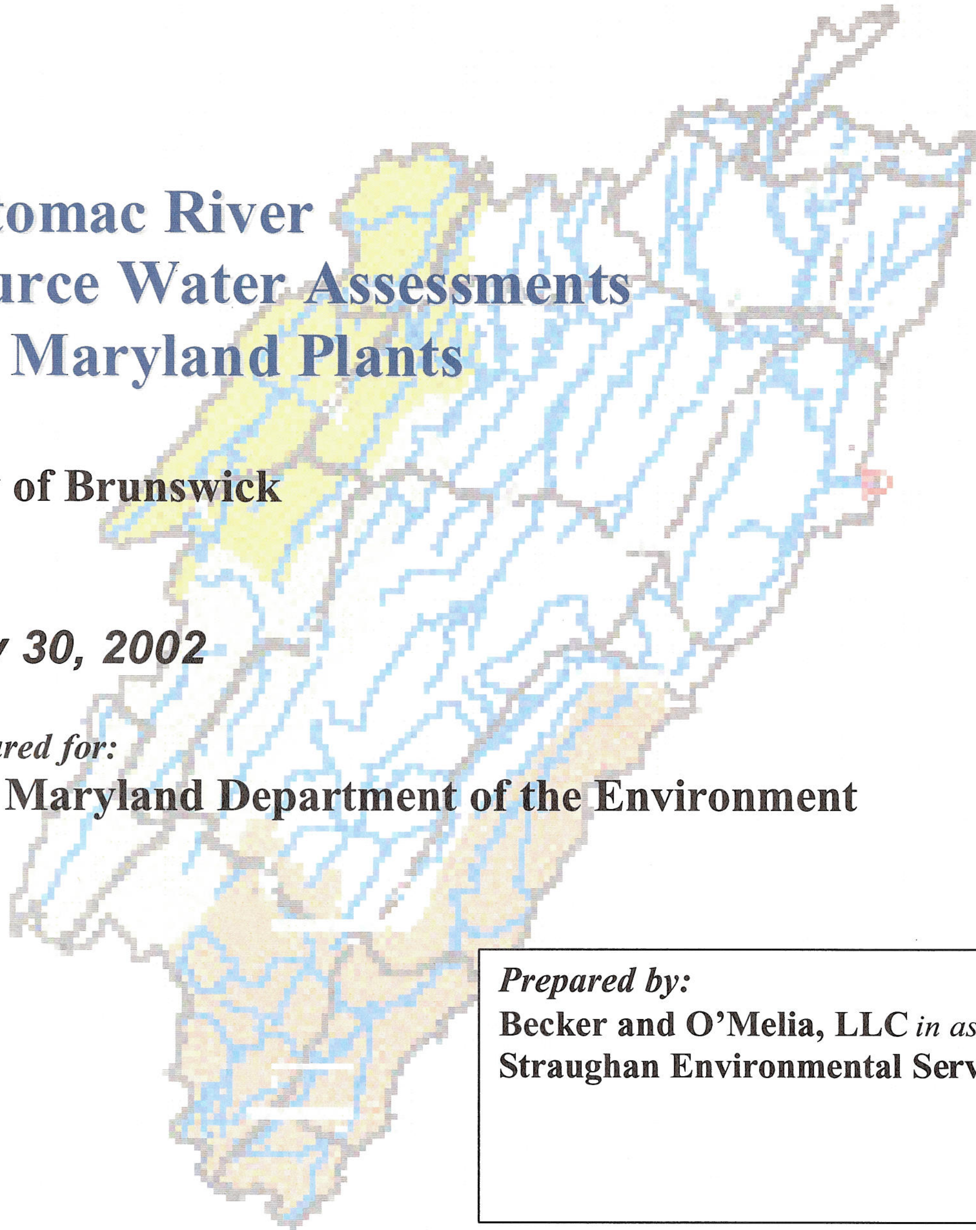
Final Report



Potomac River Source Water Assessments for Maryland Plants

City of Brunswick

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

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 the City of Brunswick'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, fecal coliforms, and atrazine.
- 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 the City of Brunswick'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 City of Brunswick's 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 Brunswick 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 Brunswick 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 Shenandoah Basin and Great Valley is dominated by agricultural land uses including cropland and pastures with a significant forested area, although very little of this 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 essentially unchanged throughout the watershed.
- Some forested areas throughout the watershed are expected to become urbanized and this development will result in increased residential development, commercial/industrial development, and roadways and similarly decreased forested areas.
- Projections include reductions in active construction activities in the headwaters, Shenandoah Valley and Great Valley.

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 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 City of Brunswick, the 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 Brunswick 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 Brunswick WTP

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

There are also significant populations of livestock within the watershed. Livestock are a confirmed and significant source of *Cryptosporidium* oocysts and *Giardia* cysts and pose a challenge to water suppliers on the Potomac River including the City of Brunswick.

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 Brunswick'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 the City of Brunswick have consistently improved the quality of water supplied to Brunswick'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 Brunswick WTP. Although somewhat less well documented and quantified, the effects of non-point sources of pollution are known to be significant in the 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] USEPA (1999).

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 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 are 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]

[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

---

[3] M^cKenzie 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 Brunswick 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, and
- development of recommendations for a Source Water Protection Plan.

- 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 Brunswick WTP. Water quality data were collected from a variety of sources and evaluated to determine the level and frequency of historical occurrences at the City of Brunswick's Intake. 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 that part of the bay watershed upstream of the Brunswick 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 Brunswick 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 Brunswick 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 Potomac Watershed is an interjurisdictional, multistate watershed encompassing approximately 9,410 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 and Middle Potomac region include a great deal of agricultural areas as well as the urban areas of Winchester, Hagerstown, Chambersburg, Harrisonburg and Staunton.

3.2 - Description of Brunswick WTP

The Brunswick WTP is a 1 MGD facility employing raw water intake and pumping, static mixing of treatment chemicals, upflow adsorption clarifiers and multimedia filtration units (Trident Microfloc ®), and chlorine disinfection. Clarification and backwash treatment residuals flow to the City's wastewater system after on-site storage, which avoids spikes at the wastewater plant.

Treatment includes addition of potassium permanganate ($KMnO_4$), alum or polyaluminum chloride (PACl) as the primary coagulant, polymers, powdered activated carbon (PAC), chlorine and lime. Alum is applied as a primary coagulant, except during the winter when PACl is applied to aid cold water treatment. KMnO4 is added for control of algae in the treatment facilities and for taste and odor control. PAC is on hand for taste and odor control, but this system was in need of repair and unavailable during the site visit.

The intake facilities include a single submerged cylindrical wedgewire screen, located approximately 300 feet from the shore. River water flows through approximately 700 feet of pipe to the raw water pump station wetwell. An air blast system located in the pumping station blasts algae, ice, and other debris from the screens. From the pump station, water is pumped through a 12-inch force main, under the C&O Canal and Tow Path and a rail yard to the treatment works.

3.3 - Results of Site Visits

The intake facilities at Brunswick have a history of problems with clogging due to sediment accumulation at the wedgewire screens in the river. As sediment collected near the intake, the plant would be forced to shut down for several days. Operators report that the City maintains a contract with commercial divers who remove sediment to a level 2-feet below the intake, twice a year. This has reportedly solved the sediment clogging problems of the past. The screens are normally submerged by more than 5 feet, but at the time of the site visit, which occurred during a very low flow event, the screens were reportedly just over 2 feet below the surface.

Treatment disruptions have also been reported due to clogging of the screens with filamentous algae growths. The air blast system reportedly clears the screens of these growths, as well as ice, which forms on the screens in the winter. Prechlorination is occasionally practiced to control algal growth within the treatment works.

The raw water pipeline travels under a significant rail yard which could represent a contamination threat due to spills in the yard. The site visit and discussions with staff did not indicate that the pipes are more deteriorated than the norm and thus represent no more significant public health threat than other passing beneath rail lines.

Operators report that no disruptions to service have been caused by spills, but staff report concern due to upstream transportation crossings. Staff further report that discharges of untreated or partially treated wastewater from the Sandy Hook WWTP have caused problems in the past. When CSOs occur in the Cumberland area, the plant is notified and shuts down while the plume is thought to be passing. These disruptions last approximately 6 hours. Operators further report that they are not notified of discharges of partially treated wastewater from the Sandy Hook WWTP. The Route 314 highway bridge crosses the Potomac just upstream of the intake. Operations staff are somewhat concerned about the potential for spills from this bridge or from the rail crossing at Harper's Ferry.

Water quality at the plant seems to be somewhat marginal for the upflow adsorption clarification process employed at the plant. Operators report difficulty operating at rated capacity when river water turbidity exceeds approximately 100 NTU. Under these circumstances backwashes are initiated as often as every 6 hours (rather than the more typical 24 hour filter runs) and occasionally operations are halted due to turbidity spikes. The operators credit the midriver location of their intake with reducing the number and intensity of turbidity spikes. The plant also experiences significant pH spikes, which are characterized by significant diurnal variations (ranging from approximately 7.8 to 8.9). The selection of alum as a primary coagulant is reportedly due to its ability to reduce this pH.

In spite of these water quality challenges, operations staff anticipate no difficulties meeting the 0.3 NTU requirements of the LT2ESWTR.

SECTION 4 - WATERSHED CHARACTERIZATION

The Bay Program watersheds include 8 Potomac River subsheds that lie upstream of Brunswick's 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
190	South Fork Shenandoah		Augusta, Page, Rockingham, Warren		
200	North Fork Shenandoah & Shenandoah		Clarke, Frederick, Rockingham, Warren, Shenandoah, Page*		Jefferson
740	Conococheague-Opequon	Washington	Clarke, Frederick	Franklin, Fulton	Morgan, Jefferson, Berkeley
730	Conococheague-Opequon	Washington*		Franklin, Adams*	
180**	Conococheague-Opequon & Middle Potomac-Catoctin	Washington, Frederick*	Loudon	Franklin, Adams	Jefferson

* subwatershed contains a very small portion of this county
** The Brunswick WTP is located within Subshed 180 and only a portion of this subshed is upstream of the intake.

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. Current land uses within the subwatersheds are also shown, organized according to Bay Program subwatershed, 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 Shenandoah Basin and Great Valley, (subsheds 190, 200, 740 and 730) is dominated by agricultural land uses including cropland and pastures with a significant forested area, although very little of this forested areas are under silviculture.

Table 2 – Land Use in the Brunswick WTP Watershed (1997)

Chesapeake Bay Program Subwatershed	160	170	175	180*	190	200	730	740	Total
	North Branch Potomac	South Branch Potomac	Cacapon-Town & Conoc. - Opequon	Conoc.- Opequon & Mid. Potomac-Catoctin	S. Fork Shen.	N. Fork Shen. & Shen.	Conoc.	Conoc.	
Low Density Residential	9,628	2,129	2,743	8,768	32,965	17,306	5,733	15,641	94,913
High Density Residential	555	96	35	1,226	808	323	781	839	4,663
Commercial/ Industrial	1,373	280	341	1,413	3,291	1,029	1,762	2,413	11,902
Roads	11,462	7,833	7,705	6,254	14,687	11,380	4,915	14,512	78,748
Pasture	62,192	131,577	56,042	74,112	239,076	175,750	30,179	126,859	895,787
Crops	18,052	5,992	20,000	108,348	66,531	68,491	102,968	100,384	490,766
Hay	28,639	24,736	32,288	55,258	91,747	88,641	48,401	107,687	477,397
Forest	695,189	762,657	671,775	145,382	606,229	509,389	113,755	488,291	3,992,667
Grass/Parks	-	-	-	279	557	117	146	341	1,440
Mining/Quarries	14,977	204	295	200	627	1,354	179	1,501	19,337
Active Construction	1,017	678	381	786	2,496	1,953	372	1,878	9,561
Forestry	3,645	4,792	5,719	284	305	974	789	-	16,508
Water/Wetlands	9,542	5,120	5,348	6,429	9,075	7,758	5,157	10,247	58,676
Total Area (acres)	856,270	946,095	802,672	408,738	1,068,394	884,465	315,135	870,593	6,152,362

* The Brunswick WTP is located within Subshed 180 and only a portion of this subshed is upstream of the intake.

o

Figure 1 1997 Land Use

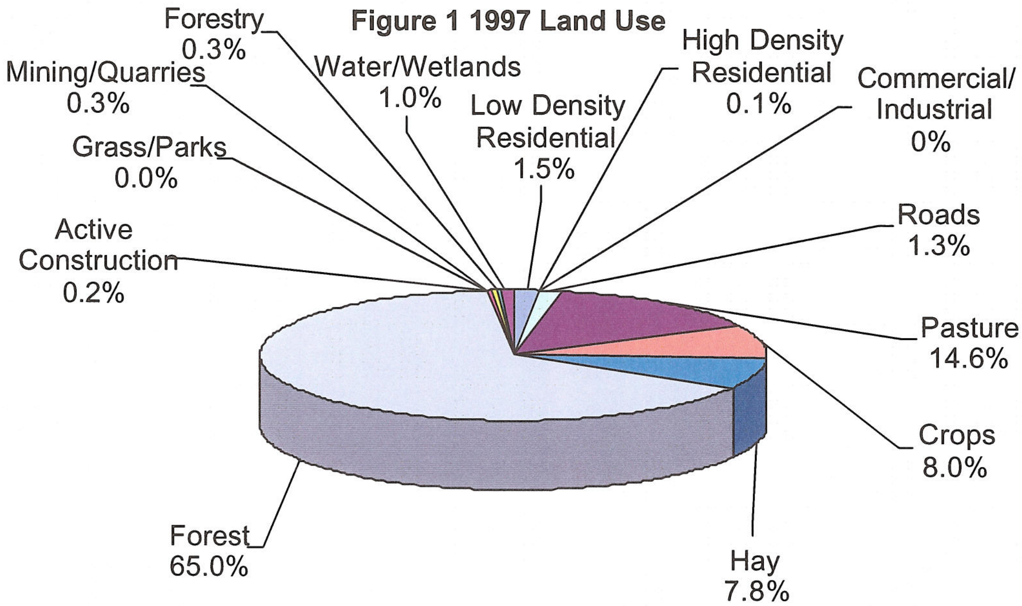


Table 3. Number of Animals by Watershed Segment.

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
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
730	65,184	27,673	156,846	36,443	49,229
740	22,055	15,933	31,631	2,697	15,781
Total	131,215	115,620	738,652	5,192,644	1,288,284

* The Brunswick WTP is located within Subshed 180 and only a portion of this subshed is upstream of the intake.

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

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 354 wastewater treatment plants in the watershed, more than 270 of which are considered minor based on treatment capacity.

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. Projected population, organized according to Chesapeake Bay Program Office (CBPO) subwatershed, is shown on Table 5. Both Table 4 and Table 5 include populations for the entire subshed in which the Brunswick is located including some areas downstream of the intake.

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
MIDDLE POTOMAC-CATOCTIN	517,551	550,987	583,142
NORTH BRANCH POTOMAC	114,423	114,490	116,427
NORTH FORK SHENANDOAH	74,092	77,318	81,313
SHENANDOAH	44,506	46,659	49,034
SOUTH BRANCH POTOMAC	29,181	30,156	29,659
SOUTH FORK SHENANDOAH	188,087	195,205	195,750
Total	1,363,562	1,424,927	1,486,431

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
180*	15% of Conococheague 26% of Middle Potomac	169,359	201,838	32,479
190	South Fork Shenandoah	195,423	214,667	19,244
200	Shenandoah South Fork Shenandoah	126,524	158,291	31,767
730	Conococheague	83,868	89,597	5,729
740	Conococheague	204,981	265,489	60,508
Total		956,044	1,113,758	157,714

* The Brunswick WTP is located within Subshed 180 and only a portion of this subshed is upstream of the intake.

4.3 - Land Use Projections

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

- Agricultural, silvicultural and mining land uses are expected to remain essentially 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.

Table 6 – Projected Land Use in the Brunswick WTP Watershed (2020)									
Chesapeake Bay Program Subwatershed	160	170	175	180*	190	200	730	740	Total
Low Density Residential	12,794	3,103	3,868	12,892	48,663	32,336	7,291	33,373	212,313
High Density Residential	738	140	50	1,802	1,193	603	993	1,791	11,550
Commercial/ Industrial	1,824	408	481	2,078	4,859	1,922	2,240	5,150	26,962
Roads	15,231	11,419	10,865	9,196	21,681	21,263	6,251	30,963	156,325
Pasture	62,192	131,577	56,042	74,112	239,076	175,750	30,179	126,859	1,102,440
Crops	18,052	5,992	20,000	108,348	66,531	68,491	102,968	100,384	773,018
Hay	28,639	24,736	32,288	55,258	91,747	88,641	48,401	107,687	639,798
Forest	688,143	758,293	667,426	137,318	582,656	483,555	110,308	449,828	4,224,598
Grass/Parks	-	-	-	279	557	117	146	341	4,363
Mining/Quarries	14,977	204	295	200	627	1,354	179	1,501	22,825
Active Construction	494	309	290	542	1,423	1,701	234	2,470	9,727
Forestry	3,645	4,792	5,719	284	305	974	789	-	17,032
Water/Wetlands	9,542	5,120	5,348	6,429	9,075	7,758	5,157	10,247	88,055
Total Area (acres)	856,271	946,093	802,672	408,738	1,068,393	884,465	315,136	870,594	7,289,005

* The Brunswick WTP is located within Subshed 180 and only a portion of this subshed is upstream of the intake.

- Projections include reductions in active construction in the headwaters, Shenandoah Valley and Great Valley.

SECTION 5 - WATER QUALITY DATA

In order to determine the historical occurrence of contaminants in the raw water at the Brunswick 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. The City of Brunswick 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 particular concern at the Brunswick WTP. The project team has reviewed historical water quality reports, and data stored in 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 the City of Brunswick and other Potomac River water suppliers.

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

- Natural Organic Matter
- *Giardia*
- *Cryptosporidium*
- Tastes and odors
- Sediment
- Algae
- Disinfection By-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 data indicate that measured concentrations do not exceed 50% of the current MCL more than 10% of the time (the "50/10" criterion). 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 Brunswick WTP.

Details of evaluations for inorganic compounds are presented in Appendix A. Of the 11 listed inorganic compounds for which data was available, 8 had no positive samples (above the detection limit) for the contaminant. Of those that include positive samples, none have been detected at concentrations exceeding 50% of the MCL. Therefore none of these inorganic chemicals will be considered a contaminant of concern at the WTP.

Details of evaluations for organic compounds are also presented in Appendix A. Of the 42 contaminants for which data was available, 37 had no positive samples (above the detection limit) for the contaminant. Of the five organic contaminants which include positive samples, none have been detected at concentrations exceeding 50% of the MCL. Details on positive organic chemical samples are presented in Table 3. In each case of a positive di(2-ethylhexyl)adipate and di(2-ethylhexyl)phthalate result, these chemicals were also found in laboratory blank samples and therefore these samples are not believed to represent the actual water quality of the river. Evaluation of MDE Water Supply Program's Public Drinking Water Information System Database indicates that none of the organic chemicals for which data was available were present at concentrations exceeding 50% of the MCL. Therefore none will be considered contaminants of concern at the City of Brunswick's WTP.

Details of evaluations for radionuclides are presented in Appendix A. Data were available for beta particles & photon emitters and for gross alpha particle activity. There were no positive samples (above the detection limit) for gross alpha particle activity. Two samples for gross beta particles and photon emitters taken on December 1, 1999 had measurements equal to 1 pCi/L. Each of these is well below the MCL of 50 pCi/L and therefore, no radionuclide is considered a contaminant of concern at the Brunswick 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 Brunswick 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 effects data to determine at what concentration a particular contaminant is expected to cause a significant health effect. Once these health effects 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 in 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 8 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 city of Brunswick's Potomac River WTP.

5.1.2.3 - Contaminants Which Affect Brunswick 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 effects or established MCL limits. Under these criteria, evaluations (as described in detail in Appendix A) were performed for alkalinity, pH, and sediment (using turbidity as a surrogate).

Monthly operating reports from January 1999 to October of 2001 were evaluated to determine the occurrence, in the raw water, of contaminants that affect the operations of treatment works. Details of these evaluations are presented in Appendix A. Alkalinity has varied from 40 mg/L to 210 mg/L with an average of 119 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 6.3 to 8.9 with an average of 7.9 and a 10% exceedance of 8.3. High pH causes problems with coagulation when metal salts (like alum) are employed. In response to coagulation difficulties during periods of elevated pH, Brunswick has switched from Alum to polyaluminum chloride (PACl) as the primary coagulant. Although PACl does not suppress pH to the extent that Alum does, it may be a more effective coagulant at elevated pHs. Raw water turbidity has varied from 1.9 NTU to 310 NTU with an average of 17 NTU. Turbidity has exceeded 35 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.

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 Brunswick 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 Brunswick 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 Brunswick 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 more consistent and relatively higher concentrations. *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.

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 Advisory Committee (FACA) for the LTESWTR finalized an Agreement in Principle, which is

---

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

expected to serve as a foundation for the LT2ESWTR. The requirements of the LT2ESWTR have not been finalized but are expected to be as follows:

- <0.075 oocyst/L in the raw water – no inactivation required beyond that required by the IESWTR
- .075 – 1 oocyst/L in the raw water – 1 log inactivation required beyond that required by the IESWTR
- 1 – 3 oocyst/L in the raw water – 2 log inactivation required beyond that required by the IESWTR
- >3 oocyst/L in the raw water – 2.5 log inactivation required beyond that required by the IESWTR

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 Brunswick WTP. Historical sampling throughout 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

---

[7] LeChevallier, et al (1991)

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]. 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] Removal in conventional secondary WWTPs ranges from 87% to 99%[15]. 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 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.

---

[8] Jurenak et al (1995)
[9] Fayer, et al. (1997)
[10] Walker et al (1999)
[11] Xia et al. (1993)
[12] Holman (1993)
[13] Walker, et al (1999)
[14] States et al. (1997)

5.1.2.4.3 - Viruses and Coliform Bacteria

Data were available for fecal coliforms including a maximum concentration of 2200 MPN/100 ml. 10% of the samples had fecal coliform counts above 1,300 MPN/100 ml. MDE presumes a public health hazard if the log mean of fecal coliform samples exceeds 200 MPN/100 ml. The log mean of the raw water samples at Brunswick was 73 MPN/100 ml. Although fecal coliforms are removed and inactivated in conventional treatment like that practiced at Brunswick's Potomac River WTP, they are an indication of fecal contamination and may indicate contamination with other fecal pathogens. Fecal coliforms are therefore considered a contaminant of concern at the WTP.

5.1.2.5 - Contaminants Which Affect the Aesthetic Quality of the Water

Appendix A presents 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. 8 sulfate samples were collected from May 1995 to April 1998. Results indicate sample concentrations ranging from 11.5 to 69 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:

- Natural Organic Matter
- *Giardia*
- *Cryptosporidium*
- Tastes and odors

---

[15] Holman (1993)

- 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 (including dieldrin, which is a contaminant of concern at other Potomac River Water Treatment Plants) remain persistent in fish tissue and sediment at urban and agricultural areas[16].

[16] 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, Conococheague-Opequon, and Middle Potomac-Catoctin 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 lower 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 Brunswick 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 within the entire Potomac River Watershed while nitrogen loading has remained roughly constant [17,18]. Nonpoint sources account for approximately 60%-70% of combined nitrogen and phosphorus loading from the entire Potomac River 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.[19]

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.[20]

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,

---

[17] CB&WMA, 1993
[18] Tawil, May 1997
[19] CB&WMA, 1993
[20] ICPRB, 1995

which represents an improvement). Monitoring from the early 1970s through the mid-1980s indicates increasing lead and chromium and decreasing trends for mercury [21]. 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 are 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 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.

---

[21] ICPRB, 1987

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 CD) 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 the increased impervious cover, which can take 60 years or longer, this effectively represents a sediment load to the Brunswick 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.[22]

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.

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 Brunswick 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 and are many river miles from the intake. Six lime dosing stations have been installed by Maryland in the headwaters of the Potomac River to control pH. 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 Brunswick 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, NOM, and dieldrin, and also increases export of other terrestrial contaminants to the Potomac River and its tributaries.

---

[22] EPA 1999

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 Brunswick 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 implementation (between no management and aggressive management scenarios) 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 dependant 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.

The management of storm water for future development was characterized based on the fraction of a segment in each state. Appropriate estimates were made and are shown on Table 7.

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			

<u>7.1.1.2 - Current Urban Practices</u>

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 5% of all development is served by dry ponds, 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) and 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

<u>7.1.1.2.2.2 - Lawn Care Education</u>

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[23] 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.

[23] Wiedemen and Cosgrove, 1998

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
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
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 Brunswick WTP is located within Subshed 180 and only a portion of this subshed is upstream 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 "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 the 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 Brunswick 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 Brunswick 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 River is largely dependant upon the availability of 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[24,25]. Thus, source water NOM concentration has a significant affect on the operations and cost of drinking water

---

[24] Owen et al. 1993
[25] AWWARF 2000

treatment. However, the most important problem associated with NOM is that it includes precursors to disinfection by-product formation (organic chemicals which, when they react with chlorine form THMs and HAAs). 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.

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[26]. These aromatic organic chemicals are somewhat more likely to be chlorine disinfection by-product precursors 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.[27]

---

[26] Bouwer et al., 1995
[27] AWWARF- 1991

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, 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 Brunswick WTP indicate relatively high 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 that 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 Brunswick 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 Brunswick 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 Brunswick 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.

<u>7.2.2.4 - Algae</u>

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 Brunswick's intake, control of algae is generally dependant 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.

7.2.2.5 - 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 dependant 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 (bacterial, macrophytic, and bioturbation from benthic macrofauna). Streambeds therefore functions as sediment sources, sinks and storage sites. [28] The Bay Program Model models TSS explicitly.

Sedimentary particles are removed efficiently in conventional treatment like that practiced at the Brunswick Plant. In water treatment plants dieldrin generally remains attached to particles and is removed in the treatment process.

7.2.2.6 - 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 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 Brunswick 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 Brunswick 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

---

[28] DiToro, D.M., 2001

(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 180, 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 downstream end of subshed 180.

WTM results showed moderate to good changes in the 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 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

Table 11 – Upper Watershed Loads From WTM

Segment		Total Nitrogen	Total Phosphorus	Total Suspended Solids
		% of Current Load		
160	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%
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%

* The Brunswick WTP is located within Subshed 180 and only a portion of this subshed is upstream of the intake.

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 nutrient 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[29]. *Giardia* cysts are similarly persistent but also 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 Brunswick 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 (CBPO model of the Potomac Watershed). These edge-of-stream loadings were adjusted according to the WTM modeling task. Future conditions without new management practices are characterized my small increases in TOC and moderate increases in TSS. Because nutrients and solids are stored in the Potomac streambed and because algal activities are concentrated in quiescent zones, little change 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 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 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%	99%	95%	- 10%
Median	102%	99%	97%	- 5%
10% Exceedance	107%	99%	94%	- 13%

[29] Rose, J.B., 1997

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	101%	96%	92%	- 9%
Median	101%	98%	96%	- 5%
10% Exceedance	101%	96%	93%	- 8%

7.4 Model Results by Contaminant Groups

The modeling approach described previously in Section 2 and in detail in this section was utilized to analyze the susceptibility of the Brunswick 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 dependant 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 or 4 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 Brunswick, and therefore further analysis of this contaminant of concern was not conducted.

7.5 - Spill Source Evaluations

The Brunswick WTP 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 Brunswick WTP. For example, management practices which may not seem cost effective when considering only the impacts on the Brunswick 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;
   - public awareness, outreach and education efforts; and
   - aggressive involvement in agricultural BMP implementation plans to address nutrient, bacteria, and pathogen loads from urban lands.
2. Further studies and monitoring including:

- additional monitoring for significant contaminants including *Cryptosporidium*, and NOM surrogates (UV-254, TOC, DOC, and/or SUVA); and
- detailed evaluations of fecal contamination to identify the most significant sources of fecal contamination to target;

3. 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.

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, Hay land	NOM, DBPs, Algae, Sediment
Water Quality Plan	Cropland, Hay land, Pasture	NOM, DBPs, Algae, Sediment
Cover Crop	Cropland	NOM, DBPs, Algae, Sediment
Tree Planting	Cropland, Hay land, Pasture	NOM, DBPs, Algae, Fecal Coliforms, *Cryptosporidium*, *Giardia*, Sediment
Buffer	Cropland, Hay land	NOM, DBPs, Algae, Fecal Coliforms, *Cryptosporidium*, *Giardia*, Sediment
Highly Erodible Land Retirement	Cropland, Hay land	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

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 Brunswick 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 Brunswick WTP

The primary improvement management activities would accomplish would be the provision of an additional barrier in the protection of the health of Brunswick's customers. Significant environmental improvements would also be achieved through improved management. The following improvements relevant to the Brunswick WTP can also be expected:

- a reduction in the amount of treatment chemicals, (including coagulant, and chlorine) required to treat water at the Brunswick 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.

REFERENCES

American Metropolitan Sewerage Agencies. 1994. Separate Sanitary Sewer Overflows: What Do We Currently Know? Washington, D.C.

Appalachian Regional Commission. 1969. Acid Mine Drainage in Appalachia

Audubon Society Website – 2001

Auer, M.T., Bagley, S.T., Stern, D.E., and Babiera, M.J..1998 A Framework for Modeling Fate and Transport of *Giardia* and *Cryptosporidium* in Surface Waters. In Lake and Reser. Manage.14, (2-3): 393-400

AWWA Research Foundation, Effective Watershed Management for Surface Water Supplies, 1991

Bagley, S.T., Auer, M.T., Stern, D.E., and Babiera, M.J..1998. Sources and Fate of *Giardia* Cysts and *Cryptosporidium* Oocysts in Surface Waters. In Lake and Reser. Manage.14, (2-3): 379-392

Cappiella, K. and K. Brown. 2000. Derivations of Impervious Cover for Suburban Land Uses in the Chesapeake Bay Watershed. Center for Watershed Protection. Ellicott City, MD.

Caraco, D. 2001. The Watershed Treatment Model. For: US EPA Office of Water and US EPA Region V. Center for Watershed Protection. Ellicott City, MD.

Chesapeake Bay and Watershed Management Administration. July 1993. Maryland Water Quality Inventory 1989-91 – A Report on the Status of Maryland Waters and the Progress Toward Meeting the Goals of the Federal Clean Water Act.

City of Rockville. 2001. Watts Branch Watershed Study and Management Plan Final Report. Rockville, MD.

Derosier, A.L., Brakebill, J.W., Denis, J.M., and Kelley, S.K.. 1998. Water-Quality Assessment of the Potomac River Basin: Water Quality and Selected Spatial Data, 1992-1996 USGS Open File Report 98-180

DiToro, D.M., "Sediment Flux Modeling", Wiley Interscience, New York, NY, 2001

DuPont, H.L., Chappel, C.L., Sterling, C.R., Okhuysen, P.C., Rose, J.B., and Jakubowski, F. (1995) The infectivity of *Cryptosporidium* parvuum in healthy volunteers. N. Engl. J. Med. 332, 855-859

Fayer, R., Speer, C. A., and Dubey, J. P., (1997) The general biology of *Cryptosporidium*. In *Cryptosporidium* and Cryptosporidiosis" (R. Fayer, Ed.), pp1-42 CRC Press, Boca Raton, FL.

Graczyk, T.K., Evans, B.M., Shiff, J.S., Karreaman, H.J., and Patz, J.A., Énvironmental and Geographical Factors Contributing to Watershed Contamination with *Cryptosporidium* parvum Oocysts" Academic Press 2000

Groisman, P.Y., and Easterling, D.R., (1994) Variability and Trends of precipitation and snowfall over the united States and Canada. J. Climate 7, 186-205

Hanley, J.B., Schuster, P.F., Reddy, M.M., Roth, D.A., Taylor, H.E., and Aiken, G.R., "Mercury on the move During Snowmelt in Vermont", EOS, Transactions, American Geophysical Union, Volume 83, Number 5, January 29, 2002

Holman, R.E., *Cryptosporidium*: A drinking water Supply Concern, Water Resources Research Institute of The University of North Carolina, November 1993

Hopkins, K., B. Brown, L. Linker and R. Mader. 2000. Chesapeake Bay Watershed Model Land Uses and Linkages to the Airshed and Estuarine Models. Chesapeake Bay Program Modeling Subcommittee. Annapolis, MD.

Houghton, J.T., Miera-Filho, L.G., Callander, B.A., Harris, N., Kattenberg, A., and Maskell, K. (1996). "Clmate Change, 1995 – The Science of Climate Change: Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change." Cambridge Univ. Press, Cambridge, UK.

Huck, P.M., Coffey, B.M., Anderson, W.B., Emelko, M.B., Maurizio, I.P., Jasmin, S.Y., and O'Melia, C.R., "Using Turbidity and Particle Counts to Monitor *Cryptosporidium* Removals by Filters" Water Science and Technology - Accepted

Interstate Commission for the Potomac River Basin (ICPRB). 1984. Potomac River Basin Water Quality 1982-1983

Interstate Commission for the Potomac River Basin (ICPRB). 1995. Summary of the state Water Quality Assessment for the Potomac River Basin

Interstate Commission for the Potomac River Basin (ICPRB). November 1987. Potomac River Basin Water Quality Status and Trend Assessment 1973-1984

Juranek, D. et. al. (1995) "*Cryptosporidium* and P:ublic Health: Workshop Report" J. Am. Water Works Assoc. 87(9), 69-80.

Karl, T.R., Knight, R.W., and Plummer, N. (1995) Trends in high-frequency climate variability in the twentieth century. Nature 377, 217-220

Lechevallier, M., Norton, W., and Lee, R. (1991) "*Giardia* and *Cryptosporidium* in filtered Drinking Water Supplies" Appl. And Envir. Microbiology, 57(9) 2617-2621.

Loehr, R. 1974. Agricultural Waste Management: Problems, Processes and Approaches, Appendix A. Department of Agricultural Enginering. Cornell University. Ithaca, NY.

MacRae, C. 1996. "Experience from Morphological Research on Canadian Streams: Is Control of the Two-year Frequency Run off Event the Best Basis for Stream Channel Protection?" Effects of Watershed Development and Management on Aquatic Systems . L. Roesner (ed.). Engineering Foundation Conference: August 4-9, 1996. Proceedings, pp.144-160. Snowbird, UT.

Maryland Department of the Environment. 1998. "1998 Maryland Clean Water Action Plan"

Maryland Department of the Environment. August 10, 1996. "Montgomery County Water Quality Monitoring Programs Stream Monitoring Protocols"

Maryland Department of Health and Mental Hygiene, Office of Environmental Programs. 1986. Continuing Planning for Water Quality Management 1986. 1986

Maryland Department of Natural Resources. 2000. Maryland Water Quality Inventory 1993-1995 – A Report on the Status of Natural Waters in Maryland Required by Section 305(b) of the Federal Water Pollution Control Act and reported to the EPA and Citizens of Maryland

Maryland Department of Natural Resources. December 1996. Maryland Unified Watershed Assessment.

Maryland Water Management Administration. 2000. Maryland Unified Watershed Assessment Factsheet

Metcalf and Eddy. 1991. Wastewater Engineering: Treatment, Disposal, and Reuse. McGraw-Hill, Inc. New York, NY.

Modeling Subcommittee of the Chesapeake Bay Program. January, 2000. Chesapeake Bay Watershed Model Land Use and Model Linkages to the Airshed and Estuarine Models.

National Academy of Engineering, Report of the Committee to Review the New York City Watershed Management, 2000

North Carolina Cooperative Extension, Best Management Practices for Agricultural Nonpoint Source Control – I Animal Waste

North Carolina Cooperative Extension, Best Management Practices for Agricultural Nonpoint Source Control – II Commercial Fertilizer

Palace, M., J. Hannawald, L. Linker, G. Shenk, J. Storrick and M. Clipper. 1998. Tracking Best Management Practice Nutrient Reductions in the Chesapeake Bay Program. Chesapeake Bay Program Modeling Subcommittee. Annapolis, MD.

Reckhow, K., M. Beaulac, and J. Simpson. 1980. Modeling Phosphorus Loading and Lake Response Under Uncertainty: A Manual and Compilation of Export Coefficients. EPA440/5-800-001. U.S. EPA, Office of Water Regulations and Standards. Washington, D.C.

Rose, J. B., (1997) Environmental Ecology of *Cryptosporidium* and Public Health Implications. Ann. Rev. Public Hlth. 18, 135-161

Roseberry, A. M., and Baumaster, D.E., (1992) Log-normal distribution for water intake by children and adults. Risk Analysis 12(1), 99-104.

Schueler, T. 1987. Controlling Urban Run off: A Practical Manual for Planning and Designing Urban Best Management Practices. MWCOG. Washington, D.C.

Schueler, T., and J. Lugbill.1990. Performance of Current Sediment Control Measures at Maryland Construction Sites. Metropolitan Washington Council of Governments. Washington, DC.

Schueler, T. Microbes and urban Watersheds: Concentrations, Sources, & Pathways, Watreshed Protection Techniques. 3(1) 554-565

Smith, R., R. Alexander, and K. Lanfear. 1991. Stream Water Quality in the Coterminous United States - Status and Trends of Selected Indicators During the 1980s. USGS. Water-Supply Paper 2400.

Smith, R.A., Alexander R.B., and Wolman, M. G., Water-Quality Trends in the Nation's Rivers, Science, Vol. 235 March 27 1987

Smullen, J., and K. Cave.1998. "Updating the U.S. Nationwide Urban Run off Quality Database." 3rd International Conference on Diffuse Pollution: August 31 - September 4, 1998. Scottish Environment Protection Agency. Edinburg, Scotland.

States, S., Stadterman, K., Ammon, L., Vogel, P., Baldizar, D., Wright, D., Conley, L., and Sykora, J. (1997) " Protozoa in River Water: Sources, Occurrence and Treatment" Journal AWWA 89(9) 74-83

Staudte, P.B., Luftweiler, P., and Kaplan, L., Disinfection by-Product Formation and Source Water Quality, Stroud Water Research Center Academy of Natural Sciences, Avondale, PA

Tawil, J.N.. May 1997. Prospective Point/Nonpoint Source Nutrient trading in the Potomac River Basin – A Case Study in Integrated Watershed Management – Thesis Presented to the Graduate faculty at the Central Washington University

Teunis, P. F. M., Medema, G. J., Kruidenier, L., Havelaar, A. H., Assessment of the risk of Infection by *Cryptosporidium* or *Giardia* in drinking water from a surface water source. Wat. Res. Vol. 31 No. 6, pp 1333-1346 1997

United States Environmental Protection Agency. 1993. *Measuring the Progress of Estuary Programs - Exhibit 6.6 Summary of Survey Findings: Tampa Bay Household Environment Survey, 1992/1993.* USEPA, Office of Wetlands, Oceans, and Watersheds, Ocean and Coastal Protection Division. Washington, D.C.

United States Geological Survey (USGS), United States Environmental Protection Agency (EPA). 1999. Source-Area Characteristics of Large Public Surface-Water Supplies in the Conterminous United States – An Information Resource for Source-Water Assessment. U.S. Geological Survey Open File Report 99-248

United States Geological Survey (USGS). 1965. Stream Quality in Appalachia as Related to Coal Mine Drainage. U.S. Geological Survey Circular 526

United States Geological Survey (USGS). 1983. Time Travel and Dispersion in the Potomac River, Cumberland, Maryland to Washington, D.C.. U.S. Geological Survey Open File Report 83-861

United States Geological Survey (USGS). 1998. Water Quality Assessment of the Potomac River Basin: Water-Quality and Selected Spatial Data, 1992-96. U.S. Geological Survey Open File Report 98-180

United States Geological Survey (USGS). 1999. Environmental Setting in the Potomac River Basin. U.S. Geological Survey Circular 1166

United States Geological Survey (USGS). 1999. The Quality of Our Nation's Waters – Nutrients and Pesticides. U.S. Geological Survey Circular 1225

USEPA (1999). Website

Walker, F.R., and Stedinger, J.R. (1999) "Fate and Transport Model of *Cryptosporidium*" *J. Environmental Engineering*, Vol. 125, No. 4, April, 1999.

Watershed Assessment Program – Office of Water Resources - West Virginia Department of Environmental Protection. 1996. An Ecological Assessment of the South Branch of the Potomac River Watershed. Report Number 0207001-1996

Weggel, J. R., and Marengo, B., A Schuylkill River Model for the Vicinity of the Queen lane Intake and the Wissahickon Creek, Philadelphia, PA, Drexel University Department of Civil & Architectural Engineering, Hydraulics & Hydrology Laboratory, Report No. 99-1 June, 1999

Wiedeman, A. and A. Cosgrove. Point Source Loadings. Chesapeake Bay Program Modeling Subcommittee. Annapolis, MD.

Winer, R. 2000. *National Pollutant Removal Database for Stormwater TreatmentPractices: 2nd Edition.* Center for Watershed Protection. Ellicott City, MD

Xiao, L. and Herd, R.P. (1994) "Infection Patterns of *Cryptosporidium* and *Giardia* in Calves" Veterinary Parasitology, 55, 257-262.