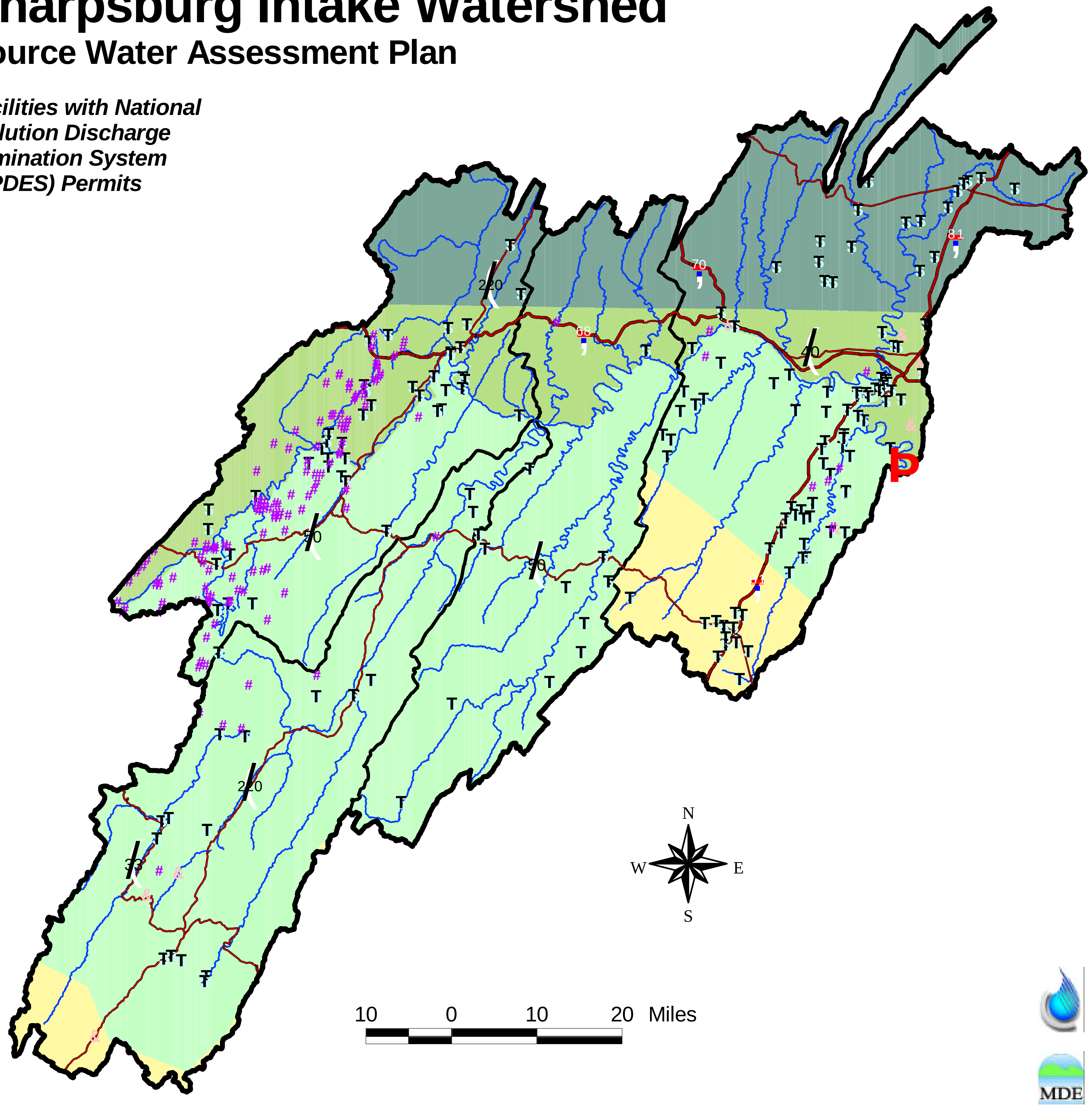
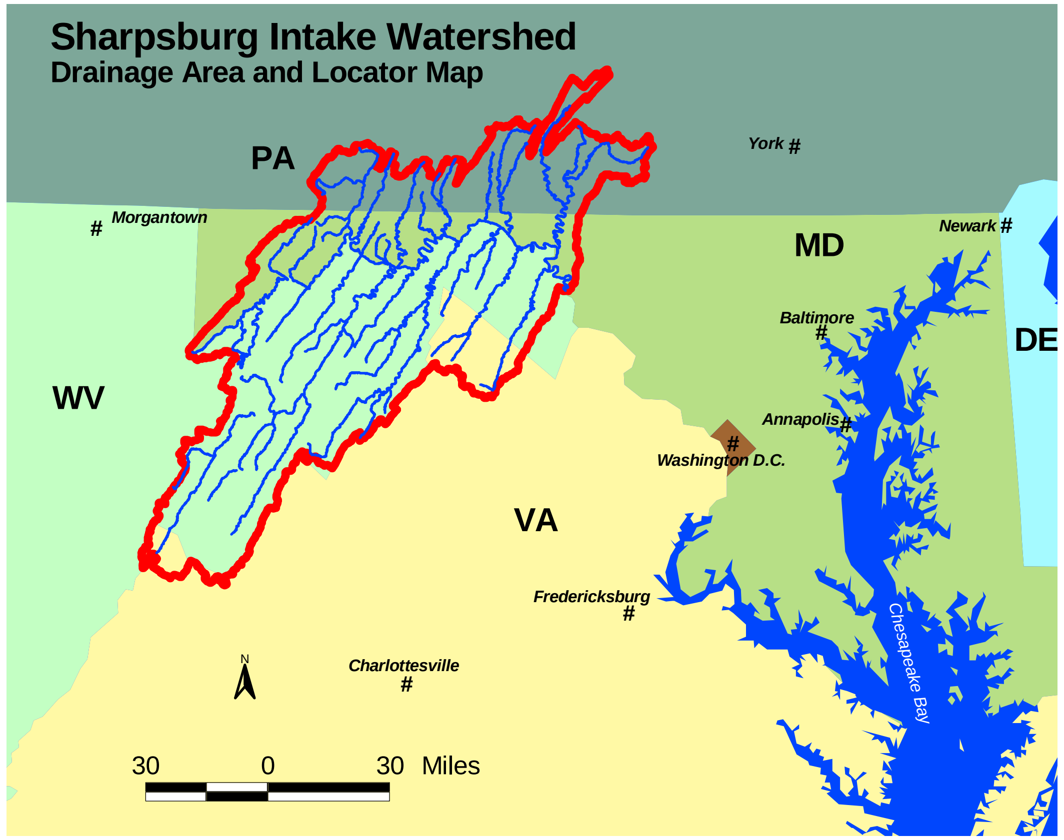
Sharpsburg Intake Watershed

Source Water Assessment Plan

Facilities with National Pollution Discharge Elimination System (NPDES) Permits




Sharpsburg Intake Watershed
Drainage Area and Locator Map

Legend

Þ	Sharpsburg Intake	▬	Interstate Highways
▭	Watershed Boundary	▬	Interstate Route Numbers
▭	Huc 8 Subwatersheds	▬	U.S. Highways
▬	Hydrology	/	U.S. Route Numbers

T Facilities with Industrial, Municipal, and Commercial NPDES Permits (does not include mining, agriculture, petroleum-related industries or WWTPs)

& Facilities with Agricultural, Forestry or Fishing NPDES Permits

Facilities with Mining NPDES Permits

Data Sources: Watershed, subwatershed and political boundaries from U.S. EPA Office of Water, Office of Science and Technology, Washington, D.C. Major roads and cities from Environmental Systems Research Institute, Redlands, CA. Hydrology from Maryland Department of the Environment. NPDES permitted sites from EPA BASINS, MDE, Virginia Department of Environmental Quality, and West Virginia Department of Environmental Protection

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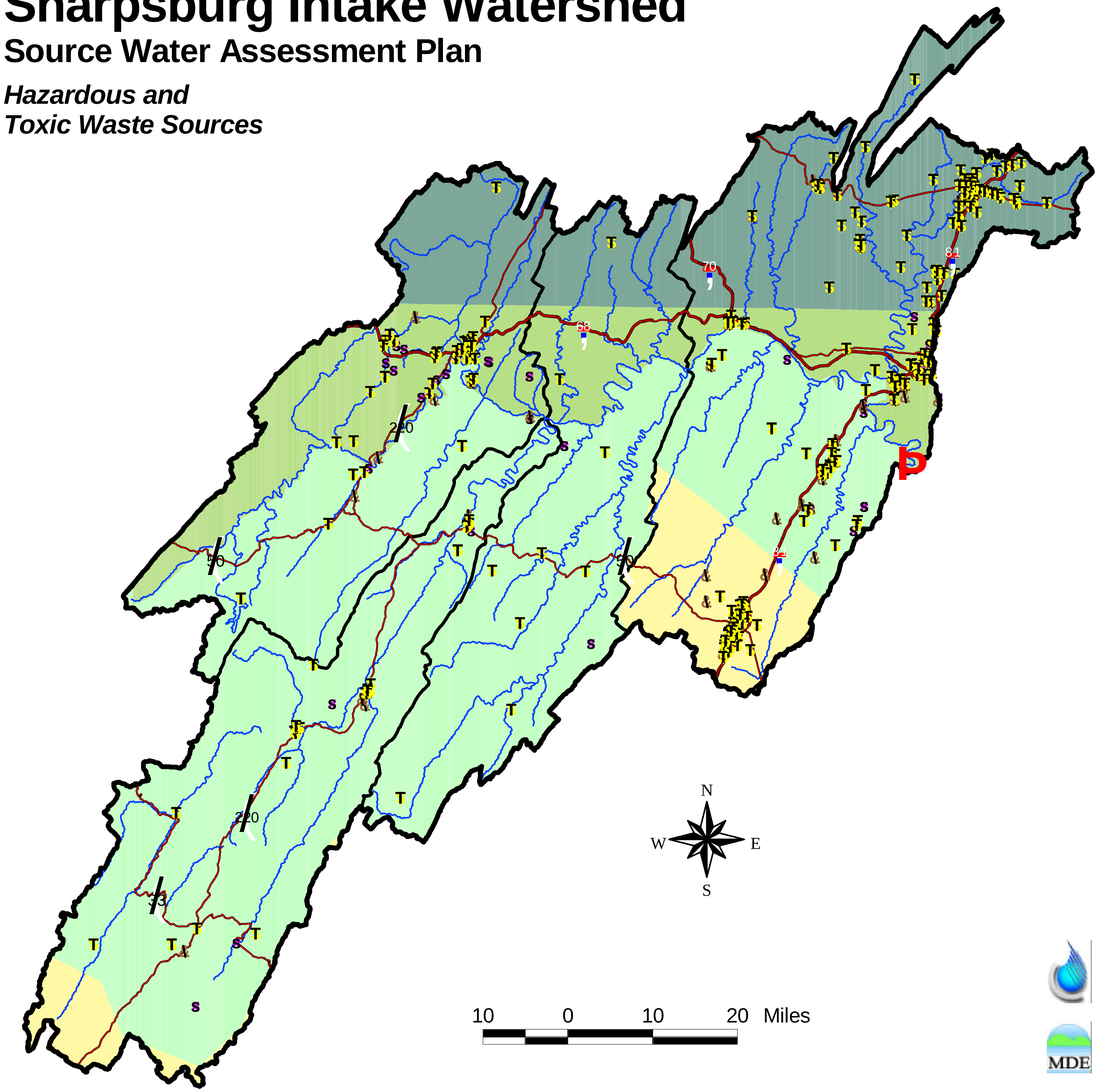
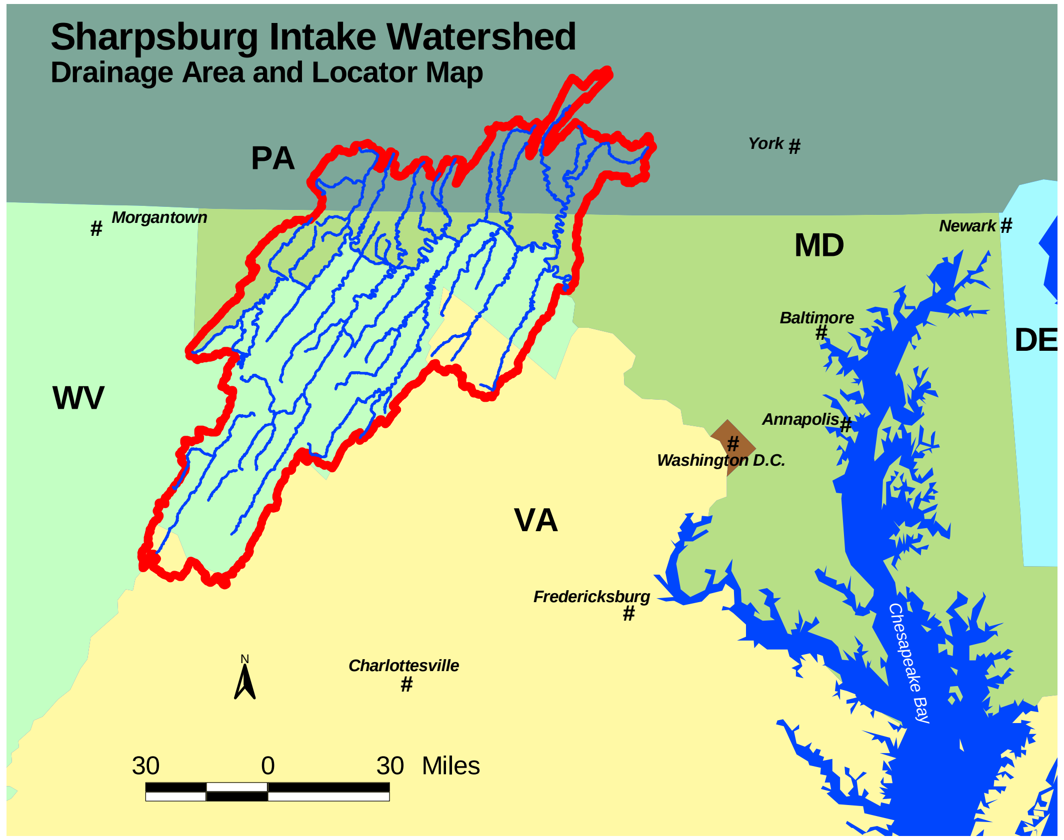
Sharpsburg Intake Watershed

Source Water Assessment Plan

Hazardous and Toxic Waste Sources





Legend

- Þ Sharpsburg Intake
- ▭ Watershed Boundary
- ▭ Huc 8 Subwatersheds
- — Hydrology
- T Resource Conservation and Recovery Information System (RCRIS) Hazardous and Solid Waste Sites
- & Toxic Release Inventory (TRI) Sites
- S Comprehensive Environmental Response Compensation and Liability Information System (CERCLIS) Sites
- — Interstate Highways
- ▪ Interstate Route Numbers
- — U.S. Highways
- / U.S. Route Numbers

Data Sources: Watershed, subwatershed and political boundaries from U.S. EPA Office of Water, Office of Science and Technology, Washington, D.C. Major roads and cities from Environmental Systems Research Institute, Redlands, CA. Hydrology from Maryland Department of the Environment. RCRIS and TRI sites from EPA BASINS. CERCLIS sites from EPA BASINS, MDE and West Virginia Department of Environmental Protection.

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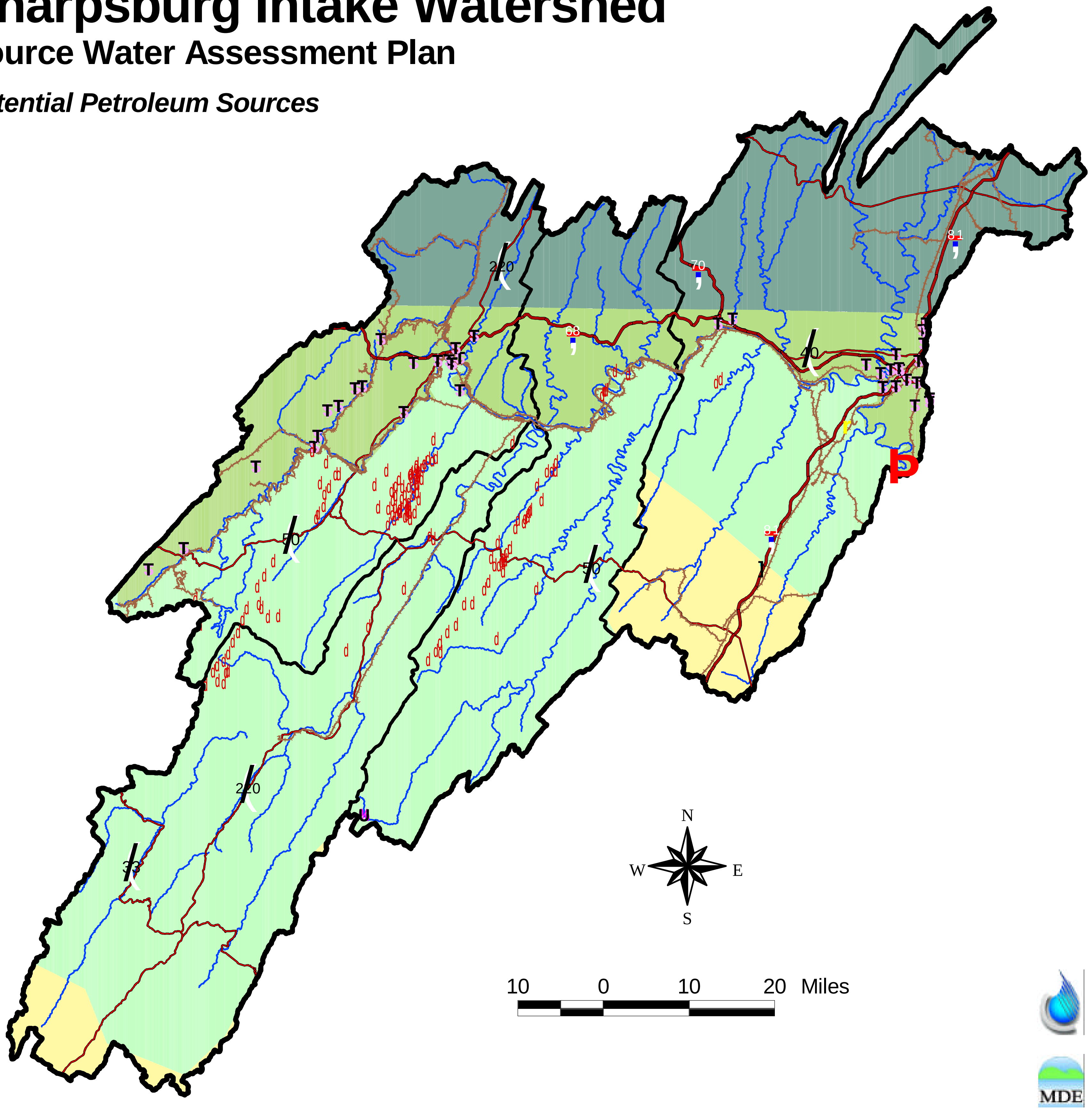
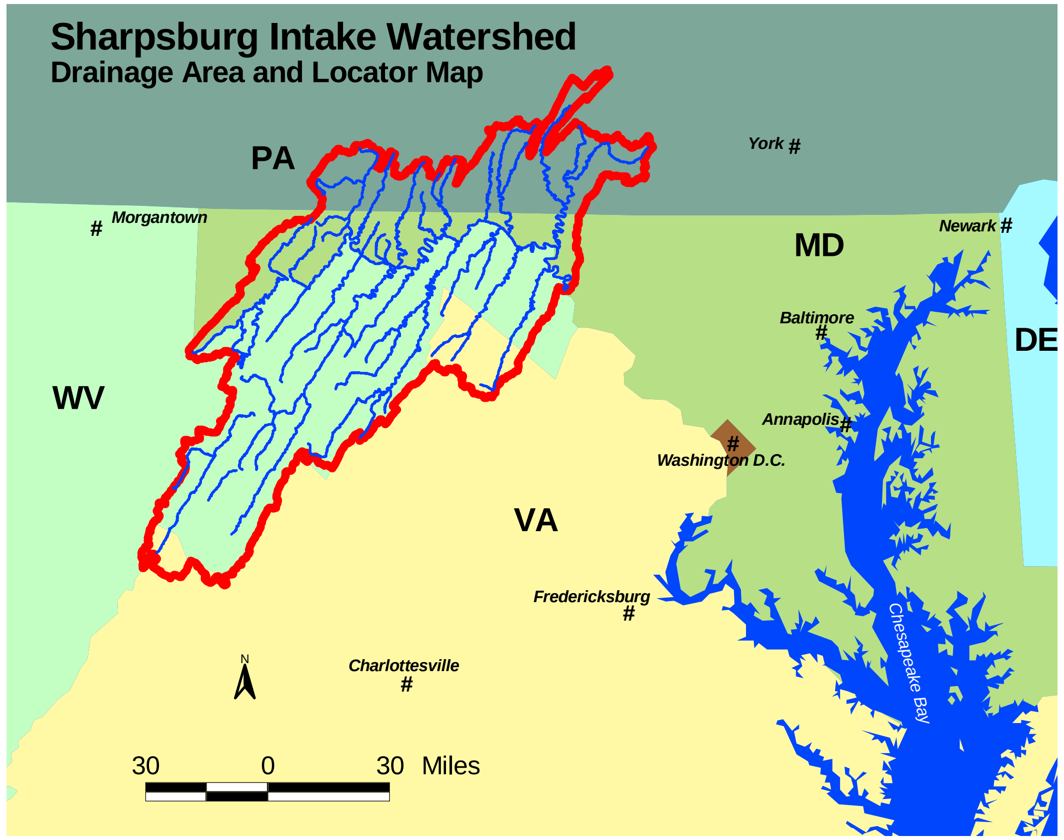
Sharpsburg Intake Watershed

Source Water Assessment Plan

Potential Petroleum Sources





Sharpsburg Intake Watershed
Drainage Area and Locator Map

Legend

- Sharpsburg Intake
- Watershed Boundary
- Huc 8 Subwatersheds
- Hydrology
- Above Ground Storage Tanks (MD only)
- Gas Service Stations with NPDES Permits
- Gas Transmission Facility with NPDES Permit
- Railroads
- Interstate Highways
- Interstate Route Numbers
- U.S. Highways
- U.S. Route Numbers
- Oil and Gas Wells (WV only)
- Petroleum Bulk Stations with NPDES Permits

Data Sources: Watershed, subwatershed and political boundaries from U.S. EPA Office of Water, Office of Science and Technology, Washington, D.C. Major roads and cities from Environmental Systems Research Institute, Redlands, CA. Hydrology from Maryland Department of the Environment. Gas transmission, bulk stations and gas service stations from EPA BASINS. Above ground storage tanks information from MDE. Oil and gas wells from West Virginia Department of Environmental Protection.

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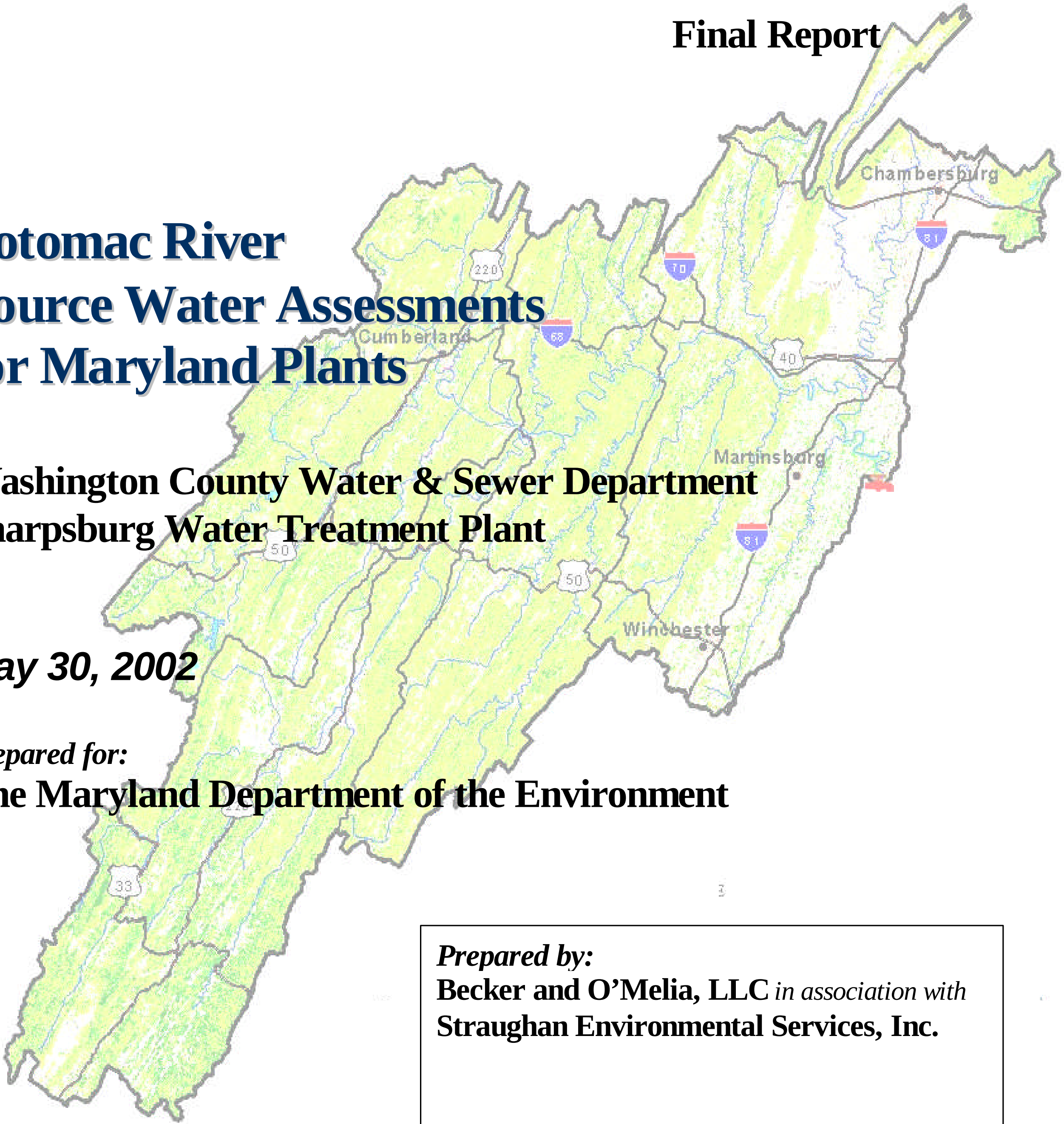
Final Report



Potomac River Source Water Assessments for Maryland Plants

Washington County Water & Sewer Department
Sharpsburg Water Treatment Plant

May 30, 2002

Prepared for:
The Maryland Department of the Environment

Prepared by:
Becker and O'Melia, LLC *in association with*
Straughan Environmental Services, Inc.

Becker and O'Melia, LLC
WATER PROCESS RESEARCHERS AND CONSULTANTS

Memo

To: John Grace

From: John O'Melia, P.E.

CC: Plato Chen, P.E., Charles R. O'Melia, P.E., Ph.D.

Date: 3/10/2006

Re: Task 12.3 Water Quality Evaluations - Sharpsburg

Becker and O'Melia, LLC (B&O'M) has performed evaluations to identify contaminants and groups of contaminants that will be the focus of the watershed assessment for the Washington County Sanitation District's (WCSD) Potomac River treatment plant serving Sharpsburg, MD. These evaluations included the following activities, which are described below:

- Identification of potential contaminants of concern,
- Data collection, organization and evaluation, and
- Selection of contaminants of concern for the project.

Based on these evaluations, we recommend the following contaminants of concern for the project:

- Organic carbon
- *Giardia*
- *Cryptosporidium*
- Tastes and odors
- Sediment
- Algae
- Disinfection By-Product Precursors
- Fecal Coliforms

Identification of potential contaminants of concern

Potential contaminants of concern were identified based on criteria established in the Maryland Source Water Assessment Plan, and project team experience with the Potomac River. Contaminants listed in Appendix 2.1 of Maryland's Source Water Assessment Plan (MD-SWAP), and other site-specific compounds that affect the water quality, were considered.

Contaminants that have a negative impact on plant operations and raw water treatability were considered for evaluation. Organic carbon is included because it can have a controlling impact on coagulation and because it is an indicator of disinfection by-product precursors. Sediment is included because of the cost and operational difficulties of removing and disposing of sediment. Contaminants that threaten the natural equilibrium and long-term sustainability of the Potomac River were also identified. Phosphorus, the limiting nutrient in the Potomac River, was considered. Consideration was also given to contaminants for which regulations are expected soon. Finally, contaminants listed on the EPA Candidate Contaminant List (CCL) and under the EPA secondary standards were also evaluated. MDE, and B&O'M collected readily available data for the list of potential contaminants of concern in Appendix A.

Based on current and future regulations, review of Potomac River water quality data, and previously prepared water quality summary reports, and evaluations performed in previous Potomac River Source Water Assessments, the following contaminants are considered to be of concern and are included as such in this SWA regardless of the results of water quality evaluations:

- Organic carbon,
- *Giardia,*
- *Cryptosporidium,*
- Tastes and odors,
- Sediment,
- Algae,
- Disinfection By-Product Precursors.

In order to comply with the Safe Drinking Water Act, and EPA and MDE regulations, the Washington County Sanitation District performs a myriad of water quality tests on raw and finished water from the WTP and within the distribution system. Monthly operating reports submitted to MDE include the results of sampling and testing. MDE also performs sampling and testing of the Sharpsburg supply and finished water. Data resulting from some of these sampling and testing activities are stored in the MDE Water Supply Program's Public Drinking Water Information System Database. Becker and O'Melia has reviewed available data for contaminants listed in Appendix A. Note that data was not available for some of these contaminants.

In accordance with Maryland's Source Water Assessment Plan, which has been reviewed and approved by EPA, B&O'M considers any contaminant which has been found in even a single finished water sample at concentrations exceeding 50% of the Maximum Contaminant Level (MCL) to be a contaminant of concern. This criterion is applied en lieu of the "50/10 rule", which is applied to raw (untreated) water data, when available. (Under the 50/10 rule, a contaminant is considered to be of concern if 10% of raw water samples exceed 50% of the MCL.) In considering contaminants for which a health advisory has been issued by EPA, data was evaluated relative to the most restrictive (lowest concentration) health advisory. If finished water sample concentrations have exceeded 50% of the most restrictive health advisory, the contaminant is considered a contaminant of concern. Results of these evaluations are presented below.

Inorganic Compounds (IOC)

Results of evaluations for inorganic compounds are presented in Table 1. Of the 11 listed inorganic compounds for which data was available, 9 had no positive samples (above the detection limit) for the contaminant. Of those that include positive samples, (nitrate and nitrite) none had been detected at concentrations exceeding 50% of the MCL. None of these inorganic contaminants will be considered a contaminant of concern at WCSD's Potomac River WTP.

Table 1 Inorganic Chemical Occurrences

Contaminant	No. Data-points	No. Non detects	Max (mg/L)	MCL (mg/L)	50% MCL (mg/L)	Exceeds 50% MCL?
Inorganic Chemicals						
Antimony	7	7	ND	.006	.003	**No**
Arsenic	6	6	ND	.01(*)	.005	**No**
Barium	7	7	ND	2	1	**No**
Beryllium	7	7	ND	.004	.002	**No**
Cadmium	7	7	ND	.005	.0025	**No**
Chromium (total)	7	7	ND	0.1	0.05	**No**
Inorganic Mercury	7	7	ND	.002	.001	**No**
Nitrate	17	3	3.5	10	5	**No**
Nitrite	3	1	.003	1	.5	**No**
Selenium	7	7	ND	.05	.025	**No**
Thallium	7	7	ND	.002	.001	**No**
* Proposed MCL based on promulgated rule						

Organic Chemicals

Results of evaluations for organic compounds are presented in Table 2. Of the 42 contaminants for which data were available, 38 had no positive samples (above the detection limit) for the contaminant. Of the 4 organic contaminants which include positive samples, atrazine had one positive sample and dalapon, di(2-ethylhexyl)adipate, and di(2-ethylhexyl)phthalate results included more than one positive sample. Only di(2-

ethylhexyl)phthalate has been detected at concentrations exceeding 50% of the MCL. Details on positive dalapon, di(2-ethylhexyl)adipate, and di(2-ethylhexyl)phthalate samples are presented in Table 3. Di(2-ethylhexyl)adipate and di(2-ethylhexyl)phthalate were also found in laboratory blank samples and therefore are not believed to represent the actual water quality of the river. Similar, unusually high concentrations of di(2-ethylhexyl)phthalate were found in results of evaluations performed at the same lab on the same day for samples collected at other facilities. Because of the history, of false positive samples and the coincidental occurrences reported at other facilities di(2-ethylhexyl)phthalate will not be listed as a contaminant of concern based solely on the results of the May 15, 1995 sample and evaluation. It is therefore not considered a contaminant of concern at the WCSD Potomac WTP.

Table 2 – Organic Chemical Occurrences

Contaminant	No. Data-points	No. Non detects	Max (μg/L)	MCL (μg/L)	50% MCL (μg/L)	Exceeds 50% MCL?
Alachlor	17	17	ND	2	1	**No**
Atrazine	21	20	.47	3	1.5	**No**
Benzene	10	10	ND	5	2.5	**No**
Benzo(a)pyrene	18	18	ND	0.2	0. 1	**No**
Carbofuran	7	7	ND	40	20	**No**
Carbon tetrachloride	10	10	ND	5	2.5	**No**
Chlordane	15	15	ND	2	1	**No**
2,4-D	11	11	ND	70	35	**No**
Dalapon	11	7	.461	200	100	**No**
1,2-Dibromo-3-chloropropane (DBCP)	14	14	ND	0.2	0. 1	**No**
o-Dichlorobenzene	10	10	ND	600	300	**No**
p-Dichlorobenzene	10	10	ND	75	37.5	**No**
1,2-Dichloroethane	10	10	ND	5	2.5	**No**
1-1-Dichloroethylene	10	10	ND	7	3.5	**No**
1, 2-Dichloroethylene - *(cis & trans)*	10	10	ND	70 (cis)	35 (cis)	**No**
1-2-Dichloropropane	10	10	ND	5	2.5	**No**
Di(2-ethylhexyl)adipate	18	16	13	400	200	**No (*)**
Di(2-ethylhexyl)phthalate	18	13	5.95	6	3	**Yes (*)**
Dinoseb	11	11	ND	7	3.5	**No**
Endrin	14	14	ND	2	1	**No**
Ethylbenzene	10	10	ND	700	350	**No**
Ethelyne dibromide	14	14	ND	0. 05	0. 025	**No**
Heptachlor	14	14	ND	0.4	0. 2	**No**
Heptachlor epoxide	14	14	ND	0. 2	0. 1	**No**
Hexachlorobenzene	14	14	ND	1	0. 5	**No**
Hexachlorocyclopentadiene	18	18	ND	50	25	**No**
Methoxychlor	14	14	ND	40	20	**No**
Oxamyl (Vydate)	7	7	ND	200	100	**No**
Pentachlorophenol	11	11	ND	1	0. 5	**No**
Picloram	11	11	ND	500	250	**No**
Simazine	18	18	ND	4	2	**No**
Styrene	10	10	ND	100	50	**No**
Tetrachloroethylene	10	10	ND	5	2.5	**No**
Toluene	10	10	ND	1,000	500	**No**
Toxaphene	8	8	ND	30	15	**No**
2,4,5-TP (Silvex)	11	11	ND	50	25	**No**
1,2,4-Trichlorobenzene	6	6	ND	70	35	**No**
1,1,1-Trichloroethane	10	10	ND	200	100	**No**
1,1,2-Trichloroethane	6	6	ND	5	2.5	**No**
Trichloroethylene	10	10	ND	5	2.5	**No**
Vinyl chloride	10	10	ND	2	1	**No**
Xylenes (total) (*)	10	10	ND	10,000	5,000	**No**

(*)Di(2-ethylhexyl)adipate and di(2-ethylhexyl)phthalate were also found in laboratory blank samples and therefore are not believed to represent the actual water quality of the river

Table 3 – Organic Contaminant Detections			
Compound	**Result (μg/L)**	**MCL(μg/L)**	**Sample Date**
Atrazine	0.47	3	June 25, 1996
Dalapon	0.461	200	May 15, 1995
Dalapon	0.19	200	May 21,1997
Dalapon	.13	200	May 12, 1999
Dalapon	.21	200	Sept. 22, 1999
Di(2-ethylhexyl)adipate	1.59	400	May 15, 1995
Di(2-ethylhexyl)adipate	13	400	June 7, 1999
Di(2-ethylhexyl)phthalate	5.95	6	May 15, 1995
Di(2-ethylhexyl)phthalate	1.4	6	June 25, 1996
Di(2-ethylhexyl)phthalate	0.5	6	Sept. 22, 1999
Di(2-ethylhexyl)phthalate	0.7	6	Apr. 6, 2000
Di(2-ethylhexyl)phthalate	1.1	6	Apr. 6, 2000

Radionuclides

Results of evaluations for radionuclides are presented in Table 4. One sample each for beta particles & photon emitters and for gross alpha particle activity were available. There were no positive samples (above the detection limit) for either radionuclide and therefore, no radionuclide is considered a contaminant of concern at the WCSD Potomac River WTP.

Table 4 – Radionuclide Occurrences						
Radionuclide	**No. Data-points**	**No. Non detects**	**Max (pCi/L)**	**MCL (pCi/L)**	**50% MCL (pCi/L)**	**Exceeds 50% MCL?**
Beta particles and photon emitters	1	1	ND	50	25	**No**
Gross alpha particle activity	1	1	ND	15	7.5	**No**

Contaminants with Established Health Advisories

Results of evaluations for contaminants with established health advisories are presented in Table 5. Data were available for 7 such contaminants. There were no positive samples (above the detection limit) for any of these contaminants. Therefore none of these contaminants are considered contaminants of concern at the WCSD Potomac River WTP.

Table 5 – Occurrences of Contaminants with Established Health Advisories (HA)

Contaminant	No. Data Points	No. Non detects	Max	HA (υg/L)	Type of HA	50% HA (υg/L)	Exceeds 50% HA?
1,3-Dichloropropene	6	6	ND	40	1/10,000	20	No
Aldrin	11	11	ND	0.2	1/10,000	0. 1	No
Dieldrin	11	11	ND	0. 2	1/10,000	0. 1	No
Hexachlorobutadiene	6	6	ND	1	lifetime	0. 5	No
Metolachlor	18	18	ND	100	lifetime	50	No
Metribuzin	15	15	ND	200	lifetime	100	No
Naphthalene	6	6	ND	100	lifetime	50	No

Contaminants with a Significant Impact on Treatment Facility Operations

Monthly operating reports from January 1999 to January of 2002 were evaluated to determine the occurrence, in the raw water, of contaminants that affect the operations of the treatment works. Results of these evaluations are presented in Table 6. Alkalinity has varied from 11 mg/L to 147 mg/L with an average of 86 mg/L. Within this range, high alkalinity is a boon to treatment. Low alkalinity can inhibit coagulation, making treatment more difficult. The 10% exceedance (alkalinity which 10% of the samples have exceeded) is therefore not relevant. pH has varied from 6.7 to 8.6 with an average of 7.8. High pH causes problems with coagulation when metal salts (like aluminum sulfate) are employed. In response to coagulation difficulties during periods of elevated pH, Sharpsburg is considering switching from aluminum sulfate to polyaluminum chloride (PACl) as the primary coagulant. Although PACl does not suppress pH to the extent that metal salt coagulants do, it may be a more effective coagulant at elevated pHs. Raw water turbidity has varied from 1.9 NTU to 233.1 NTU with an average of 10.1 NTU. Turbidity has exceeded 17.5 NTU on 10% of the days over the time period evaluated. Elevated turbidity increases the solids loading on the facility, generally increasing the demand for treatment chemicals; reducing filter run length; increasing the amount of sludge that must be processed; and perhaps increasing the amount of solids that pass through the filter to the finished water. Turbidity is therefore considered a contaminant of concern for the project.

Table 6 – Contaminants That Impact Plant Operations

Contaminant	No. Samples	Min	Max	Average	10% exceedance

Alkalinity	1096	11 mg/L	147	86	NA
Turbidity	1096	1.9 NTU	233.1	10.1	17.5
pH	1096	6.7	8.6	7.8	8.1

Microorganisms

Results of evaluations for microorganisms are presented in Table 7. Data were available for fecal coliforms including samples with more than 80 MPN/100 ml and others with 110 MPN/100mL. The test methodology applied occasionally does not allow determination of the most probable number if it exceeds 80 MPN/100 ml. 13 of 45 samples included concentrations above the limit that could be enumerated. Treating these samples as if the concentration equaled the maximum that could be enumerated, the log mean concentration equals 18.5 MPN/100 ml. 10% of the samples had fecal coliform counts above 80 MPN/100 ml. MDE presumes a public health hazard if the log mean of fecal coliform samples exceeds 200 MPN/100mL. Although fecal coliforms are removed and inactivated in conventional treatment like that practiced at the WCSD Potomac River WTP, they are an indication of fecal contamination and may indicate contamination with other fecal pathogens. Available data indicate fecal coliform concentrations in excess of 50% of the MDE standard and the MPN in some samples could be significantly higher than that. Fecal coliforms are therefore considered a contaminant of concern at the WCSD Potomac River WTP.

Table 7 – Microorganisms

Contaminant	No. Data Points	Max (MPN/100ml)
Fecal Coliforms	45	110 or “>80”
E. Coliforms	45	110 or “>80”

Contaminants with Secondary Standards

Table 8 presents the results of evaluations for parameters that affect the aesthetic quality of drinking water (those for which a secondary standard has been established). Of these contaminants, only sulfate data were available. 5 sulfate samples were collected from May 1995 to May 1999. Results indicate sample concentrations ranging from 36 to 85 mg/L. All reported concentrations are therefore well below the secondary standard of 250 mg/L and no contaminants will be considered contaminants of concern because they exceed the secondary standard.

Table 8 – Contaminants with Secondary Standards					
Contaminant	**No Data points**	**No. Non detects**	**Max (mg/L)**	**Secondary Standard (mg/L)**	**Percent of Samples Above SS**
Sulfate	5	0	85	250	0.00%

Appendix A - Potential Contaminant List

The following contaminants have been selected for data collection and consideration as contaminants of concern for WCSD's Potomac River WTP Source Water Assessment:

Regulated Contaminants

Inorganic Chemicals

Antimony – *Required by MD-SWAP*
Arsenic - *Required by MD-SWAP*
Asbestos (fiber >10 micrometers) - *Required by MD-SWAP*
Barium - *Required by MD-SWAP*
Beryllium - *Required by MD-SWAP*
Cadmium - *Required by MD-SWAP*
Chromium (total) - *Required by MD-SWAP*
Copper – *Regulated Compound*
Cyanide (as free cyanide) - *Required by MD-SWAP*
Fluoride - *Required by MD-SWAP*
Inorganic Mercury - *Required by MD-SWAP*
Nitrate - *Required by MD-SWAP*
Nitrite - *Required by MD-SWAP*
Selenium - *Required by MD-SWAP*
Thallium - *Required by MD-SWAP*

Organic Chemicals

Acrylamide
Alachlor - *Required by MD-SWAP*
Atrazine - *Required by MD-SWAP*
Benzene - *Required by MD-SWAP*
Benzo(a)pyrene – *Required by MD-SWAP*
Carbofuran - *Required by MD-SWAP*
Carbon tetrachloride - *Required by MD-SWAP*
Chlordane - *Required by MD-SWAP*
Chlorobenzene - *Required by MD-SWAP*
2,4-D - *Required by MD-SWAP*
Dalapon – *Required by MD-SWAP*
1,2-Dibromo-3-chloropropane (DBCP) - *Required by MD-SWAP*
o-Dichlorobenzene - *Required by MD-SWAP*
p-Dichlorobenzene - *Required by MD-SWAP*
1,2-Dichloroethane - *Required by MD-SWAP*
1-1-Dichloroethylene – *Required by MD-SWAP*
cis-1, 2-Dichloroethylene - *Required by MD-SWAP*
trans-1,2-Dichloroethylene - *Required by MD-SWAP*
Dichloromethane - *Required by MD-SWAP*

1-2-Dichloropropane - *Required by MD-SWAP*
Di(2-ethylhexyl)adipate – *Required by MD-SWAP*
Di(2-ethylhexyl)phthalate – *Required by MD-SWAP*
Dinoseb – *Required by MD-SWAP*
Dioxin (2,3,7,8-TCDD) – *Required by MD-SWAP*
Diquat – *Required by MD-SWAP*
Endothall – *Required by MD-SWAP*
Endrin – *Required by MD-SWAP*
Epichlorohydrin – *MCLG*
Ethylbenzene - *Required by MD-SWAP*
Ethelyne dibromide - *Required by MD-SWAP*
Glyphosate – *Required by MD-SWAP*
Heptachlor - *Required by MD-SWAP*
Heptachlor epoxide - *Required by MD-SWAP*
Hexachlorobenzene – *Required by MD-SWAP*
Hexachlorocyclopentadiene – *Required by MD-SWAP*
Lindane - *Required by MD-SWAP*
Methoxychlor - *Required by MD-SWAP*
Oxamyl (Vydate) – *Required by MD-SWAP*
Polychlorinated biphenyls (PCBs) - *Required by MD-SWAP*
Pentachlorophenol - *Required by MD-SWAP*
Picloram – *Required by MD-SWAP*
Simazine – *Required by MD-SWAP*
Styrene - *Required by MD-SWAP*
Tetrachloroethylene - *Required by MD-SWAP*
Toluene – *Regulated Compound*
Total Trihalomethanes (TTHMs) - *Required by MD-SWAP*
Toxaphene - *Required by MD-SWAP*
2,4,5-TP (Silvex) - *Required by MD-SWAP*
1,2,4-Trichlorobenzene - *Required by MD-SWAP*
1,1,1-Trichloroethane - *Required by MD-SWAP*
1,1,2-Trichloroethane - *Required by MD-SWAP*
Trichloroethylene - *Required by MD-SWAP*
Vinyl chloride - *Required by MD-SWAP*
Xylenes (total) - *Required by MD-SWAP*

Radionuclides

Beta particles and photon emitters – *Regulated Compound*
Gross alpha particle activity – *Regulated Compound*
Radium 226 and Radium 228 (combined) – *Regulated Compound*

Microorganisms

Giardia lamblia – Required by MD-SWAP - Monitoring Required

Cryptosporidium - Required by MD-SWAP - Monitoring Required
Heterotrophic plate count – *Required by MD-SWAP - Monitoring Required*
Legionella – *Required by MD-SWAP - Monitoring Required*
Total Coliforms (including fecal coliform and E. Coli) – *Required by MD-SWAP - Monitoring Required*
Turbidity – *Required by MD-SWAP - Monitoring Required*
Viruses (enteric) – *Required by MD-SWAP - Monitoring Required*

Disinfection Byproducts & Precursors

Trihalomethane Precursors (Formation Potential)
Haloacetic Acid Precursors (Formation Potential)
Total Organic Halogen (TOX)
Chlorite
Bromide
Bromate

Contaminants with significant impacts on WTP operations or the equilibrium of the Potomac River

Turbidity
pH
Alkalinity
Ammonia
TOC
DOC
UV-254
SUVA
Manganese

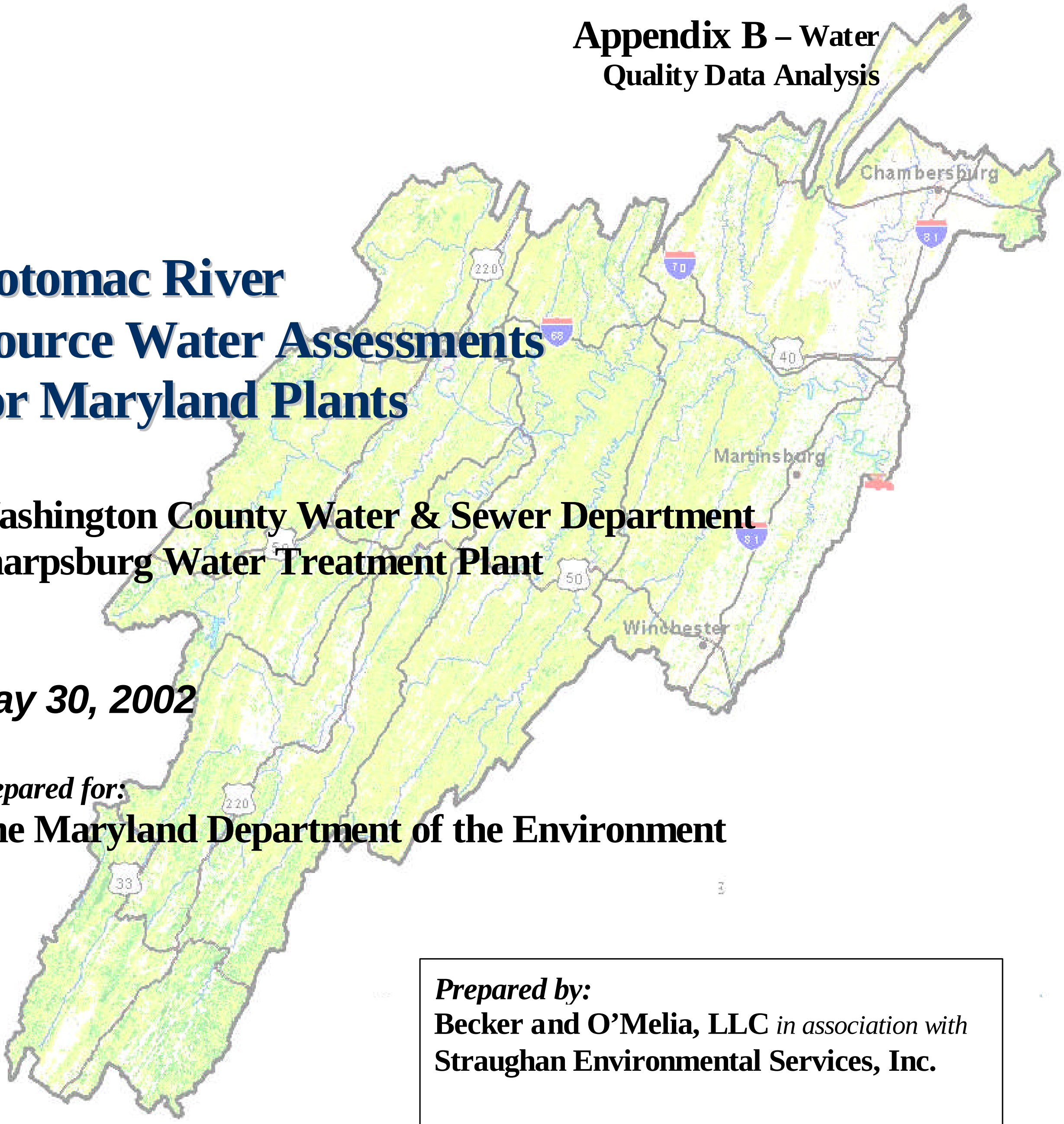
Contaminants listed for "Regulatory Determination" on the most recent (May 2000) Contaminant Candidate List

Acanthamoeba
Sodium
1,3-Dichloropropene
Aldrin
Boron
Dieldrin
Hexachlorobutadiene
Manganese
Metolachlor
Metribuzin
Naphthalene
Sulfate - *Required by MD-SWAP*

Secondary Standards

Aluminum
Chloride
Color
Copper
Corrosivity – (Langelier Index)
Foaming Agents
Iron
Manganese
Tastes and Odors
Silver
Total Dissolved Solids
Zinc

Appendix B – Water Quality Data Analysis



Potomac River Source Water Assessments for Maryland Plants

Washington County Water & Sewer Department
Sharpsburg Water Treatment Plant

May 30, 2002

Prepared for:
The Maryland Department of the Environment

Prepared by:
Becker and O'Melia, LLC *in association with*
Straughan Environmental Services, Inc.

Becker and O'Melia, LLC
WATER PROCESS RESEARCHERS AND CONSULTANTS

Becker and O'Melia, LLC
WATER PROCESS RESEARCHERS AND CONSULTANTS

Technical Memo

To: John Grace – MDE, Plato Chen, P.E - WSSC

From: John O'Melia, P.E.

Date: 3/10/2006

Re: Potomac River Source Water Assessments for Maryland Plants - Task 12.4 Data Evaluations – Sharpsburg

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Becker and O'Melia, LLC (B&O'M) has reviewed existing reports to determine, in a broad sense, the general water quality conditions in each subwatershed in the Potomac basin. This technical memo presents a summary of these evaluations as they relate to Sharpsburg's WTP. Subsequent project activities will include watershed and fate and transport modeling to estimate the extent to which these subwatersheds contribute to the contamination of Potomac WFP raw water. Limited data from the STORET database were reviewed for dieldrin, suspended solids and organic carbon occurrence and concentrations. Other sources of data and information are listed at the end of this memorandum.

INTRODUCTION

The United States Geological Survey (USGS) has found pesticides to be present in nearly all of the nation's surface waters. More than half of the waters in urban and agricultural areas have one or more pesticides greater than the guideline set for protection of aquatic life, although annual average concentrations are nearly always below drinking water standards and guidelines. Modern pesticide application techniques generally cause short term, seasonal contamination with mixtures of more than one pesticide. Current drinking water standards and guidelines are typically based on a lifetime exposure and generally do not account for pesticide mixtures and seasonal peaks of these contaminants (USGS 1999). If drinking water standards and guidelines are modified to account for concentration peaks or pesticide mixtures, additional monitoring, or additional evaluations of past monitoring may assist WCSD and MDE in planning for compliance and monitoring.

National trends indicate reductions in occurrence and concentrations of organochlorine insecticides in fish tissues, although these chemicals (including dieldrin which was identified in this project as a contaminant of concern at other WTPs on the Potomac River) remain persistent in fish tissue and sediment at urban and agricultural areas (USGS1999). An evaluation of dieldrin occurrence in the Potomac Watershed indicates widespread dieldrin contamination of fish tissue and sediment.

National trends for total nitrogen are stable and this is generally the case throughout the Potomac basin. USGS has noted a national change in the nitrogen speciation toward higher concentration of nitrate and reduced ammonia concentrations.

Little reliable data on *Cryptosporidium* oocyst concentration is currently available. An ongoing study by the Maryland Department of the Environment is expected to yield significant relevant information on the occurrence and concentrations of *Cryptosporidium* in the watershed. In other watersheds, researchers have found oocysts in a wide range of aquatic systems at a wide range of concentrations. Sources of *Cryptosporidium* include humans and other animals. Wildlife are an identified source and livestock are considered a primary source, especially where manure handling procedures cause fecal contamination of surface waters. *Cryptosporidium* oocysts are resistant to conventional disinfectants, are not removed efficiently in primary or secondary wastewater treatment and have been consistently identified in treated wastewater flows, particularly when treatment does not include filtration. WWTP effluent is therefore an important source of *cryptosporidium* oocysts. Population development and wastewater treatment failures, whether inadequate collection or treatment, are also important potential oocyst sources.

From the 1940s to the mid-1990s the population of the Potomac River Basin has increased from 1.7 million to 4.6 million, inducing environmental changes including urban development, intensive agricultural activity and increased wastewater flows. (Tawil, May 1997) It is important to note that the bulk of this urban development and increased wastewater flows have occurred in the area of the District of Columbia and other areas downstream of Sharpsburg's intake.

Since the 1970s, phosphorus and sediment loading to the watershed have decreased significantly while nitrogen loading has remained roughly constant (CB&WMA, 1993 and Tawil, May 1997). Nonpoint sources account for approximately 60%-70% of nutrient load from the watershed with a majority of this from agricultural sources. Monitoring from the early 1970's through the mid-1980s indicates increasing lead and chromium and decreasing trends for mercury (ICPRB, 1987). pH has increased over the same time period, which represents an improvement in persistent problematic acid water conditions.

In 1989 –1991, water quality in the river was dominated by nonpoint source pollutants with 70% to 97% of the annual nutrient and sediment load due to storm events. The Potomac River estuary receives enormous loads of pollutants over the long term with 15 million tons of sediment, 455 million pounds of total nitrogen, and 41 million pounds of total phosphorous carried to the estuary by the Potomac in the 8 year period ending in 1991. This represents a nutrient load significantly higher than that imposed by wastewater treatment plants in the watershed in the same period. (CB&WMA, 1993)

In 1995, 900 of 12,000 miles of streams in the Potomac River basin were thought to be impaired by nutrients. At the time, the leading source of nutrients was agricultural activities, with urban sources the second leading cause. (ICPRB, 1995)

Available data are generally organized according to USGS Hydrologic Unit Codes (HUC-8s) and this memorandum is therefore generally organized according to these HUC-8 codes.

DIELDRIN OCCURRENCE IN THE WATERSHED

An evaluation of dieldrin occurrence data from the watershed indicates that dieldrin occurs throughout the watershed. These dieldrin data are characterized by high peaks. An evaluation of this data does not reveal a significant temporal trend and neither supports nor refutes reported improvements in the watershed. All basins with available data indicated the presence of dieldrin in the water column. None of the reaches had average concentrations above 50% of the health advisory of 0.2 μg/L although intake sampling data at other WTPs in the basin did include samples above 0.1 μg/L. Dieldrin concentrations in bottom sediment were present in some samples from each subbasin for which data are available. Fish tissue sampling suggests more significant contamination of the North Branch Potomac, and Conococheague-Opequon, although these trends are not necessarily supported by sediment and water sampling. The fish tissue data demonstrated some very high peaks.

POTOMAC HEADWATERS

The 1993 Water Quality Inventory Report (MD-DNR, 2000) characterized the overall water quality of the Upper Potomac as “good” and generally suited for body contact recreation. Elevated suspended solids, nutrient and bacterial levels were noted and ascribed to agricultural activities and upstream sources. Urban activities were also thought to contribute to the elevated bacterial and nutrient levels. Subwatersheds of the Upper Potomac are shown on figure 1, 2 and 3.

According to the 1989-1991 Water Quality Inventory Report (Chesapeake Bay and Watershed Management Administration, 1993), there were 37 municipal NPDES and groundwater dischargers in the Upper Potomac at that time. Only 2 of these dischargers were permitted to discharge more than 1 mgd. The same report indicated that there were 45 industrial NPDES and groundwater dischargers, 19 of which discharge to the groundwater.

In June of 1990, MDE issued a consumptive advisory for certain species taken from the Potomac between Luke and Paw Paw due to measured dioxin contamination. Dioxin is fairly hydrophobic and tends to sorb to sediments when it enters natural water bodies. The advisory included a ban on consumption of bottom feeding fish (bullheads and channel catfish) and limits on all others. In March of 1992, this advisory was modified due to then recent monitoring which indicated lower levels of dioxin in fish tissue. The modified advisory maintained a ban on bottom feeders and limits on sunfish (MD-DNR, Dec. 1996).

The 1993-1995 Water Quality Inventory Report (MD-DNR, Dec 1996) classifies the Upper Potomac water quality as “excellent” to “poor” including high quality trout streams and streams “smothered” by acid mine drainage and supporting only algae and bacteria. Agricultural, urban and mining inputs are generally thought to be the source of incidents of poor water quality.

North Branch Potomac

The North Branch Potomac (shown on Figure 1) has been polluted by mine drainage for more than 150 years (ICPRB 1984). In 1969, the Appalachian Regional Commission report on acid mine drainage included the North Branch Potomac among those continuously or significantly affected by acid mine drainage. This report listed 130 of 3,300 miles of streams in the North Branch Watershed as “continuously or significantly” affected. Another 40 miles were considered “potentially or intermittently” affected (Appalachian Regional Commission, 1969).

North Branch Potomac monitoring from the early 1970s to the mid-1980s indicated decreasing suspended solids and increasing nitrate concentrations. pH was generally trending lower during that period suggesting worsening acid water conditions in the basin with the exception of improvements downstream of the Jennings Randolph Dam.

North Branch Potomac

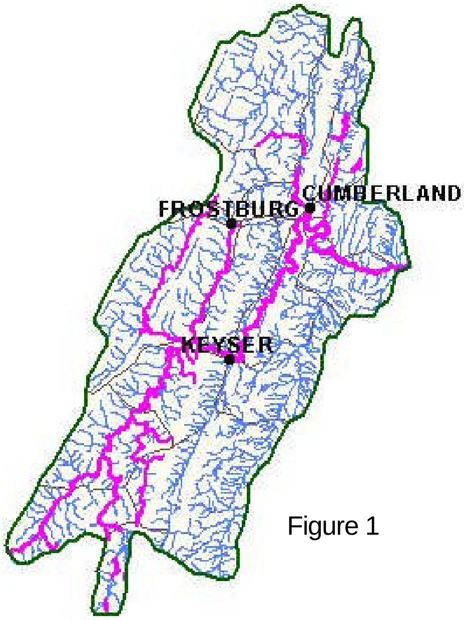


Figure 1

Potomac River Water Quality 1982-83 (ICPRB, 1984) reported “poor” water quality in the headwaters and highlands of the Potomac Watershed due to acid mine drainage from abandoned and inactive coal mines. Others found the water quality to be “poor” to “good-excellent” (ICPRB, 1989). Approximately 50 miles of the North Branch Potomac (almost half) and 700 miles of its tributaries were considered unsuitable for aquatic life at the time (ICPRB, 1989). The effects of raw sewage discharges to the North Branch from Kitzmiller, Gorman and other small towns were thought to be masked by the acid drainage from mining areas. Construction of the Jennings Randolph dam, which began operations in 1982, improved acid water conditions significantly.

The lower portions of the North Branch demonstrated better (fair) water quality though problems with abandoned mine drainage and combined sewer overflows during heavy storms persisted (ICPRB, 1989). The then new wastewater treatment facility at Cumberland serving Frostburg and LaValle was identified as a chief cause for improvements. TMDL listings in the North Branch Potomac watershed are based on nutrients, TSS, low pH, sulfates, metals, cadmium, cyanide, organic enrichment, low dissolved oxygen, ammonia, and iron. Identified sources of these contaminants include both point and nonpoint sources, natural occurrence, and acid and abandoned mine drainage.

An evaluation of recent (1992-1996) water quality data from USGS water quality monitoring station 010603000 on the North Branch Potomac near Cumberland, MD indicated an average total suspended solids concentration (TSS) of 8.9 mg/L and an average DOC of 5.2 mg/L The Savage River (which lies outside of the coal seam) had generally good water quality in the early 1990's (ICPRB, 1989). However, the George's Creek watershed, which was heavily mined at the time, demonstrated poor water quality due to acid mine drainage and raw sewage discharges (ICPRB, 1989). Water quality in the Willis Creek was considered good, with some degradation due to acid mine drainage (ICPRB, 1989).

As shown on Figure A-1 (Appendix A), monitoring of North Branch fish tissue for dieldrin found a maximum concentration of 1.6 μg/g wet tissue and an average of 0.83 μg/g wet tissue. All fish tissue samples had detectable concentrations of dieldrin, and 5 of the 12 samples were above 0.3 μg/g wet tissue, the Action Level established by the United States Food & Drug Agency (USFDA) for the sum of dieldrin and aldrin.

South Branch Potomac

The South Branch Potomac Watershed is shown on Figure 2. For 1982-1983, ICPRB estimated the South Branch Potomac water quality to be good with only localized problems due to agricultural and dairy farm runoff. The wastewater treatment facility in Romney was noted as one cause of improvements (ICPRB, 1984). From the early 1970s to the mid-1980s, hexavalent chromium increased in the South Branch, as did dissolved oxygen. Turbidity was generally also increasing over that time period. Several streams in the South Branch Potomac are currently listed for TMDLs based on NH_3-N and pathogens from agricultural landuses.

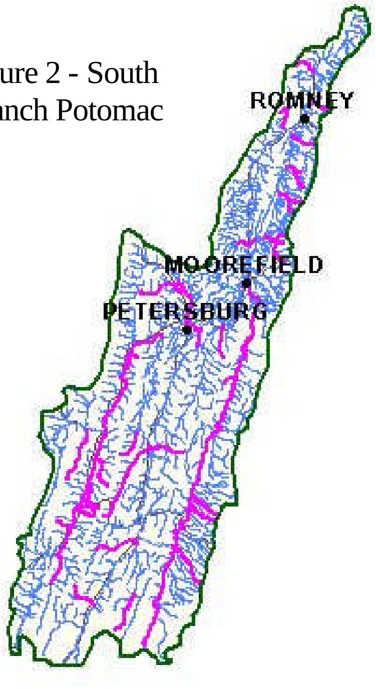


Figure 2 - South Branch Potomac

There are two USGS water quality monitoring stations on the South Branch of the Potomac for which data is included in "Water Quality Assessment of the Potomac River Basin: Water-Quality and Selected Spatial Data, 1992-96" (USGS 1998). At the South Fork of the South Branch near Moorefield, WV (Station 010608000) TSS ranged from 1.0 mg/L to 237.0 mg/L over that period (1992-1996) with an average of 34.0 mg/L and a median of 1.5 mg/L. DOC ranged from 0.7 mg/L to 14.0 mg/L with an average of 2.4 mg/L and a median of 1.6 mg/L. At the South Branch near Springfield, WV (Station 010603000) TSS ranged from 1.0 mg/L to 455.0

mg/L with an average of 53.7 mg/L and a median of 6.0 mg/L. DOC ranged from 1.2 mg/L to 6.6 mg/L with an average of 2.7 mg/L and a median of 2.1 mg/L. Monitoring of sediment for dieldrin found 2 samples with less than the detection limit, a maximum concentration of 600 µg/kg dry soil and an average of 40 µg/kg dry soil (Figure A-2). As shown on Figure A-3, monitoring of South Branch fish tissue for dieldrin found detectable concentrations in all samples, a maximum concentration of 0.07 µg/g wet tissue (all samples were below the USFDA Action Level of 0.3 µg/g wet tissue) and an average of 0.03 µg/g wet tissue.

Cacapon-Town

The Cacapon-Town watershed (shown on Figure 3) includes TMDL listings based on nutrients, suspended solids, and pathogens. Only agricultural runoff was identified as a source of these contaminants.

As shown on Figure A-4, monitoring of Cacapon-Town fish tissue for dieldrin found all samples with detectable concentrations, a maximum concentration of 0.007 µg/g wet tissue (all samples were below the USFDA Action Level of 0.3 µg/g wet tissue) and an average of 0.0018 (µg/g wet tissue).

Figure 3 - Cacapon-Town

UPPER GREAT VALLEY

The upper Great Valley includes areas of southern Pennsylvania, Maryland, Virginia and West Virginia. Major tributaries include the Conococheague, Opequon, Abrams and Antietam Creeks. This portion of the Potomac Watershed is extensively farmed and storm runoff from agricultural areas affects the entire region.

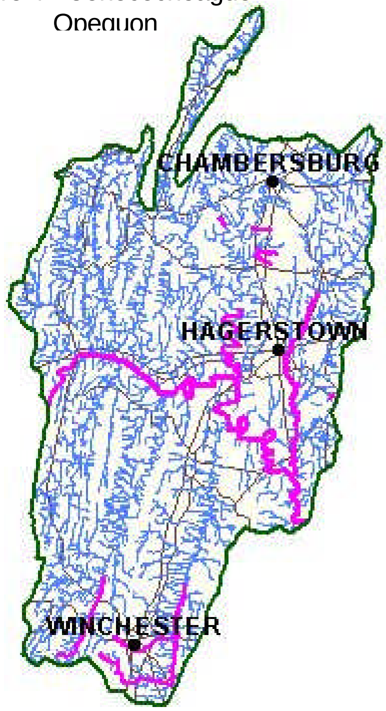
From the early 1970s to the mid-1980s, turbidity decreased in the basin. (ICPRB, 1989). Although nitrate was generally increasing in the basin, Potomac River water quality in the upper Great Valley was fair with slight improvements likely from increased treatment of wastewater. Although nonpoint sources, primarily agricultural runoff, constituted the main source of pollutants, problems persisted with failing septic systems, toxic chemicals, and inadequate treatment of municipal and industrial wastewater.

In 1982-1983 water quality in the Conococheague, Opequon, and Antietam Creeks was described as “fair” with elevated suspended solids, nutrients and bacteria due primarily to nonpoint source runoff. Water quality in a few select streams was described as “poor-fair” to “good” (ICPRB, 1984).

Conococheague-Opequon

Water quality in the Conococheague Creek (Figure 4) was considered "good" by the mid-1980s except for the lower 2 miles (just upstream of the confluence with the Potomac River), which were considered "fair-good". Industrial discharges to the Conococheague were primarily from a Pennsylvania paper mill and tannery. Researchers found that iron concentrations decreased from 1970 to the mid-1980s. Researchers also noted additional effects on the river of urban and agricultural activities at the time. The lower portion of the Conococheague was affected by agricultural and forest runoff.

Figure 4 - Conococheague-Opequon



The Opequon Creek water quality was only "fair-good" in the mid-1980s due to wastewater loads and agricultural activities. Hexavalent chromium and lead concentrations increased from 1970 to the mid-1980s. Winchester, Virginia lies in the Opequon watershed but the majority of the basin is rural. Both the Winchester WWTP and the Abrams WWTP discharge to Abrams Creek, one of three major tributaries of Opequon Creek. Orchards and pastures in the vicinity of Winchester have the potential for affecting the quality of Opequon Creek. Abrams Creek water quality was "poor-fair". Monitoring in the early 1970s detected pesticides in the water sediments and aquatic life of the Opequon. These pesticide levels were attributed to past use of pesticides in the orchards within the drainage basin (ICPRB, 1989)).

Several streams in the Conococheague-Opequon watershed are listed for TMDLs based on nutrients, suspended solids, low dissolved oxygen, organic enrichment, noxious aquatic plants, taste and odors, NH3-N, fecal coliforms, and benthic conditions. Sources for these conditions include point and nonpoint sources, natural sources, habitat modification, urban runoff, storm sewers, agricultural landuses, urban landuses, and periodic sewer overflows.

Monitoring for aqueous dieldrin found 9 samples without detectable concentrations, a maximum concentration of 1.5 μg/L and an average of 0.12 μg/L (Figure A-5). Monitoring of sediment for dieldrin found a maximum concentration of 600 μg/kg dry soil and an average of 95 μg/kg dry soil (Figure A-6). Monitoring of Conococheague-Opequon fish tissue for dieldrin found a maximum concentration of 1,000 μg/g wet tissue and an average of 14 μg/g wet tissue (Figure A-7).

During the mid-1980s, water quality in the Antietam Creek varied from "fair" in the upper reaches to "good" in the area around Sharpsburg. Primary sources of pollution included failing septic systems, agricultural runoff, and runoff from construction sites resulting in elevated suspended solids levels. In 1972, the USGS detected elevated PCB levels in the sediment of Antietam Creek. Later follow-up studies determined that PCB levels were not a concern.

SUMMARY

Despite significant population growth and development in the basin, there have been significant improvements in the general water quality of the Potomac Watershed, notably since the passage of the Clean Water Act. Improvements to and expansion of wastewater treatment facilities have caused reductions in failing septic systems and significant water quality improvements in most areas of the basin, particularly reducing bacterial contamination.

Phosphorus loadings and concentrations have been reduced and, although total nitrogen loads and concentrations have remained steady, seasonal blue-green algal blooms seem to have been reduced significantly. pH fluctuations, due to algal photosynthesis, and low dissolved oxygen conditions, which are caused by algal blooms, have been reduced.

LaVale, Frostburg, Westernport and Cumberland, Maryland and other jurisdictions in the watershed are operating their wastewater collection systems under a consent order related to combined sewer overflows (CSOs), and sewer overflows. Although the persistence of fecal coliforms downstream of these historical contamination events depends on many factors (temperature, pH, ultraviolet light conditions, flow conditions, etc.) these CSO events are clear cases of fecal contamination. A review of wastewater effluent sampling data makes it clear that *cryptosporidium* oocysts and *giardia* cysts are commonly present in sewer overflows and that these pathogens very likely persist well downstream of these overflow locations.

Although there have been notable improvements, acid water conditions in the headwaters persist due to active and abandoned mining operations. PCBs, metals and other toxics are detected in some specific areas, although these are generally thought to be the result of historical contamination and sources of these pollutants have been significantly reduced. Occurrences in the water column are most likely due to historical contamination of the streambed sediment. Although banned in the 1970s, dieldrin contamination of the sediments, fish tissue and water column have been detected through much of the basin. Because the sources of these toxic contaminants are generally controlled at this time, improvements over some time frame are reasonably expected, although it is difficult to estimate a time frame for these improvements.

APPENDIX A – DIELDRIN FIGURES

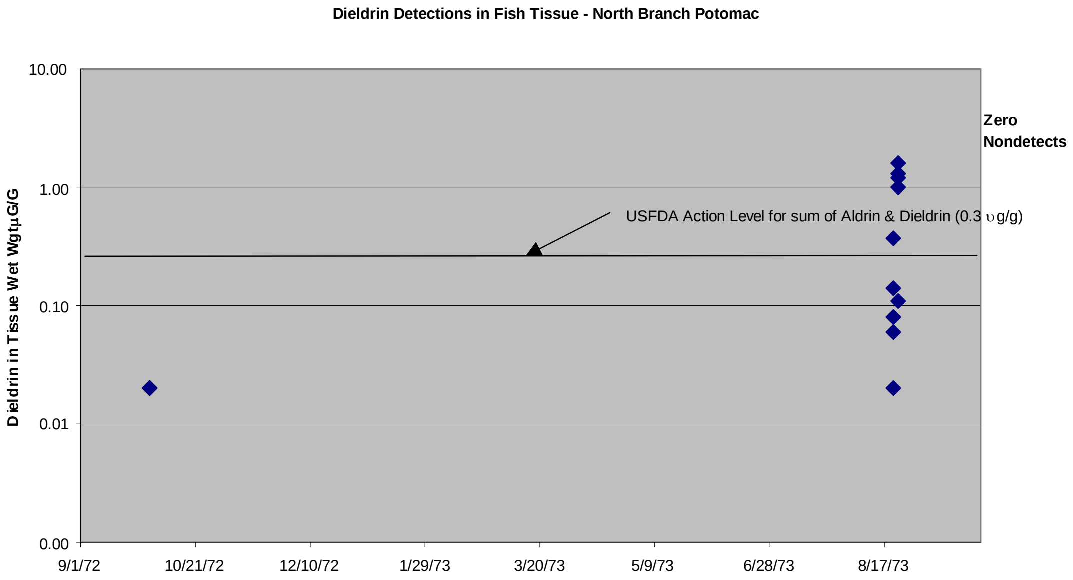


Figure A-1

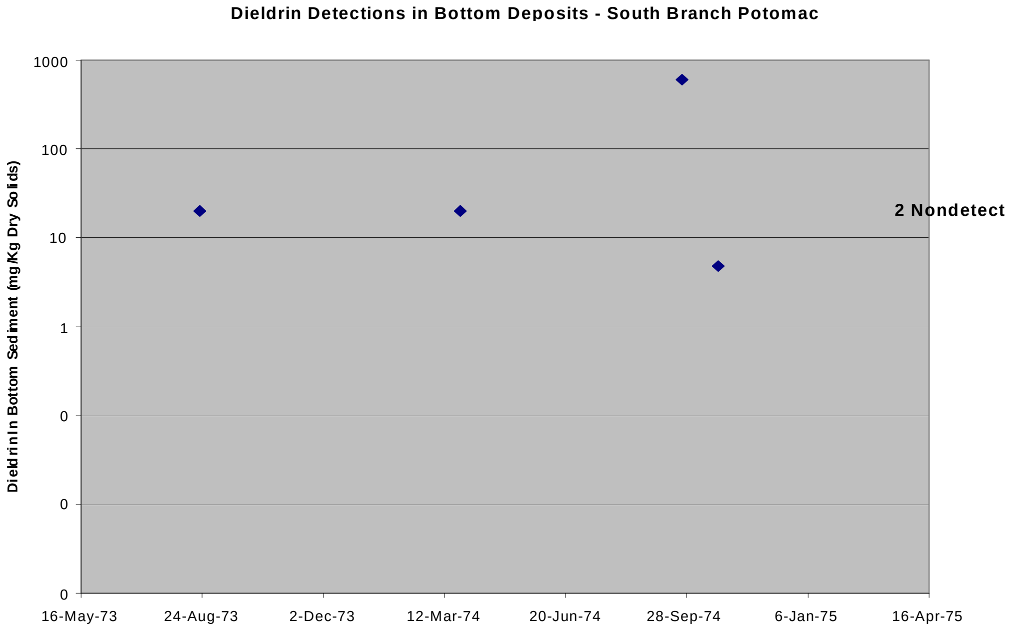


Figure A-2

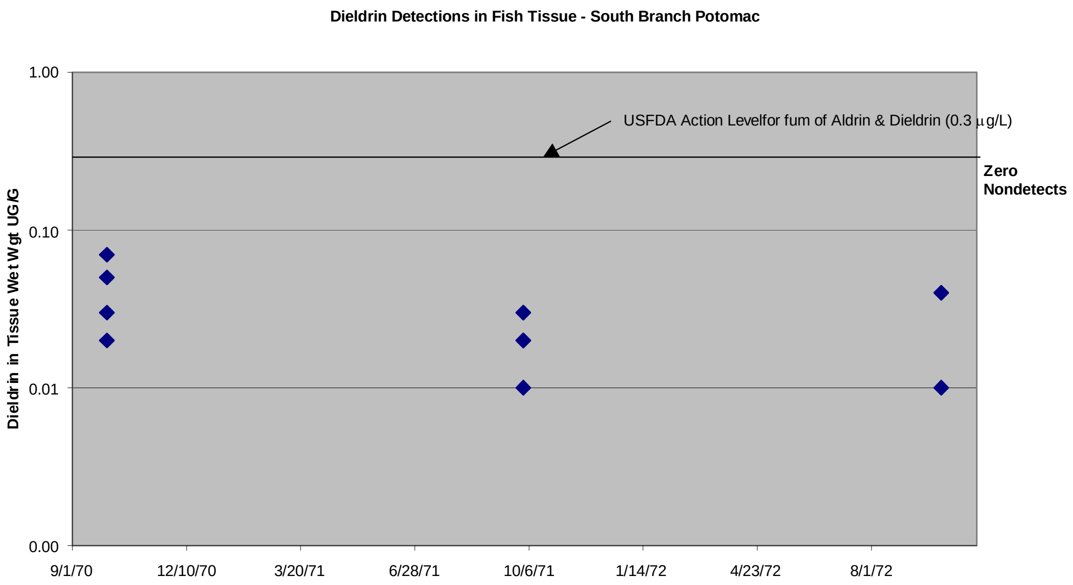

Dieldrin Detections in Fish Tissue - South Branch Potomac

Figure A-3

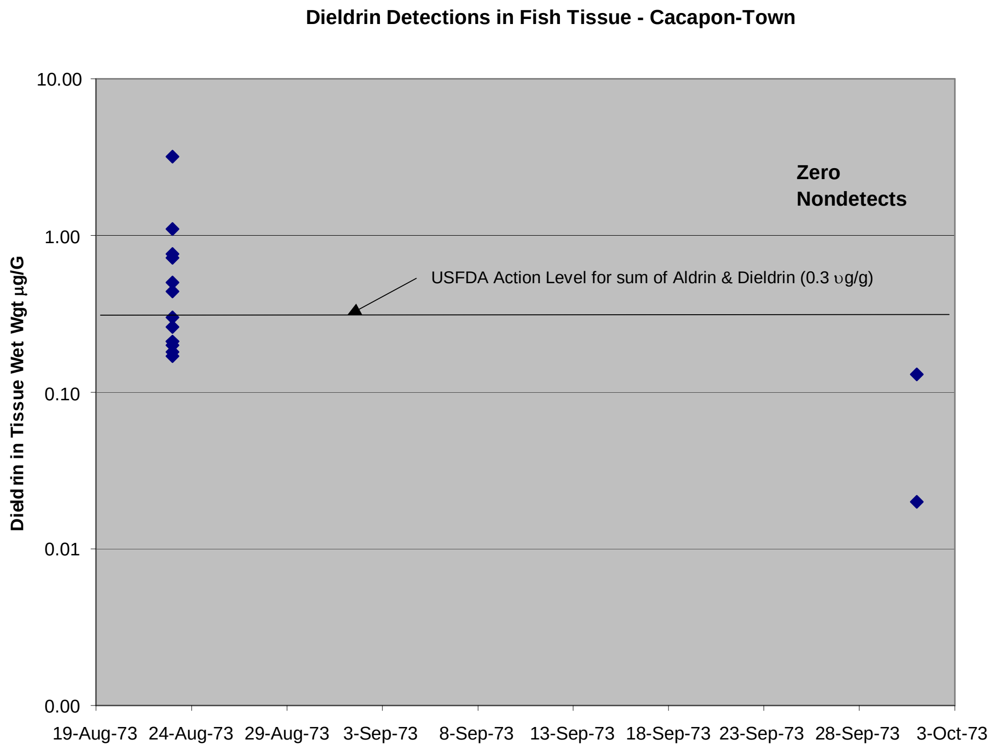

Dieldrin Detections in Fish Tissue - Cacapon-Town

Figure A-4

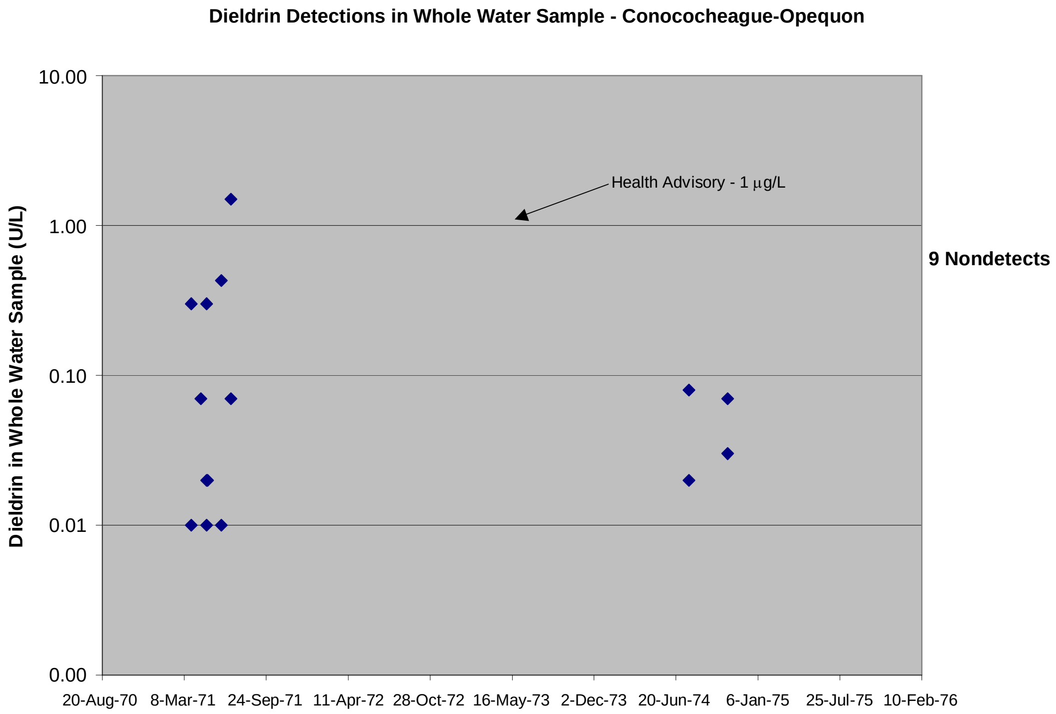


Figure A-5

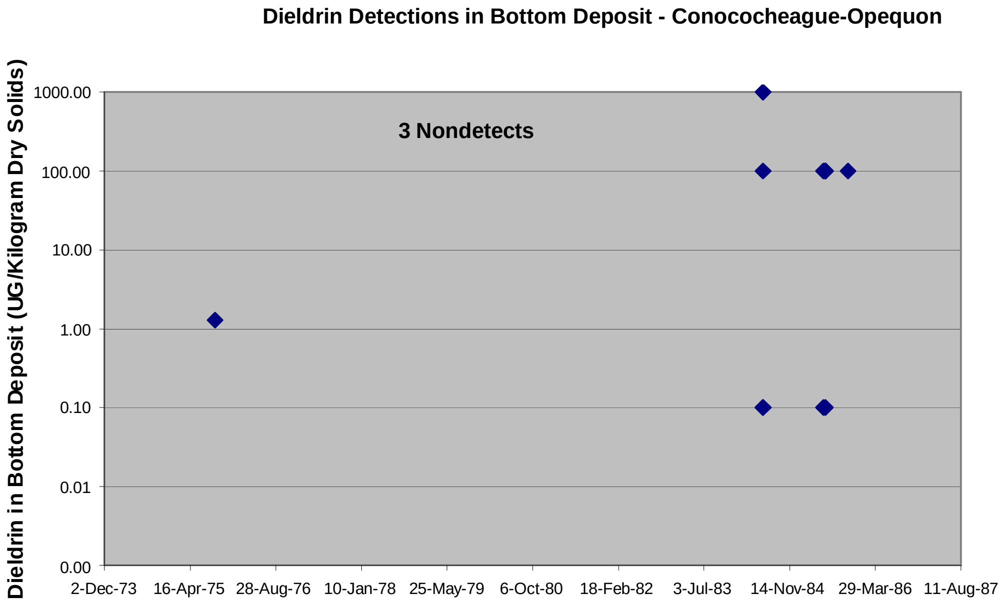


Figure A-6

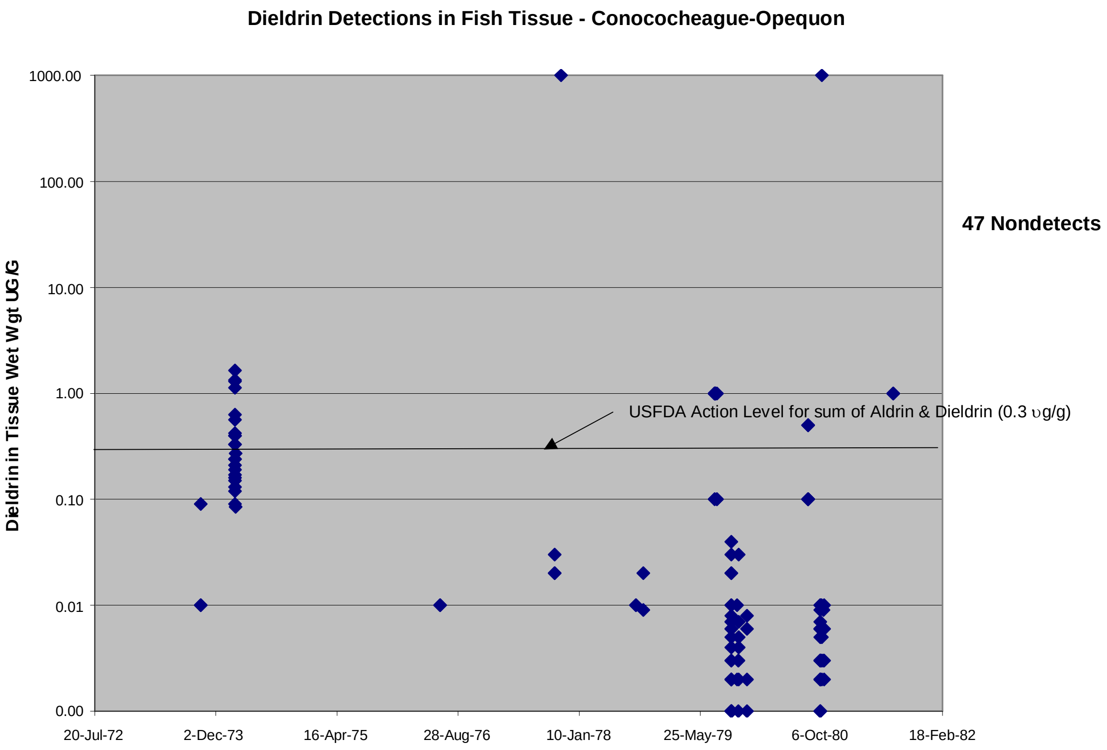

Dieldrin Detections in Fish Tissue - Conococheague-Opequon
1000.00
100.00
10.00
1.00
0.10
0.01
0.00
Dieldrin in Tissue Wet Wgt UG/G
20-Jul-72
2-Dec-73
16-Apr-75
28-Aug-76
10-Jan-78
25-May-79
6-Oct-80
18-Feb-82
USFDA Action Level for sum of Aldrin & Dieldrin (0.3 υg/g)
47 Nondetects

Figure A-7

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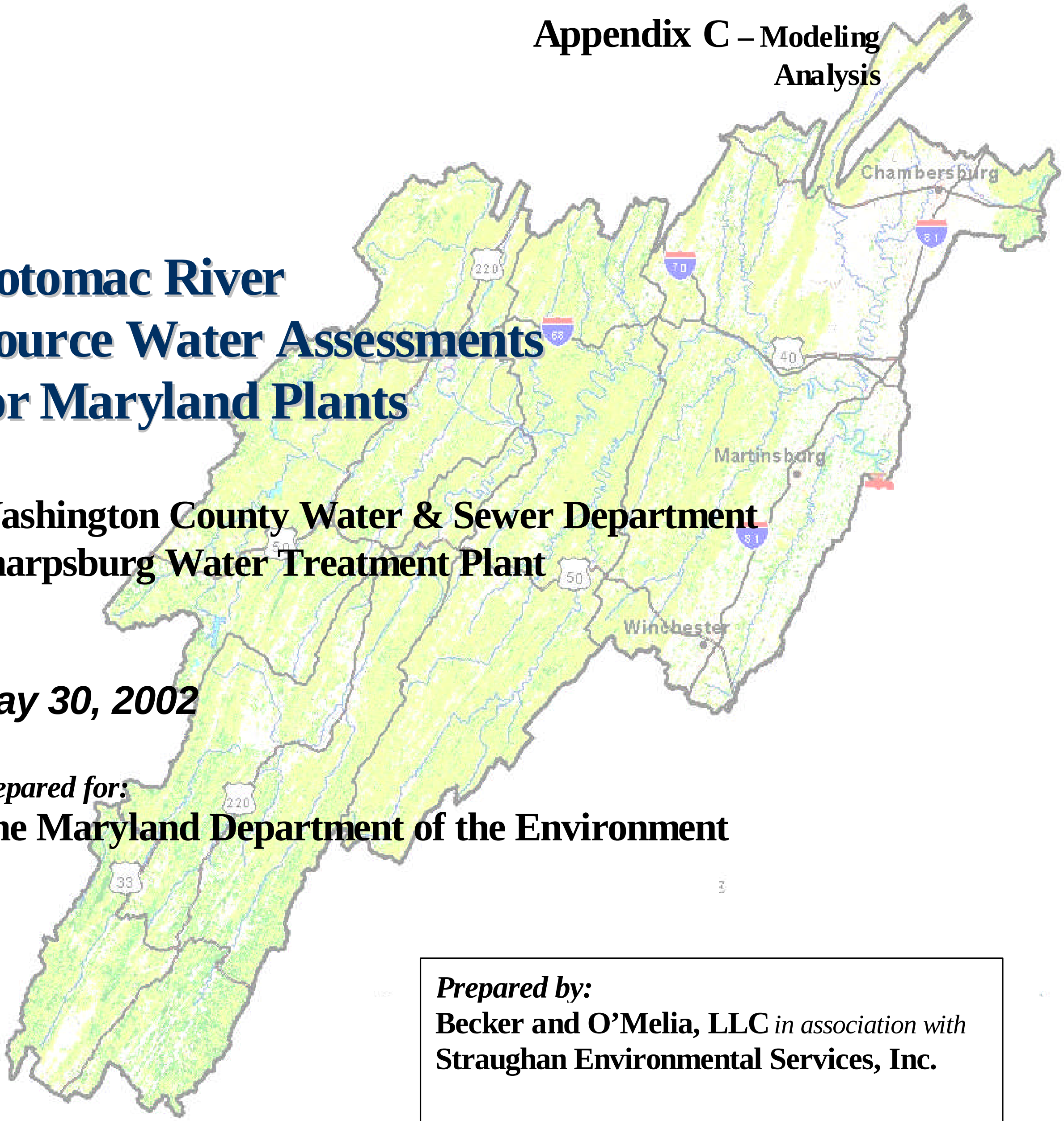
Appendix C – Modeling Analysis



Potomac River Source Water Assessments for Maryland Plants

Washington County Water & Sewer Department
Sharpsburg Water Treatment Plant

May 30, 2002

Prepared for:
The Maryland Department of the Environment

Prepared by:
Becker and O'Melia, LLC *in association with*
Straughan Environmental Services, Inc.

Becker and O'Melia, LLC
WATER PROCESS RESEARCHERS AND CONSULTANTS

Introduction

This appendix presents the approach, results, and findings of the 1-dimensional fate and transport modeling, the watershed modeling, and the 2-dimensional hydrodynamic modeling carried out in the SWA. The appendix is organized into two major sections as the work was performed (1-dimensional fate and transport modeling, and watershed modeling). Becker and O'Melia, LLC oversaw the overall modeling effort and performed the 1-dimensional fate and transport modeling using a truncated version of the EPA-Chesapeake Bay Program Office's Chesapeake Bay Watershed Model. The Center for Watershed Protection performed the watershed modeling using their Watershed Treatment Model.

Overall Modeling Task and One-Dimensional Fate and Transport Modeling

Model Selection

There is a vast array of watershed models, hydrodynamic models, and fate and transport models which could be applied to a source water assessment in a watershed like the Potomac River Basin. Based on a review of relevant literature, communications with watershed modelers familiar with the Potomac Watershed, and communications with others performing similar source water assessments, two 1-D modeling packages were selected for detailed consideration. These were the Chesapeake Bay Watershed Model, and BASINS.

The modeling needs of the project include:

- modeling of current conditions in the watershed,
- future conditions in the watershed,
- the application of various management scenarios, and
- fate and transport in the main stem of the Potomac River.

This section of the Appendix describes the criteria and evaluations that were employed to select the appropriate 1-D modeling package for the project. Six criteria for selection have been identified previously including:

1 - The range of flows and areas within the watershed for which calibration tracer testing has been performed and incorporated into the model.

Because both the CBWM and Basins use HSPF, it is feasible to use similar previous flow monitoring data sets to calibrate models built around either software.

CBWM – this model has been manually calibrated at 14 sites in the Chesapeake Bay Watershed.

Basins – Previous model development has included significant calibration efforts. It is likely that access to this data is feasible.

2 - The number of contaminants identified in Task 3a, or surrogates for those contaminants, for which fate and transport algorithms have been developed,

CBWM – the model was developed and has been employed primarily to evaluate nutrients, and includes fairly sophisticated nutrient cycle simulations. TSS simulations have also been developed, calibrated and validated. The model has the capacity to run other contaminants but may require programming of additional subroutines.

Basins – Basins includes algorithms for many contaminants, and a Basins model built for the project would likely include algorithms for each contaminant of concern. These changes are made through Basins' Windows-based graphical user interface (GUI). Though Basins has the capacity to run complex simulations of the nutrient cycle, it is common to simplify this complex system, and it is unlikely that sophisticated nutrient simulations could be included and calibrated for this project (without using the CBWM).

3 - The ease with which input and output can be coordinated with the watershed treatment model (WTM) and the 2-D model,

The 2-D mixing zone model will be used to allow estimation of the relative impacts (on the Potomac WFP raw water quality) of the main stem Potomac and Watts Branch flows. The 2-D model output will consist of a matrix of dilution values. The WTM utilizes ArcView to develop input values and to organize output, but is spreadsheet based. The interface between ArcView mapping data and the WTM is manual data entry. Basins and the CBWM utilize different user interfaces.

CBWM – The CBWM is a Unix-based program and uses an ASCI input interface, which is inconsistent with ArcView mapping. Because of the manual interface between the Task 2 mapping and Task 6 loading model, an ASCI interface should not present any difficulties in utilizing the CBWM for the 1-D fate and transport modeling.

Basins – Basins utilizes an ArcView GUI and is well suited to utilize Task 2 mapping as input to a contaminant-loading model. However, the WTM utilizes manual data input so any interface with the WTM for Basins hydrologic modeling will be manual.

4 - The usefulness of the model for future use, including the future technical support and continued model development

CBWM – Because this model was developed for the Chesapeake Bay Watershed in the 1970's, this model has been applied in the Potomac Watershed by others. This model has been selected for similar SWA evaluations in this area. The Chesapeake Bay Program Office is currently performing a significant revision of this model in order to better facilitate BMP evaluations and increase the spatial discretization of the model in the Potomac Watershed. This revision will not be complete until after the Potomac River Source Water Assessments for Maryland Plants project is completed.

Basins – WSSC is considering building and supporting a model of the Patuxent watershed based on the Basins package. WSSC therefore may soon have significant in-house Basins modeling capability and a Basins model of the Potomac may provide significant benefits beyond this project. Basins is a sophisticated software package that is widely applied to a range of watershed issues throughout the country. Formal training programs have been developed and are available. There is an active community of users who are available to offer assistance. Like the CBWM, Basins is currently undergoing a significant revision, which will not be completed in time for inclusion in this project.

5 - Model calibration for sediment fate and transport,

Because both models utilize HSPF, the two models have similar sediment capabilities.

6 - Other parameters deemed important by WSSC, MDE and B&O'M.

6a - Opportunities to coordinate with other regional Source Water Assessment Modeling Efforts

The District of Columbia has selected the CBWM to perform the Source Water Assessment for the Dalecarlia WTP and the MacMillan WTP, which withdraw water from the Potomac River just downstream from the WSSC's Potomac WFP. Selecting this model for the Potomac WFP SWA would likely provide many opportunities to coordinate the similar work on these two projects.

6b - Ability to meet the needs of the established modeling approach to the project

Basins is a modeling package that has been used by others to build models of many watersheds, including the Potomac River Watershed. Although federally funded modeling efforts have been performed and the results of these efforts are available, a calibrated, applicable Basins model of the Potomac has not been identified by the project team. Although Basins is a powerful tool capable of addressing many relevant issues in a source water assessment, implementation of this tool to this project will require that a new model be built and calibrated. Depending on the specifics of the model built (e.g. river reaches selected and subwatersheds delineated) this calibration could likely be carried out using data from previous tracer testing and calibration efforts. Building and calibrating this model would represent a significant effort that is not consistent with the project approach and scope of work.

Data available for Basins modeling, which are significant, are inappropriate for automated input to the CBWM. Basins uses ArcView/GIS files to organize data and input data to the model and to organize output data for evaluations, whereas the CBWM uses ASCI text files. The Basins dataset would allow development of a Basins model with significantly better spatial discretization than in the existing CBWM. However, the project approach includes separate detailed evaluations of local effects (Task 2) and 2-D modeling of the local area (Task 5). The purpose of the 1-D model is to evaluate fate and transport of upstream contamination. Fine spatial discretization allows more precise calculations of travel (and reaction) times and increased precision in the fate and transport modeling. In the local areas of the watershed, where travel and reaction times are short, this fine discretization is particularly important. The modeling of the local areas is to be accomplished using the watershed treatment and the mixing zone models and is therefore not included in the 1-D model. Detailed spatial discretization may therefore be less important (than in other SWA modeling tasks) due to the increased travel and reaction times from the upstream areas to be modeled.

In performing the model selection and literature review subtasks two software packages have been considered for the Task 5, 1-D fate and transport modeling. The Chesapeake Bay Watershed Model (CBWM), fits the needs of the project scope of work. The other, Basins (an EPA modeling software package which has been applied throughout the US to perform evaluations similar to this task), is a powerful tool and can also fit the needs of the project. However, application of Basins to this project would require significant efforts in model construction and calibration that are not consistent with the project approach. In order to accomplish the project's technical challenges and to meet the schedule and budget, the Chesapeake Bay Watershed Model was selected for Task 5a, 1-D modeling.

Modeling Approach

The modeling activities in the SWA will be carried out to:

- evaluate and quantify the impacts of existing point and non-point sources on the Potomac WFP raw water quality, considering both the existing intake and potential future midriver intake locations;

- evaluate and quantify the likely impacts of future point and non-point sources on raw water quality;
- evaluate the impact of these raw water contaminant concentrations on drinking water treatability at the Potomac WFP; and
- evaluate the potential for applying BMPs and BATs to mitigate the existing and future impacts on the WFP;.

In order to accomplish these goals, two modeling packages were used including the Center for Watershed Protection’s Watershed Treatment Model (WTM), and the Chesapeake Bay Watershed Model.

A model of the Potomac River was constructed by truncating the CBWM. This model referred to as the Potomac Watershed (PWS) model was run for current conditions to establish the hourly and daily average loading of each modeled parameter at the edge of the stream from each of the major subbasins designated in the CBWM. (The CBWM delineates the entire Chesapeake Basin into only 86 segments, which average approximately 700 mi^2.) Current annual loads for the major subbasins were also estimated using the WTM (described in Detail in the Watershed Treatment Modeling Section below). Note that these WTM loads were used only as a basis for comparison with future and management scenarios to estimate changes from current loads. The WTM is a simple method model and is designed to evaluate changes in annual load, which result from changes in land use and management practices. The WTM therefore models different phenomena than the PWS model. This current condition run of the WTM established the baseline for determining changes in the edge-of-stream loadings due to proposed changes in land use and watershed management.

Scenarios that represent future land use under varying management scenarios were developed and modeled using the WTM. Modeling of these scenarios yielded an annual load of each modeled parameter, from each major subbasin. Comparison of these results and the baseline loadings generated estimates in the change in the edge-of-stream loading under the modeled scenario. This change in loading was applied to the PWS Model by systematically modifying the “mass-link” parameters in the model. The mass-link parameter is utilized in the CBWM to correlate runoff and edge-of-stream loadings and to correct for differences in units. This parameter provided an opportunity to modify the hourly edge-of-stream loading from each major subbasin and to model the fate and transport from this point to the confluence with Watts Branch. Future management scenarios were run using the WTM, which allowed estimation of relative changes (i.e. percent reductions or increases) in annual loading. Changes in the hourly loadings under future and management scenarios were then estimated and input to the CBWM for evaluation of the fate and transport from the edge-of-stream to the confluence with Watts Branch.

Applying these changes in the edge-of-stream load to the PWS Model and running the model under these future and management scenarios produced hourly estimates of the concentration of modeled parameters in the main stem of the Potomac at the confluence with Watts Branch.

Results of 1-D Modeling of Watershed

Results of 1-D Modeling of Watershed

General Results

Because of the different dominating land uses in the drainage areas of the various subwatersheds, loading changes indicated by the modeling were due to implementation of different management practices. In the upper watershed (the portion of the watershed upstream of Watts Branch), only modest improvements in “edge-of-stream” water quality could be achieved in each segment by management practices and these improvements were achieved primarily through point source controls and agricultural management practices.

WTM results showed moderate to significant improvements to “edge-of-stream” loadings within the Upper Watershed under the future scenario. Expected changes are smaller for sediment. Management practices were able to reduce sediment loads slightly and phosphorus loads somewhat more. Table 1 summarizes these results as percentages of existing loads. Overall, point source nutrient loads could be changed significantly under the very aggressive treatment scenario, but urban loads typically increased, even with treatment. However, this increase in urban load did not typically increase the overall load from a segment significantly, because of the small amount of urban land. As urban areas increase in the watershed, especially beyond the planning period of this study, control of these impacts will become more important.

TABLE 1 – UPPER WATERSHED LOADS FROM WTM

SEGMENT		TOTAL NITROGEN	TOTAL PHOSPHORUS	TOTAL SUSPENDED SOLIDS
160		% OF CURRENT LOAD		
	Future-scenario 1	102%	104%	103%
	Future-scenario 2	101%	86%	100%
	Future-scenario 3	92%	73%	99%
170				
	Future-scenario 1	102%	103%	102%
	Future-scenario 2	99%	96%	99%
	Future-scenario 3	96%	91%	98%
175				
	Future-scenario 1	102%	103%	104%
	Future-scenario 2	98%	94%	100%
	Future-scenario 3	95%	87%	98%
180				
	Future-scenario 1	104%	104%	105%
	Future-scenario 2	101%	85%	94%
	Future-scenario 3	82%	66%	85%
190				
	Future-scenario 1	104%	105%	109%
	Future-scenario 2	96%	78%	100%
	Future-scenario 3	85%	72%	96%
200				
	Future-scenario 1	106%	108%	114%
	Future-scenario 2	94%	82%	102%
	Future-scenario 3	87%	75%	96%
210				
	Future-scenario 1	107%	106%	109%
	Future-scenario 2	105%	88%	97%
	Future-scenario 3	92%	72%	85%
220				
	Future-scenario 1	105%	106%	106%
	Future-scenario 2	102%	96%	98%
	Future-scenario 3	96%	88%	93%
225				
	Future-scenario 1	105%	104%	101%
	Future-scenario 2	103%	97%	96%
	Future-scenario 3	100%	91%	90%

TABLE 1 – UPPER WATERSHED LOADS FROM WTM

SEGMENT		TOTAL NITROGEN	TOTAL PHOSPHORUS	TOTAL SUSPENDED SOLIDS
730				
	Future-scenario 1	102%	102%	103%
	Future-scenario 2	78%	65%	94%
	Future-scenario 3	61%	50%	86%
740				
	Future-scenario 1	110%	110%	112%
	Future-scenario 2	97%	87%	102%
	Future-scenario 3	88%	75%	95%
750				
	Future-scenario 1	103%	102%	104%
	Future-scenario 2	100%	90%	91%
	Future-scenario 3	82%	66%	79%

The WTM modeling indicates that management practices are expected to reduce "edge-of-stream" contaminant loadings to the Potomac River and its tributaries. However, fate and transport modeling suggests that the impact these changes have on the WTP raw water are significantly delayed due to natural processes within the river. The Potomac River bed serves as a signficant source of solids, nutrients, *Cryptosporidium, Giardia*, and contaminants which sorb to sediment including NOM and dieldrin.

When left undisturbed, the streambed reaches a steady state with flow conditions such that contaminant inputs and exports are roughly equivalent. When this steady state is altered by changes in flow pattern (due to changes in impervious cover, storm water practices, or climatological trends) or by changes in contaminant loading (due to agricultural activities, urbanization, or implementation of management practices) the streambed will undergo geomorphological processes which eventually bring it back into a new steady state condition. The timescale for this return to steady state depends on many local factors but is grossly estimated at more than 60 years assuming the disturbances cease. Most disturbances in the watershed have been in place for some time, and relatively small changes are expected over the planning period of this project. Therefore, reductions in loading should not be expected to immediately affect the downstream water quality. Reduction in the loading of sediment and nutrients would therefore be expected to have little effect on the downstream water quality. Contaminants which have run off into the Potomac in the past and are stored in the sediment of the upper watershed will continue to be transported to the WFP intake whether management practices are applied or not. The modeling results reflect this process. The reduction in "edge-of-stream" nutrient loading does not cause a similar reduction in algal activity (as indicated by simulated chloraphyll a and TOC concentrations).

Regardless of these modeling results, simple mass balance considerations indicate that application of these practices will eventually have beneficial impacts roughly equivalent to the impacts on "edge-of-stream" loading (for example, a 10% reduction in phosphorus loading should eventually reduce algal activity by approximately 10%). This is also consistent with reported results by the EPA's Chesapeake Bay Program Office, which assume instantaneous changes in the streambed and have noted significant reductions in nutrient concentrations and algal activity. Based on the geomorphological evaluations performed as part of this study, for contaminants associated with sediment (including nutrients, diedrin, and turbidity), the beneficial impact may lag years behind the implementation of the practices.

Regardless of loading, the streambeds of the watershed will serve as sources of nutrients for some time and algal activity will likely persist. Though not stored in the streambed, contaminants associated with the nutirent cycle and algal activities will likely also persist. These contaminants include NOM, DBP precursors, and taste and odor causing compounds.

Cryptosporidium oocycts are thought to persist in the environment for a period of approximately 18 months, but not for periods on the timescale studied[1]. Reductions in oocyst and cyst loadings from the upper parts of the watershed would therefore be expected to reduce raw water oocyst concentrations rather quickly. Fecal bacteria, viruses, and other pathogenic organisms are even less persistent in the environment and management practices which yield reductions in "edge-of-stream" loading will have essentially immediate reductions in loadings at the Potomac WFP.

Potomac River Watershed – Summary Results

The modeling activities of this project involved adjusting the "edge-of-stream" loading of suspended solids and nutrients in the PWS Model (the CBPO model of the Potomac WFP Watershed). These "edge-of-stream" loadings were adjusted according to the WTM modeling task also described above. The in-river fate and transport was then modeled with the PWS. Because nutrients and solids are stored in the Potomac streambed, little change in the in-river concentrations was noted for solids, chloraphyll a, and ammonia under "no management", "moderate management" and "aggrressive management" scenarios (See Tables 14 though 17). A small reduction in the elevated levels (10% exceedance) of TOC was noted. This suggests that algal blooms would be reduced in the upper part of the watershed and instream production of TOC, NOM and DBP precursors would also be reduced.

The modeling approach was utilized to analyze the susceptibility of the water supply to contamination from the identified contaminants of concern. It is important to remember that the quantitative predictions from the modeling are subject to the limitations presented by the assumptions and the surrogates utilized as well as the relatively gross scale and level of detail in the models.

---

[1] Rose, J.B., 1997

The modeling approach was utilized to analyze the susceptibility of the Potomac WFP water supply to contamination from the identified contaminants of concern. The results of the modeling are discussed below and organized by contaminant group. It is important to remember that the quantitative predictions from the modeling are subject to the limitations presented by the assumptions and the surrogates utilized as well as the relatively gross scale and level of detail in the models.

Susceptibility to Group 1 Contaminants of Concern (**Cryptosporidium*****,** **Giardia*****, Fecal Coliforms, and Sediment)***

Group 1 contaminants include *Cryptosporidium*, *Giardia*, Fecal Coliforms and Sediment, These contaminants are at their highest concentrations at the plant following rainfall and increased river flow. While it is typical that high sediment levels in water correlate with elevated *Cryptosporidium*, *Giardia* and fecal coliform, management of these sources can be separate and distinct from sediment control. In addition, while sediment stored in the tributaries and river system will continue to impact the water plant into the future, the elimination or reduction of sources of fecal contamination will produce immediate benefits due to limitations concerning the survival time of pathogens in the environment.

Unlike sediment particles, *Cryptosporidium* and *Giardia* enter the environment through fecal contamination. Appropriate oocyst and cyst management practices include those that prevent fecal contamination (e.g. animal waste management, stream fencing, wastewater treatment filtration, CSO/SSO control). Where contamination is not prevented, oocysts and cysts survive for up to 18 months in the environment. They are transported through the environment in much the same way that sediment particles are transported. Appropriate management practices therefore also include those that control particle runoff to and particle transport within streams (e.g. buffer strips, structural treatment practices, erosion and sediment control).

The effectiveness of appropriate management practices in preventing fecal contamination is highly dependent on local conditions but is well demonstrated. Unfortunately, insufficient data is available to allow appropriate modeling of these practices (especially regarding *Cryptosporidium* and *Giardia*). Recommendations for prevention of fecal contamination therefore remain qualitative. Because oocysts and cysts persist in the environment, sediment particles are considered an appropriate surrogate for their transport in the environment. Sediment control management practices applied in areas which are susceptible to fecal contamination (i.e. pastures, urban areas, dairy farms) are therefore expected to control oocysts and cysts in roughly the same way they control sediment.

- The only contaminant in Group 1 which was explicitly modeled under the modeling approach was sediment/turbidity. The modeling results indicated the following regarding sediment:
  - The future "no management" scenario predicts small increases in sediment concentrations, whereas under the "aggressive" scenario, predicted solids peaks are actually *reduced* from current peaks.
  - The predicted changes are the net result of management practices in upstream subwatersheds and in-stream processes. Because solids are stored in the Potomac streambed, little change in sediment concentrations was noted under any scenario. It is important to note that the Center for Watershed Protection's Watershed Treatment Model predicts significant sediment edge-of-stream load reductions for some subwatersheds with "aggressive" implementation of management practices (as described below). Even though these reductions translate into only modest

reductions at the intake, they could be significant for local water quality improvements as well as other Potomac water plants upstream, further supporting the recommendations.

- It is important to note that nonpoint urban loads will typically increase, even with implementation of BMPs. However, this increase in urban load will not typically increase the overall load significantly because of the small amount of urban land. As urban areas increase in the watershed, especially beyond the planning period of this study, control of these impacts will become more important.

Susceptibility to Group 2 Contaminants of Concern (Natural Organic Matter, Disinfection By-Product Precursors, and Algae)

Group 2 contaminants generally present their greatest challenges to the treatment plant during low flow, warmer months. The contaminants in Group 2 were modeled using explicit and surrogate measures. Total organic carbon was modeled and served as a surrogate for natural organic matter and disinfection byproduct precursors. Chlorophyll-a, which is a constituent of algal cells, was modeled as a surrogate for algae, while total nitrogen and total phosphorus were modeled explicitly. The modeling results yielded similar findings as the Group 1 contaminants, including:

- The future “no management” scenario predicts small increases in phosphorus concentrations, while the future “aggressive” management scenario predicts a small decrease in phosphorus concentrations at the intake. It should be noted that for the “aggressive” scenario, the WTM shows significant reduction in edge-of-stream phosphorus loads in some subwatersheds. This significant reduction will be reflected by an associated long-term reduction at the Potomac WFP intake when the river sediments and the loads come into equilibrium as required by mass balance considerations, and therefore these management practices would be effective for control of phosphorus and algae. However, in the short-term, the associated reduction at the intake is much less significant due to the storage of phosphorus in the sediment. The in-river modeling utilized in this study focused on the short-term impacts of management practices, and did not account for change in storage of phosphorus, and thus the future “aggressive” scenario predicts that phosphorus and chlorophyll-a peaks are reduced only negligibly at the intake.

- As urban areas increase in the watershed, especially beyond the planning period of this study, control of the significant associated impacts will become more important.

Susceptibility to Group 3 and 4 Contaminants of Concern (Taste and Odor Causing Compounds, and Atrazine)

None of the Group 3 or 4 contaminants were modeled explicitly due to limitations of the models and the unknown nature of the taste and odor producing compounds.

Watershed Treatment Modeling

Overview

The Watershed Treatment Model (Caraco, 2001) was used to estimate changes in load under various development. These relative changes were then linked with the Chesapeake Bay Watershed Model to predict the changes in concentration resulting from various management practice and land use combinations. This document describes the assumptions made in the Watershed Treatment Model, the future land use forecasts in both watersheds, and the various management scenarios depicted.

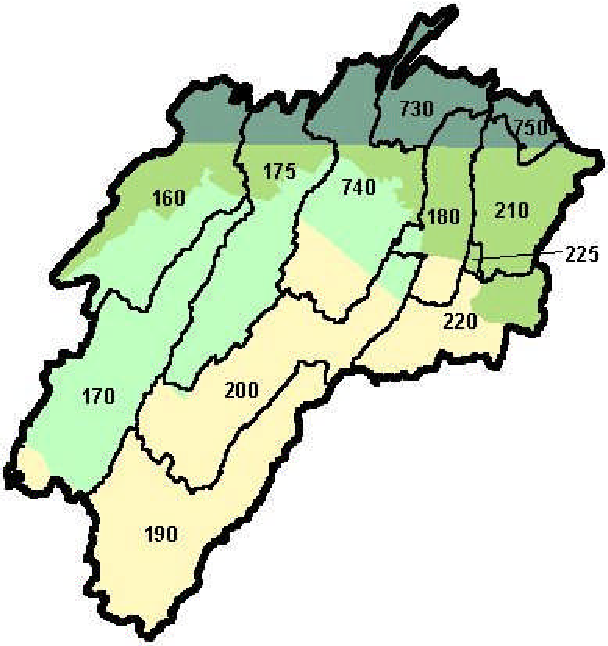
The Watershed Treatment Model (WTM) is a simple tool for the rapid assessment and quantification of various watershed treatment options. The model has two basic components: Pollutant Sources and Treatment Options. The *Pollutant Sources* component of the WTM estimates the load from a watershed without treatment measures in place. The *Treatment Options* component estimates the reduction in this uncontrolled load from a wide suite of treatment measures. The framework for this model is documented in the publication: “The Watershed Treatment Model” published in 2001 for the US Environmental Protection Agency. That publication presents several model defaults, many of which have been modified for specific application in the Potomac Watershed. In addition, the WTM version used in this Source Water Assessment accounts for a wider variety of agricultural pollutant sources, and has the ability to incorporate agricultural management practices. These model modifications were critical in assessing the Watershed. Figure 1 depicts the Watershed, divided into Chesapeake Bay Watershed Model Segments.

This document is organized as follows:

- Land Use
- Pollutant Sources
- Management Practices
- Management Scenarios
- Modeling Results

Land Use

Figure 1. Watershed Model Segments in the Upper Watershed



The Multi-Resolution Land Characteristics (MRLC) Consortium land use GIS layer was the primary source of information for land use in the watershed. For current conditions, the land use was characterized using the MRLC database, which groups land into generalized land cover categories. In addition, since consistent zoning data were not available for the entire watershed, future land use projections were made based on the projected population increase in each watershed segment. The current and future land uses in each watershed segment are reported in Tables 3 and 4.

TABLE 4. LAND USE IN THE UPPER WATERSHED-1997 (ACRES)

Chesapeake Bay Program Subwatershed	160	170	175	180	190	200	210	220	225	730	740	750
LDR	9,628	2,129	2,743	8,768	32,965	17,306	9,892	26,265	268	5,733	15,641	2,252
HDR	555	96	35	1,226	808	323	820	1,755	7	781	839	212
Commercial/ Industrial	1.373	280	341	1.413	3.291	1.029	1.592	3.054	161	1,762	2,413	422
Roads	11,462	7,833	7,705	6,254	14,687	11,380	8,574	7,597	211	4,915	14,512	1,882
Pasture	62,192	131,577	56,042	74,112	239,076	175,750	69,684	121,190	3,130	30,179	126,859	12,649
Crops	18,052	5,992	20,000	108,348	66,531	68,491	170,485	69,029	6,684	102,968	100,384	36,054
Hay	28,639	24,736	32,288	55,258	91,747	88,641	69,790	62,517	2,899	48,401	107,687	27,195
Forest	695,189	762,657	671,775	145,382	606,229	509,389	159,510	186,027	6,549	113,755	488,291	29,741
Grass/Parks	-	-	-	279	557	117	610	2,253	-	146	341	60
Mining/Quarries	14,977	204	295	200	627	1,354	1,195	2,224	-	179	1,501	69
Active Construction	1,017	678	381	786	2,496	1,953	286	1,846	51	372	1,878	48
Forestry	3,645	4,792	5,719	284	305	974	-	485	39	789	-	-
Water/Wetlands	9,542	5,120	5,348	6,429	9,075	7,758	9,415	15,705	1,609	5,157	10,247	2,650
Area (acres)	856,270	946,095	802,672	408,738	1,068,394	884,465	501,853	499,948	21,609	315,135	870,593	113,234

TABLE 5. LAND USE IN THE UPPER WATERSHED-2020 (ACRES)

Chesapeake Bay Program Subwatershed	160	170	175	180	190	200	210	220	225	730	740	750
LDR	12,794	3,103	3,868	12,892	48,663	32,336	18,861	35,820	430	7,291	33,373	2,882
HDR	738	140	50	1,802	1,193	603	1,564	2,393	11	993	1,791	272
Commercial/Industrial	1,824	408	481	2,078	4,859	1,922	3,035	4,165	259	2,240	5,150	540
Roads	15,231	11,419	10,865	9,196	21,681	21,263	16,348	10,361	338	6,251	30,963	2,409
Pasture	62,192	131,577	56,042	74,112	239,076	175,750	69,684	121,190	3,130	30,179	126,859	12,649
Crops	18,052	5,992	20,000	108,348	66,531	68,491	170,485	69,029	6,684	102,968	100,384	36,054
Hay	28,639	24,736	32,288	55,258	91,747	88,641	69,790	62,517	2,899	48,401	107,687	27,195
Forest	688,143	758,293	667,426	137,318	582,656	483,555	139,630	172,889	6,184	110,308	449,828	28,368
Grass/Parks	-	-	-	279	557	117	610	2,253	-	146	341	60
Mining/Quarries	14,977	204	295	200	627	1,354	1,195	2,224	-	179	1,501	69
Active Construction	494	309	290	542	1,423	1,701	1,235	917	25	234	2,470	87
Forestry	3,645	4,792	5,719	284	305	974	-	485	39	789	-	-
Water/Wetlands	9,542	5,120	5,348	6,429	9,075	7,758	9,415	15,705	1,609	5,157	10,247	2,650

Current Land Use

The MRLC GIS layer was clipped to Chesapeake Bay Watershed Model Segments, and each land use category in this database was then assigned to a land use category that is usable by the Watershed Treatment Model. Table 6 summarizes the land use assigned to each of the categories in the MRLC database.

TABLE 6. LAND USE CATEGORIES IN THE MRLC DATABASE

MRLC Code	MRLC Category	WTM Land Use Assigned
1	Water	Water/ Wetlands
2	Low Intensity Residential	Low Density Residential
3	High Intensity Residential	High Density Residential
4	High Intensity Commercial/ Industrial/ Transportation	Commercial/ Industrial
5	Hay/Pasture	Pasture (Later adjusted based on Census of Agriculture)
6	Row Crops	Cropland (Later adjusted based on the Census of Agriculture)
7	Other Grass/ Parks	Grass/ Parks
8	Conifer Forest	Forest
9	Mixed Forest	Forest
10	Deciduous Forest	Forest
11	Woody Wetlands	Water/ Wetlands
12	Emergent Wetlands	Water/ Wetlands
13	Quarries/ Mining	Mining
14	Rock/ Sand	None in Watershed
15	Transitional	Combination of Silviculture and Active Construction

As a first cut, all rural land use categories were assigned to a generalized rural land use. These rural land uses were then apportioned based on Census of Agriculture data for various land use categories. Chesapeake Bay Program (CBP, 1998) were used when developing the land use layer using Census of Agriculture data as follows:

- Total Hayland = (Hay, alfalfa, other tame, small grain, wild, grass silage, green chop, etc.)-(Grass silage, haylage and green chop hay)+(Land in Orchards)
- Cropland = (Total Cropland) - (Total Hayland) - (Total cropland, Cropland used only for pasture and grazing)
- Pasture = (Total cropland, cropland used only for pasture and grazing)+(Total woodland, woodland pasture)+(Other land, pastureland and rangeland other than cropland and woodland pasture)

Data in the Census of Agriculture are reported by county. The values reported by county were then multiplied by the fraction of each county within each watershed (Table 7) to estimate the total acreage within each watershed segment. For example, 46% of Washington County, Maryland is in Watershed Segment 180, so 46% of the reported acreage in the Census of Agriculture was applied to that segment. These acreages were then converted to the relative fraction of all agricultural land in each of the three agricultural land use categories (Hayland, Cropland, and Pasture; Table 8).

A large component of the urban land use in the watershed is actually highways and rural roads, many of which are not reflected in the MRLC database. To compensate for this missing information, a linear layer of roadways was clipped by Chesapeake Bay Model Segment, and divided based on the number of lanes. The total number of lane miles was then converted to the total acres of roadway by multiplying each lane by 12 feet.

The "transitional" land use category in the MRLC database was assumed to represent a combination of silviculture and active construction land uses. Active construction was represented as the total increase in urban land between 1992 and 1997, divided by 5 (to develop an average land developed per year), and then multiplied by 1.5, which assumes each construction site is in construction for 18 months. The calculation of total developed acreage between 1992 and 1997 is described in the Future Land Use section below.

Future Land Use

A population-based approach was used to forecast future land use in the watershed. The approach combined Natural Resources Inventory, MRLC land use data, and Chesapeake Bay population forecasts to project future land use in each model segment. The approach assumed a constant "urban land per individual" in each Watershed Segment, and used future population forecasts to predict a corresponding increase in urban land.

TABLE 7. FRACTION OF EACH COUNTY'S AREA IN EACH WATERSHED SEGMENT

	160	170	175	180	190	200	210	220	225	730	740	750
Maryland Counties												
WASHINGTON	0%	0%	9%	46%	0%	0%	0%	0%	0%	1%	44%	0%
MONTGOMERY	0%	0%	0%	0%	0%	0%	6%	48%	0%	0%	0%	0%
GARRETT	36%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
FREDERICK	0%	0%	0%	21%	0%	0%	72%	0%	4%	0%	0%	2%
CARROLL	0%	0%	0%	0%	0%	0%	45%	0%	0%	0%	0%	2%
ALLEGANY	63%	0%	40%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Pennsylvania Counties												
ADAMS	0%	0%	0%	1%	0%	0%	12%	0%	0%	5%	0%	30%
BEDFORD	13%	0%	16%	0%	0%	0%	0%	0%	0%	0%	0%	0%
FRANKLIN	0%	0%	0%	13%	0%	0%	0%	0%	0%	62%	5%	0%
FULTON	0%	0%	6%	0%	0%	0%	0%	0%	0%	0%	61%	0%
SOMERSET	11%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Virginia Counties												
AUGUSTA	0%	0%	0%	0%	75%	0%	0%	0%	0%	0%	0%	0%
CLARKE	0%	0%	0%	0%	0%	81%	0%	0%	0%	0%	19%	0%
FAIRFAX	0%	0%	0%	0%	0%	0%	0%	6%	0%	0%	0%	0%
FAUQUIER	0%	0%	0%	0%	0%	0%	0%	23%	0%	0%	0%	0%
FREDERICK	0%	0%	0%	0%	0%	29%	0%	0%	0%	0%	71%	0%
HIGHLAND	0%	26%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
LOUDOUN	0%	0%	0%	25%	0%	0%	0%	70%	0%	0%	0%	0%
PAGE	0%	0%	0%	0%	97%	3%	0%	0%	0%	0%	0%	0%
ROCKINGHAM	0%	0%	0%	0%	55%	45%	0%	0%	0%	0%	0%	0%
SHENANDOAH	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
WARREN	0%	0%	0%	0%	39%	62%	0%	0%	0%	0%	0%	0%
West Virginia Counties												
BERKELEY	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%
GRANT	51%	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
HAMPSHIRE	3%	28%	69%	0%	0%	0%	0%	0%	0%	0%	0%	0%
JEFFERSON	0%	0%	0%	22%	0%	46%	0%	0%	0%	0%	32%	0%
MINERAL	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
MORGAN	0%	0%	46%	0%	0%	0%	0%	0%	0%	0%	55%	0%
PENDLETON	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Table 8. Distribution of Ag Land by Segment

	hay	row crops	pasture
160	26%	17%	57%
170	15%	4%	81%
175	30%	18%	52%
180	23%	46%	31%
190	23%	17%	60%
200	27%	21%	53%
210	23%	55%	22%
220	25%	27%	48%
225	23%	53%	25%
730	27%	57%	17%
740	32%	30%	38%
750	36%	48%	17%

Data from the Natural Resources Inventory, as derived from the "State of the Land" website (www.nhq.nrcs.usda.gov/land/index), which reports results from the Natural Resources Inventory were combined with population data and current land use to develop an "urban land per person" number for each watershed. One complicating factor was that the change in population available through the State of the Land was reported by HUC-8 (See Figure 3) rather than by Watershed Segment. Thus, the following procedure was used, and data summarized in Table 9:

- Clip the MRLC land use and highway data by HUC-8 watershed to estimate the urban land in each HUC 8 in 1997.
- Apportion the Chesapeake Bay segment 1992 and 1997 population estimates into HUC 8 watersheds.
- Use the reported percent increase in developed land between 1992 and 1997 (from the "State of the Land" website to "hindcast" 1992 urban land.
- Divide the difference in urban land by the change in population to estimate the urban land per person in each HUC 8.

The urban land per person estimates were then converted into weighted urban land per person estimates by Chesapeake Bay Model Segment according to the fraction by area of each HUC 8 in each Chesapeake Bay Model Segment. This average urban land per person was then multiplied by the total increase in population between 1997 and 2020 (See Table 10) to estimate the increase in urban land in each Model Segment. The fraction of urban land in each land use category was assumed to be the same as in the 1997 land use layer. New urban land was subtracted from the forested land category.

Figure 2. HUC 8s in the Watershed

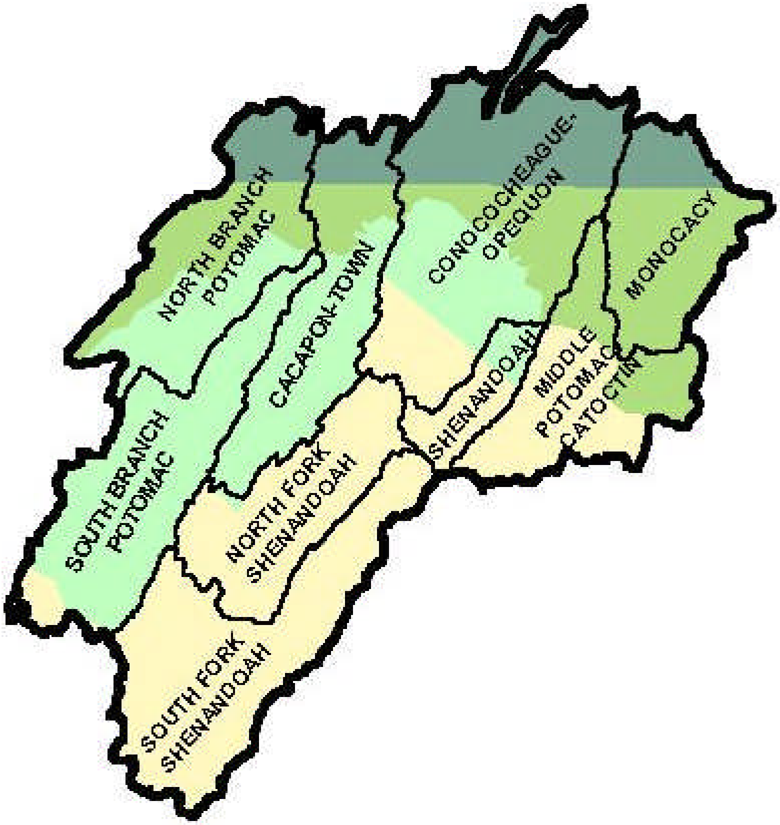


Table 9. Urban Land Per Person by HUC 8 Watershed

	Population Growth by HUC-8[1]					Land Use Change by HUC-8				Urban Land (Acre)/ new person (Increase in Urban Land/ # New People)
Huc8 name	**1992**	**1995**	**2000**	**1997 (Linear Interpolation Between 1995 and 2000)**	**# New People Between 1992 and 1997**	**1997 Acres of Urban Land (From MRLC)**	**%Change from 1992 to 1997 from State of the Land**	**1992 Acres of Urban Land[2]**	**Increase in Urban Land from 1992 to 1997**	
CACAPON-TOWN	29,328	30,344	30,998	30,606	1,278	9,005	19	7,567	1,438	1.13
CONOCOCHEAGUE	366,394	379,768	400,108	387,904	21,510	61,545	28	48,082	13,463	0.63
MIDDLE POTOMAC-CATOCTIN*	517,551	550,987	583,142	563,849	46,298	43,964	16	37,900	6,064	0.13
MONOCACY	220,058	237,680	265,524	248,818	28,760	25,550	32	19,356	6,194	0.22
NORTH BRANCH POTOMAC	114,423	114,490	116,427	115,265	842	23,322	17	19,934	3,389	4.03
NORTH FORK SHENANDOAH	74,092	77,318	81,313	78,916	4,824	22,085	11	19,896	2,189	0.45
SHENANDOAH	44,506	46,659	49,034	47,609	3,103	8,673	23	7,051	1,622	0.52
SOUTH BRANCH POTOMAC	29,181	30,156	29,659	29,957	776	10,337	28	8,076	2,261	2.91
SOUTH FORK SHENANDOAH	188,087	195,205	195,750	195,423	7,336	52,099	19	43,781	8,318	1.13

1: Based on population reports by county and Model Segment from Hopkins, et al. (2000)

2: Calculated using the equation: (1997 Urban Land) / (1+%Change/100)

TABLE 10. INCREASE IN URBAN LAND BY WATERSHED SEGMENT

	Distribution among HUC 8s	Weighted acres/person	1997 population	2020 population	Population Increase	Increase in Urban Land (acres)
160	North Branch Potomac	4.03	115,265	117,145	1,880	7,569
170	South Branch Potomac	2.91	29,957	31,582	1,625	4,733
175	Cacapon-Town 2% of Middle Potomac	0.99	30,667	35,149	4,482	4,440
180	15% of Conococheague 26% of Middle Potomac	0.26	169,359	201,838	32,479	8,307
190	South Fork Shenandoah	1.13	195,423	214,667	19,244	21,821
200	Shenandoah South Branch Potomac	0.82	126,524	158,291	31,767	26,085
210	Monocacy	0.22	216,517	304,417	87,900	18,931
220*	Middle Potomac	0.13	419,500	526,993	107,403	14,067
225**						391
730	Conococheague	0.63	83,868	89,597	5,729	3,586
740	Conococheague	0.63	204,981	265,489	60,508	37,871
750	Monocacy	0.22	32,301	38,493	6,192	1,334

* Segment 220 was clipped to include both estimated population growth and initial urban areas from within the Plant's Watershed only.

** Assumed to be 2.8% of the new urban land in 220, based on relative total segment area.

Active construction in the future is represented as the average land developed per year between 1997 and 2020, times 1.5. The increase in active construction over current levels is also subtracted from the forested land use.

All agricultural land uses are assumed to remain the same between 1997 and 2020. This assumption was based on an analysis of farmland from the Census of Agriculture between 1992 and 1997) which suggests a very slight increase (about 1%) during this period in the watershed.

Pollutant Sources

The Watershed Treatment Model divides pollutant sources into two major categories: Primary Sources and Secondary Sources. Primary Sources are typically described by broad land use categories, (e.g., pasture, cropland, single family residential). Secondary sources, on the other hand, are pollutant sources dispersed throughout the watershed whose magnitude cannot easily be estimated from readily available land use information. Many secondary sources are waste-water derived, such as Sops and septic systems. Others, such as active construction, produce land use-based loads, but typically include relatively small land areas that change rapidly.

Primary Sources

Loads from urban and non-urban primary sources are computed slightly differently in the Watershed Treatment Model. The loads from urban primary sources are calculated using the Simple Method (Schueler, 1987) to estimate the annual load. The Simple Method calculates this load by determining annual runoff based on total annual rainfall and a runoff coefficient derived from impervious cover in a drainage area or land use area. This runoff volume is then multiplied by a pollutant concentration to predict an annual pollutant load. As a simplification, concentrations for TSS, TP, and TN were used to characterize all urban land (Table 11). The impervious cover associated with each land use, and resulting annual load per acre per year, is also reported in Table 11. Loads from non-urban land uses are reported directly as pounds per acre per year.

TABLE 11. LOADING RATES FOR PRIMARY SOURCES IN THE WATERSHED TREATMENT MODEL

	Impervious Cover (%)	TN (lb/acre)	TP (lb/acre)	TSS (lb/acre)	Notes
Urban Land (Upper Watershed)					Note: Land Use in the watershed is primarily based on the MRLC database, which captures only more highly developed urban land uses. All urban loads calculated using the Simple Method (Schueler, 1987), and the following concentrations for urban runoff: TN: 2.2 mg/l (Smullen and Cave, 1998) TP: 0.4 mg/l (Smullen and Cave, 1998) TSS: 100 mg/l (US EPA, 1983)
Low Density Residential	35	6.5	1.2	297	
High Density Residential	85	14.6	2.7	663	
Commercial/ Industrial/Roads	90	15.4	2.8	700	
Rural Roads	100	17.0	3.1	773	
Grass/ Parks	10	2.3	0.4	107	
Rural Land					
Mining/ Quarries		0.2	0.5	334	Assumes 50% runoff coefficient, and the following concentrations: TN: 1.3 mg/l TP: 0.1 mg/l TSS: 82 mg/l
Cropland		11	3.9	660	TN and TP median values from Reckhow *et al.* (1980) TSS values from Smith *et al*., (1991) data for rangeland. Both values were adjusted upward so that cropland with 50% application of conservation tillage reflects literature values.
Pasture		4.6	0.7	100	TN and TP median values from Reckhow *et al.* (1980) TSS values from Smith *et al*., (1991)
Hay		4.6	0.7	100	Assumed the same as pasture
Forest		2.5	0.2	100	TN and TP median values from Reckhow *et al.* (1980) TSS values from Smith *et al.*, (1991)
Silviculture		9	2	300	Assumed the same as literature values for cropland.
Open Water		12.8	0.5	155	Derived from literature values for atmospheric deposition (See Caraco, 2001)

Secondary Sources

Several “Secondary Sources” also contributed to the total annual load of pollutants. Summary data required for these sources are included in Table 12. Default concentrations and other assumptions are described in this section, along with data sources.

TABLE 12. SUMMARY OF ALL SECONDARY SOURCES

	Current Estimates	Future Estimates	Notes
Septic Systems	Individuals on Septic	Future population growth	
Active Construction	Acres of active construction	Acres of active construction	ESC practices can be applied to this load
SSOs	Miles of Sanitary Sewer	Doesn’t change	Can repair SSOs
CSOs	Based on average flows per year, and literature concentrations	Doesn’t change	Can repair CSOs.
Illicit Connections	Based on number of households and businesses.	Doesn’t change	Can repair Illicit Connections
Channel Erosion	Difference between watershed loading rates and a typical sediment load for urban land. Future load based on percent increase in urban land.		Can be treated by upland flow control.
Lawns	Acres of lawn and assumed infiltration and subsurface concentrations	Acres of lawn in the future.	Impacted by education practices
Road Sanding	Road sand applied to open section versus closed section roads.	Increases with increase in roads.	Treated by street sweeping.
Point Source Dischargers	Discharge data	Future population growth	
Tile Drainage	Acres of cropland on poorly drained soils.	Remains the same	
Animal Waste	Animals by type	Doesn’t Change	

SEPTIC SYSTEMS

Watershed Treatment Model documentation provides detailed documentation of the assumptions used to calculate the loads from septic systems. The annual load from septic systems is calculated with the following assumptions:

1) 10% of all systems fail.
2) Of these, 10% are direct connections to the stream system (i.e., flow via surface flow). This small fraction of systems has concentrations similar to raw wastewater.
3) The remaining systems act as working systems.
4) Concentrations for working systems are:
   TSS 0 mg/L
   TP 0 mg/L
   TN 20 mg/L
5) Concentrations for failing systems (assuming that 10% are complete failures and 10% are failures to subsurface flow are:
   TSS 40 mg/L
   TP 1 mg/L
   TN 33 mg/L

The total number of individuals on septic systems is derived from septic system data from the Census of Agriculture. The Census Bureau has information from the 1990 census by county on the # of households on sewer, septic systems, or other means of sewage disposal. The total # of households was also obtained from this census to determine a % of households on sewer and septic systems. This information was aggregated to the HUC8 level, and average % on septic in each Watershed Model Segment was derived from these HUC-8 estimates based on the fraction of each Watershed Model Segment in each HUC-8. It is assumed that future growth in the watershed retains the same relative fraction of residents on septic, and that failure rates remain constant.

ACTIVE CONSTRUCTION

The load from active construction is calculated assuming a concentration of 680 mg/L (Schueler and Lugbill, 1991), and a runoff fraction of 50%, resulting in an uncontrolled load of 2,766 lbs/acre. This load can be controlled by ESC practices, as described in section 4 of this document. Areas of active construction were enumerated in Section 2.

SANITARY SEWER OVERFLOWS

SSOs are typically not tracked by communities in detail. However, some data on flows were available throughout the Potomac Watershed from a spreadsheet of CSO and SSO data obtained from the Maryland Department of the Environment. Data from these flows were sorted. Although the data were extremely variable, we used the median of all SSO flows greater than 2,000 gallons, resulting in an estimate of 32,500 gallons per overflow. The WTM default value of 140 SSOs per 1,000 miles of sanitary sewer (AMSA, 1994) was then used to estimate a typical annual flow from SSOs in each watershed segment. SSO concentrations are the following concentrations for wastewater (see Table 13):

Table 13. WTM Default Wastewater Characteristics

	Model Default	Source(s)
Sewer Use	70 gpcd	Metcalf and Eddy (1991)

TSS	400 mg/L	Based on a range of 237 to 600 mg/L (Metcalf and Eddy, 1991)
TP	10 mg/L	Based on a range of 10 to 27 mg/L (Metcalf and Eddy, 1991). The lower end of the range for phosphorus was used to account for programs to reduce phosphorus in wastewater.
TN	60 mg/L	Based on a range of 35 to 80 mg/L (Metcalf and Eddy, 1991)

In the watershed, the highly urbanized estimate of 118 feet per acre of development was applied to all urban land to develop an estimated miles of sanitary sewer in each watershed. Results are presented in Table 14.

TABLE 14. MILES OF SANITARY SEWER BY MODEL SEGMENT

Model Segment	Sanitary Sewer Length (miles)
160	40
170	58
175	72
180	262
190	852
200	429
210	283
220	715
225	10
730	190
740	435
750	66

COMBINED SEWER OVERFLOWS (CSOS)

Data input into the WTM to compute loads from CSOs included the location of CSOs, the average number of CSOs per location per year, average flow per CSO, and typical CSO concentrations. The location of CSOs was derived from two sources: the EPA listing of communities with combined sewer systems, and the Maryland Department of the Environment's list of known CSOs. These points appear on the wastewater maps produced as a part of this source water assessment. These data layers were then clipped by Chesapeake Bay Watersheds Segments to estimate the total number of CSO locations per segment.

The average number of CSOs per year and the average flow per CSO were derived from detailed analyses of three Maryland CSO communities: Frostburg, Cumberland, and LaVale. Average values of 0.466 MG per CSO and 176 CSOs per year were used in the WTM.

WTM default CSO concentrations were used, and included:

200 mg/L for TSS
2 mg/L for TP

10 mg/L for TN

ILLICIT CONNECTIONS

Illicit connections are extremely difficult to quantify, since relatively few municipalities even have programs in place to monitor them, and those that do not have easily available data about typical flows and concentrations associated with these illicit connections. Thus, very conservative estimates were used to quantify this pollutant source. Residential connections are assumed to be 1/1000, and assume a total wastewater load per person. Commercial connections use the following assumptions:

1) There is approximately 1 business per acre of industrial or commercial land use.
2) 10% of businesses have illicit connections
3) Of these, 10% are complete connections (including sanitary wastewater); the remainder are washwater only.
4) Concentrations for sanitary connections are the same as wastewater.
5) Concentrations for washwater only are as follows:
   TN: 15 mg/l, TP: 10 mg/l, TSS: 100 mg/l
6) Flows are 50 gpd for a washwater only connection, and 150 gpd for a complete connection.

CHANNEL EROSION

Channel erosion for current conditions was calculated as 1000 lb/acre of urban land minus the load from all other urban sources of sediment. Future channel erosion was simply determined as existing channel erosion times the ratio of the total future area of urban land to the total current area of urban land.

LAWNS

Loads from urban lawns used WTM default values, and are quantified as the loads lost to groundwater. Total lawn area is calculated as 80% of the non-impervious urban land in each model segment.

ROAD SANDING

Road sand can be a significant source of sediment. Road sand application rates were derived from highway department data. These data (See Table 20) provide an estimate of the typical annual application of road sand to highways in a year. These rates of application, combined with estimates of the fraction of roads that are open section, were adapted to estimate the load from road sanding

The primary source of information was the application rates by state described in Table 20, and a GIS layer of road lengths clipped by watershed. The following assumptions were made.

- Roads from the GIS roads theme were classified into these groups as follows:

Interchange	1 lane
Miscellaneous road	2 lanes
Primary route	6 lanes
Road/street class 3	2 lanes
Road/street class 4	2 lanes
Secondary route	4 lanes
Toll road	6 lanes

- Roads that are non-highway (i.e., roads 50% of all roads with 4 lanes, and all roads with 1 or 2 lanes) have an application rate only 50% of reported highway application rates, and are classified as “rural roads”.
- Rural roads are classified as open section.

TABLE 20. ROAD SANDING INFORMATION

Source	Information	Model Default Informatoin
WV Department of Highways	0.20 tons sand/lane mile/year 0.86 tons cinders/lane mile/year	1.06 tons/lane mile/year
VADOT, Staunton District	1.47 tons coarse material/lane mile/year 0.14 tons fine material/lane mile/year	1.61 tons/lane mile/year
MD SHA	1.66 tons/lane mile/year	1.66 tons/lane mile/year. Also applies to Pennsylvania.

This road information was originally aggregated at the HUC-8 level. For each HUC-8, the clipped road layer was used to derive a weighted sand application rate, based on the overlay of states and highways in the HUC-8 to develop a typical “highway application rate.” This application rate was then adjusted based on the fraction of roads in the HUC-8 that were actually rural roads. A weighted application rate was then developed using the following equation:

$$L_w = L_H (f+1)/2$$

Where:

L_w = Weighted Application Rate
L_H = Highway Application Rate
f = Fraction of roads that are highways

POINT SOURCE DISCHARGERS

The total load from point source dischargers for nitrogen and phosphorus was obtained from the Chesapeake Bay Program Data (Wiedeman and Cosgrove, 1998), which reported point source loads by segment for both 1995 and projected 2000 load. The load for 1997 was determined by interpolating between 1995 and 2000 values reported in that publication. Loads for sediment were determined by summarizing permit data from the EPA’s Permit Compliance System for 1997. Future loads were forecasted simply by multiplying current loads by the ratio of future population to current population. These values are reported in Table 21.

TABLE 21. POINT SOURCE LOADS

Segment	TN	TP	TSS
190	630,781	119,346	8,121,507
170	21,993	8,349	31,677
175	3,129	404	1,717
180	437,015	78,166	481,908
190	1,120,355	209,253	671,387
200	431,794	94,715	45,043

210	592,204	108,580	584,679
220	286,189	30,192	70,214
730	571,360	129,611	497,393
740	603,568	90,046	431,411
750	64,579	5,762	98,655

TILE DRAINAGE

Tile drains are put in place to drain fields where farming occurs on poorly drained soils. Nutrients applied to farmed land with tile drainage are not filtered by soils before reaching surface waters. Consequently, these areas have higher surface loading rates than farmed land without tile drains. The WTM default loading rates for nitrogen and phosphorus for tile drainage are from Loehr (1974) at 13.1 lb/acre for TN and 0.21 lb/acre for TP. These are values for fertilized corn on tile drainage.

In order to estimate the total area of tile drainage, soils information was obtained for the watershed from the USDA NRCS's State Soil Geographic (STATSGO) database (1994). The GIS layers obtained contained a field with drainage information. All records with poorly drained, somewhat poorly drained, or very poorly drained in the drainage field were selected and made into a new data layer. All cells corresponding to cropland from the MRLC landuse data were selected and intersected poorly drained soils to generate areas of tile drainage.

Because the original areas of cropland derived from the MRLC were adjusted when producing the area of cropland, we also adjusted the area of tile drainage accordingly, using the following equation:

$$T_f = T_0 X(C_f/C_0)$$

Where:

T_f = Final estimated area of tile drainage (acres)

T_0 = Initial estimate of the area of tile drainage, based on clipping of the MRLC database(acres)

C_f = Final estimate of cropland acreage, based on adjustments using the Census of Agriculture (acres)

C_0 = Initial estimate of the area of cropland, based on clipping of the MRLC database (acres)

ANIMAL WASTE

Loads from animal waste were characterized by a load per animal for nitrogen and phosphorus loading rates. The Chesapeake Bay Watershed Model characterizes these loadings by assuming a nitrogen or phosphorus load from manure per animal, and quantifying the number of animals in confined areas exposed to runoff. This Watershed Model then incorporates continuous modeling to determine the fraction of these nutrients that reach waterways. Since the Watershed Treatment Model does have the ability to simulate continuous runoff and nutrient cycling, these animal waste loading values were combined with available nutrient export data (Reckhow, 1980) to develop unit loading factors per animal.

The export data from Reckhow (1980) for feedlots is primarily from dairy feedlots. The typical load is approximately 2,768 lb/acre/year for nitrogen, and 268 lb/acre/year for phosphorus. Data from the Chesapeake Bay Program (Palace, et al., 1998) suggest that the annual nitrogen load from cows is approximately 123 lb/cow animal unit/year for nitrogen and 21 lb/cow animal unit/year for phosphorus. Using these factors as a template. Assuming 145 animal units per acre, the resulting manure rates are 17,800 lb/acre/year of nitrogen and 3,050 lb/acre/year of phosphorus. Dividing these manure rates by the loading rates reported in Reckhow resulted in delivery factors of approximately 0.16 for nitrogen and 0.09 for phosphorus. These delivery ratios, combined with animal waste load data (Palace et al., 1998) were used to develop an annual nutrient load (delivered) per animal per year as follows:

- Dairy: 27 lb TN, 3.0 lb TP
- Swine: 5.0 lb TN, 0.67 lb TP
- Poultry (Layers): 0.15 lb TN, 0.036 lb TP
- Poultry (Broilers): 0.48 lb TN, 0.08 lb TP

The 1997 Census of Agriculture was then used to sum up animal numbers by Watershed Segment, according to the numbers recorded by County, and the portion of each county in each Watershed Segment (Table 22). While some animals, such as beef cattle, were recorded in the watershed, they were not incorporated into these waste load estimates because their waste load is assumed to be incorporated into pasture loading rates. In addition, Based on Chesapeake Bay Program assumptions (Palace et al., 1998), it was assumed that only 15% of poultry were exposed to runoff. Thus, the data derived from Table 22 were used directly for swine and dairy, but multiplied by 15% for poultry for use in the WTM.

TABLE 22. NUMBER OF ANIMALS BY WATERSHED SEGMENT.

Segment	SWINE	DAIRY	LAYERS	BROILERS	TURKEYS
160	2,760	7,416	28,030	214,028	5,628
170	1,466	149	59,305	628,195	137,038
175	4,466	5,055	17,480	88,105	1,158
180	20,244	20,284	62,926	7,700	18,995
190	8,207	22,246	242,957	2,600,899	655,708
200	6,833	16,864	139,477	1,614,577	404,747
210	10,533	26,060	108,346	2,588	42,558
220	1,037	2,649	350	25	64
225	228	1,255	1,719	0	1,695
730	65,184	27,673	156,846	36,443	49,229
740	22,055	15,933	31,631	2,697	15,781
750	6,389	3,120	73,714	6,250	36,857
Total	149,400	148,702	922,781	5,201,507	1,369,459

Management Practices

A wide suite of practices was considered in both the watershed (Table 23). This section summarizes the assumptions used to characterize these practices.

TABLE 23. MANAGEMENT PRACTICES FOR WTM MODELING

AGRICULTURAL PRACTICES	
Practice	**Land Applied To**
Conservation Tillage	Cropland
Nutrient Management	Cropland, Hayland
Water Quality Plan	Cropland, Hayland, Pasture
Cover Crop	Cropland
Tree Planting	Cropland, Hayland, Pasture
Buffer	Cropland, Hayland
Highly Erodible Land Retirement	Cropland, Hayland
Grazing Land Protection	Pasture
Animal Waste Management	Animal Waste
Stream Fencing	Pasture
URBAN PRACTICES	
Practice	**Land Applied To**
Structural Treatment Practices	All Urban Land
Erosion and Sediment Control	Active Construction
Lawn Care Education	All Lawns (Institutional, Residential, Commercial)
Pet Waste Education	All Urban Land
Street Sweeping	Streets, Roads an Highways
Impervious Cover Disconnection	Commercial and Residential Roofs
Riparian Buffers	All Urban Land

Agricultural Practices

Agricultural practices were applied with the following assumptions:

1) In general, efficiencies reported were those reported by the Chesapeake Bay Program
2) The WTM applies practices in series, and assumes that each successive practice can treat only the remaining load after previous practices have been applied. For example, a practice that is 50% efficient will only be 10% efficient if it follows a practice with an 80% efficiency. In addition, the WTM applies two discount factors to agricultural practices. The first is an implementation factor which accounts for the level of implementation on targeted farms. The second is a discount factor applied to practices in series, which reduces efficiencies by 50% when applied as the second, third or fourth in a series.

Most of the efficiencies for these practices are provided in Table 24. Two practices are reflected not by an efficiency but by a shift in land use in the Chesapeake Bay Model. These are tree planting and retirement of Highly Erodible Land. A similar method was used for application of these practices in the Watershed Treatment Model.

TREE PLANTING

Tree planting is reflected by shifting any land use where this practice is applied to forest. This is accomplished by applying an efficiency equal to:

$$E = 1 - L_f/L_{lu}$$

Where:

E = Efficiency (as a fraction)
L_f = Load from Forest (lb/acre/year)
L_{lu} = Load from Land Use where Trees are Planted (lb/acre/year)

HIGHLY ERODIBLE LAND RETIREMENT

Highly erodible land is characterized as having four times the load of cropland. This load is subtracted from the total load for the land use where this practice is applied.

TABLE 24. EFFICIENCIES FOR AGRICULTURAL PRACTICES

Practice	Efficiency (%)			Notes
	TN	TP	TSS	
Conservation Tillage	40	70	75	Source: Palace, et al. (1998)
Nutrient Management	40	40	0	See Text
Water Quality Plan (Cropland)	10	40	40	Source: Palace, et al. (1998)
Water Quality Plan (Pasture)	40	14	14	Source: Palace, et al. (1998)
Water Quality Plan (Hay)	4	8	8	Source: Palace, et al. (1998)
Cover Crop	43	15	15	Source: Palace, et al. (1998)
Buffer	50	70	70	Source: Palace, et al. (1998); forest buffer
Grazing Land Protection	50	25	25	Source: Palace, et al. (1998)
Animal Waste Management (Swine and Dairy)	80	80	0	Source: Palace, et al. (1998)
Animal Waste Management (Poultry)	15	15	0	Source: Palace, et al. (1998)
Stream Fencing	75	75	75	Source: Palace, et al. (1998)
Highly Erodible Land Retirement	See Text			
Tree Planting	See Text			

APPLICATION OF AGRICULTURAL PRACTICES

Agricultural practice data were derived from the Chesapeake Bay Program's Database for 2000 (See Appendix A). Only practices listed in Table 24 were extracted and applied. In many cases, the total acreage in practices was greater than the total acreage in a particular land use. In many segments the total acreage in practices on conservation till cropland exceeded the total acreage of conservation tillage, and this also occurred on conventional till cropland. Where this occurred, agricultural practices were applied in series, so that the total acreage in a particular land use was never exceeded, but the total acreage in each practice as reported by the Chesapeake Bay Program was maintained. This was typically achieved by applying "nutrient management" in combination with "water quality plan." Each practice would be applied as a stand alone practice, with another representation of the practices as joint so that the total acreage in each practice was the same as reported by the Chesapeake Bay Program, yet the total acreage in cropland remained constant. In one case (Segment 225) this methodology was also used on hay.

In a few segments (190, 220, and 225), this technique was not effective because, even if all of the nutrient management and water quality plan practices were applied in series, the total acreage in practices would still exceed the total acreage of the land use in these segments. A slightly different solution to the problem was employed in these segments. In segment 190, there was a large amount of nutrient management on conservation till cropland. The solution here was to apply nutrient management in series with several other practices (cover crop, tree planting, buffer, and water quality plan) to achieve the reported acreage of nutrient management.

In segment 220, there was a large amount of cover crop and nutrient management. Nutrient management was applied in series along with cover crops in addition to being applied in series with water quality plan to achieve an acceptable practice distribution.

In segment 225, the Chesapeake Bay Program reported a large amount of cover crop applied on conservation till land. Thus, this practice was applied in series with several other practices to achieve the total acreage in cover crop applied to conservation till cropland without exceeding the total acreage in conservation till cropland.

Urban Practices - Current

Urban practices were selected from the list of practices available from the original version of the Watershed Treatment Model (Caraco, 2001), which included urban practices only. This section describes how these practices were incorporated into the Watershed Treatment Model, and any modifications made to the original assumptions of the model.

In addition to any efficiencies applied to treatment practices, the Watershed Treatment Model includes a series of "Discount Factors" that are applied to practices to reflect the level of implementation and long-term maintenance of the various practices. Discount factors are applied as multiplicative factors to adjust the load reduction. For example, if a practice removes 100 lbs/year of nitrogen, but has a single discount factor of 0.9, the removal is reduced to 90 lbs/year. If there were two discount factors of 0.9 and 0.5, the total removal would be 100X0.9X0.5, or 45 lbs/year of nitrogen. This section also discusses how discount factors were selected for each practice.

STRUCTURAL TREATMENT PRACTICES

Structural treatment practices were applied in the watershed. Assumptions were used to estimate probable practice distribution in the watershed.

PRACTICE DISTRIBUTION

Very little information was available to determine the extent to which structural practices have been employed over time. However, based on general knowledge of the area, and the state of stormwater practices throughout the region, it was assumed that 5% of all development is served by dry ponds, and that 2.5% is served by wet ponds.

PRACTICE EFFICIENCIES

Efficiencies for these practices are derived from Winer (2000) as follows:

TABLE 25. POLLUTANT REMOVAL FOR STRUCTURAL PRACTICES

	TN	TP	TSS
Dry Ponds	25%	19%	47%
Wet Ponds	33%	51%	80%
Wetlands	30%	49%	76%

DISCOUNT FACTORS FOR STRUCTURAL TREATMENT PRACTICES

The Watershed Treatment Model applies three discount factors to structural treatment practices: a capture discount to account for the fraction of annual rainfall captured by the practices, a design discount to reflect the design standards in place at the time that the practices were built, and a maintenance discount to reflect upkeep of the practice over time. A uniform set of discount factors was used to characterize practices in the watershed. These included:

- 0.9 for the "capture discount" (assumes 90% capture of annual runoff)
- 1.0 for the "design discount" (assumes typical design standards)
- 0.6 for the "maintenance discount" (assumes that relatively little maintenance occurs over time)

EROSION AND SEDIMENT CONTROL

The WTM represents erosion and sediment control with a single efficiency, a "treatability" factor to reflect the fraction of development required to implement sediment control measures, a "compliance discount" to reflect the fraction of practices installed, and an "implementation/maintenance" discount to reflect the fraction of practices that are installed and maintained properly. A uniform set of assumptions was used to characterize erosion and sediment control practices, including:

- Practice Efficiency of 70%
- Treatability Factor of 0.8
- Compliance Discount of 0.7
- Installation/ Maintenance Discount of 0.6

LAWN CARE EDUCATION

It is assumed that some level of lawn care education exists throughout the watershed. The WTM makes several default assumptions about reductions achieved through lawn care education. These include:

- 78% of the population fertilizes their lawns
- 65% of these people overfertilize
- Overfertilizers apply approximately 150lb/acre-year of N and 15 lb/acre-year of P
- A successful lawn care education will cause people to reduce fertilizer application by 50%
- 25% of N and 5% of P applied to lawns is "lost" to the environment, either as surface runoff or as infiltration.
- Of the people who receive and remember information about lawn care practices, 70% are willing to change their behavior.

The remaining input parameter to characterize lawn care education is the fraction of the population that receives, understands and remembers information about more environmentally sensitive lawn care practices. It is assumed that 20% of the population matches this description.

STREET SWEEPING

The WTM characterizes street sweeping by typical street efficiencies, applied to loads from roadways. The only discount factor applied is a "technique discount" which represents the fraction of the road that is actually swept (e.g., parked cars do not interfere, etc.). In addition, any street sweeping reduces loads from road sanding applies a reduction in road sanding equal to the "technique discount" times the road sanding load from the street area swept. It is assumed that 30% of all non-residential streets are swept on a monthly basis using a mechanical sweeper, with a technique discount of 0.8.

IMPERVIOUS COVER DISCONNECTION

Impervious cover disconnection was not explicitly accounted for.

RIPARIAN BUFFERS

The WTM reflects stream buffers as the length of stream channel covered by buffers times the typical buffer width. This practice is treated separately from agricultural buffers because buffers in agricultural areas have different efficiencies, and also are not applied to urban sources. It was assumed that 5% of the urban stream channel was treated by stream buffers. Urban stream length was estimated as 4 miles of urban stream channel per square mile of urban drainage. A fifty foot buffer width was assumed.

Urban Practices – Future Development

The change in future land use is reflected as an increase in urban land. Except in management scenarios (described in Section 5), the controls on future development are reflected based on existing programs in place within a watershed segment. Overall, it was assumed that lawn care education, erosion and sediment control, and street sweeping practices remained the same (i.e., the same fraction of development regulated as in the current situation). Management of stormwater was explicitly treated differently for new development versus existing development, however. This management was reflected by the fraction of development regulated for water quality, and the fraction of new development where flow control (i.e., control of the 1-year storm or similar "new" channel protection requirements) was in place.

The management of stormwater for future development was characterized based on the fraction of a segment in each state. The following assumptions were made (Table 26).

TABLE 26. CONTROLS ON NEW DEVELOPMENT BY STATE

State	Flow Control (%)	Water Quality Control (%)
Maryland	45	90
Pennsylvania	0	70
Virginia	0	70
West Virginia	0	25

Management Scenarios

Three management scenarios were modeled: "current management", "improved management", and "aggressive management." The "current management" scenario was described in section 4. It is reflected by existing management practices, along with future urban practices as described in Section 4.3. The two other scenarios are reflected by changes in both the existing practices and future management practices.

Management techniques included adjustments to loads from point sources, urban practices, and agricultural practices. Each practice category is described below.

POINT SOURCES

For point sources, the original database of loads and flows derived from the Chesapeake Bay Program (Wiedemen and Cosgrove, 1998) were used to develop new point source loads using revised average concentrations. For the "improved management" scenario, concentrations of 8.0 mg/L TN and 0.5 mg/L TP were used. These concentrations represent BNR nitrogen removal and fairly aggressive phosphorus control. In the "aggressive management" scenario, Limit of Technology (LOT) concentrations were used to characterize outflow concentrations (3.0 mg/L for TN and 0.075 mg/L for TP). Resulting loads are reported in Table 27.

TABLE 27. POINT SOURCE LOADS

Segment	Flow (MGD)	Load (Improved) (lb/year)		Load (Aggressive) (lb/year)	
		TN	TP	TN	TP
190	35.46	630,781*	55,449	332,695	8,317
170	0.42	10,508	657	3,941	99
175	0.07	1,751	109	657	16
180	11.6	290,225	18,139	108,834	2,721
190	32.58	815,132	50,946	305,674	7,642
200	5	125,097	7,819	46,911	1,173
210	15.7	392,804	24,550	147,302	3,683
220	8.78	219,670	13,729	82,376	2,059
730	8.38	209,662	13,104	78,623	1,966
740	9.94	248,693	15,543	93,260	2,331
750	3.12	64,579*	4,879	29,273	732

* Same as existing load without controls.

URBAN MANAGEMENT PRACTICES

In the Upper Watershed, urban management practices were reflected as a change in the management of new development, along with improved erosion and sediment control. The change in the management of new development included: reducing impervious cover and providing better and more widespread stormwater management.

“Better Site Design” techniques were reflected by reducing the impervious cover associated with certain land use classes. The assumptions for this analysis included, for both the improved management an aggressive management scenario (Schueler and Caraco, 2001):

- 25% of new development occurs with better site design
- Impervious cover for low density residential uses can be reduced by 30%
- Impervious cover for high density residential uses can be reduced by 15%
- Impervious cover for industrial/commercial uses can be reduced by 15%

In addition, the improved management scenarios assume a higher level of stormwater management on new development, reflected by higher discount factors and a greater fraction of development regulated and employing flow control measures. In the improved management scenario, it is assumed that 80% of new development requires water quality control (or at least as high as in the existing scenario), and that 50% requires channel protection flow control. For the aggressive management scenario, these values are increased to 90% and 75%, respectively. The maintenance discount factor is increased to 0.9 (from 0.7) for both scenarios.

Improved erosion and sediment control was reflected as an increase in the fraction of sites controlled, and higher discount factors. For both the improved management and aggressive management scenarios, it was assumed that 90% of sites are regulated, with compliance and maintenance discount factors of 0.9.

AGRICULTURAL MANAGEMENT PRACTICES

In the aggressive management scenario, the following assumptions were made:

- 80% of all cropland and hayland will employ nutrient management or farm plans
- 75% of all cropland will be in conservation tillage
- Buffers will be increased, based on statewide commitments of buffer restoration by Chesapeake Bay States.
- 90% of animal waste load can be treated by animal waste management systems.
- The total land treated by a particular practice is not reduced in any segment.

The bufffer assumption involved distributing the miles of stream committed to be restored in a state among each model segment, based on the total area. This was accomplished by multiplying the total miles to be restored within the state by the fraction of the state’s Chesapeake Bay Drainage within that segment. This gives the miles of buffer within each state. It was then assumed that buffers can treat 1,000 feet of agricultural land. These buffers were then divided among the agricultural land uses in the watershed based on the fraction of each use in the watershed. For example, if 75% of the agricultural land is in cropland, 75% of the buffer will be applied to cropland. For pasture, the buffer is reflected as stream fencing.

For the "increased management" scenario, agricultural practices were characterized by a reduction that is the average of the existing management scenario and the "aggressive management" scenario. Rather than applying a separate suite of practices for this scenario, this single removal value was used.

Results

Only a modest change could be achieved in each segment by management practices, and this change was achieved primarily through point source controls, and agricultural management practices.

Overall, modeling results showed little change, particularly for sediment, in the watershed. Management practices were able to reduce nutrient loads somewhat, however. Table 29 summarizes these results, both in annual loading rate, and as a fraction of existing loads. Tables 30, 31 and 32 report loads from urban sources, agricultural sources, and point sources for each scenario. Overall, point source nutrient loads could be changed significantly under the very aggressive treatment scenario, and urban loads typically increased, even with treatment. This increase in urban load did not typically increase the overall load from a segment significantly, however, because of the small amount of urban land as derived from the MRLC database.

TABLE 29 TOTAL LOAD IN THE UPPER WATERSHED UNDER VARIOUS SCENARIOS (LB/YEAR)

		TN		TP		TSS	
Segment		Load	Load as a Fraction of Current Conditions	Load	Load as a Fraction of Current Conditions	Load	Load as a Fraction of Current Conditions
160	Current	3,994,032		444,772		125,190,785	
	Future-scenario 1	4,083,269	1.02	460,418	1.04	128,753,795	1.03
	Future-scenario 2	4,030,840	1.01	381,841	0.86	125,414,979	1.00
	Future-scenario 3	3,687,056	0.92	326,449	0.73	123,685,585	0.99
170	Current	3,394,043		352,373		107,019,628	
	Future-scenario 1	3,464,938	1.02	363,320	1.03	109,367,367	1.02
	Future-scenario 2	3,370,276	0.99	339,701	0.96	106,365,921	0.99
	Future-scenario 3	3,258,536	0.96	322,415	0.91	105,017,243	0.98
175	Current	2,902,869		306,830		101,093,244	
	Future-scenario 1	2,963,603	1.02	316,627	1.03	105,322,073	1.04
	Future-scenario 2	2,854,209	0.98	287,952	0.94	101,436,130	1.00
	Future-scenario 3	2,753,779	0.95	267,305	0.87	98,767,819	0.98
180	Current	3,030,681		437,154		79,624,314	
	Future-scenario 1	3,145,031	1.04	452,841	1.04	83,675,084	1.05
	Future-scenario 2	3,070,257	1.01	371,754	0.85	75,089,288	0.94
	Future-scenario 3	2,499,727	0.82	289,459	0.66	67,791,757	0.85

TABLE 29 TOTAL LOAD IN THE UPPER WATERSHED UNDER VARIOUS SCENARIOS (LB/YEAR)

		TN		TP		TSS	
Segment		Load	Load as a Fraction of Current Conditions	Load	Load as a Fraction of Current Conditions	Load	Load as a Fraction of Current Conditions
190	Current	6,718,384		894,517		173,191,353	
	Future-scenario 1	6,996,572	1.04	942,295	1.05	189,176,788	1.09
	Future-scenario 2	6,424,317	0.96	699,835	0.78	173,292,786	1.00
	Future-scenario 3	5,701,491	0.85	648,314	0.72	165,867,917	0.96
200	Current	4,926,357		674,956		136,245,402	
	Future-scenario 1	5,239,044	1.06	727,275	1.08	154,825,293	1.14
	Future-scenario 2	4,630,243	0.94	552,337	0.82	138,620,252	1.02
	Future-scenario 3	4,298,035	0.87	505,841	0.75	130,302,900	0.96
210	Current	5,001,473		634,321		113,027,598	
	Future-scenario 1	5,344,253	1.07	671,006	1.06	122,911,636	1.09
	Future-scenario 2	5,263,233	1.05	559,895	0.88	109,583,364	0.97
	Future-scenario 3	4,588,425	0.92	457,688	0.72	96,067,450	0.85
220	Current	3,678,478		379,800		103,401,765	
	Future-scenario 1	3,862,304	1.05	402,466	1.06	109,991,490	1.06
	Future-scenario 2	3,757,955	1.02	366,400	0.96	101,798,583	0.98
	Future-scenario 3	3,543,587	0.96	334,861	0.88	96,567,150	0.93

TABLE 29 TOTAL LOAD IN THE UPPER WATERSHED UNDER VARIOUS SCENARIOS (LB/YEAR)

225	Current	204,660		19,899		4,456,014	
	Future-scenario 1	215,557	1.05	20,716	1.04	4,505,259	1.01
	Future-scenario 2	210,351	1.03	19,342	0.97	4,272,507	0.96
	Future-scenario 3	205,205	1.00	18,030	0.91	4,030,644	0.90
730	Current	3,581,213		551,762		69,484,093	
	Future-scenario 1	3,636,201	1.02	560,598	1.02	71,516,746	1.03
	Future-scenario 2	2,797,318	0.78	361,083	0.65	65,129,409	0.94
	Future-scenario 3	2,180,744	0.61	274,019	0.50	59,622,397	0.86
740	Current	5,217,122		678,398		150,138,598	
	Future-scenario 1	5,744,228	1.10	745,906	1.10	168,848,087	1.12
	Future-scenario 2	5,064,339	0.97	590,726	0.87	153,801,686	1.02
	Future-scenario 3	4,606,717	0.88	505,793	0.75	142,649,172	0.95
750	Current	1,017,363		146,643		26,984,822	
	Future-scenario 1	1,042,878	1.03	149,532	1.02	27,929,673	1.04
	Future-scenario 2	1,018,302	1.00	131,925	0.90	24,472,303	0.91
	Future-scenario 3	831,836	0.82	97,108	0.66	21,318,850	0.79

TABLE 30 POINT SOURCE LOADS UNDER EACH SCENARIO (LBYEAR)

Segment		TN	TP	TSS
160	Current	630,781	119,346	8,121,507
	Future-scenario 1	640,873	121,256	8,251,451
	Future-scenario 2	640,873	56,336	8,251,451
	Future-scenario 3	338,018	8,450	8,251,451
170	Current	21,993	8,349	31,677
	Future-scenario 1	22,345	8,483	32,184
	Future-scenario 2	10,676	668	32,184
	Future-scenario 3	4,004	100	32,184
175	Current	3,129	404	1,717
	Future-scenario 1	3,179	411	1,744
	Future-scenario 2	1,779	111	1,744
	Future-scenario 3	667	17	1,744
180	Current	437,015	78,166	481,908
	Future-scenario 1	444,007	79,417	489,619
	Future-scenario 2	294,869	18,429	489,619
	Future-scenario 3	110,576	2,764	489,619
190	Current	1,120,355	209,253	671,387
	Future-scenario 1	1,138,280	212,601	682,129
	Future-scenario 2	828,174	51,761	682,129
	Future-scenario 3	310,565	7,764	682,129
200	Current	431,794	94,715	45,043
	Future-scenario 1	438,703	96,230	45,764
	Future-scenario 2	127,099	7,944	45,764
	Future-scenario 3	47,662	1,192	45,764
210	Current	592,204	108,580	584,679
	Future-scenario 1	601,679	110,318	594,034
	Future-scenario 2	399,089	24,943	594,034
	Future-scenario 3	149,658	3,741	594,034
220	Current	286,189	30,192	70,214

TABLE 30 POINT SOURCE LOADS UNDER EACH SCENARIO (LBYEAR)

Segment		TN	TP	TSS
	Future-scenario 1	290,768	30,675	71,337
	Future-scenario 2	223,185	13,949	71,337
	Future-scenario 3	83,694	2,092	71,337
225	Current	-	-	-
	Future-scenario 1	-	-	-
	Future-scenario 2	-	-	-
	Future-scenario 3	-	-	-
730	Current	571,360	129,611	497,393
	Future-scenario 1	580,502	131,685	505,351
	Future-scenario 2	213,017	13,314	505,351
	Future-scenario 3	79,881	1,997	505,351
740	Current	603,568	90,046	431,411
	Future-scenario 1	613,225	91,487	438,314
	Future-scenario 2	252,672	15,792	438,314
	Future-scenario 3	94,752	2,369	438,314
750	Current	64,579	5,762	98,655
	Future-scenario 1	65,612	5,854	100,233
	Future-scenario 2	65,612	4,957	100,233
	Future-scenario 3	29,741	744	100,233

TABLE 31. URBAN NON-POINT SOURCE LOADS UNDER EACH SCENARIO				
Segment		TN	TP	TSS
160	Current	553,182	69,254	25,830,154
	Future-scenario 1	649,942	84,400	29,967,812
	Future-scenario 2	637,268	80,433	27,771,667
	Future-scenario 3	636,095	79,846	27,184,944
170	Current	283,583	35,311	11,601,094
	Future-scenario 1	365,034	46,997	14,384,631
	Future-scenario 2	358,373	43,298	12,579,586
	Future-scenario 3	358,068	43,146	12,427,425
175	Current	245,575	34,174	13,872,983
	Future-scenario 1	317,132	44,836	18,536,838
	Future-scenario 2	308,068	42,081	17,124,361
	Future-scenario 3	307,678	41,886	16,929,516
180	Current	414,587	48,526	19,829,512
	Future-scenario 1	542,102	64,575	24,678,875
	Future-scenario 2	532,526	61,443	22,728,930
	Future-scenario 3	532,173	60,994	22,067,249
190	Current	1,066,968	132,391	58,176,244
	Future-scenario 1	1,386,162	181,536	76,508,197
	Future-scenario 2	1,317,687	162,602	65,200,654
	Future-scenario 3	1,312,560	160,038	62,637,191
200	Current	632,310	82,778	34,963,368
	Future-scenario 1	1,002,674	138,748	56,125,941
	Future-scenario 2	953,035	122,157	45,631,067
	Future-scenario 3	947,820	119,550	43,023,882
210	Current	700,621	58,119	21,525,876
	Future-scenario 1	1,083,625	97,043	33,388,563
	Future-scenario 2	1,071,821	93,373	31,233,810
	Future-scenario 3	1,062,579	90,032	28,891,415

TABLE 31. URBAN NON-POINT SOURCE LOADS UNDER EACH SCENARIO

Segment		TN	TP	TSS
220	Current	909,478	99,830	44,822,722
	Future-scenario 1	1,120,608	124,564	52,686,661
	Future-scenario 2	1,100,016	117,542	47,990,634
	Future-scenario 3	1,096,547	115,807	46,256,080
225	Current	21,154	2,037	862,871
	Future-scenario 1	32,867	2,919	944,751
	Future-scenario 2	32,611	2,842	899,600
	Future-scenario 3	32,416	2,771	850,617
730	Current	338,503	36,754	14,206,601
	Future-scenario 1	392,968	44,206	16,576,038
	Future-scenario 2	404,369	42,654	15,376,484
	Future-scenario 3	403,731	42,335	15,057,254
740	Current	844,432	95,154	38,030,571
	Future-scenario 1	1,458,037	168,913	60,579,429
	Future-scenario 2	1,423,915	158,322	54,593,907
	Future-scenario 3	1,417,353	155,042	51,313,050
750	Current	118,429	12,863	4,893,353
	Future-scenario 1	146,343	15,934	5,973,915
	Future-scenario 2	144,449	15,289	5,547,843
	Future-scenario 3	144,204	15,167	5,425,689

TABLE 32. AGRICULTURAL NON-POINT SOURCE LOADS UNDER EACH SCENARIO

Segment		TN	TP	TSS
160	Current	2,231,461	235,632	89,760,114
	Future-scenario 1	2,213,846	234,223	89,055,522
	Future-scenario 2	2,195,385	228,094	87,912,851
	Future-scenario 3	2,176,924	221,965	86,770,179
170	Current	2,694,597	279,070	94,593,257
	Future-scenario 1	2,683,689	278,197	94,156,953
	Future-scenario 2	2,607,544	266,095	92,960,551
	Future-scenario 3	2,531,397	253,992	91,764,034
175	Current	2,268,273	249,726	86,389,603
	Future-scenario 1	2,257,400	248,855	85,954,550
	Future-scenario 2	2,198,930	232,320	83,481,084
	Future-scenario 3	2,140,459	215,786	81,007,618
180	Current	1,514,350	266,109	58,316,400
	Future-scenario 1	1,494,192	264,497	57,510,095
	Future-scenario 2	1,431,664	232,254	50,874,245
	Future-scenario 3	1,369,136	200,011	44,238,395
190	Current	3,179,362	410,655	112,937,112
	Future-scenario 1	3,120,431	405,941	110,579,853
	Future-scenario 2	3,021,714	383,172	106,003,393
	Future-scenario 3	2,916,582	359,750	101,141,988

TABLE 32. AGRICULTURAL NON-POINT SOURCE LOADS UNDER EACH SCENARIO

200	Current	2,821,983	397,030	100,034,508
	Future-scenario 1	2,757,397	391,863	97,451,104
	Future-scenario 2	2,610,023	349,411	91,740,938
	Future-scenario 3	2,462,648	306,959	86,030,771
210	Current	2,030,755	406,451	89,457,703
	Future-scenario 1	1,981,055	402,475	87,469,699
	Future-scenario 2	1,879,637	358,073	76,296,180
	Future-scenario 3	1,778,219	313,671	65,122,661
220	Current	1,525,081	233,238	56,074,512
	Future-scenario 1	1,493,198	230,688	54,799,174
	Future-scenario 2	1,459,015	216,811	51,302,295
	Future-scenario 3	1,424,832	202,934	47,805,415
225	Current	76,152	15,185	3,343,717
	Future-scenario 1	75,337	15,120	3,311,081
	Future-scenario 2	71,947	14,024	3,123,481
	Future-scenario 3	68,557	12,898	2,930,600
730	Current	1,402,023	264,104	53,980,815
	Future-scenario 1	1,393,404	263,414	53,636,072
	Future-scenario 2	1,256,723	223,064	48,448,290
	Future-scenario 3	1,120,042	182,713	43,260,507
740	Current	2,946,179	448,894	110,088,294
	Future-scenario 1	2,850,022	441,201	106,242,024
	Future-scenario 2	2,662,364	383,051	97,181,145
	Future-scenario 3	2,466,779	324,900	89,309,488
750	Current	542,310	111,549	21,582,083
	Future-scenario 1	538,877	111,274	21,444,794
	Future-scenario 2	477,016	90,705	18,413,495
	Future-scenario 3	415,155	70,135	15,382,196

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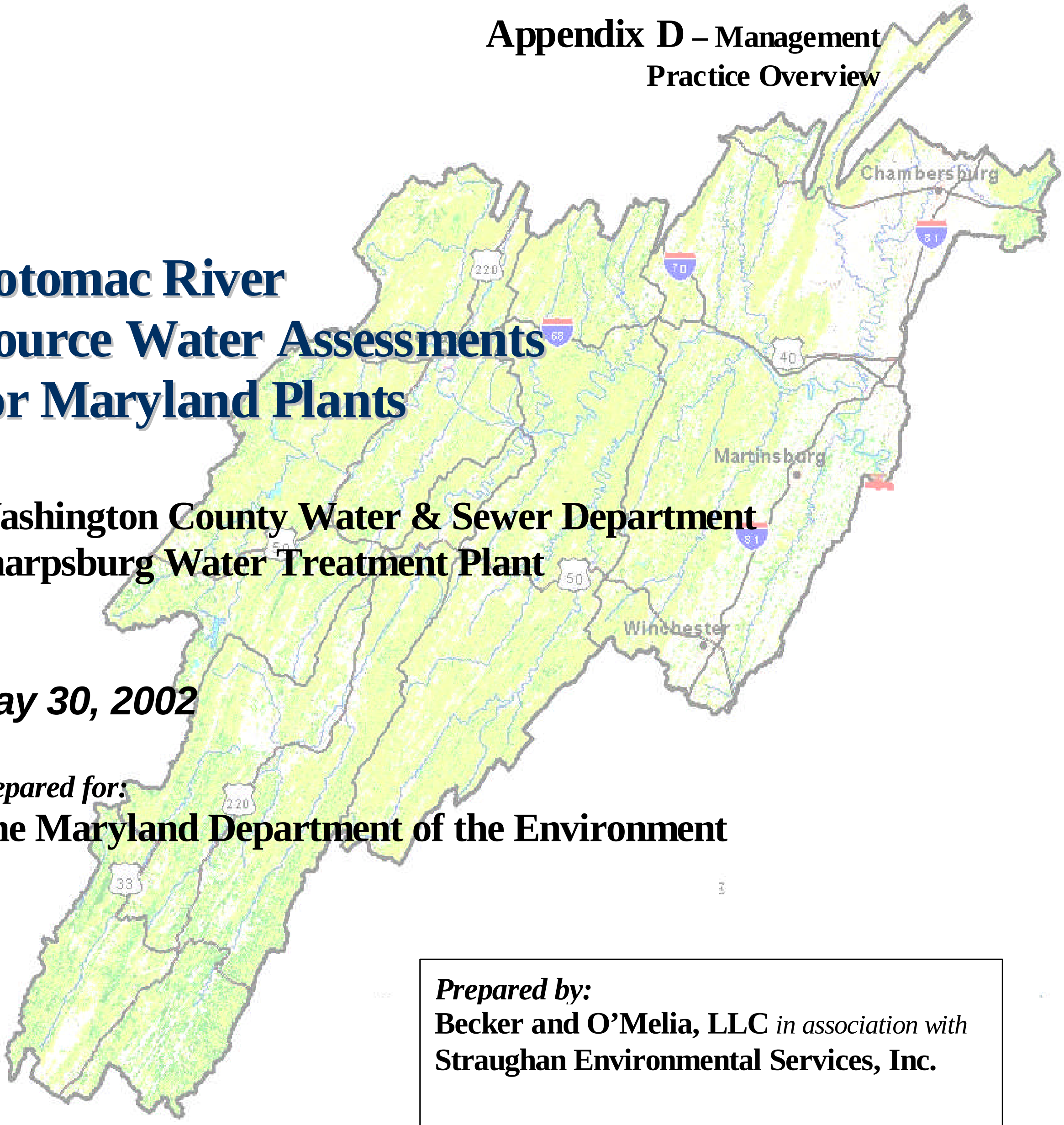

Appendix D – **Management Practice Overview**

Potomac River Source Water Assessments for Maryland Plants

Washington County Water & Sewer Department
Sharpsburg Water Treatment Plant

May 30, 2002

Prepared for:
The Maryland Department of the Environment

Prepared by:
Becker and O'Melia, LLC *in association with*
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SECTION 1 - MANAGEMENT PRACTICES

Sources of contaminants in the Potomac River include agricultural practices (which can contribute nitrogen, phosphorus, sediment, pesticides, pathogens and organic matter); urbanization and lawn and pavement run off (which can contribute pesticides, pathogens, sediment and nutrients); municipal wastewater treatment plants (which can contribute nutrients, organic wastes, pathogens, and toxic household substances); septic systems (which can contribute nutrients, pathogens, and other organic wastes); and destruction of shoreline vegetation.

Sediment loads to the WTP reduce filter run length, increase treatment residuals (which must be processed and disposed of), and transport other nutrients and pollutants to the Potomac River and the Washington County's intake. Major sediment sources include streambank erosion, construction sites, urban areas, mining, and forests. Urbanization increases impervious area and stream flows and thus increases erosion of receiving streambeds.

Field loss of strongly bound pesticides (including dieldrin) is proportional to sediment loss. More weakly bound pesticides (including atrazine) enter streams primarily in solution.[1]

The Maryland Sediment and Erosion Control Standards and Specifications establish design standards for groups of BMPs that were reviewed by MDE and performance standards for new BMPs. This manual of design practices and performance standards was developed to encourage environmentally sensitive site designs which reduce the generation and runoff of waterborne pollutants.

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[1] NC Cooperative Extension – 2

Management practices for control of *Cryptosporidium* include restricting livestock access to waterbodies and waterways, containment of manure, lagoon treatment of manure, manure disinfection, isolation of calves from the herd, and restriction of human body contact recreation.

Soils with high mineral content tend to have lower amounts of NOM than clays and silts, but practices that control erosion will reduce NOM loading to natural waters. Specific NOM control practices that are recommended for consideration in the Potomac Watershed include:

- development controls,
- public education and participation,
- increased conservation tillage and contour farming,
- improved grazing practices and animal waste management,
- improved haul roads, skid paths, slash disposal and post disturbance erosion control during forest harvesting,
- buffer zones, and storm water management practices (detention ponds, storm water retention and diversion).

Sediment control management measures are of two types: those that reduce erosion and those that reduce delivery after erosive forces dislodge sediment particles. The principal mechanism of erosion at the field is raindrop impact. Stream channels can be a significant sediment source and control measures that reduce erosion without reducing run off may not significantly reduce suspended solids until a steady state between the flow conditions and the streambed is reached. The time scale for this equilibration is highly variable but is thought to take 60 years or more. When considering these control measures in the Potomac Watershed it is important to note that there may be a significant time lag between control measure implementation and water quality changes.[2]

1.1 - Urban Best Management Practices (BMP)

Effective management practices in urban areas include structural and nonstructural controls. Land-use controls to restrict future development are the most effective source water quality protection in most of the Potomac Watershed where sparse current development precludes the need for structural urban storm water BMPs. There is more certainty that controlling sources of contamination will prevent source water degradation than pollutant removal following contamination. Although the watershed is largely undeveloped, little development is projected over the next 20 years and land use controls may not significantly impact water quality. However, because little development is expected, the cost of these control measures is similarly small and these measures may pay very big dividends over a longer time frame. Major land use BMPs include density restrictions, cluster development and impervious surface limits, prohibited land use, and structural controls.

1.1.1 - Density Restrictions

The most common type of land use control for protection of urban watersheds is restriction of development density. Density restrictions may be defined for critical areas whether due to sensitivity (e.g. riparian areas) or threat (e.g. inadequate sewage disposal facilities) or for the entire watershed. The proximity to drinking water plant intakes should be an important consideration when evaluating this practice. Density restrictions are usually codified through lot size restrictions.

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[2] NC Cooperative Extension – 2

1.1.2 - Cluster Development and Impervious Surface Limits

Cluster development concentrates development and its associated threats in an area of a tract in exchange for maintaining open space in another area. This allows protection of more sensitive areas even when average densities are similar to large lot restrictions. It also reduces infrastructure costs allowing more efficient use of sanitary sewers and structural BMPs. Cluster development may produce a similar contaminant loading on impervious cover, but allows for efficient location of BMPs and may avoid the need for septic systems. Impervious surfaces still serve as significant sources of contamination in urban areas and also increase storm flows.

1.1.3 - Prohibited Land use

Land uses that threaten to reduce source water quality and could therefore be prohibited under a watershed protection plan include industrial development, commercial or high density residential development, concentrated animal feeding operations, grazing, and recreation.

1.1.4 - Structural Controls for Urban Development

Structural BMPs, which filter, detain, or reroute surface water run off include wet retention ponds, dry detention ponds, infiltration controls, and diversion structures. In some existing urban areas within the watershed, siting of structural BMPs is a major challenge. Structural controls generally have a relatively high capital and maintenance requirements but when implemented and maintained properly may significantly improve water quality. Removal efficiencies for some structural BMPs are given on Table 1.

Table 1 Estimated Pollutant Removal Efficiencies for Structural Treatment Practices[1]

Treatment Practice	TSS	TN	TP	Bacteria
Dry Pond	3	19	5	10[5]
Dry Extended Detention	31[2]	20	61	60[5]
Wet Pond	80	33	51	70
Wetland	76	30	49	78

WQ Swale[3]	81	50[5]	34	0[5,6]
Filters[4]	86	38	59	37
Infiltration	90[2, 5]	51	70	90[5]

1. All the removal efficiencies were derived from Winer (2000)
2. Efficiency based on fewer than five data points
3. Refers to open channel practices designed for water quality
4. Excludes vertical sand filters and filter strips
5. Removal rates adjusted based on best professional judgment
6. WQ Swales attract wildlife and pets and are thought to both remove and “generate” bacteria

Criteria for structural controls include four categories: hydrologic conditions, pollutant removal capability, environmental and aesthetic amenities, and physical suitability. (AWWARF 1991)

1.1.4.1 - Wet Retention Ponds

Retention ponds are one of the most effective structural BMPs for protecting water quality and have demonstrated high removal rates for sediment and nutrients. Removal efficiencies vary based on the contaminant of concern and the size of the permanent pool. Wet retention ponds provide a quiescent area for algal and macrophytic activity, which produces NOM. Wet ponds also impound run off and promote sedimentation. In addition, wet ponds are effective at reducing downstream flows. Routine inspection and proper maintenance are required for wet retention ponds to be effective.

1.1.4.2 - Storm Water Wetlands

Storm water wetlands are structural practices similar to storm water ponds that incorporate wetland plants into the design. As storm water run off flows through the wetland, pollutant removal is achieved through settling and biological uptake within the practice.

Wetlands are among the most effective storm water practices in terms of pollutant removal, and also offer aesthetic value. While natural wetlands can sometimes be used to treat storm water run off that has been properly pretreated, storm water wetlands are fundamentally different from natural wetland systems. Storm water wetlands are designed specifically for the purpose of treating storm water run off, and typically have less biodiversity than natural wetlands both in terms of plant and animal life. There are several design variations of the storm water wetland, each design differing in the relative amounts of shallow and deep water, and dry storage above the wetland.

Wetlands are widely applicable storm water management practices. Like storm water ponds, they have limited applicability in highly urbanized settings, and in arid climates, but have few other restrictions. Most wetland designs can provide water quality, channel protection, overbank flood, and extreme flood control. However, due to the tendency of wetlands to intercept water tables, they do not typically meet recharge requirements.

1.1.4.3 - Dry Detention Ponds

Dry detention ponds do not maintain a permanent water surface and are up to 60% effective for particle removal, though they are generally ineffective for removal of dissolved pollutants.

1.1.4.4 - Infiltration Controls

Infiltration controls (including infiltration basins, trenches, dry wells and porous pavement) are structural BMPs that increase percolation of water into soil. Water quality improves due to pollutant removal through physical (filtration), chemical (adsorption) and biological processes.[3]

Infiltration practices capture and temporarily store water before allowing it to infiltrate into the soil over a two-day period. These practices are an excellent technique for meeting any recharge requirement and may also provide storm water detention and channel protection storage in certain limited cases.

1.1.4.5 - Filtering Practices

The majority of filtering practices, with the exception of bioretention, are sand filters. Sand filters are usually two-chambered storm water practices; the first is a settling chamber, and the second is a filter bed utilizing sand or another filtering media. As storm water flows into the first chamber large particles settle out, and then finer particles and other pollutants are removed as storm water flows through filtering media. There are several modifications of the basic sand filter design, including the surface sand filter, underground sand filter, perimeter sand filter, organic media filter, and the pocket sand filter. All of these filtering practices operate on the same basic principle. Modifications to the traditional surface sand filter are made primarily to fit sand filters into more challenging design sites or to improve pollutant removal.

There are some restrictions at the site level, however, that may restrict the use of sand filters as a storm water management practice, such as available hydraulic head.

1.2 - Agricultural Best Management Practices

Nutrient agricultural nonpoint sources can be minimized through sound agricultural management, but today in many areas of the Potomac watershed, agricultural management

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[3] AWWARF 1991

practices are often nearly optimized, so opportunities for improvements are somewhat limited. Agricultural BMPs are of two types; either reducing application or preventing excess contaminants from entering waterbodies. Due to the variety of control mechanisms for phosphorus, an integrated system of BMPs is ideal, including timing fertilizer application to coincide with maximum crop uptake, and determining application rate based on soil testing. Changes to fertilizer application rate must be assimilated with production concerns. Other agricultural BMP recommendations include animal waste management, grazing practices, filter strips, conservation and no till farming, cover crops, contour farming, drainage control, fertilizer incorporation, sedimentation basins and flow control.

1.2.1 - Animal-Waste Management

Animal waste BMPs may include land application as fertilizer or supplemental moisture, reuse of liquid for flushing, reuse of solids as bedding or litter, reuse as an energy source, and reuse as animal feed. Manure is generated in higher concentrations due to increased livestock and poultry production at large confinement facilities. Manure application to cropland adds nutrients, but also improves soil tillage, reduces run off and improves infiltration, and thus may reduce sediment (and adsorbed nutrient) run off. BMPs for animal wastes may eliminate immediate run off, and suppress odors by controlling rate, timing, and method of manure application. The type of handling and storage system affects nutrient losses and run off. Application should depend on soil testing, manure testing, infiltration rate, and distance to streams and ditches. Keys to successful animal waste management include adequate storage and separation of stormwaters from barnyard waste.

Rate and timing of application should depend on crop needs, climate, animal species, and waste handling methods to effectively protect waterbodies.

1.2.2 - Grazing Practices

BMPs for grazing lands are intended to prevent overgrazing and include spreading water supplies, spreading mineral and feed supplements, rotating animals between pastures, and allowing animals to graze only when a plant food is growing rapidly. Pastureland should be maintained to restrict animals from waterbodies and rotate grazing to prevent grass cover reduction.

1.2.3 - Filter Strips

Vegetative filter strips and run off diversion are excellent BMPs. Filter strips are very effective in treating animal waste run off, though concentrated flow may kill vegetation, and the efficiency depends on soil type, soil texture, size of the treatment area, rate and consistency of discharge, treatment frequency and time of year.

1.3.4 - Conservation Tillage

Conservation tillage includes a variety of tillage practices (including no tillage, chisel tillage, and ridge tillage) that minimize erosion and protect the soil surface by retaining crop residues. No and low tillage BMPs can significantly reduce erosion and reduce sediment run off. Implementation of these practices have contributed to improving water quality in the Potomac. Conservation tillage practices prevent erosion by reducing detachment and transport. Conservation tillage practices reduce nutrient load and erosion from cropland but can increase the amount of NOM produced by decaying plant matter. Generally the reduction in erosion and nutrient loading achieved through conservation tillage practices will cause a reduction in NOM much greater than any increase produced by decay of plant matter left on fields. Experience consistently establishes the success of conservation tillage to dramatically reduce sediment loss and reduce run off volume, sediment and nutrient concentration.

Production yields under conservation tillage are generally higher than conventional tillage, especially in dry years and dry areas. Yields may be lower in poorly drained soils or wet years. Conservation tillage also reduces labor and fuel costs and increases pesticide usage and costs, generally resulting in reduced total production costs. When yields are increased or unaffected, conservation tillage practices are more profitable and improve water quality.

1.2.5 - Cover Crops

Cover crops (close growing grasses, legumes or small grains) are grown seasonally for soil protection, and are widely adopted for soil retention. Cover crops keep nitrogen from infiltrating groundwater during fall and winter runoff periods. They also protect soil from raindrop impact and reduce run off during non-growing seasons. Large reductions in erosion are achieved by sod crop rotation, which is expensive due to the loss of cash crop during years when sod crops are grown. Sod crops rotated into row crops improve soil structure, organic matter content, and infiltration, and in erosive marginal cropland may be the only method of significantly reducing erosion.

The effect on yield depends on soil moisture because the cover crop can increase transpiration, and on climate because the cover crop delays soil warming in the spring. Cover crops are effective at reducing erosion, but because of productivity concerns are likely to have limited application to the Potomac Watershed.

1.2.6 - Contour Farming

Contour farming modifies tillage, planting and cultivation on lands with slopes of 2% to 8% in order to reduce sheet and rill erosion. EPA rates contour farming as good for sediment export control and fair for phosphorus export control. Soil erosion on both cropland and pastureland is reduced by contour farming on sloping cropland, which increases rainfall infiltration and thus reduces run off. Pesticides and nutrients that adsorb to particles are also reduced under contour farming. Crop yields under contour farming increase in dry areas and seasons and decrease in wet or poorly drained areas.

1.3 - Forestry Best Management Practices

Although water quality impacts from forested land uses are generally much less than those from urban or agricultural uses and timber management can be compatible with water quality objectives, poor forestry management can produce a variety of nonpoint sources of pollutants including turbidity, nutrients, temperature (which contributes to algal growth and NOM production), NOM, and oxygen demand. Forestry BMPs include buffer strips; design and construction of haul roads, skid trails and landings; postdisturbance erosion control; seasonal operating restrictions, and slash disposal. BMPs for roads and skid trails should be given special consideration because of their disproportionate erosional impacts.

1.3.1 - Design and Construction of Haul Roads, Skid Trails, and Landings

BMPs for the commercial forest transportation networks include avoiding disturbance to sensitive areas and minimizing the total area of facilities. Roads should conform to natural contours and machinery should be restricted to operation within predesignated areas.

1.3.2 - Seasonal Operating Restrictions

Restrictions on winter logging, to avoid erosion, and in summer to avoid ignition of wildfires may help maintain the water quality and reliability of the Potomac River.

1.3.3 - Slash Disposal

BMPs for management of woody debris include removing slash to locations away from streams and retaining woody debris within the riparian zone to reduce channel scour and streambank erosion.

1.4 - Public Education and Participation

A successful water supply protection program relies on the understanding and support of citizens, particularly property owners. Public education will play a critical role in protection efforts in the Potomac and will affect the acceptability of mandatory controls, the effectiveness of voluntary controls, and support by landowners, local officials and other stakeholders.

1.5 – Riparian Buffers

As a protective cover, vegetation can significantly affect raindrop impact, soil infiltration characteristics, surface run off filtering, and biological uptake of nutrients and other contaminants.[4]

Areas adjacent to streams and reservoirs are the most sensitive in the watershed, so retention of undisturbed, vegetated buffers is one of the most effective source water protection practices. Effective watershed management programs generally include some means of establishing buffer zones. Buffer zone protection is generally created either by acquisition (by utility or cooperating jurisdiction), regulatory restrictions on development, and other land management activities. Buffer width should be based on local conditions including slope, stream classification, estimated time of travel for a set storm event, the size and location of the stream, the character of adjacent development, and the degree of political support for watershed protection programs. Where buffer zone width is regulated, there are generally two approaches:

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[4] AWWARF 1991

fixed width and variable width. Fixed width requirements primary advantage is the ease in administration. Their primary disadvantage is their lack of sufficient flexibility to protect sensitive areas outside the designated width. Variable width buffer zones provide greater flexibility, but are more susceptible to successful legal challenges and require more on-site investigation and evaluation.[5]

1.6 - Plan Review

Water quality protection and improvement may be achieved through review of plans, permits, designs and other documents related to residential development, structural BMPs, water and sewer service, and septic systems. Although the size and diversity of the Potomac Watershed may preclude a single plan review group, it may be practical for the proposed source water protection group to review state and local requirements that preserve hydrology and provide for water quality renovation. Stakeholders, including State and local regulatory authorities, could then be involved to develop the most promising method for implementing these requirements. This could be coordinated by a watershed protection group (once formed) and may improve compliance with watershed protection regulations and policies. Regulations could be written to require review by the utility, but a more common approach involves an informal agreement between the utility and the responsible agencies.

1.7 - Written Agreements

Watershed controls could likely be established through written agreements with public or private landowners at a fraction of the cost of land acquisition. Written agreements would almost certainly be entered into voluntarily and thus would require a willing acceptance of land use restrictions by the landowner, who may require compensation. Because of the tremendous

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[5] AWWARF 1991

number of landowners in the watershed, negotiation and enforcement of agreements for any but the most critical areas would likely prove impractical.

SECTION 2 - COSTS FOR URBAN MANAGEMENT PRACTICES

This section presents cost data for use with the Watershed Treatment Model. Data are presented first for structural Stormwater Treatment Practices, then for Stormwater Control Programs, and then program costs for these urban programs. These data are presented as annualized costs, as well as broken down into separate construction and maintenance costs for each practice.

2.1 Stormwater Treatment Practices

This section summarizes available cost information structural treatment practices. We report data for both new stormwater management and stormwater retrofits. For each practice, we present costs for construction and design, and typical maintenance costs. While data are available for specific practices, we present "lumped" data that distinguishes small (< 5 acre impervious) sites from large (>5 acre impervious) sites, rather than presenting costs for individual practice types. Typical small site practices include filtering systems, water quality swales, and infiltration trenches. Large site practices are dominated by ponds and wetlands.

2.1.1 Practices for New Development

Costs for new development are derived from a memo produced by the Center for Watershed Protection to the United States Environmental Protection (Caraco, 1998), which summarized costs for a variety of practices. The costs presented in Table 2 are typical construction costs per acre of impervious cover derived from this memo, with ponds representing large site unit costs, and sand filters representing small site unit costs. Design and contingencies are estimated at 25% of construction costs. Maintenance costs are assumed to be 5% of construction for "large site" practices, and 10% for small site practices. For these analyses, we assume that the life of the practice is twenty years.

Table 2 Costs for Stormwater Treatment Practices for New Development				
Site Size	**Construction Cost ($/imp. Acre)**	**Design/ Engineering ($/imp. Acre)**	**Annual Maintenance Cost ($/imp. Acre)**	**Total Annual Cost ($/imp. Acre/year)**
Small	$15,000	$3,750	$1,500	$2,440
Large	$6,200	$1,550	$310	$700

2.1.2 Stormwater Retrofits

For stormwater retrofits, costs can be broken into similar categories. In addition to the construction costs, a retrofit inventory needs to be conducted. The inventory, in which candidate sites are identified and visited, and concepts drawn, costs approximately $200 per retrofit. This estimate was made based on data from retrofit inventories conducted in Maryland and Vermont. In addition, the costs per impervious acre are different than practices for new development. First, retrofits are most often applied to relatively large drainage areas, so it is difficult to obtain data for actual construction costs for retrofits on small sites. Second, retrofits of existing facilities involve very little actual construction, and thus have relatively small construction costs. The construction costs presented in Table 3 represent average costs for retrofits throughout Montgomery County, Maryland, and in Burlington, Vermont. In the WTM, one can assume that a watershed with a large amount of existing ponds, and in particular dry ponds, will have a relatively large amount of retrofits of existing facilities.

Table 3 Costs for Stormwater Retrofits					
Retrofit	**Retrofit**	**Construction**	**Design/**	**Annual**	**Total Annual**

Type	**Inventory**	**Cost ($/imp. Acre)**	**Engineering ($/imp. Acre)**	**Maintenance Cost ($/imp. Acre)**	**Cost ($/imp. Acre/year)**
Modification of Existing Factility	200	9,500	2,380	480	1,070
New Retrofit	200	15,600	3,900	780	1,750

Table 4 Summary of Cost Data for Stormwater Programs

Practice	Capital Cost	Life (Years)	Annual Costs	Notes
Watershed Education	Varies	N/A	Varies	See above for a more detailed discussion
Erosion and Sediment Control	$1,100/acre	1 year	$275/acre/year	Initial cost is actual practices. Annual costs include costs of inspectors and other program elements. Additional costs may include ordinance adoption and education costs.
Street Sweeping	$75,000-$150,000/ sweeper	5-8 years	$15-$30/curb-mile/year	Cost and life varies depending on sweeper type. Additional costs may include disposal and costs to change parking rules.
Rooftop Disconnection	$0.70/sf (Residential) $9.25/sf (Commercial)	20 years	minimal	Additional costs may include ordinance writing and education.
Urban Riparian Buffers	$9,000/acre to establish	20 years	Minimal	Additional costs include ordinance development and homeowner education. In many cases, buffer establishment may not be necessary. May also include a resource inventory to establish buffer quality.
Catch Basin Cleaning	$150,000/ truck	15 years	$30,000/driver/ year	This section presents costs based on sweeping frequency. Does not include additional maintenance or disposal costs.
Marina Pumpout	$14,000/	15	$100/slip/year	May also include an educational effort. This section

Table 4 Summary of Cost Data for Stormwater Programs				
Practice	**Capital Cost**	**Life (Years)**	**Annual Costs**	**Notes**
	pumpout	years		normalizes to $/slip/year.
Land Reclamation	$1,500-$28,800/acre	10	Minimal	Costs vary depending on technique. May be supplemented with education, conservation easement, or land purchase.
Impervious Cover Reduction	Varies	Varies	Varies	Case study in Frederick County, MD suggests $50,000 for a roundtable process to agree on code revision principles and $140,000 to actually revise them.
Illicit Connection Removal	$1,250-$1,500/ connection	20 years	None	Reported cost of detection. Does not include repair costs.
CSO Repair/ Abatement	Varies	Varies	Varies	This section presents costs for various technologies.
SSO Repair/ Abatement	Varies	Varies	Varies	This section presents costs for various technologies.
Septic System Repair	Pumpout: $150 Inspection: $45 Replacement: $3,500	Varies System: 12 to 20years	Depends on frequency.	See text for breakdowns based on frequency of inspection/ pumpout. May also need to conduct an education effort, or develop an ordinance to require maintenance.
Stream Channel Protection	$125/linear foot	5 years	Minimal	Should be accompanied with stormwater retrofits. May also require an analysis of stream habitat quality.

Table 4 Summary of Cost Data for Stormwater Programs				
Practice	Capital Cost	Life (Years)	Annual Costs	Notes

2.1.3 Education

Costs for education can be summed up by specific program costs (Table 5), and used to estimate the costs of the desired elements. In this case, the user of the WTM can estimate the influence that the program has based on research on various media types. These assumptions are included in the WTM model.

Alternatively, we have provided example programs at four levels of funding in Table 6. These data, combined with some assumptions regarding watershed size can be used to estimate the awareness factor for a given program. The four levels of program implementation presented in Table 6 reflect four levels of program implementation, and an associated awareness factor. It is assumed that these programs are implemented at a fairly large scale (assume 500,000 people).

In a small subwatershed, it cannot be assumed that a "scaled back" program can work as effectively. For example, a watershed with only 50,000 people most likely cannot achieve 40% awareness with $25,000 (10% of the maximum budget of $250,000). This is because many of the most effective outreach tools (e.g., television ads) can only be applied on a fairly large scale. However, a watershed plan for a small watershed may pay only a portion of an outreach plan for a larger municipality. For example, $10,000 may go toward a larger regional effort that includes television advertising. The awareness levels in Table 4 are based on the range of effectiveness of various educational programs, as reported in Table 5.

Table 5 Unit Prices for Watershed Outreach

Budget Item	Estimated Unit Cost
Billboards	$500-$1500 per month, 6 month minimum
Brochure Development	$75-$650
Coloring Books	$.33 per book
Decals	$.15 per decal
Educational Video	$1,000 per minute of finished video
Newspaper advertisements in local paper	$30-$90 per column inch
Photo Displays	$110 per display
Posters	Prices per 5000: $2.50 per poster (4 color, 2-sided 11x17) $0.65 per poster (2 color, 24x36)
Printed Materials (Flyers and brochures)	$.10-$.50 per printed material
Public Attitude Phone Survey	$15,000 per survey (survey of 1000 residents)
Radio Public Service Announcement	$35 per PSA
Slides	$3.00-$4.00 per slide
Soil Test Kit (includes testing cost but not sampling cost)	$10
Stickers	$.03 per sticker
Stormdrain Stencils	Order of 50 - $14.00 each
TV Public Service Announcement	$2,500 per PSA
T-Shirts	2 Color, Front and Back 500 - $4.65 each
Web Site Development	$169-$2,104 per site
Other Outreach Materials: Magnets Tote Bags	Prices per 1000: $.23 each $2.20 each

Table 5 Unit Prices for Watershed Outreach

Budget Item	Estimated Unit Cost
Stickers	$.07 each

Source: Council of State Governments, Getting In Step A Guide to Effective Outreach in Your Community; National Oceanic and Atmospheric Administration, Dealing with Annex V - A Guide for Ports; and Center for Watershed Protection, Rapid Watershed Planning Handbook.

Table 6 Four Levels of Educational Program Implementation

Program Budget	Population Reporting Increased Awareness
Estimate of the materials or staff time that a watershed education budget of $10,000 might purchase: About 20-30% of a full-time staff person's time 3-4 TV Public Service Announcements 20-25 Newspaper Advertisements in local paper 20,000 Flyers/Brochures 15,000 Color Posters (24X36, 2 Color) 3 Billboards ($500 per month, 6 month minimum) One 10 Minute Video Public Attitude Survey: Phone Survey of 500 Residents Mail Survey of 1000 Residents	18%
Preliminary estimate of the materials or staff time that a watershed education budget of $50,000 might purchase: 1-2 full-time staff people time 16-20 TV Public Service Announcements 100-125 Newspaper Advertisements in local paper (4X4 column) 100,000 Flyers/Brochures 75,000 Color Posters (24X36, 2 Color) 16 Billboards ($500 per month, 6 month minimum) Five 10 Minute Videos Public Attitude Survey: Phone Survey of up to 3000 Residents Mail Survey of up to 6000 Residents	24%
Preliminary estimate of the materials or staff time that a watershed education budget of $100,000 might purchase: 2-4 full-time staff people time 30-40 TV Public Service Announcements 200-250 Newspaper Advertisements in local paper (4X4 column) 200,000 Flyers/Brochures 150,000 Color Posters (24X36, 2 Color) 33 Billboards ($500 per month, 6 month minimum) Ten 10 Minute Video Public Attitude Survey: Phone Survey of up to 6500 Residents Mail Survey of up to 12000 Residents.	32%
Preliminary estimate of the materials or staff time that a watershed education budget of $250,000 might purchase:	40%

Table 6 Four Levels of Educational Program Implementation

Program Budget	Population Reporting Increased Awareness
4-8 full-time staff people time 50-80 TV Public Service Announcements 400-500 Newspaper Advertisements in local paper (4X4 column) 500,000 Flyers/Brochures 300,000 Color Posters (24X36, 2 Color) 80 Billboards ($500 per month, 6 month minimum) 25 10 Minute Videos Public Attitude Survey: Phone Survey of up to 14,000 Residents Mail Survey of up to 30,000 Residents....	

Table 5 Educational Programs and Reported Increases in Awareness

Campaign	Reported Increase	Agency
Street Signs - Motor Oil	33	San Francisco Water Pollution Prevention Program
Multi-media Campaign	40	same as above
TV Ads on oil recycling	32	same as above
Utility Bills on safer house cleaners	16	same as above
TV ads on Gardening Practices	13	same as above
1994-1996 Pesticide Ad Campaign	23	King County Local Hazardous Waste Management Program
1997-1998 Pesticide Ad Campaign	36	same as above
1997 Pesticide Brochure	24	same as above
1998 Storm Drain Education	37	Los Angeles County Stormwater Pollution Prevention Program
Pollution in Stormwater System	40	City of Eugene Stormwater Program
Clean Water Campaign regarding pesticides	38	City of Fort Worth, Texas Water Department

Sources: Elzufon (2000), Swann (1999)

2.2 *Erosion and Sediment Control*

The costs of erosion and sediment control (ESC)include both implementation costs and program costs in the form of ESC inspectors. Implementation costs are presented as a cost per acre for practices in Table 6, with the default value of $1,100/acre cleared.

Additional program costs will be incurred to pay for inspectors on site. The default assumption is that the annual salary of an erosion and sediment control inspector is $37,000. Assuming at least one inspector per site (from Brown and Caraco, 1997), and that one inspector can inspect an average of 50 sites per year, and that the average site size is 2.7 acres, the average salary is approximately $275/acre. Therefore, the total program and implementation cost is approximately $1,375/acre. Other program costs may include: ordinance development, and contractor training and education.

Table 6 Costs for Erosion and Sediment Control: Implementation

Unit: $/acre cleared

Cost	Source	Description
800	Suburban Maryland Building Industry Association, 1990	Cited in Economics of Watershed Protection.
1500	Paterson, et al. 1993.	Source reported as $/acre. Average field installation cost in NC.
800	Chesapeake Bay Program, 1998.	Source reported as $/acre for sediment control for subdivision development.
500-1500	Chesapeake Bay Program, 1998.	Source reported as $/cleared acre
1206-1742	Science Applications International Corporation, 1999.	Includes O&M costs. Source reports average of 27 model sites of differing soil erodibility and slope. 1 acre average = 1206, 3 acre average =

		4598, 5 acre average = 8709. Convert to $/acre and take the average.
Default Cost: $1100/acre		

2.3 *Street Sweeping*

Street sweeping costs include both costs to by a sweeper and the operation/ maintenance costs to maintain them. These estimated annualized costs are included in Table 7 These data were developed with the following assumptions:

- One sweeper serves 8,160 curb miles during a year (SWRPC, 1991).
- Streets are approximately 45 feet wide (to convert to $/acre/year).
- Raw cost and life data are included in Table 8

This analysis does not include disposal, operator training, or changes to parking codes that may be required to effectively sweep streets.

Table 7 Annualized Sweeper Cost Data ($/acre/year)

Sweeper Type	Weekly Sweeping		Monthly Sweeping	
	Operation and Maintenance	Capital Costs	Operation and Maintenance	Capital Costs
Mechanical	286	18	66	4
Vacuum-assisted	143	22	33	5

Table 8 Sweeper Cost Data

Sweeper Type	Life (Years)	Purchase Price ($)	Operation and Maintenance Costs ($/curb mile)	Sources
Mechanical	5	75,000	30	Finley, 1996; SWRPC, 1991
Vacuum-assisted	8	150,000	15	Satterfield, 1996; SWRPC, 1991

2.4 Rooftop Disconnection

Rooftop disconnection can be applied to both commercial and residential properties, and costs include both the cost of applying practices that treat rooftop runoff and the educational costs to implement the program. The default implementation costs are $0.035/sf/year for residential applications and $0.46/sf/year for commercial applications. The following describes how we arrived at these costs. Program costs primarily include the educational costs described above, but may also include additional costs such as ordinance development.

Table 9 Costs for Green Rooftops

Unit: $\$/\text{ft}^2$		
Cost	**Description**	**Source**
3.00	Estimated cost is for extensive green roof and drainage layer, does not include contractor fees.	Johnston and Newton.
3.40	Source reported costs as an amount given for grant $, as well as a percentage of total production costs.	Environmental Services City of Portland, 1998
2.60 - 19.50	Source reported green roofs are 30% more expensive than conventional roofs including retrofits. Source gave conventional roof construction costs. This info was used to determine green roof cost.	Environmental Services City of Portland, 1998.
5.10-9.70	Labor and construction costs.	Peck, et al.,1999
17.50	Labor, materials and structural upgrade cost.	
	Materials and installation cost.	
	Do-it-yourself green roof installation in 1987$	
	Professionally designed and installed green roof in 1987$	

55.00	Re-roofing and green roof cost.	www.peck.ca/grhcc/main.htm
Default Cost: $18.00/square foot		

Table 10 Costs for Rain Barrels

Unit: $/gallon

Cost	Source
1.70	Plow and Hearth www.plowhearth.com/product.asp
2.00	Jerry Baker www.jerrybaker.com
2.50	Burpee Seeds and Plants www.burpee.com
2.55	Portland Rainbarrel Company www.teleport.com/~bardelp/
1.70	Gardener’s Supply Company www.gardeners.com
1.50	D&P Industries, Inc. www.therainbarrel.com
0.90	Berry Hill www.berryhill.on.ca
2.50	Spruce Creek www.sprucecreekrainsaver.com
1.50-2.45	The Green Culture www.composters.com
1.80	Plastmo www.rio.com/~plastmo/gardnh2o.html
1.55	Arbour www.arbourshop.com
1.10-1.60	Green Venture www.greenventure.on.ca/rain.html

Default Cost: $1.70/gallon

Table 11 Costs for Cisterns

Unit: $/gallon

Cost	Source
0.20-1.10	Texas Metal Cisterns www.texasmetalcisterns.com
0.80-1.00	Jade Mountain www.jademountain.com/waterProducts/cistern.html
0.50-1.20	Red Ewald, Inc., 2001
0.70-1.00	Forest Lumber Company www.forestlumber.com/products/cistern.html
Default Cost: $0.80/gallon	

Table 12 Costs for Dry Wells/French Drains

Unit: $/cubic foot storage

Cost	Source
3.00	CWP, 1997
5.00	US EPA 1999a
Default Cost: $4.00/cubic foot of storage (mean of above values)	

Assuming that each practice is used to treat a one inch rainfall event, the cost in $/sf of rooftop can be determined by converting default costs using the following equations.

For costs in $/gallons, the cost in $/sf can be determined by multiplying by the factor

(1 gallon/0.134 cubic feet)• 1'/12" = 0.62 gallons/cf-in

For costs in $/cf, the cost in $/sf can be calculated by dividing by 12".

The resulting costs (to the nearest 5 cents) are:

Practice	$/square foot
Rainbarrel	1.05

Cistern	0.50
Green Roof	18.00
Dry Well/French Drain	0.35

To estimate the cost of impervious cover disconnection for a residential area, assume that 1/4 of residents simply disconnect their downspout so it drains to a pervious area (assume no cost). Another 1/4 of residents use a dry well or french drain and half the residents use rainbarrels. The weighted average cost can then be determined as:

$$C_{residential} = 0.25 \bullet \$0 + 0.25 \bullet \$0.35 + 0.5 \bullet \$1.05 = \$0.70/sf$$

For commercial or industrial areas, assume ½ use cisterns and ½ use green roofs. Thus the cost can be determined as:

$$C_{commercial} = 0.5 \bullet \$18.00 + 0.5 \bullet \$0.50 = \$9.25/sf$$

Assuming that the average life of these structures is 20 years, and that maintenance costs are minimal, the average annual cost is $0.035/sf/year for residential applications and $0.46/sf/year for commercial applications.

2.5 Urban Riparian Buffers

The costs of urban riparian buffers include some programmatic costs, including educational costs outlined in this section and other program items, such as ordinance development, described in this section. The maintenance costs are typically as low or less than as the costs associated with other public land (CWP, 1998b). Further, we do not address the opportunity cost associated with loss of developable land within the buffer. It is assumed that much of the buffer is consumed by undevelopable land, such as wetlands and floodplains. If the buffer needs to be established, the cost of tree planting can be assumed to be approximately $9,000/acre (CWP, 1998a).

2.6 Storm Sewer/ Catch Basin Cleaning

Costs for catch basin cleaning include the cost of a vactor truck, and the operator's salary. Typcial costs are as follows:

Truck: $150,000
Salary: $30,000
Life: 15 years

Assuming that each truck has the capacity to hold sediment from four catch basins, and that the truck can be filled and material landfilled twice in a day, each truck can clean eight catch basins per day. Further assuming a 200-day year, each truck can make 1600 catch basin cleanings per /year.

Using these assumptions, the annual labor and equipment costs for catch basin cleaning are included in Table 13. This cost does not include other maintenance and disposal costs.

Table 13 Street Sweeping Costs ($/cb-year)

	Labor	**Equipment**
Semi-Annual Cleaning	38	13
Monthly Cleaning	225	75

2.7 Marina Pumpout

Costs for marina pumpout include the cost to install the system, upkeep and maintenance, and educational costs. Table 14 summarizes installation costs, and presents the model default value of $14,000. Maintenance costs are assumed to be $100/slip/year (US EPA Gulf of

Mexico Program, 2000). Assuming a fifteen year life (US EPA, 1993), and that each pumpout station serves 160 slips, the costs can be summarized as:

Capital costs: \$14,000/160 slips /15 year ≈ \$6/slip-year

Thus, total capital and O&M costs are approximately \$106/slip-year.

Table 14 Costs for Marina Pumpout: Installation

Unit: (\$/year)

Cost	Source
\$16,000	US EPA Gulf of Mexico Program. 2000.
\$12,000-15,000	US EPA Gulf of Mexico Program. 1997.
\$12,500	CWP 1998a
Model Default:\$14,000	

In order to make pumpout stations successful, they should be accompanied by an educational effort. The data in this section can be helpful to formulate these costs. In addition some cost data specific to marinas is included in Table 15.

Table 15 A Review of Three Educational Case Studies for Marinas (RI Sea Grant, 1992)

BMP	Cost	Educational Value	Cost effectiveness
Conducting Workshops	Low cost (\$16 per facility) but requires considerable investment of time	Ranked last among customer choices for receiving information Low turn out Only 31% of attendees have used BMP's	Low unless attendance is tied to a more popular marina event
Distributing Literature	\$52.80 per marina for distribution through display rack (\$45 for rack and \$7.80 for copies) \$45.36 if done through monthly	Ranked second as the most popular way of receiving information 75% reported reading factsheets and 91% of these readers indicated that they began using practices learned	High if monthly mailing method is used

	mailing		
Posting Signs	$105	Ranked first as the most popular way of receiving information	Very cost effective since signs can be used for several years.

The cost of implementation and O&M can vary depending on the type of system installed. Table 16 presents summary data for various systems. Please note that the capital costs are relatively high because they assume a 12% interest rate over the life of the practice.

Table 16 Annual Per Slip Pumpout Costs for Three Collection Systems (USEPA, 1993)

	Marina wide	Portable/Mobile System	Slipside system
Small Marina 200 slips			
Capital Cost	15[b]	15[c]	102[b]
O&M Cost	110	200	50
Total Cost (slip/year)	125	215	152
Medium Marina 500 slips			
Capital Cost	17	10	101
O&M Cost	90	160	40
Total Cost (slip/year)	107	170	141
Large Marina 2000 slips			
Capital Cost	16	10	113
O&M Cost	80	140	36
Total Cost (slip/year)	96	150	149

[b] Based on 12% interest, 15 years amortization

[c] 12% interest, 15 years on piping; 125interest, 15 years on portable units

2.8 Land Reclamation

In the WTM, land reclamation is represented by a shift in land use from one that produces significant pollutant loads to one that more closely mimics background levels. This can be accomplished in several ways, including amending compacted urban soils, establishing grass cover on vacant land, or tree planting. Costs for each of these are included in Table 17. Additional program costs may include establishing a conservation easement, homeowner education, and land purchase. It can safely be assumed that soil ammendment and/or revegetation will last up to ten years.

Table 17 Costs Associated with Land Reclamation

Practice	Cost	Reference
Cost to install a compost-amended lawn.	$28,800/acre (labor included) $8,700 (excluding labor)	Schueler, 2000
Sod	$8,700/acre	Caraco, 1997
Seeding w/ mulch	$1,500/acre	Caraco, 1997
Tree Planting	$9,000/acre	CWP, 1998a

2.9 Impervious Cover Reduction/ Better Site Design

Data suggest that the cost to the developer is actually less when Better Site Design techniques are used on site (CWP, 1998b). However, costs may be incurred to implement Better Site Design at the program level. A case study of this is Frederick County, Maryland, which conducted a Roundtable Process to review and modify their codes, and then actually went through the process of modifying existing code changes. The roundtable process cost approximately $50,000. The county followed up this process by revising their codes and ordinances. This code revision costed approximately $140,000 (Frederick County, 2001).

2.10 Illicit Connection Removal

The primary cost to a government agency to remove illicit connections is the cost to detect each connection. This cost ranges between $1,250 and $1,500/connection (Claytor and Brown, 1996). The cost of actually removing these connections is typically born by the private sector, and is incurred in response to a violation. This cost is not included in this document.

2.11 CSO Repair/ Abatement

CSO repair/abatement includes a wide variety of options including sewer separation, retention basins, maximization of in-line storage, inflow reduction, disinfection methods, pollution prevention, and floatables control. These techniques are cost-estimated using a wide variety of units such as cost per capita, cost per gallon of CSO removed, cost per cubic foot of basin capacity, etc (Table 18). The actual cost of CSO abatement as well as operation and maintenance costs will vary with the practice(s) used and also with the individual situation (i.e., site characteristics, current condition of sewer system, design flow of basin, etc). If a community chooses to repair its CSOs, an in-depth cost study will be necessary.

Table 18 Costs for CSO Repair/Abatement

Unit: N/A

Cost	**Description**	**Source**
Range of Alternatives		
$1025/person served by combined sewer system	Source reported estimated cost of controlling CSOs in the US using a range of CSO control alternatives, as well as the # of people served by CSOs in the US.	US EPA, 1998.
Separation		
$33,733/acre	Average of 3 projects taken.	US EPA, 1999b
$0.21/gallons CSO removed	Separation of sanitary and storm sewer	Zukovs, *et al., 1996*
WWTP Treatment/ Disinfection		

Table 18 Costs for CSO Repair/Abatement

$0.27/gallons CSO removed	Storage, transportation and treatment to convey CSOs to WWTP	Zukovs, *et al.,* 1996
$0.06/gallons CSO removed	Regional high-rate treatment to partially treat CSOs locally in satellite facilities and capture and retain CSOs for treatment at WWTP	Zukovs, *et al.,* 1996
$3342/cfs	Source reported capital costs for design flow of 2500 cfs. Average of chlorine, chlorine dioxide, and ozone disinfection methods.	EPA. 1999b
System Storage		
$2.68/gallon of capacity	Total cost and basin capacity for 9 projects. Converted to $/gallon of capacity and averaged.	EPA. 1999c

2.12 SSO Repair/ Abatement

SSOs may be prevented or eliminated through a series of practices. Costs for these practices are reported in Table 19. Specific costs will vary depending on the community's needs, and condition of the system.

Table 19 SSO Repair/ Abatement Costs

Item	Cost	Source
Sewer Replacement	$200-$500/lf	Parsons Engineering Sciences, *et al.,*1999

Maintenance (Specific Items)	Jet Cleaning: $0.50/lf Tv Inspection:$1.00/lf Root Removal:$1.00/lf Joint Testing:$15.00/lf Manhole Inspection: $90.00 per manhole	
Overall O&M	$0.53/lf	USEPA, 1999d
Inflow Identification (Specific Items)	Flow Metering/ Rainfall Gauging - $50-$150 per meter day Modeling - $.05-$.25/lf Smoke Testing - $.20-$.40/lf Dye Flooding/TV - $100-$1,000 per set up	Eastern Research Group, 1995
Overall Inflow Identification	$0.50-$3.00/lf	

2.13 Septic System Inspection/Repair

Septic system inspection and repair costs vary depending on the frequency of inspection and cleanout. Default values are presented for three levels of inspection and repair in Table 20. Example program costs are reported in Table 21. Available data also suggest a cost of approximately $3,500 to upgrade an existing failing system. Higher costs, up to $6,500 may be incurred to upgrade to highly effective systems such as the recirculating sand filter.

Table 20 Default Costs for System Inspection

Unit: ($/household):

Cost ($/system/year)	**Program**
$95	Annual Inspection and Pumpout Once Every Three Years
$75	Annual Inspection and Pumpout Once Every Five Years
$55	Inspection Every Three Years and Pumpout Once Every Five Years

Assumptions:

Inspections cost $45 Pumpouts Cost $150

Table 21 Costs for Septic System Inspection Programs (Include all program costs)

Unit: ($/household):

Cost	Source
$70/year (1988 dollars)	US EPA. 1993.
$218/year	Hoover 1997
$95/year	Bilanin and Tervala.1999.
$40-$50 dollars per inspection $150-$250 annual O&M cost	MDE and MOP, 2000

2.14 Stream Channel Protection

In addition to upstream flow control, in-stream rehabilitation is often required to prevent streambank erosion. Table 22 summarizes available cost data on in-stream channel protection. Other associated costs may include a retrofit inventory, and perhaps staff to run the program. Other possible stream restoration costs include a natural resources inventory, habitat evaluation, and some possible land purchase or conservation easements.

Table 22 Costs for Channel Protection: Implementation

Unit: $/linear foot

Cost	Source	Description
109	Brown, 2000	Source reported total cost for stream restoration projects as well as project length and type.

142	Chesapeake Bay Program. 1998.	Source reported total cost and length of project.
117	Montgomery County, Maryland. 2001.	Unpublished cost data from throughout Montgomery County, Maryland.
Default Cost: $125/foot		

2.15 Urban Program Costs

In addition to the specific costs presented in this section, some general program costs may be incurred to pay for various stormwater control programs and stormwater treatment practices. Table 23 summarizes a few of these costs, adapted from the Rapid Watershed Handbook (CWP, 1998a).

Table 23 Overall Program Costs

Ordinance Adoption	$15,000/ordinance
Zoning Change	$15,000 per zoning change
Land Trust - Seed Money	$25,000
Channel Assessment	$1,500/mile
Site ID for Restoration	$600/site
Stream Assessment (Rapid)	$500/reach (200 feet)
Riparian Cover/ Wetlands Assessment	$750/mile
Stream Restoration Assessment	$2,500/subwatershed
Conservation Easement Acquisition	$2,500 per acre

Note: Assumes a 10 square mile subwatershed

SECTION 3 -AGRICULTURAL COSTS

The following section presents coats for the practices included in the Watershed Treatment Model. The data in this section represent a combination of itemized costs for particular items and overall costs. An important factor to consider when using any of these data is where a particular cost was incurred. Some sources report total cost savings for practices, which include savings to the farmer for materials such as fertilizer, for example. Other costs represent program costs incurred, and do not account for cost savings. In addition, costs vary significantly depending on the region of the country. The user should consult the soil and water conservation office for detailed local information.

Please note that all costs in this section are in 2001 dollars and were developed by adjusting from 1999 costs to 2001 costs using the producer's price index for that time period.

3.1 - Conservation Tillage

Conservation tillage can include a range of practices from mulch-till to no-till planting. These practices require different equipment and level of planning, and thus have significantly different costs. Table 24 summarizes cost data for implementing conservation tillage.

Table 24. Conservation Tillage Costs

Source	Capital Costs	Annual Cost	Notes
Smolen and Humenik, 1989	$ 10/acre - $53/acre Median: $27/acre	None reported	Does not incorporate
Camacho, 1991	None reported	$22/acre	Typical annual data from the Chesapeake Bay region.

3.2 - No Till/ Strip Till

In this practice, soils are left undisturbed from harvest through planting, and planted in a narrow strip. Costs are presented below.

Table 25. No Till/ Strip Till Costs

Source	Capital Costs	Annual Cost	Notes
Parsons, *et al.* (2001)	0	\$20-\$45	Most expensive for larger farms. Small and medium farms at the lower price range.
Camacho, 1991	None reported	\$14	Typical annual data from the Chesapeake Bay region.

3.3 - Crop Rotation

Crop rotation in itself does not necessarily incur a very large cost, and may even result in cost savings over time, but an associated cost may be the planting of a cover crop during the winter season. One typical cost is the use of a cover crop is approximately \$12/acre/year within the Chesapeake Bay Basin.

3.4 - Integrated Pest Management (IPM)

When all costs and benefits are considered, IPM typically results in a net cost benefit due to improved yields, and savings on pesticide application . One direct cost associated with IPM, though is the time spent scouting for insects. Some typical scouting costs in coastal areas are provided in Table 26 below.

Table 26. IPM Scouting Costs
(Source: US EPA, 1993)

Crop	Price Range

Corn	$6 - $10
Soybean	$4 - $8
Wheat	$4 - $7
Rice	$6 - $11
Cotton	$7 - $12
Fresh Vegetables	$31 - $50
Hay (Alfalfa)	$2.50 - $6.50
Notes: Ranges represent regional variation and “high” and “Low” for each region. Some costs include soil sampling as well.	

3.5 - Nutrient Management

Overall, nutrient management is a net benefit to farmers, although some costs may be incurred in order to develop nutrient management plans. Parsons, et al. (2001) estimates overall savings of between $8 and $12 for corn, but a cost of between $2 and $6 for grass. Overall, this practice appears to be the most cost-effective when applied to larger farms.

3.6 - Grazing Management

Grazing management is a broad practice that refers to a series of practices designed to restrict cattle from entering sensitive areas, such as riparian areas or highly erodible soils. The practice can include specific measures, such as water source development, stream fencing, and vegetation of sensitive areas. Costs for these specific measures are included in Table 27 below.

Table 27. Costs for Grazing Management
(Source: US EPA, 1993)

Practice	**Capital Cost**	**Comments**
Vegetative Establishment	$75-$370/acre	
Fencing	$2,900-$5,000/mile ($3,100 median)	Represents nationwide data for permanent fencing. Overall, the costs are constant, except for Alabama, which has a significantly higher cost.
Water Development	$0.25 - $1.62/lf of Pipeline ($0.43/lf median)	Three cost from California, Oregon, and Nebraska. Nebraska had a much higher cost than the other two states.
	$480 to $1400 /Well ($1,400 median)	Regional data from Kansas, Alabama, and Oregon. Oregon was significantly lower than other regions.

3.7 - Animal Waste Management

Animal waste management can include a variety of practices designed to reduce nutrient and pathogen export resulting from animal waste. The data in Table 28 below summarize costs for various animal waste management techniques.

Table 28. Costs for Animal Waste Management (Parsons, *et al.* 2001)

PRACTICE	FARM	TYPE	CAPITAL	ANNUAL
Manure storage	Small	liquid	247/au	1/au
		stack	336/au	-8/au
	Medium	liquid/no pump	102/au	-2/au
		liquid/pump	174/au	-1/au
Barnyard	Small	VFS	119/au	-3/au
		to pit	96/au	-2/au
	Medium	VFS	111/au	-3/au
		to pit	105/au	-3/au
Milkhouse	Small	VFS	33/au	-1/au
		to pit	26/au	-1/au
	Medium	VFS	19/au	-1/au
		to pit	21/au	-1/au
	Large	to pit	9/au	-1/au
Feed formulation	Small	--	0	-2/au
	Medium	--	0	-2/au
	Large	--	0	-2/au
Manure export	large	--	144/au	-13/au

Manure Storage: Storage in a pit, lagoon, or stacking facility.
Barnyard: Conveyance of barnyard runoff to manure storage, a settling basin or filter strip.s
Milkhouse: Conveyance of milkhouse waste to manure storage, a settling basin or a filter strip.
Feed formulation: Change in feed composition to reduce nutrient export
Manure Export: Export or sale of manure so that approximately 15% of manure phosphorus is exported..
VFS: Vegetated Filter Strip

3.8 - Conservation Buffers

Conservation buffers include a variety of practices designed to provide filtration of agricultural runoff as water flows from the edge of the farm field to the stream. Some practices include grassed filter strips, grassed waterways with a vegetated filter, and riparian forest buffers. Some typical costs for these practices are included in Table 29.

Table 29. Costs of Conservation Buffers

Practice	Capital Cost	Annual Cost	Source	Notes
Row Crop Field Buffer	$2/acre	$2/acre/yr	Parsons, et al. (2001)	
Pasture Field Buffer	$125-$240/acre	Savings of $2 to $6/acre/yr	Parsons, et al. (2001)	Initial capital cost includes fencing or other mechanisms to keep livestock away from streams
Hay Field Buffer	0	$8-$20/acre/yr	Parsons, et al. (2001)	
Waterways		$1.25/lf/yr	Camacho, 1991	Assumes a 10-year lifespan.
Reforestation		$60/ac/yr	Camacho, 1991	Dollars per acre reforested. Assumes a 10-year lifespan
Grassed Waterways	$150/acre		Barbarika, 1987	As reported in US EPA, 1993

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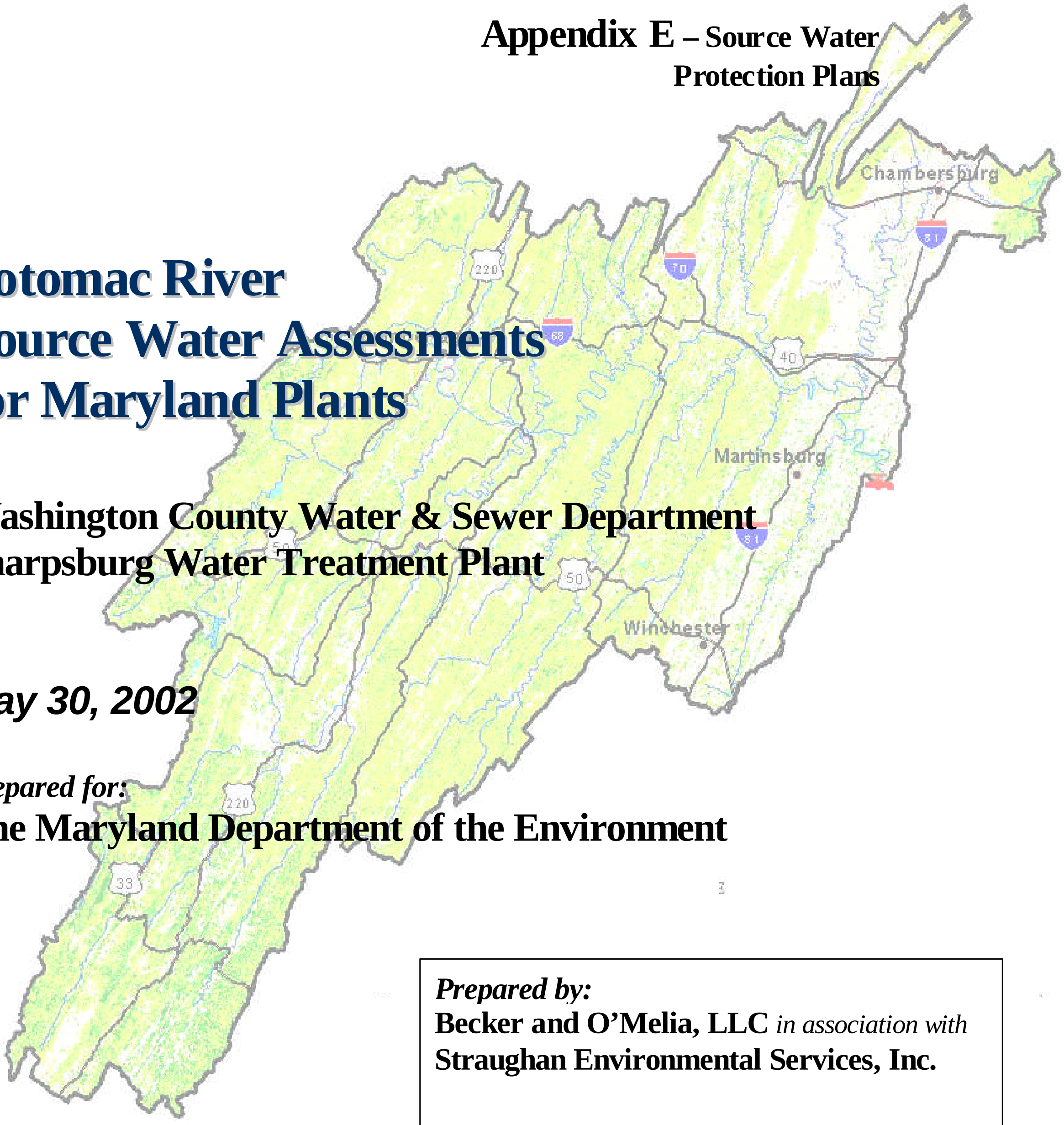
Appendix E – **Source Water Protection Plans**



Potomac River Source Water Assessments for Maryland Plants

Washington County Water & Sewer Department
Sharpsburg Water Treatment Plant

May 30, 2002

Prepared for:
The Maryland Department of the Environment

Prepared by:
Becker and O'Melia, LLC *in association with*
Straughan Environmental Services, Inc.

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WATER PROCESS RESEARCHERS AND CONSULTANTS

INTRODUCTION

The historically separate goals of safer drinking water and cleaner natural waters are converging. Pollution sources within the Potomac Watershed are diverse, and protection of this valuable resource will rely on management and control strategies that may lie beyond the authority of Washington County and MDE. These issues will likely prove very difficult to address without the involvement of many watershed stakeholders. Some US drinking water utilities have been engaged in effective source water protection for some time, and these utilities generally maintain close working relationships with local government and watershed councils. Many of these utilities have implemented land exchange agreements with land management agencies, and/or with farmers to implement BMPs. The experiences of several utilities in establishing and maintaining water supply protection programs are summarized below. Review and comparison of successful source water protection plans demonstrates the importance of coordination (whether through formal or informal partnerships) among the active players in watershed management including water utilities; federal, state and local governments; watershed councils; and grassroots organizations. These stakeholders will have a range of missions, jurisdictions, and authorities and may be better able to fulfill each mission with close partnerships. Important steps in implementation of an effective watershed program that would be facilitated by a watershed protection work group include;

- Establishment of goals for a watershed program,
- Public outreach,
- Study and program design activities,
- Legal, financial, and institutional arrangements,
- Implementation of a watershed protection program, and

- Monitoring and evaluation of the effectiveness of the program.

A brief review of select ongoing source water protection programs maintained by U.S water authorities follows.

NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION

The New York City Department of Environmental Protection (DEP) provides drinking water to 9 million customers in New York City. The water supply system includes 19 reservoirs in the Croton, Catskill and Delaware watersheds, which total 1,969 square miles in area. These sources are not filtered, although there are plans to filter the Croton supply. DEP funds the voluntary Watershed Agricultural Program in order to promote implementation of agricultural and other BMPs within the watershed. The program is administered by the Watershed Agricultural Council, which determines how funds will be spent and reviews whole farm plans which are prepared by local teams of staff from soil and water conservation districts, the Cooperative Extension Service, and the Natural Resource Conservation Service. DEP committed $35.2 million to the program from 1995 to 1999 to fund activities including:

- whole farm planning, design, and engineering (described in detail below);
- implementation and construction of BMPs;
- program management;
- administration,
- outreach; and
- research and technical support for the farmers.

By 1997, 287 of the 350 eligible farms in the Croton Watershed had signed up for the Watershed Agricultural Program. 155 of these completed whole farm plans and signed implementation agreements.

Whole Farm Planning includes multiple barriers, which may include:

- pollutant source control,
- herd health maintenance,
- sanitation and calf housing improvements
- soil sampling
- management of grass and hay production to reduce excess fertilization,
- integrated pest management,
- landscape controls,
- barnyard improvements,
- manure storage,
- scheduled, direct manure spreading,
- animal waste composting,
- stream corridor controls,
- streambank stabilization,
- animal watering systems, and
- vegetative buffers.

Like the Potomac Watershed, the Croton Watershed spreads across many jurisdictions and includes many land uses. Improved relationships with local, state and federal agencies have allowed coordination on important aspects of the watershed management plan. Most of these BMPs conserve farm resources while protecting New York's water supply. Monitoring programs are underway which measures the water quality impact of the program. The results of this monitoring are also used to calibrate individual farm specific models of water quality impacts.

DEP has committed $10 million to a 10-year watershed land acquisition program in the Catskills and Delaware systems. Another $10 million of DEP funds and $7.5 million of state funds have been similarly committed to purchases in the Croton Watershed. Lands have been prioritized for purchase based on natural features and proximity to DEP intakes and conveyance systems. DEP will work with local communities and provide up to $20,000 to each town to supplement the review process.[1]

MASSACHUSETTS WATER RESOURCES AUTHORITY

Massachusetts Water Resources Authority (MWRA) provides drinking water to more than 2 million customers in Boston and 45 neighboring communities. MWRA utilizes 3 surface water sources including the Quabbin and Wachusett reservoirs. The Metropolitan District Commission (MDC) is responsible for managing the watersheds. MWRA and MDC staff use GIS-based mapping of the watershed to identify pollution sources including septic systems, recreational activities, storm water run off, logging, petroleum storage, and natural impacts as a basis for watershed protection plans. The GIS maps have also assisted notification and implementation of regulations, which has improved relations with affected communities and landowners. The Watershed Protection Act, passed by the Massachusetts Legislature in 1992, prohibits any land disturbing or polluting activities (including most new construction) within 400 feet of drinking water reservoirs and 200 feet of tributaries.

After a large rainfall event, source water quality can decrease and contaminant concentrations can increase significantly. MWRA works with storm water and erosion control project petitioners to review all plans and designs. Massachusetts legislation requires MWRA review of all proposed changes within 400 feet of designated tributaries,

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[1] NAE 2000

wetlands and flood plains. Annual watershed sanitary surveys help MWRA identify areas of concern. After identification of a threat, MWRA works with the responsible party to mitigate the situation. MWRA also provides technical assistance to communities to revise sediment and erosion control requirements.[2]

CHESTER WATER AUTHORITY

The Chester Water Authority provides drinking water to a population of 200,000 in Chester, Pennsylvania. The primary water supply is the Octoraro Reservoir and its 140 square mile watershed. Treatment includes filtration. Watershed partners include conservation commissions, farmers, a local watershed association, Partners for Wildlife, the Pennsylvania Fish and Boat Commission, and the Pennsylvania Department of Conservation and Natural Resources. These partnerships bridge the gap between Chester Water Authority customers who do not live in the watershed, and watershed landowners who do not drink the authority's water, a situation generally the same as WCW&SD's. Management practices promoted by the partnership include streambank fencing, barnyard management, crop rotation, and riparian buffers throughout the watershed. In order to stress the flexibility of BMP implementation, the partnership supports buffer strips that are smaller than recommended by textbooks. The partnership assists farmers in seeking financial aid from federal, state and local agencies.[3]

SYRACUSE WATER DEPARTMENT

The Syracuse Water Department provides drinking water to 160,000 customers in Syracuse New York. The primary source of supply is Skaneatles Lake, which has a 37 square mile watershed. Watershed partners include the County Board of Health, local governments, and the New York State Department of Environmental Conservation

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[2] AWWARF 1991

[3] EPA 1999

(NYSDEC). The water system assists NYSDEC in uncovering watershed problems and the State allows the utility to review and comment on any shoreline disturbance permit that affects the lake. The water utility has been designated as the County Board of Health's official representative for observing septic system percolation tests. SWD staff are included in the review of building permits to make sure that they are not in conflict with concerns for water quality. Skaneatles, NY rewrote its zoning laws to allow SWD to review zoning actions including applications for building permits and subdivision actions to ensure compliance with watershed rules.[4]

SALEM PUBLIC WORKS DEPARTMENT

The Salem Public Works Department provides drinking water to 150,000 customers in Salem, Oregon. The primary source of supply is the North Santiam River, which has a 600 square mile watershed at the point of withdrawal. Watershed partners include the North Santiam Watershed Forum, U.S. Army Corps of Engineers, U.S. Bureau of Land Management, and the U.S. Forest Service. In the past, winters with high rainfall and flooding caused persistent high raw water turbidity, which disrupted Salem's slow sand filtration process forcing the City to use alternate sources of supply, install temporary treatment works, and curtail use. This prompted the City and the U.S. Forest Service to negotiate a Memorandum of Understanding for forestry management in the watershed. This agreement clarifies responsibilities for maintaining quality water for the City's use. The City and the Forest Service agreed upon joint monitoring and share equally in the cost of operating 10 sampling sites. The Salem Public Works Department has also been active in a voluntary watershed council, which represents timber

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[4] AWWARF 1991

production, agriculture, local enterprise, cities, environmentalists, recreation interests, and local residents.[5]

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

The San Francisco (California) Public Utilities Commission treats water from 6 reservoirs on Tuolumne River, and Rattlesnake and Moccasin Creeks in the Hetch-Hetchy Watershed System, which is 760 square miles in area. Watershed partners include California Department of Health services, California Highway Patrol, Community Health Service District, County Planning and Environmental Health Organizations, Hetch-Hetchy Watershed Working Group, National Park Service, Regional Water Quality Control Board/Central Valley Region, U.S. Bureau of Land Management, and U.S. Environmental Protection Agency. In order to meet requirements of the SDWA and the SWTR, and to maintain filtration avoidance for its unfiltered sources, the San Francisco Public Utilities Commission completed a watershed sanitary survey and a watershed management plan, which called for a watershed working group that will meet until the management plan is well underway. The philosophy of the working group is to include any potential stakeholder, and input from numerous stakeholders has been solicited. The management plan's success depends upon coordination with and participation of stakeholders and upon agencies that administer the watershed lands. Potential conflicts among stakeholders that must be addressed include horse corrals within the watershed, improperly functioning toilets in a national park, and responsibility for water quality monitoring. Including community members in the

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[5] AWWARF 1991

assessment phase has increased public support of drinking water protection measures. This is important, since many of the critical protection measures are under local control.[6]

CONTRA COSTA WATER DISTRICT

The Contra Costa Water District in Concord, California provides drinking water to 400,000 customers. The primary source waters are the Sacramento and San Joaquin rivers. The Los Vaqueros Reservoir Watershed has an area of 18,500 acres. The water district has a water resources group within the planning department that is active in Central Valley source water protection including participation in hearings of the Central Valley Regional Water Quality Control Board (which issues NPDES permits). The utility has worked with other stakeholders to provide incentives for the mitigation of agricultural drainage discharges, to test treatment of agricultural run off, and to remediate mine drainage. Grazing and farming are permitted where biological resource and fire management needs are critical and where the potential risks of water quality degradation are low. Fencing along all major tributaries keeps cattle out of the water and provides a vegetative buffer. Monitoring of 5 sites are carried out under this program including organic, inorganic, bacteriological, and nutrient parameters.

LOS ANGELES DEPARTMENT OF WATER AND POWER

The Los Angeles (California) Department of Water and Power (LADWP) supplies drinking water to 3.7 million customers. The primary source water is the Owens River/Mono basin within the Eastern Sierra Watershed. Approximately 2.2 million acres of this watershed supply the city's raw water. The LADWP, US Forest Service, and Bureau of Land Management own 98% of the watershed. LADWP owns 314,000 acres of which 260,000 are leased for ranching (247,000 acres), recreation and commercial ventures. Lease policies designed to protect the water supply and water quality are set

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[6] AWWARF 1991

forth in a LADWP document. Individual Ranch Management Plans are being prepared jointly with each of the Lessees. LADWP staff conduct inspections to ensure compliance. Range management guidelines require users of the land to:

- keep livestock, salts and animal supplements away from source waters and riparian zones,
- consult with LADWP prior to initiation of water diversions, and
- adhere to irrigation practices that minimize run off, erosion and return flows.

The county agricultural commissioner administers pesticide and herbicide use permits.

Urban expansion in the watershed conforms to Inyo County's General Plan, which includes a land use policy to manage the groundwater basins to ensure water quality and quantity. Overnight camping is prohibited throughout the city owned portion of the watershed. Waste receptacles, portable toilets and regular watershed patrolling are also employed.[7]

METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

Metropolitan Water District of Southern California (MWD) provides drinking water to 16 million customers. Primary source waters include the Colorado River and California State Water Project. Watersheds include Lake Matthews (39 square miles), Colorado River Basin (150,000 square miles), and California State Water Project (42,000 square miles). Lake Matthews and Colorado River basins are sparsely populated, but significant urbanization is expected in each of these watersheds. In cooperation with landowners, a residential developer, local county representatives, and Flood Control and Conservation staff, MWD has developed a watershed management plan to mitigate the impacts this development will have on water quality. One key element of the Lake Matthews management strategy is to use a series of wetlands to remove pollutants from the first flush and nuisance flows and to provide habitat for wildlife. Constructed water quality ponds would provide first flush diversion and a sediment basin would remove sediment before it enters Lake Matthews. [8]

SWEETWATER AUTHORITY

The Sweetwater Authority (Chula Vista, California) provides drinking water to 165,000 customers. The primary sources of raw water are the Colorado River, California State Project Water and groundwater. Increasing urbanization threatens the water quality of the Sweetwater Reservoir. An Urban Run off Diversion System (URDS) has been constructed to mitigate these threats. Facilities constructed in the first phase diverted low flows and first flush run off from the watershed at a cost of $6.5 million. The system has reduced salt, mineral, nutrient, pathogen and coliform loadings.[9]

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[7] AWWARF 1991
[8] AWWARF 1991
[9] AWWARF 1991

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