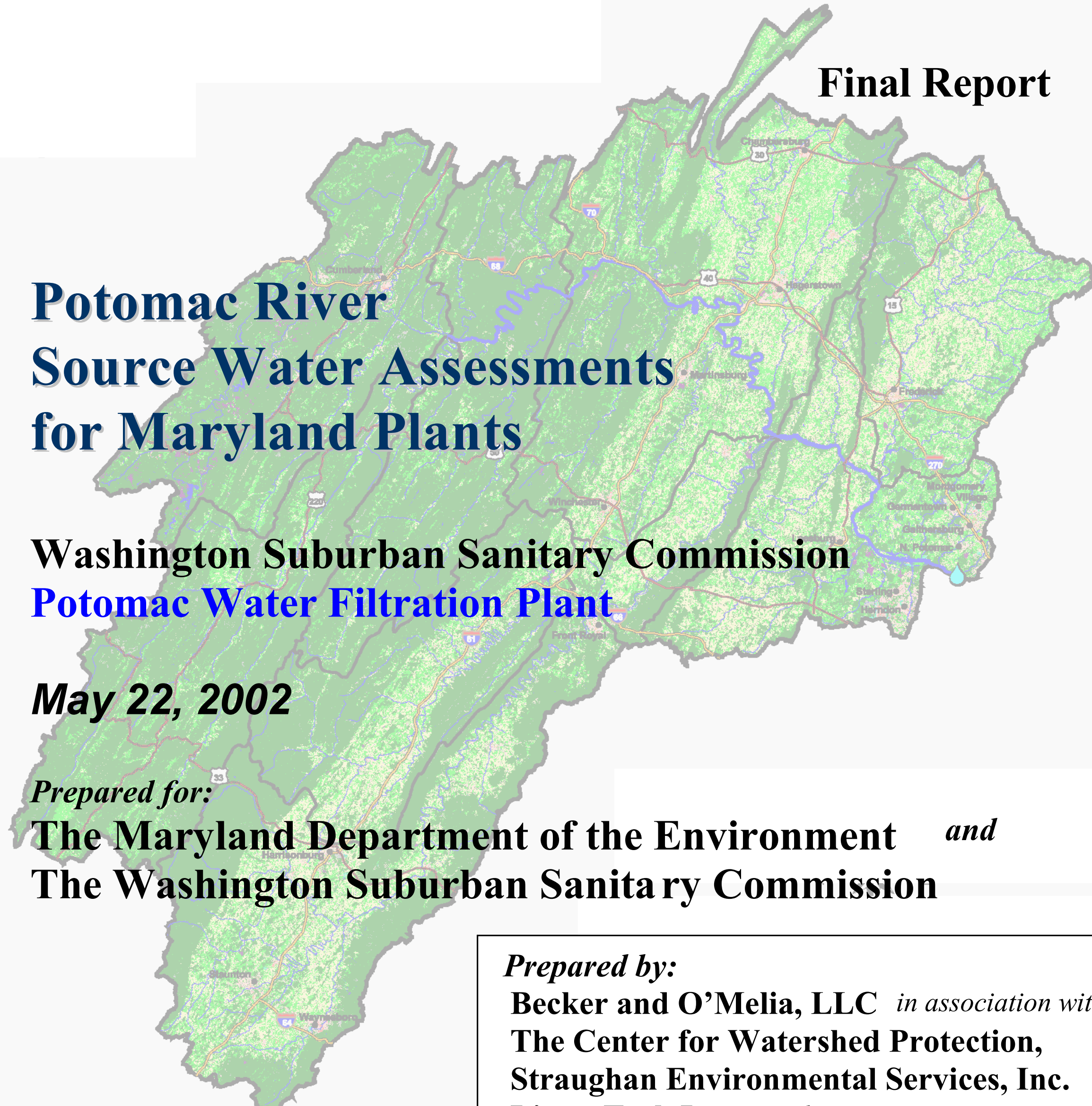
Final Report



Potomac River Source Water Assessments for Maryland Plants

Washington Suburban Sanitary Commission
Potomac Water Filtration Plant

May 22, 2002

Prepared for:
The Maryland Department of the Environment ***and***
The Washington Suburban Sanitary Commission

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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. Readily available clean natural water is a necessity for drinking water supply, but is not adequate for optimum protection of the public health. Provision of the safest drinking water feasible calls for watershed protection measures beyond those applied for protection of clean natural waters. 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 the WSSC Potomac Water Filtration Plant (WFP) was conducted to meet the above requirement and was undertaken as a joint effort by the Maryland Department of the Environment (MDE) and WSSC, 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 WSSC 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 WSSC 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 WSSC finished water has always met these limits and other applicable water quality standards. It also 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 the Potomac WFP:

- 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 Potomac WFP SWA include:

- The dynamic nature of the Potomac River's water quality at the existing intake as well as its potential for DBP formation in the very long WSSC distribution system are major challenges to providing safe drinking water and need to be better understood and managed.
- The watershed is primarily forested (60%) with significant agricultural (35%) and some urban (4%) land uses. Current local urban and upstream agricultural land uses appear to negatively impact the source water quality for the Potomac WFP.
- 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, ammonia, sediment/turbidity, algae, fecal coliforms, and dieldrin. Sources of these contaminants are present throughout the watershed. Rapid changes in water quality are also a concern.
- While evaluation of the specific impacts of particular sources of contaminants of concern on the WSSC intake was not feasible, modeling was used to predict the overall impact of management practices on source water quality. Future conditions are expected to show a small deterioration in source water quality at the Potomac WFP 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.
- Watts Branch causes sudden negative changes in raw water quality and treatability at the Potomac WFP intake. Negative changes are characterized by sudden and extreme increases in suspended solids, fecal coliforms, as well as decreases in pH and alkalinity. The rapid changes in water quality make it challenging for the plant operational staff to accurately adjust coagulant dosage and pH to achieve optimum particle removal. These impacts are out of proportion with the upper watershed impacts relative to watershed size.

A submerged channel intake (at a mid-channel location) would allow the Potomac WFP to effectively avoid these impacts.
- The Potomac WFP 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 Potomac WFP SWA include:

- A watershed protection group representing all 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.
- Serious consideration should be given to an upgraded intake structure with flexibility to withdraw water from a submerged midchannel location.
- 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;
  - tracking the progress and implementation of the Watts Branch Watershed Studies that are being conducted by the Montgomery County Department of Environmental Protection, and the City of Rockville.
  - aggressive involvement in upstream 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. In the Watts Branch basin, it is prudent to consider support of ongoing enhancement of management practices in highly developed areas to reduce solids and possibly fecal contaminants. These have more promise for solids reduction than those in the upper watershed; however raw water quality improvements are not to be expected immediately.
  - 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 WSSC's Potomac WFP 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,
- improved protection from pathogens including *Cryptosporidium* and *Giardia,*
- reducing the number and severity of taste and odor episodes which occur in the WSSC system, and
- reducing ammonia levels and chlorine demand in the raw water.

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

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

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 Potomac WFP. The following summarizes the main tasks of the SWA for the Potomac WFP:

- 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 and WSSC 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 (> 11,400 square miles) 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 Potomac WFP 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 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. Evaluation of the individual impacts of particular contaminant sources on the WSSC intake was not considered feasible for the project. Several management scenarios were evaluated within each of the major subwatersheds to determine the impacts of increased management. These scenarios includes suites of practices applied to appropriate land use types and best available technologies (BAT) applied at point sources Management options must be discussed and coordinated with all of 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 primary differences between the four management scenarios are: 1) the extent to which existing management practices are practiced within the various subwatersheds; and 2) the amount of new management practices which are added within the various subwatersheds. For the "current and "future no management" scenarios, controls on future development are set based on existing programs in place within the watershed segment.

Future increased management scenarios in Watts Branch are generally characterized by implementation of the City of Rockville's recently developed Watts Brach Plan throughout the Watts Branch drainage area. In this subwatershed, the aggressive scenario is distinguished from the moderate scenario by the level of implementation of this plan (size of facility, degree of monitoring and inspection, etc.).

For future moderate and aggressive improved management scenarios in the watershed above Watts Branch, the Chesapeake Bay Program database of loads and flows are used to develop point source loads based on improved treatment practices. In the "aggressive management" scenario, Limit of Technology (LOT) concentrations are used to characterize outflow concentrations from point sources. For nonpoint sources, reasonable urban, agricultural and forestry management practices are assumed including a change in the management of new development. In all scenarios and all areas of the watershed, the management practice efficiency estimates for both the “moderate management” and “aggressive management” scenarios were developed based on CWP experience and expertise (Schueler and Caraco, 2001).

Based on CWP modeling of these scenarios, the Bay Program model was modified to evaluate only that part of the watershed upstream of the Potomac WFP intake. The Bay Program model is a one-dimensional model that assumes uniform water quality across the width and depth of the Potomac River. It is therefore not able to evaluate localized effects of particular tributaries, such as Watts Branch, which has been shown to significantly impact the raw water quality at the Potomac WFP. Two-dimensional modeling was required in order to evaluate:

- the impact of Watts Branch at the current Potomac WFP intake near the shore of the Potomac, and
- the impact of Watts Branch at a potential midchannel intake location.

A general two-dimensional model was built using the Cornell Mixing Zone Model (CORMIX). This model was run under a wide range of simulated Watts Branch and Potomac River flows to perform the intended evaluations. The modeling results were compared with historical river sampling data and operator experience at the plant to estimate the effects of Watts Branch and the benefits of a potential submerged channel intake.

A screening level spreadsheet approach was taken to further assess the impact of Seneca Creek on the existing intake and potential submerged channel intake, and the relative potential for contamination from that tributary.

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 WSSC intake under several flow conditions.

Key Findings

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

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

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

Inventory of Potential Contaminants of Concern

Raw water data from approximately 1985 to 2001 were reviewed for 109 contaminants that were deemed potentially of concern, including 73 which have established MCLs. These data indicate that none of the 73 contaminants that have established MCLs have been detected at levels that meet the criteria established in the Maryland Source Water Assessment Plan for contaminants of concern. Several of the other 36 contaminants were identified as contaminants of concern (as described in Section 5 of the report).

Algae, natural organic matter (indicated by TOC), sediment (indicated by turbidity) and ammonia were identified as contaminants of concern because of their impacts on WFP operation at the levels detected in the untreated water. Although it is not currently regulated in drinking water supply, dieldrin was identified as a contaminant of concern based on levels detected in the untreated water. Taste and odor causing compounds (indicated by the threshold odor number) and fecal coliforms were also selected based on levels detected in the untreated water. *Cryptosporidium*, *Giardia* and disinfection by-product precursors were identified as contaminants of concern based only on their importance in drinking water supply and a review of watershed activities, rather than their past presence in the water supply. Identified contaminants of concern to the WSSC's Potomac WFP therefore include:

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

To facilitate the assessment of the extent that these contaminants may reach the WSSC intake, these contaminants have been classified into four 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 and ammonia. Taste and odor causing compounds are numerous and can affect consumer confidence in their drinking water. Ammonia affects chlorine demand and causes a particular type of taste and odor problem associated with its reaction with chlorine. These contaminants of concern are grouped together because of their relationship to taste and odor problems. Algae can also produce noxious tastes and odor compounds, and while listed in Group 2, algae levels may affect taste and odors.

Group 4 – dieldrin. Dieldrin, a pesticide which has been banned from manufacture for several decades, is a possible carcinogen which is persistent in the environment. It is strongly associated with sediment, and therefore is likely to be transported in the river and removed in the plant similar to sediment. There have only been three detections of dieldrin in the Potomac WFP intake water (out of 34 samples), but it has also been detected throughout the watershed in the water column, in sediment, and in fish tissue. While this compound has similar fate and transport as sediment, it has been separated from the Group 1 contaminants because it is no longer in manufacture and general use and thus opportunities for control are limited. Because of the ban of its manufacture, it is expected that the dieldrin levels throughout the watershed will eventually decrease.

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 Potomac WFP 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. Overall, there are 450 industrial and municipal WWTPs upstream of the Potomac intake, with a combined discharge flow of more than 134 MGD. This is 3.3% of the median Potomac River flow. Existing permits allow more than 93 MGD of discharge from municipal wastewater facilities and more than 170 MGD of discharge from industrial facilities.

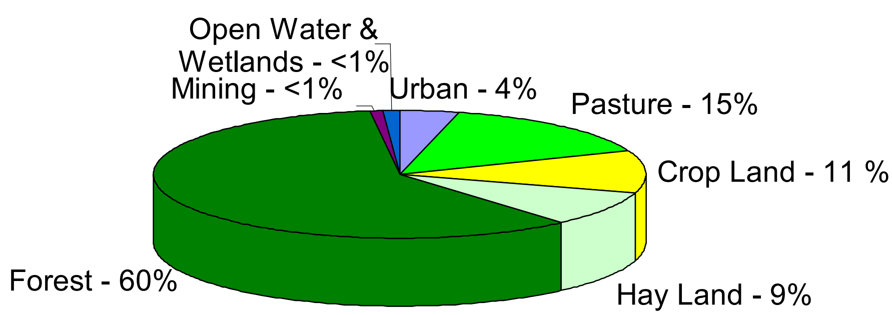
Nonpoint Sources

Nonpoint sources are significant sources of *Cryptosporidium* oocysts, *Giardia* cysts, fecal coliforms, sediment, dieldrin, natural organic matter, nutrients which stimulate algae, taste and odor causing compounds, and ammonia. Impacts of nonpoint sources are quantified based on aggregate land uses in the subwatersheds of the basin. Specific findings are presented separately for the local Watts Branch area and the area above Watts Branch.

Current land uses in the watershed above the Watts Branch are shown graphically on Figure ES-1. Evaluation of this data 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 are dominated by agricultural land uses with significant forested area, (although very little of these forested areas are under silviculture);
- the lower parts of the watershed include the bulk of the developed land in the watershed (both residential and commercial/ industrial) but also include substantial amounts of forest and agricultural land.

Figure ES-1 : 1997 Land Use in Upper Watershed



Current local urban and upstream agricultural land uses, including livestock operations, appear to negatively impact the source water quality for the Potomac WFP. 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.

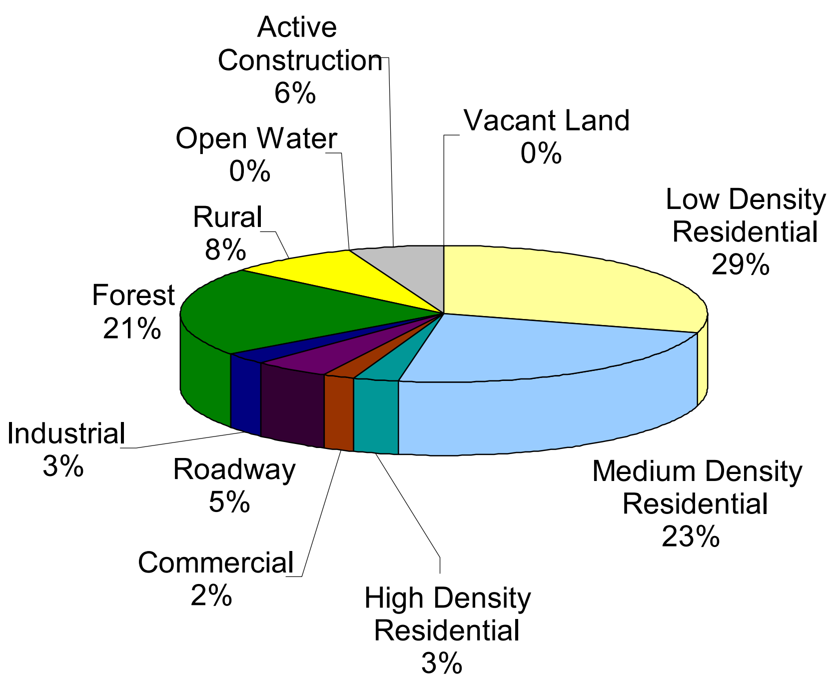
- Projections include reductions in active construction activities in the headwaters, Shenandoah Valley and Great Valley.

Active construction is expected to increase in the lower parts of the watershed, although not in the critical Watts Branch Watershed.

Land Use in the Watts Branch Watershed

In contrast to the entire Potomac watershed which includes 4% urban land uses, this watershed includes about 70% urban land uses (residential, commercial, and active construction) as shown on figures ES-2 and ES-3. In the future, this watershed will include about 87% urban land uses, assuming existing zoning across the watershed and assuming

Figure ES-2 : 1997 Watts Branch Land Use



that all forest in the riparian buffer remains in its current state. The current imperviousness is 16.3% and it is expected to increase to 20.4% in the year 2020.

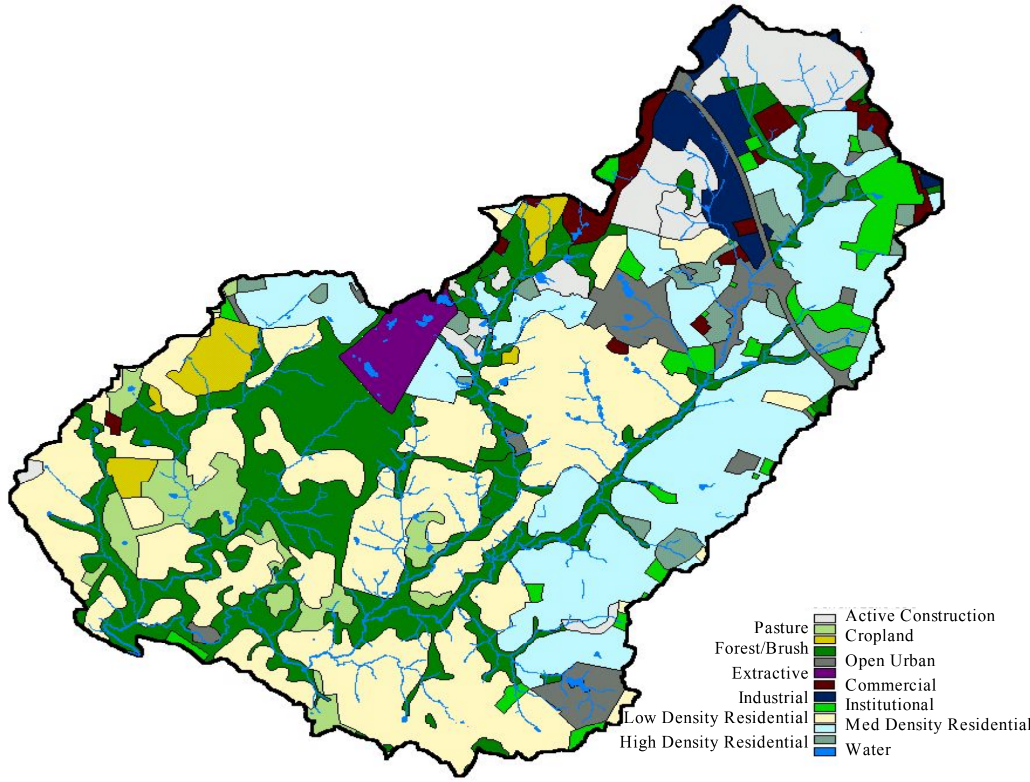


Figure ES-3 Watts Branch Land Use

GIS, field, and geomorphic evaluations indicate that development in the Watts Branch Watershed has increased impervious cover and increased the number and severity of storm flows. These changes in the hydrology of Watts Branch have disturbed the steady state of the streambed, causing streambed erosion and increased suspended solids in the Watts Branch flow. Observations made in the field indicate that the Watts Branch streambed is adjusting to conform with hydrologic changes that are most likely related to increases in impervious cover due to urbanization. Increased impervious surface coverage in the watershed increases flow velocities, which transport larger particles, including those that otherwise maintain stable streambed habitats. Without changes to the runoff conditions, the resulting erosion and solids loading is expected to continue until the streambed reaches a steady state with the new hydrologic pattern; this steady state may require decades to achieve.

Watershed management efforts currently underway in the Watts Branch watershed include a study by the Montgomery County Department of Environmental Protection to identify priority stream restoration and stormwater management projects to improve both habitat and water quality of the watershed. The City of Rockville has completed a similar study for their jurisdiction, and is currently is the phase of implementing top-ranked projects.

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 Potomac WFP water supply to contamination from the identified contaminants of concern. The results of the modeling are discussed below and organized by contaminant group. Also, a discussion of the modeling results specifically focused on the influence of Watts Branch and Seneca Creek on the intake water quality is presented. 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.

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 immediate benefits due to limitations concerning the survival time of pathogens in the environment.

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

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

The only contaminant in Group 1 which was explicitly modeled under the modeling approach was sediment/turbidity. The modeling results indicated the following regarding sediment:

- *For the watershed above Watts Branch*:
  - The future "no management" scenario predicts small increases in sediment concentrations, whereas under the "aggressive" scenario, predicted solids peaks are actually *reduced* by 4% from current peaks.
  - The predicted changes are the net result of management practices in upstream subwatersheds and in-stream processes. Because solids are stored in the Potomac streambed, little change in sediment concentrations was noted under any scenario. It is important to note that the Center for Watershed Protection's Watershed Treatment Model predicts significant sediment "edge-of-stream" load reductions for some subwatersheds with "aggressive" implementation of management practices. Even though these reductions translate into only modest reductions at the Potomac Plant intake, they could be significant for local water quality improvements as well as other Potomac water plants upstream, further supporting the recommendations.
  - It is important to note that nonpoint urban loads will typically increase, even with implementation of BMPs. However, this increase in urban load will not typically increase the overall load significantly because of the small amount of urban land. As urban areas increase in the watershed, especially beyond the planning period of this study, control of these impacts will become more important.

- *For the Watts Branch watershed:*
  - The results of the detailed evaluations indicate the following predicted outcomes of simulated future and management scenarios:
    - Predicted year 2020 TSS loading from Watts Branch is reduced by 4% from current loads with no change in management practices, due to the reduction in active construction.
    - Moderate management will reduce predicted Watts Branch solids loading by 7% of current loads.
    - Aggressive implementation of management practices reduces predicted future Watts Branch solids loadings by 15% of current loads.

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

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

- *For the watershed above Watts Branch:*
  - The future "no management" scenario predicts small increases in phosphorus concentrations, while the future "aggressive" management scenario predicts a small decrease in phosphorus concentrations at the intake. It should be noted that for the "aggressive" scenario, the WTM shows significant reduction in "edge-of-stream" phosphorus loads in some subwatersheds. This significant reduction will be reflected by

an associated long-term reduction at the Potomac WFP intake when the river sediments and the loads come into equilibrium as required by mass balance considerations, and therefore these management practices would be effective for control of phosphorus and algae. However, in the short-term, the associated reduction at the intake is much less significant due to the storage of phosphorus in the sediment. The in-river modeling utilized in this study focused on the short-term impacts of management practices, and did not account for change in storage of phosphorus, and thus the future "aggressive" scenario predicts that phosphorus and chlorophyll-a peaks are reduced only negligibly at the intake.

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

- *For the Watts Branch watershed:*
  - The results of the detailed evaluations indicate the following predicted outcomes of simulated future and management scenarios:
    - Predicted nitrogen and phosphorus loads to the Watts Branch increase by 6% and 2% of current loads, respectively, by 2020 if management practices are not modified.
    - Moderate management practices will limit the predicted increase in future nitrogen loads to 5% of current loads with no predicted increase in future phosphorus loads from current levels.
    - Aggressive implementation of management practices will actually *reduce* predicted future nitrogen loads by 1% from current loads and predicted future phosphorus loads by 9% from current loads.

<u>Susceptibility to Group 3 and 4 Contaminants of Concern (taste and odor producing compounds, ammonia, and dieldrin)</u>

None of the Group 3 or 4 contaminants were modeled explicitly due to limitations of the models and the uncertain nature of the taste and odor producing compounds identified in the untreated water. Water quality monitoring indicates episodic occurrences of taste and odor causing compounds in the untreated water, but no corresponding problems with the treated water. Because WSSC customers do not register taste and odor complaints during these events, it is thought that these compounds are removed in the treatment process. However, WSSC does receive occasional complaints, which reportedly correlate with high levels of ammonia (rather than taste and odor causing compounds) in the raw water. (Note: while ammonia is generally modeled as part of the nitrogen cycle, the ammonia peaks observed in the raw water generally occur during winter.) Taste and odor causing compounds (with the exception of ammonia as described above) would generally be concern during summer months when algal blooms occur in stagnant areas of the Potomac River.

Dieldrin is generally associated with sediment particles and would be expected to reach the Potomac WFP intake during storm events. Based on plant operating experience, the taste and odor producing compounds present in the raw water seem to be removed efficiently in the Potomac plant, and therefore further analysis of this contaminant of concern was not conducted. The reported occasional taste and odor problems appear to be due to winter ammonia peaks, which can react with chlorine to form offensive chloramine compounds. Also, as indicated previously, dieldrin has not been manufactured for several decades and levels are eventually expected to decrease throughout the watershed.

Influence of local tributaries on the Potomac WFP existing and potential intake water quality

As described previously, a modeling and historical data evaluation was conducted to assess the impacts of two local tributaries, Watts Branch and Seneca Creek, on the water quality at the existing Potomac WFP intake and a potential submerged channel intake. The key findings of this modeling were:

- Existing Intake - In virtually all of the flow scenarios anticipated, the impact of Watts Branch on sediment concentrations at the existing intake is significant and is more severe than would be expected under complete mixing of the Potomac River and Watts Branch flows. This occurs because the Watts Branch flow stays adjacent to the Maryland bank of the Potomac River. This result is supported by two-dimensional modeling, evaluation of river sampling data, and operator experience.
- Potential Submerged Channel Intake Upgrade - Another important finding is that, under all modeled flow conditions, the main body of the simulated plume or jet from Watts Branch does not extend beyond the unnamed island approximately 100 to 150 feet from the Maryland bank of the Potomac.
- From the analysis and evaluation of river sampling data, it can be concluded that Watts Branch significantly impacts the current intake location but would not impact an intake located beyond the unnamed island. Thus, a submerged channel intake structure would provide flexibility to avoid Watts Branch impacts and to obtain better raw water quality at the Potomac Plant.
- Assuming conservative contaminants and complete mixing of Seneca Creek with the Potomac River in the five miles between the Seneca/Potomac confluence and the Potomac Plant intake, the impact of Seneca Creek on intake water quality may be similar at the current withdrawal point and the potential mid-channel withdrawal point of a submerged channel intake. Although Seneca Creek is significantly further upstream of the intake (relative to Watts Branch) it has a much larger flow than Watts and may have a significant impact on raw water quality in the future, regardless of intake location. In order to assure safe water, opportunities to protect the Seneca Creek watershed should be maximized. The past activities in Watts Branch, which have lead to the current treatment challenges, should be controlled to the extent feasible in the Seneca Creek Watershed.

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. To date, the MDE/WSSC Joint Task Force has held three public meetings discussing the project goals approach and results of the assessment. Important input has been received through these meetings and the review of the executive summary by others outside the project team. A summary of the comments received have been compiled along with the project team's response in Appendix H. 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 Montgomery and Prince Georges County libraries, 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

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. Readily available clean natural water is a necessity for drinking water supply, but is not adequate for optimum protection of the public health. Provision of the safest drinking water feasible calls for watershed protection measures beyond those applied for protection of clean natural waters. 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 the WSSC Potomac Water Filtration Plant (WFP) was conducted to meet the above requirement and was undertaken as a joint effort by the Maryland Department of the

Environment (MDE) and WSSC, 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 WSSC 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 WSSC 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 WSSC finished water has always met these limits and other applicable water quality standards. It also 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.

1.1 - New Water Supply Challenges

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 may require somewhat different management practices, and thus the need has been identified for SWAs.

The Washington Suburban Sanitary Commission (WSSC), 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, public concern, and the WSSC's continuing commitment to provide water of the highest quality, the Potomac Water Filtration Plant (WFP) 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 Potomac WFP

Raw water quality at the Potomac WFP (Figure 1) presents a major treatment challenge and needs to be better understood and managed to provide additional barriers of protection for

Figure 1 – WSSC's Potomac Water Filtration Plant

the safety of WSSC's treated water. Although the WSSC's Potomac WFP has always produced water that meets or does better than the US Environmental Protection Agency's (EPA) drinking water standards, its operators have many challenges due to sudden extreme variations in raw water quality. The existing intake is located on the bank of the Potomac River and is adjacent to several islands including Watkins Island and an unnamed island directly across from the existing WFP intake (occasionally referred to as "Intake Island"). Depending on flow and run off conditions, the source water at the intake can be largely isolated from the main flow of the Potomac and heavily influenced by local run off from Watts Branch.

Based on previous experience at the WFP and historical water quality data (as discussed in Section 5), WSSC believes that Watts Branch and its watershed have a significant negative impact on the source water quality (with respect to turbidity, pH, and fecal contamination) and operations at the Potomac WFP. WSSC and others have previously studied this tributary and the main channel of the Potomac. The WSSC has taken a proactive approach to the problems caused by Watts Branch in considering the construction of a new, submerged channel intake to isolate the WFP from these and other local sources of point and nonpoint source contaminants. An intensive sampling effort of several potential intake locations was undertaken in 1999. Relocation of the intake could provide an important additional protective public health barrier to the customers of the WSSC and have a significant impact on the operation of the Potomac WFP. Thus, portions of this study were designed to evaluate the impact that Watts Branch has on the Potomac WFP.

Another significant challenge is related to the levels of natural organic matter (NOM) in the raw water. The NOM affects plant operations and, in combination with WSSC's lengthy distribution system, significantly impacts the amount of disinfection by-products in the finished water. Thus, management practices to control NOM in the raw water were evaluated as part of this study.

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 WSSC.

1.3 - Overall Strategy for Meeting These New Challenges

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 system management to prevent or mitigate contamination.

The extent to which WSSC'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 WSSC have consistently improved the quality of water supplied to WSSC's customers since the Potomac WFP was constructed more than 40 years ago. 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 Potomac WFP. 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]

1.4 - 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'

[1] USEPA (1999).

susceptibility to contamination, and inform the public of the results of this assessment. Based on this guidance, MDE has developed the Maryland Source Water Assessment Program under which this project has been executed.

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

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

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[2] USEPA 1999

SECTION 2 - BACKGROUND

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

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

2.1 - Legislation

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

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[3] McKenzie 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 - MDE and WSSC Partnership

In accordance with these goals, MDE and WSSC have formed a Joint Task Force to perform a detailed study of the river and to increase our understanding of the threats to the Potomac. As a key step to meeting these goals, the Joint Task Force has carried out this project in accordance with Section 1453 of the Safe Drinking Water Act Amendments of 1996, the USEPA's Source Water Assessment and Protection Guidance for States, the Potomac River Protection Act, and the Maryland Source Water Assessment Plan. The immediate objective of the project is to produce an SWA for the Potomac WFP that meets the technical, and schedule requirements of the SDWA, the Maryland Source Water Assessment Plan, the Potomac River Protection Act, and the Memorandum of Understanding between MDE and WSSC. The implicit goal of the legislative and regulatory requirements and guidance, and the goal of this project are to start a process of protecting the Potomac River from contaminants that affect the quality of drinking water and the cost of treatment. Therefore, aside from the regulatory requirements, the primary goal and focus of this SWA is to provide the scientific and engineering basis for a source water protection program. This SWA also forms a basis for recommendations that will improve public health protection for WSSC's customers while improving operational efficiency, reliability, and flexibility at the Potomac WFP.

The SWA program has pinpointed problems, and outlined potential options for mitigation of problems. This and previous work demonstrate the importance of protecting the Potomac River as a water supply, but final identification and implementation of solutions is dependent on further studies and is left to local communities and other stakeholders.

2.3 - 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 Potomac WFP 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 and WSSC 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.

2.3.1 - 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 attached Map # 1 - Basemap (on attached compact disc).

2.3.2 - 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 Potomac WFP. Water quality data were collected from a variety of sources and evaluated to determine the level and frequency of historical occurrences at the WSSC Intake. This allowed selection of a list of contaminants that were considered of particular concern at the Potomac WFP. 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 watershed were reviewed. Historical data for some particular contaminants of concern (including TOC, and dieldrin) were collected and evaluated to determine historical trends. These evaluations are described in detail in Appendix C and summarized in this report under Section 5.2, "Review of Historical Ambient Water Quality Data and Reports".

2.3.3 - 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. Evaluation of the individual impacts of particular contaminant sources on the WSSC intake was not considered feasible for the project. Several management scenarios were evaluated to determine the impacts of increased management within the watershed. These scenarios includes suites of practices applied to appropriate land use types and best available technologies (BAT) applied at point sources. Based on potential sources within each subbasin, appropriate management practices were selected to reduce the "edge-of-stream" loading of contaminants. For purposes of this project, the "edge-of-stream" loading is defined as the loading to the main stem or some major tributaries of the Potomac River. 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 detail in Appendix E and summarized in this report under Section 7, "Susceptibility Analysis".

2.3.4 -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 Potomac WFP 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 Potomac WFP intake. This modeling effort is described in detail in Appendix E and summarized in this report under the subsection titled "Susceptibility Analysis".

The Bay Program model is a one-dimensional model that assumes uniform water quality across the width and depth of the Potomac River. It is therefore not able to evaluate localized effects of particular tributaries like Watts Branch. Two-dimensional modeling was required in order to evaluate:

- the impact of Watts Branch at the current Potomac WFP Intake (on the shore of the Potomac), and
- the impact of Watts branch at a potential submerged channel intake location.

A two-dimensional model was built using the Cornell Mixing Zone Model (CORMIX). This uncalibrated model was run under a wide range of simulated Watts Branch and Potomac River flows to perform the intended evaluations. The modeling results were compared with historical river sampling data and operator experience at the plant to estimate the effects of Watts Branch and to estimate the benefits of a relocated (submerged channel) intake. A simple screening level historical flow analysis was performed to assess the impact of Seneca Creek on the current and submerged channel intake locations. These evaluations are also described in detail in Appendix E and summarized in this report under the section titled "Susceptibility Analysis".

A time of travel model was run by the Interstate Commission for the Potomac River Basin to disaggregate the potential contaminant sources according to the flow time from the edge of the stream to the WSSC intake under several flow conditions. The significant potential sources were grouped by their time of travel to the plant under various flow conditions in the River.

2.3.5 – 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 Potomac WFP 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.

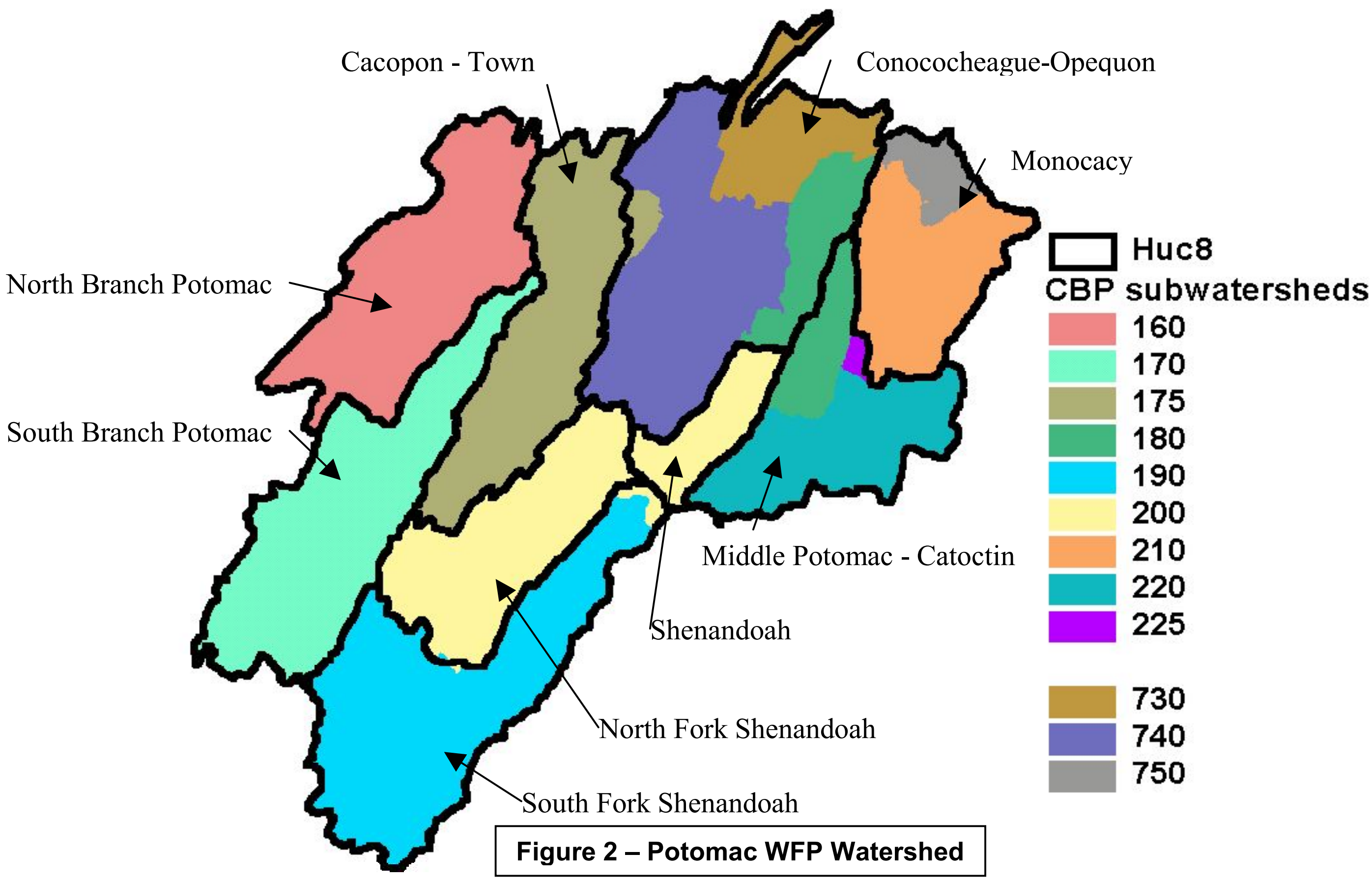


Figure 2 – Potomac WFP Watershed

Figure 2 shows the Potomac WFP drainage basin, subwatersheds defined by the Environmental Protection Agency's Chesapeake Bay Program Office (CBPO), and United States Geological Survey designated 8-digit Hydrologic Unit Code (HUC-8) subwatersheds. The

Potomac WFP Watershed is an interjurisdictional, multistate watershed encompassing over 11,400 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 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. The lower parts of the watershed include urban areas of Frederick, Westminster, Potomac, and Rockville.

3.2 - Description of Potomac WFP and WSSC System

At the location of the intake, the Potomac River is divided by Watkins Island with approximately 60% of the river flowing to the Virginia side of the island and 40 % to the Maryland side where the Potomac WFP intake is located. In order to maintain a pool of water for the intake to draw from, a weir structure has been constructed just downstream of the intake from the Maryland shore to an unnamed island and continuing from the unnamed island to Watkins Island. Watts Branch, which drains part of Rockville, flows into the Potomac River approximately 1,800 feet upstream of the intake.

WSSC provides drinking water to Montgomery and Prince George's counties from the Potomac WFP and the Patuxent WFP. The Potomac WFP was constructed approximately 40 years ago and has undergone several expansion and improvement construction projects. The current rated reliable capacity is approximately 160 million gallons per day (mgd) and the average annual production is just over 120 mgd.

The Potomac WFP is a conventional WFP employing raw water intake and pumping, rapid mixing of treatment chemicals, flocculation, sedimentation, filtration, disinfection and finished water storage and pumping. At different times in the past both ferric chloride and alum have been used at the Potomac WFP, but currently polyaluminum chloride (PACl) is applied as the primary coagulant. Alum and ferric chloride can significantly depress pH but PACl has only a slight impact on pH. A temporary sulfuric acid feed system has been constructed to deal with seasonal high pH episodes by reducing the pH of coagulation. The system is intended primarily to deal with these extreme pH events. The plant disinfects with free chlorine. The plant has powdered activated carbon (PAC) facilities, which could be used in response to some taste and odor episodes, but plant staff report that in recent years these facilities have not been needed.

3.3 - Results of Site Visits

3.3.1 - Site Observations

The Potomac WFP site includes an intake structure on the shore of the Potomac River (Figure 3). The original intake facility, constructed during the original plant construction 40 years ago, was abandoned when the plant was improved in approximately 1980. A new pump station (Pump Station No. 2) was also constructed, new water mains were installed, and other water mains were retrofitted at that time. Currently, raw water is pumped from these pumping stations to unit operations and process treatment facilities.

3.3.2 - Intake Integrity, Operator Concerns and Other Observations

WSSC personnel report that the raw water pipes are drained and inspected annually, and remain in good condition. Some leaking (infiltration) at the pipe joints is reported, but it is considered to be insignificant by WSSC operations staff. No evidence exists that the groundwater in the area is contaminated. Therefore, no likelihood exists that the leaking results in contamination to the raw water supply.

FIGURE 3 – POTOMAC WFP INTAKE STRUCTURE

During September and October, large amounts of aquatic grasses, which grow in the Potomac River during the summer, break up during autumn storms and flow downstream. The grasses and leaves occasionally accumulate on and clog the bar screens, thus threatening intake operations. Significant efforts are required to remove the debris from the racks and keep the raw water intake open. WSSC personnel must clear the trash racks using rakes, clam tongs, and cranes to remove the debris.

Additional maintenance is required during periods with extreme winter temperatures and low river flow, because granular ice forms during these periods to clog the bar screens. Although the traveling trash rack rake usually breaks up this ice, special equipment must be brought to the facility during periods of extreme cold to break up, clear, and scoop the accumulated ice out of the intake structure.

Based upon field inspection observations, review of design drawings, and discussions with WSSC personnel, the intake facilities appear to be adequately designed, well maintained, and in good operating condition. The control weir constructed in the river appears to be structurally intact and effectively controls the water level. All concrete work appears to be in good condition, and the site visit team observed no evidence of significant metal corrosion on the bar screens or the 36-inch metal cylinders, which are used to deflect floating debris and prevent objects from entering the intakes. No settlement, binding, misalignment, shifting, or vibration was observed or reported for any of the intake structures or gates. No significant accumulation of silt was observed or reported in any of the intake bays or raw water pipes.

The assessment did not reveal any threats of contamination entering the intake facilities. In addition, the assessment did not reveal any unusual susceptibility to system failure. During a review of records, an on-site inspection, and on-site interviews, no overall structural deficiencies were identified, and the intake facilities appeared to be functioning well.

The plant operations staff noted several operational issues related to water quality. Seasonal episodes of high pH, with significant diurnal variations, have caused difficulty in achieving proper coagulant dose. The most significant operational challenge at the plant is associated with sudden and significant changes in water quality, which occur as a result of local storm events and localized run off conditions. WSSC staff report little difficulty in operating under the wide range of raw water quality conditions, but have significant difficulty adjusting to the very sudden increases in turbidity and other contaminants, which occur during these local storm events. Staff estimate that these difficult situations occur approximately six times per year. It is important to note that these transitional periods, when the plant is adjusting to the suddenly deteriorated conditions, are coincident with the first flush flow from storm events, which are thought to impact many important water quality parameters such as sediment, pathogens, pH, and alkalinity.

SECTION 4 - WATERSHED CHARACTERIZATION

4.1 - Watershed Above Watts Branch

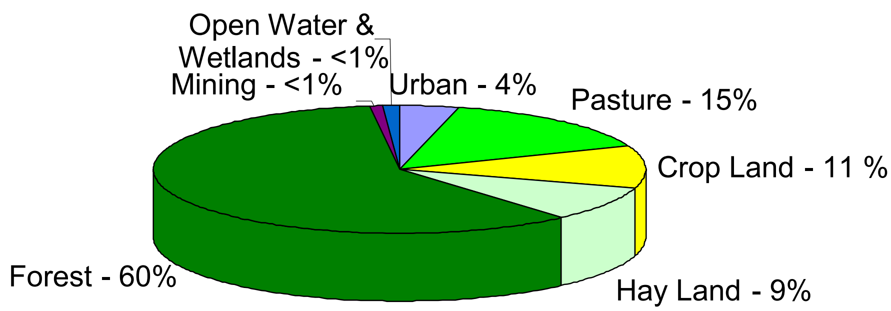
The Bay Program watersheds include 11 Potomac River subsheds that lie upstream of the Potomac WFP intake. These subsheds (shown previously on Figure 2) generally comprise the areas described on Table 1.

Historical maximum daily average Potomac River flow at the location of the intake was estimated in this study (based on modeling results presented in Appendix E) at 164,000 cfs and the estimated median daily average flow was 6,267 cfs. Historical maximum daily average Watts Branch flow was estimated in this study at 902 cfs and the estimated median daily average flow was 44 cfs.

4.1.1 - Current Land use, Livestock and Population

Detailed land use is shown on maps included in the appendices (on attached CD). Approximate current land use distribution in the watershed is shown on Figure 4.

Figure 4 – 1997 Land Use in Upper Watershed



1997 land uses within the subwatersheds are shown, organized according to Bay Program subwatershed, in Table 2. Evaluations of this land use data indicate:

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
750	Monocacy	Frederick,* Carroll*		Adams	
210	Monocacy	Montgomery, Frederick, Carroll		Adams	
220	Middle Potomac-Catoctin	Montgomery	Fairfax, Loudon, Fauquier		
225	Middle Potomac - Catoctin	Montgomery			
* subwatershed contains a very small portion of this county					

- 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 these forested areas are under silviculture;
- the lower parts of the watershed (subsheds 750, 180, 210, 220 and 225) include the bulk of the developed land in the Potomac WFP watershed (both residential and commercial/ industrial) but also include substantial amounts of forest and agricultural land

Estimated future land uses are shown on Table 3 for comparison purposes and are discussed later.

Current estimates of livestock in throughout the watershed are shown on Table 4. In 2000, the human population in the watershed was approximately 1,756,000. There are currently 450 wastewater treatment plants in the watershed, more than 350 of which are considered minor based on treatment capacity, and there are approximately 422,000 septic systems in the watershed.

TABLE 2. LAND USE IN THE POTOMAC WFP WATERSHED-1997 (ACRES)

Chesapeake Bay Program Subwatershed	160	170	175	180	190	200	210	220	225	730	740	750	Total
	North Branch Potomac	South Branch Potomac	Cacapon-Town & Conoc. - Opequon	Conoc.-Opequon & Mid. Potomac-Catoctin	S. Fork Shen.	N. Fork Shen. & Shen.	Monoc.	Mid. Potomac - Catoctin	Mid Potomac - Catoctin	Conoc. - Opequon	Conoc. - Opequon	Monoc.	
Low Density Residential	9,628	2,129	2,743	8,768	32,965	17,306	9,892	26,265	268	5,733	15,641	2,252	133,590
High Density Residential	555	96	35	1,226	808	323	820	1,755	7	781	839	212	7,457
Commercial/ Industrial	1,373	280	341	1,413	3,291	1,029	1,592	3,054	161	1,762	2,413	422	17,111
Roads	11,462	7,833	7,705	6,254	14,687	11,380	8,574	7,597	211	4,915	14,512	1,882	94,012
Pasture	62,192	131,577	56,042	74,112	239,076	175,750	69,684	121,190	3,130	30,179	126,859	12,649	1,102,440
Crops	18,052	5,992	20,000	108,348	66,531	68,491	170,485	69,029	6,684	102,968	100,384	36,054	773,018
Hay	28,639	24,736	32,288	55,258	91,747	88,641	69,790	62,517	2,899	48,401	107,687	27,195	639,798
Forest	695,189	762,657	671,775	145,382	606,229	509,389	159,510	186,027	6,549	113,755	488,291	29,741	4,374,494
Grass/Parks	-	-	-	279	557	117	610	2,253	-	146	341	60	4,363
Mining/Quarries	14,977	204	295	200	627	1,354	1,195	2,224	-	179	1,501	69	22,825
Active Construction	1,017	678	381	786	2,496	1,953	286	1,846	51	372	1,878	48	11,792
Forestry	3,645	4,792	5,719	284	305	974	-	485	39	789	-	-	17,032
Water/Wetlands	9,542	5,120	5,348	6,429	9,075	7,758	9,415	15,705	1,609	5,157	10,247	2,650	88,055
Total Area (acres)	856,270	946,095	802,672	408,738	1,068,394	884,465	501,853	499,948	21,609	315,135	870,593	113,234	7,286,006

TABLE 3. LAND USE IN THE UPPER WATERSHED-2020 (ACRES)													
Chesapeake Bay Program Subwatershed	**160**	**170**	**175**	**180**	**190**	**200**	**210**	**220**	**225**	**730**	**740**	**750**	**Total**
	North Branch Potomac	South Branch Potomac	Cacapon -Town & Conoc. - Opequon	Conoc.- Opequon & Mid. Potomac- Catoctin	S. Fork Shen.	N. Fork Shen. & Shen.	Monoc.	Mid. Potomac - Catoctin	Mid Potomac - Catoctin	Conoc. - Opequon	Conoc. - Opequon	Monoc.	
Low Density Residential	12,794	3,103	3,868	12,892	48,663	32,336	18,861	35,820	430	7,291	33,373	2,882	212,313
High Density Residential	738	140	50	1,802	1,193	603	1,564	2,393	11	993	1,791	272	11,550
Commercial/ Industrial	1,824	408	481	2,078	4,859	1,922	3,035	4,165	259	2,240	5,150	540	26,962
Roads	15,231	11,419	10,865	9,196	21,681	21,263	16,348	10,361	338	6,251	30,963	2,409	156,325
Pasture	62,192	131,577	56,042	74,112	239,076	175,750	69,684	121,190	3,130	30,179	126,859	12,649	1,102,440
Crops	18,052	5,992	20,000	108,348	66,531	68,491	170,485	69,029	6,684	102,968	100,384	36,054	773,018
Hay	28,639	24,736	32,288	55,258	91,747	88,641	69,790	62,517	2,899	48,401	107,687	27,195	639,798
Forest	688,143	758,293	667,426	137,318	582,656	483,555	139,630	172,889	6,184	110,308	449,828	28,368	4,224,598
Grass/Parks	-	-	-	279	557	117	610	2,253	-	146	341	60	4,363
Mining/Quarries	14,977	204	295	200	627	1,354	1,195	2,224	-	179	1,501	69	22,825
Active Construction	494	309	290	542	1,423	1,701	1,235	917	25	234	2,470	87	9,727
Forestry	3,645	4,792	5,719	284	305	974	-	485	39	789	-	-	17,032
Water/Wetlands	9,542	5,120	5,348	6,429	9,075	7,758	9,415	15,705	1,609	5,157	10,247	2,650	88,055
Total Area (acres)	856,271	946,093	802,672	408,738	1,068,393	884,465	501,852	499,948	21,608	315,136	870,594	113,235	7,289,005

TABLE 4. NUMBER OF ANIMALS BY WATERSHED SEGMENT.

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

4.1.2 - 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 5. Projected population, organized according to Chesapeake Bay Program Office (CBPO) subwatershed, is shown on Table 6.

Table 5 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
MONOCACY	220,058	237,680	265,524
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	**1,583,620**	**1,662,207**	**1,755,955**

Table 6 – 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
210	Monocacy	216,517	304,417	87,900
220	Middle Potomac	419,500	526,993	107,403
730	Conococheague-Opequon	83,868	89,597	5,729
740	Conococheague-Opequon	204,981	265,489	60,508
750	Monocacy	32,301	38,493	6,192
Total		1,624,362	1,983,661	359,209

4.1.3 - Land Use Projections

Projected future (year 2020) land uses within the watershed, summarized according to the Bay Program subwatersheds, are shown on Table 3 (above). Evaluation of these projections indicates:

- Agricultural, silvicultural and mining land uses are expected to remain unchanged throughout the watershed.

- Some forested areas throughout the watershed are expected to urbanize and this will result in increased residential development, commercial/industrial development, and roadways, with similarly decreased forested areas.
- Projections include reductions in active construction in the headwaters, Shenandoah Valley and Great Valley.
- Active construction is expected to increase in the lower parts of the watershed, although not in the critical Watts Branch Watershed.

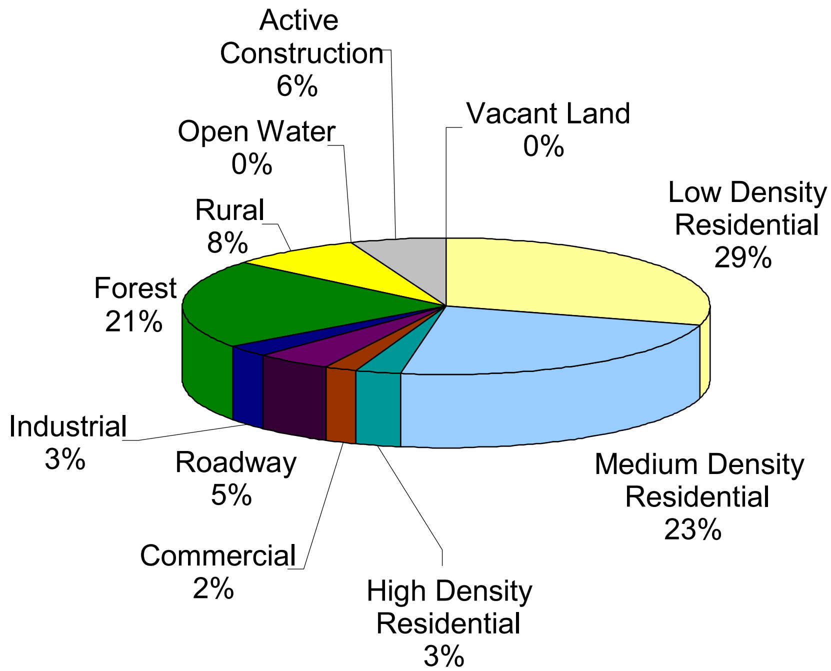
4.2 - Watts Branch Watershed

The Watts Branch watershed has a drainage area of approximately 22 square miles. Watts Branch flows southwest through Rockville and Potomac, Maryland, to its confluence with the Potomac River approximately 1,800 feet north of the PWFP. Several tributaries, including Piney Branch, flow into Watts Branch north of the Potomac River. Most of Watts Branch flows through a narrow, forested, riparian corridor; however, residential, commercial, transportation (including Interstate 1-270), and recreational uses are present. Due to this development, the watershed consists of approximately 16% impervious surface, which inhibits infiltration of precipitation and causes increased overland flow, which carries higher amounts of sediments and pollutants into Watts Branch.

4.2.1 - Current and Future Land use

The current and future land uses in Watts Branch are shown on maps included in the appendices (in attached CD) and figures 5 & 6, and are summarized in Table 7. Because this watershed is primarily urbanized, rural land uses were lumped into a somewhat broad "rural" category. Future land use was characterized by assuming current zoning across

Figure 5 1997 Watts Branch Land Use



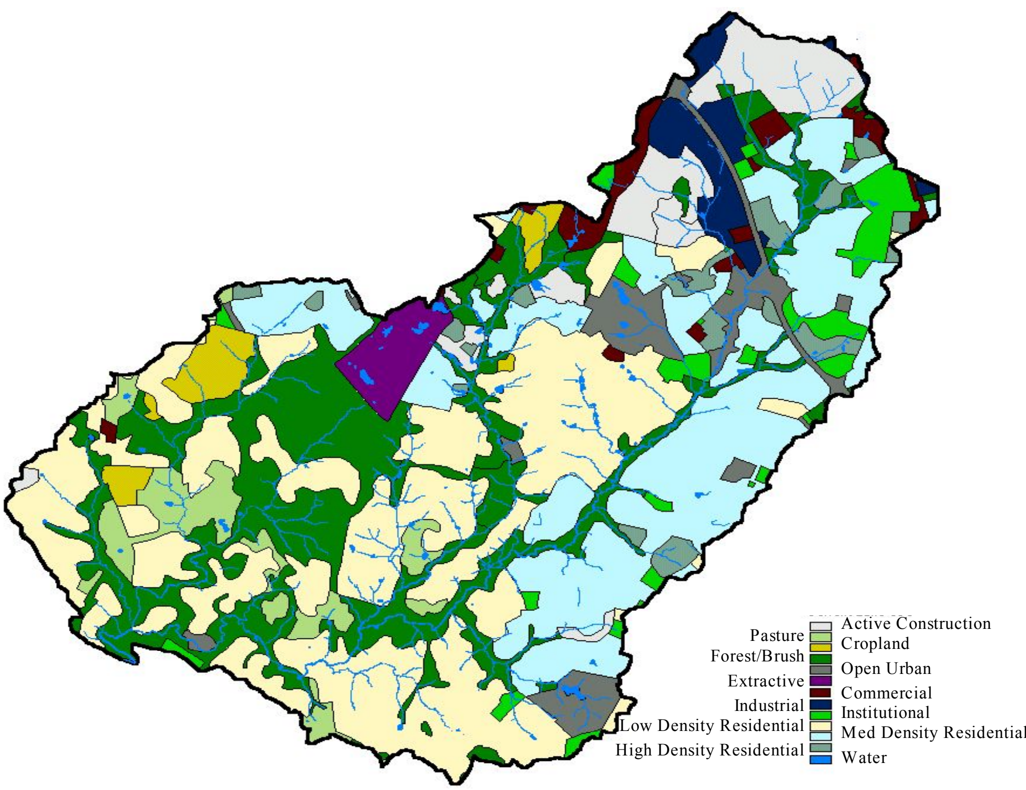


Figure 6 Watts Branch Land Use

the watershed, and assuming that all forest in the riparian buffer remains in its current state.

Evaluation of this data indicates projections for this watershed (which dominates Potomac WFP raw water quality at times including local storm events) include:

- Continued urbanization of rural and forested lands, and
- Reductions in active construction.

Table 7. Current and Future Land Use in Watts Branch

Land Use Category	Impervious Cover	Area in 1997 (acres)	Area in 2020 (acres)	Change (acres)
Low Density Residential	11%	4,183	6,291	2,108
Medium Density Residential	23%	3,338	3,339	1
High Density Residential	40%	380	1,109	729
Commercial	72%	300	301	1
Roadway	80%	651	651	0
Industrial	53%	389	437	48
Forest	0%	3,015	1,906	(1,110)
Rural	0%	1,162	0	(1,162)
Open Water	0%	10	10	0
Active Construction	0%	818	201	(617)
Vacant Land	0%	0	0	0
Overall Impervious Cover (%)		**16.3%**	**20.4%**	

4.2.2 - Geomorphic Evaluations

Development in the Watts Branch Watershed has increased impervious cover, and increased the number and severity of storm flows. These changes in the hydrology of Watts Branch have disturbed the steady state of the streambed, causing streambed erosion and increased suspended solids in the Watts Branch flow. This erosion and solids loading is expected to continue until the streambed reaches a steady state with the new hydrologic pattern. To evaluate the extent of this disturbance and to estimate the likelihood that solids loadings will persist, a geomorphic evaluation of the Watts Branch was performed.

Evaluations at eight stations (Shown on Figure 7) along the stream were performed. The geomorphic study is described in detail in Appendix D and summarized below.

None of the Watts Branch stream reaches at the eight stations examined in the geomorphic evaluations were classified as "stable" (channel metrics within the expected

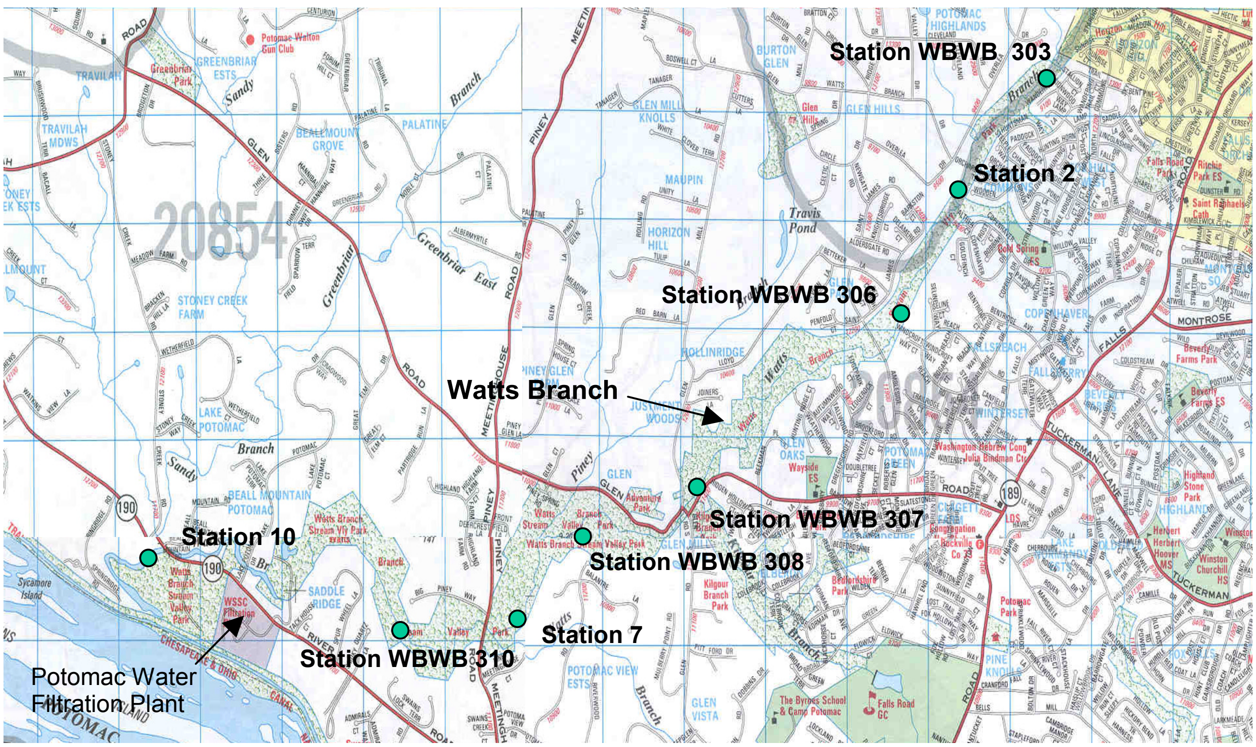


Figure 7: Approximate locations of sampling stations
Basemap Source: Alexandria Drafting Company, 1999. Greater Washington, DC Map. Used with permission.
Scale: 1 inch = Approximately 4,000 feet

range of variance [i.e., one standard deviation from the mean]). All stream reaches were classified as either "transitional" (channel metrics within an expected range of variance for a stable condition but the channel shows signs of stress), or "in adjustment" (the channel is outside of the expected range of variance and evolving toward a new steady state position).

Five of the eight habitat sampling stations are classified as having suboptimal habitat and three of the sites are classified as having marginal habitat. Channel alterations and riparian vegetation zones consistently score in the optimal range at most of the stations, and vegetative bank cover and bank stability score in the marginal category. The accompanying photographs (Figures 8, 9, and 10) illustrate examples of the diverse habitat encountered during the field investigation.

The results of the geomorphic study indicate that Watts Branch is in a transitional

Figure 8 – Facing right bank from midstream. Note woody debris. Date: 8-2-01

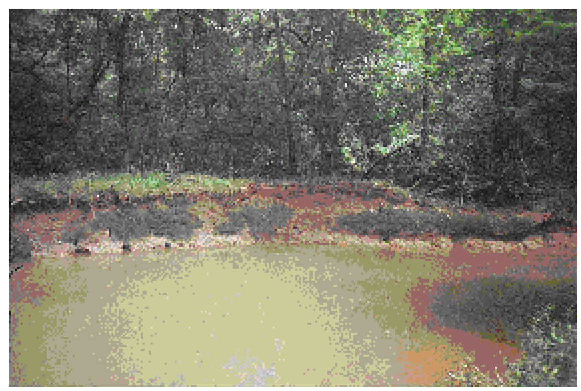


Figure 10 – Facing left bank from midstream. Note severely eroded banks. Date: 8-15-01

Figure 11 - Facing right bank from midstream. Note pool habitat. Date: 8-4-01.

state. Preliminary observations made in the field associated with cross sectional, longitudinal, rapid geomorphic assessment (RGA), and habitat data indicate that Watts Branch is adjusting to conform with changes that are most likely related to increases in impervious cover due to urbanization.

The instability of the riffle habitats is most likely due to increased impervious surface coverage in the watershed and increased velocities that transport larger particles, including those that once helped maintain stable riffle habitats. The loss of riffle habitats will most likely result in a reduction of macroinvertabrate habitat and a decrease in food sources for other stream inhabitants.

SECTION 5 - WATER QUALITY DATA

In order to determine the historical occurrence of contaminants in the raw water at the Potomac WFP, 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 and WSSC and MDE regularly monitor for these and other water quality parameters. These data are an important resource for evaluation of the Potomac River as a drinking water supply. A review of these data, data from other WTPs on the Potomac, and other ambient water quality monitoring data has established contaminants that are of concern at the Potomac WFP. The project team has reviewed historical water quality reports, and data stored in the EPA's STORET and ICR databases, WSSC's Management System Operating Techniques (MOST) and Laboratory Information Management System (LIMS) databases, and MDE's Public Drinking Water Information System Database, as well as Monthly Operating Reports submitted to MDE by WSSC and other Potomac River WTPs.

Based on these results and operational and other considerations, the following contaminants were identified as being of particular concern at the WSSC's Potomac WFP:

- Natural Organic Matter
- *Giardia*
- *Cryptosporidium*
- Tastes and odors
- Sediment/Turbidity
- Algae
- Disinfection By-Product Precursors
- Ammonia
- Fecal Coliforms
- Dieldrin

It is important to reiterate that these evaluations were based on raw water quality data, and that WSSC has always met or done better than applicable safe drinking water quality standards in the finished water from the plant.

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 WSSC experience at the Potomac WFP. Contaminants listed in Appendix 2.1 of Maryland's Source Water Assessment Plan (MD-SWAP), and other site-specific compounds that affect the water quality were considered.

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 evaluated. WSSC, 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 MDE SWAP, contaminants for which there is an MCL will not be listed as contaminants of concern if existing data indicate that measured concentrations in raw water 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 WSSC Potomac WFP.

Although no regulated contaminants had 10% of the samples exceeding 50% of the MCL, the data include several samples of raw water with contaminant concentrations greater than the MCL. In each case, tap water samples taken the same day indicated a concentration of the contaminant well below the MCL. This is generally due to removal of the contaminant in the treatment works.

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, heterotrophic plate counts, and TOC. While the raw water concentrations of some of these contaminants are at a level requiring the implementation of the treatment techniques and therefore became contaminants of concern (such as turbidity and TOC as discussed below), the Potomac WFP meets or exceeds all relevant treatment technique requirements. Raw water legionella data are not available, but data for the others were evaluated. Fecal coliforms, e. coli, *Giardia*, *Cryptosporidium*, viruses, and HPC are discussed in section 5.1.2.4 below.

<u>5.1.2.2 - Contaminants with Established Health Advisories</u>

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 has been a recent reduction in the MCL), these are unregulated contaminants. In this assessment, the health advisory that correlates to the lowest drinking water concentration was used to establish the criterion for selection of contaminants of concern from this category.

Because the risk assessment for establishment of health advisories is similar to that for establishing MCLs, the 50/10 criterion was applied to these parameters as well.

Evaluation of WSSC's sampling records (as described in detail in Appendix A) indicated that 9 of the 10 contaminants with established health advisories have 10% exceedance values that are less than 50% of the health advisory and are not to be considered contaminants of concern for the project. There are data available for 34 dieldrin samples; the 10% exceedance dieldrin sample in Potomac WFP raw water is 0.0001 mg/L, which is less than the most restrictive health advisory of 0.0002 mg/L (representing a 1 in 10,000 increased cancer risk for a lifetime exposure) but equal to 50% of the health advisory. Dieldrin therefore exceeds the 50/10 criterion at the Potomac WFP.

5.1.2.2.1 - Dieldrin

Dieldrin ($C_8H_8C_{16}O$) is a by-product of aldrin (natural processes convert aldrin to dieldrin), a pesticide historically used on cotton, corn and citrus crops, and used for termite, mosquito and locust control. Dieldrin is carcinogenic to mice. Most uses of dieldrin were banned in the mid-1980s and it is no longer produced in the US. Dieldrin has a sediment-water partition coefficient of 10,000 (L/kg) indicating that most dieldrin will adsorb to surfaces in natural waters rather than remaining in the aqueous phase. Dieldrin has been shown to be persistent in soils. Although dieldrin in the raw water is most likely adsorbed to particles and removed in the treatment process, dieldrin is considered a contaminant of concern at the WSSC's WFP based on the 50/10 criterion.

5.1.2.3 - Contaminants Which Affect Potomac WFP Operations

Some contaminants in natural waters significantly affect WFP 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 pH, ammonia, algae, NOM (using TOC as a surrogate), and sediment (using turbidity as a surrogate).

5.1.2.3.1 - pH

There is a secondary MCL for pH based on aesthetic considerations, and pH can have a significant impact on treatment operations at WFPs. Episodes of high pH and significant diurnal variations in pH have caused coagulation difficulties at the WFP in the past. In addition to the acid feed system recently installed to assist with these episodes, the coagulant selection has been changed recently and plant operations staff report that the coagulation process is less sensitive to these pH variations. pH levels remain a concern and WSSC continues to carefully monitor raw water pH for significant changes. pH variations are thought to result from algae in the river. Because algae are considered a contaminant of concern of the project (discussed in section 5.1.2.3.3) and because of the plant upgrades and recent experience of the operations staff, raw water pH will not be considered an issue of concern for this project.

5.1.2.3.2 - Ammonia

WSSC staff have reported significant chlorine demand exerted by ammonia in the raw water. Consistent with WSSC experience, the data indicate episodes of elevated ammonia concentrations in the raw water. From January 1985 to January 1997, raw water ammonia: exceeded 0.1 mg/l (exerting greater than 1 mg/l Cl_2 demand) on 90 days; exceeded 0.2 mg/L (greater than 2 mg/l Cl_2 demand) 30 times; and exceeded 0.3 mg/l (greater than 3 mg/L Cl_2 demand) 16 times. These episodes generally occur in the winter. These elevated ammonia concentrations exert a significant chlorine demand and are reported causes of taste and odor episodes, typically associated with snowmelt. Because of these problems, ammonia is considered a contaminant of concern.

5.1.2.3.3 - Algae, TOC, and Turbidity

High turbidity levels and moderate TOC and algae levels indicate that significant levels of each of these contaminants are regularly present in the raw water. The untreated water turbidity always exceeds the regulatory level for finished water (which is always less than 1.0 NTU and less than 0.3 NTU more than 95% of the time). The untreated water TOC levels almost always exceeds 2.0 mg/L, the standard requiring the plant to remove some amount of TOC. The Potomac WFP has always met or done better than the standards for turbidity and TOC in the finished water. While algae counts are not particularly high (there is no drinking water quality standard for algae), high raw water pH and dissolved oxygen resulting from algal activity in the River have historically been observed during dry, low flow periods. These variations create various treatment challenges at the plant. On the basis of this information, algae, organic carbon, and turbidity are considered contaminants of concern at the plant.

5.1.2.4 - Disinfection and Disinfection By-Products

Under the Information Collection Rule (ICR), WSSC and other large utilities collected and evaluated disinfection by-product, *Cryptosporidium* and *Giardia* samples. This sampling was carried out from June 1997 to October 1998.

5.1.2.4.1 - Disinfection By-Products

At the Potomac WFP, 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. WSSC staff report that DBPs themselves have not been detected in the raw water of the Potomac WFP, which is not surprising as 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. Historical finished water DBP data indicates that WSSC is meeting the prevailing DBP regulations (80 μg/L for THMs and 60 μg/L for HAAs as a system-wide running annual average), and WSSC is working to optimize system operations to minimize DBP formation. Depending upon the degree to which DBPs are minimized, the plant may or may not have to make treatment changes (*e.g.*, conversion to chloramination for secondary disinfection) to meet the anticipated future DBP regulations spelled out in the negotiations on the Disinfection By-Products Rule. Because of the significance of the DBP issue and the role of watershed activities in limiting DBPs, DBP precursors are considered a contaminant of concern at the WSSC's Potomac WFP.

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

[4] Holman (1993)
[5] Graczyk et al. (2000)
[6] DuPont et al., (1995)
[7] LeChevallier, et al (1991)

form they are resistant to many environmental conditions and disinfectants. *Giardia* cysts can be reliably removed and inactivated in conventional water treatment.

Data from the Information Collection Rule (ICR) collected from June 1997 to October 1998 suggest that both *Giardia* and *Cryptosporidium* are occasionally present in the raw water at the Potomac WFP. Evaluations of these 16 samples (as described in detail in Appendix A) indicated 13 with nondetectable concentrations, and a maximum of 0.51 oocyst/L. It is important to note that the ICR testing and sampling protocols employed have a low recovery rate and a high detection limit and that, as sampling and testing techniques are refined in future sampling, results are likely to differ.

Cryptosporidium data recently collected by MDE and evaluated by a new method seem to indicate more consistent and relatively higher (compared to ICR sampling) concentrations. In order to protect the public from the threat of *Cryptosporidium* oocysts, the USEPA recently issued the Interim Enhanced Surface Water Treatment Rule (IESWTR) and is currently developing the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR). The IESWTR lowered the turbidity standard at plants like the WSSC's Potomac WFP from 0.5 ntu to 0.3 ntu, 95% of the time. Currently the IESWTR requires 2-log (99%) removal/inactivation of *Cryptosporidium* oocysts, but also gives 2-log removal credit for a properly operated filtration plant. This removal credit is based on several studies which show that filtration plants can typically remove 99%, or 2-log, of oocysts or particles in the size range of oocysts.

Requirements of the Long Term 2, Enhanced Surface Water Treatment Rule (LT2ESWTR) will impose *Cryptosporidium* inactivation requirements [beyond those of the Interim Enhanced Surface Water Treatment Rule (IESWTR)] based on the results of future required monitoring with newer protocols (relative to the ICR methods). In September of 2000 the Federal Advisory Committee (FACA) for the LTESWTR finalized an Agreement in Principle which is expected to serve as a foundation for the LT2ESWTR. The requirements of the LT2ESWTR have not been finalized but are expected to 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 source water protection 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 Potomac WFP. 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 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 sanitary sewage ranging from 10 to 20,000 oocysts/L. [13, 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 do indicate that wastewater filtration is an important technology in reducing oocyst concentrations in wastewater effluent. New York City is funding microfiltration membrane processes at wastewater treatment plants in their watershed to remove oocysts.

Giardia and *Cryptosporidium* are considered contaminants of concern because of the limited amount of monitoring data, uncertainty in previous nearby 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.

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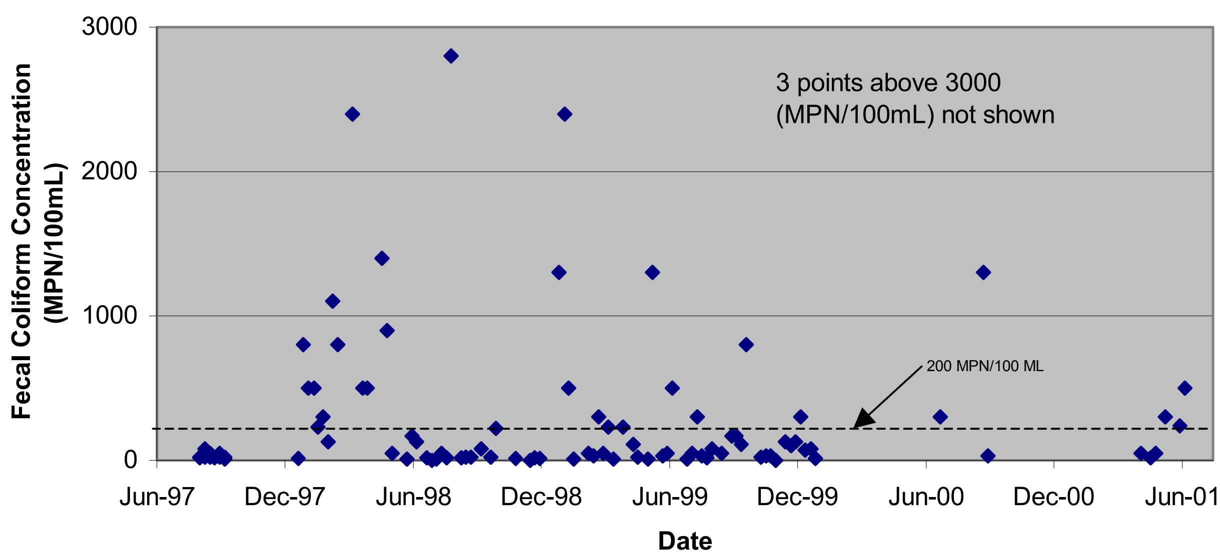
[8] Jurenak et al (1995)
[9] Fayer, et al. (1997)
[10] Walker et al (1999)
[11] Xia et al. (1993)
[12] Holman (1993)
[13] Walker, et al (1999)
[14] States et al. (1997)
[15] Holman (1993)

5.1.2.4.3 - Viruses and Coliform Bacteria

Viruses, e. coli and total coliforms are also regularly present in the raw water. Treatment facilities at the WFP reliably remove or inactivate the contaminants. MDE presumes a public health hazard if the log mean of fecal coliform samples exceeds 200 MPN/100 mL. Although fecal coliforms are removed and inactivated in the Potomac WFP, they are an indication of fecal contamination and may indicate contamination with other fecal pathogens. Evaluation of available data (as described in detail in Appendix A) indicate that the 10% exceedance for fecal coliforms exceeds 50% of the MDE standard, so fecal coliforms are considered a contaminant of concern at the Potomac WFP. Recent data on raw water fecal coliform concentration are shown on Figure 11. Viruses, e. coli, and total coliforms will not be considered contaminants of concern for the project.

Figure 11 - Potomac WFP Raw Water Fecal Coliform Concentration



5.1.2.5 - Contaminants Which Effect the Aesthetic Quality of the Water

Parameters affecting the aesthetic quality of the water were evaluated by comparing raw water data against the established secondary standards (*i.e.*, SMCLs). Evaluations of these data indicate that only color and tastes and odors are regularly present in the raw water at concentrations above the secondary standard. Therefore, color and taste and odor causing compounds will be considered contaminants of concern for the project. Color is generally a result of elevated levels of NOM, which has already been selected as a contaminant of concern.

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
- Sediment/Turbidity
- Algae (and their limiting nutrient, phosphorus)
- Disinfection By-Product Precursors
- Ammonia
- Fecal Coliforms
- Dieldrin

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. Particular attention was paid to the contaminants of concern, but historical data on other contaminants were also reviewed in order to present a more complete picture of overall water quality in the watershed.

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 the Potomac WFP) remain persistent in fish tissue and sediment at urban and agricultural areas[16].

5.2.1.1 - Dieldrin

An evaluation of dieldrin occurrence data indicates that dieldrin occurs throughout the watershed. As shown on figures in Appendix C, 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 river bed sediment samples. All subwatersheds with available data indicated the presence of dieldrin in the water column.

[16] USGS 1999

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, Middle Potomac-Catoctin, and Monocacy than in other subsheds, although sediment and water sampling do not necessarily support this. 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 Potomac WFP. Ammonia (NH_4) has been associated with taste and odor issues at the Potomac WFP and other treatment plants that chlorinate. Ammonia also exerts a chlorine demand of approximately 10 parts of chlorine per part of ammonia.

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 also been reduced.

Since the 1970s, phosphorus and sediment loading to the watershed have decreased significantly while nitrogen loading has remained roughly constant [17,18]. Nonpoint sources account for approximately 60%-70% of combined nitrogen and phosphorus loading from the 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 River basin were thought to be impaired by nutrients. At the time, the leading source of nutrients was agricultural activities, with urban sources the second leading cause.[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, 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

[17] CB&WMA, 1993
[18] Tawil, May 1997
[19] CB&WMA, 1993
[20] ICPRB, 1995
[21] ICPRB, 1987

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.

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 (Map 1)
- Land use (Map 2)
- Hazardous and toxic waste sources (Map 3)
- Potential petroleum sources (Map 4)
- Facilities with NPDES permits (Map 5)
- Potential sewage problem areas (Map 6)

6.1 - Point Sources

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

6.2 - Nonpoint Sources

6.2.1 - Urban

Urban and suburban areas within the watershed (shown on the landuse maps in attached compact disc) contribute nutrients, sediment, NOM, taste and odor causing compounds, *Giardia*, *Cryptosporidium*, fecal coliform and other bacteria, and heavy metals to the Potomac River. Lawn and pavement run off also increases instream flow and stream bed erosion. Until the streambed downstream of urbanized areas reaches a steady state with the new streamflow pattern, which can take 60 years or longer, this effectively represents a sediment load to the Potomac WFP. 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 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, pesticides, NOM, *Cryptosporidium*, *Giardia*, and fecal coliform and other bacteria.

6.2.4 - Mining

Mining activities in the Potomac WFP 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 Potomac WFP intake. Six lime dosing stations have been installed by Maryland in the headwaters of the Potomac River to control pH. Many of the historic water quality impacts are therefore mitigated by natural attenuation before reaching the intake and affecting the WFP. Contaminants from mining operations can include acid drainage.

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.

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[22] EPA 1999

SECTION 7 - SUSCEPTIBILITY ANALYSIS

Computer modeling was utilized to analyze the susceptibility of the Potomac WFP water supply to contamination from the identified contaminants of concern. This section describes these efforts and results. First, the modeling approach is described in detail. Second, because of the limitations of current modeling capabilities, each contaminant of concern could not be modeled directly, and therefore a discussion of the fate, transport, and treatment characteristics of the contaminants of concern is presented. Third, results of the model are discussed in detail and are presented by geographic model segments and also by contaminant group. Finally, a discussion of the modeling results specifically focused on the influence of Watts Branch and Seneca Creek on the intake water quality is presented.

7.1 – Modeling Approach

The WSSC is taking a proactive approach in addressing reduced and variable water quality (due to local sources) by considering the construction of a new submerged channel intake. Previous studies have evaluated the extent to which these potential intake modifications would isolate the WFP from these local sources of point and nonpoint source contaminants. An intensive sampling effort of several potential intake locations was undertaken in 1999. A review of these data indicates that relocation of the intake may cause dramatic and positive changes to the raw water quality at the WFP. If this is correct, potential intake modifications could provide an important protective barrier to the customers of the WSSC and have a significant impact on the operation of the Potomac WFP. This source water assessment was therefore designed to analyze the susceptibility of the intake with consideration of both the existing and submerged channel intake locations.

Using the information collected in previous tasks, the project team performed the following activities:

- Computer Modeling Simulations (described below and in Appendix E), which included:
  - Fate and Transport Modeling
  - Future Scenario Modeling
  - Treatment Scenario Modeling
  - Time of Travel Modeling
  - 2-D Modeling

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 Potomac WFP. 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 practices), and
- Future management conditions (with implementation of management practices), including
  - moderate management conditions [with intermediate (between no management and aggressive management scenarios) implementation of management practices]
  - aggressive management conditions (with aggressive implementation of 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 E, and current data is shown in detail on maps included in the appendices (attached compact disc). Watershed management programs for each of these scenarios were developed based on data evaluation, and project team experience with watershed management practices both within and outside of the watershed. It is important to note that the level of detail in these evaluations may not be sufficient to make firm watershed management planning decisions and these decisions are highly dependent on local conditions and the input of other stakeholders. The details of each management scenario (as summarized below and described in detail in Appendix E) 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

In both Watts Branch and the Upper Watershed (the portion of the Potomac Watershed upstream of Watts Branch), 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.

In the Upper Watershed (the portion of the Potomac Watershed upstream of Watts Branch), the management of storm water for future development was characterized based on the fraction of a segment in each state. The following estimations were made (Table 8).

TABLE 8. 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

Due to programs that have been implemented, continued excellent management was assumed in Watts Branch for the future no management scenario, including 90% control for water quality, and 70% control for channel erosion.

The management practices are categorized as:

- Agricultural,
- Urban Structural,
  - Upper Watershed,
  - Watts Branch,
- Urban Nonstructural
  - Upper Watershed,
  - Watts Branch

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 9. 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 9. EFFICIENCIES FOR AGRICULTURAL PRACTICES

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

7.1.1.2 - Current Urban Practices

7.1.1.2.1 - Structural Treatment Practices

Structural treatment practices were applied in both Watts Branch and the Upper Watershed and evaluated separately. The project team has extensive experience with management practices in Watts Branch. There are also significant detailed data on BMP implementation in the Watts Branch Watershed. In Watts Branch, the practices were therefore generally derived from known information, while more assumptions were used to estimate probable practice distribution in the Upper Watershed.

7.1.1.2.1.1 - Structural Practice Distribution – Watts Branch

Due to differences in available data, information was gathered separately for the portions of the Watts Branch Watershed in Montgomery County and in the City of Rockville. Montgomery County maintains a fairly detailed GIS layer of Storm water Management practices, including the drainage area, type of practice, and total impervious area draining to the practice. The total area in each type of practice within the Montgomery County portion of the watershed was obtained by overlaying this information with the Watts Branch Watershed boundary. This analysis indicated that of the area within the watershed, but outside of Rockville:

- 30 acres drain to Dry Ponds,
- 69 acres drain to Wet Ponds, and
- 19 acres drain to Wetlands

For the portion of the watershed in the City of Rockville, existing acreages captured by management practices were derived from data in the appendices to the Watts Branch Watershed Plan[23]. The resulting areas under each practice were:

- 413 acres drain to Dry Ponds, and
- 160 acres drain to Wet Ponds

Thus, the entire Watts Branch drainage is depicted as having the following distribution:

- 443 acres drain to Dry Ponds,
- 229 acres drain to Wet Ponds, and

[23] City of Rockville, 2001

- 19 acres drain to Wetlands

7.1.1.2.1.2 - Structural Practice Distribution – Upper Watershed

In the Upper Watershed (the portion of the Potomac Watershed upstream of Watts Branch), very little information is available to determine the extent to which structural practices have been employed over time. However, based on general knowledge of the area, and the state of 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.

7.1.1.2.1.3 - Structural Practice Efficiencies

Ideal efficiencies (before the application of discount factors) for these practices are derived from Winer (2000) are shown on Table 10:

TABLE 10. POLLUTANT REMOVAL FOR STRUCTURAL PRACTICES

	TN	TP	TSS
DRY PONDS	25%	19%	47%
WET PONDS	33%	51%	80%
WETLANDS	30%	49%	76%

Discount Factors for Structural Treatment Practices

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.

In the Upper Watershed, a uniform set of discount factors was used to characterize practices in the Upper Watershed. 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)

In Watts Branch, more information was available about current practices in the watershed (particularly in the Rockville portion). In general, it appeared that practices were undersized and would capture less annual runoff than in the Upper Watershed, with some maintenance needs. The discount factors used were:

- 0.6 for the "capture discount" (assumes 60% capture of annual runoff)
- 1.0 for the "design discount" (assumes typical design standards)
- 0.75 for the "maintenance discount" (assumes a slightly better than average maintenance record)

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.

In the Upper Watershed, 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

In Watts Branch, the majority of existing active construction takes place on very highly visible, large projects. Therefore, it is thought that the practices in place are "state of the art" and highly maintained. The erosion and sediment control assumptions in Watts Branch are as follows:

- Practice Efficiency of 80%,
- Treatability Factor of 1.0,
- Compliance Discount of 0.9, and
- Installation/ Maintenance Discount of 0.95.

7.1.1.2.2.2 - Lawn Care Education

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

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

The remaining input parameter to characterize lawn care education is the fraction of the population that receives, understands and remembers information about more environmentally sensitive lawn care practices. In the Upper Watershed, it is assumed that 20% of the population matches this description. In Watts Branch a very aggressive program is in place in Montgomery County, and it is assumed that the residents of Rockville are also impacted by this education effort. Thus, the fraction of citizens impacted is increased to 40%.

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.). In the Upper Watershed, 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.

In Watts Branch, fairly detailed information is available to characterize street sweeping programs in both Montgomery County and the City of Rockville. This information is as follows:

In Montgomery County:

- 95% of residential areas in the County are swept once per year by regenerative air,
- Arterial roads/major streets are swept by regenerative air once per month for 10 months of the year,
- Commercial/ business district streets are swept 3 times per week

In the City of Rockville:

- Public streets in commercial areas are swept twice per week with a vacuum sweeper.
- Arterial streets are swept once per month with a vacuum sweeper
- Residential streets are swept twice per year with a vacuum sweeper
- Commercial/ business district streets are swept twice per week

GIS maps and street maps were reviewed, and combined with actual impervious cover layers of streets and parking lots to determine approximately which roads fell into these various categories.

7.1.1.2.2.4 - Impervious Cover Disconnection

Impervious cover disconnection was not explicitly accounted for in the Upper Watershed. In Watts Branch, it was assumed that 50% of the rooftop area classified as low density residential was disconnected.

7.1.1.2.2.5 - 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. In the Upper Watershed, 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.

In Watts Branch, the actual length of stream with forested buffers was measured, and a fifty foot buffer width 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[24] 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

[24] Wiedemen and Cosgrove, 1998

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 11.

TABLE 11. POINT SOURCE LOADS

SEGMENT	FLOW (MGD)	LOAD (IMPROVED) (LB/YEAR)		LOAD (AGGRESSIVE) (LB/YEAR)	
		TN	TP	TN	TP
160 – NORTH BRANCH POTOMAC	35.46	630,781*	55,449	332,695	8,317
170 – SOUTH BRANCH POTOMAC	0.42	10,508	657	3,941	99
175 – CACAPON-TOWN & CONOCOCHEAGUE- OPEQUON	0.07	1,751	109	657	16
180 – CONOC.-OPEQUON	11.6	290,225	18,139	108,834	2,721
190 - SOUTH FORK SGENANDOAH	32.58	815,132	50,946	305,674	7,642
200 – N. FORK SHENANDOAH & SHENANDOAH	5	125,097	7,819	46,911	1,173
210 – MONOCACY	15.7	392,804	24,550	147,302	3,683
220 – MIDDLE POTOMAX – CATOCTIN	8.78	219,670	13,729	82,376	2,059
730 – CONOCOCHEAGUE - OPEQUON	8.38	209,662	13,104	78,623	1,966
740 – CONOCOCHEAGUE – OPEQUON	9.94	248,693	15,543	93,260	2,331
750 - MONOCACY	3.12	64,579*	4,879	29,273	732
* Same as existing load without controls.					

7.1.2.2 - Urban Management Practices

In the Upper Watershed, 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.

7.1.2.4 - Watts Branch

In Watts Branch, appropriate improved management includes storm water retrofits, and some enhanced storm water programs. In the "moderate management" scenario, recommended management focuses on implementation of storm water retrofits called for in the Watts Branch Watershed Management Plan for the City of Rockville[25]. This plan calls for retrofitting several existing storm water management facilities, to increase the water quality treatment and channel protection storage provided by storm water practices. This increase is reflected as an impervious cover capture for various water quality practices, and a capture of impervious cover to reduce flows for the purpose of channel protection.

7.1.2.5 - Moderate Management

Table 12 summarizes how these benefits are accounted for. It lists the recommended practices in Watts Branch, along with impervious cover capture, and percent target storage for channel protection and water quality. For channel protection, the net benefit of these practices could be summarized as the product of impervious cover capture and target storage volume. The

[25] Rockville, 2001

result was a capture of 266 acres of impervious cover, or roughly 25% of the impervious cover within the Rockville portion of Watts Branch.

For water quality practices, a discount was applied to reflect the type of retrofit. For example, a simple modification to an existing facility (e.g., addition of a forebay or wetland plantings) resulted in treatment of only 20% of the impervious cover draining to the facility. One existing facility (SM-23) was modified to increase the total drainage to the facility. This practice received a 50% discount. The resulting increase in water quality capture within the Rockville portion of Watts Branch was:

- 50 additional acres draining to dry ponds,
- 70 additional acres to draining wet ponds, and
- 8 additional acres draining to wetlands.

Table 12. Storm Water Retrofit Accounting in the Rockville Portion of Watts Branch

Practice ID	Impervious Area Capture (Acres)	Storm water Practice Type	Channel Protection Storage (% of target)	Water Quality Storage (% of target)	Discount Applied to Water Quality Practices*	"Effective" Water Quality Capture (% of target)
SM-1	18	Dry pond	100	100	0.2	20
SD-12	9	Dry pond	100	100	1	100
SM-18	20	Dry pond	54	0	0	0
O-3	16	Dry pond	100	93	1	93
SM-20	54	Dry pond	98	37	0.2	7.4
SD-6	10	Dry pond	44	100	1	100
SD-16	9	Dry pond	100	100	1	100
SD-22	8	Wetland	100	100	1	100
SM-8	13	Wet Pond	100	0	1	0
SM-24	68	Wet Pond	30	20	0.2	4
SM-23	44	Wet Pond	73	69	0.5	34.5
SD-8	45	Wet Pond	100	80	1	80
SM-9	9	Wet Pond	100	100	0.2	20
SD-24	20	Wet Pond	92	70	1	70

* 0.2 applied to enhanced existing practices (assumes a 20% increase over existing performance. For practice SM-23, a value of 0.5 was used due to increased drainage to the practice.

7.1.2.6 - Aggressive Management

The "aggressive management" scenario in Watts Branch assumes implementation of a watershed plan in the Montgomery County portion of the watershed that is similar to that planned for the City of Rockville. Two major differences between the Montgomery County portion of Watts Branch and the portion in the City of Rockville are that

- Montgomery County development is overall of much lower density, and
- a greater portion of the Montgomery County portion of the watershed appears to be uncontrolled.

These two factors suggest that capturing a large portion of existing impervious cover may be more difficult in the Montgomery County portion of the watershed. As a result, it is unrealistic to assume the same capture (as a fraction of existing watershed development) in Montgomery County as in the City of Rockville.

A set of estimates was used to account for these distinctions and to develop a "comparable" watershed strategy in the Montgomery County portion of Watts Branch. These estimates include the following:

For existing Montgomery County facilities:

- 12% of existing dry ponds receive advanced treatment as dry ponds.
- 13% of all facilities add additional water quality storage as wet ponds.
- 27% of all area draining to existing facilities receives channel protection storage.

For uncontrolled Montgomery County development:

- 7.5% of area drains to dry ponds for water quality control.
- 12% of area drains to wet ponds or wetlands for water quality control.
- 21% of area controlled for channel protection

This results in addition of the following practices in the Montgomery County portion of Watts Branch:

- 20 additional acres captured by dry water quality ponds
- 35 additional acres captured by wet water quality ponds
- 21% of impervious cover in the lower watershed captured for channel protection.

7.2 – Fate, Transport, and Treatment Evaluations 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 Potomac WFP intake to contamination from sources in the watershed, it is important to account for the attenuation which will take place in the watershed. The models generally take these processes into account. However, current state of the art models do not have the capability to model all of the contaminants of concern specifically, and therefore fate, transport, and treatment characteristics of each of the contaminants of concern were considered to supplement the model results. These characteristics and their relationship to the modeling approach are discussed below.

7.2.1 - General Fate, Transport, and Treatment Characteristics of Contaminant Groups

To facilitate the assessment of the extent that the identified contaminants of concern may reach the WSSC intake, these contaminants have been classified into four 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
- Group 3 - Taste and Odor Causing Compounds and Ammonia and
- Group 4 – Dieldrin

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

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

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

Natural organic matter, which can be represented by total organic carbon, includes disinfection by-product precursors and increases coagulant demand. Algae may increase disinfection by-product levels, increase coagulant demand, and interfere with filter operations. The growth and activity of algae in the Potomac Watershed is largely dependent upon the availability of 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 and Ammonia.

Taste and odor causing compounds are numerous and can affect consumer confidence in their drinking water. Ammonia affects chlorine demand and causes a particular type of taste and odor problem associated with its reaction with chlorine. These contaminants of concern are grouped together because of their relationship to taste and odor problems. Algae can also produce noxious tastes and odor compounds, and while listed in Group 2, algae levels may affect taste and odors.

7.2.1.4 - Group 4 – Dieldrin.

Dieldrin, a pesticide which has been banned from manufacture for several decades, is a possible carcinogen which is persistent in the environment. It is strongly associated with sediment, and therefore is likely to be transported in the river and removed in the plant similar to sediment. There have only been three detections of dieldrin in the Potomac WFP intake water (out of 34 samples), but it has also been detected throughout the watershed in the water column, in sediment, and in fish tissue. While this compound has similar fate and transport as sediment, it has been separated from the Group 1 contaminants because it is no longer in manufacture and general use and thus opportunities for control are limited. Because of the ban of its manufacture, it is expected that the dieldrin levels throughout the watershed will eventually decrease.

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[26,27]. Thus, source water NOM concentration has a significant effect on the operations and cost of drinking water treatment. However, the most important problem associated with NOM is that it includes precursors to disinfection by-product formation. NOM is a mixture of organic chemical compounds present in natural waters including the Potomac River. Because NOM is a complex mixture of many chemicals, direct measurement is impractical and surrogate measurements are

[26] Owen et al. 1993
[27] AWWARF 2000

typically made to evaluate NOM levels. Total organic carbon (TOC) is a common surrogate for NOM.

Because of regulations regarding DBPs and health concerns, WSSC has moved the point of chlorination to a point down stream of the filters in the plant. WSSC staff report that this is as far down stream in the treatment process as possible while reliably providing sufficient chlorine contact time to meet *Giardia* inactivation requirements. By applying post-filter chlorination, WSSC takes advantage of TOC removal that occurs due to coagulation reactions and subsequent flocculation, sedimentation and filtration. The DBP precursors that are removed in these processes are not exposed to chlorine and therefore do not form DBPs.

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[28]. These aromatic organic chemicals are somewhat more likely to be chlorine DBP precursors (organic chemicals which, when they react with chlorine form THMs and HAAs) than in non-aromatic organic matter. NOM from terrestrial activities may therefore be somewhat more likely to produce DBPs than NOM produced within the waterbody. However, terrestrial NOM is larger and coagulates more efficiently than NOM generated with in the waterbody. Terrestrial NOM is therefore more likely

[28] Bouwer et al., 1995

to be removed in the treatment process before reacting with chlorine and potentially forming DBPs.

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.[29]

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 and, 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 at the Potomac WFP indicate TOC levels ranging from 1.1 mg/L to 8.4 mg/L and 10% of samples have TOC over 5.0 mg/L with no clear seasonal trends. These are relatively high levels for a run of the river intake and suggest relatively high

[29] AWWARF- 1991

NOM and DBP precursors. Although finished water TOC data indicates that the plant is typically removing more than the required amount of TOC, TOC control measures still have the potential to lower treatment costs and sludge production while improving taste and odor problems and possibly reducing DBP levels in finished water.

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 Potomac WFP 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 practices at the Potomac WFP. *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 Potomac WFP, 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.

The flashy nature of Watts Branch causes rapid deterioration in raw water quality and difficult challenges to the Potomac WFP operations staff in setting the proper coagulant dose. These periods of reduced raw water quality are caused by run off from a developed area, and urban storm waters have often been shown to include high concentrations of oocysts.[30] There is therefore a possibility that elevated oocyst concentrations are present in the raw water at the time when particle and oocyst removal efficiencies are more likely to be reduced.

7.2.2.3 - Algae

Under appropriate environmental conditions, algae are formed in natural waters. In the Potomac River, seasonal algal blooms have historically formed when sufficient phosphorus is available in quiescent areas of the river. Since phosphorus is the so-called "limiting nutrient" in the river upstream of the WSSC's intake, control of algae is generally dependent on control of phosphorus. Algae cells are low-density particles and once they form in the river, they are efficiently transported. They are sensitive to low light and low nutrient conditions and are generally not expected in significant concentrations far from blooms in quiescent zones. Photosynthetic activities and cell mortality can have a significant effect 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

[30] Schuler et al.

TOC concentrations, which are a suitable surrogate for NOM. However, the TOC simulation in the Bay Program model has not been calibrated.

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

7.2.2.4 - Sediment and Dieldrin

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 stormflow. The fate and transport of sediment and other particles is therefore dependent on processes within the streambed. Relevant processes include physical processes (sedimentation, scour, etc.), chemical processes (organic and inorganic reactions within the pore water and at the streambed surface), and biological (bacterial, macrophytic, and bioturbation from benthic macrofauna). Streambeds therefore functions as sediment sources, sinks and storage sites. [31] TSS is modeled explicitly by the Bay Program Model.

Dieldrin has an affinity for organic matter and, in natural waters, dieldrin is generally absorbed in the natural organic layer on the surface of particles. Once in the waterbody, fate and transport of dieldrin is therefore dependent on the fate and transport of the sedimentary particles to which it has sorbed.

[31] DiToro, D.M., 2001

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

7.2.2.5 - Tastes and Odors

A wide range of compounds including ammonia and 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. Raw water total odor number data from the Potomac Plant indicate consistent and significant levels of taste and odor causing compounds in untreated water at the Potomac Plant, although these compounds seem to be removed efficiently in the Potomac plant. WSSC does have a history of occasional, moderate taste and odor episodes, which plant staff report are related to elevated raw water ammonia concentrations. Ammonia concentrations reach very significant levels in the winter and are thought to be associated with runoff events.

Once in the plant, ammonia reacts with chlorine, increasing the chlorine dose required to achieve disinfection. One part of ammonia will exhaust approximately 10 parts of chlorine, so even relatively small concentrations of ammonia can increase the chlorine usage at the plant significantly. Ammonia and chlorine react to form chloramines, which cause aesthetic problems in systems that maintain a free chlorine residual, as does the WSSC.

7.3 – Model Results for Watershed Segments

Four primary modeling tools were combined to estimate the susceptibility of the Potomac WFP to contamination from watershed activities. These are watershed modeling, contaminant fate and transport modeling, two-dimensional hydrodynamic modeling of the Potomac River from the confluence with Watts Branch to the existing and potential intake structure locations, and time of travel modeling. 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 intake location. ICPRB's time of travel model was used to estimate the time of travel from various points in the watershed to the intake in order to categorize and evaluate potential spill sources.

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 Potomac WFP intake water quality and had a higher degree of resolution in the urban watersheds near the current intake.

Three computer modeling packages were used including the Center for Watershed Protection's Watershed Treatment Model (WTM), the Chesapeake Bay Watershed Model, and The Cornell Mixing Zone Model (CORMIX). In order to evaluate the relative impacts of Watts Branch on the WFP, the watershed was evaluated in three parts as shown on Figure 12:

- the Potomac River Watershed above Watts Branch,
- the Watts Branch watershed, and

- the Potomac River, north of Watkins Island, from the confluence with Watts Branch to the existing and potential intake locations.

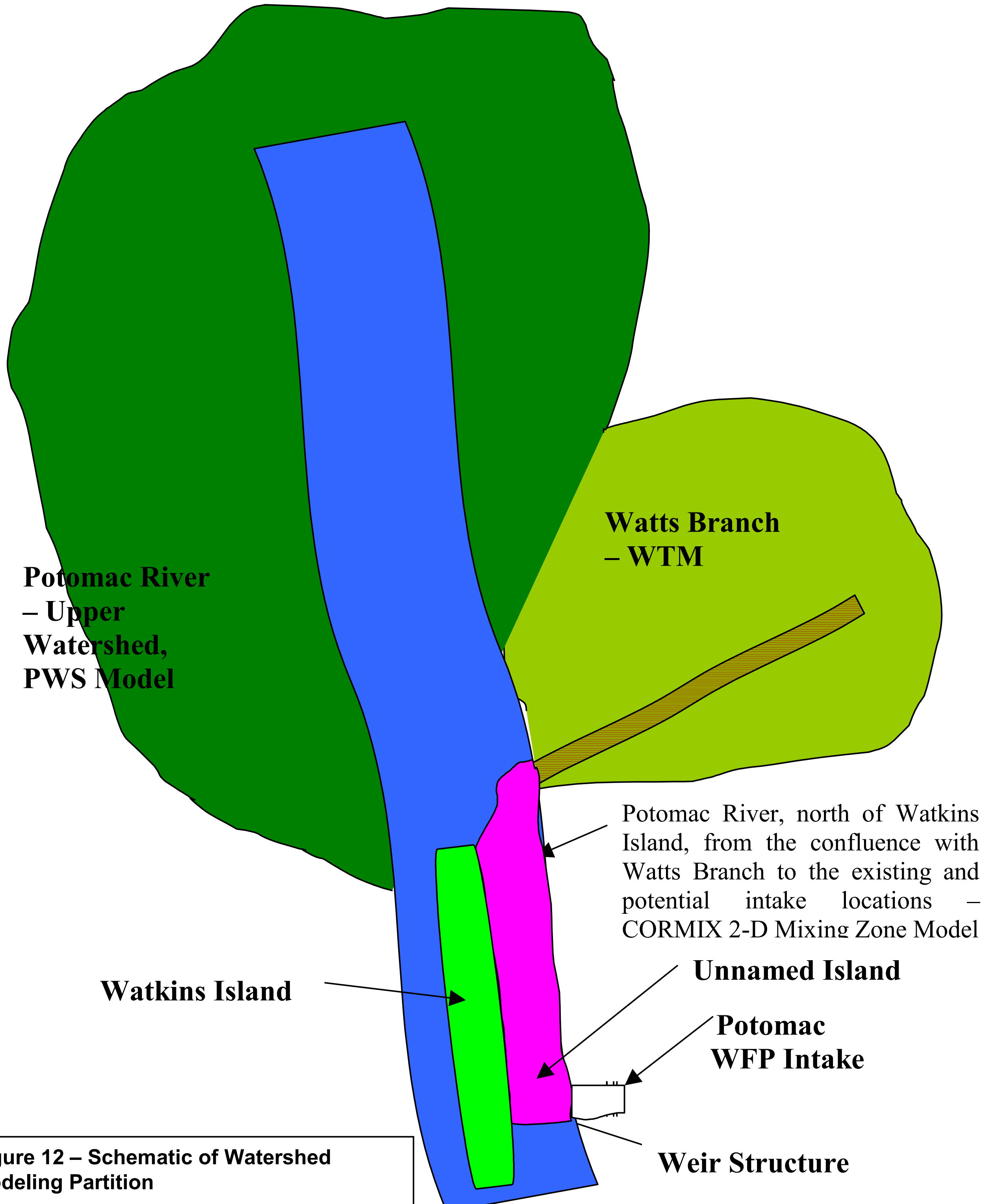


Figure 12 – Schematic of Watershed Modeling Partition

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.

7.3.1 - Potomac River Watershed Above Watts Branch

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 Potomac WFP's watershed, from the headwaters to the confluence of the river with Watts Branch, was developed based on EPA's Chesapeake Bay Watershed Model (CBWM). This model was designated as the Potomac WFP 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 confluence with Watts Branch.

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

WTM results showed moderate to significant improvements to "edge-of-stream" loadings within the Upper Watershed under the future scenario. Expected changes are smaller for sediment. Management practices were able to reduce sediment loads slightly and phosphorus loads somewhat more. Table 13 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. Appendix E includes more detailed model output by source for each management scenario.

TABLE 13 – 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%

TABLE 13 – UPPER WATERSHED LOADS FROM WTM				
SEGMENT		TOTAL NITROGEN	TOTAL PHOSPHORUS	TOTAL SUSPENDED SOLIDS
	Future-scenario 2	99%	96%	99%
	Future-scenario 3	96%	91%	98%
175				
	Future-scenario 1	102%	103%	104%
	Future-scenario 2	98%	94%	100%
	Future-scenario 3	95%	87%	98%
180				
	Future-scenario 1	104%	104%	105%
	Future-scenario 2	101%	85%	94%
	Future-scenario 3	82%	66%	85%
190				
	Future-scenario 1	104%	105%	109%
	Future-scenario 2	96%	78%	100%
	Future-scenario 3	85%	72%	96%
200				
	Future-scenario 1	106%	108%	114%
	Future-scenario 2	94%	82%	102%
	Future-scenario 3	87%	75%	96%
210				
	Future-scenario 1	107%	106%	109%
	Future-scenario 2	105%	88%	97%
	Future-scenario 3	92%	72%	85%
220				
	Future-scenario 1	105%	106%	106%
	Future-scenario 2	102%	96%	98%
	Future-scenario 3	96%	88%	93%
225				
	Future-scenario 1	105%	104%	101%
	Future-scenario 2	103%	97%	96%
	Future-scenario 3	100%	91%	90%
730				
	Future-scenario 1	102%	102%	103%
	Future-scenario 2	78%	65%	94%
	Future-scenario 3	61%	50%	86%
740				
	Future-scenario 1	110%	110%	112%
	Future-scenario 2	97%	87%	102%
	Future-scenario 3	88%	75%	95%
750				
	Future-scenario 1	103%	102%	104%
	Future-scenario 2	100%	90%	91%
	Future-scenario 3	82%	66%	79%

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

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

Regardless of these modeling results, simple mass balance considerations indicate that application of these practices will eventually have beneficial impacts roughly equivalent to the impacts on “edge-of-stream” loading (for example, a 10% reduction in phosphorus loading should eventually reduce algal activity by approximately 10%). This is also consistent with reported results by the EPA’s Chesapeake Bay Program Office, which assume instantaneous changes in the streambed and have noted significant reductions in nutrient concentrations and algal activity. Based on the geomorphological evaluations performed as part of this study, for contaminants associated with sediment (including nutrients, diedrin, and turbidity), the beneficial impact may lag years behind the implementation of the practices. Dieldrin (banned years ago, yet still detected in whole water and sediment samples) is a good example of this phenomeneon. Dieldrin loading was reduced or nearly eliminated after its banning and the benefits of this management practice are yielding significant benefits now. However, dieldrin could still be associated with sediment in the watershed, both on the land and in the streambed.

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

Cryptosporidium oocycts are thought to persist in the environment for a period of approximately 18 months, but not for periods on the timescale studied[32]. Reductions in oocyst and cyst loadings from the upper parts of the watershed would therefore be expected to reduce raw water oocyst concentrations rather quickly. Fecal bacteria, viruses, and other pathogenic organisms are even less persistent in the environment and management practices which yield reductions in "edge-of-stream" loading will have essentially immediate reductions in loadings at the Potomac WFP.

7.3.1.1 - Potomac River Above Watts Branch - Results

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

7.3.2 - Watts Branch

[32] Rose, J.B., 1997

TABLE 14– POTOMAC RIVER ABOVE WATTS - TSS

Suspended Solids			
	% Change from Current Scenario		
	2020 No Man	2020 Mod Man	2020 Agg Man
Average	101.6%	99.8%	98.7%
Median	100.7%	100.1%	99.9%
10% Exceedance	100.5%	98.1%	96.1%

TABLE 15 – POTOMAC RIVER ABOVE WATTS - CHLOR.

Chlor. A			
	% Change from Current Scenario		
	2020 No Man	2020 Mod Man	2020 Agg Man
Average	100.1%	100.1%	100.1%
Median	100.2%	100.2%	100.2%
10% Exceedance	99.8%	99.8%	99.8%

Table 16 – Potomac River Above Watts - TOC

TOC			
	% Change from Current Scenario		
	2020 No Man	2020 Mod Man	2020 Agg Man
Average	100.6%	99.0%	98.3%
Median	100.2%	99.7%	99.4%
10% Exceedance	100.3%	98.6%	97.7%

Table 17 – Potomac River Above Watts -

Ammonia			
	% Change from Current Scenario		
	2020 No Man	2020 Mod Man	2020 Agg Man
Average	101.4%	99.9%	99.8%
Median	101.3%	99.9%	99.8%
10% Exceedance	100.6%	97.7%	97.7%

An annual load model of the Watts Branch Watershed was constructed using the WTM. Similar to the approach to the Potomac above Watts Branch (described above), the WTM was used to estimate relative changes in loading rather than actual concentrations. The WSSC river sampling data were used to establish existing water quality conditions of the Watts Branch.

In Watts Branch, the load is dominated by channel erosion, and future management practices focus on this source. With full watershed implementation, of storm water retrofits, the sediment load from Watts Branch at the confluence with the Potomac River could be reduced by 15% compared to existing loads. Interestingly, even if these practices were not implemented, it appears that the sediment load will decline over time due to a shift of existing construction to developed land as ongoing construction projects are completed. Table 18 summarizes the Watts Branch loads to the Potomac River under each modeled management scenario.

Storm water retrofits would alter the streamflow from the current flow pattern to one that is more similar to past flow patterns and more appropriate for the existing streambed conditions. The streambed would then become immediately more stable. Flow control practices are therefore expected to yield more immediate results than sediment runoff control practices (which are expected to take on the order of 60 years or more to yield full improvements).

7.3.2.1 - Watts Branch - Results

Noting that the modeling was performed using literature based (rather than site specific) parameter values, the results of this modeling indicate the following predicted outcomes of simulated future and management scenarios (these results represent the anticipated changes in loading from Watts Branch to the Potomac River):

- Nitrogen and phosphorus loads are expected to increase slightly by 2020 if management practices are not modified.
- Year 2020 TSS loading is expected to be slightly reduced with no change in management practices due to the reduction in active construction.
- Moderate management practices will slightly reduce future nutrient loads, but not to current levels.
- Moderate management will increase the expected reduction in solids loading.
- Aggressive management practices will reduce future nutrient loads below current loads.

- Aggressive future management practices will further reduce solids loading.

Table 18 Total Load in Watts Branch Under Various Scenarios (lb/year)						
	TN		TP		TSS	
	Load (LB/Year)	Load as a Percent of Current Conditions	Load (LB/Year)	Load as a Percent of Current Conditions	Load (LB/Year)	Load as a Percent of Current Conditions
Current	71,744	-	14,062	-	6,912,614	-
Future-scenario 1	75,813	106%	14,312	102%	6,651,177	96%
Future-scenario 2	75,008	105%	13,992	100%	6,403,264	93%
Future-scenario 3	70,804	99%	12,752	91%	5,870,181	85%

7.3.3 - Potomac River from Watts Confluence to Existing and Potential Intake Locations

A two-dimensional mixing zone model of this critical reach of the Potomac River was developed to determine the relative impacts of Watts Branch on the current and potential (submerged channel) intake locations. Because of data deficiencies, this model was not calibrated. It is important to note that the mixing zone model simulates only hydrologic phenomena and does not simulate physical or chemical processes that contaminants may undergo. Because the modeled reach of the river is short, this assumption is considered reasonable relative to the contaminants of concern. The 2-D model is a near field model and appropriate for evaluations of the existing intake. The potential locations for a relocated submerged channel intake are at or beyond the limits of this near field model, so advection and dispersion calculations and assumptions were made to augment the mixing zone model analysis of the relocated intake.

7.3.3.1 - Impact of Watts Branch on Existing Intake

The model was run at a variety of Potomac River and Watts Branch flow conditions to estimate the dilution ratio (fraction of Watts Branch flow in the WFP raw water) under a wide range of flow conditions. These runs were used to evaluate both the existing and potential intake locations. Detailed results are presented in Appendix E.

The existing intake is located on the shore of a channel that cuts between the Maryland bank and a small island approximately 100 feet off shore, referred to as "Intake Island" or "Unnamed Island". Watts Branch, a small local stream, discharges to the Potomac River approximately 1,800 feet above the existing intake. Watkins Island is a long narrow island that divides the Potomac River into two relatively equal parts in the vicinity of the existing intake.

Operational data that show the occurrence of TSS-induced problems at the Potomac WFP, and water quality data show the elevated TSS levels in Watts Branch relative to the Potomac River. Evaluation of these data indicates a significant impact by Watts Branch on the current intake location. The two dimensional computer simulation hydrodynamic modeling study was performed to quantify the specific impacts observed at the existing intake that are attributable to Watts Branch and to better understand whether relocation of the intake to a location between the intake island and Watkins Island would offer relief from these operational problems. To the extent feasible under the limitations of the supplemental calculations, the impact of Seneca Creek was also evaluated.

In virtually all of the flow scenarios anticipated, the impact of Watts Branch on water quality at the existing intake was significantly more severe than would be expected under complete mixing of the Potomac River and Watts Branch flows. This occurs because the Watts Branch flow stays adjacent to the Maryland bank of the Potomac River.

7.3.3.2 - Potential Benefits of a Relocated, Submerged Channel Intake

Another important finding of this evaluation is that under all flow conditions, the main body of the simulated plume or jet from Watts Branch does not go outside of the intake island. From the analysis, it can be concluded that Watts Branch impacts the current intake location but would not impact an intake relocated beyond the "intake island" (i.e. a submerged channel intake). This condition is illustrated on Figure 13.

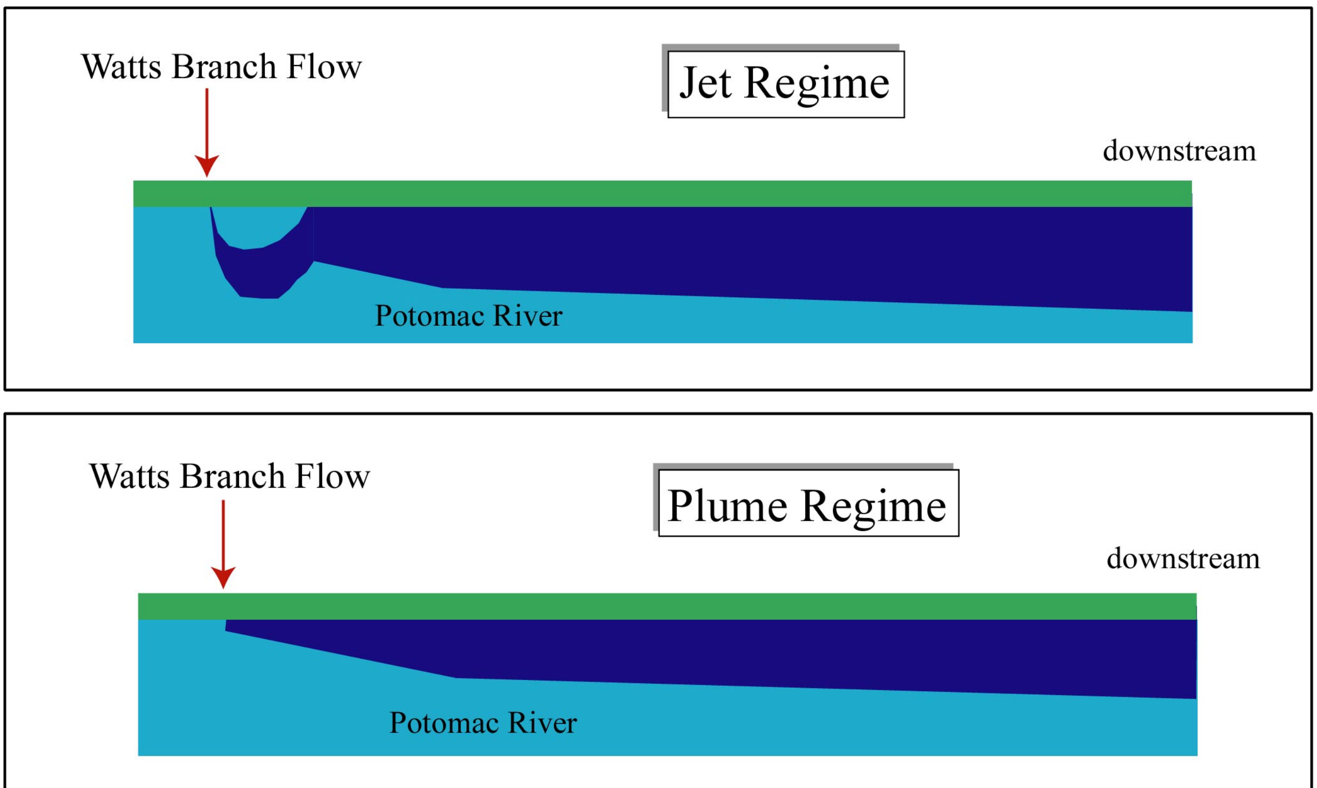


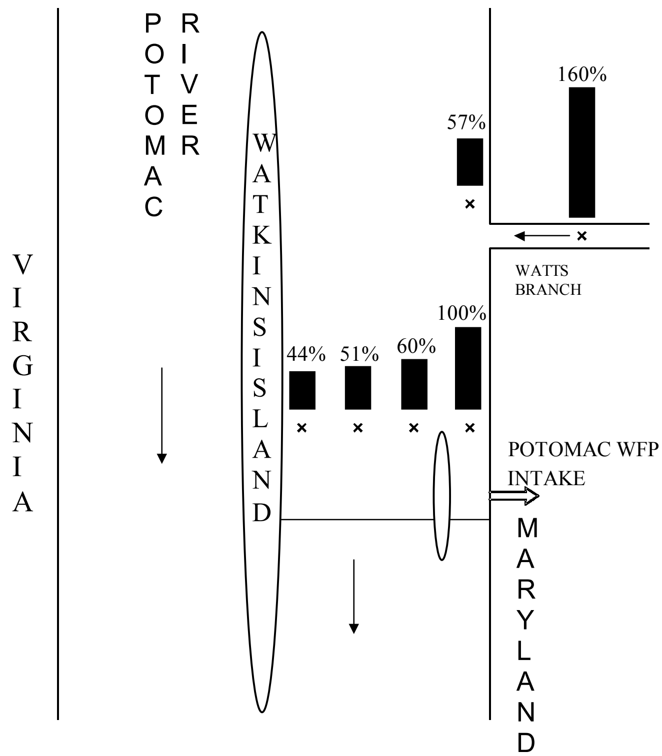
Figure 13 – Mixing Zone Model of Watts Branch Flow

A screening level spreadsheet approach was taken to further assess the benefits of relocating the WSSC intake to the potential submerged channel location and the relative potential for contamination from Seneca Creek. The Seneca Creek watershed is larger than either the Muddy Branch or Watts Branch watershed, and more than 50% of the time, flow from Seneca Creek makes up 2% to 5% of the flow in the Potomac River north of Watkins Island. There is also a significant amount of time (greater than 10%) where Seneca Creek flow makes up 10 to 25% of the total Potomac River flow on the Maryland (North) side of Watkins Island. Assuming conservative contaminants and complete mixing of Seneca Creek with the Potomac River in the five miles between the confluence and the Potomac WFP intake, the impact of Seneca Creek on intake water quality may be similar at the current shore intake and the potential mid-channel intake. These assumptions are not unreasonable given the distance between Seneca Creek and the intake and the substantial flow from Seneca Creek.

In 1999 and 2000, WSSC collected water quality from the Watts Branch, the Potomac River upstream of Watts Branch, the section of the Potomac beyond Unnamed Island, and the intake. Samples were collected during base-flow (non-storm) and storm events. Figure 14 presents turbidity data for the 18 storm events. The turbidity data has been and normalized with intake turbidity assigned a value of 100%. Turbidity at the other sample points are presented as a percentage of the intake channel turbidity.

Figure 14 - POTOMAC RIVER TURBIDITY

COMPOSITE OF 18 STORM



The sampling and modeling results independently confirm operator experience and indicates that Watts Branch does have an inordinate impact on the present WSSC intake during storm events. Conclusions that can be drawn from the two-dimensional hydrodynamic modeling and the sampling data evaluations include:

- The Potomac WFP experiences significant operational problems that are related to the impact of Watts Branch during storm events,
- Both the two-dimensional hydrodynamic modeling results and WSSC's field sampling results indicate that Watts Branch has a sudden and significant negative impact on water quality at the Potomac WFP's current shore intake,

- Both the two-dimensional hydrodynamic modeling results and field sampling results indicate that Watts Branch impacts do not extend beyond the "intake island" approximately 100 feet off of the Maryland bank. This modeling and field data suggest that relocating the intake beyond the intake island can eliminate the plant operational problems associated with Watts Branch,
- The computer simulation modeling results indicate somewhat less of an impact of Watts Branch at the current Potomac WFP intake (i.e., more dilution) than indicated by field sampling results. This may be an indication of limitations of the modeling or due to the fact that the model is based on daily average flows and not the shorter duration (less than 24 hours) events, which are associated with the flashy Watts Branch.

7.3.3.3 - Impact of Seneca Creek

To better assess the relocation of the intake to the potential submerged channel location, more effort to define the impact of Seneca Creek would be useful. Data collection would be a key component of more thorough assessment of this submerged channel location. If deemed necessary, sampling of TSS values on Seneca Creek could be taken along with measurements above Seneca Creek on the Potomac River.

More detailed modeling and a more complete TSS dataset would allow for a more rigorous assessment of intake relocation issues, but it is clear that any impact of Seneca Creek on the submerged channel intake location will be very small compared to the current impact of Watts Branch on the existing intake. Because of the many local islands and other factors, the Potomac River has extremely complex hydraulic characteristics in the vicinity of the WSSC intake and this more rigorous assessment would be a significant modeling challenge. Advancing from the application of simple models to a more complex model would also require a substantial data collection effort including detailed bathymetric data. The river bed in this area is known to include many large boulders and many cross sections may be required to well characterize the river bed in this area.

7.4 Model Results by Contaminant Groups

The modeling results were also organized by contaminant group and are presented in this format below.

7.4.1 - Susceptibility to Group 1 Contaminants of Concern

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 soon after their reduction due to the relatively short survival time of pathogens in the environment.

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

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

The only contaminant in Group 1 which was explicitly modeled under the modeling approach was sediment/turbidity. The modeling results indicated the following regarding sediment:

- For the watershed above Watts Branch:
  - The future "no management" scenario predicts small increases in sediment concentrations, whereas under the "aggressive" scenario, predicted solids peaks are actually *reduced* by 4% from current peaks.
  - The predicted changes are the net result of management practices in upstream subwatersheds and in-stream processes. Because solids are stored in the Potomac streambed, little change in sediment concentrations was noted under any scenario. It is important to note that the Center for Watershed Protection's Watershed Treatment Model predicts significant sediment "edge-of-stream" load reductions

for some subwatersheds with “aggressive” implementation of management practices. Even though these reductions translate into only modest reductions at the Potomac Plant intake, they could be significant for local water quality improvements as well as other Potomac water plants upstream, further supporting the recommendations.

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

- For the Watts Branch watershed:
    - The results of the detailed evaluations indicate the following predicted outcomes of simulated future and management scenarios:
        - Predicted year 2020 TSS loading is reduced by 4% from current loads with no change in management practices, due to the reduction in active construction.
        - Moderate management will reduce predicted solids loading by 7% of current loads.
        - Aggressive implementation of management practices reduces predicted future solids loadings by 15% of current loads.

7.4.2 - Susceptibility to Group 2 Contaminants of Concern

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

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

- The results of the detailed evaluations indicate the following predicted outcomes of simulated future and management scenarios:
  - Predicted nitrogen and phosphorus loads to the Watts Branch increase by 6% and 2% of current loads, respectively, by 2020 if management practices are not modified.
  - Moderate management practices will limit the predicted increase in future nitrogen loads to 5% of current loads with no predicted increase in future phosphorus loads from current levels.
  - Aggressive implementation of management practices will actually *reduce* predicted future nitrogen loads by 1% from current loads and predicted future phosphorus loads by 9% from current loads.

7.4.3 - Susceptibility to Group 3 and 4 Contaminants of Concern

None of the Group 3 or 4 contaminants were modeled explicitly due to limitations of the models and the uncertain nature of the taste and odor producing compounds identified in the untreated water. Water quality monitoring indicates episodic occurrences of taste and odor causing compounds in the untreated water, but no corresponding problems with the treated water. Because WSSC customers do not register taste and odor complaints during these events, it is thought that these compounds are removed in the treatment process. However, WSSC does receive occasional complaints, which reportedly correlate with high levels of ammonia (rather than taste and odor causing compounds) in the raw water. (Note: while ammonia is generally modeled as part of the nitrogen cycle, the ammonia peaks observed in the raw water are attributed to storm runoff containing ammonia.) Based on plant operating experience, the taste and odor producing compounds present in the raw water seem to be removed efficiently in the

Potomac plant, and therefore further analysis of this contaminant of concern was not conducted. The reported occasional taste and odor problems appear to be due to winter ammonia peaks, which can react with chlorine to form offensive chloramine compounds. Also, as indicated previously, dieldrin has not been manufactured for several decades and levels are eventually expected to decrease throughout the watershed.

7.4.4 - Influence of Local Tributaries on the Potomac WFP

As described previously, a modeling and historical data evaluation was conducted to assess the impacts of two local tributaries, Watts Branch and Seneca Creek, on the water quality at the existing Potomac WFP intake and a potential submerged channel intake. The key findings of this modeling were:

- Existing Intake - In virtually all of the flow scenarios anticipated, the impact of Watts Branch on sediment concentrations at the existing intake is significant and is more severe than would be expected under complete mixing of the Potomac River and Watts Branch flows. This occurs because the Watts Branch flow stays adjacent to the Maryland bank of the Potomac River. This result is supported by two-dimensional modeling, evaluation of river sampling data, and operator experience.
- Potential Submerged Channel Intake Upgrade - Another important finding is that, under all modeled flow conditions, the main body of the simulated plume or jet from Watts Branch does not extend beyond the unnamed island approximately 100 to 150 feet from the Maryland bank of the Potomac.
- From the analysis and evaluation of river sampling data, it can be concluded that Watts Branch significantly impacts the current intake

location but would not impact an intake located beyond the unnamed island. Thus, an additional submerged channel intake structure would provide flexibility to avoid Watts Branch impacts and to obtain better raw water quality at the Potomac Plant.

- Assuming conservative contaminants and complete mixing of Seneca Creek with the Potomac River in the five miles between the Seneca/Potomac confluence and the Potomac Plant intake, the impact of Seneca Creek on intake water quality may be similar at the current withdrawal point and the potential mid-channel withdrawal point of a submerged channel intake.

7.5 - Spill Source Evaluations

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

SECTION 8 – KEY FINDINGS AND RECOMMENDATIONS FOR SOURCE WATER PROTECTION PLAN

8.1 - Key Findings

8.1.1 – General Findings

General findings of the Potomac SWA include:

- The dynamic nature of the Potomac River's water quality at the existing intake as well as its potential for DBP formation in the very long WSSC distribution system are major challenges to providing safe drinking water and need to be better understood and managed.
- The watershed is primarily forested (60%) with significant agricultural (35%) and some urban (4%) land uses. Current local urban and upstream agricultural land uses appear to negatively impact the source water quality for the Potomac WFP.
- 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, ammonia, sediment/turbidity, algae, fecal coliforms, and dieldrin. Rapid changes in water quality are also a concern.
- While evaluation of the specific impacts of particular sources of the contaminants of concern on the WSSC intake was not feasible, modeling was used to predict the overall impact of management practices on source water quality. Future conditions are expected to show a small deterioration in source water quality at the Potomac WFP 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 in the short term. 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 controlling phosphorus and algae at the intake in the long-term.

- Watts Branch causes sudden negative changes in raw water quality and treatability at the Potomac WFP intake. Negative changes are characterized by sudden and extreme increases in suspended solids, fecal coliforms(and likely other fecal contaminants such as *Cryptosporidium* oocysts and *Giardia* cysts), and other contaminants that run off of urban and peri-urban areas as well as decreases in pH and alkalinity. These impacts are out of proportion with the upper watershed impacts relative to watershed size. A submerged channel intake (at a mid-channel location) would allow the Potomac WFP to effectively avoid these impacts.
- The Potomac WFP is vulnerable to spills from a variety of sources in the watershed.

8.1.2 – Findings for Specific Contaminant Groups

The modeling approach was utilized to analyze the susceptibility of the Potomac WFP water supply to contamination from the identified contaminants of concern. The results of the modeling are discussed below and organized by contaminant group. Also, a discussion of the modeling results specifically focused on the influence of Watts Branch and Seneca Creek on the intake water quality is presented. 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.

8.1.2.1 - 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 immediate benefits due to limitations concerning the survival time of pathogens in the environment.

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

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

The only contaminant in Group 1 which was explicitly modeled under the modeling approach was sediment/turbidity. The modeling results indicated the following regarding sediment:

- *For the watershed above Watts Branch*:
    - The future "no management" scenario predicts small increases in sediment concentrations, whereas under the "aggressive" scenario, predicted solids peaks are actually *reduced* by 4% from current peaks.
    - The predicted changes are the net result of management practices in upstream subwatersheds and in-stream processes. Because solids are stored in the Potomac

streambed, little change in sediment concentrations was noted under any scenario. It is important to note that the Center for Watershed Protection's Watershed Treatment Model predicts significant sediment "edge-of-stream" load reductions for some subwatersheds with "aggressive" implementation of management practices. Even though these reductions translate into only modest reductions at the Potomac Plant intake, they could be significant for local water quality improvements as well as other Potomac water plants upstream, further supporting the recommendations.

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

- *For the Watts Branch watershed:*
    - The results of the detailed evaluations indicate the following predicted outcomes of simulated future and management scenarios:
        - Predicted year 2020 TSS loading from Watts Branch is reduced by 4% from current loads with no change in management practices, due to the reduction in active construction.
        - Moderate management will reduce predicted Watts Branch solids loading by 7% of current loads.
        - Aggressive implementation of management practices reduces predicted future Watts Branch solids loadings by 15% of current loads.

8.1.2.2 - 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. The modeling results yielded similar findings as the Group 1 contaminants, including:

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

predicts that phosphorus and chlorophyll-a peaks are reduced only negligibly at the intake.

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

- *For the Watts Branch watershed:*
  - The results of the detailed evaluations indicate the following predicted outcomes of simulated future and management scenarios:
    - Predicted nitrogen and phosphorus loads to the Watts Branch increase by 6% and 2% of current loads, respectively, by 2020 if management practices are not modified.
    - Moderate management practices will limit the predicted increase in future nitrogen loads to 5% of current loads with no predicted increase in future phosphorus loads from current levels.
    - Aggressive implementation of management practices will actually *reduce* predicted future nitrogen loads by 1% from current loads and predicted future phosphorus loads by 9% from current loads.

8.1.2.3 - Susceptibility to Group 3 and 4 Contaminants of Concern (taste and odor producing compounds, ammonia, and dieldrin)

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. (note: while ammonia is generally modeled as part of the nitrogen cycle, the ammonia peaks observed in the raw water generally occur during winter). Taste and odor causing compounds (with the exception of ammonia as described above) would generally be a concern during summer months when algal blooms occur in stagnant areas of the Potomac River. Dieldrin is generally associated with sediment particles and would be expected to reach the Potomac WFP intake during storm events. Based on plant operating experience, the taste and odor producing compounds present in the raw water seem to be removed efficiently in the Potomac plant, and therefore further analysis of this contaminant of concern was not conducted. The reported occasional taste and odor problems appear to be due to winter ammonia peaks, which can react with chlorine to form offensive chloramine compounds. Also, as indicated previously, dieldrin has not been manufactured for several decades and levels are eventually expected to decrease throughout the watershed.

8.1.3 - Influence of Local Tributaries on the Potomac WFP Existing and Potential Intake Water Quality

As described previously, a modeling and historical data evaluation was conducted to assess the impacts of two local tributaries, Watts Branch and Seneca Creek, on the water quality at the existing Potomac WFP intake and a potential submerged channel intake. The key findings of this modeling were:

- Existing Intake - In virtually all of the flow scenarios anticipated, the impact of Watts Branch on sediment concentrations at the existing intake is significant and is more severe than would be expected under complete mixing of the Potomac River and Watts Branch flows. This occurs because the Watts Branch flow stays adjacent to the Maryland bank of the Potomac River. This result is supported by two-dimensional modeling, evaluation of river sampling data, and operator experience.
- Potential Submerged Channel Intake Upgrade - Another important finding is that, under all modeled flow conditions, the main body of the simulated plume or jet from

Watts Branch does not extend beyond the unnamed island approximately 100 to 150 feet from the Maryland bank of the Potomac.

- From the analysis and evaluation of river sampling data, it can be concluded that Watts Branch significantly impacts the current intake location but would not impact an intake located beyond the unnamed island. Thus, a submerged channel intake structure would provide flexibility to avoid Watts Branch impacts and to obtain better raw water quality at the Potomac Plant.

Assuming conservative contaminants and complete mixing of Seneca Creek with the Potomac River in the five miles between the Seneca/Potomac confluence and the Potomac Plant intake, the impact of Seneca Creek on intake water quality may be similar at the current withdrawal point and the potential mid-channel withdrawal point of a submerged channel intake. Although Seneca Creek is significantly further upstream of the intake (relative to Watts Branch) it has a much larger flow than Watts and may have a significant impact on raw water quality in the future, regardless of intake location. In order to assure safe water, opportunities to protect the Seneca Creek watershed should be maximized. The past activities in Watts Branch, which have lead to the current treatment challenges, should be controlled to the extent feasible in the Seneca Creek Watershed.

8.2 - 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 WSSC's mission. For example, management practices which may not seem cost effective when considering only the impacts on the Potomac WFP 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.
- Montgomery County's implementation of watershed planning (including a study to identify priority stream restoration and stormwater management projects to improve both habitat and water quality of the Watts Branch watershed), transfer of development rights, storm water management, watershed education, storm water retrofits and management plans.
- City of Rockville implementation of a Watts Branch Watershed plan.
- Floodplain preservation in Maryland
- Chesapeake Resource Protection Areas in Virginia which limit 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 (i.e. 303d or TMDL) process.

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

8.3 – Recommendations

8.3.1 – General Recommendations

General recommendations of the Potomac WFP SWA include:

- A watershed protection group representing all 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.
- Serious consideration should be given to an upgraded intake structure with flexibility to withdraw water from a submerged midchannel location.
- 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;
    - tracking the progress and implementation of the Watts Branch Watershed Studies that are being conducted by the Montgomery County Department of Environmental Protection, and the City of Rockville;
    - aggressive involvement in upstream 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. In the Watts Branch basin, it is prudent to consider support of ongoing enhancement of management practices in highly developed areas to reduce solids and possibly fecal contaminants. These have more promise for solids reduction than those in the upper watershed; however raw water quality improvements are not to be expected immediately.
- 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

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 19. As *Cryptosporidium* in raw water poses a threat, appropriate fecal contamination management practices are recommended and should be implemented to improve public health protection. While these recommendations related to fecal contamination are justified, detailed evaluation of fecal contamination sources was not conducted in this project but is needed to identify the most significant sources of fecal contamination to target.

These management practices are recommended for consideration as a starting point for development of a source water protection program. This program should integrate management practices that are directly related to the contaminants of concern and the Potomac WFP source water quality (the more immediate concern) with those that relate to broader water quality issues, which are important for improved potable water supply and public health protection in the long term.

8.3.2 – Management Practices Recommended for Groups of Contaminants

The management practices that may have the most significant impacts on the levels of contaminants of concern at the intake are those focused on limiting pathogens, nutrients, and rapid changes in water quality. The specific management practices recommended to address the different groups of contaminants of concern include:

8.3.2.1 - Group 1 Contaminants

Source water control of C*ryptosporidium*, G*iardia* and fecal coliforms depends on management of fecal contamination sources. Recommended practices include:

- in agricultural areas - tree planting, buffer strips, grazing land protection, stream fencing and animal waste management;

TABLE 19. MANAGEMENT PRACTICES RECOMMENDED FOR CONSIDERATION		
AGRICULTURAL PRACTICES		
Practice	**Applied To**	**For Control of**
Conservation Tillage	Cropland	NOM, DBPs, Algae, Sediment, Dieldrin
Nutrient Management	Cropland, Hay land	NOM, DBPs, Algae, Sediment
Water Quality Plan	Cropland, Hay land, Pasture	NOM, DBPs, Algae, Sediment, Dieldrin
Cover Crop	Cropland	NOM, DBPs, Algae, Sediment, Dieldrin
Tree Planting	Cropland, Hay land, Pasture	NOM, DBPs, Algae, Fecal Coliforms, *Cryptosporidium*, *Giardia*, Sediment, Dieldrin
Buffer	Cropland, Hay land	NOM, DBPs, Algae, Fecal Coliforms, *Cryptosporidium*, *Giardia*, Sediment, Dieldrin
Highly Erodible Land Retirement	Cropland, Hay land	NOM, DBPs, Algae, Sediment, Dieldrin
Grazing Land Protection	Pasture	NOM, DBPs, Algae, Fecal Coliforms, *Cryptosporidium*, *Giardia*, Sediment, Dieldrin
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, Dieldrin, Ammonia
Erosion and Sediment Control	Active Construction	NOM, DBPs, Algae, Fecal Coliforms, *Cryptosporidium*, *Giardia*, Sediment, Dieldrin
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, Dieldrin, Ammonia
Impervious Cover Disconnection	Commercial and Residential Roofs	Sediment, Dieldrin
Riparian Buffers	All Urban Land	NOM, DBPs, Algae, Fecal Coliforms, *Cryptosporidium*, *Giardia*, Sediment, Dieldrin, Ammonia

- in urban areas - CSO/SSO control, wastewater filtration, structural treatment practices, erosion and sediment control, pet waste education, and riparian buffers.

Recommended practices for sediment control include:

- in agricultural areas - conservation tillage, nutrient management, water quality planning, cover crops, tree planting, buffer strips, highly erodible land retirement, grazing land protection, and stream fencing;
- in urban areas - structural treatment practices, erosion and sediment control, lawn care education, street sweeping, impervious cover disconnection, and riparian buffers.

8.3.2.2 - Group 2 Contaminants of Concern

Source water control of natural organic matter and disinfection by-product precursors depends on management of phosphorus and terrestrial sources of natural organic matter. Control of algae also depends on phosphorus control. Recommended practices for control of these contaminants are described later and include:

- in agricultural areas - conservation tillage, nutrient management, water quality planning, cover crops, tree planting, buffer strips, highly erodible land retirement, grazing land protection, and animal waste management;
- in urban areas - structural treatment practices, erosion and sediment control, lawn care education, pet waste education, and riparian buffers.

8.3.2.3 - Group 3 and 4 Contaminants of Concern

Because ammonia appears to be related to winter storm runoff, control of ammonia likely depends on deicing practices and runoff management practices. A survey of deicing practices (including sales and distribution of compounds including significant ammonia levels) should be performed and, if deemed appropriate based on this survey, a public education program to modify these practices should be considered.

Because dieldrin has been banned from manufacturing for many years, the only effective short-term control in the water depends on the management practices listed previously for erosion and flow conditions in the Potomac and its tributaries to reduce transport of sediment.

8.4 - Potential Water Quality Impacts 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 WSSC's Potomac WFP 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,
- improved protection from pathogens including *Cryptosporidium* and *Giardia,*
- reducing the number and severity of taste and odor episodes which occur in the WSSC system, and
- reducing ammonia levels and chlorine demand in the raw water.

8.5 - Potential Benefits to the Potomac WFP

The primary improvement that source water protection management activities would accomplish would be the provision of an additional barrier in the protection of the health of the WSSC's customers. Environmental improvements would also be achieved through improved watershed management. The following improvements relevant to the Potomac WFP can also be expected:

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

8.6 - Planning Level Cost Information

WSSC staff report that constructing a submerged midchannel intake structure has recently been estimated (as part of WSSC's Potomac WFP Water Quality/Reliability Study) to cost approximately $15 million. As described above, this would likely provide

WSSC sufficient flexibility to avoid the detrimental impacts of Watts Branch during storm events. This approach effectively changes the drainage area for the intake when staff withdraw from the midchannel intake, and provides immediate intake water quality enhancement and meaningful return on funding provided by the WSSC rate payers. However, it does not otherwise provide watershed protection in its strictest terms. In other words, this would have no beneficial impacts on the Watts Branch. Implementation of the aggressive management program in the entire Watts Branch watershed would not dramatically alleviate the impacts on the WFP, but would improve the quality and environment of the stream. Any benefits to the intake water quality from aggressive management in Watts Branch will occur after many years and not in the immediate future. It is important to bear these differences in mind when comparing the costs of these options. The cost of implementing the aggressive management program in the Watts Branch watershed over the next 11 years is approximately $6 million to $8 million dollars.

Appendix F 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.

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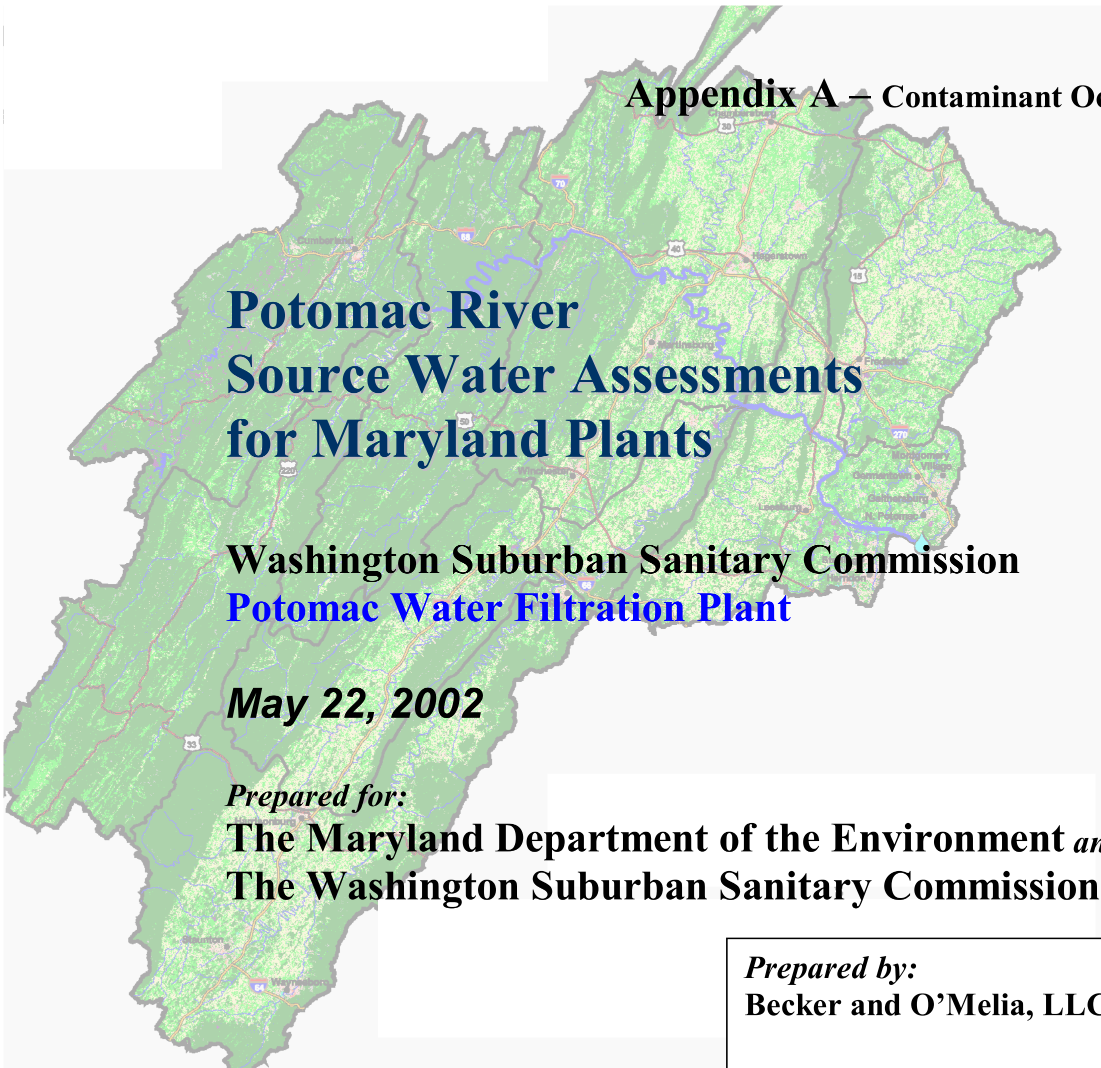

Appendix A – Contaminant Occurrence

Potomac River Source Water Assessments for Maryland Plants

Washington Suburban Sanitary Commission
Potomac Water Filtration Plant

May 22, 2002

Prepared for:
The Maryland Department of the Environment *and*
The Washington Suburban Sanitary Commission

Prepared by:
Becker and O'Melia, LLC

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

Technical Memo

To: John Grace

From: John O'Melia, P.E. (B&O'M); and Plato Chen (WSSC)

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

Date: 5/2/05

Re: Potomac River Source Water Assessments for Maryland Plants - Task 3a Contaminant Inventory

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Becker and O'Melia, LLC (B&O'M) has performed evaluations to identify contaminants and groups of contaminants that will be the focus of the watershed assessment for the WSSC's Potomac WFP. These evaluations included the following activities, which are described below:

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

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

- Organic carbon (TOC, DOC, color, UV-254)
- *Giardia*
- *Cryptosporidium*
- Tastes and odors
- Sediment (turbidity, TSS)
- Algae
- HAAs and THMs (these will be examined using organic carbon (TOC) as a surrogate for precursors)
- Ammonia

- Fecal Coliforms
- Dieldrin

Identification of potential contaminants of concern

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

Contaminants that have a negative impact on plant operations and raw water treatability were considered for evaluation. Organic carbon (TOC or DOC) was included because it can have a controlling impact on coagulation and because it is an indicator of disinfection by-product precursors. Sediment (measured as turbidity or TSS) was included because of the cost and operational difficulties of removing and disposing of sediment. Contaminants that threaten the natural equilibrium and long-term sustainability of the Potomac River were also identified. Phosphorus, the limiting nutrient in the Potomac River, 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 evaluated. WSSC, MDE, and B&O'M collected readily available data for the list of potential contaminants of concern in Appendix A.

Data collection, organization and evaluation

Monitoring data from WSSC's MOST System and Laboratory Information System (LIMS) were collected and evaluated. These datasets include data from 1985 to 1999. For identified potential contaminants of concern that were not included in these WSSC databases, data provided by MDE were evaluated. Finally, data collected under the Information Collection Rule were accessed via EPA databases.

These datasets were compiled into several databases including an inorganic contaminant database (comprised of data from Most Report 1) an organic contaminant database (comprised of data from Most reports 15 and 27 and LIMS) and an ICR contaminant database (comprised of data from MDE and EPA). Queries were executed for each parameter to create a table of all measurements of the parameter. These data tables were exported into spreadsheets for further evaluations.

After data were collected and compiled, several parameters were removed from consideration including:

- Acrylamide and Epichlorohydrin are regulated because they are present in some polymers used in drinking water treatment. Finished water concentrations of these chemicals are controlled by testing polymers and taking care to see that polymers dosages are maintained below that which may violate the MCL. WSSC staff report that no polymers are used in treatment at the Potomac WFP. Acrylamide and Epichlorohydrin are therefore not expected in raw water, not a watershed issue, and not contaminants of concern for the project.

- Fluoride is a regulated chemical which is added to drinking water to promote strong teeth. No raw water fluoride concentration data are available at Potomac WFP, but WSSC reports that fluoride is constantly added and that no finished water concentrations have exceeded the MCL of 4 mg/L. Fluoride is therefore not considered a contaminant of concern.

- No raw water Radium 226 or Radium 228 data are available because MDE has provided WSSC with a waiver of the monitoring requirement for these chemicals. These radionuclides will therefore not be considered contaminants of concern.

- Chlorite is a concern at treatment plants that use chlorine dioxide for disinfection and it is a byproduct of chlorine dioxide production. WSSC does not use chlorine dioxide. Where chlorite is an issue, its presence in the raw water is not relevant to the potential problem. Chlorite will therefore not be considered a contaminant of concern.

- Bromide forms disinfection byproducts, including Bromate, when ozonated. Tap water Bromate concentrations are therefore a concern when ozonation is employed, (note that WSSC does not use ozone). When tap water Bromate is a concern, the raw water Bromide concentration is a concern, but Bromate is not expected in the raw water. Bromate will therefore not be considered a contaminant of concern.

- Acanthamoeba and Sodium are listed for "Regulatory Determination" on EPA's May 2000 Contaminant Candidate List. This listing is one of the steps in establishing a regulation (or MCL) for a contaminant. If these potential contaminants are regulated in the future, there will likely be monitoring requirements associated with these regulations. However, no monitoring is required at this time and the project team's search for data on these contaminants did not yield any such data. These potential contaminants will not be considered contaminants of concern.

The results of the data evaluations are presented in tables 1 through 5.

Table 1 presents the results of evaluations for contaminants with enforceable standards (Maximum Contaminant Levels) including organic chemicals, inorganic chemicals, and radionuclides. 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). None of the contaminants listed in Table 1 meets this criterion and none are to be considered contaminants of concern for the project.

The data include several of the contaminants indicating raw water at concentrations greater than the MCL. As shown below, in each case the tap water sample taken the same day indicated a concentration of this contaminant well below the MCL (except the 1,1,2-trichloroethene sample which did not have a corresponding tap sample; however, this one sample result appears to be an outlier because 1,1,2-trichloroethene was frequently observed in the raw water samples but always at concentrations several orders of magnitude lower).

Contaminant	Raw Conc.	Tap Conc. (*)	MCL
Dichloromethane	5.4	0.45 (μg/l)	5
Nitrite	2000	ND	1000
1,1,2-Trichloroethane	10.4	not sampled	5

(*) ND = not detected

Table 1 – Contaminants with Enforceable Standards

Contaminant	No. Data-points	No. zero or ND	Min	Max	10% exceedance	Units (μg/L)	MCL (μg/L)	50% MCL (μg/L)	Exceeds 50/10 rule?
Inorganic Chemicals									
Antimony	14	14	0	0	0		6	3	**No**
Arsenic	670	670	0	0	0		50	25	**No**
Asbestos (fibers >10 micrometers)	8	8	0	0	0	MFL	7 MFL	3.5 MFL	**No**
Barium	695	695	0	0	0		2,000	1,000	**No**
Beryllium	261	261	0	0	0		4	2	**No**
Cadmium	674	674	0	0	0		5	2.5	**No**
Chromium (total)	708	708	0	0	0		10	5	**No**
Copper	703	702	0	1	0		Act. Lev. – 1,300	650	**No**
Cyanide (as free cyanide)	35	35	0	0	0		200	100	**No**
Inorganic Mercury	651	651	0	0	0		2	1	**No**
Lead	689	689	0	0	0		Act. Lev. – 15	7.5	**No**
Nitrate	540	15	0	5,000	3,000		10,000	5,000	**No**
Nitrite	531	528	0	2,000	0		1,000	500	**No**
Selenium	656	656	0	0	0		50	25	**No**
Thallium	262	262	0	0	0		2	1	**No**
Organic Chemicals									
Alachlor	42	41	0	0.12	0		2	1	**No**
Atrazine	40	33	0	0.4	0.2		3	1.5	**No**
Benzene	56	54	0	0.11	0		5	2.5	**No**

Table 1 – Contaminants with Enforceable Standards									
Contaminant	**No. Data-points**	**No. zero or ND**	**Min**	**Max**	**10% exceed ance**	**Units (µg/L)**	**MCL (µg/L)**	**50% MCL (µg/L)**	**Exceeds 50/10 rule?**
Benzo(a)pyrene	39	39	0	0	0		0.2	0. 1	**No**
Carbofuran	17	17	0	0	0		40	20	**No**
Carbon tetrachloride	57	56	0	0.21	0		5	2.5	**No**
Chlordane	22	22	0	0	0		2	1	**No**
Chlorobenzene	56	55	0	0.1	0		100	50	**No**
2,4-D	20	19	0	0.15	0		70	35	**No**
Dalapon	12	12	0	0	0		200	100	**No**
1,2-Dibromochloropropane (DBCP)	19	19	0	0	0		0.2	0. 1	**No**
o-Dichlorobenzene	57	53	0	0.21	0		600	300	**No**
p-Dichlorobenzene	59	52	0	0.26.	0.1		75	37.5	**No**
1,2-Dichloroethane	56	54	0	0.1	0		5	2.5	**No**
1-1-Dichloroethylene	56	55	0	0.1	0		7	3.5	**No**
1, 2-Dichloroethylene - *(cis)*	56	56	0	0	0		70	35	**No**
1, 2-Dichloroethylene - *(trans)*	57	55	0	0.18	0		100	50	**No**
Dichloromethane	68	45	0	5.4	0.6		5	2.5	**No**
1-2-Dichloropropane	56	54	0	0.08	0		5	2.5	**No**
Di(2-ethylhexyl)adipate	39	35	0	0.78	0.08		400	200	**No**
Di(2-ethylhexyl)phthalate	40	26	0	5.11	0.96		6	3	**No**
Dinoseb	12	12	0	0	0		7	3.5	**No**
Dioxin (2,3,7,8-TCDD)	12	12	0	0	0		0. 00003	0.000015	**No**
Diquat	20	20	0	0	0		20	10	**No**
Endothall	11	11	0	0	0		100	50	**No**
Endrin	14	14	0	0	0		2	1	**No**
Ethylbenzene	59	55	0	0.2	0		700	350	**No**
Ethylene dibromide	7	7	0	0	0		0. 05	0. 025	**No**
Glyphosate	12	12	0	0	0		700	350	**No**
Heptachlor	16	16	0	0	0		0.4	0. 2	**No**
Heptachlor epoxide	24	24	0	0	0		0. 2	0. 1	**No**
Hexachlorobenzene	29	29	0	0	0		1	0. 5	**No**
Hexachlorocyclopentadiene	32	32	0	0	0		50	25	**No**
Lindane	12	12	0	0	0		0. 2	0. 1	**No**

Table 1 – Contaminants with Enforceable Standards									
Contaminant	**No. Data-points**	**No. zero or ND**	**Min**	**Max**	**10% exceed ance**	**Units (μg/L)**	**MCL (μg/L)**	**50% MCL (μg/L)**	**Exceeds 50/10 rule?**
Methoxychlor	19	19	0	0	0		40	20	**No**
Oxamyl (Vydate)	39	39	0	0	0		200	100	**No**
Polychlorinated biphenyls (PCBs)	17	17	0	0	0		0. 5	0. 25	**No**
Pentachlorophenol	4	4	0	0	0		1	0. 5	**No**
Picloram	12	12	0	0	0		500	250	**No**
Simazine	38	32	0	0.3	0.1		4	2	**No**
Styrene	56	56	0	0	0		100	50	**No**
Tetrachloroethylene	56	55	0	0.06	0		5	2.5	**No**
Toluene	64	49	0	0.31	0.14		1,000	500	**No**
Toxaphene	25	25	0	0	0		30	15	**No**
2,4,5-TP (Silvex)	15	15	0	0	0		50	25	**No**
1,2,4-Trichlorobenzene	56	47	0	0.2	0.09		70	35	**No**
1,1,1-Trichloroethane	58	55	0	0.6	0		200	100	**No**
1,1,2-Trichloroethane	58	54	0	10.49	0		5	2.5	**No**
Trichloroethylene	57	55	0	0.17	0		5	2.5	**No**
Vinyl chloride	57	55	0	0.12	0		2	1	**No**
Xylenes (total) (*)	74	68	0	0.2	0		10,000	5,000	**No**
(*) 115 para and meta samples. 11 ND ortho samples									
Radionuclides									
Beta particles and photon emitters	6	0	2	5	5	pCi/L	50 pCi/L	25 pCi/L	**No**
Gross alpha particle activity	7	4(*)	-2	3.3	3.3	pCi/L	15 pCi/L	7.5 pCi/L	**No**
(*) 4 readings <0 pCi/L									

Table 2 presents the occurrences of contaminants for which EPA has issued health advisories. For these contaminants, the health advisory that correlates to the lowest drinking water concentration was used to establish the criterion for selection as contaminants of concern. 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. 9 of these 10 contaminants have 10% exceedance values which are less that 50% of the health advisory and are not to be considered contaminants of concern for the project.

Data collected included 34 Dieldrin measurements, 31 of which are reported as 0 or non-detects. The 10% exceedance value is 0.0001 mg/L, which is less than the health advisory of 0.0002 (representing a 1 in 10,000 cancer risk) but equal to 50% of the HA. Dieldrin ($C_8H_8Cl_6O$) is a by-product of Aldrin (organisms convert Aldrin to Dieldrin) and a pesticide historically used on cotton, corn and citrus crops, and used for termite, mosquito and locust control. Dieldrin is carcinogenic to mice. Most uses were banned in the mid-1980s and it is no longer produced in the US. Dieldrin has an Octanol-Water Partition Coefficient (at 25°C) of $10^{5.48}$ (mol / L Octanol per mol / L water) and is persistent in soil. It has solubility in water of 2 mg/l. Although any Dieldrin in the raw water is most likely adsorbed to particles and removed in the treatment process, Dieldrin is considered a contaminant of concern for the project.

Table 2 – Contaminants with Health Advisories									
Contaminant	**No. Data Points**	**No. Zero or ND**	**Min**	**Max**	**10% exceed-ance**	**Health Advis. (*) (υg/L)**	**Type of HA**	**50% HA (υg/L)**	**Exceeds 50/10 rule?**
1,3-Dichloropropene	7	7	0	0	0				
Aldrin	29	28	0	0.1	0	0. 3	10 day/ 10kg	0. 15	No
Boron	632	632	0	0	0	600	lifetime	300	No
Dieldrin	34	31	0	0.19	0.1	0. 2	1/10000	0. 1	Yes
Hexachlorobutadiene	56	32	0	0.21	0.12	1	lifetime	0. 5	No
Metolachlor	33	28	0	0.3	0.1	100	lifetime	50	No
Metribuzin	32	32	0	0	0	200	lifetime	100	No
Naphthalene	57	52	0	0.17	0.06	100	lifetime	50	No
Silver	707	707	0	0	0	100	lifetime	50	No
Zinc	712	711	0	1	0	2,000	lifetime	1,000	No

(*) *the most restrictive (lowest concentration) HA has been selected in each case.*
Lifetime – the concentration of chemical in drinking water that is not expected to cause any adverse noncarcinogenic effects for a lifetime of exposure
10 day/kg – the concentration of chemical in drinking water that is not expected to cause any adverse noncarcinogenic effects for up to 10 days exposure in a 10 kg child.
1,10,000 cancer – the concentration of chemical in drinking water corresponding to an estimated lifetime cancer risk of 1 in 10,000.

Table 3 presents the results of evaluations for contaminants which affect WFP operations. Episodes of high pH and significant diurnal variations in pH have caused coagulation difficulties at the WFP in the past. An acid feed system has recently been installed at the plant to assist with these episodes. The coagulant selection has been changed recently and plant staff reports that the coagulation process is no longer sensitive to these pH variations. Although WSSC continues to carefully monitor raw water pH for significant changes, particularly during storm events, on the basis of the plant upgrades and recent experience of the operations staff, raw water pH will not be considered an issue of concern for this project.

WSSC staff have reported significant chlorine demand exerted by ammonia in the raw water. Consistent with WSSC experience, the data indicate episodes of elevated ammonia concentrations in the raw water. These elevated ammonia concentrations exert a significant chlorine demand and cause taste and odor episodes. Algae, TOC and turbidity measurements suggest that high levels of each of these contaminants are regularly present in the raw water. Ammonia, algae, organic carbon, and turbidity are considered contaminants of concern for the project.

Contaminant	No. zero or ND values	No. Raw Water Data Points	Min	Max	10% exceed.	units
Algae	9	618	0	137000	3200	No./cc
Ammonia (free ammonia as N)	159	616	0	1.44	0.11	Mg/L
PH	0	978	7.3	9.0	8.3	pH units
Alkalinity	0	1095	30	130	55	mg/L as CaCO3
TOC	0	572	1.1	8.4	4.97	mg/L
Turbidity	0	4383	1	1091	74	NTU
Manganese	4051	4059	0	8	.001	mg/L

Data from the Information Collection Rule (ICR), collected from June 1997 to October 1998 were also evaluated. Table 4 presents the results of evaluations of data related to disinfection and disinfection byproducts (although no DBP formation potential data is available). ICR data collected for *Giardia* and *Cryptosporidium* suggest that both of these disinfection resistant pathogens are occasionally present in the raw water. *Giardia* and *Cryptosporidium* will be automatically listed as contaminants of concern because of the importance of watershed management in the multiple barrier approach to minimizing pathogen threats. Requirements of the Long Term 2, Enhanced Surface Water Treatment

Table 4 - Parameters Related to Disinfection and DBPs

Contaminant	No. zero or ND values	No. Raw Water Data Points	Min	Max	10% exceedance	units	Reg. Require.
Microorganisms							
Giardia lamblia	6	16	0	227.9	127.5	No./100L	TT (*)
Cryptosporidium	13	16	0	51	22	No./100L	TT
Heterotrophic plate count (*)	0	24	530	37,000	11,000	CFU/ml	5.0%
Fecal Coliforms	2	279	0	>16,000	1,600	MPN/100mL	
Total Coliforms	2	347	0	>16,000	11,800	TC/100 mL	TT
E. Coli	0	77	1	9,500	590	e coli/100 mL	
Viruses (enteric)	13	18	0	148.3	105.5	MPN/100 mL	TT
(*) HPC Data from non-storm event data in WSSC river sampling data							
Disinfection Byproducts & Precursors							
Total Organic Halogen (TOX)	0	3	31	67	67	mg/L	
Bromide	5	5	0	0	0	mg/L	

Rule will impose *Cryptosporidium* inactivation requirements based on the results of monitoring, which will be required. The requirements are expected to be as follows:

- <0.075 oocyst/L – no inactivation required
- .075 – 1 Oocyst/L – 1 log inactivation required
- 1 – 3 Oocyst/L – 2 log inactivation required
- >3 Oocyst/L – 2.5 log inactivation required

The regulatory definition of "inactivation" is expected to include a toolbox of practices including inactivation, removal, and watershed practices. For instance, utilities are expected to get 0.5 log inactivation credit for watershed protection programs and 0.5 log credit for maintaining filtered water turbidity below 0.15 NTU.

Viruses, E. Coliforms and Total Coliforms are also regularly present in the raw water. The presence of these parameters suggests fecal contamination, but treatment facilities at the WFP reliably remove or inactivate the contaminants. These will not be considered contaminants of concern for the project. MDE presumes a public health hazard if the log mean of Fecal Coliform samples exceeds 200 MPN/100mL. Although Fecal Coliforms are removed and inactivated in the Potomac WFP, they are an indication of fecal contamination and may indicate contamination with other fecal pathogens. Because the 10% exceedance for Fecal Coliforms exceeds 50% of this standard, Fecal Coliforms are considered a contaminant of concern.

Table 5 presents the results of evaluations of parameters which affect the aesthetic quality of the water (those for which secondary standards have been established). Only color and tastes and odors are regularly present in the raw water at concentrations above the secondary standard. Therefore, color and taste and odor causing compounds will be

Table 5 - Parameters with secondary standards

Contaminant	**No. zero or ND values**	**No. Raw Water Data Points**	**Min**	**Max**	**10% exceed-ance**	**Units**	**Rank**	**Sec. Stnd. (mg/L)**	% above SS
Aluminum	1012	1267	0	8	1	mg/L	1140	0.05	0.88%
Chloride	0	699	5	108	30	mg/L	629	250	0.00%
Color	3	5308	0	200	35	CU	4777	15	48.40%
Foaming Agents - *(MBAS)*	189	189	0	0	0	mg/L	171	0.5	0.00%
Iron	3093	4067	0	38	0.001	mg/L	3660	0.3	0.00%
Tastes and Odors (TON)	1	992	0	2000	1000	TON	872	3 (TON)	91.63%
Silver	707	707	0	0	0	mg/L	636	0.1	0.00%
Sulfate	0	427	2	111	57	mg/L	385	250	0.00%
Total Dissolved Solids	0	4662	71	911	268	mg/L	4195	500	0.02%
Zinc	711	712	0	0.001	0	mg/L	640	5	0.00%

considered contaminants of concern for the project.

Selection of contaminants of concern for the project

Contaminants with enforceable standards

As indicated in Table 1, no contaminants with enforceable standards are present in the raw water at concentrations above 50% of the MCL, more than 10% of the time. Therefore, none of these contaminants will be considered contaminants of concern for the project.

Contaminants with Health Advisories (but without MCLs)

Of the contaminants with health advisories that were evaluated, only Dieldrin is present at levels that exceed the 50/10 criteria. Therefore, only Dieldrin will be considered a contaminant of concern for the project.

Contaminants Which Affect WFP Operations

Based on evaluation of the raw water quality data, ammonia, algae, TOC and turbidity are regularly present at levels that significantly affect operations at the WFP. These will each be considered contaminants of concern for the project.

Contaminants Related to Disinfection and DBPs

Giardia and *cryptosporidium* will be automatically listed as contaminants of concern because of the importance of watershed management in the multiple barrier approach to minimizing pathogen threats.

Contaminants with Secondary (Aesthetic) Standards

Raw water quality indicates that color and taste and odor causing compounds are regularly present at levels exceeding the secondary standard. Although the WFP receives few customer complaints related to aesthetics (presumably because these contaminants are reduced in the treatment works) color and taste and odor causing compounds are considered contaminants of concern for the project.

Appendix A - Potential Contaminant List

The following contaminants have been selected for data collection and consideration as contaminants of concern for the Potomac WFP Source Water Assessment:

Regulated Contaminants

Inorganic Chemicals

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

Organic Chemicals

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

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

Radionuclides

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

Microorganisms

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

Disinfection Byproducts & Precursors

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

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

Turbidity
pH
Alkalinity
Ammonia
TOC
DOC
UV-254
SUVA
Manganese

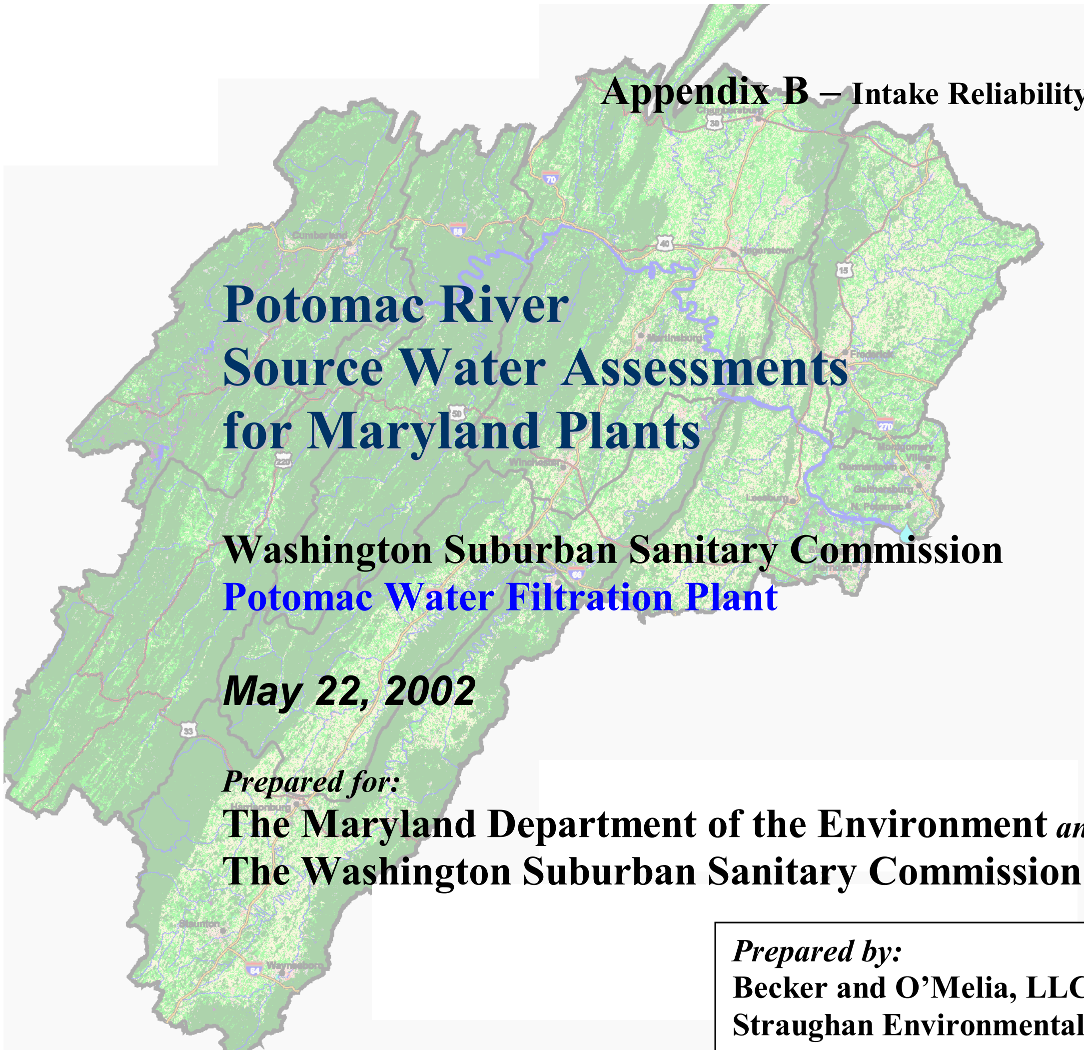
Contaminants listed for "Regulatory Determination" on the most recent (May 2000) Contaminant Candidate List

Acanthamoeba
Sodium
1,3-Dichloropropene
Aldrin
Boron
Dieldrin
Hexachlorobutadiene
Manganese

Metolachlor
Metribuzin
Naphthalene
Sulfate - *Required by MD-SWAP*

Secondary Standards

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



Appendix B – **Intake Reliability Analysis**

Potomac River Source Water Assessments for Maryland Plants

Washington Suburban Sanitary Commission

Potomac Water Filtration Plant

May 22, 2002

Prepared for:

The Maryland Department of the Environment ***and***
The Washington Suburban Sanitary Commission

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

Becker and O'Melia, LLC

WATER PROCESS RESEARCHERS AND CONSULTANTS

To: Mr. Plato Chen, P.E.

From: John E. Parkes, P.E. and John O'Melia

Date: September 19, 2001

Re: Structural Integrity Analysis, Potomac Filtration Plant Intake
Source Water Assessment, Task 3b.

To support the Source Water Assessment underway by Becker and O'Melia, LLC, Straughan Environmental Services, Inc., (SES) evaluated the structural integrity and overall conditions associated with the intake facilities at the Washington Sanitary Sewer Commission's (WSSC's) Potomac Filtration Plant in Potomac, Maryland. SES performed the following tasks as part of its assessment:

- Reviewed available data pertaining to the raw water intake, such as engineering design plans, specifications, and available operation and maintenance records;

- Performed an on-site inspection of the above water intake facilities on May 18, 2001; and

- Conducted interviews with WSSC's Principal Environmental Engineer, Plato Chen, P.E., and Water Plant Operator, Danny Pendergraft.

This technical memorandum summarizes the results of SES's investigation. Attachment A presents detailed notes recorded during the site inspection, and Attachment B presents the site investigation checklist.

Facility Background and Description

The Potomac Filtration Plant was constructed approximately 40 years ago. The original intake facility included two 60-inch raw water mains that were connected to a single pump station, Pump Station No. 1. The plant was improved in approximately 1980, when the original intake was removed, and a new intake was constructed just downstream of the original intake. A new pump station, Pump Station No. 2 was also constructed, new water mains were installed, and other water mains were retrofitted at that time.

The existing intake facilities include three intake bays: two bays were constructed for the raw water intake, and a third, smaller bay was constructed to flush debris, sediment, etc. around the weir to a downstream location. Each bay has a 36-inch floating metal cylinder that rises and falls with the river to deflect debris and prevent debris from entering the intakes. Trash racks are included at each intake bay, with a trash rake and traveling trash rake boom that rides on rails on the platform above the bar screens.

Both raw water intake bays include three concrete compartments. Each concrete compartment in the intake facilities has a sluice gate that controls raw water flow to a 72-inch raw water main.

The 72-inch pre-stressed concrete pipes are connected to the back wall (earth retaining wall) of the concrete compartment. Two of the 72-inch pipes convey water to a common wet well and to Pump Station No. 1 (the original pump station). The remaining pipes convey water to individual wet wells in Pump Station No. 2. Raw water is pumped from the pump stations to unit operations and process treatment facilities.

Operations and Maintenance

WSSC records and files maintenance activities as monthly reports. Based on observations made during the field inspection of May 18, 2001 and discussions with WSSC personnel, SES noted the following:

- Little or no maintenance is required for the 36-inch cylinders that deflect floating debris and prevent debris from entering the intake.

- WSSC personnel report that the 72-inch raw water pipes are drained and inspected annually, and remain in good condition. Some leaking occurs at the pipe joints (infiltration), but it is considered to be insignificant by WSSC operations staff. No evidence exists that the groundwater in the area is contaminated. Therefore, no likelihood exists that the leaking results in contamination to the raw water supply.

- Ongoing maintenance is performed for the stainless-steel traveling screens and the trash rack. The traveling screens are greased monthly and inspected annually when worn parts are replaced. The trash rack rake occasionally malfunctions, and spare parts are kept on site for periodic maintenance and repairs.

- Bar screens or trash racks require some maintenance, mostly during the late summer and early autumn, to ensure that they are effective at collecting debris and preventing the intakes from becoming clogged. During September and October, large amounts of loose, stringy aquatic grasses, which grow in the Potomac River during the summer, break up during autumn storms and flow downstream. The grasses and autumn leaves accumulate in the bar screens and threaten intake operations. Significant efforts are required to remove the debris from the racks and keep the raw water intake open. WSSC personnel must clear the trash racks using rakes, clam tongs, and cranes to remove the debris.

- Additional maintenance is required during periods with extreme winter temperatures and low river flow, because granular ice forms during these periods to clog the bar screens. Although the traveling trash rack rake usually breaks up this ice, special equipment must be brought to the facility during periods of extreme cold to break up, clear, and scoop the accumulated ice out of the of the intake structure.

Overall Integrity and Condition of Intake Facilities

Based upon its field inspection observations, review of design drawings, and discussions with WSSC personnel, the intake facilities appear to be adequately designed, well maintained, and in good operating condition as noted below:

- The control weir constructed in the river appears to be structurally intact and controls the water level.

- All concrete work appears to be in good condition, and SES observed no evidence of metal corrosion on the bar screens (trash racks) or of the 36-inch metal cylinders, which are used to deflect floating debris and prevent objects from entering the intakes.

- No settlement, binding, misalignment, shifting, or vibration was observed or reported for any of the intake structures or gates.

- No accumulation of silt was observed or reported in any of the intake bays or raw water pipes.

Summary

The assessment did not reveal any threats of contamination entering the intake facilities. In addition, the assessment did not reveal any susceptibility to system failure.

Recommendations

Based on its review of records, an on-site inspection, and on-site interviews, SES identified no overall structural deficiencies, and the intake facilities appeared to be functioning well. SES offers the following recommendations to address the seasonal maintenance and operational challenges.

- Investigate options to retrofit the structure or provide a supplemental structure to prevent or alleviate the collection of grasses on the bar screen during late summer and autumn. Options include the installation of a deflection structure(s), such as a wall, dike, or rock vane, at the intake or upstream of the intake to include a wall.

- Provide a portable steam generator and hose to prevent the accumulation of ice during the winter.

SES appreciates this opportunity to work with Becker and O'Melia, LLC. Should you have any questions about this review and supporting data, do not hesitate to call me at 301-989-3265.

Attachment A

Site Inspection Notes
Structural Integrity and Overall Condition
Potomac Filtration Plant Intake Facilities
May 18, 2001

A. Facility Summary and Observations

1. A concrete weir has been constructed in the Potomac River, on the downstream side of the intake. The first portion of the weir extends from the bank to an unnamed island in the river, and the second portion connects extends from this unnamed island to Wadkins Island in the river. The weir was constructed to stabilize the streambed and to control the river water level.

2. Rock excavation has been performed to deepen the stream channel in front of the intake. As a result of this excavation, the lowest point in the stream channel is at the face of the intake.

3. The facility includes three intake bays. Two bays were constructed for the raw water intake, and a third, smaller bay was constructed to flush debris, sediment, etc. around the weir to a downstream location.

4. Each bay has a 36-inch floating metal cylinder at its face that rises and falls with the river level. The purpose of the cylinders is to deflect and prevent floating river debris and objects from entering the intakes.

5. Inclined bar screens (also referred to as trash racks) were installed at each intake bay.

6. A trash rake and traveling trash rake boom and equipment rides on rails on the platform above the bar screens. The trash rake housing is located at the upstream side of the intake and includes a trash pit.

7. Both raw water intake bays include three concrete compartments. Each compartment has a sluice gate that controls raw water flow to a 72-inch raw water main.

8. Each concrete compartment is fitted with ladders and catwalks just downstream of the sluice gates. They provide access for inspection and maintenance of the gates, concrete works, and 72-inch mains.

9. The walls in each concrete compartment are fitted with grooves that are used to install stop logs or a stop plate. (The stop logs would be installed as necessary to repair or replace the sluice gates.)

10. Six 72-inch pre-stressed concrete pipes are connected to the back wall (earth retaining wall) of the concrete compartments. Two of the 72-inch pipes are connected to the old 60-inch pipes (salvaged as part of the 1980 improvements) and convey water to a common wet well and to Pump Station No. 1 (the original pump station). The remaining four 72-inch pipes convey water to individual wet wells and to Pump Station No. 2.

11. The downstream end of each 72-inch raw water main includes a stainless-steel traveling screen. The raw water must pass through this screen before it is pumped. The traveling screen normally remains stationary until a pre-set differential head (from upstream to downstream) activates it to travel (i.e., to rotate). During the autumn, the traveling screens operate continuously to prevent leaves from accumulating.

12. Raw water is pumped from the pump stations to unit operations and process treatment facilities.

B. Operations and Maintenance

1. Three 36-inch floating metal cylinders rise and fall with the water level and deflect and keep floating debris from entering the intakes. Grooves or guides in the concrete walls guide the cylinders. Little or no maintenance is required.

2. The bar screens (i.e., trash racks) require little maintenance during most of the year, but require substantial maintenance in late summer and autumn. During September and October, large amounts of loose, stringy aquatic grasses, which grow in the Potomac River during the summer, break up during autumn storms and flow downstream. These grasses and autumn leaves accumulate in the bar screens and threaten intake operations. Significant efforts are required to remove the debris from the racks and keep the raw water intake open. WSSC personnel clear the trash racks using rakes, clam tongs, and cranes to remove the debris.

3. Additional maintenance is required during periods of extreme winter temperatures and low river flows. Granular ice can form during these periods to clog the bar screens. Although the traveling trash rack rake usually breaks up this ice, special equipment must be brought to the facility during periods of extreme cold to break up, clear, and scoop the accumulated ice out of the of the intake structure.

4. When too much sediment or debris collects upstream of the weir, it is flushed around the weir to a riverside location downstream. This is performed through the third intake bay, the small bay located at the face of the weir.

5. The traveling trash rack rake occasionally malfunctions. It requires periodic maintenance and repairs. Spare parts are kept on hand.

6. The 72-inch raw water pipes are reportedly drained and inspected yearly. The pipes are reported to be in good condition. Some leaking at the pipe joints (infiltration) occurs, but this it is considered to be insignificant by WSSC operations staff. No evidence exists that the groundwater in the area is contaminated, and therefore, there is no likelihood that the leaking results in contamination to the raw water supply. No significant accumulations of sediment in the pipes have been observed.

7. The stainless-steel traveling screens require ongoing maintenance and grease monthly. The screens are taken apart annually, inspected, worn parts are replaced.

8. Maintenance records are kept and filed as monthly reports.

C. Integrity and Condition

1. The intake facilities appear to have no errors or design deficiencies.

2. The control weir across the river appears to be structurally intact and performing its purpose.

3. All concrete work as reported and as observed appears to be in good condition.

4. There is no observed or reported evidence of corrosion of the metal bar screens (trash racks) or of the 36-inch metal cylinders.

5. No settlement, binding, misalignment, shifting, or vibrations of any of the intake structures or gates was reported.

6. There is no silting in of the intake bays or raw water pipes

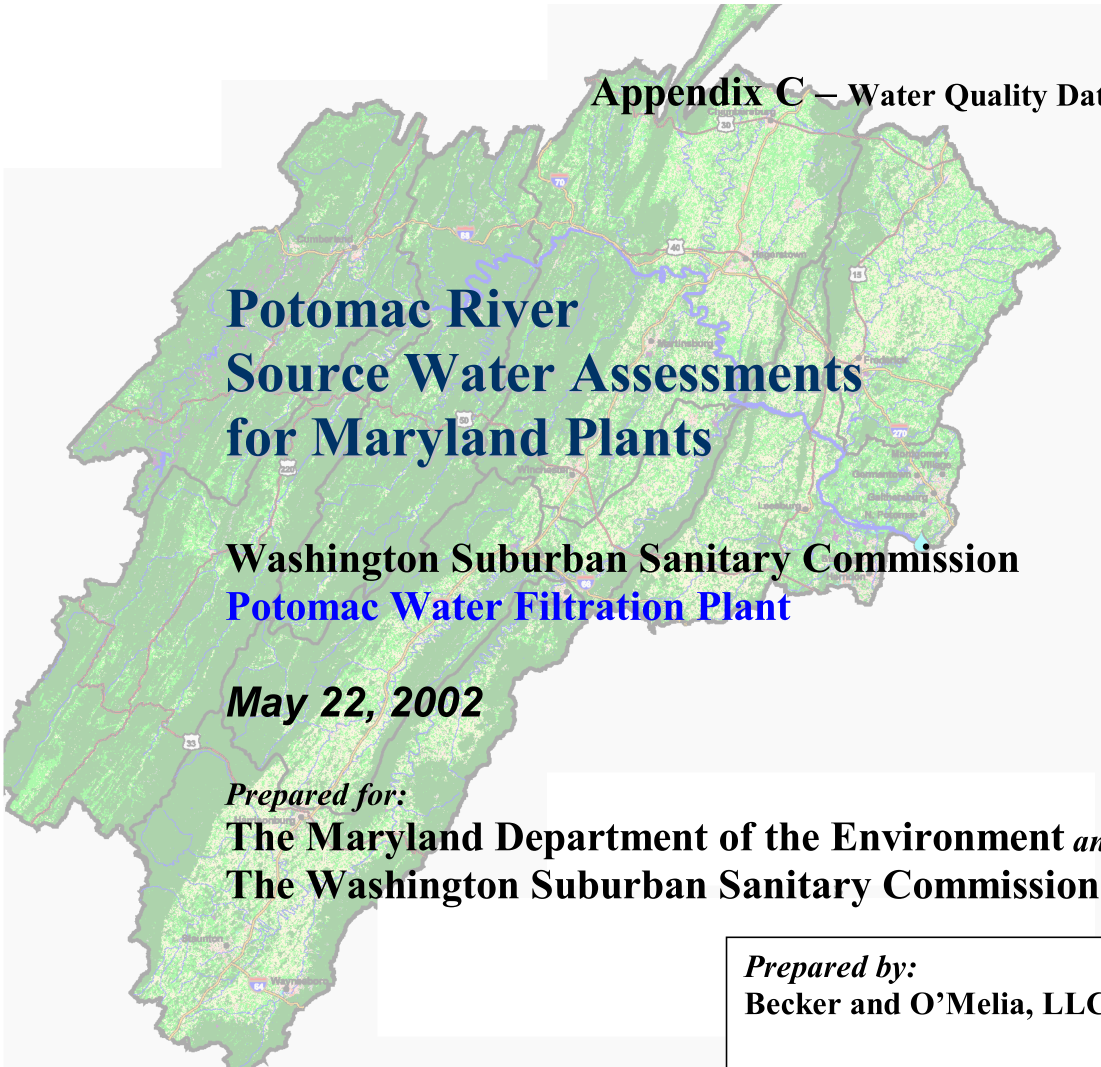
7. Seasonal river grasses have at times clogged the bar screens, which has resulted in near critical conditions to supply raw water to meet system demand.

8. At the time of the visit there was no notable presence of algae, color, or smell associated with the raw water at the intake facilities.

Attachment B

Field Inspection Checklist
Intake Structural Integrity Analysis
Potomac Filtration Plant Intake Facilities

1. Identify any scouring, silting in.
2. Identify ice conditions, ice effects, adverse runoff conditions.
3. Note any algae, color, smell issues.
4. Identify canal diversions
5. Identify devices or mechanisms used to prevent algal scum, trash, logs and fish from entering system.
6. Identify and review records kept regarding maintenance, malfunctions, selective withdrawals (elevations, locations), water levels, depth openings, etc.
7. Recap – multiple depth openings, algal scum, deflection of debris, fish, etc.
8. Find out if and why the intake has ever failed.
9. Find out whether steel and metal screens and racks are coated with corrosion resistant material.
10. Inspect curtain wall and the effects of ice, ice blockage, and floatable debris.
11. Inspect the traveling screen.
12. Identify how trash racks/screens are removed for inspection, maintenance, mechanical screening, or hydraulic jet cleaning.
13. Identify any settling, shifting of structures, or binding of gates.
14. Identify procedures for the lubrication, maintenance and repair of intake structures and any worn, corroded, loose, broken parts.
15. Identify any design errors or deficiencies.
16. Identify whether any vibration occurs and if so, its effects.
17. Identify and describe procedures for cleaning trash screens.
18. Identify whether there is a screen bypass?
19. Describe valves on the intake: slide gates, gate valves, butterfly valves (fully open or control flow?).



Appendix C – **Water Quality Data Review**

Potomac River Source Water Assessments for Maryland Plants

Washington Suburban Sanitary Commission
Potomac Water Filtration Plant

May 22, 2002

Prepared for:
The Maryland Department of the Environment *and*
The Washington Suburban Sanitary Commission

Prepared by:
Becker and O'Melia, LLC

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

Technical Memo

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

From: John O'Melia, P.E.

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

Date: 5/2/05

Re: Potomac River Source Water Assessments for Maryland Plants - Task 4 Data Evaluations

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

INTRODUCTION

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

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

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

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

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. MDE's stormwater design manual discourages infiltration practices in these areas to protect groundwater resources.

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

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

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

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

Figure 1 shows the Potomac WFP drainage basin, subwatersheds defined by the Environmental Protection Agency's Chesapeake Bay Program Office (CBP), and United States Geological Survey designated 8-digit Hydrologic Unit Codes (HUC-8) subwatersheds. The fate and transport modeling for the project will organize evaluations according to CBP subwatersheds, which are designated by 3 digit codes and corresponding shading on Figure 1. Data reviewed in this memorandum are generally organized according to USGS HUC-8s. This memorandum is therefore generally organized according to these HUC-8 codes.

DIELDRIN OCCURRENCE IN THE WATERSHED

An evaluation of dieldrin occurrence data from the watershed indicates that dieldrin occurs throughout the watershed. As shown on figures A-1, A-2, and A-3 (Appendix A), these dieldrin data are characterized by high peaks. An evaluation of this data does not reveal a significant temporal trend and neither supports nor refutes reported improvements in the watershed. Average whole water dieldrin concentrations are presented on Figure 2. All basins with available data indicated the presence of dieldrin in the water column. None of the reaches had average concentrations above 50% of the health advisory of 0.2 μg/L. Dieldrin concentrations in bottom sediment are presented in Figure 3. Again, dieldrin was present in some samples from each subbasin for which data are available. Fish tissue sampling suggests more significant contamination of the North Branch Potomac, Conococheague-Opequon, Middle Potomac-Catoctin, and Monocacy although these trends are not necessarily supported by sediment and water sampling. The fish tissue data demonstrated some very high peaks, which significantly affect the arithmetic mean concentration. The median concentrations, which are less severely influenced by these peaks, are presented on Figure 4.

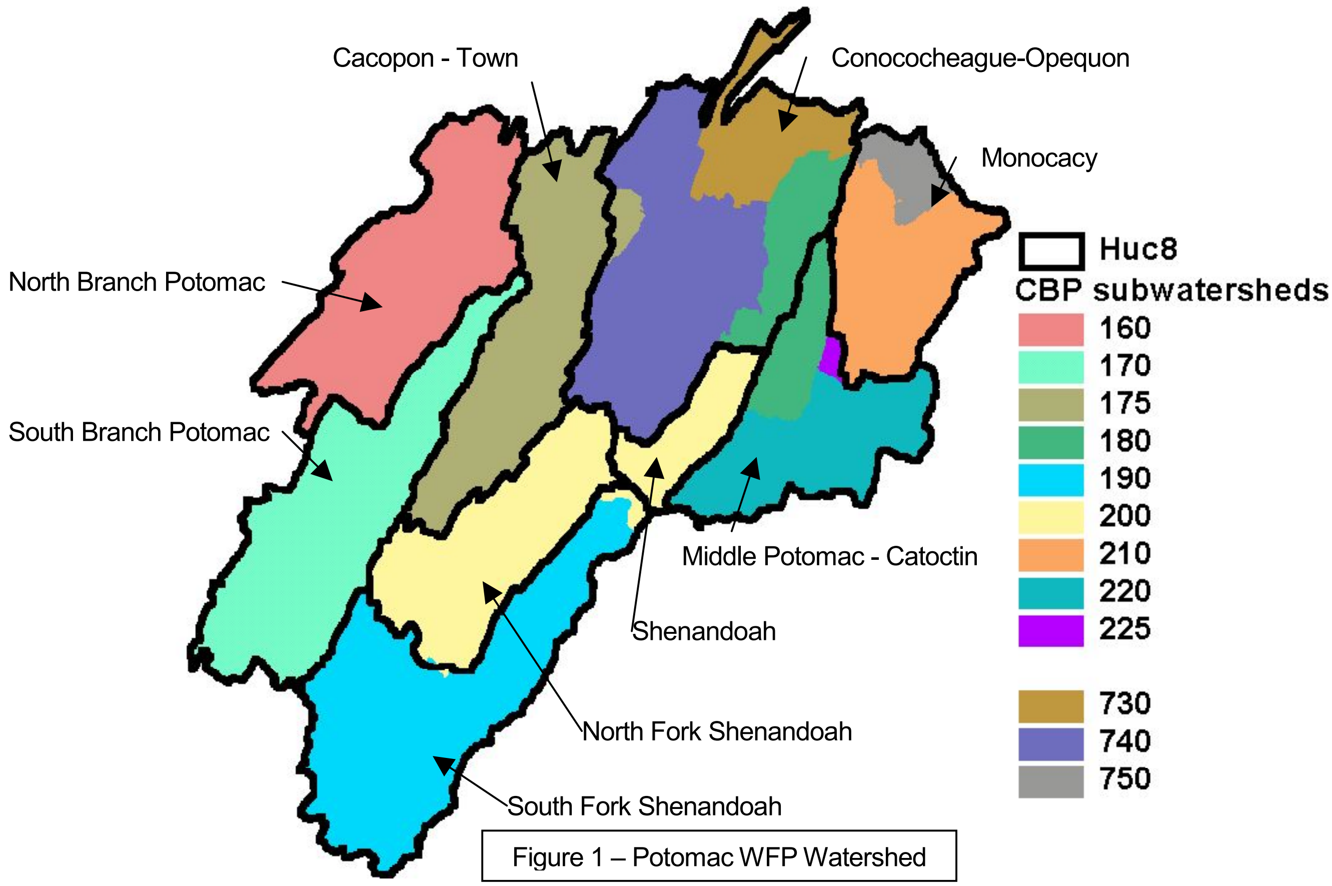


Figure 1 – Potomac WFP Watershed

Figure 2 – Dieldrin in Whole Water Sample

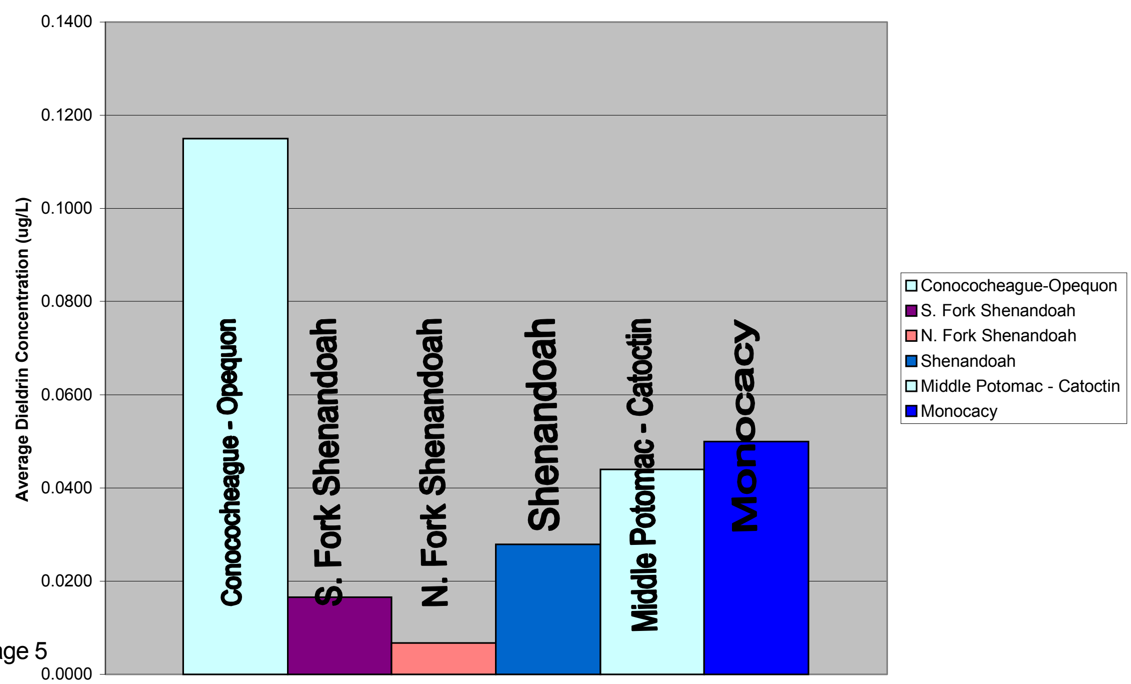
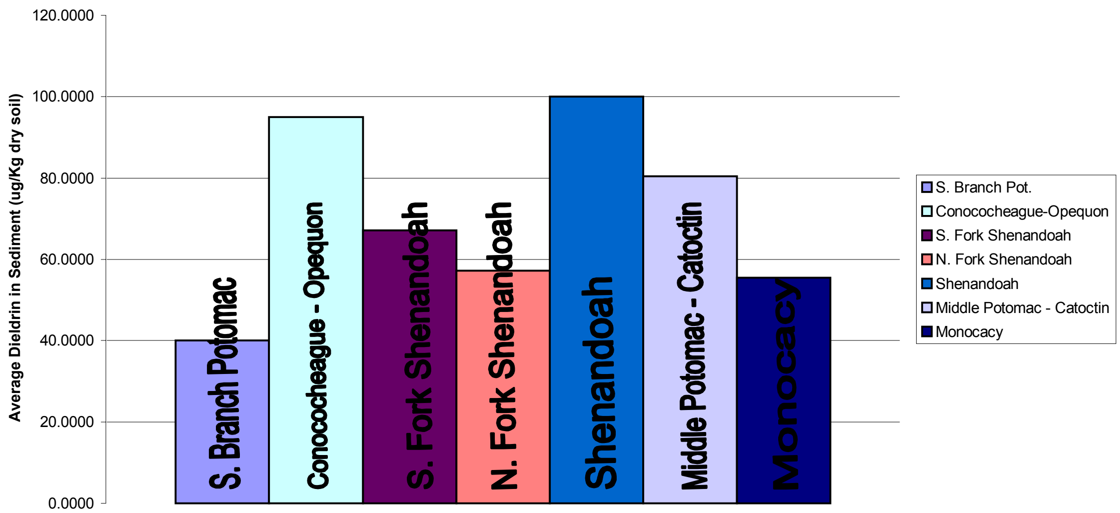


Figure 3 - Average Dieldrin Sediment Concentrations in Potomac WFP

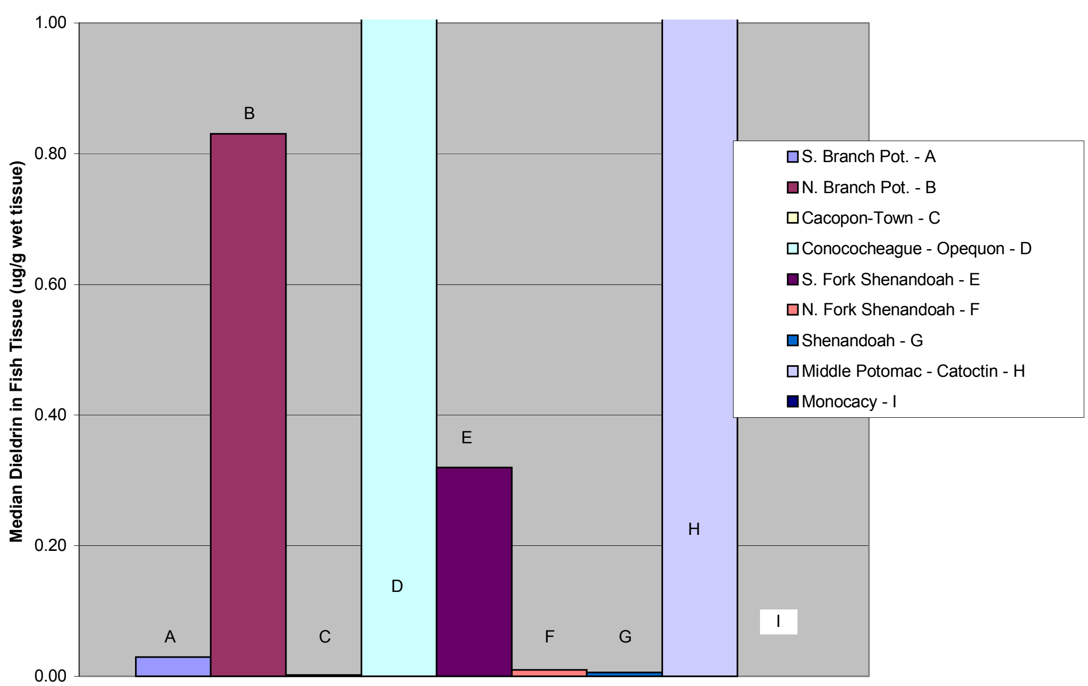


POTOMAC HEADWATERS

The 1993 Water Quality Inventory Report (Maryland Department of Natural Resources, 2000) characterized the overall water quality of the Upper Potomac as "good" and generally suited for body contact recreation. Elevated suspended solids, nutrient and bacterial levels were noted and ascribed to agricultural activities and upstream sources. Urban activities were also thought to contribute to the elevated bacterial and nutrient levels. Subwatersheds of the Upper Potomac are shown on figure 5, 6 and 7.

According to the 1989-1991 Water Quality Inventory Report (Chesapeake Bay

Figure 4 – Dieldrin Concentration in Fish Tissue – Potomac WFP Watershed



and Watershed Management Administration, 1993), there were 37 municipal NPDES and groundwater dischargers in the Upper Potomac at that time. Only 2 of these dischargers were permitted to discharge more than 1 mgd. The same report indicated that there were 45 industrial NPDES and groundwater dischargers, 19 of which discharge to the groundwater.

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

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

North Branch Potomac

The North Branch Potomac (shown on Figure 5) has been polluted by mine drainage for more than 150 years (ICPRB 1984). In 1969, the Appalachian Regional Commission report on acid mine drainage included the North Branch Potomac among those continuously or significantly affected by acid mine drainage. This report listed 130 of 3,300 miles of streams in the North Branch Watershed as "continuously or significantly" affected. Another 40 miles were considered "potentially or intermittently" affected (Appalachian Regional Commission, 1969).

North Branch Potomac

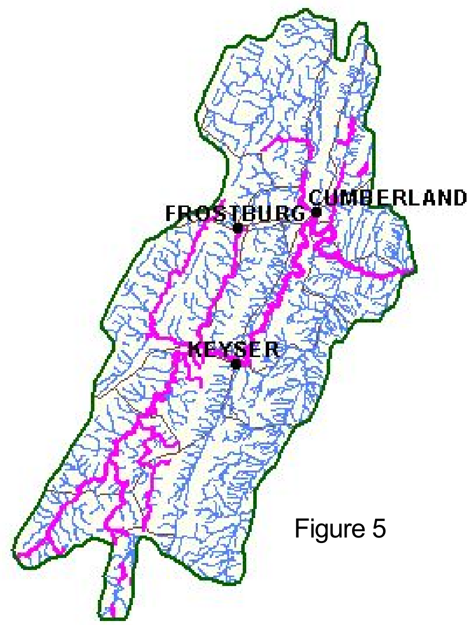


Figure 5

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

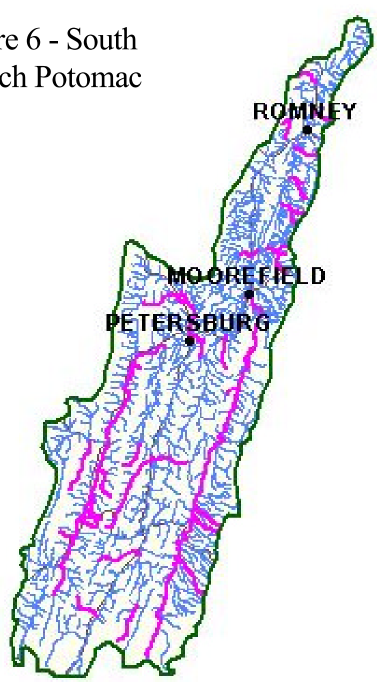
Potomac River Water Quality 1982-83 (ICPRB, 1984) reported "poor" water quality in the headwaters and highlands of the Potomac Watershed due to acid mine drainage from abandoned and inactive coal mines. Others found the water quality to be "poor" to "good-excellent" (ICPRB, 1989). Approximately 50 miles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

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

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

As shown on Figure A-4 (Appendix A), monitoring of North Branch fish tissue for dieldrin found a maximum concentration of 1.6 μg/g wet tissue and an average of 0.83 μg/g wet tissue. All fish tissue samples had detectable concentrations of dieldrin, and 5 of the 12 samples were above 0.3 μg/g wet tissue, the Action Level established by the United States Food & Drug Agency (USFDA) for the sum of dieldrin and aldrin.

Figure 6 - South Branch Potomac



South Branch Potomac

The South Branch Potomac Watershed is shown on Figure 6. For 1982-1983, ICPRB estimated the South Branch Potomac water quality to be good with only localized problems due to agricultural and dairy farm runoff. The wastewater treatment facility in Romney was noted as one cause of improvements (ICPRB, 1984). From the early 1970s to the mid-1980s, hexavalent chromium increased in the South Branch, as did dissolved oxygen. Turbidity was generally also increasing over that time period. Several streams in the South Branch Potomac are currently listed for TMDLs based on NH3-N and pathogens from agricultural landuses.

There are two USGS water quality monitoring stations on the South Branch of the Potomac for which data is included in "Water Quality Assessment of the Potomac River Basin: Water-Quality and Selected Spatial Data, 1992-96" (USGS 1998). At the South Fork of the South Branch near Moorefield, WV (Station 010608000) TSS ranged from 1.0 mg/L to 237.0 mg/L over that period (1992-1996) with an average of 34.0 mg/L and a median of 1.5 mg/L. DOC ranged from 0.7 mg/L to 14.0 mg/L with an average of 2.4 mg/L and a median of 1.6 mg/L. At the South Branch near Springfield, WV (Station 010603000) TSS ranged from 1.0 mg/L to 455.0 mg/L with an average of 53.7 mg/L and a median of 6.0 mg/L. DOC ranged from 1.2 mg/L to 6.6 mg/L with an average of 2.7 mg/L and a median of 2.1 mg/L. Monitoring of sediment for dieldrin found 2 samples with less than the detection limit, a maximum concentration of 600 μg/kg dry soil and an average of 40 μg/kg dry soil (Figure A-5). As shown on Figure A-6, monitoring of South Branch fish tissue for dieldrin found detectable concentrations in all samples, a maximum concentration of 0.07 μg/g wet tissue (all samples were below the USFDA Action Level of 0.3 μg/g wet tissue) and an average of 0.03 μg/g wet tissue.

Cacapon-Town

The Cacapon-Town watershed (shown on Figure 7) includes TMDL listings based on nutrients, suspended solids, and pathogens. Only agricultural runoff was identified as a source of these contaminants.

As shown on Figure A-7, monitoring of Cacapon-Town fish tissue for dieldrin found all samples with detectable concentrations, a maximum concentration of 0.007 μg/g wet tissue (all samples were below the USFDA Action Level of 0.3 μg/g wet tissue) and an average of 0.0018 (μg/g wet tissue).

Figure 7 - Cacapon-Town

UPPER GREAT VALLEY

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

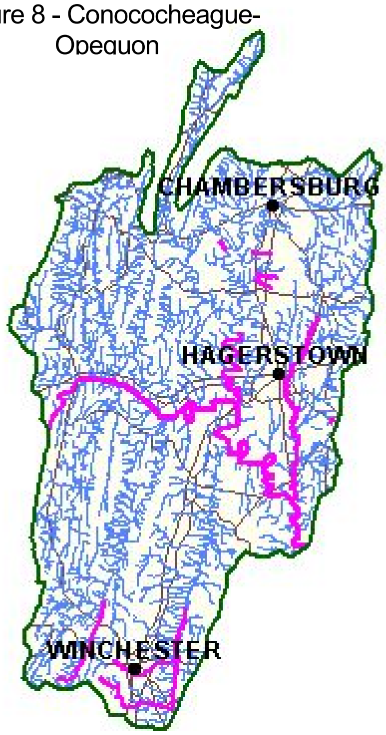
From the early 1970s to the mid-1980s, turbidity decreased in the basin. (ICPRB, 1989). Although nitrate was generally increasing in the basin, Potomac River water quality in the upper Great Valley was fair with slight improvements likely from increased treatment of wastewater. Although nonpoint sources,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

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

Conococheague-Opequon

Water quality in the Conococheague Creek (Figure 8) was considered "good" by the mid-1980s except for the lower 2 miles (just upstream of the confluence with the Potomac River), which were considered "fair-good". Industrial discharges to the Conococheague were primarily from a Pennsylvania paper mill and tannery. Researchers found that iron concentrations decreased from 1970 to the mid-1980s. Researchers also noted additional effects on the river of urban and agricultural activities at the time. The lower portion of the Conococheague was affected by agricultural and forest runoff.

Figure 8 - Conococheague-Opequon



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

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

Monitoring for aqueous dieldrin found 9 samples without detectable concentrations, a maximum concentration of 1.5 μg/L and an average of 0.12 μg/L (Figure A-8). Monitoring of sediment for dieldrin found a maximum concentration of 600 μg/kg dry soil and an average of 95 μg/kg dry soil (Figure A-9). Monitoring of Conococheague-Opequon fish tissue for dieldrin found a maximum concentration of 1,000 μg/g wet tissue and an average of 14 μg/g wet tissue (Figure A-10).

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

Shenandoah River Basin

Figure 10 - Main Stem Shenandoah

The Shenandoah is the largest tributary to the Potomac making up 21 percent of the watershed. Water quality in the Shenandoah varies from "good" to good-excellent" (ICPRB, 1989). Landuse within the watershed is primarily agricultural and forest although municipal wastewater and urban and suburban runoff contributes to reduced water quality.

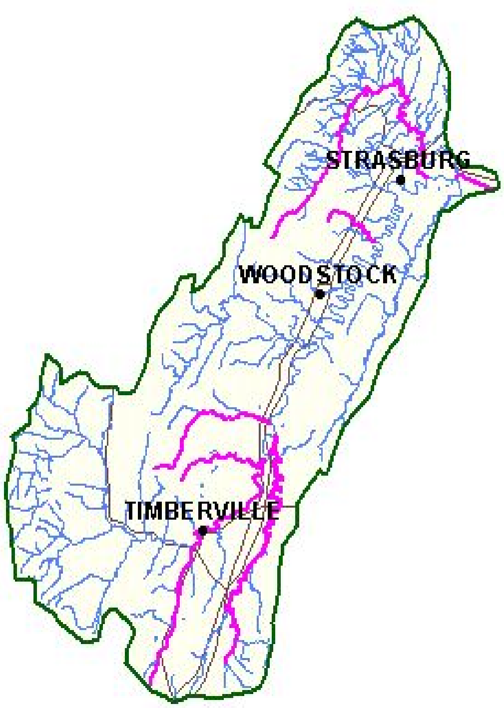
High levels of mercury were discovered in the fish and sediments of the South River and the South Fork of the Shenandoah in 1977 resulting in a ban on eating fish from these waterbodies. This ban was later reduced to an advisory setting recommended limits on fish consumption, but this was due to a change in the United States Food and Drug Administration allowable mercury levels rather than measured improvements in the sediments or fish tissue. A manufacturing plant which has not used mercury since 1950 has been identified as the source of the mercury in these rivers. A study completed in 1982 found it infeasible to clean up the mercury pollution. Mercury contamination in the bottom sediment will likely remain a persistent problem for some time (ICPRB, 1989).

Monitoring of the main stem Shenandoah (shown on Figure 10) for aqueous dieldrin found 3 of 7 samples with concentrations below the detection limit, a maximum concentration of 0.1 μg/L and an average concentration of 0.028 μg//L. As shown on Figure A-11 in Appendix A, monitoring of main stem Shenandoah sediment for dieldrin found all samples positive with a maximum and average concentration of 100 μg/kg dry soil. Monitoring of main stem Shenandoah fish tissue for dieldrin found 7 of 14 with concentrations below the detection limit, a maximum concentration of 0.03 μg/g wet tissue (all samples were below the USFDA Action Level of 0.3 μg/g wet tissue) and an average of 0.0064 μg/g wet tissue (Figure A-12).

Although the Shenandoah Basin is large and diverse, water quality in the basin was described by several researchers as ranging from fair to excellent and generally found to be gradually improving. Nonpoint sources were found to affect some localized areas.

North Fork Shenandoah

Figure 11 - North Fork



In general, water quality in the North Fork of the Shenandoah (shown on Figure 11) varied from "fair-good" in the upper watershed to "good" in the lower reaches. Several streams in the North Fork Shenandoah basin are listed for TMDLs based on NH3-N, fecal coliforms, benthic conditions, chlorine, cyanide, and PCBs. Identified sources of these contaminants in the basin include fish farming, agricultural activities, and industrial discharges.

At the Shenandoah River gage at Millville, W. Va. (Station 010636500) TSS ranged from 1.0 mg/L to 1250.0 mg/L over the period from 1992 to 1996 with an average of 103.0 mg/L and a median of 10.5 mg/L. DOC ranged from 1.8 mg/L to 7.5 mg/L with an average of 3.2 mg/L and a median of 2.7 mg/L.

Monitoring for aqueous dieldrin found 21 of 24 samples with concentrations below the detection limit, a maximum concentration of 0.1 μg/L and an average of 0.0067 μg/L (Figure A-13). Monitoring of sediment for dieldrin found all samples positive, a maximum concentration of 120 μg/kg dry soil and an average of 57.2 μg/kg dry soil (Figure A-14). Monitoring of tissue from fish taken from the North Fork of the Shenandoah for dieldrin found 23 of 41 samples with concentrations below the detection limit, a maximum concentration of 0.7 μg/g wet tissue (all samples were below the USFDA Action Level of 0.3 μg/g wet tissue) and an average of 0.01 μg/g wet tissue (Figure A-15).

South Fork Shenandoah

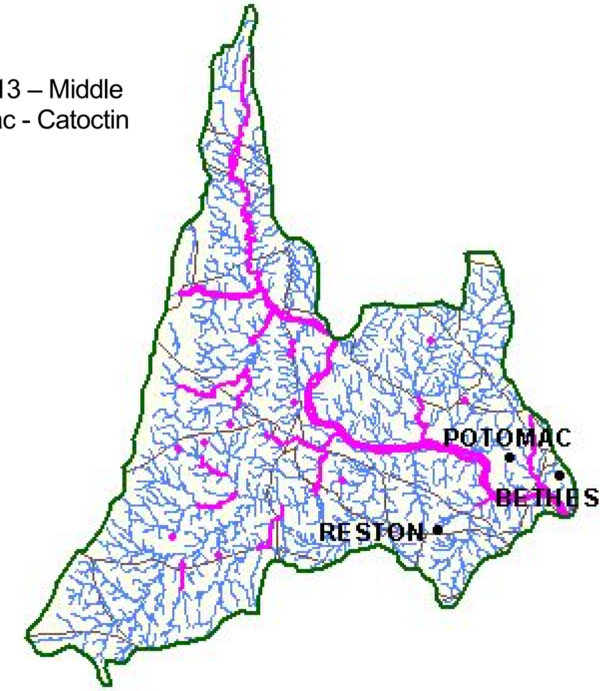
Figure 12 - South Fork Shenandoah

The South River of the South Fork (shown on Figure 12) demonstrated “good-excellent” water quality in the upper segment, which is primarily forested with significant agricultural activities. Water quality in the middle segment was only fair due to wastewater discharges. Improvements were noted due to upgrades at industrial discharge facilities. The lower reaches of the South River have been the most heavily impacted in the past, but increased municipal and industrial treatment had resulted in measurable improvements by the mid-1980s. Total nitrogen, nitrate, nitrite and ammonia concentrations increased from 1970 to the mid-1980s while TOC and mercury decreased over the same period.

The South Fork of the Shenandoah includes streams listed for TMDLs based on low dissolved oxygen, fecal coliforms, benthic conditions, NH3-N, nitrate, nitrite, BOD5, TKN, mercury, and PCBs. Several streams discharging directly to the main stem Shenandoah are listed for TMDLs based on fecal coliforms, PCBs, NH3-N, and benthic conditions. Only industrial discharges have been identified as a source of these contaminants.

Monitoring for aqueous dieldrin found 4 of 33 samples positive with a maximum concentration of 0.1 μg/L and an average of 0.012 μg/L (Figure A-16). Monitoring of sediment for dieldrin found all samples positive, a maximum concentration of 320 μg/kg dry soil and an average of 67.1 μg/kg dry soil (Figure A-17). Monitoring of South Fork of the Shenandoah fish tissue for dieldrin found 6 of 29 samples with concentrations below the detection limit, a maximum concentration of 1 μg/g wet tissue (4 of 29 samples were above the USFDA Action Level of 0.3 μg/g wet tissue) and an average of 0.32 μg/g wet tissue (Figure A-18).

Figure 13 – Middle Potomac - Catoctin



MIDDLE POTOMAC

Middle Potomac total phosphorus loads were significantly reduced between 1965 and 1995 (MD-DNR, 1996). The ambient total phosphorus has decreased but not as dramatically as the loads. Total nitrogen loads and concentrations in the basin increased significantly from 1966 to 1995 due to increases in population and wastewater discharge volume (MD-DNR, 1996). The Middle Potomac – Catoctin Watershed is shown on Figure 7.

The Middle Potomac suffered significant algal blooms in the summers of 1983, 1984 and 1985. By the early 1990s these summer blooms were limited to embayment areas. Seasonally high pH in lower tidal areas have been attributed to the photosynthetic activity of these blooms. (MD-DNR, 1996)

In 1993 – 1995 the water quality in the Middle Potomac was characterized as poor-good with elevated bacteria, suspended sediment, and nutrients. Primary pollutant sources included urban runoff, combined sewer overflows, construction activities, mining activities, and municipal and industrial wastewater discharges. (MD-DNR, 1996)

Several streams in the Middle Potomac-Catoctin watershed are listed for TMDLs based on pathogens, organics, nutrients, suspended solids, fecal coliforms, NH3-N, TKN, pH, and benthic conditions.

Monitoring for aqueous dieldrin found 26 of 75 samples with less than detectable levels, a maximum concentration of 0.2 μg/L and an average concentration of 0.044 μg/L (Figure A-19). Monitoring of sediment for dieldrin found all samples with detectable concentrations, a maximum concentration of 208 μg/kg dry soil and an average of 77.5 μg/kg dry soil (Figure A-20). Monitoring of Middle Potomac-Catoctin fish tissue for dieldrin found 33 of 66 samples with concentrations below the detection limit, a maximum concentration of 1,000 μg/g wet tissue and an average of 15.2 μg/g wet tissue (Figure A-21). One very high sample, which is the only sample above the USFDA Action level of 0.3 (μg/g wet tissue), has a significant affect on the average concentration. Aside from this maximum sample, the average concentration is 0.01 μg/g wet tissue.

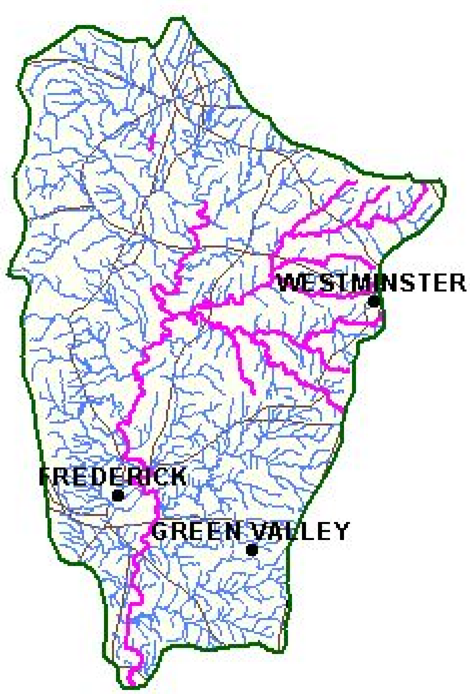
POTOMAC PIEDMONT

Researchers in the early 1980s describe water quality in the Potomac Piedmont basin as fair to good or good-excellent (ICPRB, 1989 and CB&WMA, 1993). Conditions were considered to be improving due to improved wastewater treatment, although a few overloaded treatment facilities continued to cause water quality problems. Other noted problems included localized septic system failures and runoff from urban and agricultural landuses.

Monocacy

The Potomac WFP watershed includes the Monocacy watershed as well as urban and suburban areas of Montgomery County, Maryland and Fairfax County, Virginia. The Monocacy Watershed is shown on Figure 8. Rapid urbanization in these areas and in Frederick County has significantly affected the water quality in the basin for some time. By the mid-1980s, water quality of the main stem Potomac at Point of Rocks was affected by faulty septic systems and agricultural runoff but still deemed to be good. The soils in the area are not well suited for septic systems. In the upper areas of the Monocacy watershed, water quality was "good-excellent" in the mid 1980s.

Monocacy Watershed



Overall, the Monocacy water quality was "good" with localized areas only "fair". Highly erodible soils in the watershed cause water quality degradation and consistently high suspended solids concentrations. Rock Creek, the major tributary to the Monocacy, was degraded in Pennsylvania during the mid-1980s by insufficiently treated wastewater, agricultural runoff and failing septic systems. These waters rarely met federal or state water quality standards. Several streams in the Monocacy watershed are listed for TMDLs based on nutrients, suspended solids, organic enrichment, low dissolved oxygen, and habitat alteration. Identified sources of these contaminants include agricultural uses and point and nonpoint sources.

At the Monocacy River gage at Reich's Ford Bridge near Frederick, Md. (Station 010643020) TSS ranged from 4.0 mg/L to 619.0 mg/L over the period from 1992 to 1996 with an average of 88.1 mg/L and a median of 29.0 mg/L. DOC ranged from 1.8 mg/L to 8.2 mg/L with an average of 4.2 mg/L and a median of 3.3 mg/L.

Monitoring for aqueous dieldrin found 3 of 5 samples with concentrations below the detection limit, a maximum of 0.1 µg /L and an average of 0.05 µg /L. Monitoring of sediment for dieldrin found 2 of 2 samples positive with a maximum concentration of 61 µg/kg dry soil and an average of 55.5 µg/kg dry soil (Figure A-22). Monitoring of Monocacy fish tissue for dieldrin found 28 of 80 samples with concentrations below the detection limit, a maximum concentration of 1000 μg/g wet tissue and an average of 37.6 μg/g wet tissue. Three sample from late October 1982 had concentrations of 1000 μg/g and were the only samples above the USFDA Action Level of 0.3 μg/g. Aside from these samples, the average concentration is 0.06 μg/g.

Lower Potomac WFP Watershed

Researchers described the water quality in the lower Potomac as poor to good in the mid-1980s having improved significantly due to improvements to wastewater treatment facilities (MD-DNR, 1996). From 1970 to the mid 1980s, submerged aquatic vegetation began to return, suggesting improvements in water quality although significant algal blooms occurred in 1983 and 1984.

The Water Quality Inventory for 1989-91 reported fair to good water Potomac River quality in the metro-DC area with seasonally high pH. These high pH conditions were attributed to summer blooms of blue-green algae (Chesapeake Bay and Watershed Management Administration, 1993). A significant reduction in total phosphorus concentrations began in 1965, while total nitrogen remained approximately unchanged from 1966 to 1986. Local sources of pollutants that contribute to degradation of the water quality included urban runoff, combined sewer overflows, construction activities, mining, and industrial discharges.

At the Potomac River gage at Chain Bridge near Washington, D.C. (Station 01646580) TSS ranged from 3.0 mg/L to 932.0 mg/L over the period from 1992 to 1996 with an average of 122.4 mg/L and a median of 28 mg/L. DOC ranged from 1.7 mg/L to 25 mg/L with an average of 5.0 mg/L and a median of 3.4 mg/L.

In 1993-95 Lower Potomac water quality was classified as good and generally suitable for water contact recreation. The main stem continued to suffer summer algal blooms. Some low-lying areas suffered from low pH levels (<6.5) while some upper areas exhibited elevated pH levels (>8.5). (MD-DNR, 1996)

In the mid-1980s, water quality of the Seneca Creek ranged from fair to good, with problems caused by agricultural and stormwater runoff. Urban areas of Poolesville, Damascus, Germantown and Gaithersburg contribute to the stress placed on the Seneca Creek. By the early 1990s, water quality in Seneca Creek was characterized as "good" (CB&WMA, 1993). Degradation was characterized by elevated bacterial, nutrient and suspended sediment concentrations. This degradation was caused by agricultural runoff, urban runoff, construction activities, highway runoff and suburban development (CB&WMA, 1993). Data from the Seneca Creek Water Quality Monitoring Station (SEN0008) indicated elevated nitrate, total nitrogen, orthophosphate and total phosphorus levels. Based on benthic macroinvertabrate surveys, the water quality in the lower Seneca was considered good (CB&WMA, 1993). Earlier data indicate elevated levels of some toxic substances but resampling in the late 1980's did not find any toxics. As of the early 1990s Seneca Creek was no longer listed as toxic impaired. (CB&WMA, 1993)

Two lakes on the Seneca, Seneca Lake (approximately 50 acres) and Clopper Lake (approximately 90 acres) were classified as eutrophic in 1989 and mesotrophic in 1991. Elevated nutrients and sediment loads threaten the “good” water quality. (CB&WMA, 1993)

SUMMARY

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

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

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

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

The watershed treatment modeling tasks for this project are currently being performed by B&O’M and the Center for Watershed Protection will provide a more precise view of water quality conditions throughout the basin and at the Potomac WFP intake. The review of monitoring data, as described in this memorandum, will be used as a real world check by the modelers on the results of the modeling tasks.

APPENDIX A – DIELDRIN FIGURES

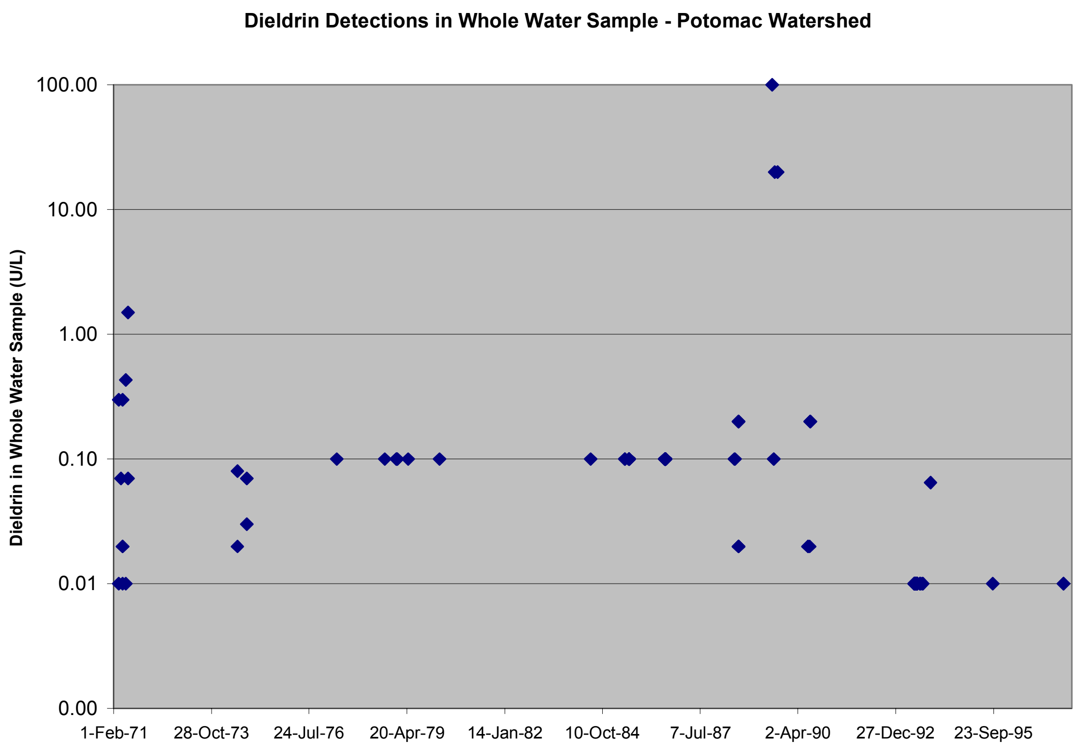
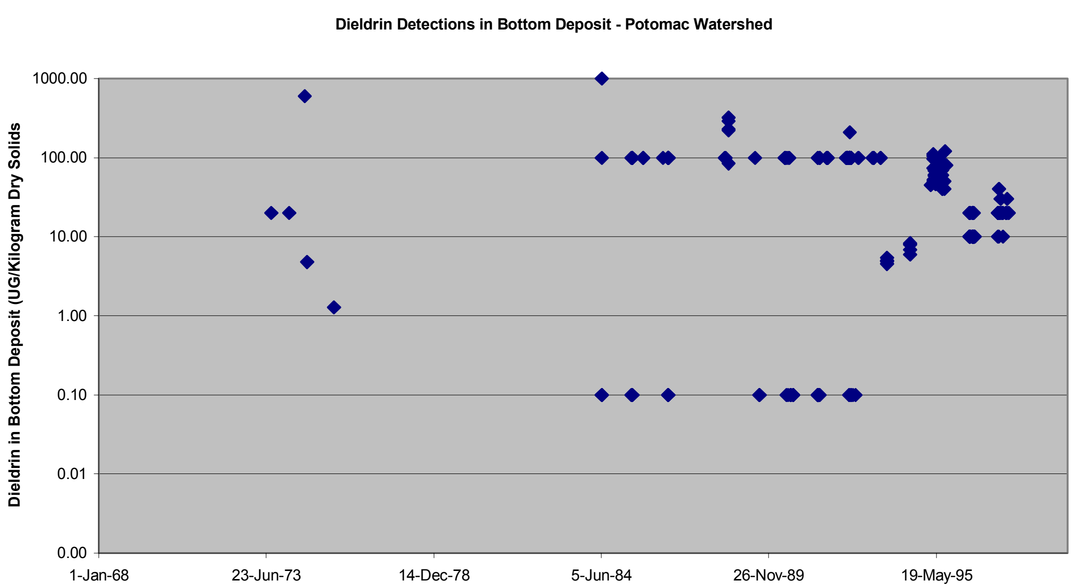


Figure A-1



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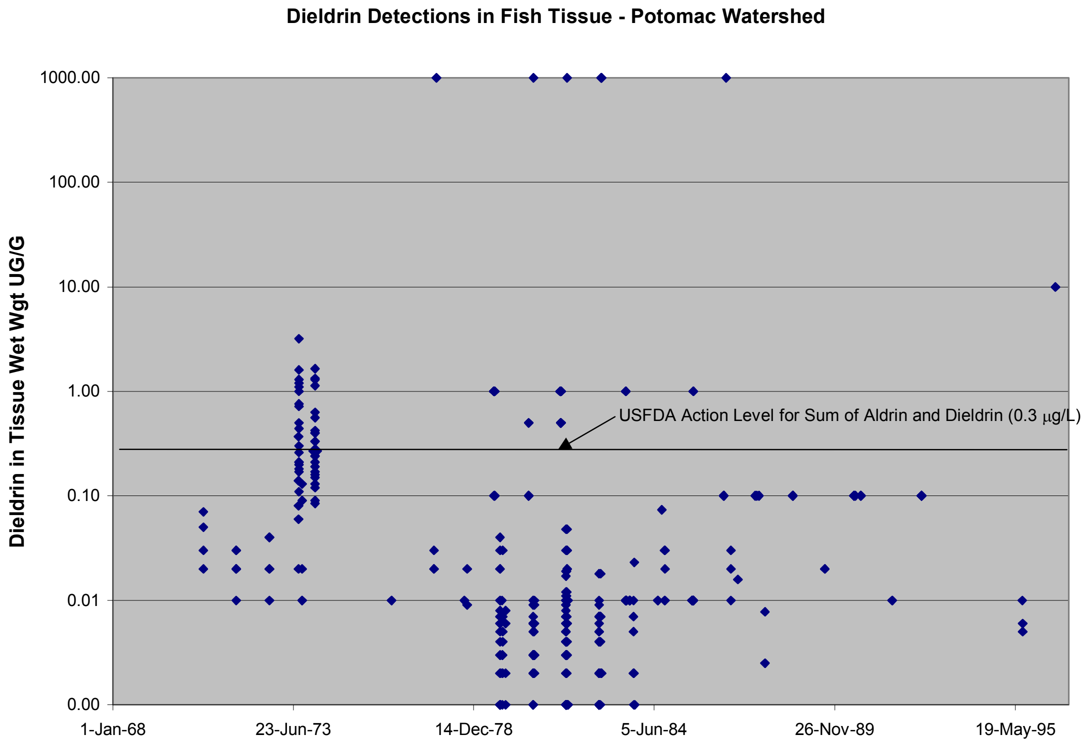

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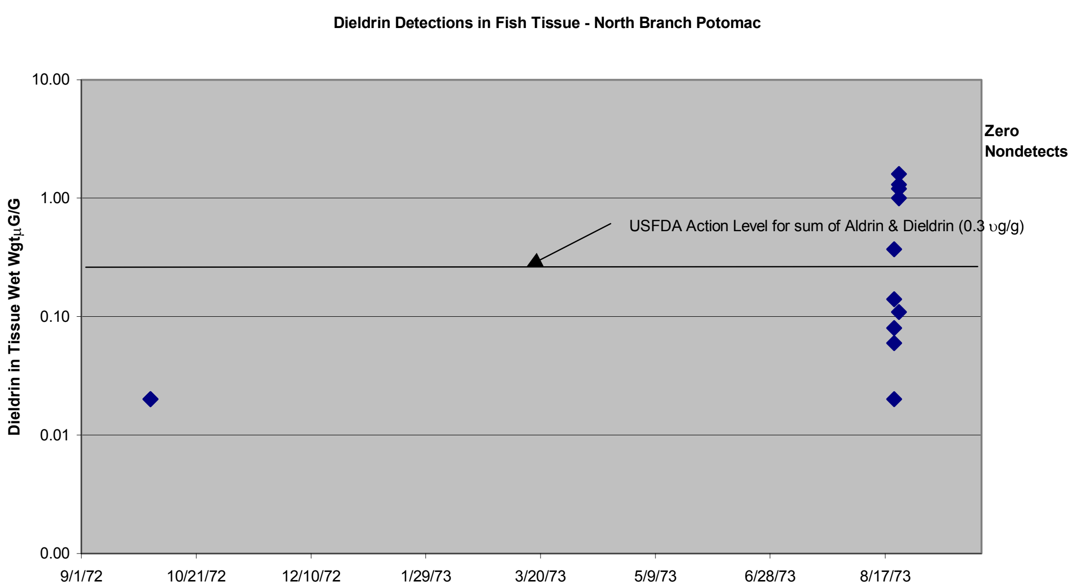

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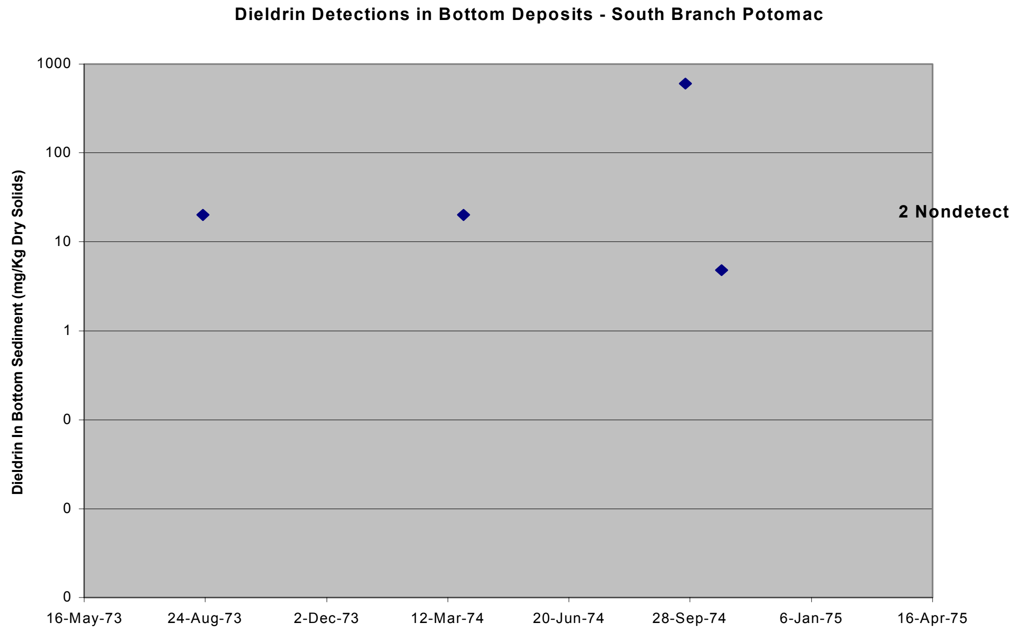

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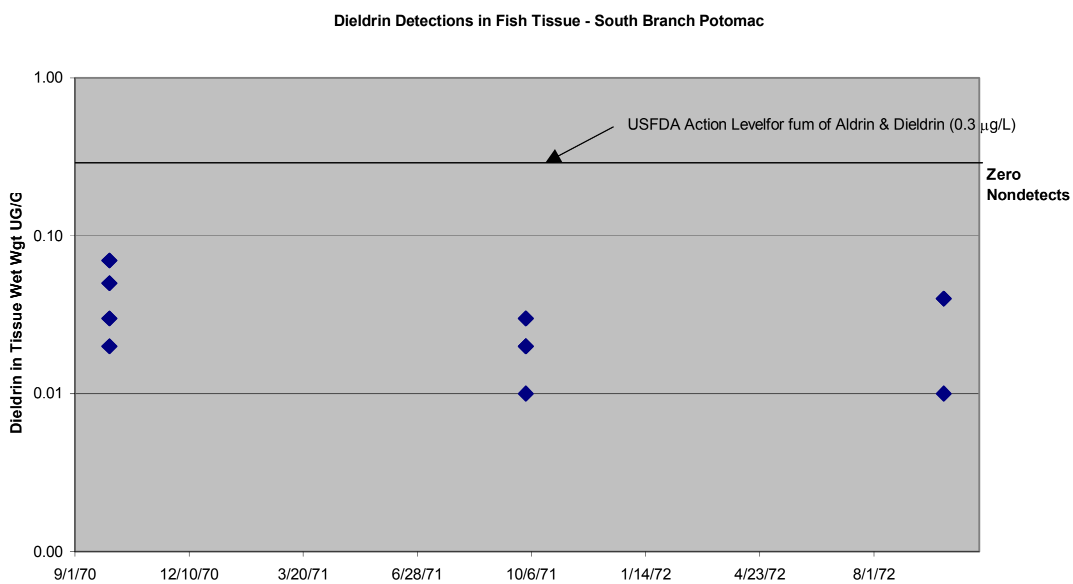

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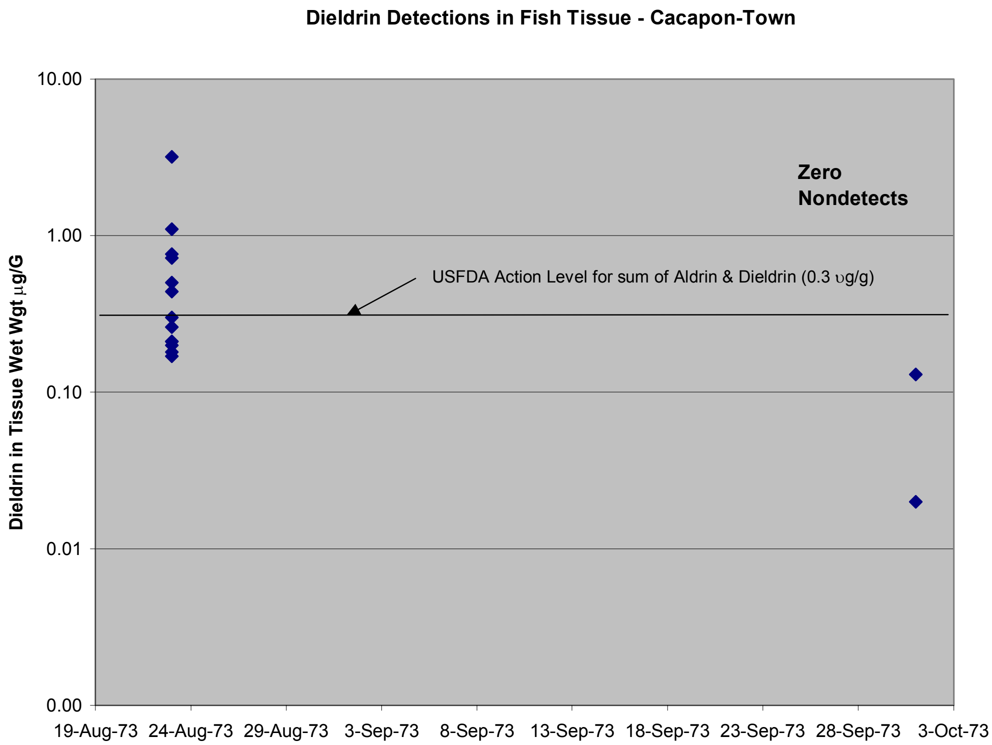

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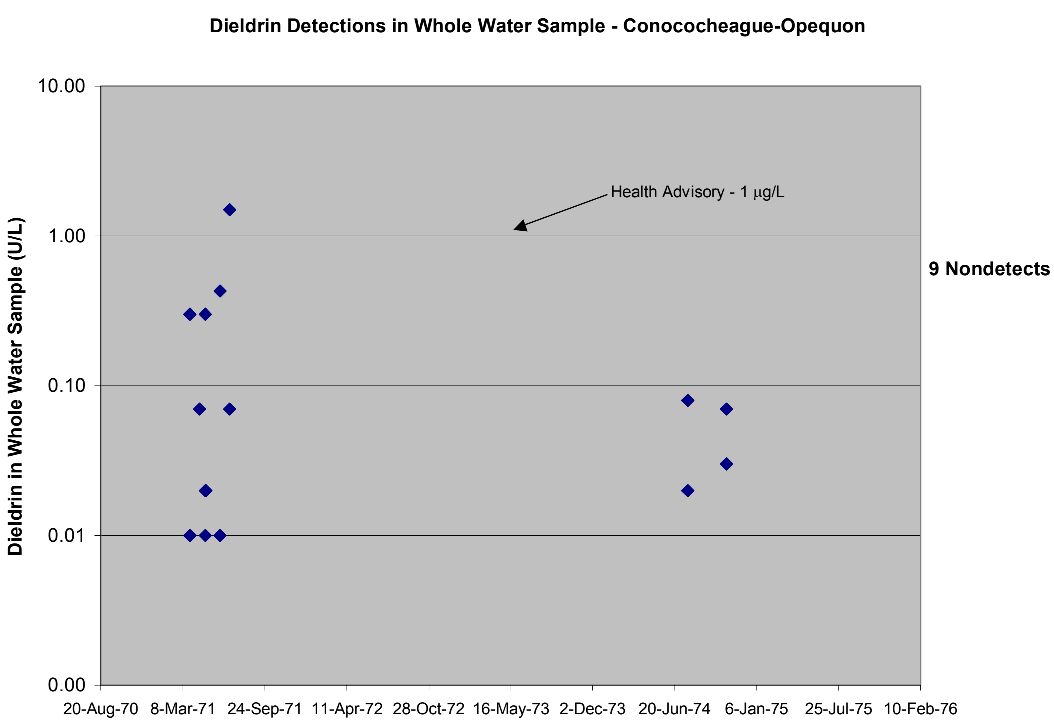

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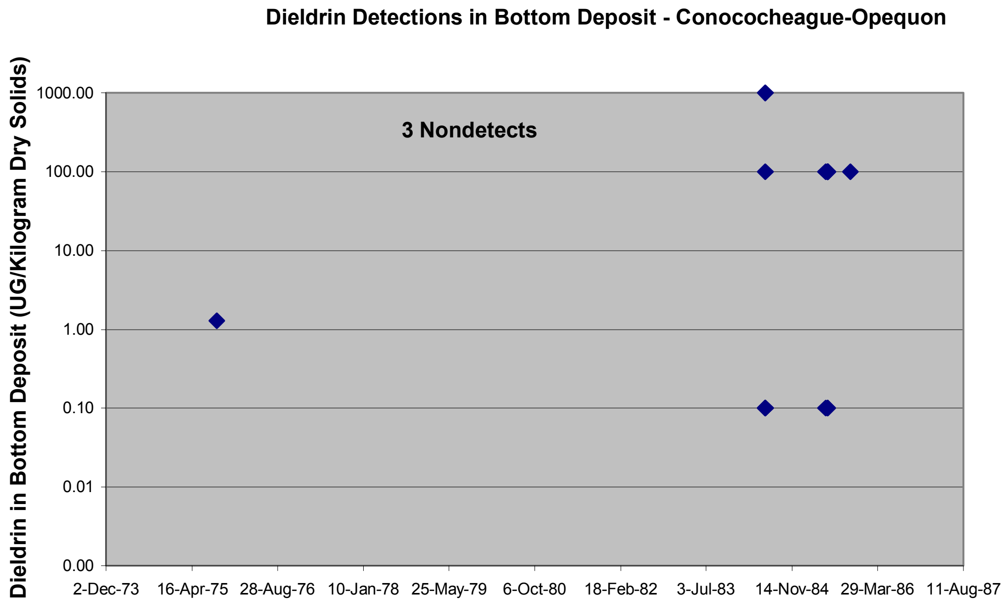

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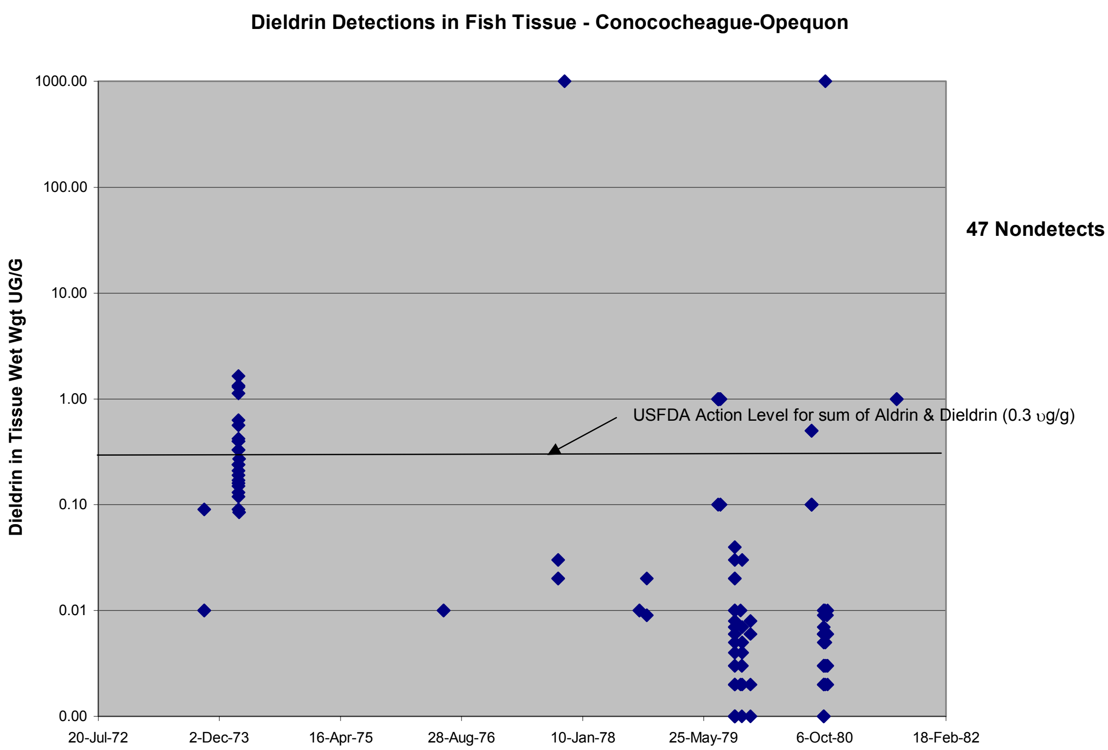

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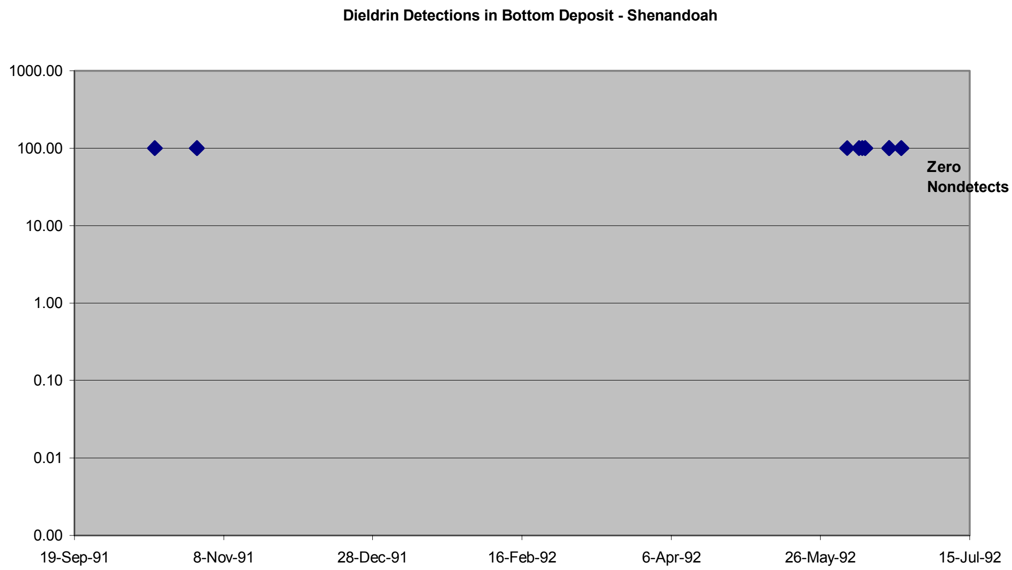

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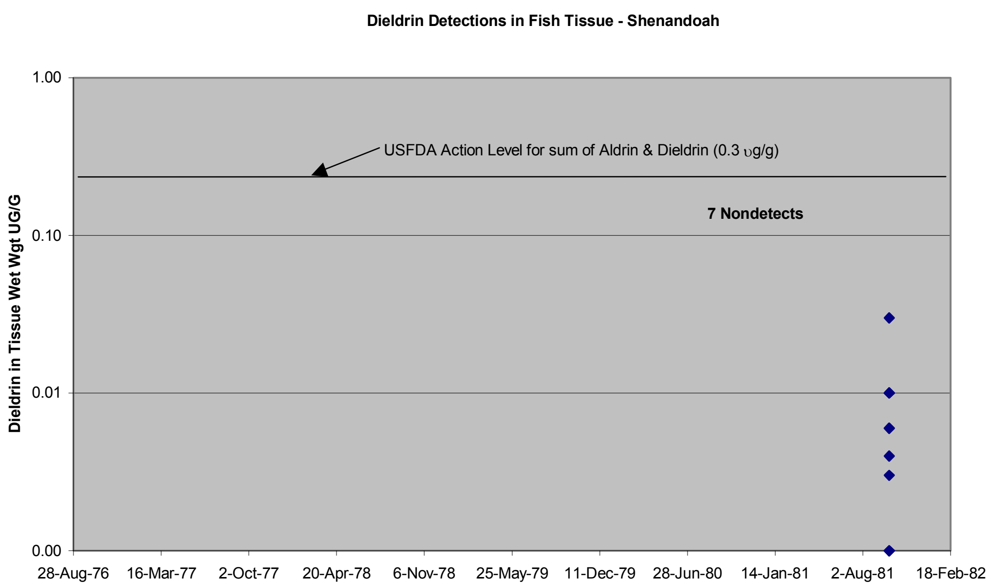

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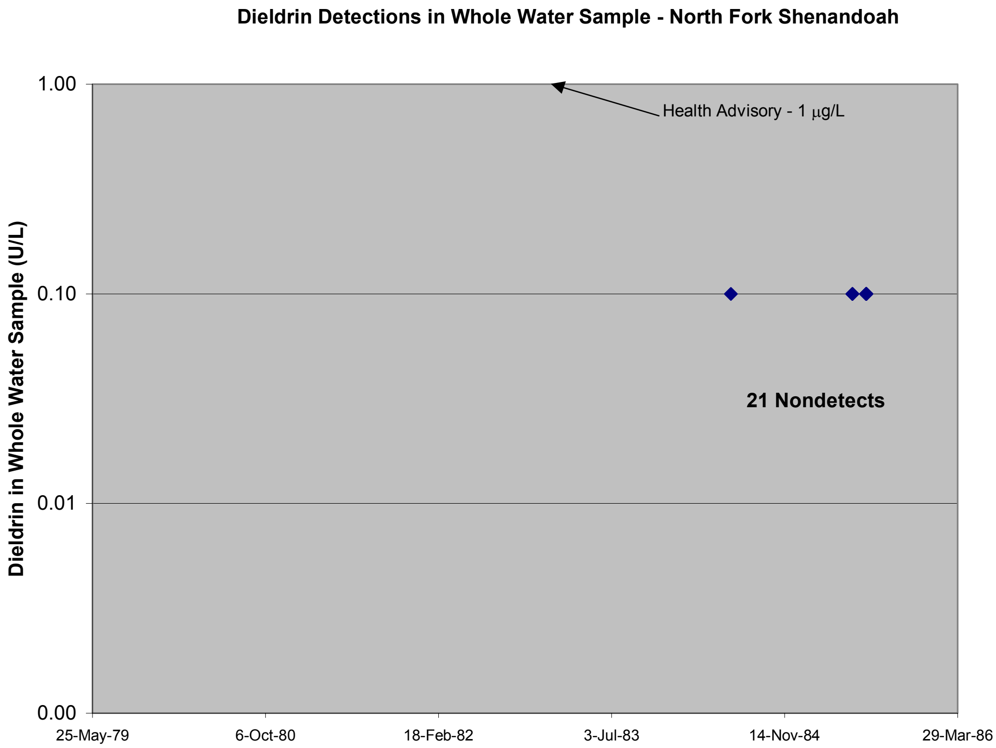

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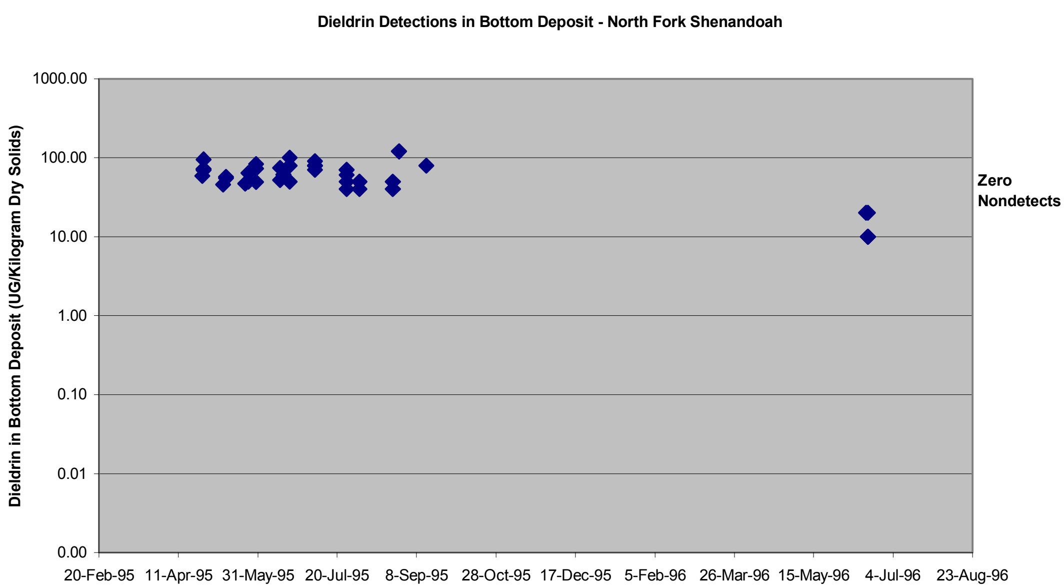

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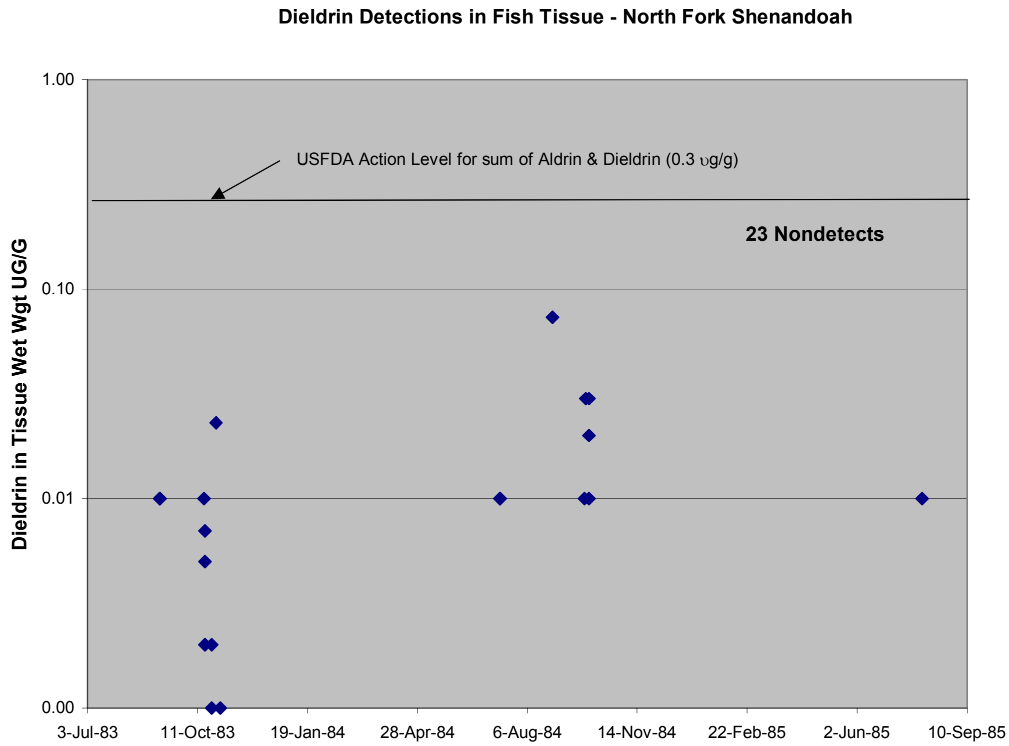

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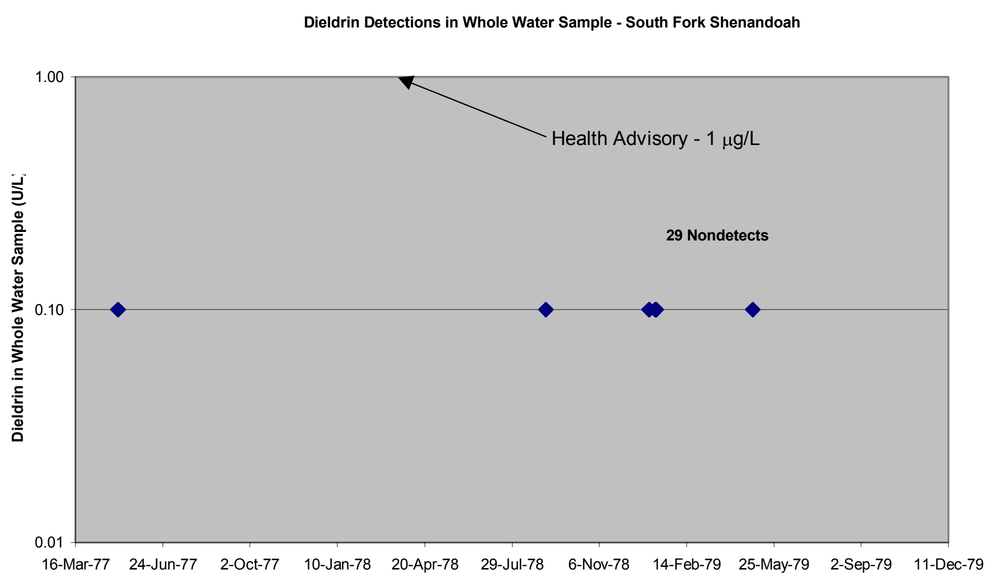

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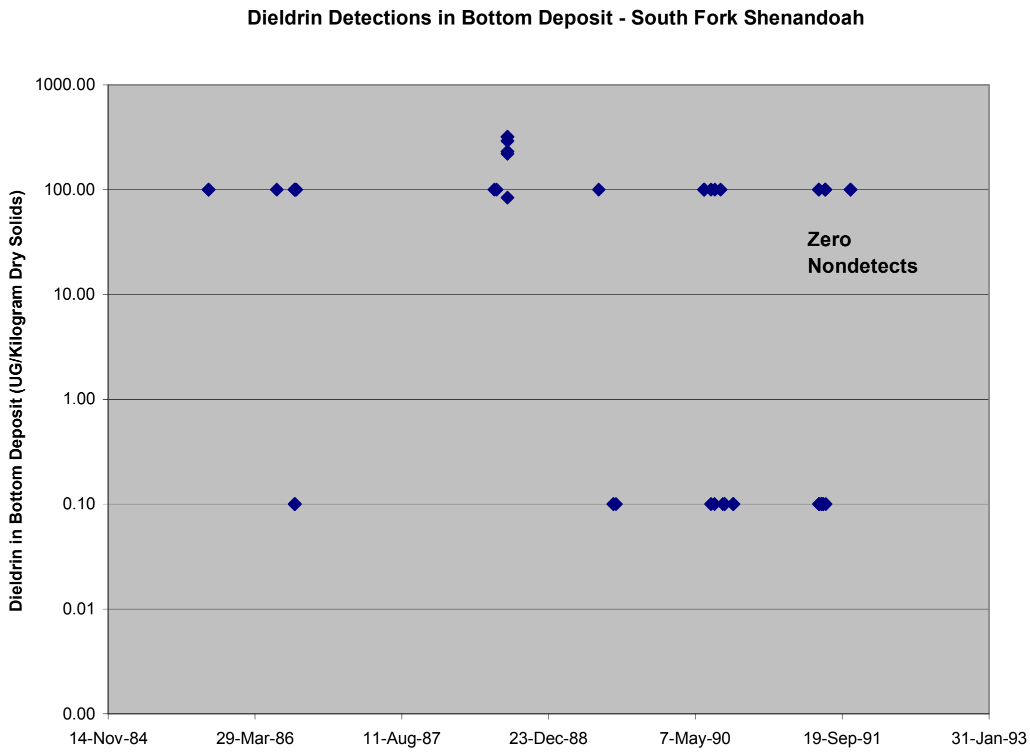

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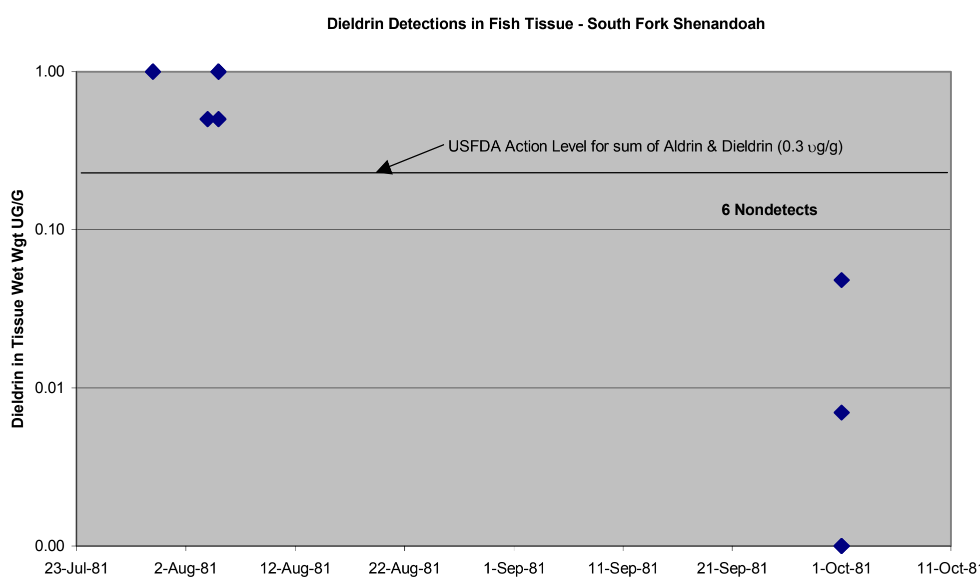

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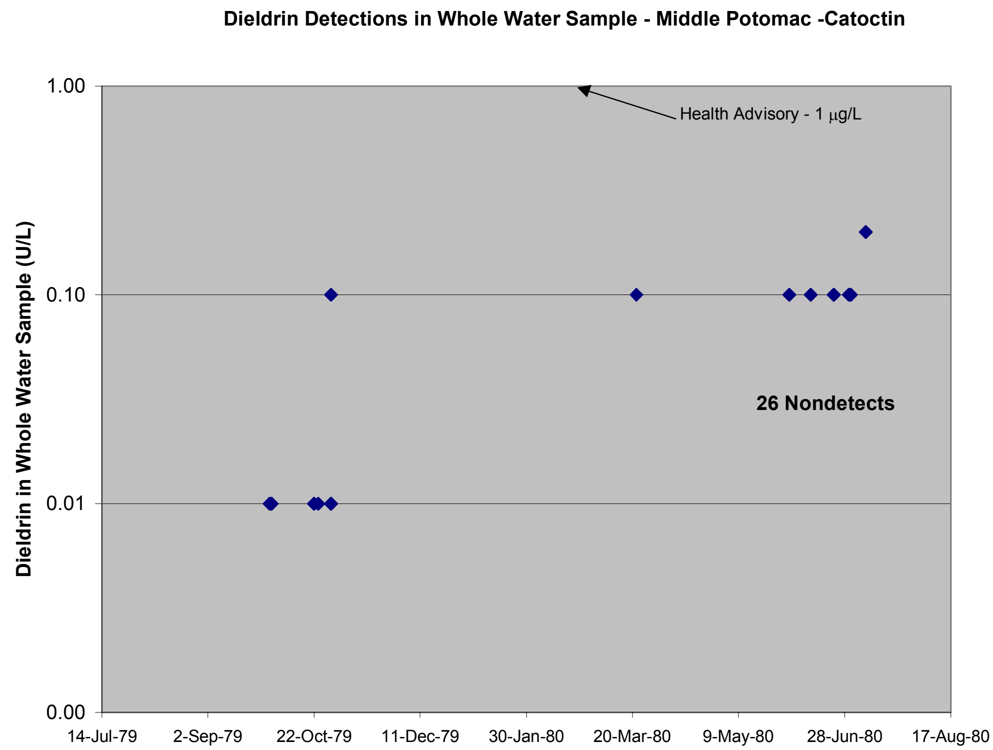

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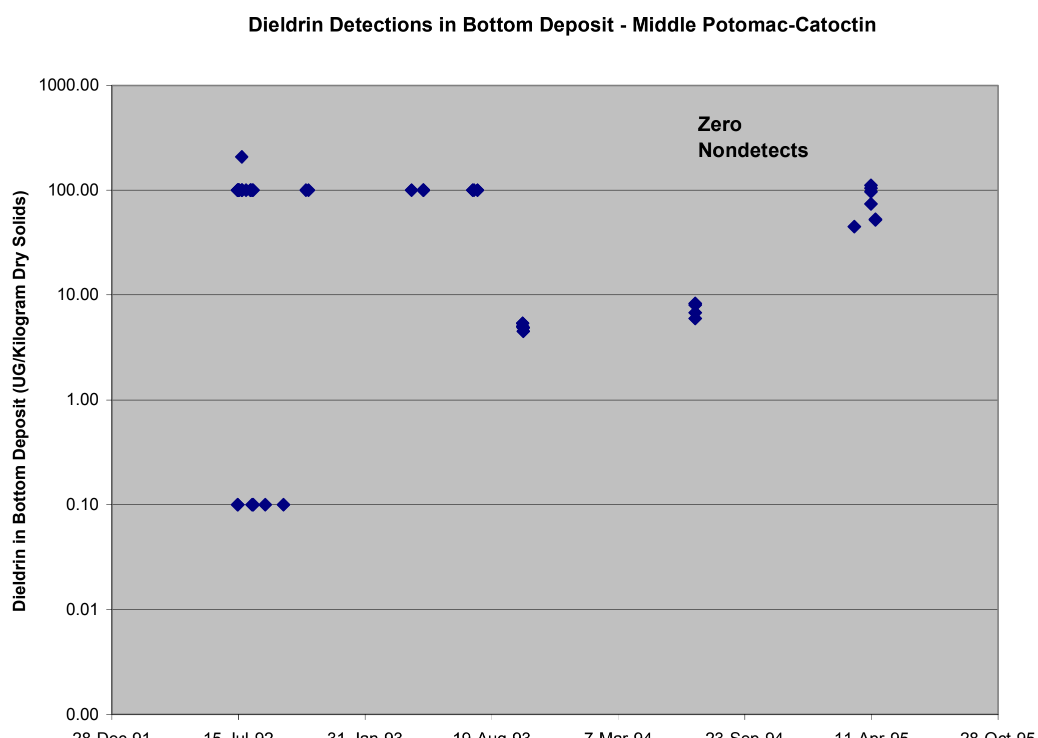

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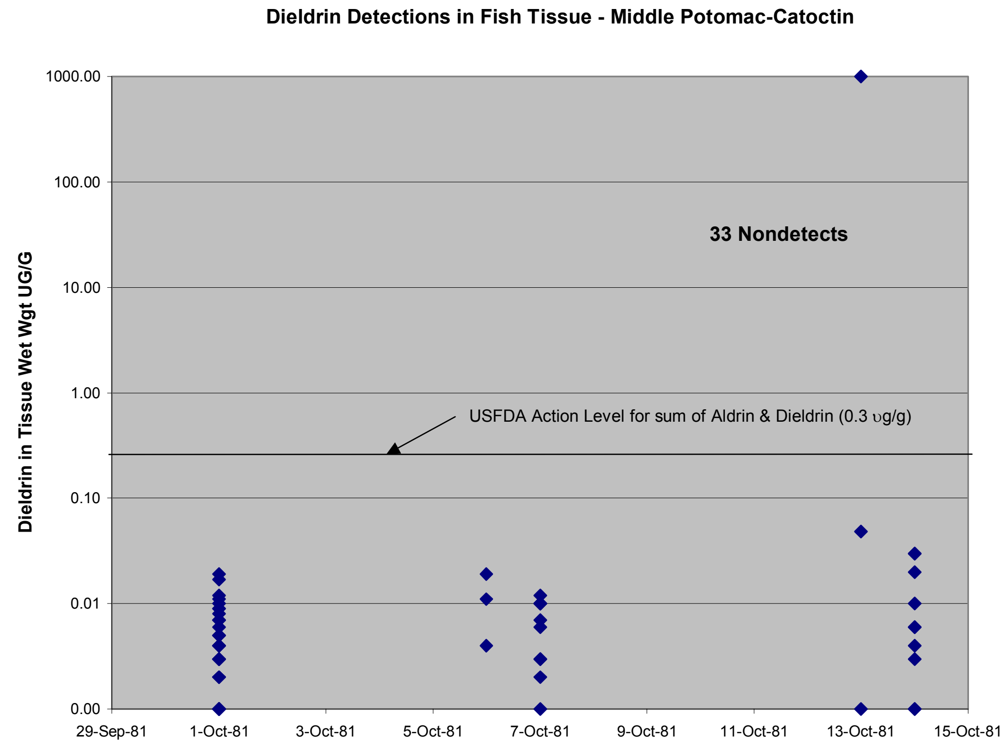

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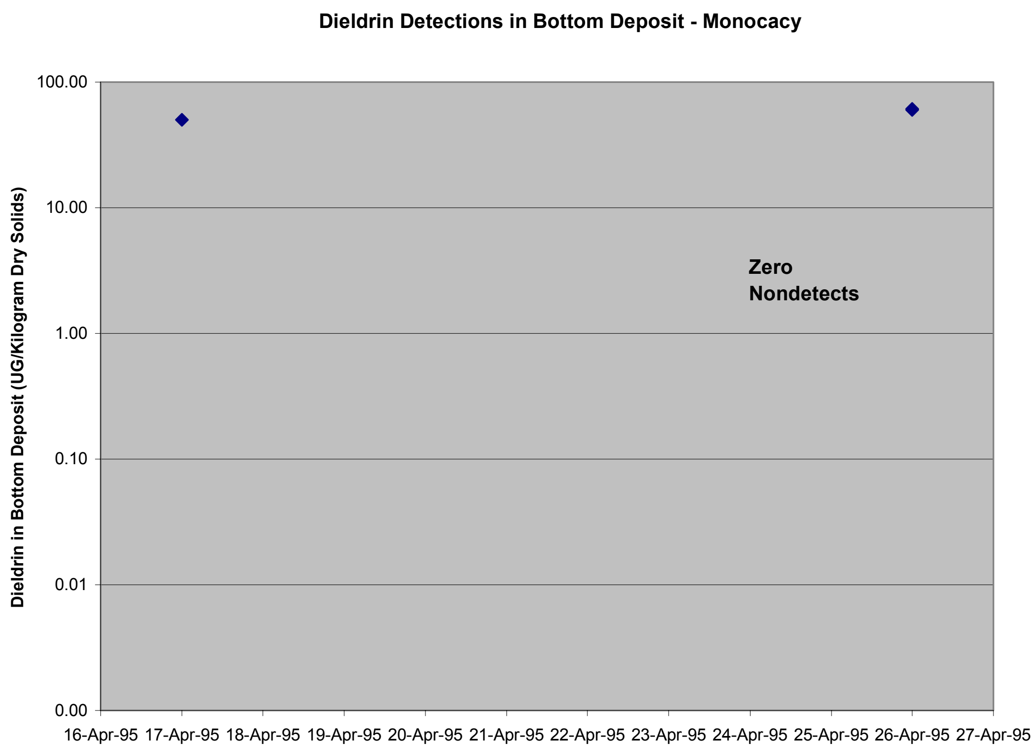

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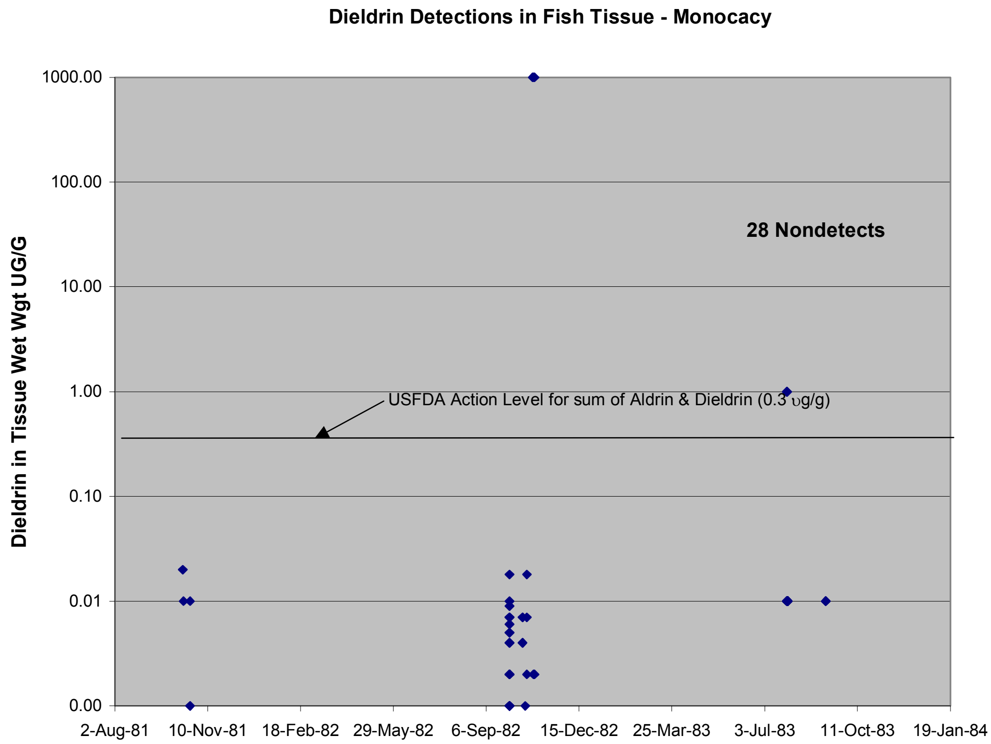
Dieldrin Detections in Fish Tissue - Monocacy
Dieldrin in Tissue Wet Wgt UG/G
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100.00
10.00
1.00
0.10
0.01
0.00
28 Nondetects
USFDA Action Level for sum of Aldrin & Dieldrin (0.3 ug/g)
2-Aug-81
10-Nov-81
18-Feb-82
29-May-82
6-Sep-82
15-Dec-82
25-Mar-83
3-Jul-83
11-Oct-83
19-Jan-84

Figure A-23

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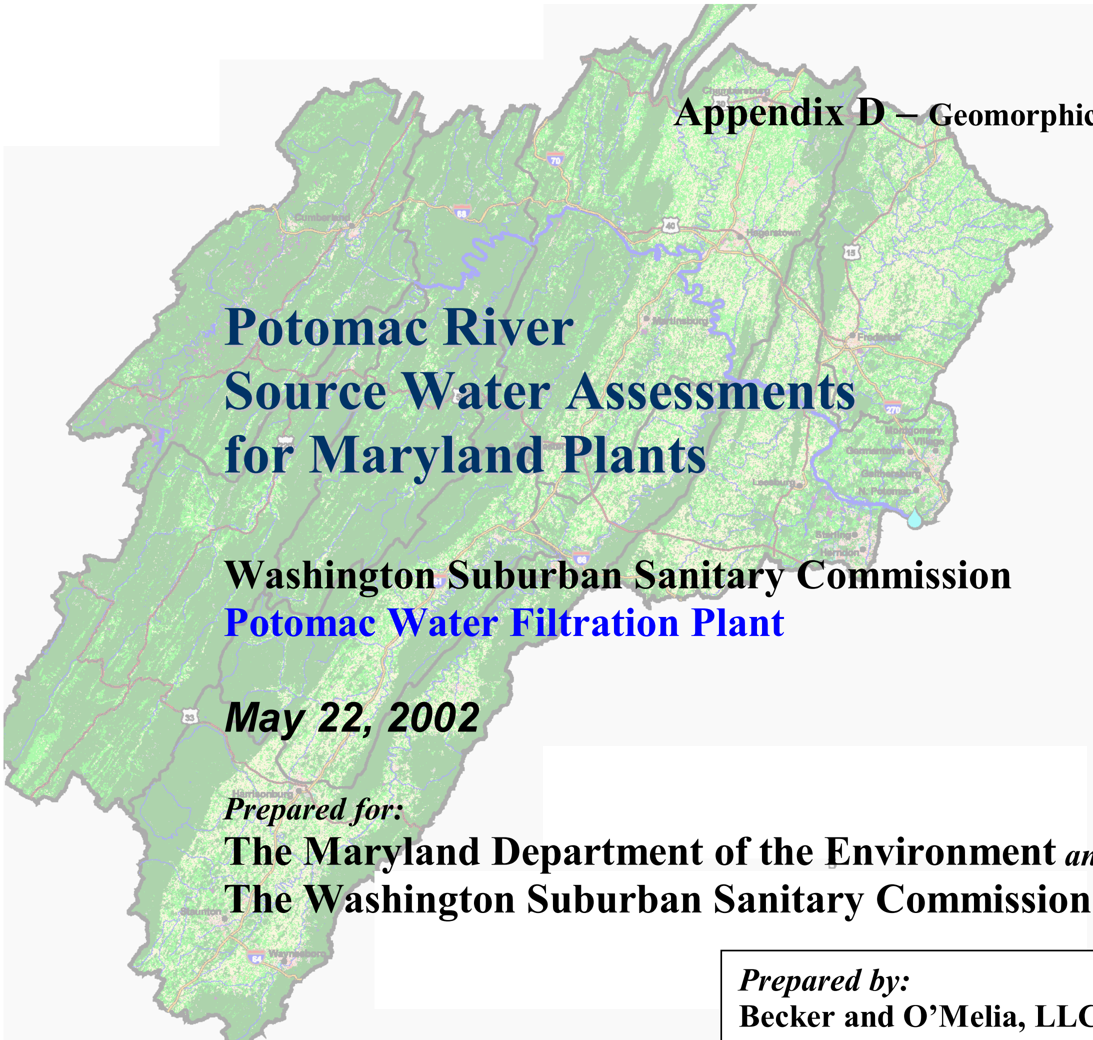


Appendix D – Geomorphic Analysis

Potomac River
Source Water Assessments for Maryland Plants

Washington Suburban Sanitary Commission
Potomac Water Filtration Plant

May 22, 2002

Prepared for:
The Maryland Department of the Environment *and*
The Washington Suburban Sanitary Commission

Prepared by:
Becker and O'Melia, LLC *in association with*
The Center for Watershed Protection , and
Straughan Environmental Sciences, Inc.

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

INTRODUCTION

WSSC, in its effort to understand and manage the protection of drinking water for its customers, has been studying the Potomac River, including its watershed and its tributaries. The purpose of these studies has been to identify potential pollution sources, including non-point source pollutants and sediments, that affect both the quality of the drinking water and the operation of the Potomac Water Filtration Plant (PWFP) (see Figure 1). Recently, increases in sediment and pollutant loads, which decrease the efficiency of the plant's operation, have been observed and reported by the PWFP staff.

WSSC suspects that Watts Branch, a tributary to the Potomac River that empties into the Potomac River just upstream of the PWFP, may be one of the sources of increased sediment because its banks have been eroding over the past several years.

WSSC retained a consultant team, led by Becker and O'Melia and supported by Straughan Environmental Services, Inc. (SES) to further investigate the condition of Watts Branch. WSSC will use the information collected in this investigation and other related studies to decide whether the PFWP intake structures should be relocated, and which best management practices and stream restoration concepts would best protect the Potomac River as a drinking water source.

This memorandum describes the field studies SES conducted to develop an estimate of channel-produced sediment from Watts Branch. The Center for Watershed Protection is using this information to study the empirical relationship between channel enlargement and watershed impervious cover.

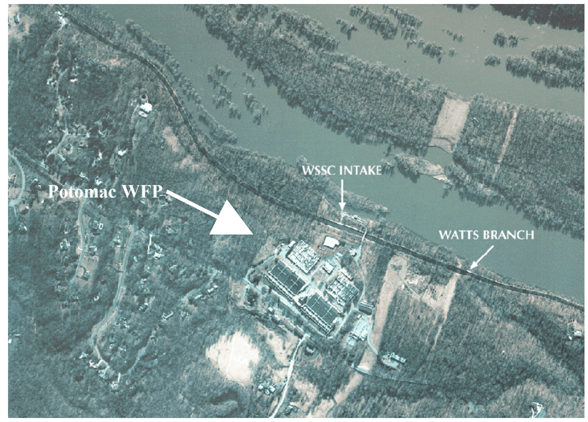


Figure 1: Aerial photograph of the Potomac Water Filtration Plant.

Study Area

The Watts Branch watershed has a drainage area of approximately 22.05 square miles. Watts Branch flows southwest through Rockville and Potomac, Maryland, to its confluence with the Potomac River approximately 1,800 feet north of the PWFP (see Figure 2). Several tributaries, including Piney Branch, flow into Watts Branch north of the Potomac River. Most of Watts Branch flows through a narrow, forested, riparian corridor; however, residential, commercial, transportation (including Interstate 1-270), and recreational uses are present. Due to this development, the watershed consists of approximately 30% impervious surface, which inhibits infiltration of precipitation and causes increased overland flow, which carries higher amounts of sediments and pollutants into Watts Branch.

METHODOLOGY

SES conducted a limited geomorphic survey at eight locations in Watts Branch (see Figure 2 and Table 1).

Table 1
APPROXIMATE LOCATIONS OF SAMPLING STATIONS

Station	WSSC Coordinates*
WBWB 303	65213 N; -50659 E
Station 2	62890 N; -52636 E
WBWB 306	65011N; -51054 E
WBWB 307	57339 N; -58880 E
WBWB 308	56736 N; -60775E
Station 7	54820 N; -63225 E
WBWB 310	Not available
Station 10	56056 N; -71743E

*Indicates location of manhole cover closest to station

The field survey included cross-sectional investigations, longitudinal profile evaluations, Rapid Geomorphic Assessment (RGA), habitat assessment, and sediment analysis at all locations.

Cross-sectional Investigations

Cross-sectional investigations are used to determine bankfull cross-sectional area, stream discharge, and erosion rates by recording and plotting elevations relative to their location along a line perpendicular to the stream channel. Three cross-sections (upstream, midstream, and downstream) were evaluated at each of the eight sampling stations, and the average cross-sectional area at each sampling station was compared to the respective drainage area. All cross-sections were surveyed using methods similar to those outlined in *Stream Channel Reference Sites: An Illustrated Guide to Field Technique* (United States Department of Agriculture, 1994).

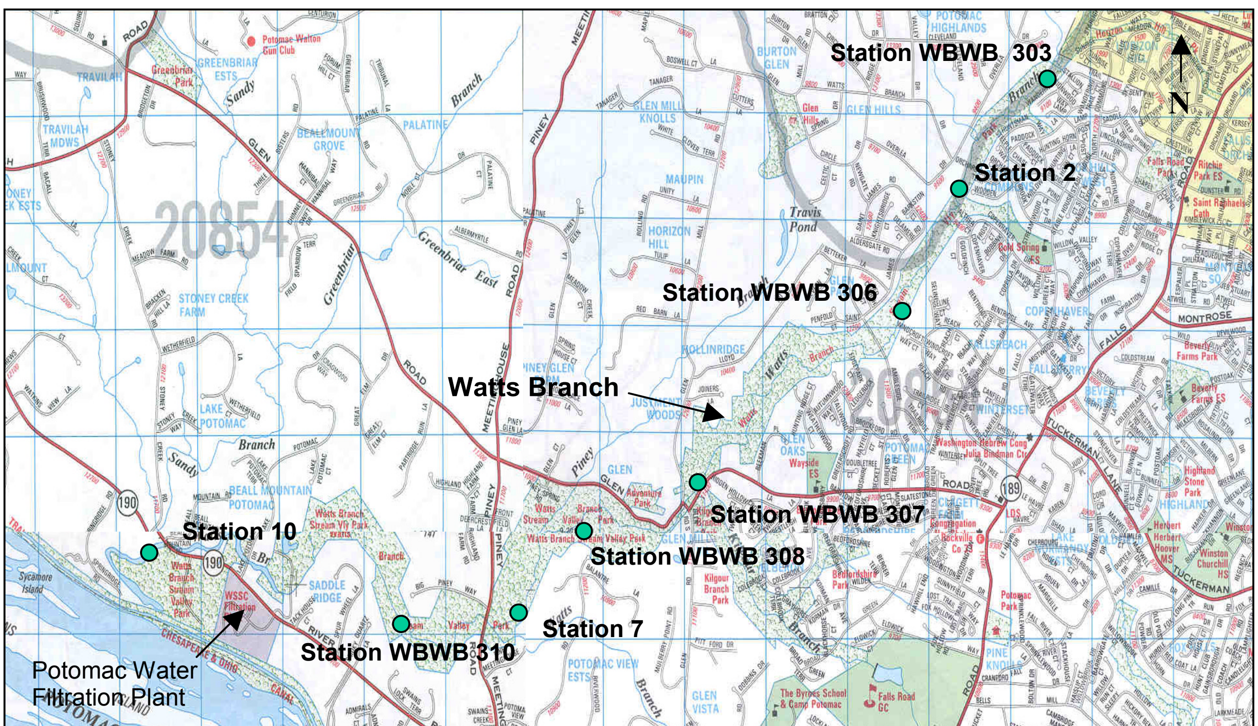


Figure 2: Approximate locations of sampling stations. Basemap Source: Alexandria Drafting Company, 1999. Greater Washington, DC Map. Used with permission. Scale: 1 inch = Approximately 4,000 feet

In addition to the cross-sectional data, SES conducted pebble counts at riffle cross sections (see Figure 3). Pebble counts are conducted by recording sizes of 100 random samples (pebbles), which are plotted against their cumulative percentage. These data yield D35, D50, and D84 designations that correspond to the particle sizes that are equal to, or less than 35%, 50%, and 84% of the collected sample. For example, at station WBWB 303, the D84 particle size is 93.0 mm. This means that 84% of the particles collected at this site are 93.0 mm or less in size and 16% of the particles are greater than 93.0 mm. These data assist in determining stream velocity and predicting erosion rates since larger particles are carried by streams with high velocities.

Figure 3. Station 307, facing upstream at midstream cross section. Date: 8-3-01.

Longitudinal Profiles

Longitudinal profiles yield information required to establish the existing surface water slope, channel bed characteristics, and bankfull stage by determining the bed and water surface elevations relative to the distance measured along the thalweg (deepest part of the stream). Longitudinal profiles were conducted at each station, beginning at the upstream cross-section and extending to the downstream cross-section following methods outlined in *Stream Channel Reference Sites: An Illustrated Guide to Field Technique* (United States Department of Agriculture, 1994).

Slopes were calculated using water surface elevations from the head of an upstream riffle to the head of a downstream riffle along each longitudinal profile.

Rapid Geomorphic Assessment

SES conducted an RGA at each of the eight stations to characterize the current and past geomorphic conditions of the stream and to support the development of the enlargement data (see Figure 4). The RGA provides an assessment of the stream's current stability and can be used to determine if a stream reach is aggrading or degrading (accumulating or losing sediment). The RGA score is tabulated to determine if a stream reach is geomorphically stable, transitional (showing signs of stress), or in adjustment (evolving towards a new equilibrium position).

Figure 4. Station 303, stream assessment crew documenting results of RGA and Habitat Assessment Surveys. Date: 8-2-01

Habitat Assessment

SES conducted a habitat assessment at each station. To record the data, SES used the Habitat Assessment Field Data Sheet similar to that in Appendix A of *Rapid Bioassessment Protocols For Use in Wadeable Streams and Rivers: Periphyton, Benthic, Macroinvertebrates, and Fish* (EPA, 1999).

The following ten habitat parameters were evaluated at each sample point:

- Epifaunal substrate/available cover;
- Embeddedness;
- Velocity/depth regime;
- Sediment deposition;
- Channel flow status;
- Channel alteration;
- Frequency of riffles;
- Bank stability;
- Vegetative protection; and
- Riparian vegetative zone width.

These habitat assessment parameters were ranked using a numeric scale from 0 to 20 (with 20 as the most favorable) to assess the quality of instream habitat for macroinvertebrates and fish. A final habitat ranking was determined by summing the ratings for each of the 10 habitat parameters. A score between 166 and 200 is indicative of optimal habitat; a score between 113 and 166 is indicative of suboptimal habitat; a score between 60 and 113 is indicative of a marginal habitat; and a score between zero and 60 is indicative of poor habitat.

FINDINGS

Cross Sectional Investigations

Average cross sectional areas ranged from 123.7 square feet at Station WBWB 303 to 235.8 square feet at Station 10. A positive relationship was evident between cross-sectional area and watershed area (i.e., average cross-sectional area increased with increasing contribution from the watershed). Table 2 presents the data associated with the cross-sectional areas.

No observable trend was evident from the pebble count data collected at the mid-stream cross section at each station. Table 3 presents the D35, D50, and D84 particle sizes. Examples of the variable substrate encountered during the field investigation are shown in the following photographs.

Figure 5. Station 303, streambed at midstream cross section. Streambed consists primarily of silt with some cobble, indicating a flat, relatively deep pool area of the stream. Date: 8-2-01.

Figure 6. Station 307, streambed at midstream cross section. Streambed consists primarily of cobble, indicating higher velocities and a greater slope than those that occur within the reach shown in Figure 5. Date: 8-3-01

Table 2 CROSS-SECTIONAL AREAS AND ASSOCIATED DRAINAGE AREAS					
	Cross-Sectional Area (square feet)				Associated Drainage Area
Station Number	Upstream	Midstream	Downstream	Average	(square miles)
WBWB 303	122.7	100.6	148.0	123.7	6.32
Station 2	124.5	145.9	98.3	122.9	7.29
WBWB 306	138.6	117.3	144.2	133.4	8.28
WBWB 307	147.9	120.2	135.5	134.5	9.16
WBWB 308	173.7	98.4	155.1	142.4	10.87
Station 7	149.3	144.4	188.6	160.7	14.63
WBWB 310	165.2	197.3	155.7	167.9	15.83
Station 10	183.5	260.1	263.9	235.8	22.05

Table 3 PEBBLE COUNT DATA			
Station Number	D34 (mm)	D50 (mm)	D84 (mm)
WBWB 303	9.92	28.6	93.0
Station 2	4.0	23.6	72.0
WBWB 306	0.21	2.0	64.0
WBWB 307	22.99	32.0	64.0
WBWB 308	0.18	0.4	52.0
Station 7	24.16	34.1	101.0
WBWB 310	14.12	25.6	49.0
Station 10	2.55	11.8	89.0

Longitudinal Profile Investigations

Results of the longitudinal profile investigations indicated that a diverse habitat is present in Watts Branch that includes deep pools, glides, runs, and some riffle environments. Based on observations of bed materials and channel structures, many of the riffles are unstable. As a result, the riffles are beginning to lose their ability to retain appropriately sized particles required to hold the riffles in place. Slopes determined from longitudinal profiles ranged from 0.010% to 0.569% (see Table 4).

Table 4 WATER SURFACE SLOPES DETERMINED FROM LONGITUDINAL PROFILE DATA	
Station	Percent Slope
WBWB 303	0.010
Station 2	0.569
WBWB 306	0.397
WBWB 307	0.271
WBWB 308	0.317
Station 7	0.553
WBWB 310	0.096
Station 10	0.067

Rapid Geomorphic Assessment

SES observed evidence of aggradation at all eight stations, and observed evidence of degradation at Stations WBWB 307, WBWB 310, and 10. None of the stream reaches at these stations were classified as "stable" (channel metrics are within the expected range of variance [i.e., one standard deviation from the mean]). All stream reaches were classified as either "transitional" (channel metrics are within expected range of variance for a stable condition but channel shows signs of stress), or "in adjustment" (channel is outside of the expected range of variance and evolving toward a new equilibrium position). Table 5 presents information collected during the RGA and Figure 7 illustrates an example of eroded banks that were encountered during the field investigation.

Table 5 RAPID GEOMORPHIC ASSESSMENT DATA			
Station Number	**Evidence of Aggradation**	**Evidence of Degradation**	**Current Status of Stream Reach**
WBWB 303	Yes	No	Transitional
Station 2	Yes	No	In Adjustment
WBWB 306	Yes	No	Transitional
WBWB 307	Yes	Yes	In Adjustment
WBWB 308	Yes	No	In Adjustment
Station 7	Yes	No	Transitional
WBWB 310	Yes	Yes	In Adjustment
Station 10	Yes	Yes	In Adjustment

Figure 7. Station 2, facing left bank at midstream cross section. Note severely eroded banks. Date: 8-15-01.

Figure 8. Station 306, facing right bank at midstream cross section. Note woody debris. Date 8-2-01.

Habitat Evaluation

Five of the sampling stations were classified as having suboptimal habitat and three of the sites were classified as having marginal habitat (see Table 6). Channel Alterations and Riparian Vegetation Zones consistently scored in the optimal range at most of the stations, and vegetative bank cover and bank stability scored in the marginal category; however, most other parameters received variable scores. The accompanying photographs illustrate examples of the diverse habitat encountered during the field investigation.

Figure 9. Station 308, facing right bank at midstream cross section. Note pool habitat. Date 8-4-01.

Table 6 SUMMARY OF HABITAT ASSESSMENT SCORES											
Sampling Station number	**Epifaunal Substrate/ Available Cover**	**Embeddedness**	**Velocity/ Depth Regime**	**Sediment Deposition**	**Channel Flow Status**	**Channel Alteration**	**Frequency of Riffles**	**Bank Stability (LB/RB)**	**Vegetative Protection (LB/RB)**	**Riparian Vegetative Zone Width (LB/RB)**	**Overall**
WBWB 303	M	M	S	M	S	O	S	M/ S	S/ P	O/ S	S
Station 2	M	M	S	M	S	O	M	P/P	M/M	O/O	S
WBWB 306	S	M	S	M	S	O	S	S/ M	S/ M	O/O	S
WBWB 307	S	M	S	S	S	O	O	M/M	M/M	M/M	S
WBWB 308	S	S	S	M	M	O	O	M/M	M/M	O/O	M
Station 7	S	S	M	M	S	O	O	M/M	M/M	M/O	M
WBWB 310	M	M	M	P	S	O	P	P/P	M/M	O/O	M
Station 10	S	S	O	M	S	S	S	P/ M	M/M	O/O	S

Key: O=Optimal, S=Suboptimal, M=Marginal, and P=Poor

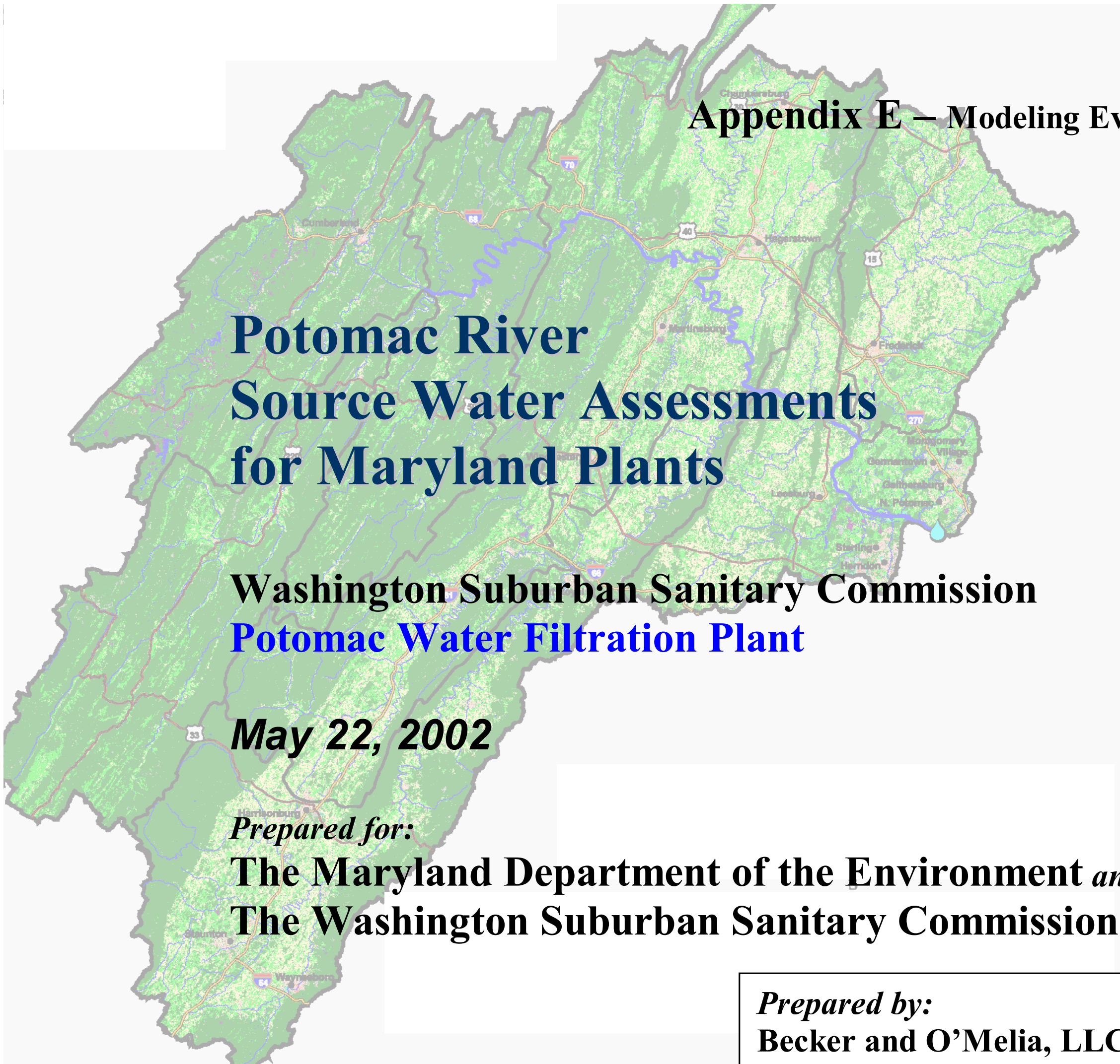
DISCUSSION

The results of the limited geomorphic study indicate that Watts Branch is in a transitional state. Preliminary observations made in the field associated with cross sectional, longitudinal, RGA, and habitat data indicate that Watts Branch is adjusting to conform with changes most likely related to increases in impervious cover due to urbanization. Additional sediment analysis and entrainment studies are needed to verify initial results of the limited geomorphic analysis and to identify more precisely the cause of the system's instability.

The instability of the riffle habitats is most likely due to increased impervious surface coverage in the watershed and increased velocities that transport larger particles, including those that once helped maintain stable riffle habitats. The loss of riffle habitats will most likely result in a reduction of macroinvertebrate habitat and a decrease in food sources for other stream inhabitants.

Additional information will be generated from the data presented in this memorandum through the development of the empirical relationship between channel enlargement and watershed impervious cover. This relationship is being developed by the Center for Watershed Protection. As outlined previously, information generated through these studies may ultimately be used in decision making processes associated with best management practices, restoration concept plans, and the potential relocation of the Potomac Water Filtration Plant intake structure.

Appendix E – Modeling Evaluations



Potomac River Source Water Assessments for Maryland Plants

Washington Suburban Sanitary Commission
Potomac Water Filtration Plant

May 22, 2002

Prepared for:
The Maryland Department of the Environment *and*
The Washington Suburban Sanitary Commission

Prepared by:
Becker and O'Melia, LLC *in association with*
The Center for Watershed Protection,
Straughan Environmental Sciences, Inc.,
Limno Tech Inc., and
Delon Hampton, Chartered

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

Introduction

This appendix presents the approach, results, and findings of the 1-dimensional fate and transport modeling, the watershed modeling, and the 2-dimensional hydrodynamic modeling carried out in the SWA for the WSSC's Potomac WFP. The appendix is organized into three major sections as the work was performed (1-dimensional fate and transport modeling, watershed modeling, and 2-dimensional hydrodynamic modeling – subwatershed contribution assessment). Becker and O'Melia, LLC oversaw the overall modeling effort and performed the 1-dimensional fate and transport modeling using a truncated version of the EPA-Chesapeake Bay Program Office's Chesapeake Bay Watershed Model. The Center for Watershed Protection performed the watershed modeling using their Watershed Treatment Model. LimnoTech, Inc., with assistance from Delon Hampton Associates, Chartered, performed the 2-dimensional modeling of the Potomac River from the Watts Branch confluence to the existing and potential intakes using the Cornell Mixing Zone Model (CORMIX), and also evaluated the impacts of Seneca Creek on the intake.

Overall Modeling Task and One-Dimensional Fate and Transport Modeling

Model Selection

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

The modeling needs of the project include:

- modeling of current conditions in the watershed,
- future conditions in the watershed,
- the application of various management scenarios,
- fate and transport in the main stem of the Potomac River, and
- 2-D modeling of the river reach from the confluence with Watts Branch to the weir structure just downstream of the location of the existing and proposed intakes.

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

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

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

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

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

2 - The number of contaminants identified in Task 3a, or surrogates for those contaminants, for which fate and transport algorithms have been developed, CBWM – the model was developed and has been employed primarily to evaluate nutrients, and includes fairly sophisticated nutrient cycle simulations. TSS simulations have also been developed, calibrated and validated. The model has the capacity to run other contaminants but may require programming of additional subroutines.

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

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

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

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

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

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

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

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

5 - Model calibration for sediment fate and transport,

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

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

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

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

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

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

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

In performing the model selection and literature review subtasks two software packages have been considered for the Task 5, 1-D fate and transport modeling. The Chesapeake Bay Watershed Model (CBWM), fits the needs of the project scope of work. The other, Basins (an EPA modeling software package which has been applied throughout the US to perform evaluations similar to this task), is a powerful tool and can also fit the needs of the project.

However, application of Basins to this project would require significant efforts in model construction and calibration that are not consistent with the project approach. In order to accomplish the project's technical challenges and to meet the schedule and budget, the Chesapeake Bay Watershed Model was selected for Task 5a, 1-D modeling.

Modeling Approach

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

- evaluate and quantify the impacts of existing point and non-point sources on the Potomac WFP raw water quality, considering both the existing intake and potential future midriver intake locations;
- evaluate and quantify the likely impacts of future point and non-point sources on raw water quality;
- evaluate the impact of these raw water contaminant concentrations on drinking water treatability at the Potomac WFP;
- evaluate the potential for applying BMPs and BATs to mitigate the existing and future impacts on the WFP; and
- evaluate the impact on drinking water treatability of relocating the intake to a ptential midriver location.

In order to accomplish these goals, three modeling packages were used including the Center for Watershed Protection's Watershed Treatment Model (WTM), the Chesapeake Bay Watershed Model, and The Cornell Mixing Zone Model (CORMIX).

In order to evaluate the relative impacts of Watts Branch on the WFP, the watershed was evaluated in three parts:

- the watershed above Watts Branch,
- the Watts Branch watershed, and
- the Potomac River, north of Watkins Island, from the confluence with Watts Branch to the existing and proposed intake locations.

These areas are shown schematically on Figure 1.

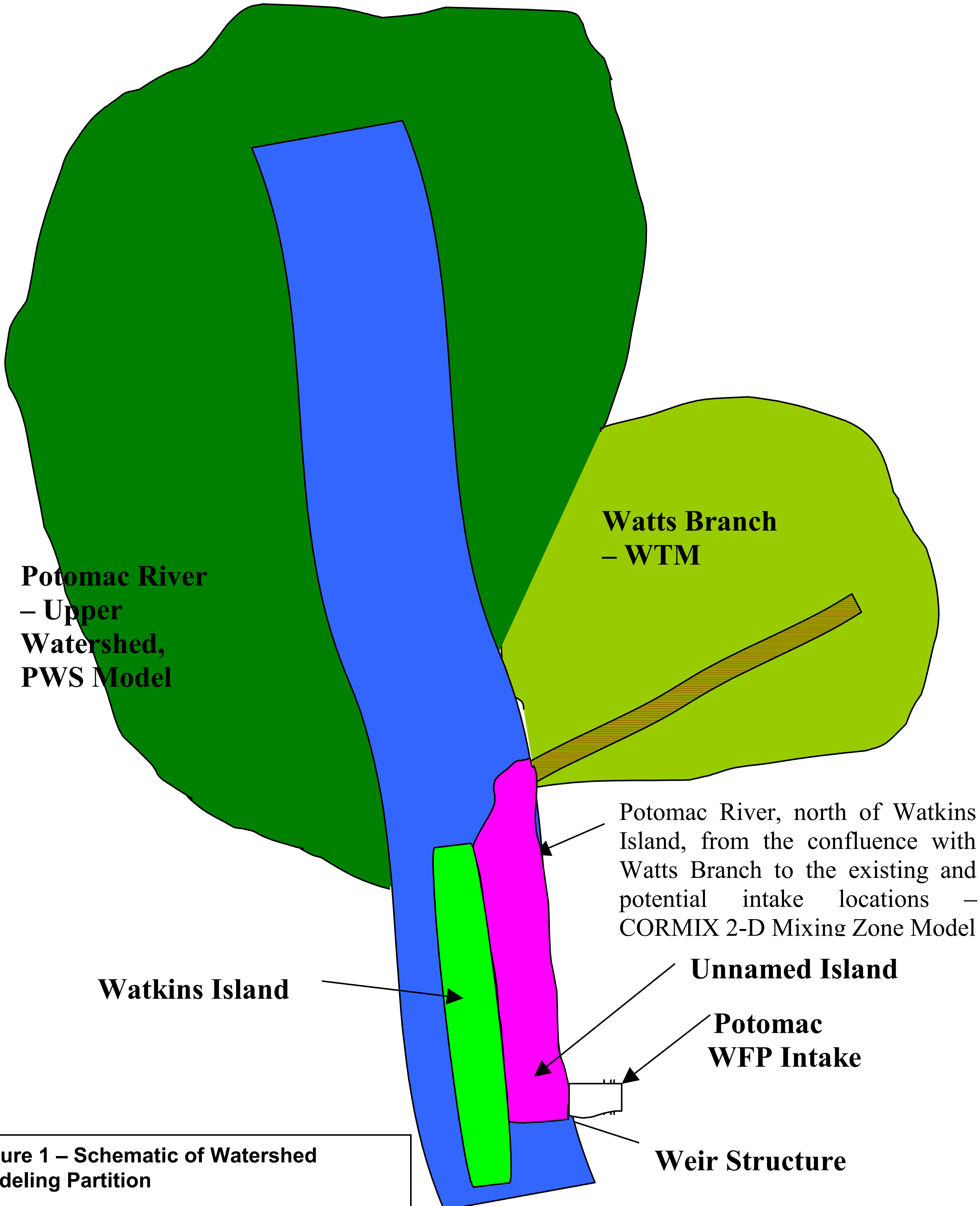


Figure 1 – Schematic of Watershed Modeling Partition

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

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

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

Results of 1-D Modeling of Watershed above Watts Branch

Results of 1-D Modeling of Watershed above Watts Branch

General Results

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

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

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

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

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

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

Regardless of these modeling results, simple mass balance considerations indicate that application of these practices will eventually have beneficial impacts roughly equivalent to the impacts on "edge-of-stream" loading (for example, a 10% reduction in phosphorus loading should eventually reduce algal activity by approximately 10%). This is also consistent with reported results by the EPA's Chesapeake Bay Program Office, which assume instantaneous changes in the streambed and have noted significant reductions in nutrient concentrations and algal activity. Based on the geomorphological evaluations performed as part of this study, for contaminants associated with sediment (including nutrients, diedrin, and turbidity), the beneficial impact may lag years behind the implementation of the practices. Dieldrin (banned years ago, yet still detected in whole water and sediment samples) is a good example of this phenomeneon. Dieldrin loading was reduced or nearly eliminated after its banning and the benefits of this management practice are yielding significant benefits now. However, dieldrin could still be associated with sediment in the watershed, both on the land and in the streambed.

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

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

Potomac River Above Watts Branch – Summary Results

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

[1] Rose, J.B., 1997

The modeling approach was utilized to analyze the susceptibility of the Potomac WFP water supply to contamination from the identified contaminants of concern. 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.

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

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

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

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

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

- The only contaminant in Group 1 which was explicitly modeled under the modeling approach was sediment/turbidity. The modeling results indicated the following regarding sediment:
    - The future “no management” scenario predicts small increases in sediment concentrations, whereas under the “aggressive” scenario, predicted solids peaks are actually *reduced* by 4% from current peaks.
    - The predicted changes are the net result of management practices in upstream subwatersheds and in-stream processes. Because solids are stored in the Potomac streambed, little change in sediment concentrations was noted under any scenario. It is important to note that the Center for

Watershed Protection's Watershed Treatment Model predicts significant sediment edge-of-stream load reductions for some subwatersheds with "aggressive" implementation of management practices (as described below). Even though these reductions translate into only modest reductions at the Potomac Plant intake, they could be significant for local water quality improvements as well as other Potomac water plants upstream, further supporting the recommendations.

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

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

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

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

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

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

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. (note: while ammonia is generally modeled as part of the nitrogen cycle, the ammonia peaks observed in the raw water are attributed to storm runoff containing ammonia in road deicing compounds). Based on plant operating experience, the taste and odor producing compounds present in the raw water seem to be removed efficiently in the Potomac plant, and therefore further analysis of this contaminant of concern was not conducted. The reported occasional taste and odor problems appear to be due to winter ammonia peaks, which can react with chlorine to form offensive chloramine compounds. Also, as indicated previously, dieldrin has not been manufactured for several decades and levels are eventually expected to decrease throughout the watershed.

Watershed Treatment Modeling

Overview

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

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

Modeling in Watts Branch was much more detailed than modeling in the Upper Watershed, due to the scale at which modeling was conducted, and the resulting additional available data. In addition, Watts Branch is highly urbanized relative to the Upper Watershed. As a result, the management scenarios focus on the urban rather than the rural land uses in this watershed. For each section of this document, the modeling assumptions and results are discussed separately for Watts Branch and the Upper Watershed.

This document is organized as follows:
- Land Use
- Pollutant Sources
- Management Practices
- Management Scenarios
- Modeling Results

Land Use

Watts Branch Land Use

The current and future land uses in Watts Branch (See Figure 2) are summarized in Table 2. Because this watershed is mostly urbanized, rural land uses were lumped into the broad "rural" category. Future land use was characterized by simply assuming existing zoning across the watershed, and assuming that all forest in the riparian buffer remains in its current state.

Figure 1. Watershed Model Segments in the Upper Watershed

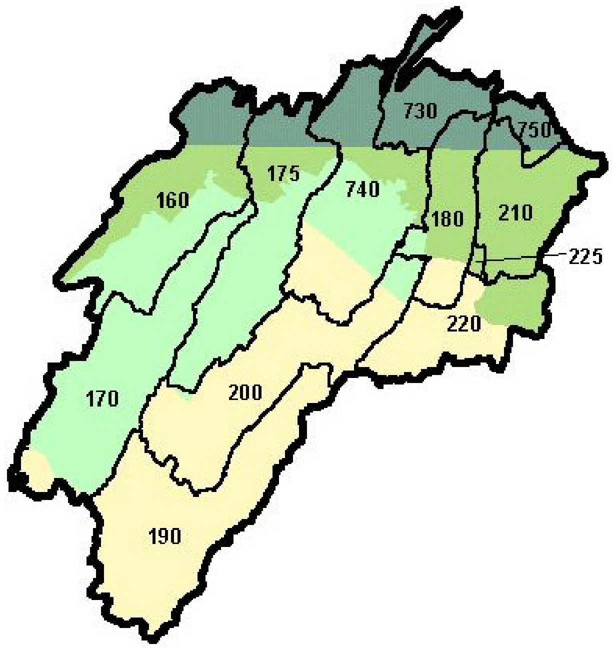


Figure 2. Land Use in Watts Branch

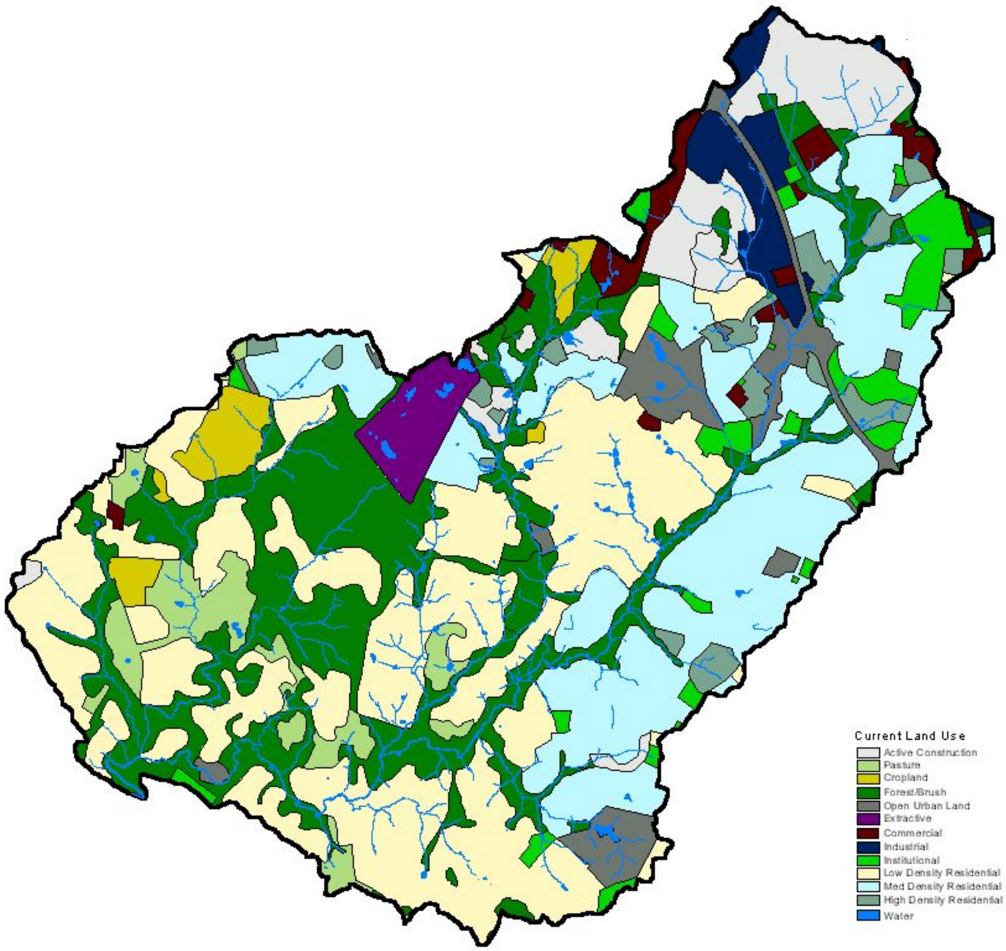


Table 2. Current and Future Land Use in Watts Branch

Land Use Category	Impervious Cover	Area in 1997 (acres)	Area in 2020 (acres)	Change (acres)
Low Density Residential	11%	4,183	6,291	2,108
Medium Density Residential	23%	3,338	3,339	1
High Density Residential	40%	380	1,109	729
Commercial	72%	300	301	1
Roadway	80%	651	651	0
Industrial	53%	389	437	48
Forest	0%	3,015	1,906	(1,110)
Rural	0%	1,162	0	(1,162)
Open Water	0%	10	10	(9)
Active Construction	0%	818	201	(617)
Vacant Land	0%	0	0	0
Resulting Impervious Cover (%)		**16.3%**	**20.4%**	

In order to assess the impervious cover associated with each land use we applied impervious cover were applied, using data primarily adapted from Cappiella and Brown (2000), which reports impervious cover data for various land use types throughout the Chesapeake Bay Basin. These impervious cover data are also reported in Table 2. As a confirmation, these assumptions were compared with impervious cover estimates made by summing up actual impervious cover, in the form of buildings, roads, and driveways. The results were very similar; the estimate derived from this land use-impervious cover relationships was 16.3%, versus the 16.1% derived from actual summation of impervious cover.

The future land use in the upper (Rockville) portion of Watts Branch was taken from the Watts Branch Watershed Plan (City of Rockville, 2001) assuming full buildout. For the portion of Watts Branch in Montgomery County, future land use was characterized by equating zoning categories to the land use categories described earlier (Table 3), and assuming full build-out. Land use changes were reflected by the conversion of rural and forestland to new zoned land use. Watts Branch is largely built out, with much of future development (by total area) occurring as low density development in the lower watershed (See Table 2).

TABLE 3. AREA WITHIN EACH ZONING CATEGORY IN THE MONTGOMERY COUNTY PORTION OF WATTS BRANCH

Montgomery County Zoning Code	Zoning Category	Watershed Treatment Model Land Use	Area (Acres)
C1	Convenience Commercial	Commercial	4.1
C2	General Commercial		0.2
RS	Rural Service Zone/Ag Zone		22.1
C3	Highway Commercial		0.7
C4	Limited Commercial		3.7
MXN	Mixed Use Neighborhood Zone/PUD	High Density Residential	168.3
PD3	Planned Unit Development		36.0
RT100	Residential Townhouse		0.2
I2	Heavy Industrial	Industrial	283.7
LSC	Life Sciences Center		50.4
R90	Single Family	Low Density Residential	7.7
R90 PRU12			20.9
RE			19.1
RE1			1186.9
RE2			4829.1
RE2C			391.7
RE2TDR			49.0
R150	Single Family	Medium Density Residential	288.8
R200 I			780.3
R200 TDR			617.7

Active construction in the future is represented as the average land developed per year between 1997 and 2020, times 1.5, or approximately 6.5% of the total development. This assumes that all zoned development will occur, and remain in construction for an average of 18 months. Construction is not a zoned land use, and the zoned land needs to be adjusted to account for this. Consequently, the increase in acreage for each urban land use category was reduced by 6.5%.

Upper Watershed

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

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

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

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

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

Current Land Use

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

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

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

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

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

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

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

Future Land Use

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

TABLE 7. FRACTION OF EACH COUNTY'S AREA IN EACH WATERSHED SEGMENT												
	160	170	175	180	190	200	210	220	225	730	740	750
Maryland Counties												
WASHINGTON	0%	0%	9%	46%	0%	0%	0%	0%	0%	1%	44%	0%
MONTGOMERY	0%	0%	0%	0%	0%	0%	6%	48%	0%	0%	0%	0%
GARRETT	36%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
FREDERICK	0%	0%	0%	21%	0%	0%	72%	0%	4%	0%	0%	2%
CARROLL	0%	0%	0%	0%	0%	0%	45%	0%	0%	0%	0%	2%
ALLEGANY	63%	0%	40%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Pennsylvania Counties												
ADAMS	0%	0%	0%	1%	0%	0%	12%	0%	0%	5%	0%	30%
BEDFORD	13%	0%	16%	0%	0%	0%	0%	0%	0%	0%	0%	0%
FRANKLIN	0%	0%	0%	13%	0%	0%	0%	0%	0%	62%	5%	0%
FULTON	0%	0%	6%	0%	0%	0%	0%	0%	0%	0%	61%	0%
SOMERSET	11%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Virginia Counties												
AUGUSTA	0%	0%	0%	0%	75%	0%	0%	0%	0%	0%	0%	0%
CLARKE	0%	0%	0%	0%	0%	81%	0%	0%	0%	0%	19%	0%
FAIRFAX	0%	0%	0%	0%	0%	0%	0%	6%	0%	0%	0%	0%
FAUQUIER	0%	0%	0%	0%	0%	0%	0%	23%	0%	0%	0%	0%
FREDERICK	0%	0%	0%	0%	0%	29%	0%	0%	0%	0%	71%	0%
HIGHLAND	0%	26%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
LOUDOUN	0%	0%	0%	25%	0%	0%	0%	70%	0%	0%	0%	0%
PAGE	0%	0%	0%	0%	97%	3%	0%	0%	0%	0%	0%	0%
ROCKINGHAM	0%	0%	0%	0%	55%	45%	0%	0%	0%	0%	0%	0%
SHENANDOAH	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
WARREN	0%	0%	0%	0%	39%	62%	0%	0%	0%	0%	0%	0%
West Virginia Counties												
BERKELEY	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%
GRANT	51%	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
HAMPSHIRE	3%	28%	69%	0%	0%	0%	0%	0%	0%	0%	0%	0%
JEFFERSON	0%	0%	0%	22%	0%	46%	0%	0%	0%	0%	32%	0%
MINERAL	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
MORGAN	0%	0%	46%	0%	0%	0%	0%	0%	0%	0%	55%	0%
PENDLETON	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Table 8. Distribution of Ag Land by Segment			
	hay	row crops	pasture
160	26%	17%	57%
170	15%	4%	81%
175	30%	18%	52%
180	23%	46%	31%
190	23%	17%	60%
200	27%	21%	53%
210	23%	55%	22%
220	25%	27%	48%
225	23%	53%	25%
730	27%	57%	17%
740	32%	30%	38%
750	36%	48%	17%

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

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

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

Figure 3. HUC 8s in the Upper Watershed

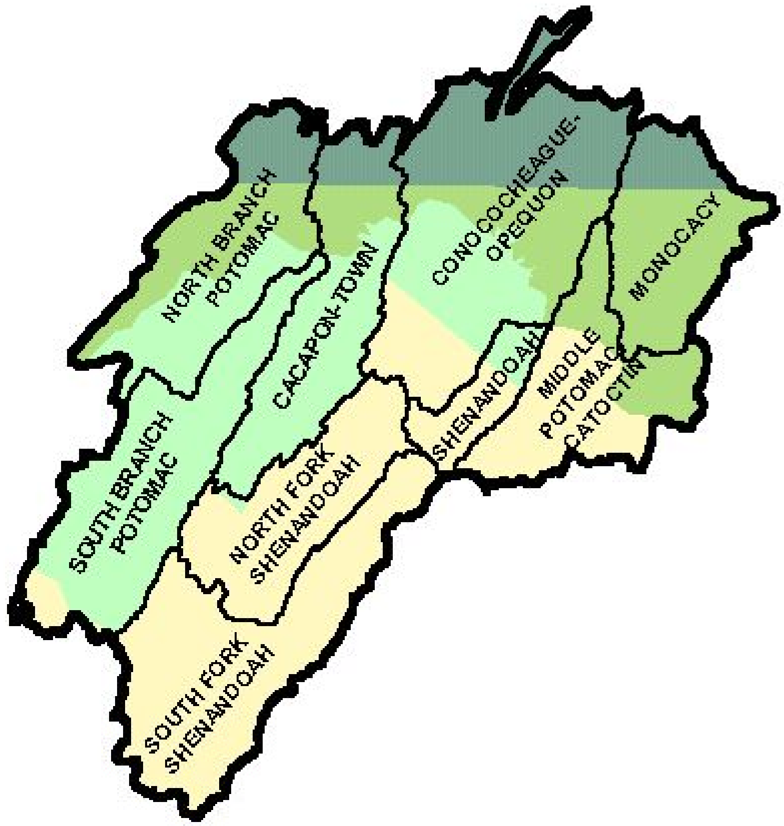


Table 9. Urban Land Per Person by HUC 8 Watershed

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

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

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

TABLE 10. INCREASE IN URBAN LAND BY WATERSHED SEGMENT

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

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

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

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

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

Pollutant Sources

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

Primary Sources

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

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

	Impervious Cover (%)	TN (lb/acre)	TP (lb/acre)	TSS (lb/acre)	Notes
Urban Land (Upper Watershed)					Note: Land Use Classifications in the Upper Watershed and Watts Branch differ because of the level of detail in the information available from the two sources. Land Use in the Upper Watershed is primarily based on the MRLC database, which captures only more highly developed urban land uses. All urban loads calculated using the Simple Method (Schueler, 1987), and the following concentrations for urban runoff: TN: 2.2 mg/l (Smullen and Cave, 1998) TP: 0.4 mg/l (Smullen and Cave, 1998) TSS: 100 mg/l (US EPA, 1983)
Low Density Residential	35	6.5	1.2	297	
High Density Residential	85	14.6	2.7	663	
Commercial/ Industrial/Roads	90	15.4	2.8	700	
Rural Roads	100	17.0	3.1	773	
Grass/ Parks	10	2.3	0.4	107	
Urban Land (Watts Branch)					
Low Density Residential	11	2.7	0.5	121	
Medium Density Residential	23	4.6	0.8	209	
High Density Residential	40	7.3	1.3	334	
Commercial	53	12.5	2.3	568	
Industrial	72	9.4	1.7	429	
Roadway	80	13.8	2.5	626	
Rural Land					
Mining/ Quarries		0.2	0.5	334	Assumes 50% runoff coefficient, and the following concentrations: TN: 1.3 mg/l TP: 0.1 mg/l TSS: 82 mg/l
Cropland		11	3.9	660	TN and TP median values from Reckhow *et al.* (1980) TSS values from Smith *et al.*, (1991) data for rangeland. Both values were adjusted upward so that cropland with 50% application of conservation tillage reflects literature values.
Pasture		4.6	0.7	100	TN and TP median values from Reckhow *et al.* (1980) TSS values from Smith *et al.*, (1991)
Hay		4.6	0.7	100	Assumed the same as pasture
Forest		2.5	0.2	100	TN and TP median values from Reckhow *et al.* (1980) TSS values from Smith *et al.*, (1991)
Silviculture		9	2	300	Assumed the same as literature values for cropland.
Open Water		12.8	0.5	155	Derived from literature values for atmospheric deposition (See Caraco, 2001)

Secondary Sources

In both Watts Branch and the Upper Watershed, several "Secondary Sources" also contributed to the total annual load of pollutants. Summary data required for these sources are included in Table 12. Default concentrations and other assumptions are described in this section, along with data sources.

TABLE 12. SUMMARY OF ALL SECONDARY SOURCES

	Current Estimates	Future Estimates	Notes
Septic Systems	Individuals on Septic	Future population growth	No septics in Watts Branch
Active Construction	Acres of active construction	Acres of active construction	ESC practices can be applied to this load
SSOs	Miles of Sanitary Sewer	Doesn't change	Can repair SSOs
CSOs	Based on average flows per year, and literature concentrations	Doesn't change	Can repair CSOs. None in Watts Branch
Illicit Connections	Based on number of households and businesses.	Doesn't change	Can repair Illicit Connections
Channel Erosion	**In Watts**: Field Geomorphic Assessment. **In Upper Watershed**: Difference between watershed loading rates and a typical sediment load for urban land. Future load based on percent increase in urban land.		Can be treated by upland flow control.
Lawns	Acres of lawn and assumed infiltration and subsurface concentrations	Acres of lawn in the future.	Impacted by education practices
Road Sanding	Road sand applied to open section versus closed section roads.	Increases with increase in roads.	Treated by street sweeping.
Point Source Dischargers	Discharge data	Future population growth	None in Watts.
Tile Drainage	Acres of cropland on poorly drained soils.	Remains the same	None in Watts.
Animal Waste	Animals by type	Doesn't Change	None in Watts.

SEPTIC SYSTEMS

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

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

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

ACTIVE CONSTRUCTION

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

SANITARY SEWER OVERFLOWS

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

Table 13. WTM Default Wastewater Characteristics

	Model Default	Source(s)

Sewer Use	70 gpcd	Metcalf and Eddy (1991)
TSS	400 mg/L	Based on a range of 237 to 600 mg/L (Metcalf and Eddy, 1991)
TP	10 mg/L	Based on a range of 10 to 27 mg/L (Metcalf and Eddy, 1991). The lower end of the range for phosphorus was used to account for programs to reduce phosphorus in wastewater.
TN	60 mg/L	Based on a range of 35 to 80 mg/L (Metcalf and Eddy, 1991)

The total miles of sanitary sewer in Watts Branch was estimated using a sewer layer provided by Montgomery County, Maryland. This was missing large chunks of data for several residential areas. In order to account for sewer in these areas, an average density was used. This sewer density was estimated using existing data to determine the density of sewer line for a typical low density and a high density residential development. On average a low density residential development had 57 feet of sewer line per acre of drainage. High density residential developments had feet pr acre of development. The areas with missing data were categorized as either low or high density development, based on their land use category. These areas were then multiplied by the corresponding sewer density. The resulting numbers combined with the length of the existing sewer layer equaled the total number of sewer length in the watershed.

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

TABLE 14. MILES OF SANITARY SEWER BY MODEL SEGMENT

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

COMBINED SEWER OVERFLOWS (CSOS)

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

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

WTM default CSO concentrations were used, and included:
200 mg/L for TSS
2 mg/L for TP
10 mg/L for TN

ILLICIT CONNECTIONS

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

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

CHANNEL EROSION

A different methodology was used to calculate channel erosion from Watts Branch than from the Upper Watershed. In Watts Branch, a detailed watershed assessment was conducted. In the Upper Watershed, a simple difference between the load from urban land and typical watershed loading rates was used to determine channel erosion.

Watts Branch

In Watts Branch, fairly detailed field work was conducted recently in the Montgomery County portion of the watershed, and earlier in the Rockville portion of the watershed to characterize current, probable pre-development, and probable future channel cross sections. This information, combined with an estimated time for the channel to reach equilibrium, is used to estimate the annual sediment load from channel erosion. This analysis was based on work developed from previous analyses in Austin, Texas, Canada, Vermont, and further refined in the Rockville portion of Watts Branch. The original source of these methodologies is MacRae (1996).

As a part of this assessment, ten points were surveyed from the top of the Montgomery portion of the Watts Branch main stem to the bottom of the watershed. At each point, impervious cover was calculated at various points in time to estimate an "average age of development." The results of this analysis are included in Table 15.

TABLE 15. AVERAGE AGE OF DEVELOPMENT AT SEVERAL POINTS IN THE MONTGOMERY COUNTY PORTION OF WATTS BRANCH

Study Point ID	Total Study Point Area (sq ft)	1948	1968	1979	1997	Age of Development (1997)	Build-Out (2020)	Age of Development (2020)
1	6.32	2.32%	12.83%	22.09%	27.06%	25.72	35.71%	38.23
2	7.29	2.32%	11.69%	21.26%	25.81%	25.53	32.86%	39.27
3	8.28	2.32%	10.98%	20.33%	25.08%	25.11	31.47%	39.48
5	9.16	2.32%	10.24%	19.76%	25.64%	23.90	29.56%	41.44
6	10.87	2.32%	9.66%	18.88%	23.02%	25.04	26.74%	42.09
7	14.63	2.32%	8.09%	15.51%	19.73%	24.12	23.82%	39.96
8	15.83	2.32%	7.72%	15.01%	19.20%	23.89	24.42%	38.10
10	22.05	2.32%	6.41%	11.75%	16.13%	22.58	19.88%	37.97

In order to determine channel erosion both at current level of imperviousness, and with forecasted build-out impervious cover, the "Ultimate Channel Enlargement Ratio" was determined for both the current level of impervious, and under build-out conditions.

$$R_{ult} = (0.0013)\, I^2 + (0.0168)\, I + 1$$

Where:

R_{ult} = Ultimate Enlargement Ratio

I = Impervious Cover (%)

Since the "ultimate" enlargement ratio represents the area the channel will eventually reach, it is also necessary to determine where the channel is on this path; the age of development, along with the ultimate enlargement ratio, are used to determine the current enlargement ratio (i.e., the ratio of the current channel area to the pre-development area) using the following equation:

$$R_{cur} = 1+(R_{ult}-1)(1.032X(t_i-t_l)/(t_e-t_l)-0.028)$$

Where:

R_{cur} = Current enlargement ratio

R_{ult} = Ultimate enlargement ratio

t_i = average age of development (years)

t_l = lag time (time for the channel to start responding to development (2.5 years)

t_e = time for the channel to completely enlarge (67 years)

In Watts Branch, current channel areas are available from recent field work. These cross sectional areas are divided by the current enlargement ratio to "hindcast" a pre-developed channel area. The data for this process are summarized in Table 16.

Thus, at each station, and at upstream stations in the Rockville portion of Watts Branch from previous work, the current channel width, ultimate channel width, time the channel has been eroding (as represented by average age of development), and years for the channel to reach ultimate enlargement (assumed to be 67 years) were determined. These data are combined to represent channel erosion by combining stations into representative reaches, and using average values to that, for each reach, the annual erosion rate in pounds per year is given by:

$$E = 88 (L) (A_{ult} - A_{cur})/(67-T)$$

Where:

- E = Erosion rate (lbs/year)
- 88 = Density of soil (lbs/cubic foot)
- L = Reach length (feet)
- A_{ult} = Ultimate average reach channel area (square feet)
- A_{cur} = Current average reach channel area (square feet)
- 67 = Length of time for a channel to reach ultimate channel area (years)
- T = Average age of development within a reach. (years)

Data from previous work in Watts Branch is used to characterize the Rockville portion of the watershed, and figure 4 illustrates study points conducted in this study for the Montgomery County portion. Results of this analysis are provided in Table 17. The resulting channel erosion is approximately 4,046 tons/year of sediment, and 1,031 tons/year of this occurs in the City of Rockville. A significant portion of this sediment occurs as bedload, and is not a part of the suspended solids load. It was assumed that half of the channel erosion contributes to the suspended portion of the load, and that the remainder is bedload. Thus, the value entered into the WTM was 2,023 ton/year.

Figure 4. Study Points for the Montgomery County Channel Erosion Analysis

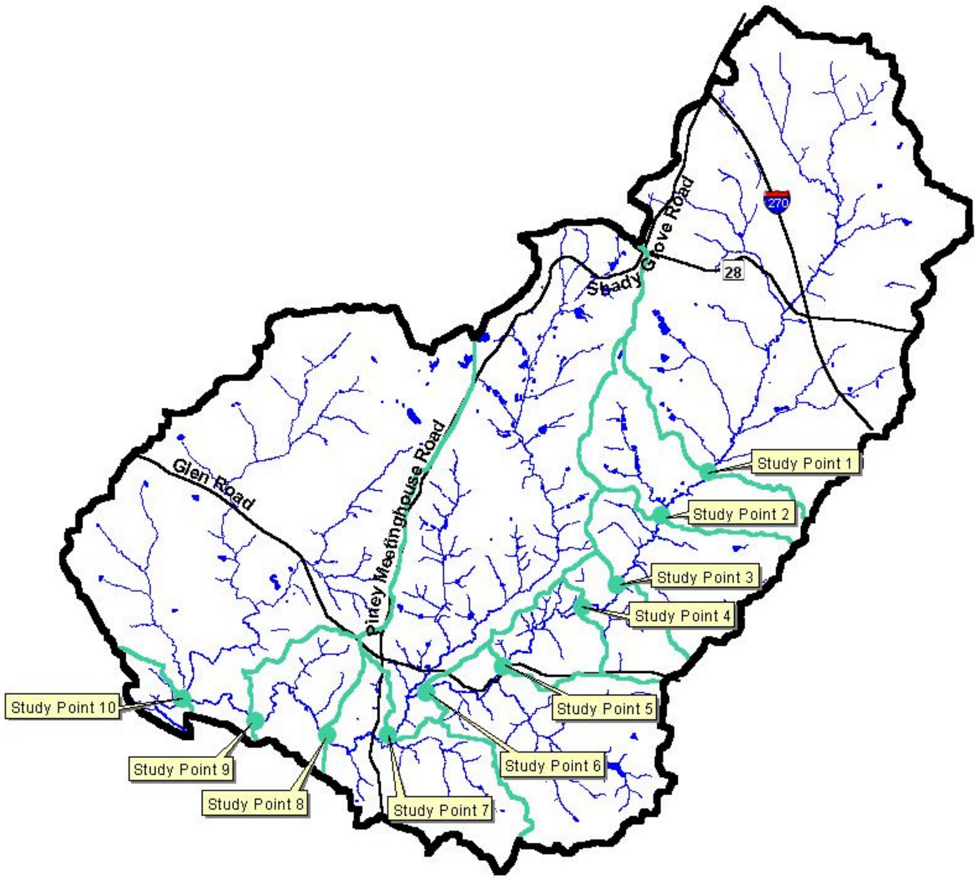


TABLE 16. GEOMORPHOLOGY PARAMETERS FOR CURRENT LEVELS OF DEVELOPMENT IN WATTS BRANCH – 1997 DATA							
Study Point ID	1997 Impervious Cover	1997 Ultimate Enlargement Ratio	1997 Average Age of Development (years)	1997 Current Enlargement Ratio	Measured Channel Area (SF)	Pre-Developed Channel Area	Ultimate Channel Area
1	27.06%	2.41	25.72	1.48	123.80	38.23	200.88
2	25.81%	2.30	25.53	1.44	122.20	39.27	194.80
3	25.08%	2.24	25.11	1.41	133.40	39.48	211.32
5	25.64%	2.29	23.90	1.40	134.50	41.44	218.92
6	23.02%	2.08	25.04	1.36	153.60	42.09	234.80
7	19.73%	1.84	24.12	1.27	160.80	39.96	233.36
8	19.20%	1.80	23.89	1.25	167.90	38.10	241.65
10	16.13%	1.61	22.58	1.18	235.80	37.97	321.92

Table 17. Channel Erosion in Watts Branch (Current Levels of Imperviousness)								
Station	Current X-Section Avg (ft^2)	Ultimate X-Section Avg (ft^2)	Difference X-Section Avg (ft^2)	Length of Reach (ft)	Sediment Volume (ft^3)	Average t_l (years)	Time left to Enlarge (years)	Average Annual Erosion (tons/year)
Rockville Portion	-	-	-	-	979,820	-	-	1,031
WAT1 - WAT2	123.00	197.84	74.84	3,543	265,176	25.88	41.13	282
WAT2 - WAT3	127.80	203.06	75.26	4,157	312,842	25.63	41.38	330
WAT3 - WAT5	133.95	215.12	81.17	7,956	645,812	25.32	41.68	669
WAT5 - WAT6	144.05	226.86	82.81	4,469	370,122	24.51	42.50	383
WAT6 - WAT7	157.20	234.08	76.88	2,839	218,299	24.47	42.53	226
WAT7 - WAT8	164.35	237.50	73.15	4,110	300,648	24.58	42.42	308
WAT8 - WAT10	201.85	281.78	79.93	10,167	812,661	24.01	43.00	817
							Total	4,046

Another question this analysis was used to answer was what the total channel erosion will be in 2020, assuming build-out occurs by that point. A similar analysis was used, substituting the ultimate channel enlargement ratio for full build-out and average age of development in 2020. Both of these values reflect future (2020) conditions. However, the average current channel cross-sectional area reflects current (use 1997) conditions. Thus, when determining the average annual sediment load, the time for the channel to reach its ultimate condition is:

67-T (average age of development in 2020) + 23(years from 1997 to 2020), or
90-T

This process is summarized in Tables 17 and 18.

Upper Watershed

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

Table 18. Geomorphology Parameters for Current Levels of Development in Watts Branch – 2020 Data				
Study Point ID	**2020 Impervious Cover**	**2020 Ultimate Enlargement Ratio**	**Pre-Developed Channel Area**	**Ultimate Channel Area**
1	35.71%	3.22	38.23	268.43
2	32.86%	2.77	39.27	234.53
3	31.47%	2.57	39.48	242.79
5	29.56%	2.53	41.44	242.11
6	26.74%	2.23	42.09	251.79
7	23.82%	1.85	39.96	234.44
8	24.42%	2.00	38.10	268.19
10	19.88%	1.69	37.97	338.89

Table 19. Channel Erosion in Watts Branch (Future Imperviousness)								
Station	**Current X-Section Avg (ft^2)**	**Ultimate X-Section Avg (ft^2)**	**Difference X-Section Avg (ft^2)**	**Length of Reach (ft)**	**Sediment Volume (ft^3)**	**Average t_l (years)**	**Time left to Enlarge (years)**	**Average Annual Erosion (ton/year)**
Rock WAT1 - WAT1	-	-	-	-	2,292,684	-	-	1,834
WAT1 - WAT2	123.00	251.48	128.48	3,543	455,246	38.75	51.25	391
WAT2 - WAT3	127.80	238.66	110.86	4,157	460,859	39.38	50.63	401
WAT3 - WAT5	133.95	242.45	108.50	7,956	863,277	40.46	49.54	767
WAT5 - WAT6	144.05	246.95	102.90	4,469	459,901	41.77	48.24	420
WAT6 - WAT7	157.20	243.11	85.91	2,839	243,942	41.03	48.98	219
WAT7 - WAT8	164.35	251.31	86.96	4,110	357,405	39.03	50.97	309
WAT8 - WAT10	201.85	303.54	101.69	10,167	1,033,906	38.04	51.97	875
							Total	5,215

LAWNS

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

ROAD SANDING

Road sand can be a significant source of sediment. In both Watts Branch and the Upper Watershed, road sand application rates were derived from highway department data. These data (See Table 20) provide an estimate of the typical annual application of road sand to highways in a year. These rates of application, combined with estimates of the fraction of roads that are open section, were adapted to estimate the load from road sanding in both the Upper Watershed and in Watts Branch. Because of the scale and detail of information available, slightly different assumptions were made in Watts Branch versus the Upper Watershed.

UPPER WATERSHED

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

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

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

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

TABLE 20. ROAD SANDING INFORMATION

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

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

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

Where:

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

WATTS BRANCH

The clipped roads layer available from the Watts Branch watershed was divided into more detailed categories by further subdividing roads into further categories, including:

- Rural/Forest
- Low Density Residential
- Medium Density Residential
- Arterial
- Highway (I-270)

The following assumptions were made in Watts Branch:

- All low density residential and rural/forest roads are open section
- 50% of medium residential roads are open section
- Highway application rate (1.66 tons/lane-mile) is applied to I-270
- 50% of this value is applied to arterial streets and parking lots
- 25% is applied to all other roads.
- 90% delivery ratio for closed section roads
- 35% delivery ratio for open section roads.

The resulting inputs for Watts Branch are:

- 54% open section
- 819,160 pounds of sand applied per year.

POINT SOURCE DISCHARGERS

No point source dischargers were accounted for in Watts Branch. In the Upper Watershed, the total load from point source dischargers for nitrogen and phosphorus was obtained from the Chesapeake Bay Program Data (Wiedeman and Cosgrove, 1998), which reported point source loads by segment for both 1995 and projected 2000 load. The load for 1997 was determined by interpolating between 1995 and 2000 values reported in that publication. Loads for sediment were determined by summarizing permit data from the EPA's Permit Compliance System for 1997. Future loads were forecasted simply by multiplying current loads by the ratio of future population to current population. These values are reported in Table 21.

TABLE 21. POINT SOURCE LOADS

Segment	TN	TP	TSS
190	630,781	119,346	8,121,507
170	21,993	8,349	31,677
175	3,129	404	1,717
180	437,015	78,166	481,908
190	1,120,355	209,253	671,387
200	431,794	94,715	45,043
210	592,204	108,580	584,679
220	286,189	30,192	70,214
730	571,360	129,611	497,393
740	603,568	90,046	431,411
750	64,579	5,762	98,655

TILE DRAINAGE

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

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

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

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

Where:

T_f = Final estimated area of tile drainage (acres)

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

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

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

ANIMAL WASTE

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

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

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

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

TABLE 22. NUMBER OF ANIMALS BY WATERSHED SEGMENT.

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

740	22,055	15,933	31,631	2,697	15,781
750	6,389	3,120	73,714	6,250	36,857
Total	149,400	148,702	922,781	5,201,507	1,369,459

Management Practices

A wide suite of practices was considered in both the Upper Watershed and in Watts Branch (Table 23). This section summarizes the assumptions used to characterize these practices.

TABLE 23. MANAGEMENT PRACTICES FOR WTM MODELING	
AGRICULTURAL PRACTICES	
Practice	**Land Applied To**
Conservation Tillage	Cropland
Nutrient Management	Cropland, Hayland
Water Quality Plan	Cropland, Hayland, Pasture
Cover Crop	Cropland
Tree Planting	Cropland, Hayland, Pasture
Buffer	Cropland, Hayland
Highly Erodible Land Retirement	Cropland, Hayland
Grazing Land Protection	Pasture
Animal Waste Management	Animal Waste
Stream Fencing	Pasture
URBAN PRACTICES	
Practice	**Land Applied To**
Structural Treatment Practices	All Urban Land
Erosion and Sediment Control	Active Construction
Lawn Care Education	All Lawns (Institutional, Residential, Commercial)
Pet Waste Education	All Urban Land
Street Sweeping	Streets, Roads an Highways
Impervious Cover Disconnection	Commercial and Residential Roofs
Riparian Buffers	All Urban Land

Agricultural Practices

Agricultural practices were applied with the following assumptions:

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

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

TREE PLANTING

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

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

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

HIGHLY ERODIBLE LAND RETIREMENT

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

TABLE 24. EFFICIENCIES FOR AGRICULTURAL PRACTICES

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

APPLICATION OF AGRICULTURAL PRACTICES

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

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

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

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

Urban Practices - Current

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

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

STRUCTURAL TREATMENT PRACTICES

Structural treatment practices were applied in both Watts Branch and in the Upper Watershed. In Watts Branch, the practices were derived from known information, while assumptions were used to estimate probable practice distribution in the Upper Watershed.

PRACTICE DISTRIBUTION – WATTS BRANCH

In Watts Branch, information was gathered separately for the portion of the watershed in Montgomery County and the portion in Rockville. In Montgomery County, the County maintains a fairly detailed GIS layer of Stormwater Management practices, including the drainage area, type of practice, and total impervious area draining to the practice. The total area in each practice within the Montgomery County portion of the watershed was obtained by overlaying this theme with the Watts Watershed Boundary. The result was:

30 acres to Dry Ponds
69 acres to Wet Ponds
19 acres to Wetlands

For the portion of the watershed in the City of Rockville, existing acreages captured by management practices were derived from appendices to the Watts Branch Watershed Plan (City of Rockville, 2001). Field sheets from the watershed study reported drainages to various practices. The resulting areas were:

413 acres to Dry Ponds
160 acres to Wet Ponds

Thus, the entire drainage was depicted as having the following distribution:

443 acres to Dry Ponds
229 acres to Wet Ponds
19 acres to Wetlands

PRACTICE DISTRIBUTION – UPPER WATERSHED

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

PRACTICE EFFICIENCIES

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

TABLE 25. POLLUTANT REMOVAL FOR STRUCTURAL PRACTICES

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

DISCOUNT FACTORS FOR STRUCTURAL TREATMENT PRACTICES

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

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

In Watts Branch more information was available about most of the practices in the watershed (particularly in the Rockville portion). In general, it appeared that practices were undersized, with some maintenance needs. The discount factors used were:

- 0.6 for the "capture discount" (assumes 60% capture of annual runoff)
- 1.0 for the "design discount" (assumes typical design standards)
- 0.75 for the "maintenance discount" (assumes a slightly better than average maintenance record)

Erosion and Sediment Control

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

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

In Watts Branch, the majority of existing active construction takes place on very highly visible, large projects. Therefore, it is assumed that the practices in place are "state of the art" and highly maintained. Therefore, the ESC assumptions in Watts Branch are as follows:

- Practice Efficiency of 80%
- Treatability Factor of 1.0
- Compliance Discount of 0.9
- Installation/ Maintenance Discount of 0.95

Lawn Care Education

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

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

The remaining input parameter to characterize lawn care education is the fraction of the population that receives, understands and remembers information about more environmentally sensitive lawn care practices. In the Upper Watershed, it is assumed that 20% of the population matches this description. In Watts Branch a very aggressive program is in place in Montgomery County, and it is assumed that the residents of Rockville are also impacted by this education effort. Thus, the fraction of citizens impacted is increased to 40%.

STREET SWEEPING

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

In Watts Branch, fairly detailed information was available to characterize street sweeping programs in both Montgomery County and the City of Rockville. This information is as follows:

Montgomery County:

- 95% of residential areas in County swept 1/year by Regenerative air
- Arterial roads/major streets 1/month for 10 months of the year – by regenerative air
- Commercial/ business district streets are swept 3X/week

City of Rockville:

- Public streets in commercial areas swept twice per week with a vacuum sweeper.
- Arterial streets swept once per month with a vacuum sweeper
- Residential streets are swept twice per year with a vacuum sweeper
- Commercial/ business district streets are swept twice per week

GIS maps and street maps were reviewed, and combined with actual impervious cover layers of streets and parking lots to determine approximately which roads fell into these various categories.

The WTM cannot reflect some of the detail regarding the frequency of sweeping. In addition, parking lots are privately held, and thus there was little data to characterize their sweeping practices. The following depiction of practices in both jurisdictions was used:

- Residential streets are swept annually, using a vacuum sweeper in Rockville and a regenerative air sweeper in Montgomery County
- Arterial streets are swept monthly, using a vacuum sweeper in Rockville and a regenerative air sweeper in Montgomery County
- Commercial streets are swept weekly, using a mechanical sweeper
- Parking lots are swept annually, using a vacuum sweeper in Rockville and a regenerative air sweeper in Montgomery County

IMPERVIOUS COVER DISCONNECTION

Impervious cover disconnection was not explicitly accounted for in the Upper Watershed. In Watts Branch, it was assumed that 50% of the rooftop area classified as low density residental was disconnected.

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. In the Upper Watershed, 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.

In Watts Branch, the actual length of stream with forested buffers was measured, and a fifty foot buffer width assumed. (In reality, the buffer width was greater than this, but this is the maximum width that can be reflected by the WTM).

Urban Practices – Future Development

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

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

TABLE 26. CONTROLS ON NEW DEVELOPMENT BY STATE

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

In Watts Branch, excellent future management was assumed, including 90% control for water quality, and 70% control for channel erosion.

Management Scenarios

In both the Upper Watershed and in Watts Branch, three management scenarios were modeled: “current management”, “improved management”, and “aggressive management.” The ”current management” scenario was described in section 4. It is reflected by existing management practices, along with future urban practices as described in Section 4.3. The two other scenarios are reflected by changes in both the existing practices and future management practices.

Upper Watershed Scenarios

In the Upper Watershed, management techniques included adjustments to loads from point sources, urban practices, and agricultural practices. Each practice category is described below.

POINT SOURCES

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

TABLE 27. POINT SOURCE LOADS

Segment	Flow (MGD)	Load (Improved) (lb/year)		Load (Aggressive) (lb/year)	
		TN	TP	TN	TP
190	35.46	630,781*	55,449	332,695	8,317
170	0.42	10,508	657	3,941	99
175	0.07	1,751	109	657	16
180	11.6	290,225	18,139	108,834	2,721
190	32.58	815,132	50,946	305,674	7,642
200	5	125,097	7,819	46,911	1,173
210	15.7	392,804	24,550	147,302	3,683
220	8.78	219,670	13,729	82,376	2,059
730	8.38	209,662	13,104	78,623	1,966
740	9.94	248,693	15,543	93,260	2,331
750	3.12	64,579*	4,879	29,273	732
* Same as existing load without controls.					

Urban Management Practices

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

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

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

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

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

Agricultural Management Practices

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

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

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

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

WATTS BRANCH

In Watts Branch, future management included stormwater retrofits, and some enhanced stormwater programs. In the "improved management" scenario, management focused on implementing stormwater retrofits called for in the Watts Branch Watershed Management Plan for the City of Rockville (Rockville, 2001). This plan calls for retrofitting several existing stormwater management facilities, to increase the water quality treatment and channel protection storage provided by stormwater practices. This increase is reflected as an impervious cover capture for various water quality practices, and a capture of impervious cover to reduce flows for the purpose of channel protection.

IMPROVED MANAGEMENT

Table 28 summarizes how these benefits were accounted for. It lists the recommended practices in Watts Branch, along with impervious cover capture, and percent target storage for channel protection and water quality. For channel protection, the net benefit of these practices could be summarized as the sum product of impervious cover capture and target storage volume. The result was a capture of 266 acres of impervious cover, or roughly 25% of the impervious cover within the Rockville portion of Watts Branch.

For water quality practices, a discount was applied to reflect the type of retrofit. For example, a simple modification to an existing facility (e.g., addition of a forebay or wetland plantings) resulted in treatment of only 20% of the impervious cover draining to the facility. One practice (SM-23) was an existing facility which was modified to increase the total drainage to the facility. This practice received a 50% discount. The resulting increase in water quality capture within the Rockville portion of Watts Branch was:

50 acres to dry ponds
70 acres to wet ponds
8 acres to wetlands

Table 28. Stormwater Retrofit Accounting in the Rockville Portion of Watts Branch

Practice ID	Impervious Area Capture (Acres)	Stormwater Practice Type	Channel Protection Storage (% of target)	Water Quality Storage (% of target)	Discount Applied to Water Quality Practices*	"Effective" Water Quality Capture (% of target)
SM-1	18	Dry pond	100	100	0.2	20
SD-12	9	Dry pond	100	100	1	100
SM-18	20	Dry pond	54	0	0	0
O-3	16	Dry pond	100	93	1	93
SM-20	54	Dry pond	98	37	0.2	7.4
SD-6	10	Dry pond	44	100	1	100

SD-16	9	Dry pond	100	100	1	100
SD-22	8	Wetland	100	100	1	100
SM-8	13	Wet Pond	100	0	1	0
SM-24	68	Wet Pond	30	20	0.2	4
SM-23	44	Wet Pond	73	69	0.5	34.5
SD-8	45	Wet Pond	100	80	1	80
SM-9	9	Wet Pond	100	100	0.2	20
SD-24	20	Wet Pond	92	70	1	70
* 0.2 applied to enhanced existing practices (assumes a 20% increase over existing performance. For practice SM-23, a value of 0.5 was used due to increased drainage to the practice.						

AGGRESSIVE MANAGEMENT

The "Aggressive Management" scenario in Watts Branch assumes a similar level of watershed plan in the Montgomery County portion of the watershed. Two major differences between the Montgomery County portion of Watts Branch versus the portion in the City of Rockville are that the development is overall a much lower density, and a greater portion of the existing watershed appears to be uncontrolled. These two factors suggest that capturing a large portion of existing impervious cover may be more difficult in the Montgomery County portion of the watershed. As a result, it would be unrealistic to assume the same capture (as a fraction of existing watershed development) in Montgomery County.

Because of this difficulty in making direct comparisons, a set of assumptions was used to develop a "comparable" watershed strategy in the Montgomery County portion of Watts Branch. These assumptions included the following (derived from the Watts Branch Plan):

For existing facilities:

- 12% of existing dry ponds receive advanced treatment as dry ponds.
- 13% of all facilities add additional water quality storage as wet ponds.
- 27% of all area draining to existing facilities receives channel protection storage.

For uncontrolled development:

- 7.5% of area drains to dry ponds for water quality control.
- 12% of area drains to wet ponds or wetlands for water quality control.
- 21% of area controlled for channel protection

This results in addition of the following practices in the Montgomery County portion of Watts Branch:

- 20 acres captured by dry water quality ponds
- 35 acres captured by wet water quality ponds
- 21% of impervious cover in the lower watershed captured for channel protection.

Results

This section presents results for the Upper Watershed and for Watts Branch. Because of the different dominating land uses in these drainage areas, changes were dominated by different management practices. In the Upper Watershed, only a modest change could be achieved in each segment by management practices, and this change was achieved primarily through point source controls, and agricultural maangement practices. In Watts Branch, change was achieved through urban management techniques.

Upper Watershed

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

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

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

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

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

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

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

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

TABLE 30 POINT SOURCE LOADS UNDER EACH SCENARIO (LBYEAR)

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

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

Table 31. Urban Non-Point Source Loads Under Each Scenario				
Segment		TN	TP	TSS
220	Current	909,478	99,830	44,822,722
	Future-scenario 1	1,120,608	124,564	52,686,661
	Future-scenario 2	1,100,016	117,542	47,990,634
	Future-scenario 3	1,096,547	115,807	46,256,080
225	Current	21,154	2,037	862,871
	Future-scenario 1	32,867	2,919	944,751
	Future-scenario 2	32,611	2,842	899,600
	Future-scenario 3	32,416	2,771	850,617
730	Current	338,503	36,754	14,206,601
	Future-scenario 1	392,968	44,206	16,576,038
	Future-scenario 2	404,369	42,654	15,376,484
	Future-scenario 3	403,731	42,335	15,057,254
740	Current	844,432	95,154	38,030,571
	Future-scenario 1	1,458,037	168,913	60,579,429
	Future-scenario 2	1,423,915	158,322	54,593,907
	Future-scenario 3	1,417,353	155,042	51,313,050
750	Current	118,429	12,863	4,893,353
	Future-scenario 1	146,343	15,934	5,973,915
	Future-scenario 2	144,449	15,289	5,547,843
	Future-scenario 3	144,204	15,167	5,425,689

Table 32. Agricultural Non-Point Source Loads Under Each Scenario				
Segment		TN	TP	TSS
160	Current	2,231,461	235,632	89,760,114
	Future-scenario 1	2,213,846	234,223	89,055,522
	Future-scenario 2	2,195,385	228,094	87,912,851
	Future-scenario 3	2,176,924	221,965	86,770,179
170	Current	2,694,597	279,070	94,593,257
	Future-scenario 1	2,683,689	278,197	94,156,953
	Future-scenario 2	2,607,544	266,095	92,960,551
	Future-scenario 3	2,531,397	253,992	91,764,034
175	Current	2,268,273	249,726	86,389,603
	Future-scenario 1	2,257,400	248,855	85,954,550
	Future-scenario 2	2,198,930	232,320	83,481,084
	Future-scenario 3	2,140,459	215,786	81,007,618
180	Current	1,514,350	266,109	58,316,400
	Future-scenario 1	1,494,192	264,497	57,510,095
	Future-scenario 2	1,431,664	232,254	50,874,245
	Future-scenario 3	1,369,136	200,011	44,238,395
190	Current	3,179,362	410,655	112,937,112
	Future-scenario 1	3,120,431	405,941	110,579,853
	Future-scenario 2	3,021,714	383,172	106,003,393
	Future-scenario 3	2,916,582	359,750	101,141,988

Table 32. Agricultural Non-Point Source Loads Under Each Scenario

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

Watts Branch

In Watts Branch, the load is dominated by Channel Erosion, and future management practices focus on this source. With full watershed implementation, of stormwater retrofits, the sediment load could be reduced by 15% compared to existing loads. Interestingly, even if these practices were not implemented, it appears that the sediment load will decline over time due to a shift of existing construction to developed land. Table 33 summarizes the overall loads under each management scenario. Tables 33 through 36 show actual model output for these scenarios, including the change relative to existing loads.

TABLE 33 TOTAL LOAD IN WATTS BRANCH UNDER VARIOUS SCENARIOS (LB/YEAR)

	TN		TP		TSS	
	Load	Load as a Fraction of Current Conditions	Load	Load as a Fraction of Current Conditions	Load	Load as a Fraction of Current Conditions
Current	71,744	-	14,062	-	6,912,614	-
Future-scenario 1	75,813	1.06	14,312	1.02	6,651,177	0.96
Future-scenario 2	75,008	1.05	13,992	1.00	6,403,264	0.93
Future-scenario 3	70,804	0.99	12,752	0.91	5,870,181	0.85

TABLE 34. WATTS CURRENT LOADS

	Area (acres)	TN lb/year	TP lb/year	TSS lb/year
URBAN SOURCES				
Urban Land	9,242	47,456	7,501	1,596,534
Active Construction	818	1,430	715	714,961
SSOs		1,202	200	8,015
Illicit Connections		546	177	4,190
Channel Erosion		8,092	4,046	4,046,000
Road Sanding	-	-	-	123,488
RURAL SOURCES				
Rural Land	1,162	5,347	814	116,246
Forest	3,016	7,540	603	301,587
Open Water	10	132	5	1,593
TOTAL LOAD	**14,249**	**71,744**	**14,062**	**6,912,614**

Table 35. Watts Loads With Growth - No Change in Management							
	Area	TN		TP		TSS	
	(acres)	lb/year	% of Current	lb/year	% of Current	lb/year	% of Current
URBAN SOURCES							
Urban Land	12,129	60,352	127%	9,140	122%	1,907,243	119%
Active Construction	201	428	30%	214	30%	214,138	30%
SSOs		1,202	100%	200	100%	8,015	100%
Illicit Connections		546	100%	177	100%	4,190	100%
Channel Erosion		8,387	104%	4,194	104%	4,193,625	104%
Road Sanding	-	-		-		131,749	107%
RURAL SOURCES							
Rural Land	-	-	0%	-	0%	-	0%
Forest	1,906	4,766	63%	381	63%	190,624	63%
Open Water	10	132	100%	5	100%	1,593	100%
TOTAL LOAD	**14,246**	**75,813**	**106%**	**14,312**	**102%**	**6,651,177**	**96%**

TABLE 36. WATTS LOADS WITH GROWTH – IMPLEMENT ROCKVILLE PLAN (SCENARIO 2)							
	Area	TN		TP		TSS	
	(acres)	lb/year	% of Current	lb/year	% of Current	lb/year	% of Current
URBAN SOURCES							
Urban Land	12,129	60,041	127%	9,067	121%	1,906,330	119%
Active Construction	201	428	30%	214	30%	214,138	30%
SSOs		1,202	100%	200	100%	8,015	100%
Illicit Connections		546	100%	177	100%	4,190	100%
Channel Erosion		7,893	98%	3,947	98%	3,946,625	98%
Road Sanding	-	-		-		131,749	107%
RURAL SOURCES							
Rural Land	-	-	0%	-	0%	-	0%
Forest	1,906	4,766	63%	381	63%	190,624	63%
Open Water	10	132	100%	5	100%	1,593	100%
TOTAL LOAD	**14,246**	**75,008**	105%	**13,992**	100%	**6,403,264**	93%

TABLE 36. WATTS LOADS WITH GROWTH – IMPLEMENT ROCKVILLE PLAN THROUGHOUT THE WATERSHED (SCENARIO 3)	Area	TN		TP		TSS	
	(acres)	lb/year	% of Current	lb/year	% of Current	lb/year	% of Current
URBAN SOURCES							
Urban Land	12,129	57,822	122%	8,486	113%	1,865,408	117%
Active Construction	201	428	30%	214	30%	214,138	30%
SSOs		216	18%	36	18%	1,439	18%
Illicit Connections		519	95%	169	95%	3,980	95%
Channel Erosion		6,923	86%	3,461	86%	3,461,250	86%
Road Sanding	-	-		-		131,749	107%
RURAL SOURCES							
Rural Land	-	-	0%	-		-	0%
Forest	1,906	4,766	63%	381		190,624	63%
Open Water	**10**	**132**	100%	**5**		**1,593**	100%
TOTAL LOAD	**14,246**	**70,804**	**99%**	**12,752**	**91%**	**5,870,181**	85%

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Two Dimensional Hydrodynamic Modeling - Subwatershed Contribution Assessment

Summary

- The Potomac WFP experiences operational problems that appear related to high TSS in Watts Branch during storm events.
- Both the Cormix modeling results and some of WSSC's field sampling results indicate that Watts Branch has a significant negative impact on water quality at the Potomac WFP's current shore intake.
- Both Cormix modeling results and some field sampling results indicate that Watts Branch impacts do not extend beyond a small island approximately 100 feet off of the Maryland bank referred to as the "intake island". This modeling and field data suggest that the plant operational problems associated with Watts Branch can be eliminated by relocating the intake beyond the intake island.
- The Cormix modeling results indicate generally that Watts Branch has less impact at the current Potomac WFP intake (i.e., more dilution) than indicated by field sampling results. This may be due to the fact that the model is based on daily flows and not shorter duration events which are associated with flashy Watts Branch.

Introduction

The Washington Suburban Sanitary Commission (WSSC) operates a water supply intake on the Potomac River above Washington, DC in Montgomery County, MD that is adjacent to its Potomac Filtration Plant. The existing WSSC intake is a side-river intake that is located on the Maryland bank of the river. The Potomac Filtration Plant experiences operational problems that are attributed, by plant operators, to the presence of high concentrations of total suspended solids (TSS) in local streams during storms.

The existing intake occupies a small channel that cuts between the Maryland bank and a small island approximately 100 feet off of the Maryland bank referred to as the "intake island". As shown in Figure 1, Watts Branch, a small local stream, discharges to the Potomac River approximately 1,800 feet above the existing intake. Muddy Branch and Seneca Creek also drain local areas within Montgomery County and discharge to the Potomac River further upstream. Operational problems or impacts at the existing intake due to Muddy Branch and Seneca Creek may also be important, but are thought to be substantially less than Watts Branch. Watkins Island is a long narrow island that essentially divides the Potomac River into two relatively equal parts in the vicinity of the existing intake.

The WSSC has a variety of operational data that shows the occurrence of TSS-induced problems at the Potomac Filtration Plant, and water quality data to show the elevated TSS levels in Watts Branch relative to the Potomac River. The water quality data includes sample results for about forty events over one year taken at six sites in the vicinity of the plant intake, illustrating an impact by Watts Branch on the current intake location. However, , no detailed modeling studies have been undertaken to quantify the specific impacts observed at the existing intake that are attributable to Watts Branch. Further, the WSSC would like to understand whether or not relocation of the intake to a location between the intake and Watkins islands (also shown in Figure 1) would offer relief from TSS-induced operational problems attributed to Watts Branch and other local streams.

The purpose of this investigation is two-fold. Task 1 is intended to evaluate the impact of Watts Branch on the existing intake. This was accomplished through a combination of 2-D river modeling to identify dilution and hydrologic assessment. Task 2 is intended to assess potential benefits associated with relocation of the intake away from the Maryland bank to a mid-river location. This was accomplished with a simple screening level hydrologic assessment of flow occurrence frequencies matching the contribution of flow from Watts Branch, Muddy Branch and Seneca Creek with the Potomac River.

The remainder of this report addresses data collection, hydrologic analysis, Watts Branch analysis, intake relocation analysis, analysis of results and recommendations.

Data Collection & Analysis

To determine the impact of the present intake location and assess the benefits associated with relocating the WSSC intake, data were collected and analyzed. Daily flow data for Seneca Creek, Watts Branch and the Potomac River were collected from the USGS web site. Table 37 details the period of record, location, drainage area and USGS gage number for each of the flow records. The USGS and EPA STORET databases were searched for water quality data. Limited water quality data were found for these streams, but much of it was very old, and not enough relevant data were available to assist with calibration of the dilution model.

Visual surveys of the study area were also part of the data collection process. The area near the WSSC intake was inspected along with the area where Watts Branch enters the Potomac. This confluence was particularly important as Watts Branch flows beneath the C&O Canal just before entering the Potomac. Watts Branch crosses under the canal through a culvert, altering the velocity of Watts Branch. Field measurements of the culvert made by Straughan Environmental allowed for proper estimation of the flow velocity from Watts. An estimate the width and depth of Watts Branch along with a determination of flow conditions at the junction of Watts Branch and the Potomac River were made by visual inspection.

Other datasets detailing the topography and location of stream channels in the area of interest were also collected for this task. USGS Digital Elevation Models (DEMs) were collected along with stream channel GIS data from the EPA RF3 database (EPA, 1998). The DEMs were used to delineate the Seneca Creek, Muddy Branch and Watts Branch watersheds. Montgomery County also provided detailed land use maps for the Watts Branch area. Data from the WSSC were also used in this task. Rainfall data at the WSSC intake were used in determining wet-weather flow in Watts Branch, and water quality data were provided for Watts Branch and various locations in the Potomac River near the intake.

To perform the modeling tasks of this project, flows for the Potomac River, Watts Branch, Seneca Creek, and Muddy Branch were needed. To determine the Potomac River flow at the intake, the flow was scaled upwards based upon the ratio of the size of the watershed at the gage (9651 sq.mi.) and that above the WSSC intake (11430 sq.mi.). The flow in Seneca Creek is gaged at a point that covers 78% of the entire watershed. Again, the gage flow was scaled based upon the ratio of the gaged watershed (101 sq.mi.) and the entire watershed (129.6 sq.mi.). There is a dam in the upper reaches of the Seneca Creek watershed, but the impact of that dam and reservoir on flow in the system was measured in the downstream gage used for this watershed. Flow from USGS gage 01648000, Rock Creek at Sherill Drive in Washington, DC, was also used indirectly in the modeling process as Rock Creek was used as a surrogate for determining peak flows in Watts Branch.

The gage on Watts Branch is located in the upper reaches of the watershed. Scaling this gage to represent the flow in the entire basin was not appropriate. Therefore, synthetic flow records for Watts Branch were calculated using two methods. The simple method is a procedure commonly used to estimate flow in urban watersheds (MWCOG, 1987). This method uses the following equation:

$$Q = 0.042 (R_v * I * P_j * A)$$

where: Q = flow (cfs)

R_v = runoff coefficient
I = rainfall intensity (inches/hour)
P_j = fraction of rainfall events that produce runoff (0.9 was used)
A = drainage area (acres)
0.042 = factor used to convert acres*inches/hour to cfs

The runoff coefficient was determined using rainfall at the intake and available flow data in the small gaged section of Watts Branch. A runoff coefficient of 0.38 was calculated for this sub watershed of Watts Branch. This part of the watershed is significantly more developed than the lower reach of the watershed, and a reduction of 15% was applied to the runoff coefficient when used for the entire watershed, resulting in a final runoff coefficient of 0.32. The calculated reduction was determined by rough estimation of the changes in land use shown in maps provided by Montgomery County, Maryland.

The simple method is dependent upon rainfall and cannot be used for dry-weather flows. To assemble a complete record of data, scaling was used. The Seneca Creek gage was used as a surrogate for Watts Brach. The flow was scaled using the ratio of the Seneca Creek watershed (at the gage) to the Watts Branch watershed. Both flow records (scaling and simple) were used in completing this task. Simple scaling was used in Muddy Branch as the size of the Watts Branch and Muddy Branch watersheds are extremely similar, 22 and 19.2 sq. miles, respectively.

Task 1 – Modeling Watts Branch
CORMIX

To determine the impact of Watts Branch on the current WSSC intake, the CORMIX (Cornell Mixing Zone) Model was used (Jirka, 1996). This model predicts the dilution, trajectory, and geometry of flow at various distances downstream of a discharge. In CORMIX, the flow from Watts Branch is modeled as a neutrally buoyant discharge to the Potomac River. In running the CORMIX model for this task, assumptions had to be made. In the model, a straight, rectangular channel with a uniform velocity represents the Potomac River. Also, the area of interest (the WSSC intake) is approximately 1800 ft below the discharge point at Watts Branch. While CORMIX was developed to analyze both near-field and far-field mixing, dilution values at this distance from the discharge point can only be looked at as estimates of the actual conditions. Further assumptions and the model inputs used in CORMIX are described in Appendix A.

The location of the discharge plume or jet is important due to the possible relocation of the intake. The model calculates the location of this discharge in the Potomac River. The discharge from Watts Branch could act as a plume or jet depending upon the velocity of the flow from both the Potomac River and Watts Branch (see Figure 3). In all model events simulated, the main body of the plume or jet did not go outside of the intake island. For the purpose of this study, the main body of the discharge is defined by the centerline of the discharge plume or jet plus one standard deviation of distance on either side of the centerline.

With the use of collected input data and synthetic flows, the CORMIX model was run for a wide range of flows in both the Potomac River and Watts Branch. For each set of flow values, a dilution value at the WSSC intake 1800 ft below Watts Branch was calculated by CORMIX. In CORMIX, the dilution value is defined as follows:

$$D = \frac{V_w + V_p}{V_w}$$

where: D = Dilution value
V_w = volume of Watts Branch water at the intake
V_p = volume of Potomac River water at the intake

In this application, smaller dilution values indicate conditions where Watts Branch flows exhibit a larger impact on the conditions at the existing intake. The calculated dilution values are shown in Table 38. Not all values could be calculated directly from CORMIX. In transitional conditions, the discharge could not be adequately defined as either a plume or jet when calculating far-field results. In order to complete the dilution table for transitional conditions, near-field results from CORMIX were adjusted through interpolation to produce far-field dilution values using the far-field calculations of similar flow patterns.

Probability Analysis

The dilution values presented in the previous section do not specify the likelihood of occurrence of these combinations of Potomac River and Watts Branch flows. To determine the likelihood of occurrence, joint probability analysis of the Potomac River and Watts Branch flows (1930 to 2000) were calculated. The results of these calculations are presented in Table 39, and these results provide insight into the dilution values presented in Table 38. For example, a Watts Branch flow between 27.9 and 43.4 cfs is likely to occur in combination with a Potomac River flow between 2611 and 3487 cfs 1.079% of the time. Using Table 38, a dilution ratio of 12 would be expected for that condition.

Hourly Peaking Factors

The dilution ratios described in Table 38 were developed from daily flows in Watts Branch and the Potomac River. For a small, flashy stream like Watts Branch, the hourly peak flow will be significantly higher than the daily average flow. A peaking factor that estimates the magnitude of the hourly peak flow based upon the daily average flow was developed using two different techniques.

The hourly peak flow for Watts Branch can be estimated by using the calculated hourly peak flow factor for another similar watershed. In this situation, hourly flow data were available for the nearby Rock Creek watershed. Analyzing this hourly flow record, an hourly peaking factor of 2.5 to 3.0 was calculated. While the gaged portion of Rock Creek is larger than Watts Branch, 62 versus 22 sq. miles, the land uses and topography are very similar. Therefore, it is believed that this peaking factor would be appropriate for Watts Branch.

To confirm the validity of the estimated peaking factor, another method of calculating the hourly peaking factor was used. A simple rainfall/runoff model of the watershed was developed using the TR-55 Method (USDA, 1986). A synthetic rainfall event corresponding to the three times per year storm (expected return interval of four months) was used, and the calculated hydrograph for that event is given as Figure 4. This hydrograph confirms the flashy nature of the Watts Branch watershed and shows a peaking factor of approximately 3.0. This should be considered when Table 39 is reviewed.

Task 2 – Assessment of Intake Relocation

Using the flows collected and synthetically created in section 2, a time series based assessment of all flows at the proposed mid-river intake location can be analyzed. The occurrence frequencies for tributary flows that represent various percentages of Potomac River flow have been given in Figures 5 through 7. In each figure, the top graph shows the occurrence frequencies for Watts and Muddy Branch flow, while the bottom graph details the occurrence frequencies for Seneca Creek as a percentage of Potomac River flow. The three figures vary slightly as each was created using different synthetic flow techniques and varying time periods. Figure 5 is based upon wet-weather data only, and Watts and Muddy Branch flows were created using the simple method. Figure 6 is also based upon wet-weather data only, but Watts and Muddy Branch flows were created using the scaling process. Also using a scaling process, Figure 7 shows the results for both dry and wet weather periods.

Analysis of Results

The relative impact of Watts Branch on the current intake location can be analyzed using the results presented in Section 4. For various values of Watts Branch and Potomac River flow, Table 38 presents the calculated dilution value. In almost all of the flow scenarios presented, the dilution value at the existing intake is significantly less (lower dilution value) than would be expected under complete mixing of the Potomac River and Watts Branch flows. This occurs because the Watts Branch flow stays attached to the Maryland bank of the Potomac River. Under some very unusual conditions (high Watts Branch flow with low Potomac River flow), the dilution value is actually higher than expected under complete mixing. For these rare cases, the flow from Watts Branch forms a jet that is not attached to the Maryland shore. In this situation, a recirculation bubble of Potomac River water is found at the current intake location, increasing the expected dilution value (Fischer, 1979). It is important to note that under all flow conditions, the main body of the plume or jet from Watts Branch does not go outside of the intake island.

The given dilution values were based upon the joint occurrence of daily flows from Watts Branch and the Potomac River. Table 3 provides information detailing the probability of these joint flow occurrences. The results shown in Table 3 follow expected statistical probabilities. Low flows in Watts Branch normally correspond with low flows in the Potomac River. There are exceptions, but instances where large daily flows in Watts Branch occur with low flows in the Potomac River are very rare. However, this may not be valid for flows less than daily averages. High flows for short periods in Watts Branch may be more frequent than shown in Table 39 and Figures 5 - 7.

The dilution ratios presented were based upon daily flows in Watts Branch. The hydrograph presented in Figure 4 illustrates the flashy nature of Watts Branch, with significantly higher flow for a period of approximately five hours during a storm event. With this information, one can expect that actual dilution values at the intake will be even smaller than that calculated in CORMIX for short periods of time during a storm.

A screening level spreadsheet approach was taken to assess the benefits of relocating the WSSC intake to a mid-river location (see Figure 1). Figures 5, 6 and 7 present the potential impact of

Watts Branch, Muddy Branch, and Seneca Creek by representing the flow of these tributaries as a percentage of the total Potomac River flow at that time. Analyzing the results of Figures 5, 6 and 7 it is important to note that both Watts Branch and Muddy Branch make up less than 10% of the total Potomac River flow over 90% of the time, based on daily flow data. In fact, over 50% of the time, these two tributaries to the Potomac River make up less that 1% of the total Potomac River flow at the proposed mid-river WSSC intake. The analysis presented above is valid no matter what synthetic flow calculation was used in determining the flow from Muddy Branch and Watts Branch. Again, it is important to remember that the ratio for flows with duration much shorter than one day may be higher than the reported values.

The Seneca Creek watershed is larger than either the Muddy Branch or Watts Branch watershed. More than 50% of the time, flow from Seneca Creek makes up 2 to 5% of the total flow in the Potomac River. There is also a significant amount of time (greater than 10%) where Seneca Creek flow makes up 10 to 25% of the total Potomac River flow. The calculations shown in Figures 5, 6 and 7 are based entirely upon flow calculations, using flow as a surrogate for the impact of solids. Assuming complete mixing of Seneca Creek with the Potomac River in the five miles between the confluence and the Potomac WFP intake, the impact of Seneca Creek on intake water quality may be similar either at the current shore intake or the proposed mid-channel intake. Seneca Creek has a dam in the upper reaches of the watershed that may lower the solids seen from Seneca Creek.

From the above analysis, it can be concluded that Watts Branch impacts the current intake location but would not impact an intake relocated beyond the “intake island.

Recommendations

The results presented in the previous section show that Watts Branch does have a significant impact on the present WSSC intake. This analysis is limited though, and to better assess the magnitude of this impact, additional steps can be taken. One particular step would be to perform a rigorous assessment of the correlation between operational problems seen at the plant along with local rainfall and flows in Watts Branch. This type of assessment would enhance the definition of the duration of the operational problems and the threshold TSS values that initiate problems at the present WSSC intake location.

To assess the relocation of the intake to a mid-river location, more effort to define the impact of Seneca Creek would be useful. Data collection is a key component of proper assessment of this mid-river location. Sampling of TSS values on Seneca Creek should be taken along with TSS measurements above Seneca Creek on the Potomac River. Further modeling may also be warranted before making a decision to move the existing WSSC intake. Literature review and agency interviews should be completed to find out if any hydrodynamic modeling has been done in this study area and also to identify any survey data that may exist to better define the bathymetric characteristics of this complex area of the Potomac River.

Assembling this bathymetric data and a more complete TSS dataset would allow for a more rigorous assessment of intake relocation issues and determine if additional modeling is needed. The Potomac River has extremely complex hydraulic characteristics in the vicinity of the WSSC intake and this more rigorous assessment would be a significant modeling challenge. Advancing from the application of simple models to a more complex model would also require a substantial data collection effort.

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Table 37: USGS stations used in this project **Gage Name**	**Gage #**	**Drainage Area (sq.mi.)**	**Latitude**	**Longitude**	**Flow Data**	**WQ Data**
Potomac River @ Point of Rocks, MD	01638500	9651	39°16’25”	77°32’35”	1895-2000	1959-1992
Seneca Creek @ Dawsonville, MD	01645000	101	39°07’41”	77°20’13”	1930-2000	1959-1995
Watts Branch @ Rockville, MD	01645200	3.7	39°05’03”	77°10’38”	1957-1987	1960-1986

Table 38 - CORMIX ANALYSIS (dilution ratio at the intake, 1800 ft downstream from Watts Branch)

	2nd Percentile	5th Percentile	10th Percentile			**Potomac River Flow at the Intake (cfs)**					90th Percentile
Watts Flow (cfs)	1264	1551	1904	2611	3487	4696	6267	8151	10804	15160	23822
5.2 (10th Percentile)	30	38	93	133	175	233	300	392	526	720	1150
12.2 (20th	13	13	14	27	36	102	137	175	225	316	489
17.4 (30th	11	12	13	14	26	35	90	125	163	220	346
27.9 (40th	10	11	11	12	13	22	28	37	103	144	220
43.5 (50th	7.5	8.6	9.8	10	12	12	14	24	31	85	145
64.4 (60th	6.1	6.5	7.8	9.2	9.5	10	12	13	21	30	94
92.3 (70th	5.2	5.7	6.2	7.3	9.1	9.2	11	12	15	21	32
132.3 (80th	4.7	4.9	5.3	6.1	7.2	8.5	9	10	11	14	23
207.2 (90th	4.3	4.5	4.6	5	5.7	6.2	8.1	8.7	9	11	13
237.3 (92nd	4.2	4.4	4.5	4.8	5.4	6.1	6.8	8.6	8.9	10	12
289.1 (95th	3.9	4.1	4.4	4.6	4.9	5.6	6.4	7.5	8.5	9.1	10
389.4 (98th	3.6	3.8	4.1	4.4	4.6	4.9	5.6	6.2	7.2	8.6	9.2
902.5	2.4	2.7	3	3.4	3.8	4.1	4.4	4.6	4.9	5.7	6.5

Key:
= Watts Branch
= Watts Branch Plume/Jet
= Watts Branch Jet

NOTES:

- a reasonable estimate of the velocity from Watts Branch can be found using the following empirical relationship: Q = 174.1 *
- the Potomac River flow shown here is the total flow in the river. Only 45% of that flow would be found at the
- the estimated values were calculated using the near-field results of the scenario and the far-field results of similar

Joint Probability Table (Percentages)

	2nd Percentile	5th Percentile	10th Percentile			Potomac Flow at Inlet (cfs) / Total Potomac Flow (cfs)					90th Percentile	Maximum
Watts Flow (cfs)	569 / 1264	698 / 1551	857 / 1904	1175 / 2611	1569 / 3487	2113 / 4696	2820 / 6267	3668 / 8151	4862 / 10804	6822 / 15160	10720 / 23822	78341 / 164000
5.2 (10th Percentile)	1.826%	2.026%	2.170%	2.014%	0.993%	0.454%	0.254%	0.137%	0.086%	0.051%	0.043%	0.027%
12.2	0.141%	0.759%	1.658%	3.089%	2.159%	1.564%	0.786%	0.313%	0.196%	0.141%	0.059%	0.031%
17.4	0.012%	0.145%	0.731%	2.209%	2.147%	1.791%	1.220%	0.645%	0.379%	0.176%	0.121%	0.043%
27.9	0.016%	0.043%	0.239%	1.255%	2.049%	1.912%	1.635%	1.294%	0.727%	0.383%	0.203%	0.074%
43.5	0.004%	0.027%	0.070%	0.614%	1.079%	1.631%	1.959%	1.713%	1.568%	0.946%	0.512%	0.137%
64.4	0.008%	0.016%	0.047%	0.254%	0.536%	0.966%	1.607%	1.857%	1.685%	1.310%	0.899%	0.328%
92.3	0.008%	0.004%	0.047%	0.176%	0.301%	0.520%	1.103%	1.705%	2.061%	1.986%	1.517%	0.657%
132.3	0.000%	0.012%	0.023%	0.109%	0.278%	0.368%	0.587%	0.954%	1.611%	2.342%	1.986%	1.517%
207.2 (90th Percentile)	0.004%	0.012%	0.023%	0.117%	0.250%	0.297%	0.450%	0.673%	1.111%	1.697%	2.440%	2.878%
237.3 (92nd Percentile)	0.004%	0.000%	0.000%	0.020%	0.039%	0.063%	0.098%	0.098%	0.133%	0.246%	0.454%	0.845%
289.1 (95th Percentile)	0.000%	0.000%	0.012%	0.020%	0.098%	0.133%	0.121%	0.168%	0.219%	0.305%	0.544%	1.373%
389.4 (98th Percentile)	0.004%	0.000%	0.020%	0.031%	0.102%	0.117%	0.188%	0.207%	0.215%	0.317%	0.450%	1.333%
902.5 (maximum)	0.000%	0.000%	0.008%	0.000%	0.059%	0.074%	0.086%	0.141%	0.137%	0.246%	0.340%	0.911%

Table 39: Joint probability of various Potomac River and Watts Branch flows

Note: The above reflects probability based on daily average flow. Higher percentages of Watts Branch flow may be more probable for short periods of time.

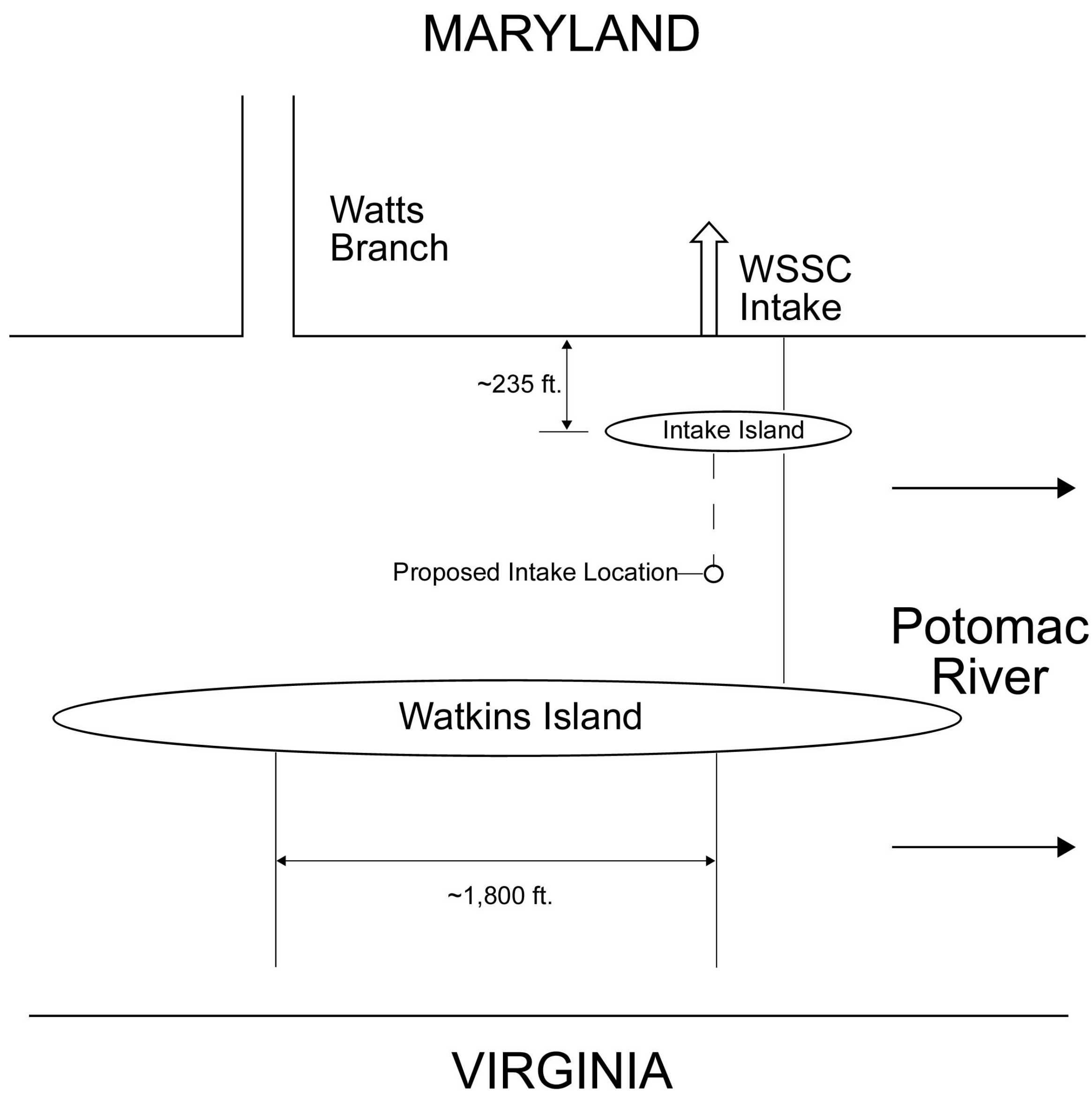


Figure 1: A schematic view of the area near the WSSC intake. This figure is not to scale, y-axis has been exaggerated to provide adequate detail at the intake.

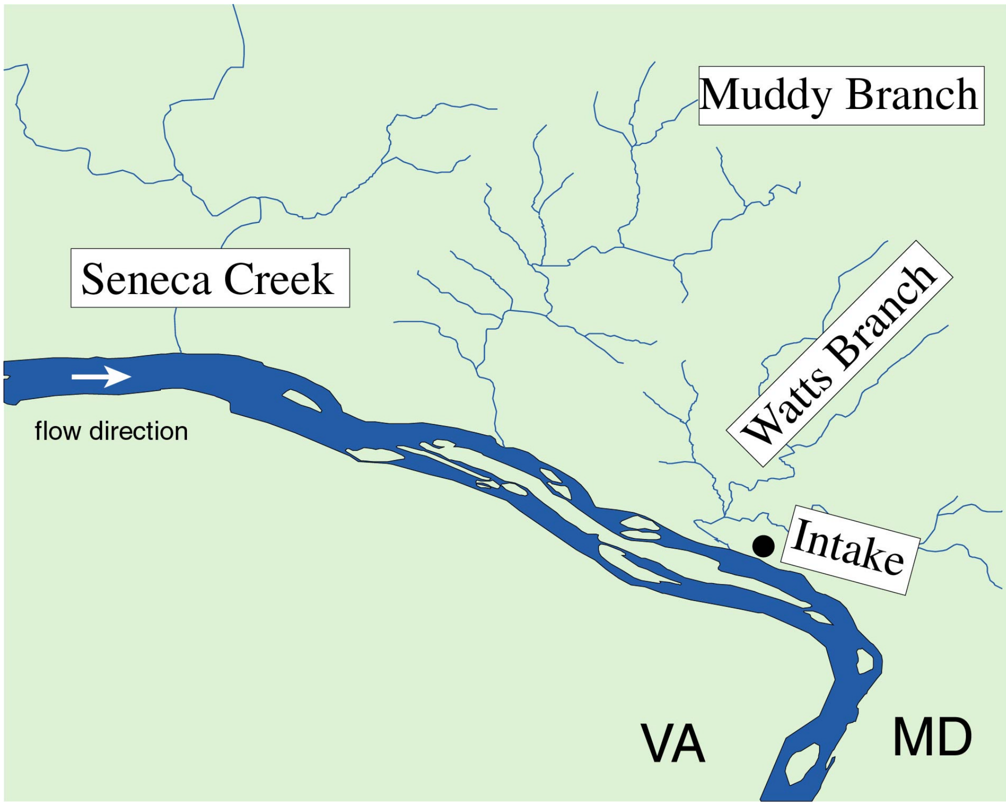


Figure 2: Three significant tributaries above the WSSC intake

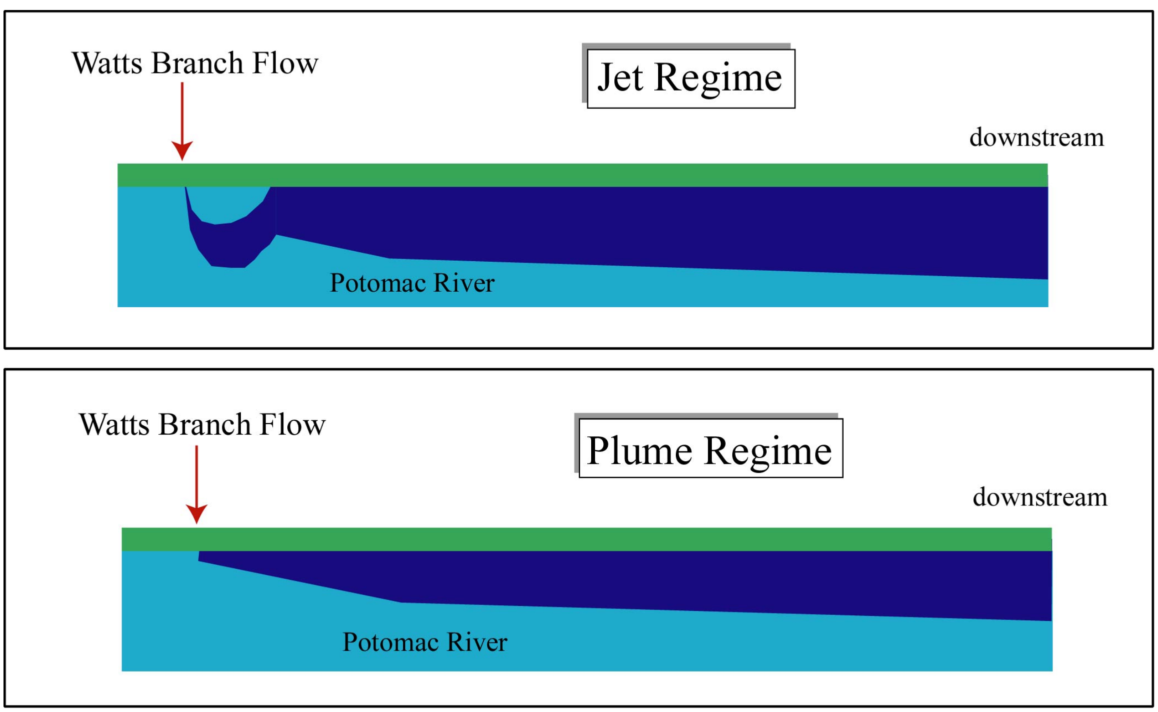


Figure 3: A schematic example of the jet and plume regimes produced by CORMIX

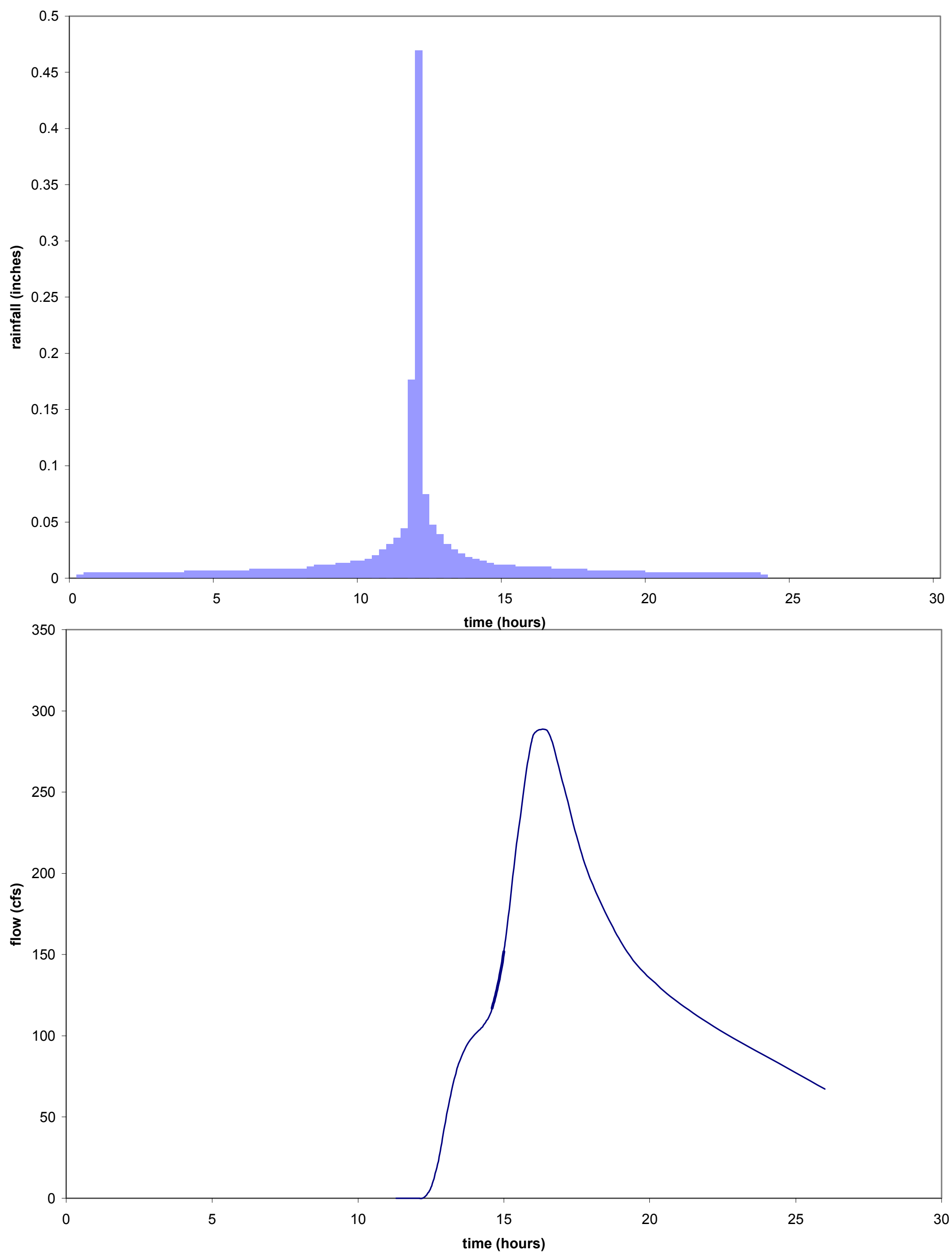


Figure 4: The hyetograph (top) and hydrograph (bottom) for the 3 times per year storm in Watts Branch

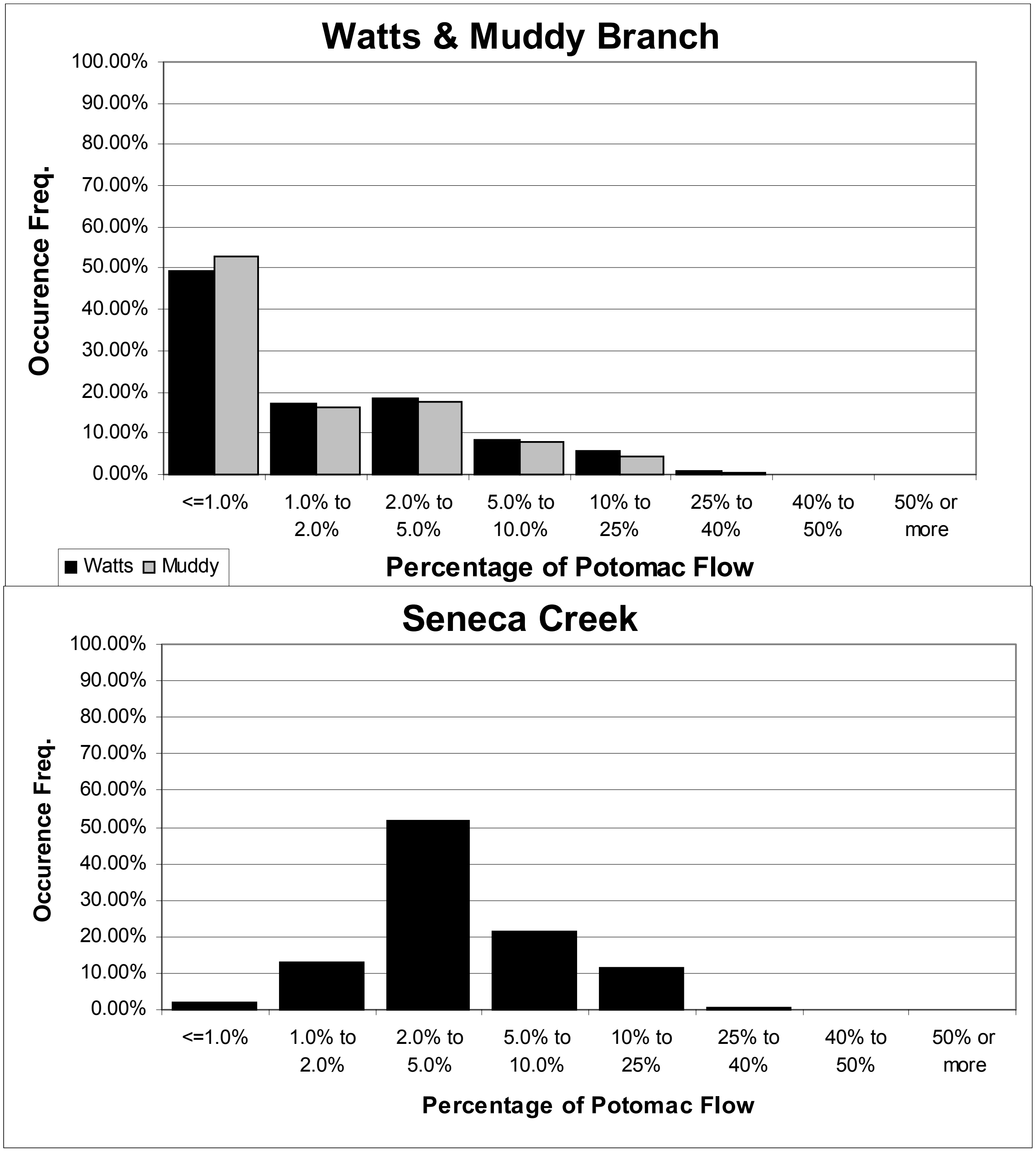


Figure 5: Estimated Flow Occurrence Frequencies calculated using the Simple Method

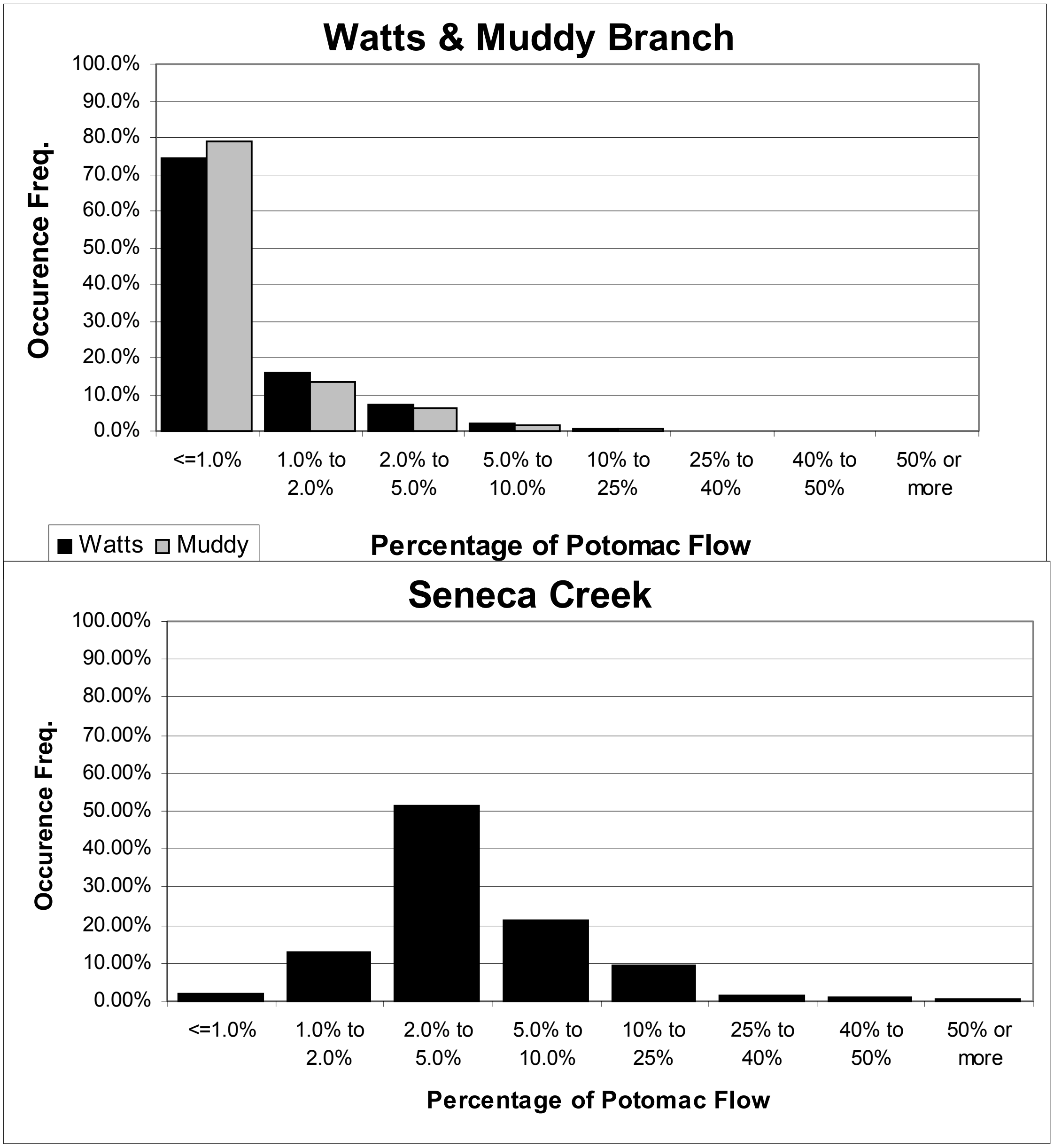
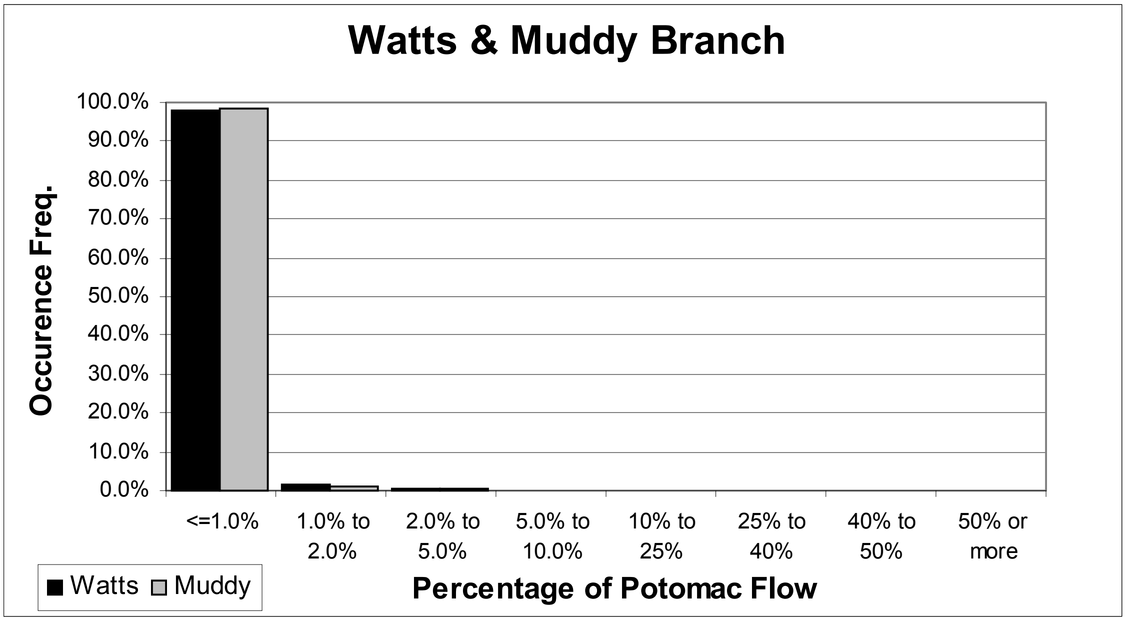


Figure 6: Estimated flow occurrence frequencies calculated using scaling (wet weather only)



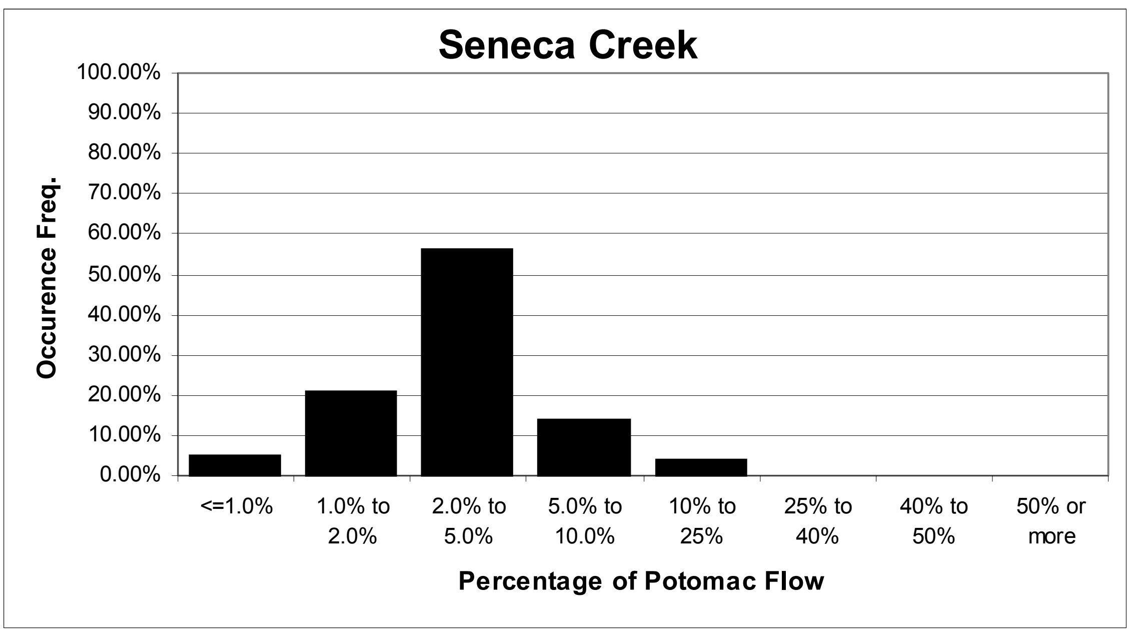


Figure 7: Estimated flow occurrence frequencies calculated using scaling (all flows)

APPENDIX A: CORMIX Assumptions and Inputs

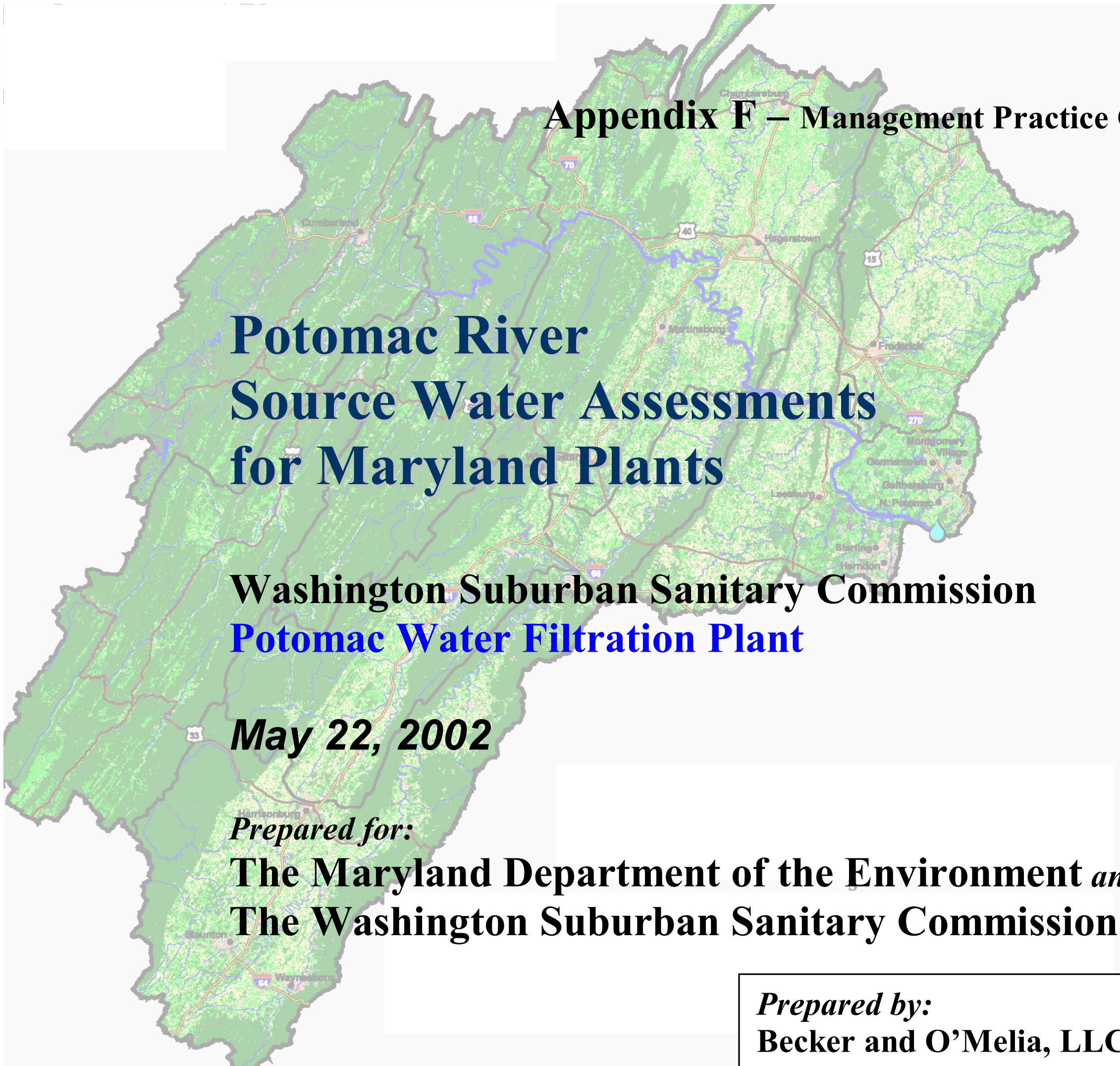
As mentioned in Section 3, the development of a CORMIX model for this task requires the use of assumptions to simplify the natural world. In this application of CORMIX, the following was assumed:

- The Potomac River and Watts Branch flows are considered to be uniform. The flows were modeled as fresh water streams with a temperature of 10° C.
- Steady flows were assumed in both the Potomac River and Watts Branch.
- All channels are rectangular in shape.
- The discharge from Watts Branch to the Potomac River is modeled as a surface discharge.

Variables defining the Potomac River, Watts Branch and the ambient conditions were also set in the CORMIX model. These include those shown in Table A1 below.

Table A1: Variables defined in CORMIX

Variable	Value
Ambient Conditions	
Wind Speed	2 meters/sec
Manning's n	0.035
Potomac River	
Average Depth	1.4 m
Depth at Watts Branch	1.4 m
Watts Branch	
Depth at outlet	0.35 m
Width at outlet	6 m



Appendix F – Management Practice Overview

Potomac River
Source Water Assessments
for Maryland Plants

Washington Suburban Sanitary Commission

Potomac Water Filtration Plant

May 22, 2002

Prepared for:

The Maryland Department of the Environment ***and***
The Washington Suburban Sanitary Commission

Prepared by:
Becker and O'Melia, LLC *in association with*
The Center for Watershed Protection

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

SECTION 1 - MANAGEMENT PRACTICES

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

Sediment loads to the WFP reduce filter run length, increase treatment residuals (which must be processed and disposed of), and transport other nutrients and pollutants to the Potomac River and the WSSC's intake. Major sediment sources include streambank erosion, construction sites, urban areas, mining, and forests. Urbanization increases impervious area and stream flows and thus increases erosion of receiving streambeds. Critical to the Potomac WFP is the Watts Branch, which drains urban areas of Rockville, Maryland and experiences significant erosion of the streambed due to increased magnitude and number of flow events that result from storms.

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

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

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[1] NC Cooperative Extension – 2

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

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

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

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

1.1 - Urban Best Management Practices (BMP)

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

1.1.1 - Density Restrictions

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

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[2] NC Cooperative Extension – 2

1.1.2 - Cluster Development and Impervious Surface Limits

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

1.1.3 - Prohibited Land use

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

1.1.4 - Structural Controls for Urban Development

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

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

Treatment Practice	TSS	TN	TP	Bacteria
Dry Pond	3	19	5	10[5]

Dry Extended Detention	31[2]	20	61	60[5]
Wet Pond	80	33	51	70
Wetland	76	30	49	78
WQ Swale[3]	81	50[5]	34	0[5,6]
Filters[4]	86	38	59	37
Infiltration	90[2, 5]	51	70	90[5]

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

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

1.1.4.1 - Wet Retention Ponds

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

1.1.4.2 - Storm Water Wetlands

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

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

1.1.4.3 - Dry Detention Ponds

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

1.1.4.4 - Infiltration Controls

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

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

1.1.4.5 - Filtering Practices

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

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

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[3] AWWARF 1991

1.2 - Agricultural Best Management Practices

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

1.2.1 - Animal-Waste Management

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

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

1.2.2 - Grazing Practices

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

1.2.3 - Filter Strips

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

1.3.4 - Conservation Tillage

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

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

1.2.5 - Cover Crops

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

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

1.2.6 - Contour Farming

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

1.3 - Forestry Best Management Practices

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

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

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

1.3.2 - Seasonal Operating Restrictions

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

1.3.3 - Slash Disposal

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

1.4 - Public Education and Participation

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

1.5 – Riparian Buffers

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

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

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[4] AWWARF 1991

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

1.6 - Plan Review

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

1.7 - Written Agreements

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

[5] AWWARF 1991

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

SECTION 2 - COSTS FOR URBAN MANAGEMENT PRACTICES

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

2.1 Stormwater Treatment Practices

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

2.1.1 Practices for New Development

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

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

2.1.2 Stormwater Retrofits

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

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

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

Table 4 Summary of Cost Data for Stormwater Programs				
Practice	**Capital Cost**	**Life (Years)**	**Annual Costs**	**Notes**
Watershed Education	Varies	N/A	Varies	See above for a more detailed discussion
Erosion and Sediment Control	$1,100/acre	1 year	$275/acre/year	Initial cost is actual practices. Annual costs include costs of inspectors and other program elements. Additional costs may include ordinance adoption and education costs.
Street Sweeping	$75,000-$150,000/ sweeper	5-8 years	$15-$30/curb-mile/year	Cost and life varies depending on sweeper type. Additional costs may include disposal and costs to change parking rules.
Rooftop Disconnection	$0.70/sf (Residential) $9.25/sf (Commercial)	20 years	minimal	Additional costs may include ordinance writing and education.
Urban Riparian Buffers	$9,000/acre to establish	20 years	Minimal	Additional costs include ordinance development and homeowner education. In many cases, buffer establishment may not be necessary. May also include a resource inventory to establish buffer quality.
Catch Basin Cleaning	$150,000/ truck	15 years	$30,000/driver/ year	This section presents costs based on sweeping frequency. Does not include additional maintenance or disposal costs.
Marina Pumpout	$14,000/	15	$100/slip/year	May also include an educational effort. This section

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

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

2.1.3 Education

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

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

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

Table 5 Unit Prices for Watershed Outreach	
Budget Item	**Estimated Unit Cost**
Billboards	$500-$1500 per month, 6 month minimum
Brochure Development	$75-$650
Coloring Books	$.33 per book
Decals	$.15 per decal
Educational Video	$1,000 per minute of finished video
Newspaper advertisements in local paper	$30-$90 per column inch
Photo Displays	$110 per display
Posters	Prices per 5000: $2.50 per poster (4 color, 2-sided 11x17) $0.65 per poster (2 color, 24x36)
Printed Materials (Flyers and brochures)	$.10-$.50 per printed material
Public Attitude Phone Survey	$15,000 per survey (survey of 1000 residents)
Radio Public Service Announcement	$35 per PSA
Slides	$3.00-$4.00 per slide
Soil Test Kit (includes testing cost but not sampling cost)	$10
Stickers	$.03 per sticker
Stormdrain Stencils	Order of 50 - $14.00 each
TV Public Service Announcement	$2,500 per PSA
T-Shirts	2 Color, Front and Back 500 - $4.65 each
Web Site Development	$169-$2,104 per site
Other Outreach Materials: Magnets Tote Bags	Prices per 1000: $.23 each $2.20 each

Table 5 Unit Prices for Watershed Outreach	
Budget Item	**Estimated Unit Cost**
Stickers	$.07 each
Source: Council of State Governments, Getting In Step A Guide to Effective Outreach in Your Community; National Oceanic and Atmospheric Administration, Dealing with Annex V - A Guide for Ports; and Center for Watershed Protection, Rapid Watershed Planning Handbook.	

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

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

Table 5 Educational Programs and Reported Increases in Awareness		
Campaign	Reported Increase	Agency
Street Signs - Motor Oil	33	San Francisco Water Pollution Prevention Program
Multi-media Campaign	40	same as above
TV Ads on oil recycling	32	same as above
Utility Bills on safer house cleaners	16	same as above
TV ads on Gardening Practices	13	same as above
1994-1996 Pesticide Ad Campaign	23	King County Local Hazardous Waste Management Program
1997-1998 Pesticide Ad Campaign	36	same as above
1997 Pesticide Brochure	24	same as above
1998 Storm Drain Education	37	Los Angeles County Stormwater Pollution Prevention Program
Pollution in Stormwater System	40	City of Eugene Stormwater Program
Clean Water Campaign regarding pesticides	38	City of Fort Worth, Texas Water Department
Sources: Elzufon (2000), Swann (1999)		

2.2 *Erosion and Sediment Control*

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

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

Table 6 Costs for Erosion and Sediment Control: Implementation

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

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

2.3 *Street Sweeping*

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

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

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

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

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

Table 8 Sweeper Cost Data

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

2.4 *Rooftop Disconnection*

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

Table 9 Costs for Green Rooftops

Unit: $/ft²		
Cost	**Description**	**Source**
3.00	Estimated cost is for extensive green roof and drainage layer, does not include contractor fees.	Johnston and Newton.
3.40	Source reported costs as an amount given for grant $, as well as a percentage of total production costs.	Environmental Services City of Portland, 1998
2.60 - 19.50	Source reported green roofs are 30% more expensive than conventional roofs including retrofits. Source gave conventional roof construction costs. This info was used to determine green roof cost.	Environmental Services City of Portland, 1998.
5.10-9.70	Labor and construction costs.	
17.50	Labor, materials and structural upgrade cost.	
	Materials and installation cost.	
	Do-it-yourself green roof installation in 1987$	
	Professionally designed and installed green roof in 1987$	Peck, et al.,1999

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

Table 10 Costs for Rain Barrels	
Unit: $/gallon	
Cost	**Source**
1.70	Plow and Hearth www.plowhearth.com/product.asp
2.00	Jerry Baker www.jerrybaker.com
2.50	Burpee Seeds and Plants www.burpee.com
2.55	Portland Rainbarrel Company www.teleport.com/~bardelp/
1.70	Gardener's Supply Company www.gardeners.com
1.50	D&P Industries, Inc. www.therainbarrel.com
0.90	Berry Hill www.berryhill.on.ca
2.50	Spruce Creek www.sprucecreekrainsaver.com
1.50-2.45	The Green Culture www.composters.com
1.80	Plastmo www.rio.com/~plastmo/gardnh2o.html
1.55	Arbour www.arbourshop.com
1.10-1.60	Green Venture www.greenventure.on.ca/rain.html
Default Cost: $1.70/gallon	

Table 11 Costs for Cisterns	
Unit: $/gallon	
Cost	**Source**
0.20-1.10	Texas Metal Cisterns www.texasmetalcisterns.com
0.80-1.00	Jade Mountain www.jademountain.com/waterProducts/cistern.html
0.50-1.20	Red Ewald, Inc., 2001
0.70-1.00	Forest Lumber Company www.forestlumber.com/products/cistern.html
Default Cost: $0.80/gallon	

Table 12 Costs for Dry Wells/French Drains	
Unit: $/cubic foot storage	
Cost	**Source**
3.00	CWP, 1997
5.00	US EPA 1999a
Default Cost: $4.00/cubic foot of storage (mean of above values)	

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

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

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

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

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

Practice	$/square foot
Rainbarrel	1.05

Cistern	0.50
Green Roof	18.00
Dry Well/French Drain	0.35

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

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

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

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

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

2.5 Urban Riparian Buffers

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

2.6 *Storm Sewer/ Catch Basin Cleaning*

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

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

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

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

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

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

2.7 *Marina Pumpout*

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

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

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

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

Table 14 Costs for Marina Pumpout: Installation	
Unit: ($/year)	
Cost	**Source**
$16,000	US EPA Gulf of Mexico Program. 2000.
$12,000-15,000	US EPA Gulf of Mexico Program. 1997.
$12,500	CWP 1998a
Model Default:$14,000	

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

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

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

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

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

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

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

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

2.8 Land Reclamation

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

Table 17 Costs Associated with Land Reclamation

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

2.9 Impervious Cover Reduction/ Better Site Design

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

2.10 Illicit Connection Removal

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

2.11 CSO Repair/ Abatement

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

Table 18 Costs for CSO Repair/Abatement

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

Table 18 Costs for CSO Repair/Abatement		
$0.27/gallons CSO removed	Storage, transportation and treatment to convey CSOs to WWTP	Zukovs, *et al.,* 1996
$0.06/gallons CSO removed	Regional high-rate treatment to partially treat CSOs locally in satellite facilities and capture and retain CSOs for treatment at WWTP	Zukovs, *et al.,* 1996
$3342/cfs	Source reported capital costs for design flow of 2500 cfs. Average of chlorine, chlorine dioxide, and ozone disinfection methods.	EPA. 1999b
System Storage		
$2.68/gallon of capacity	Total cost and basin capacity for 9 projects. Converted to $/gallon of capacity and averaged.	EPA. 1999c

2.12 SSO Repair/ Abatement

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

Table 19 SSO Repair/ Abatement Costs

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

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

2.13 Septic System Inspection/Repair

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

Table 20 Default Costs for System Inspection

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

Inspections cost $45 Pumpouts Cost $150

Table 21 Costs for Septic System Inspection Programs (Include all program costs)	
Unit: ($/household):	
Cost	**Source**
$70/year (1988 dollars)	US EPA. 1993.
$218/year	Hoover 1997
$95/year	Bilanin and Tervala.1999.
$40-$50 dollars per inspection $150-$250 annual O&M cost	MDE and MOP, 2000

2.14 Stream Channel Protection

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

Table 22 Costs for Channel Protection: Implementation		
Unit: $/linear foot		
Cost	**Source**	**Description**
109	Brown, 2000	Source reported total cost for stream restoration projects as well as project length and type.

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

2.15 Urban Program Costs

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

Table 23 Overall Program Costs

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

Note: Assumes a 10 square mile subwatershed

SECTION 3 -AGRICULTURAL COSTS

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

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

3.1 - Conservation Tillage

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

Table 24. Conservation Tillage Costs

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

3.2 - No Till/ Strip Till

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

Table 25. No Till/ Strip Till Costs			
Source	**Capital Costs**	**Annual Cost**	**Notes**
Parsons, *et al.* (2001)	0	$20-$45	Most expensive for larger farms. Small and medium farms at the lower price range.
Camacho, 1991	None reported	$14	Typical annual data from the Chesapeake Bay region.

3.3 - Crop Rotation

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

3.4 - Integrated Pest Management (IPM)

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

Table 26. IPM Scouting Costs (Source: US EPA, 1993)	
Crop	**Price Range**

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

3.5 - Nutrient Management

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

3.6 - Grazing Management

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

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

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

3.7 - Animal Waste Management

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

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

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

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

3.8 - Conservation Buffers

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

Table 29. Costs of Conservation Buffers

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

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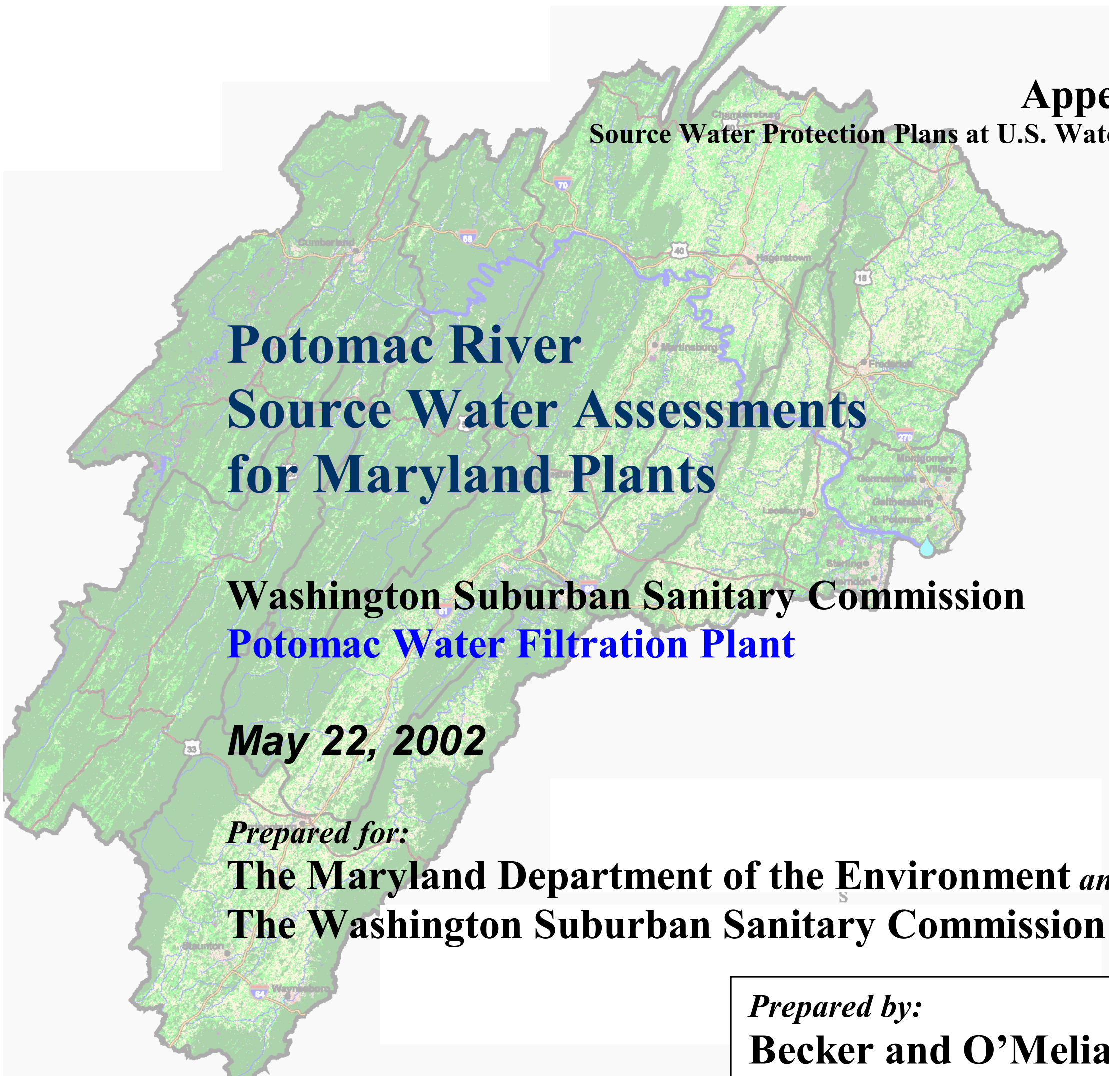

Appendix G
Source Water Protection Plans at U.S. Water Supplies

Potomac River Source Water Assessments for Maryland Plants

Washington Suburban Sanitary Commission
Potomac Water Filtration Plant

May 22, 2002

Prepared for:
The Maryland Department of the Environment *and*
The Washington Suburban Sanitary Commission

Prepared by:
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WATER PROCESS RESEARCHERS AND CONSULTANTS

INTRODUCTION

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

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

- Monitoring and evaluation of the effectiveness of the program.

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

NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION

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

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

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

Whole Farm Planning includes multiple barriers, which may include:

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

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

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

MASSACHUSETTS WATER RESOURCES AUTHORITY

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

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

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[1] NAE 2000

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

CHESTER WATER AUTHORITY

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

SYRACUSE WATER DEPARTMENT

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

[2] AWWARF 1991
[3] EPA 1999

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

SALEM PUBLIC WORKS DEPARTMENT

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

[4] AWWARF 1991

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

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

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

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[5] AWWARF 1991

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

CONTRA COSTA WATER DISTRICT

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

LOS ANGELES DEPARTMENT OF WATER AND POWER

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

[6] AWWARF 1991

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

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

The county agricultural commissioner administers pesticide and herbicide use permits.

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

METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

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

SWEETWATER AUTHORITY

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

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

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Appendix H – Summary of Public Comments and Responses

Potomac River
Source Water Assessments
for Maryland Plants

Washington Suburban Sanitary Commission
Potomac Water Filtration Plant

May 22, 2002

Prepared by:

The Maryland Department of the Environment

SUMMARY OF PUBLIC COMMENTS AND RESPONSES

regarding the

EXECUTIVE SUMMARY AND PRESENTATION OF PROJECT RESULTS

for the

SOURCE WATER ASSESSMENT of the WSSC

POTOMAC FILTRATION PLANT

Comments were provided during the discussion at a public meeting held on May 14, 2002 in Rockville and to MDE via email prior to May 24, 2002.

1. **Comment:** The recommendation for giving serious consideration to constructing a submerged channel intake to affect raw water quality improvements was appreciated.

   Response: No change to summary needed.

2. **Comment:** The Executive Summary did not advocate forcefully enough for the creation of a watershed protection group as this group is essential to address mid-term and long-term protection measures.

   Response: The Executive Summary first recommendation advocates the formation of a watershed protection group, and the project team considers this key to ongoing protection of the water supply. The recommendation also recognizes that granting a group authority separate from environmental regulatory agencies at federal, state and local levels may not be appropriate. A watershed drinking water protection group should be working with existing authorities to address issues of concern for drinking water protection. The project team believes that a watershed protection group is needed to provide guidance for future studies and coordinate with local, state and federal agencies drinking water concerns which are necessary to improve water quality across the Potomac River basin. This is discussed further in response to comment number 13.

3. **Comment:** The Executive Summary appears to be geared towards justifying the construction of a new mid-channel intake on the Potomac for the WSSC plant.
   Response: It was hypothesized that the current WSSC intake along the bank of the MD shore is adversely affected by storm events from the Watts Branch Watershed. Data collected by the WSSC prior to initiating the source water assessment (SWA) demonstrated disproportional impacts from Watts Branch. A key component of the SWA took a detailed look at Watts Branch and its impact. As part of the Susceptibility Analysis and modeling effort, the flow of Watts Branch was modeled and results were interpreted for the current intake location and for a potential mid-channel intake. However, a substantial effort was also made modeling contamination from the watershed upstream of Watts Branch, which would effect both the current intake location and a potential mid-channel intake location.

4. **Comment:** The words used to describe actions involved in modeling future scenarios, Aggressive and Moderate Management, are confusing. Could there be a better word to describe the efforts of implementing management scenarios?
   Response: The Executive Summary was modified to better define these terms. These terms reflect the degree of future management approaches and options undertaken and modeled to obtain estimates of the level of benefits of implementing various management practices. The expertise of the Center for Watershed Protection was relied upon to define moderate and aggressive management scenarios.

5. **Comment:** Based on observations of construction sites in the City of Rockville a comment was made that better enforcement of sediment/erosion control laws would achieve greater degrees of pollution reduction than predicted by the model.
   Response: Increased enforcement of sediment/erosion control laws is incorporated into the model. A lot of the sediment contributed by Watts Branch is a result of channel erosion from changed hydraulics not sediment lost from construction activity. Enforcement of sediment control laws is important and violations should be referred to the delegated authority, which in this case is the City of Rockville.

6. **Question:** Are we (MDE, WSSC) looking at all the pesticides? The USGS identified other pesticides in the raw water of the Potomac. Should these be listed as contaminants of concern? Were pharmaceutical/hormone chemicals looked at (tested for) during the assessment?

   Response: Under current regulations, WSSC tests for approximately 2 dozen pesticides and 10 unregulated pesticides. WSSC also tests monthly for the presence of pesticides in its 'raw water" (directly from the Potomac). This data did not show that any pesticides were 50% or greater than any of the maximum contaminant levels in 10% or more of the samples. Atrazine and simazine were detected in 7 of 40 and 6 of 38 samples respectively. Two other pesticides were detected one time. All levels were well below maximum contaminant levels. The highest value of Atrazine detected was 0.4 parts per billion or about 13% of the maximum contaminant level. The highest value of simazine detected was 0.3 parts per billion or about 7.5% of the maximum contaminant level. The USGS data was reviewed and because levels did not meet the criteria for consideration no other pesticides were included. Appendix A and C provide more detail on the data reviewed. Pharmaceutical and hormonal compounds in drinking water sources are a relatively new concern, and was not within the scope of this assessment. No testing or sampling was done for the assessment; existing water quality data was reviewed to determine contaminants of concern.

7. **Question:** Would a mid-channel intake, or an intake closer to the streambed (sediment) increase the likelihood of pesticide contamination, and has the number of pesticides detected at the WSSC plant increased over the past few years?

   Response: As described above, pesticide detection is not common at the WSSC Filtration Plant; it is not likely that a mid-channel intake would increase the likelihood of pesticides entering the finished water supply. Detections of pesticides at the Potomac Filtration Plant have not increased during the past few years. Pesticides (herbicides) are more likely to be detected in samples collected during runoff events following their application in the spring. Atrazine and simazine pesticide usage in Maryland has decreased over the past decade.

8. **Question:** Why are concentrations of Ammonia higher during the winter?
   Response: According to water plant operators on the Potomac River, elevated ammonia is not a common occurrence but it does occasionally happen during the winter season, usually with snow melt. While the reason for elevated concentrations is not known, it is speculated that this it is due to ammonia based de icing compounds applied to impervious surfaces.

9. **Question:** It has been shown that certain contaminants are found in higher concentrations from Watts Branch during storm events. How many samples were taken to determine/justify this belief?
   Response: Eighteen storm event samples were analyzed by the WSSC laboratory at several different points near the Potomac intake. Watts Branch storm runoff also has lower alkalinity water than the main stem of the Potomac.

10. **Question:** Why the focus on a mid-river (channel) intake?
    Response: A mid-channel intake is one option of dealing with the localized effects of Watts Branch, which is especially important because of the rapid change in water quality it can induce at the Potomac Filtration Plant during a storm. The rapid change in water quality makes it challenging for the operational staff to accurately adjust coagulant dosage and pH to achieve optimum particulate removal. Optimum particle removal ensures a greater removal of cysts and oocysts.

11. **Comment:** Are the models used in the assessment peer reviewed, and what is their reliability? Especially the coupling of the Chesapeake Bay Program Model and Water Treatment Model(WTM). No other data is presented to support the Watts Branch sediment reduction predictions than the models. How can we have

confidence in the sediment/turbidity reductions estimates for Watts Branch or the upstream watersheds?

Response: The CORMIX model, which was used to model the hydrodynamics of Watts Branch, mixing with the Potomac River is the ideal model used for this type of analysis. The selection of this model was based on the recommendations of LimnoTech Inc. who have significant experience and expertise in flow modeling and considering the degree of accuracy needed for a SWA. The CORMIX model is a published peer reviewed model. The model provided estimates of mixing ratios between the Potomac River and Watts Branch at the current and hypothetical intake location.

The Chesapeake Bay model is the best available to account for fate and transport of contaminants in the Potomac River system. The model was calibrated to the Potomac Water Filtration Plant.

Scenarios that represent future land use and management scenarios were developed based on predicted future conditions and modeled using the Watershed Treatment Model (WTM) developed by the Center for Watershed Protection. 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 Chesapeake Bay Model by modifying the hourly “edge-of-stream” loading from each major subbasin based on the annual load changes predicted by the WTM. The results of the model runs for the upper parts of the watershed were discussed with ICPRB modelers (who are performing similar evaluations for the District of Columbia’s SWA) and EPA-CBPO modelers (who developed and maintain the Chesapeake Bay Watershed Model). The project team has confidence in these results because…the results are consistent with other similar modeling efforts in the area, and consistent with what one would expect given the type and magnitude of growth planned in the watershed.

It’s worth noting that the Watts Branch predictions did not rely on linkage of any model with the WTM model. The Watts Branch sediment reductions estimates were based on field work, geomorphic analysis and the WTM load estimates. The project team has confidence in the Watts Branch estimates because…of the expertise and knowledge regarding Watts Branch at the Center for Watershed Protection, the level of detail of these evaluations was much greater than in other areas, and because the Center for Watershed Protection has a great deal of experience applying this model in this fashion.

12. **Comment:** It seems that WSSC is trying to do the same thing that Fairfax County Water Authority did, build a new intake to avoid the problem of water quality, when money should be spent improving the quality of water, especially in Watts Branch.
Response: This report advocates making improvements to water quality in Watts Branch. The analysis shows that the level of improvement achievable are not nearly as great as can be obtained through an alternate intake location. Avoiding the impacts of Watts Branch as soon as possible would be a benefit to the public health of all the people who are served by the Potomac Filtration Plant. As discussed previously, Watts Branch has a disproportional influence on the water quality at the Potomac Filtration Plant and is a significant operational challenge.

13. **Comment:** What is the potential for successful watershed protection, without as yet, a budget or guidance?
Response: The assessment is the first step in the process of watershed protection. To protect the source watershed, in this case the 11,000+ square mile Potomac River watershed, cooperation will be needed between many inter-jurisdictional governments. Organizations such as the Interstate Commission of the Potomac River Basin, and the Environmental Protection Agency (Region III) and Washington Council of Governments will be important to this process. There is also the potential for money to become available for source water protection efforts, similar to the Well Head protection grant given to states by the federal government. Protecting the Potomac River as a source of drinking water is an important task, one in which MDE will be a fully committed partner.

14. **Comment:** What percentage of the impervious area of the Watts Branch watershed could be addressed in the aggressive management approach?

Response: The aggressive management approach covers 24% of the impervious land in the Watts Branch watershed.

15. **Comment:** The model results show that even with aggressive management scenarios, the benefit of reducing sediment at the Potomac Filtration Plant does not seem that substantial.

Response: At this point in time, the Potomac River is not in a one-to-one steady-state situation with sediment loading and reduction. There is a substantial amount of sediment contained within the river system (streambed). Even if sediment input into the river were substantially decreased, it would take years to see the benefit of these practices (this was inferred from the model results and is consistent with other evaluations of similar geomorphological processes). Without additional disturbance within the watershed eventually the river system would return to a one-to-one situation. Sediment loading reduction from the land would result in reduction of sediment within the river. However, the benefits of a substantial reduction in the loading of contaminants, such as fecal bacteria, *Cryptosporidium*, and *Giardia,* which are associated with sediment, would be approximately immediate.

16. **Comment:** Montgomery County Department of Environmental Protection is beginning to develop a watershed management plan that will implement stream restoration and stormwater management projects in Watts Branch. The Executive Summary should acknowledge these efforts.

Response: The Executive Summary has been modified to do so.

17. **Comment:** Agree that safe drinking water is one of the most important public health issues in any society.

Response: No change needed.

18. **Comment:** Agree with cited benefits of source water protection in overview and would add the benefits of clean water for intakes.

Response: The second paragraph has been modified to address this comment.

19. **Comment:** The need for a submerged channel intake should be explained as a cost for failure to adequately protect intake from excessive phosphorous and algae.

Response: The need for submerged channel intake is a result of sudden water quality changes due to the proximity to Watts Branch and not specifically related to phosphorous or algae. Development in Watts Branch basin has been going on for a number of years, as has the water treatment challenge at the Potomac Water Filtration Plant. No change in the wording is proposed.

20. **Comment:** More detail should be provided on the location of contaminant sources and causes of contaminants of concern in particular and their history in the basin as this is essential to the ultimate goal of source water protection. Was this step contemplated? Comments were made concerning dieldrin, wastewater treatment plant locations, and land uses associated with specific contaminants.

Response: This information is primarily contained within the body of the report. The contaminants of concern are not unique to any one source or portion of the watershed but are throughout the watershed. Certain subwatersheds have a greater amount of sources and these are indicated in several different tables in the main report. Some detail is provided in the executive summary on pages vi, viii and ix. A complete discussion is found in Sections 4, 5, 6 and 7 of the full report. The discussions identify the types of sources within the basin of the contaminants of concern and their relative significance as the data allowed. Specific maps showing land use, contamination sources including wastewater plant locations are part of the complete report. A full discussion on dieldrin is found in Appendix C of the report.

21. **Comment:** The phrase “cost-effective” should be added to modify better watershed management practices on page iv of the executive summary..

Response: The study did not assess the cost-effectiveness of improved watershed management practices. The report emphasizes the primary benefit as an additional basis for public health protection. No change to the wording is proposed.

22. **Comment:** Clarification was requested relating impervious cover in the Watts Branch Watershed, contaminants of concern and major treatment challenges and why Group 1 contaminants are highest following rainfall.
    Response: The Executive Summary was modified to reflect in more detail how the impervious cover in Watts Branch creates a major treatment challenge to the Potomac Filtration Plant. Issues of alkalinity, pH, fecal coliform and the quick response of the river to rainfall are described in relation to plant operations.

23. **Comment:** Geographical context of the management practices was requested.
    Response: The full report does provide geographic context. Management practices were applied based on land uses within each of the Chesapeake Bay Program subbasins. Results of the modeling by subbasins is found in Section 7 of the full report.

24. **Comment:** Why will non point urban loads increase, even with BMP implementation?
    Response: The increase is due to the increase in urban land (development) upstream of the intake.

25. **Comment:** Given current drought conditions, a more detailed explanation on low flow on Group 2 contaminants is warranted.
    Response: The project modeling period covered typical hydraulic conditions. Seasonal low flow occurrences are included in the model runs. The project scope did not include the particular impacts of drought conditions on algae, natural organic matter or disinfection by-product precursors. We are not able to quantify drought effects on these constituents.

26. **Comment:** More detail on types of management practices to achieve nitrogen and phosphorous loads should be provided.

    Response: The full report describes this in more detail (Section 7).

27. **Comment:** Please clarify what is the unknown nature of the taste and odor compounds.

    Response: The text has been modified to improve this description.

28. **Comment:** Please clarify the Seneca Creek impact on the Potomac Water Filtration Plant intake.

    Response: The text was modified to better describe the impact.

29. **Comment:** What data is available to describe the mixing of Seneca Creek and the Potomac River up to the Potomac Plant intake.

    Response: No site specific data was available.

30. **Comment:** The public participation process should be described in the Executive Summary.

    Response: A section has been added to describe this and the comments received on the executive summary have been included in this appendix of the report.

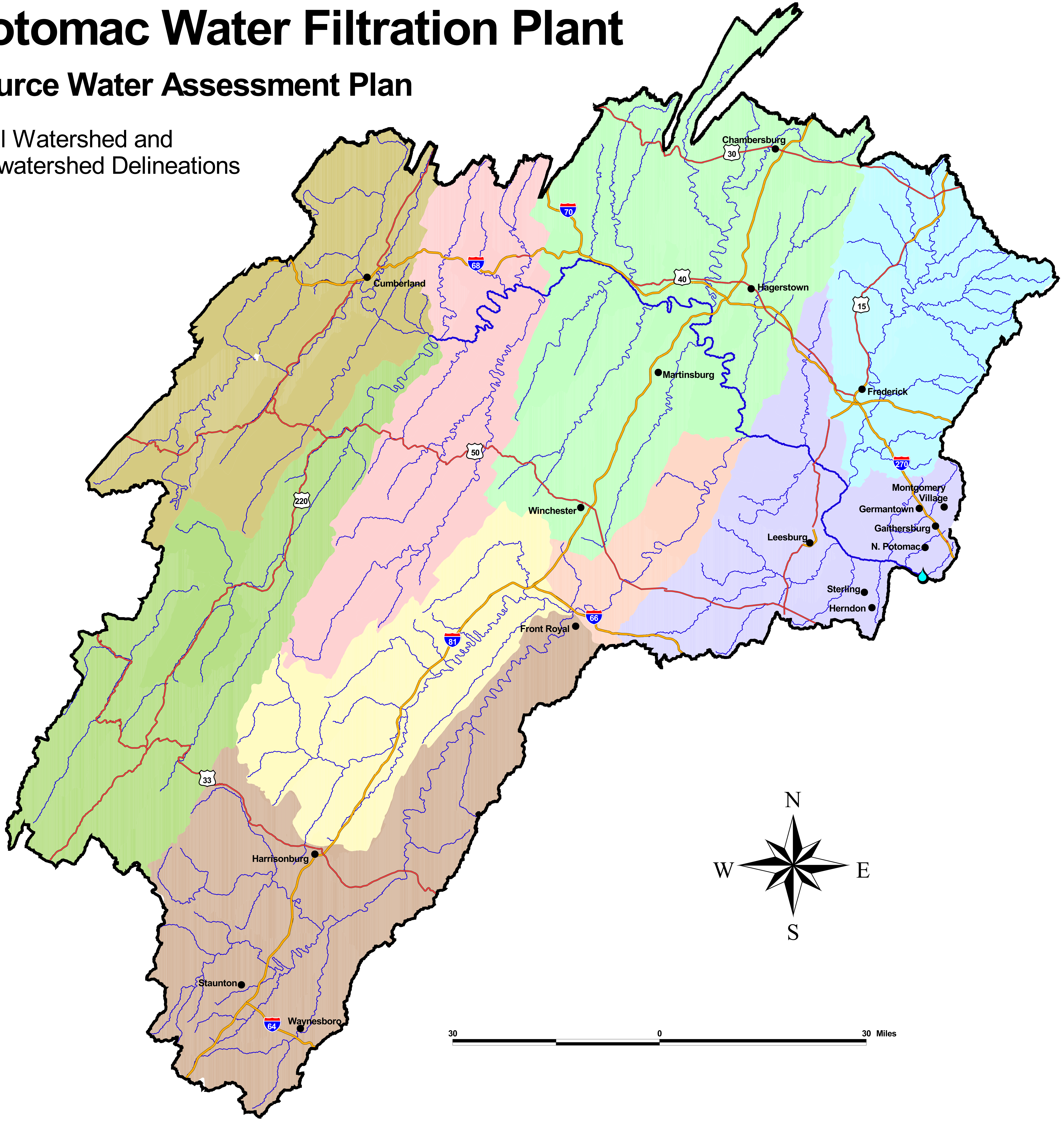
31. **Comment:** The multiple barrier approach that includes source water protection is the appropriate public policy objective.

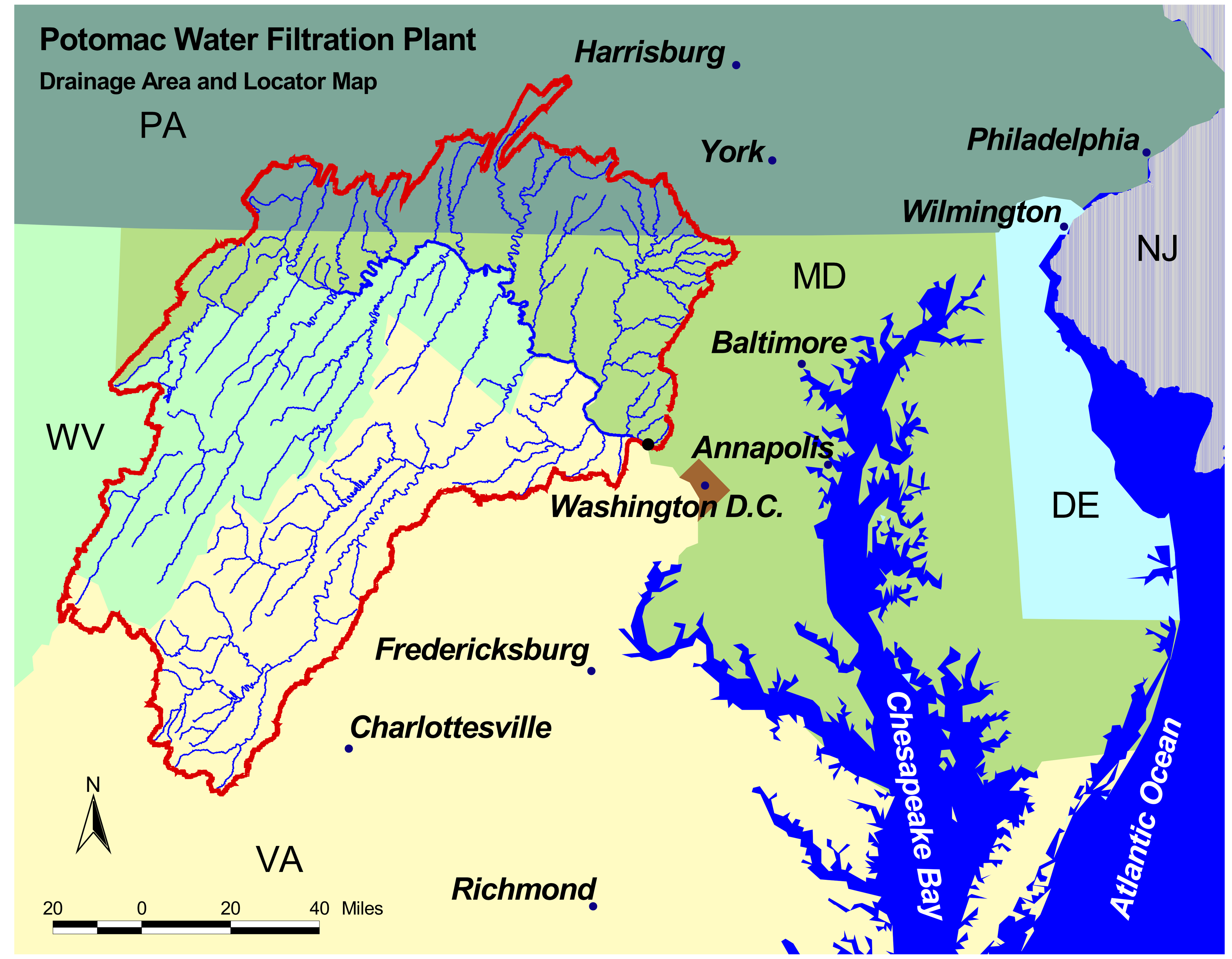
    Response: No change in Executive Summary is needed.

Potomac Water Filtration Plant

Source Water Assessment Plan

Final Watershed and
Subwatershed Delineations





Legend

- Potomac Water Filtration Plant Intake
- Watershed Boundary
- Hydrology
- Major Cities
- Interstate Highways
- Interstate Route Numbers
- U.S. Highways
- U.S. Route Numbers

HUC 8 Subwatersheds

- Capacon-Town
- Conococheague- Opequon
- Middle Potomac- Catoctin
- Monocacy
- North Branch Potomac
- North Fork Shenandoah
- Shenandoah
- South Branch Potomac
- South Fork Shenandoah

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

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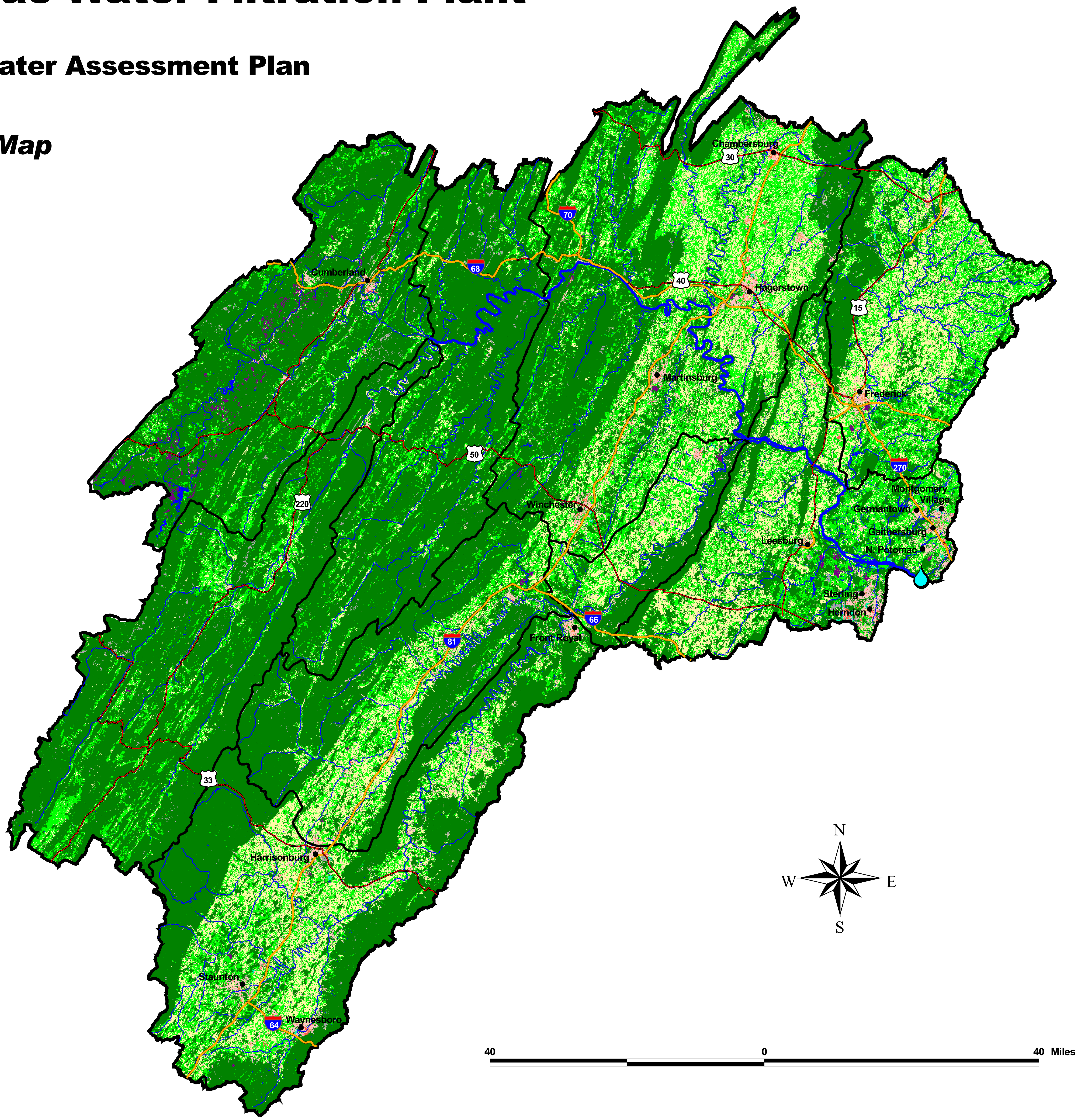
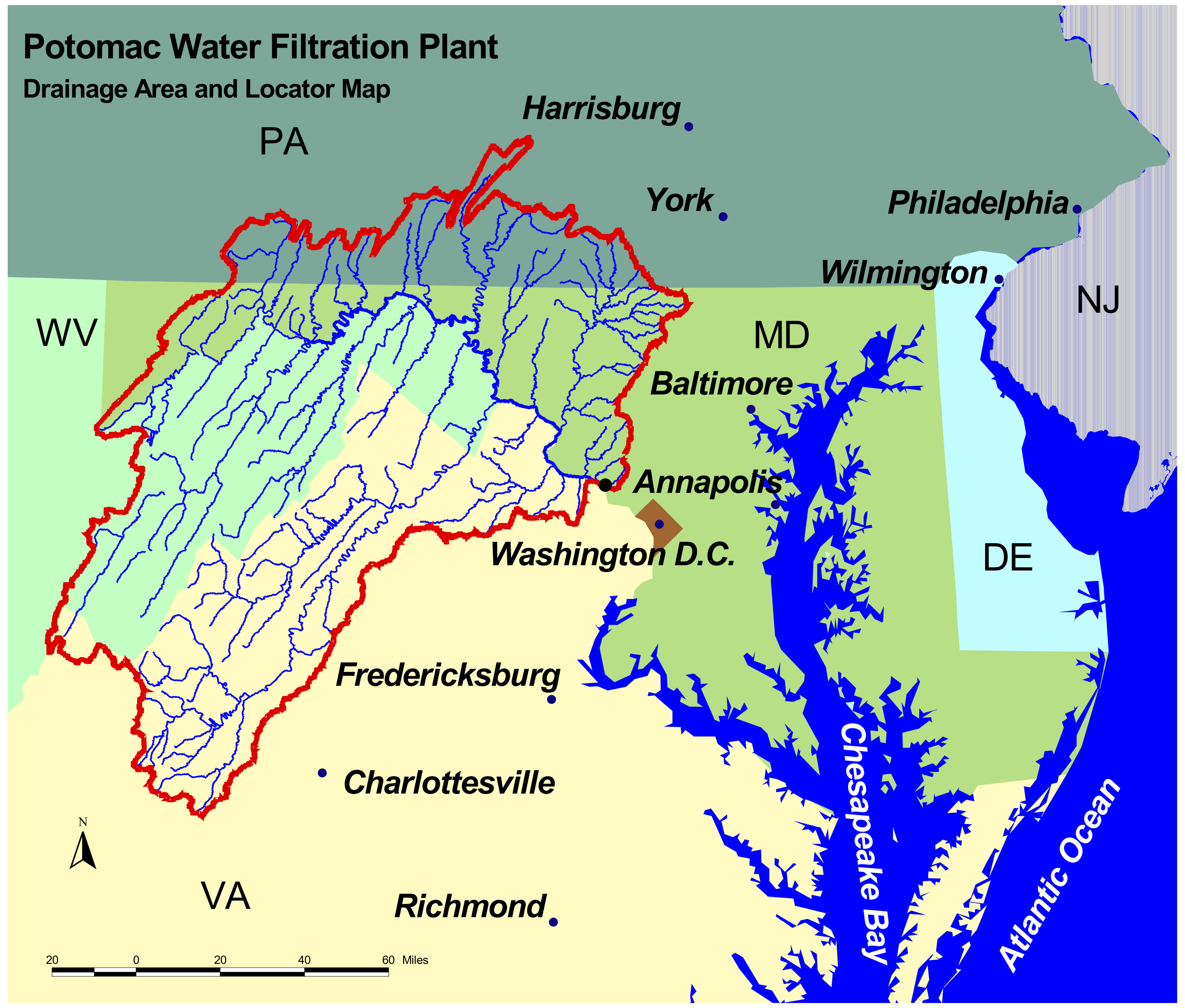
Potomac Water Filtration Plant

Source Water Assessment Plan

Landuse Map





Legend

- Watershed boundary
- HUC 8 Subwatersheds
- Hydrology
- Potomac Water Filtration Plant intake
- Major cities
- Interstate Highways
- Interstate Route numbers
- U.S. Highways
- U.S. Route numbers

Landuse

- Water/Wetlands
- Low Intensity Residential
- High Intensity Residential
- High Intensity Commercial/Industrial
- Hay/Pasture
- Row Crops
- Other Grass/Parks
- Forest
- Quarries/Mining
- Transitional
- No Data

Sources: watershed, subwatershed and political boundaries from EPA Office of Water, Office of Science and Technology, Washington, D.C. Hydrology from Maryland Department of the Environment, Baltimore, MD. Landuse from Multi-Resolution Land Characteristics Consortium (MRLC)

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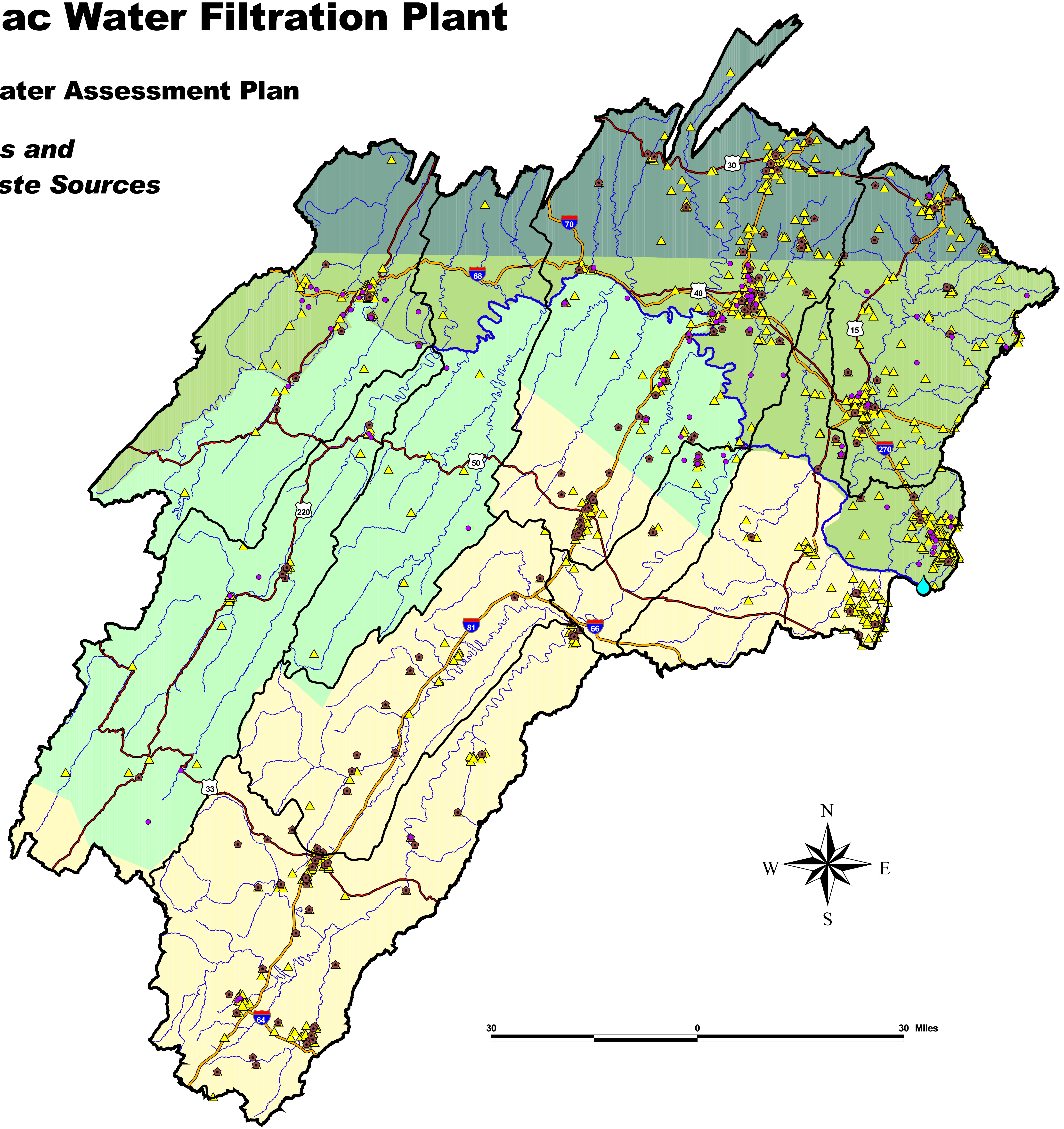
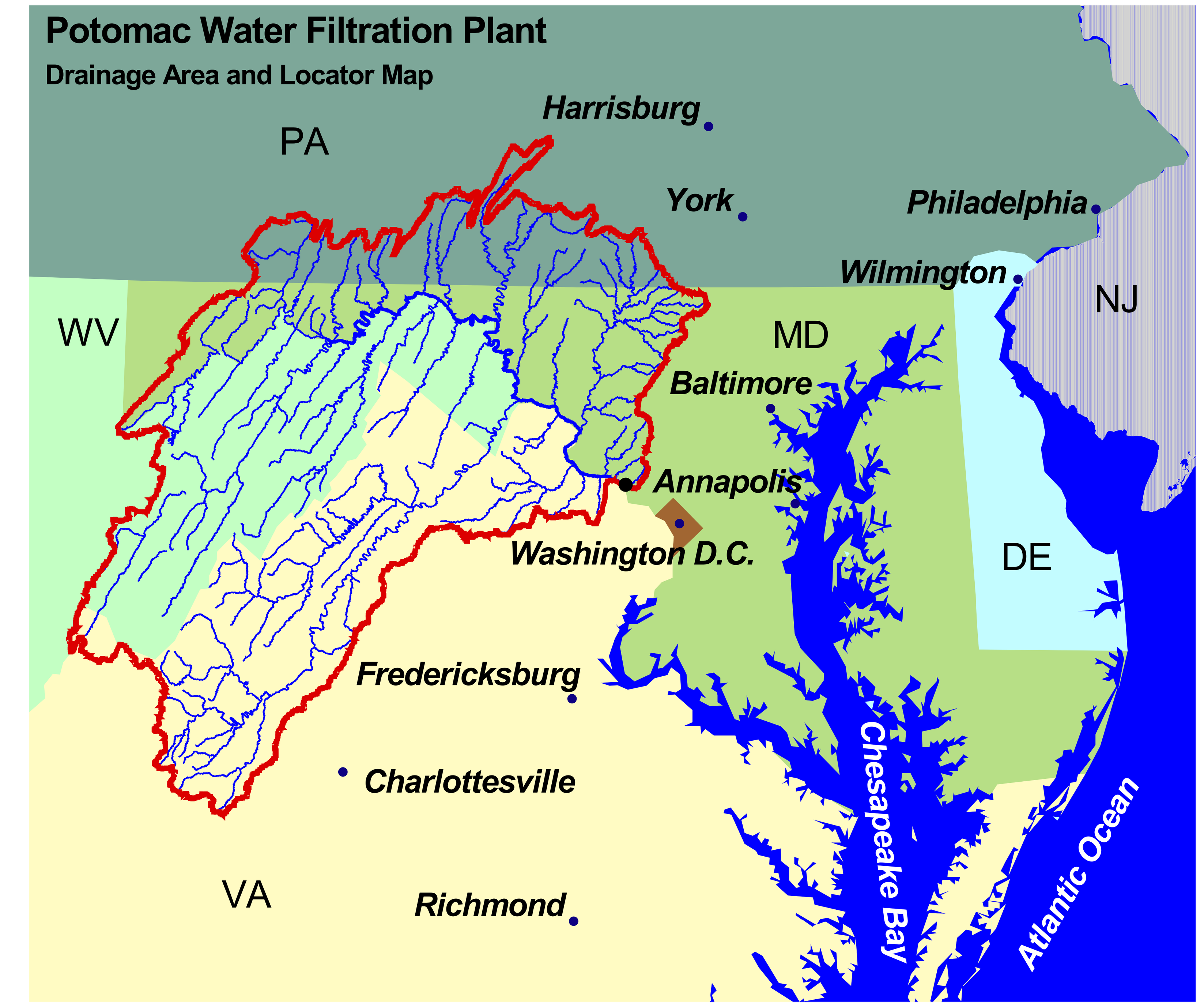
Potomac Water Filtration Plant

Source Water Assessment Plan

Hazardous and Toxic Waste Sources





Legend

- Watershed boundary
- HUC 8 Subwatersheds
- Hydrology
- Potomac Water Filtration Plant intake
- Resource Conservation and Recovery Information System (RCRIS) Hazardous and Solid Waste Sites
- Toxic Release Inventory (TRI) sites
- Comprehensive Environmental Response Compensation and Liability Information System (CERCLIS) sites
- Interstate Highways
- U.S. Highways
- U.S. Route numbers
- Interstate Route numbers

Sources: watershed, subwatershed and political boundaries from EPA Office of Water, Office of Science and Technology, Washington, D.C. Hydrology from Maryland Department of the Environment, Baltimore, MD. RCRIS and TRI sites from EPA BASINS. CERCLIS sites from EPA BASINS, Maryland Department of the Environment, and West Virgina Department of Environmental Protection.

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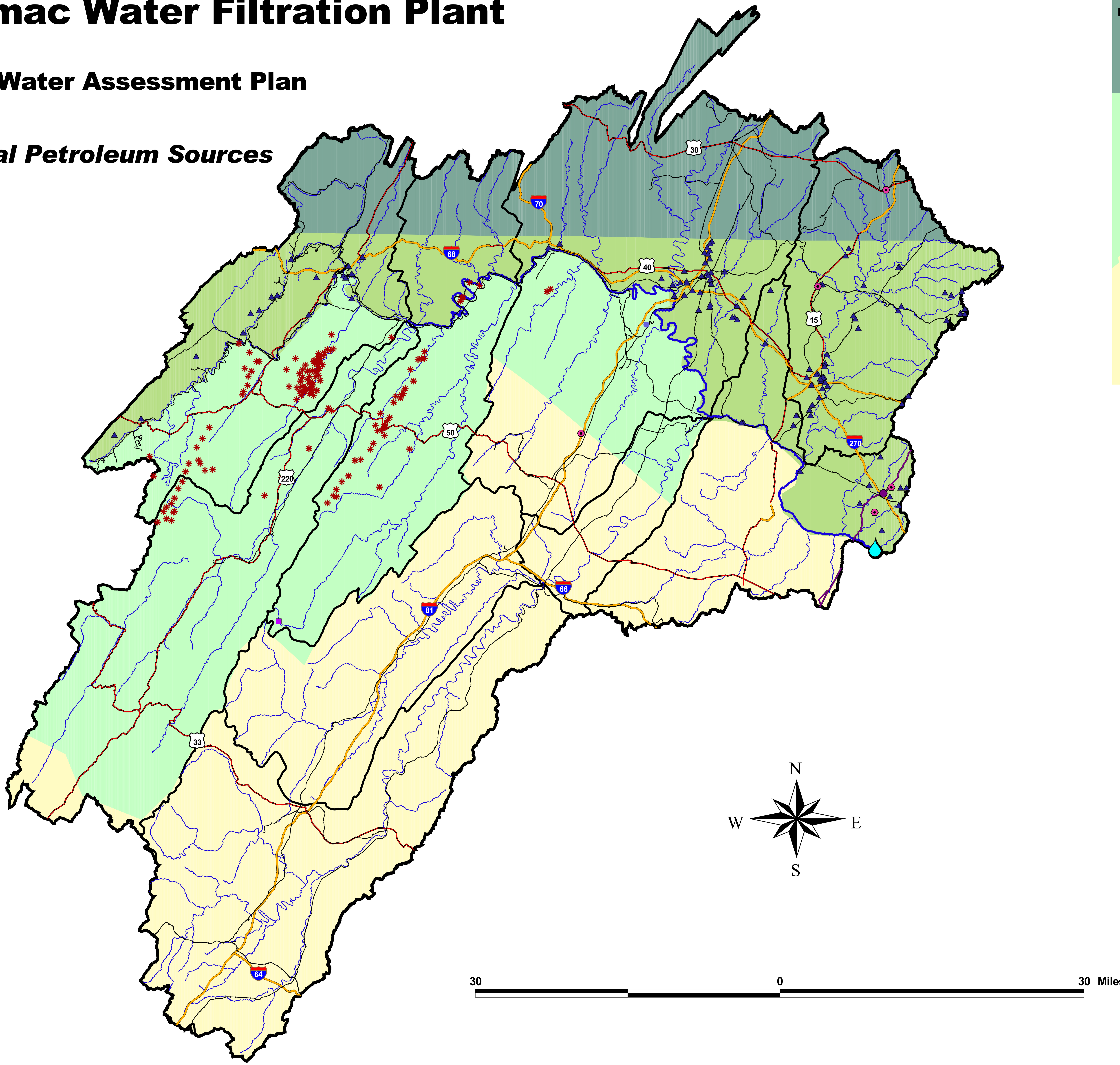
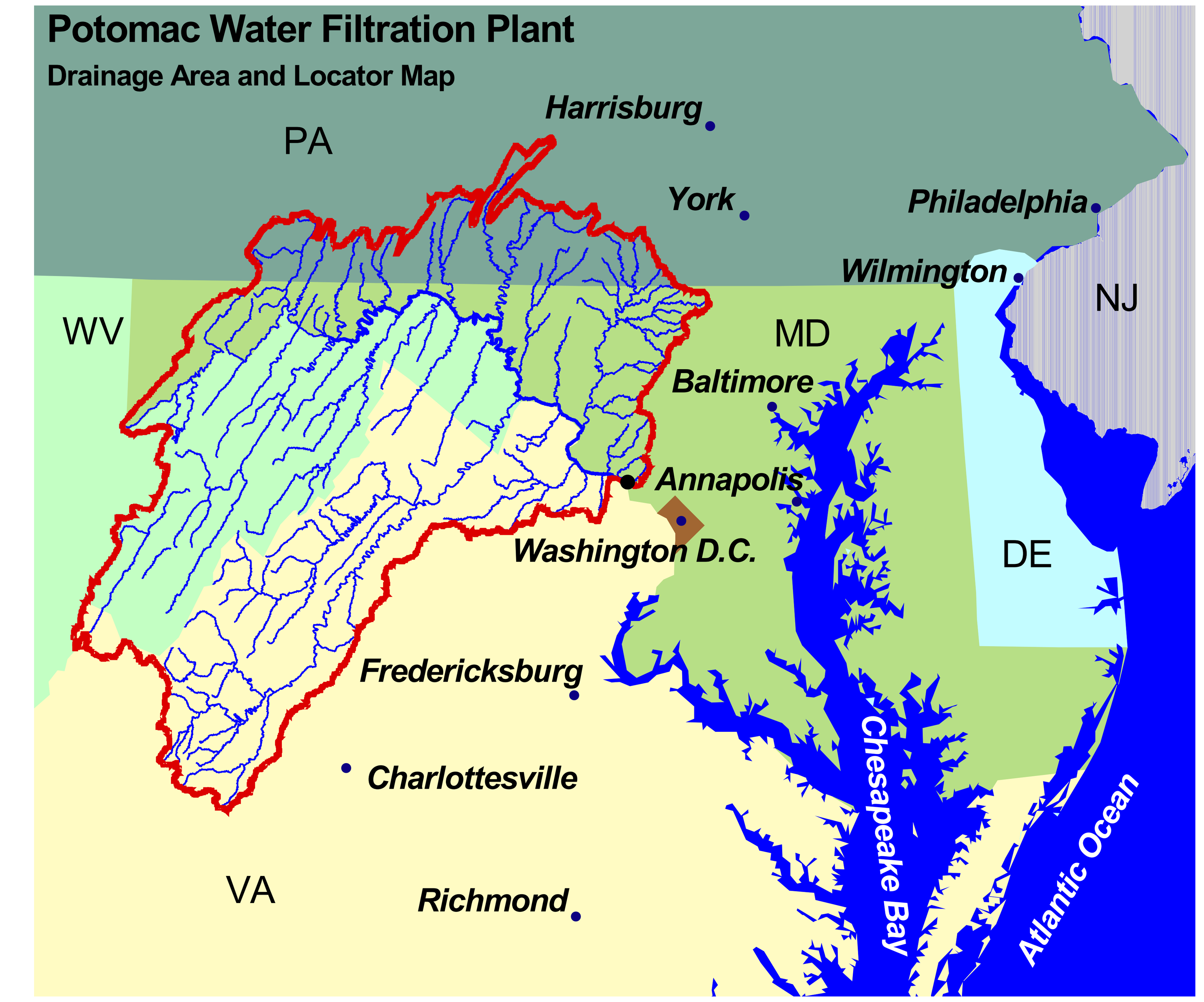
Potomac Water Filtration Plant

Source Water Assessment Plan

Potential Petroleum Sources





Legend

- Watershed boundary
- HUC 8 Subwatersheds
- Railroads
- Hydrology
- Potomac Water Filtration Plant intake
- Above ground storage tanks (MD only)
- Oil and gas wells (WV only)
- Gas service stations with NPDES permits
- Gas transmission facility with NPDES permit
- Colonial petroleum pipeline
- Colonial petroleum tanks
- Petroleum bulk stations with NPDES permits
- Interstate Highways
- U.S. Highways
- Interstate Route numbers
- U.S. Route numbers

Sources: watershed, subwatershed and political boundaries from EPA Office of Water, Office of Science and Technology, Washington, D.C. Hydrology from Maryland Department of the Environment, Baltimore, MD. Gas transmission, bulk stations and gas service stations from EPA BASINS. Above ground storage tanks and Colonial Pipeline information from Maryland Department of the Environment. Oil and gas wells from West Virginia Department of Environmental Protection

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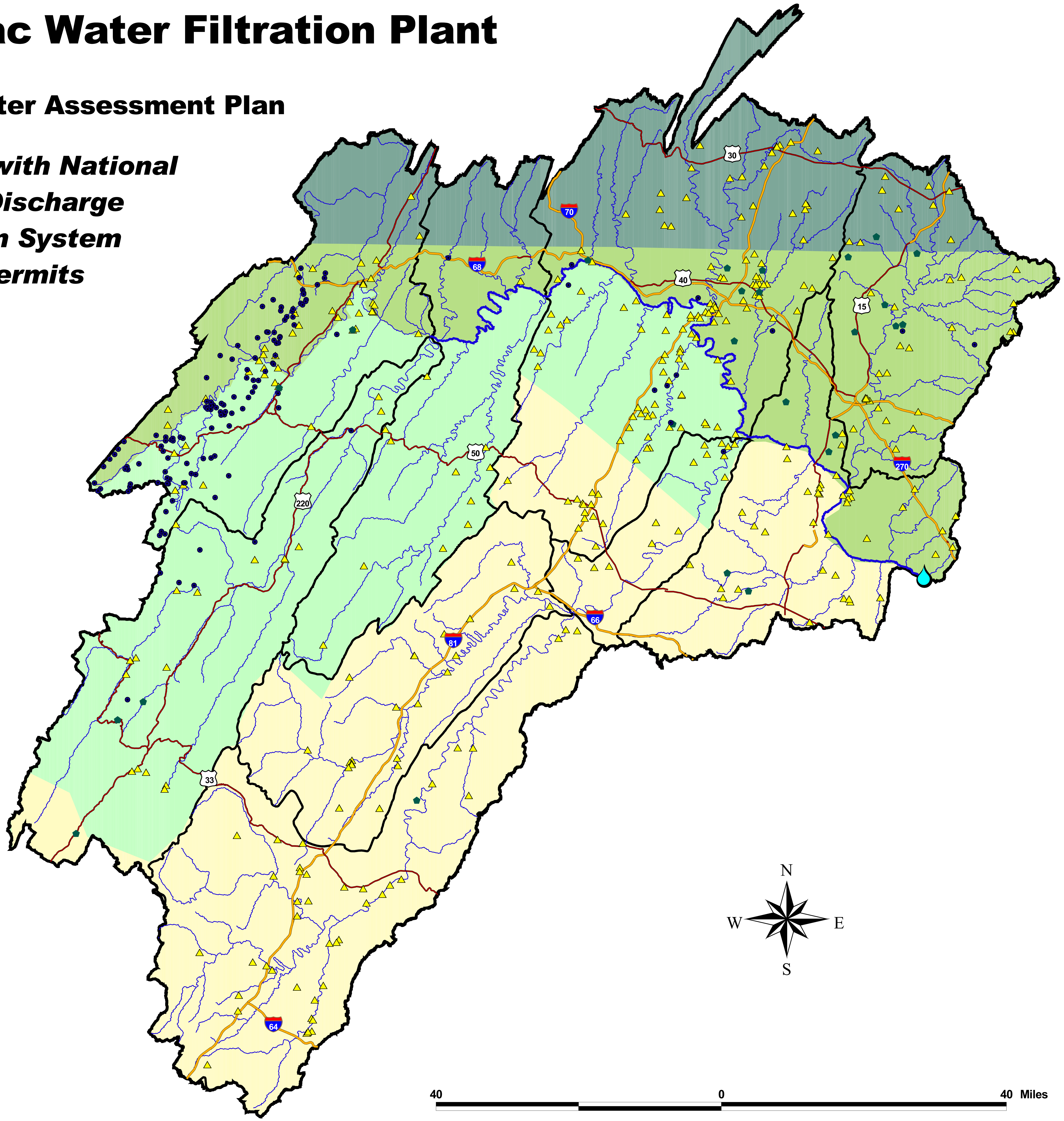
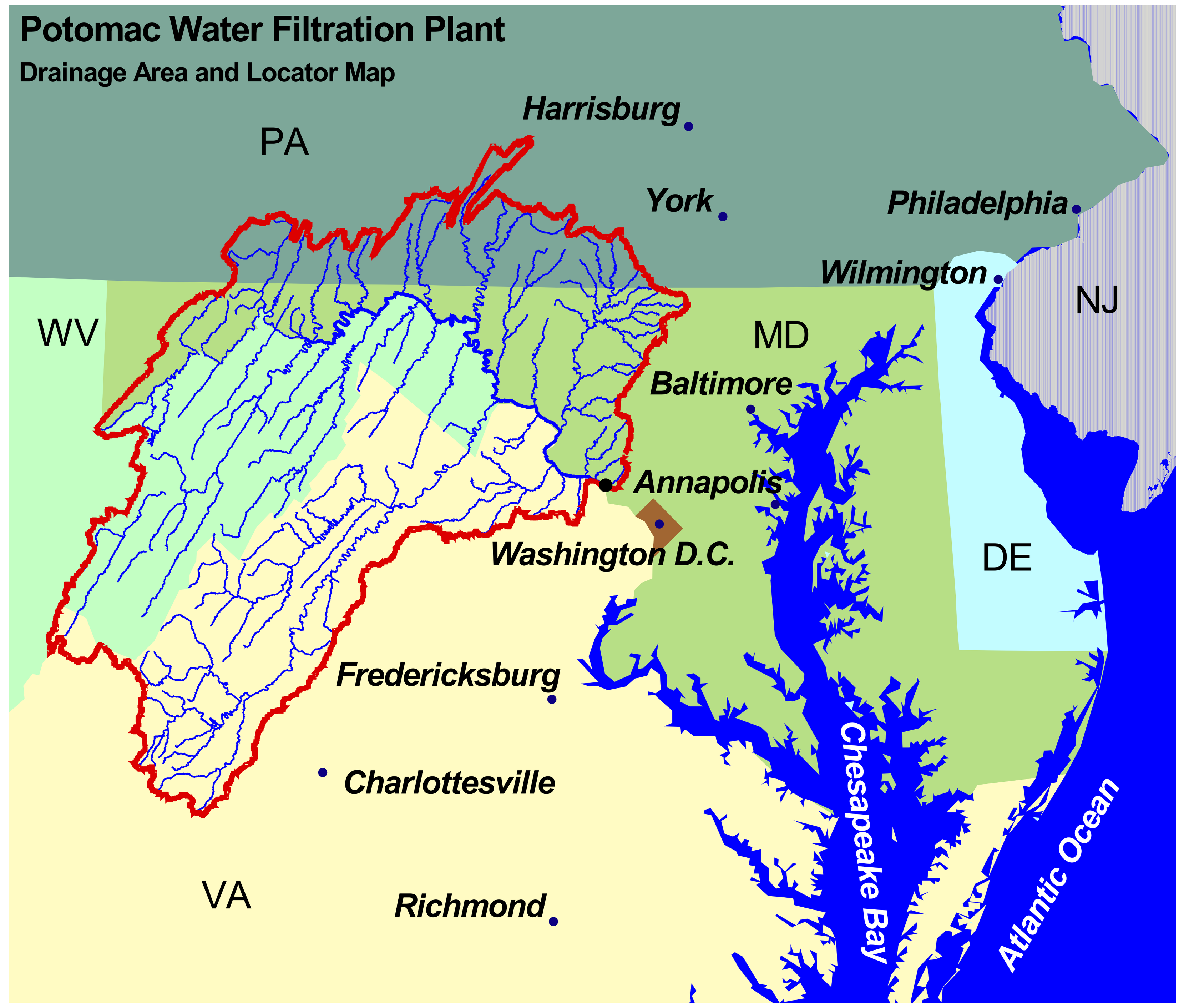
Potomac Water Filtration Plant

Source Water Assessment Plan

Facilities with National Pollution Discharge Elimination System (NPDES) Permits





Legend

- Watershed boundary
- HUC 8 Subwatersheds
- Hydrology
- Potomac Water Filtration Plant intake
- Facilities with Industrial, Municipal, and Commercial NPDES Permits (does not include mining, agriculture, petroleum-related industries or WWTPs)
- Facilities with Agricultural, Forestry or Fishing NPDES permits
- Facilities with Mining NPDES permits
- Interstate Highways
- U.S. Highways
- U.S. Route numbers
- Interstate Route numbers

Sources: watershed, subwatershed and political boundaries from EPA Office of Water, Office of Science and Technology, Washington, D.C. Hydrology from Maryland Department of the Environment, Baltimore, MD. NPDES permitted sites from EPA BASINS, Maryland Department of the Environment, Virginia Department of Environmental Quality, and West Virginia Department of Environmental Protection

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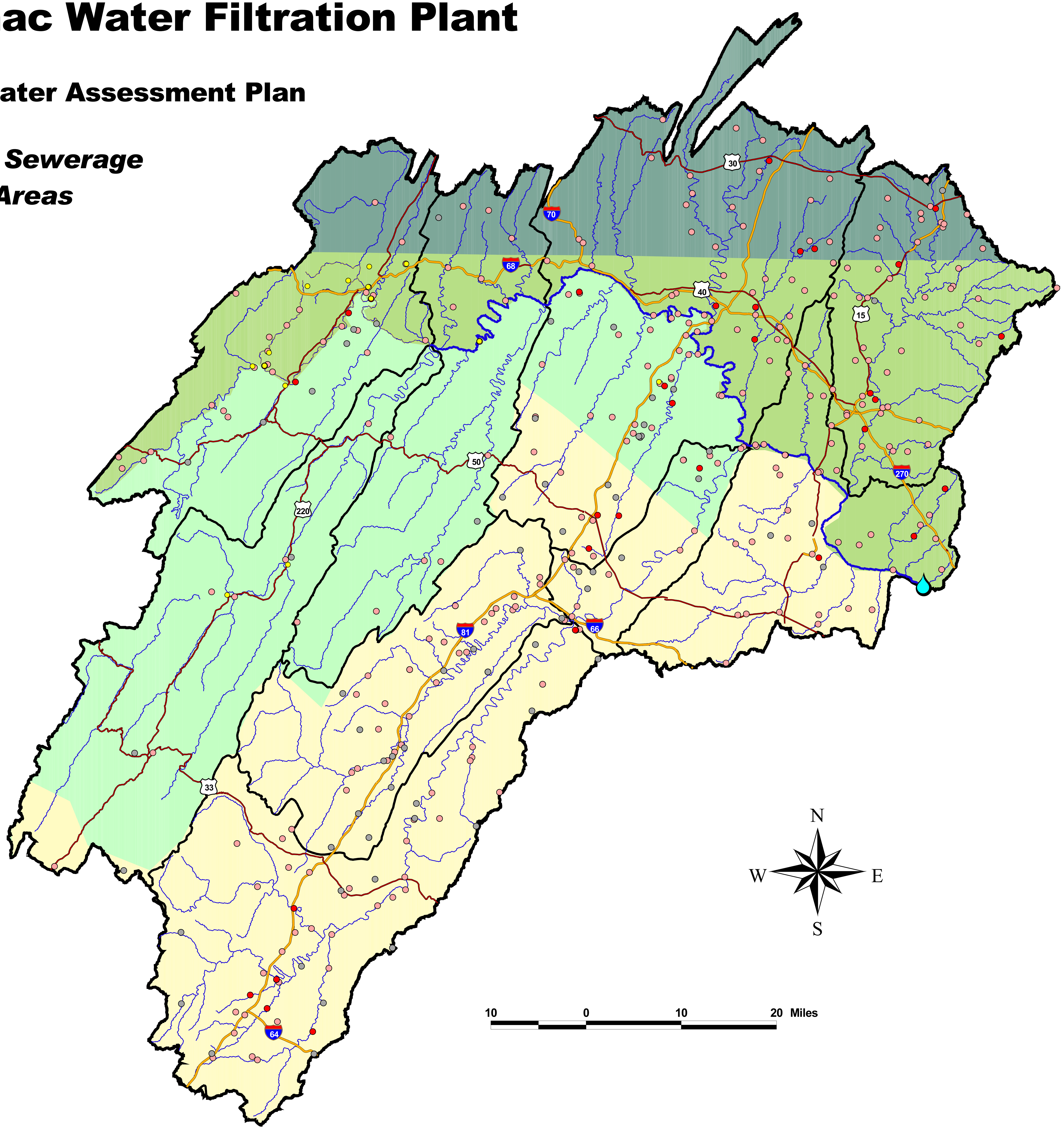
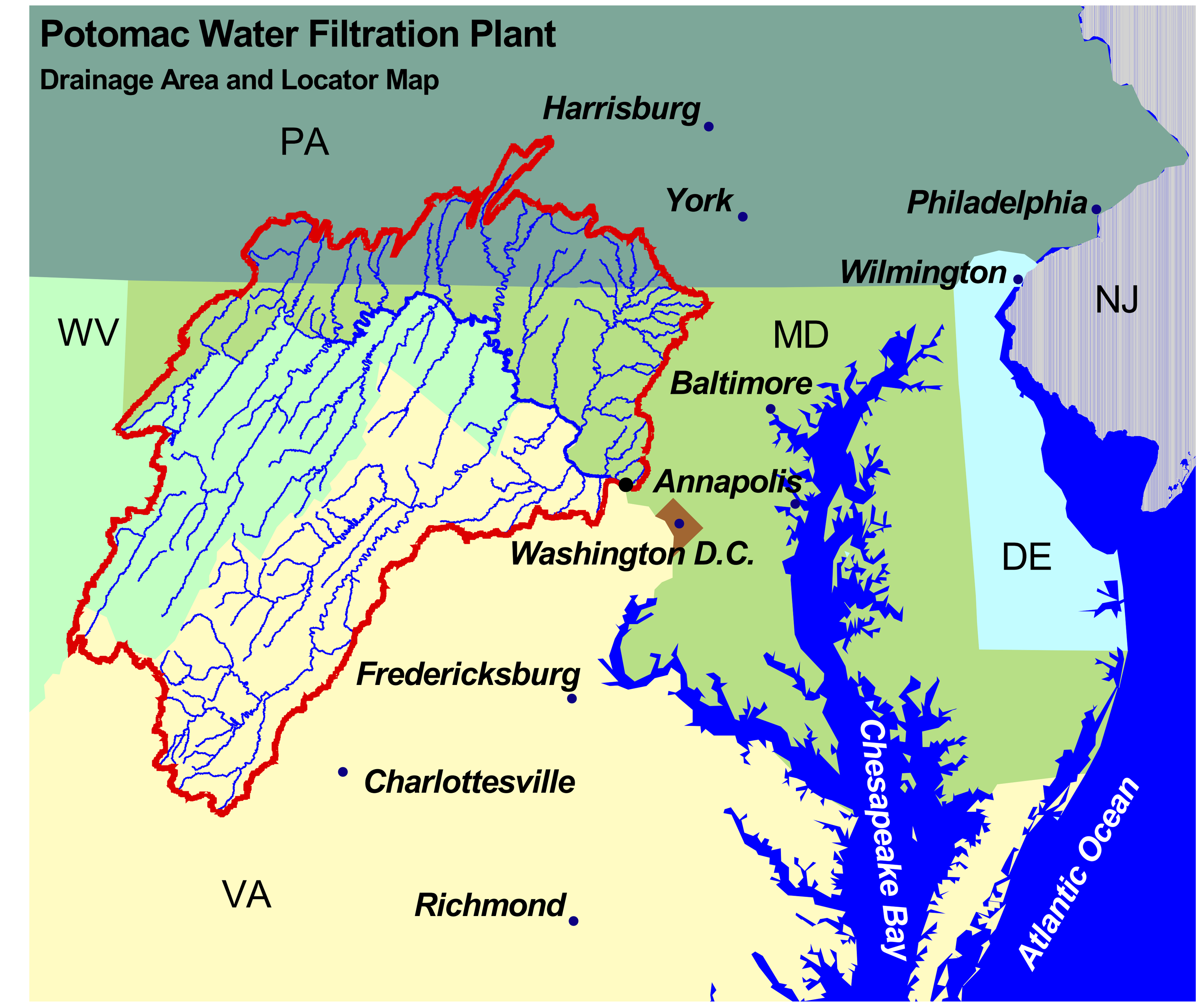
Potomac Water Filtration Plant

Source Water Assessment Plan

Potential Sewerage Problem Areas





Legend

- Watershed boundary
- HUC 8 Subwatersheds
- Hydrology
- Potomac Water Filtration Plant intake
- Major Wastewater/Sewage Treatment Plants*
- Minor Wastewater/Sewage Treatment Plants*
- Wastewater/Sewage Treatment Plants, Size Unknown
- Existing CSO Locations
- Reaches Susceptible to CSOs
- Interstate Highways
- U.S. Highways
- U.S. Route numbers
- Interstate Route numbers

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

Sources: watershed, subwatershed and political boundaries from EPA Office of Water, Office of Science and Technology, Washington, D.C. Hydrology from Maryland Department of the Environment, Baltimore, MD. Wastewater and sewage treatment plants from EPA BASINS, Maryland Department of the Environment, and Virginia Department of Environmental Quality. CSO data from EPA and Maryland Department of the Environment

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