E.1 Scope and Purpose of the Source Water Assessment

The Potomac River is the sole source of water for the residents of the District of Columbia. The U.S. Army Corp of Engineers, through the Washington Aqueduct, operates two intakes on the Potomac River at [REDACTED] to supply water to the nation's capital. While the Aqueduct's treatment facilities have proven more than adequate to process raw water from the Potomac River, increasingly, the importance of protecting the quality of source water for drinking supplies has been recognized. Under the provisions of the 1996 Safe Drinking Water Act Amendments, each state is required to develop a Source Water Protection Program (P. L. 104-182, Section 1453). The first step in the development of such a program is a source water assessment (SWA) of the drinking water source of each water supply intake. Each SWA must contain the following four components:

1. A delineation of the watershed contributing source water to the intake;
2. An inventory of potential contaminants and their sources within the delineated watershed;
3. An analysis of the susceptibility of source water to potential contamination from these sources; and
4. Communication of the results of source water assessment to the public.

The District of Columbia's SWA takes two additional steps beyond the required components. First, watershed delineation, contaminant inventory, and the susceptibility analysis are integrated into a GIS Search and Query Tool. The Search and Query Tool enables the user to sort and rank potential sources of contaminants by type of contaminant, location, and travel time. Second, the Chesapeake Bay Program's Watershed Model was adapted for use in the SWA to evaluate the susceptibility of D.C.'s source water to contamination from sediment, nutrients, pathogens, and pesticides. The use of a recognized assessment tool like the Watershed Model will facilitate the integration of source water protection into ongoing regional environmental protection programs like the Chesapeake Bay Program.

E.2 PCS Inventory and Susceptibility Analysis

An inventory and analysis of potential point source contaminants for a source water is one of four major tasks required by the EPA SWA guidelines. Availability of these data to a community water supply can provide valuable information for decision-making processes. Knowledge of a contaminants location in relation to a water supply can be used in the evaluation of the overall risk to a water supply or can be used in the event of an accidental or intentional spill.

For the D.C. SWA's evaluation, inventory and analysis of potential contaminant sources (PCSs) within the watershed above the WAD intakes was completed and used to determine what potential contaminants were likely to impact the public (drinking) water systems (PWSs) at the surface intakes. The susceptibility analysis was was based on the delineation of time of travel boundaries upriver from the [REDACTED] intake. In addition, a GIS application was developed which used these time of travel boundaries to query and spatially analyze these data for their potential threat to the public water supply.

E.2.1 PCS Inventory

The PCS inventory includes data from federal and state sources and consists of discharge and release inventories, hazardous waste sites, landfills, underground and above ground storage tanks and other activities identified through local field surveys. The National Pollution Discharge Elimination System (NPDES) was used as a base resource to provide information on regulated sites and activities within the Potomac basin. The state and local data provided additional site-specific information on small quantity generators or facilities that are not maintained on the federal level.

E.2.2 Analysis

Due to the large number of facilities and sites within the basin, a ranking process was developed to allow for identification of PCSs, and to determine the potential risk of each site to the water supply. A time of travel analysis was used to categorize facilities within the PCS database. Travel times of 10 and 24 hours on the mainstem of the Potomac at different flow levels were used to delineate travel time boundaries (Chapter 3). Facilities falling inside these segments were considered to have a higher potential for contamination than ones falling outside these modeled boundaries (Chapter 4).

E.2.3 GIS Search and Query Tool

A GIS application was developed to facilitate this large data collection effort. Knowing that the source water assessment is the first step in developing a source water protection plan, D.C. decided to use GIS as a foundation for initial analysis and also for future modeling and analysis in the protection phase. This search and query tool was created on an ESRI ArcGIS 8.3 framework, using standard Visual Basic–Application (VBA) coding. Most of the application is form and macro driven, meaning buttons and button combinations on user forms activate internal programming to perform desired functions.

The application contains a variety of base map data layers, from county and state lines to stream reaches and roadways. Introducing the PCSs to the base layers creates an interactive map, providing the user the ability to perform spatial analysis for sites throughout the basin. The Search and Query application allows the user to perform surveys of contaminants in the time of travel segments based on the susceptibility ranking. Simple surveys can be performed using a one-click tool set or for more complex surveys a user-defined query can be performed with additional ArcView tools.

E.2.4 Susceptibility Analysis Results

Currently, all facilities in the available databases have been categorized and ranked. Approximately 5,000 sites or permitted facilities have been evaluated for their contamination potential. Based on the susceptibility analysis a list of sites was generated that could potentially affect the D.C. source water and falls into three categories.

The first category is sources of fecal contamination. This would include wastewater treatment plants(WWTPs) with a permitted discharge rating above 1MGD, combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs) and large scale poultry and processing facilities. Figure E.2.1 illustrates the locations of these activities and their location relative to the D. C. intakes.

The second category includes sources of petroleum contamination. Figure E.2.2 details the locations of pipelines transporting refined product, above ground storage tanks (ASTs), and tank farms within the basin.

The third category is locations where an accidental spill can enter a receiving water in a short period of time and travel to the intakes within 24 hours. Figure E.2.3 shows locations where major roads and rivers and creeks intersect within the 24 hour time of travel boundary. The map also shows the location of the railroad along the C&O canal and could also be a source of contamination in the event of a rail accident.

Figure E.2.1. Potential sites for fecal contamination

[REDACTED]

Figure E.2.2. Potential sites for petroleum contamination

[REDACTED]

Figure E.2.3. Potential spill points within 24hr boundary

[REDACTED]

E.3 The Use of the Chesapeake Bay Program's Watershed Model in the Susceptibility Analysis for the District of Columbia's Source Water Assessment

The watershed for the District of Columbia's intakes on the Potomac River encompasses a large geographic area lying wholly outside its boundaries in four neighboring states. The District of Columbia already participates in a regional partnership to reduce pollutant loads from the Potomac River Basin that enter Chesapeake Bay—the Chesapeake Bay Program (CBP), in the interest of finding common ground between the protection of its drinking water supply and the CBP's strategies to reduce nutrient, sediment, and toxic contaminant loads to the bay. The CBP Watershed Model and the methodology behind it was used to help perform the susceptibility analysis for the source water assessment.

The Watershed Model simulates the fate and transport of nutrient and sediment loads from point and nonpoint sources throughout the Chesapeake Bay Basin. The Potomac River portion of the model is calibrated against observed flows at the [REDACTED] intake and against water quality data collected 1.2 miles downstream at Chain Bridge. The Potomac portion of the Watershed Model is, on a regional scale, a computer simulation model of water quality at D.C.'s source water intakes. It can be used to help determine the upstream sources of nutrient and sediment loads, which potentially effect source water quality.

Moreover, the sources of nutrient and sediment loads--wastewater treatment plants, septic systems, agricultural operations--are also sources of other constituents that can have an impact on source water quality. Pathogens, for example, are associated with livestock, manure disposal, failing septic systems, and wastewater treatment plants. Pesticides are applied as part of the same agronomic schedule of planting, fertilizing, and harvesting that is already represented in the Watershed Model. For this reason, the Watershed Model was extended so it can provide a regional analysis of the sources of other constituents that could adversely impact drinking water supplies. Modifying the Watershed Model to represent these other constituents extends a recognized management tool that has already been used to develop strategies for pollution reduction and prevention. It provides a way of evaluating how these strategies might impact source water quality and a common language for explaining that impact to stakeholders and regional partners in the Bay Program.

The Watershed Model was therefore used for three tasks in the susceptibility analysis:

1. The Watershed Model was used to characterize the size and sources of nutrient and sediment loads, both under current conditions and in the face of population growth;

2. The Watershed Model was modified to represent the fate and transport of fecal coliform bacteria, which serve as indicators of water-borne pathogens; and

3. The Watershed Model was modified to evaluate the susceptibility of D.C.'s source water to contamination by pesticides.

E.3.1 Current and Future Nutrient and Sediment Loads at the Source Water Intakes

Nutrient and sediment loads can adversely impact source water quality. Sediment and particulate organic matter must be removed to ensure proper treatment for drinking water. Excess nutrient loads can lead to algal growth, which in turn can lead to taste and odor problems.

The CBP 2000 Progress Scenario, which represents current conditions, was used to calculate nutrient and sediment loads delivered to the Washington Aqueduct intakes Figures E.3.1, E.3.2, and E.3.3 show the breakdown of average annual sediment, nitrogen, and phosphorus loads, respectively, by source.

According to the CBP 2000 Progress Scenario, a total of 1.6 million tons of sediment are delivered each year. Half of the load comes from crops and hay. A quarter of the load comes from pasture. Only 11% comes from forest and 14% comes from urban land. About a third of the load comes from the Shenandoah Valley, but the middle Potomac region is also a large source of sediment.

The loads of total nitrogen come from a wider variety of sources. Crops are the largest source of nitrogen, accounting for 37% of the total average annual load of 35 million pounds. Urban nonpoint source loads constitute the second largest source, accounting for 16% of the total. Nitrogen loads from pasture runoff constitute 15% of the load. Point sources, such as wastewater treatment plants, contribute 9% of the load. Agricultural sources still dominate urban sources. Fifty-six percent of the load comes from crops, pasture, or runoff from feedlots. Thirty percent of the load comes from point sources, septic systems, and urban land. Forests account for only 14% of the total delivered nitrogen loads. The sources are also more geographically diverse. The largest source of loads is the heavily urbanized lower Potomac region, just above the intakes at [REDACTED], which delivers 12% of the load. The middle Potomac region contributes almost the same load.

Crops also contribute nearly one-third of the annual total phosphorus load of 3.2 million pounds. The next largest source is pasture, delivering nearly 25% of the annual load. Point sources are the third largest source, contributing 20% of the load, and nonpoint sources from urban land contribute 16% of the load. The contribution from forests is almost negligible. Inorganic phosphorus is transported primarily bound to sediments, so it is not surprising that the 35% of the delivered load comes from the Shenandoah Valley. Point source loads from the Valley are also the highest in the basin. The Monocacy and the lower Potomac region each also deliver over 10% of the total annual load.

The CBP has projected the population growth in modeling segments for the years 2010 and 2020. The basin population of nearly 2 million is expected to increase by nearly 10% in each decade. The percent change is greatest in the Monocacy region; Frederick County in Maryland is expected to grow by over 30% in the next twenty years. The rate of growth is over 10% per decade in the lower Potomac region, which already has three-quarters of a million people, nearly 37% of the basin total.

Figure E.3.1 Simulated Average Annual Sediment Loads By Source Under Current Conditions

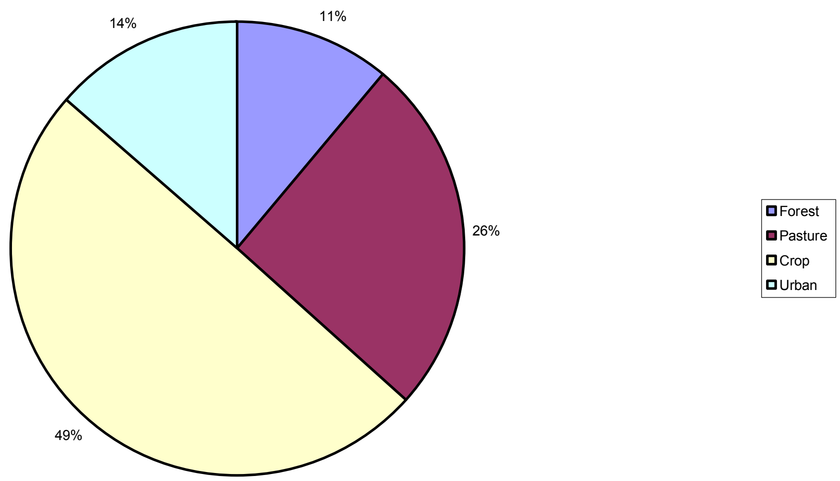


Figure E.3.2 Simulated Average Annual Total Nitrogen Loads By Source Under Current Conditions

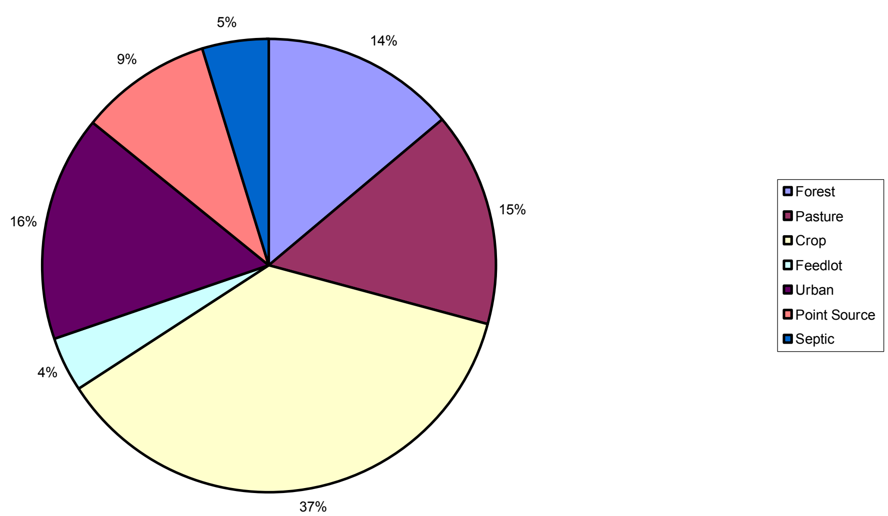
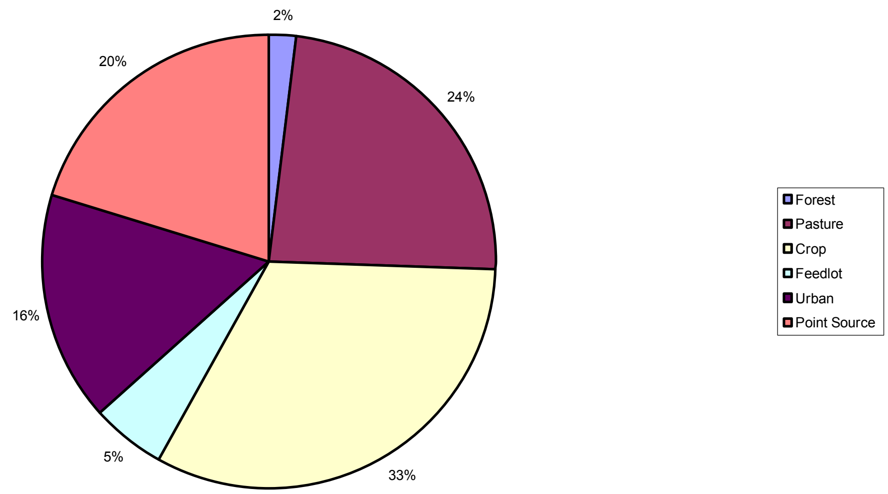


Figure E.3.3 Simulated Average Annual Total Phosphorus Loads By Source Under Current Conditions



A modeling scenario was developed to estimate nutrient and sediment loads under the population increase and land use changes projected for 2010. The scenario was intended to represent future conditions under current levels of BMP implementation for agricultural and urban nonpoint sources and current levels of point source controls.

An analysis of the impact of population growth on source water quality using the Watershed Model indicates that the growth in population upstream of the intakes will have little impact on sediment and nitrogen loads. Simulated loads from these two constituents decrease slightly under 2010 conditions. The increase in loads from urban land is balanced by a decrease in loads from agricultural land. Sediment loads remain dominated by agricultural sources.

Total phosphorus loads under 2010 conditions increase by 10%, mainly due to increased loads from point sources. The additional load from point sources more than outweighs the loss in load from the land use changes. With no additional point source controls, that trend will only increase as the population increases 2010-2020.

E.3.2 Simulation of Fecal Coliform Bacteria Using the Watershed Model

To better understand the sources of fecal coliform bacteria observed at the WAD intakes, the CBP Watershed Model was modified to simulate the fate and transport of fecal coliform bacteria. The same segmentation, land uses, and hydrology used in the reference scenario of the Watershed Model were used in the Fecal Coliform Model, and a similar methodology was used to estimate input loads of fecal coliform bacteria. The EPA guidance on developing pathogen TMDLS (2000) and numerous fecal coliform TMDLs developed in Virginia and West Virginia were also used to develop the Fecal Coliform Model.

The purpose of the Fecal Coliform Model is to help identify the sources and geographic origin of fecal coliform bacteria observed at the WAD's water supply intakes. This will help to identify the source and origin of fecal material that is a potential source of pathogens. Loads from the following sources were developed as inputs into the model:

1. Bacteria from livestock waste deposited on pasture and transported in runoff;
2. Bacteria, transported in runoff, from manure and poultry litter applied to crops and hay;
3. Bacteria in runoff from feedlots and concentrated animal operations;
4. Bacteria in runoff from urban land;
5. Bacteria in deer scat and geese droppings, deposited in forests and agricultural land and transported in runoff;
6. Bacteria loads from Combined Sewer Overflows (CSOs) and Sanitary Sewer Overflows (SSOs) in the North Branch of the Potomac;
7. Bacteria discharged in effluent from wastewater treatment plants;
8. Bacteria draining directly into waterbodies from failing septic systems;
9. Bacteria from cattle directly defecating into streams; and
10. Bacteria from geese and other waterfowl directly defecating into streams.

An analysis of observed fecal coliform bacteria concentrations shows that the mean concentration at high flows tends to be larger than the mean concentration at low flows, although generally there are several orders of magnitude in the range of observed concentrations under all flow conditions. The Fecal Coliform Model was calibrated against the geometric mean of the observed data for different flow conditions at or near the outlet of each modeling segment. The model was then used to analyze the fecal coliform bacteria loads. Figure E.3.4 compares the average annual load input into the rivers and streams of the Potomac Basin by source. Figure E.3.5 shows the load actually delivered to the WAD intakes. Delivered loads represent the bacteria that are survive transport and arrive at the intakes. Figure E.3.6 shows the geographic distribution of delivered loads.

Agricultural loads dominate all other sources. In-stream deposition by cattle is the largest input source, followed by loads in runoff from pasture, cropland and feedlots. Fecal coliform bacteria from failing septic systems are the largest human source of input loads. Many of the fecal coliform bacteria which enter the streams and rivers of the Potomac Basin, however, die-off before reaching the WAD intakes. Ninety-eight percent of the delivered load occurs under storm flow conditions. The dominant sources of delivered loads are runoff form pasture, feedlots, and cropland. Because fecal coliform bacteria die-off while being transported downstream, the regions of the basin closest to the intakes tend to contribute the most to delivered loads. More than half the load comes from the lower Potomac region downstream of the confluence of the Shenandoah.

Figure E.3.4 Average Annual Fecal Coliform Loads Input into Streams and Rivers in the Potomac Basin By Source

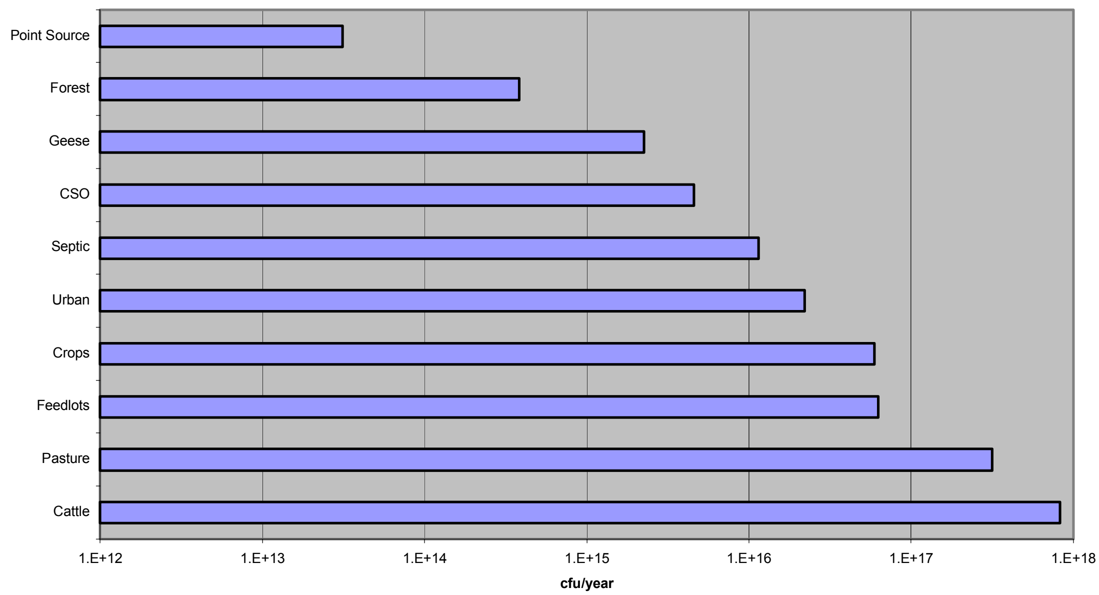


Figure E.3.5 Average Annual Fecal Coliform Loads Delivered at WAD Intakes By Source

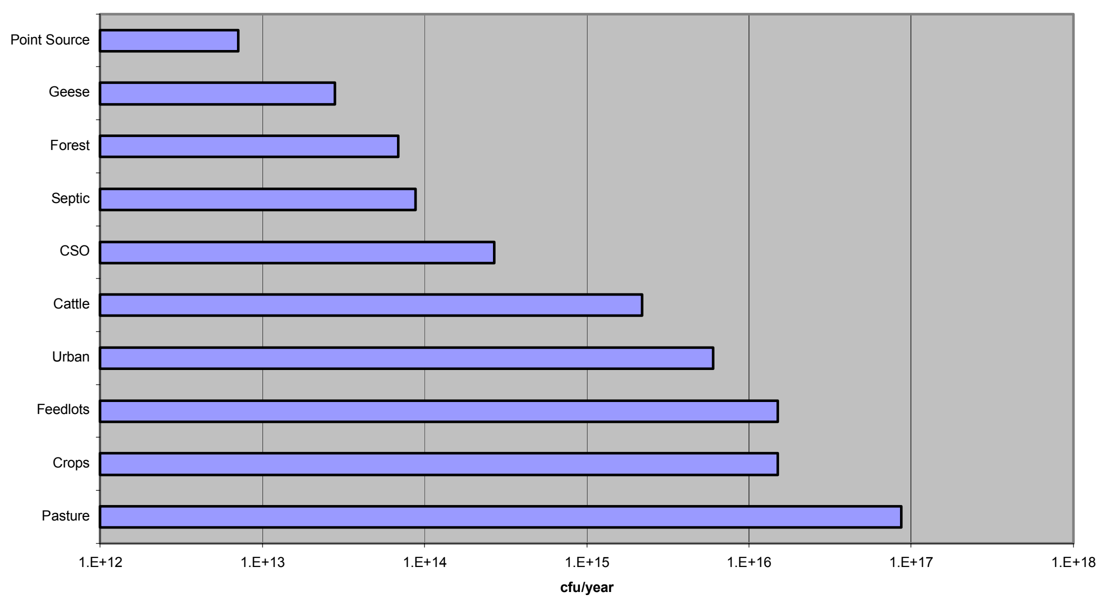
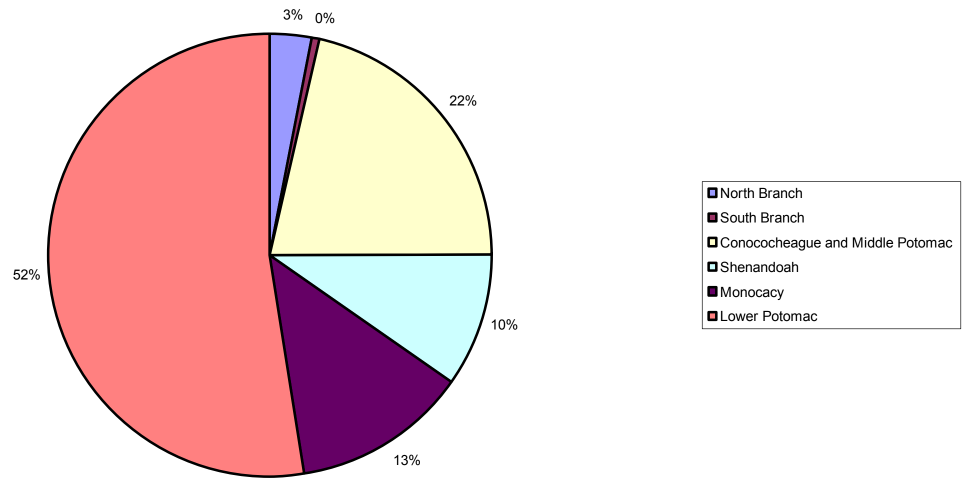


Figure E.3.6 Percent of Average Annual Delivered Fecal Coliform Load By Region



Fecal coliform bacteria are indicator organisms which are used to detect the presence of fecal material; they themselves are not pathogenic. The Fecal Coliform Model, by simulating the connection between the sources of fecal material and observed fecal coliform concentrations, provides a framework for analyzing the susceptibility of D.C. 's source water supply to water-borne pathogens. The susceptibility of D.C.'s source water to a type of pathogen contamination can be evaluated by comparing the source of the pathogens and their die-off rate in transport to the source and die-off rate of fecal coliforms. Pathogens can be distinguished by (1) whether they are specific to people or found in cattle or other animals, and (2) whether their die-off rate in the aquatic environment is less than or great than that or fecal coliform bacteria. The first factor determines which type of source is an important potential source for the pathogen. The second factor determines whether areas of the basin are potentially important sources of the pathogen. If a pathogen's decay rate is comparable to the coliform decay rate, areas in the Piedmont and the Middle Potomac region will be more important sources that the rest of the basin. If the pathogen's die-off rate is smaller, the geographic location of the source will be less important in determining the susceptibility of D.C.'s source water to specific pathogens.

Figure E.3.7 shows the classification of representative pathogens according to these criteria. Many bacteria pathogens behave like fecal coliforms and the model's simulated delivered loads will be a good guide to the relative importance of sources by type and location. The potential sources of pathogenic viruses, which only originate in human hosts and which do not die-off in the aquatic environment, are most likely to be failing septic systems, CSO, and other wastewater treatment failures. The regions with heavy cattle production, like the middle Potomac, Concocheague, and the Shenandoahs, are likely to be important potential sources of Giardia and Cryptosporidium--pathogenic protozoa that most likely die-off more slowly in rivers and streams than fecal coliform bacteria.

Figure E.3.7 Matrix For Pathogen Susceptibility Analysis

	Die-Off In Transport	No Die-Off
Human and Animal Sources	E. Coli Salmonella	Giardia Cryptosporidium
Human Sources Only	S. Typhi V. Chlorerae	Viruses

E.3.3 Pesticides

To assess the susceptibility of the District of Columbia's source water to pesticide contamination, the DOH recommended adapting the CBP Watershed Model to simulate the daily fate and transport of pesticides. The Watershed Model was modified to simulate the fate and transport of atrazine, a widely used herbicide in the Potomac River Basin.

The primary purpose of this model was to help quantify the risk posed by atrazine applications if they are applied under adverse hydrological conditions. Because atrazine is primarily transported to surface water in runoff, the risk of atrazine transport is increased if there is a storm with surface runoff following an application. The best time to apply atrazine is before a gentle rain with little runoff, so that the atrazine infiltrates into the soil. The Base Case Scenario of the model represents the recommended timing of atrazine applications.

Five additional scenarios were run, each increasing the amount of atrazine applied under hydrologically unfavorable conditions. For each model segment, dates with high runoff to rainfall ratios were chosen and atrazine application rates on those dates were increased at 20% intervals. Table E.3.1 shows for each scenario the average number of days per year on which simulated concentrations were greater than the maximum contaminant level (MCL) for atrazine of 3 ug/l.

Table E.3.1 Average Annual Simulated Violations of the Atrazine MCL

Scenario	Average Number of Days With Concentrations Above MCL of 3 ug/l
Base Case	0
20% Applied Under Hydrologically Adverse Conditions	1
40% Applied Under Adverse Conditions	7
60% Applied Under Hydrologically Adverse Conditions	22
80% Applied Under Hydrologically Adverse Conditions	33
100% Applied Under Hydrologically Adverse Conditions	51

Since the primary health risk from herbicides comes from chronic exposure, sustained concentrations at the MCL are necessary before atrazine poses a health risk. The results of these simulations suggest that the risk of sustained periods when the concentration of atrazine is above its MCL, while not negligible, are moderately low. The relatively low susceptibility of D.C.'s source water to pesticide contamination is due to dilution. The amount of herbicide applied is relatively small compared to the volume of flow in the Potomac. To sustain an atrazine concentration over the MCL in the month of June, approximately 20 to 25 percent of the atrazine applied in the basin would have to be lost from the field. Losses in the Potomac Basin can be expected to average about 1-2% annually. The susceptibility analysis for atrazine was extrapolated to two other pesticides, metolachlor and 2,4-D by comparing physical and chemical characteristics, application rates, and health action levels of these two pesticides with atrazine's. The susceptibility of D.C.'s source water was moderately low to contamination from these other pesticides as well.

E.4 Public Participation and Communication of Results

The final task as outlined in the EPA Federal Guidelines for Source Water Assessments calls for communication of results to the stakeholders through various forms of media and also through the use of public meetings. It should first be noted that the SWA Program itself was the direct result of planning and communication by the stakeholders of the District of Columbia. Prior to the implementation of the Program, numerous meetings took place in the form of citizen and technical advisory committees. These meetings provided a forum for discussion dealing with the concerns and interests of the stakeholders regarding the best method for development of a source water assessment.

E.4.1 Public Meetings and Outreach

Once the Program was approved, a first public meeting hosted by the Metropolitan Washington Council of Governments (MWCOG) was called in January of 2000 to provide information to the stakeholders on the scope of the work. A second public meeting was held in September of 2001 to discuss the progress of the assessment and to get feedback from the community on expected results from the survey. A final meeting was held to discuss the findings of the survey and to provide information on Source Water Protection within the Potomac River Basin.

A webpage was created by MWCOG to provide outreach to the citizenry of DC and to provide details of the scope and progress of the source water assessment. This webpage was updated and maintained through the public review stage of the project and was linked to DC Department of Health's website and ICPRB's website.

As an additional form of outreach, an interactive map was also created to provide locational and site-specific data on NPDES facilities throughout the basin. Users could find information on activities within their watershed and view their proximity to receiving streams and rivers or other water bodies. This service was discontinued in October of 2001 due to the potentially sensitive nature of the data.

E.5 Recommendations For Source Water Management and Protection

The purpose of this source water assessment is to determine the sources of potential pollutants that might impair the quality of Potomac River's waters, in order to better protect the District of Columbia's water supply. Given the character of the Potomac River Basin upstream of the WAD intakes, the most likely sources of potential pollutants to the intakes are toxic chemical spills, agricultural activities, and inadequate wastewater treatment. The following recommendations will help protect the quality of the District of Columbia's source water from the Potomac River:

- Real-time monitoring to detect spills and toxic chemical releases;
- More frequent monitoring of pesticide concentrations during the spring and early summer when concentrations are highest;
- Establishing an Emergency Response Network and an Emergency Response Plan to protect all water intakes on the Potomac River;
- Accelerating efforts to mitigate CSOs in the North Branch of the Potomac River;
- Assisting rural communities in identifying and repairing failing septic systems and inadequate wastewater treatment systems;
- Continuing to reduce phosphorus loads from wastewater treatment plants;

- Integrating source water protection into federal, state, and regional efforts to promote the use of agricultural BMPs such as streambank fencing, riparian buffers, soil conservation, and animal waste management; and;

- More cooperation among the basin states and among the water utilities on source water protection as well as greater integration of source water protection into other environmental programs.