SEVERN RIVER

Watershed Management Master Plan

Final Report

February 2006

KCI TECHNOLOGIES

ANNE ARUNDEL COUNTY
MARYLAND

CH2MHILL

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Final Report

Submitted to:

Anne Arundel County
Office of Environmental and Cultural Resources
Watershed Management Program

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Executive Summary

Introduction

Purpose of Watershed Plan

As part of the National Pollutant Discharge Elimination System (NPDES) permit for its Municipal Separate Storm Sewer System (MS4), Anne Arundel County has developed a comprehensive Watershed Management Master Plan for the Severn River. The estuarine part of the River is currently on the 303(d) list for nutrients, sediment and bacteria. As a tributary to the Chesapeake Bay, the Severn River is also facing issues that are affecting aquatic resources Bay-wide.

The Watershed Management Master Plan has been developed to characterize the watershed's baseline conditions and resources, assess existing and potential concerns, and propose restoration and preservation improvements with a systematic watershed perspective.

Phased Approach to the Scope

Due to the extensive scope of the study, the Severn River Watershed Management Plan was undertaken in a series of multi-year phases. In Phase I, the existing environmental studies and GIS coverages for the watershed were assessed. Initial public involvement activities were also performed during this phase. This was the basis for the work done in Phase II, which included a characterization of the current condition of the watershed. Phase III focused on forecasting future conditions, identifying and prioritizing problem areas, and developing a variety of management alternatives. Phase IV concentrated on completing additional more detailed stream assessments and modeling and on summarizing all the work of the project.

Public Involvement

During Phase I, two public stakeholder workshops and a survey distributed to over 3,500 residents of the Severn River watershed were used to identify public environmental concerns and problems within the watershed, identify data sources that can help with various elements of the Phase II analysis, and identify additional stakeholders to participate in the project.

The first public stakeholder workshop on May 3, 2001 featured a presentation on the history of development in the watershed and various aspects of the watershed master planning process. Participants at this meeting identified overall watershed issues and concerns and identified specific problems within the watershed. The second public stakeholder workshop on May 17, 2001 included a summary of the issues heard from the stakeholders at that previous meeting. Workshop participants prioritized particular streams that they would like to see studied in detail. Workshop participants identified and then prioritized a list of pollutants of concern that would be potentially modeled later on in the project.

Current Watershed Condition

Environmental Setting

The Severn River watershed is located within the Coastal Plain physiographic province, which is geologically the youngest in the state. The Coastal Plain is made up of unconsolidated sedimentary deposits eroded by streams flowing from the adjacent Piedmont Province. The topography within the watershed ranges from nearly level to very steep. Steep slopes border the headwater tributaries and downstream floodplains along the northern and southern shoreline of the Severn River. Elevations range from sea level, along the shores of the Chesapeake Bay, to 300 feet.

The geology within the watershed is dominated by sand, gravel, silt, and clay of the Cretaceous age. Within the Severn River watershed lie four geologic formations that are hydrologically characterized as aquifers. These formations consist of the Aquia, Magothy, Patapsco-Raritan, and Patuxent Formations, the last two of which are the most heavily used groundwater sources in Maryland.

Unique Ecology

In 1971, the Severn River was designated as one of Maryland's Scenic Rivers. Many unique and ecologically important natural features can be found within the borders of its watershed. Within the state of Maryland, Anne Arundel County possesses the highest quantity of freshwater bogs, which qualify as wetlands of special state concern. Bogs within the Severn River Watershed include Arden Bog, Arlington Echo, Cypress Creek, Lakewood, Carrollton, Forked Creek and Sullivan's Cove. These areas are important as they serve as water filters, improving water quality within the watershed, and creating habitat for rare, threatened and endangered flora and fauna.

Jabez Branch, the largest tributary to Severn Run, is the only Coastal Plain stream that supports a naturally reproducing population of brook trout. Jabez Branch has a series of springs and dense forest cover that provide the cool water necessary for brook trout reproduction.

Land Use and Development

Land use in the watershed is diverse. Portions are highly developed, containing the City of Annapolis, shopping centers, subdivisions, and industrial parks. The free-flowing section of Severn Run, however, is a Natural Resource Area managed by Maryland Department of Natural Resources (MDNR). Many of the south shore watersheds remain forested. The single most dominant land use is single family residential, at all densities, at 38%. Forest is next, at 32%. When the 6% of open space maintained in turf is added to the forested areas, there is an equal amount of residential and vegetated land use. Fifteen percent of the watershed is taken up with denser land uses: commercial and industrial property and the City of Annapolis.

Other than the watersheds which drain the City of Annapolis (College Creek, Weems Creek, Spa Creek, and Back Creek), the most densely developed tributaries are Woolchurch Cove (50% impervious), Picture Spring Branch (33%), Pointfield Branch (32%), Bear Branch (30%), and Carr Creek (28%). These subwatersheds drain some parts of Odenton, the commercial areas along I-97, and the Naval Surface Warfare Center.

Sewered/Unsewered Areas

Twenty-six percent of the watershed is currently served by sanitary sewer systems. An additional 21% is planned to receive sewer service at some time in the future. This leaves over half of the watershed remaining with on-site sewage systems. Most of these areas are on the south shore, which is currently undeveloped or zoned for low-density residential development.

Stream Assessment

A total of 152 miles of stream were assessed during the stream walk portion of the Watershed Study. During this assessment the stream flow type was assigned, habitat assessments were conducted, a geomorphological assessment was completed and infrastructure features were inventoried and rated based on their impact on the stream's overall health. Following the stream walk a biological assessment was completed throughout the watershed at 63 sites and a Rosgen Level II classification was completed at 95 sites.

Stream Type

Perennial streams are most abundant with 89.37 miles making up 58.8% of the total for the entire Watershed. Ephemeral streams comprise 19.5% of the channels.

Geomorphology

Geomorphic assessment and Rosgen classification was conducted on 92.63 miles of the 152 total miles of streams with 381 separate reaches and cross-sections conducted throughout the Watershed. Based on the stream walk, E type channels make up the majority of the stream miles throughout the Watershed, comprising 34.6% of the total. E channels are most prevalent in the downstream reaches of tributaries as they enter the floodplain of the subwatershed's main channel. G channels are also common and make up 27.9% of the total. Entrenched G type channels are typical of both mainstem channels and the upstream portions of tributaries as they flow out of steep, narrow headwater valleys with erodable materials. C type channels are most prevalent in the downstream mainstem reaches of Severn Run Mainstems 2 and throughout Severn Run Mainstem, 3 and 4.

Following the stream walk geomorphic assessment, 95 sites were targeted for further study and a complete Rosgen Level II assessment and classification was completed. As in the stream walk, the majority of channels were E, G and C type. The majority of channels have sand as the dominant substrate type.

Habitat Assessment

Habitat Assessments were conducted for a total of 89 miles of 152 total miles of perennial streams in the Watershed for 352 distinct reaches. The mean Maryland Physcial Habitat Index (MPHI) score for the entire Watershed is 44.05, Fair, while the median is 39.10, in the upper part of the Poor range. The stream length weighted MPHI score for the Watershed is in the Fair range with a score of 58.13. Overall, 40% of the stream miles were rated Good, 24% were rated Fair, 29% were Poor, and 6% were Very Poor.

Bioassessment

In support of the stream assessment, a comprehensive bioassessment was conducted, providing biological assessment for much of the watershed. A total of 63 sites were assessed for water quality, macroinvertebrates and physical habitat in 30 of the Severn's subwatersheds. Twenty-four of the 63 sites were in subwatersheds that drain directly to the Severn River while 39 of the sites were in the Severn Run drainage area. The watersheds were selected based on their overall condition, imperviousness, land use and their predicted ability to support varying levels of aquatic biota. The intent was to select sites that would yield Index of Biotic Integrity (IBI) scores ranging from Very Poor and Poor classifications, to Fair and Good classifications.

The bioassessment scores ranged from a low of 1.0 in Brewer Creek to a high of 4.4 in Jabez Branch on a scale of 1 to 5. The mean score is 2.6, which would indicate a Poor condition. Forty of the 63 sites were in the Poor to Very Poor range and only three sites scored in the Good range. Scores in Severn Run increased from Fair to Good downstream as the drainage area increases. Sites along the north and south shores of the tidal Severn were generally Poor and Very Poor, with the exception of a few sites on the south shore.

Field water quality measurements were collected in-situ at upstream, midstream and downstream locations at all monitoring stations so that an average for the reach could be calculated. The Maryland Department of the Environment (MDE) has established acceptable standards for several of the parameters for each designated Stream Use Designation. The water quality samples were generally within the COMAR limits and typical of coastal plain streams. Eight sites had higher acidity than the standards call for, and one site did not meet the standard for dissolved oxygen.

Water Quality

Computer models were used to evaluate pollutant loads in stormwater runoff from the Severn River watershed to its receiving waters. Runoff and point source water quality modeling was conducted using

PLOAD, a GIS implementation of the Simple Method. Septic system loads and groundwater loads were modeled using GWLF.

Calculations were performed on each catchment and subwatershed using land use, percent impervious, and other data within each of the watersheds. Seven parameters were analyzed based on input from Anne Arundel County staff and stakeholders, including nutrients and metals.

Results were presented as total loads and as loads per acre for runoff pollutants. Without completing a receiving water analysis, it is not possible to determine the relationship of pollutant loading to the overall health of the estuarine Severn River. Other conclusions can be inferred from the model results, however.

- For nutrients, annual reported loads from point sources were higher than modeled runoff loads. Point source loads were estimated in PLOAD from reported monitoring data, while runoff loads were estimated using land use mapping and pollutant loading factors. The point sources were the U.S. Naval Academy discharging to Carr Creek and the Annapolis Water Reclamation FC discharging to the tidal Severn. These two sources represented 79% of the total phosphorus (TP), 73% of the nitrate-nitrite (NOx), and 54% of the total nitrogen loads from the model.
- Fecal coliform loads were more than 2,000 times higher from runoff than from point sources. Again, the same two point sources were the sources of the discharges.
- When runoff loads are normalized by area, loads are within the typical range for residential and commercial land uses. TN loads are 3.4 lb/ac/yr, TP loads are 0.43 lb/ac/yr, and NOx loads are 1.13 lb/ac/yr. By way of comparison, if the Severn River watershed was completely forested, loading rates in lb/ac/yr would be 0.49 for TN, 0.23 for NOx, and 0.06 for TP. Other than the subwatersheds draining the City of Annapolis, Woolchurch Cove had the highest runoff loads per acre for both TN and TP. Bear Branch, Pointfield Branch, Yantz Creek, Carr Creek, Jabez Branch 3, and Picture Spring Branch are also among the highest areas for runoff loads. They are also among the subwatersheds with the highest imperviousness.
- For metals, the highest annual loads were from runoff. The only significant point source was from is the International Paper facility in Picture Spring Branch, which draws groundwater for its cooling systems. The groundwater is naturally high in copper, with concentrations that are acceptable by drinking water standards. Point source copper loads were 58 lb/yr from this source, versus 1,347 lb/yr from runoff, or 4% of the total loads.
- Normalized loads for zinc, copper, and lead were 0.21, 0.03, and 0.09 lb/ac/yr, respectively, within the typical range for residential land uses. They are 2 to 8 times higher than the loads from equivalent forested areas.
- In order to determine the overall effectiveness of the over 1400 BMPs in the Severn River watershed, a scenario was run assuming that no BMPs existed. It was found that BMPs treat runoff from approximately 14 percent of the land, producing the overall pollutant reductions of 5 to 7 percent.

Loads from septic systems were modeled to estimate the share of nitrogen and phosphorus contributed by these sources. Especially for nitrogen, septic systems can be significant source of loads even if they are working properly. The modeling showed that for nitrogen, septic systems were the major source, producing 57% of the annual load, with runoff providing 26% and groundwater 17%. This was not the case for phosphorus, where runoff was the primary source at 74%, with groundwater contributing 25% of the load and septic systems just 1 %.

Hydrology and Water Balance

Computer models were run to develop information on rainfall-runoff relationships using twenty-five years of rainfall data. Water balance modeling was conducted using GWLF, and peak flow analysis was modeled with TR-20. Discounting the subwatersheds draining Annapolis, the results showed that twenty percent of the rainfall was returned to the atmosphere through evaporation or transpiration by plants. Seventy-four percent infiltrated to shallow groundwater and six percent ran off into streams. Deep aquifer recharge was not modeled.

Since the shallow groundwater component represents baseflow to the streams, the modeling shows that on average, over the watershed, about ninety-two percent of streamflow comes from baseflow, and eight percent from storm runoff.

Future Watershed Condition

The purpose of modeling future conditions is to determine the degree of impact that proposed development will have on watershed conditions and to estimate the effectiveness of proposed projects and improvements. For the Severn River watershed plan, future conditions were based on land use scenarios developed from the County's 2001 zoning map. The County was interested in determining the effectiveness of existing stormwater management regulations and stream buffer regulations, so three future conditions scenarios were developed to assess these measures.

- Basemap 1 consisted of future land use changes
- Basemap 2 added SWM controls according to current design criteria
- Basemap 3 added buffer regulations according to current ordinances

Water Quality

Water quality modeling results show the SWM program appears to be more effective than buffer regulations at reducing phosphorus from new development. The model is probably underestimating the effectiveness of the buffers, however, since the filtering capability of the buffers is not included as a BMP pollutant reduction. The SWM program reduces future TP loads by 6% over the whole watershed, with the highest absolute reduction in Picture Spring Branch (PSB) and the highest percentage reduction in Severn Run Trib 9 (ST9). Similarly, the buffer regulations show a 4% reduction for the watershed with the highest absolute reduction in Picture Spring Branch (PSB) and the highest percent reduction in Ringgold Cove (RGC).

While both nitrogen and phosphorus loads increased with future development, septic system loads were reduced by almost sixty percent with the additional sewer service to be provided under the County's sewer plan, so that the overall load to the Severn River was reduced. Buffers were also effective at reducing septic system loads by three percent by displacing development to areas served by sewer systems.

Hydrology and Water Balance

Future development has the effect of reducing evapotranspiration and infiltration to groundwater, while increasing direct runoff flows by about six percent. SWM regulations modeled the second scenario help restore natural hydrology somewhat by increasing infiltration and decreasing direct runoff by one percent compared to future conditions. Adding the effect of existing buffer regulations increased evapotranspiration and infiltration an decreased runoff by another one percent.

All of the subwatersheds modeled showed significant increases in peak flows as future development occurred. Some SWM facilities were modeled in the second scenario for drainage areas larger than 10 acres, and these showed a reduction in the peak, but not back to the level of existing conditions. Incorporating stream buffer regulations in the third scenario provided additional reduction in peak flows due to the lower development and imperviousness associated with the buffer land uses.

Analysis, Problem Identification, and Ranking

The purpose of this section is to develop a quantifiable method to determine which subwatersheds and stream reaches are most in need of restoration or protection. The problem area ranking task of the Severn River Watershed Management Master Plan was a critical step in integrating historical environmental data, stream assessment monitoring, and watershed-modeling results to begin identifying problems and determine which are the most significant.

Subwatershed Ranking

The approach to the task was collaborative. A series of meetings was held with a small group of County staff, stakeholders, and consultants to discuss the approach. The procedure would have to include the following steps:

1. Choose a set of ranking criteria or indicators to characterize condition with a minimum of duplication.
2. Quantify or score each indicator, preferably in a normalized fashion so that, for instance, one subwatershed's score could be directly compared with that of another.
3. Weight the indicators against each other so that the ones that are most important in establishing watershed health or vulnerability would have the highest consideration.
4. Develop two sets of indicators to identify the priorities for watershed restoration and preservation.

The selected indicators for subwatershed condition provided information on stream habitat, runoff characteristics, modeled water quality, landscape characteristics, and aquatic living resources.

The results of the restoration ranking showed many of the same watersheds that had high pollutant loads and imperviousness were rated in poor condition and high priority for restoration. The top five in order were Woolchurch Cove, Picture Spring Branch, Jabez Branch 3, Weems Creek, and Hacketts to Sandy Point.

Preservation ranking showed that the watersheds most in need of preservation were Maynadier Creek, Severn Run 4, Gumbottom Branch 2, Indian Creek Branch, and Brewer Pond.

Development of Watershed Guidelines for TP

The purpose of the watershed management guidelines is to provide a quantifiable method to identify relatively unimpaired systems and to determine a level of quality that is acceptable to meet designated uses and goals of the governing bodies. The WISE model, which links bioassessment data with watershed characteristics, was used to help develop the guidelines.

Statistical relationships were not as strong as could be expected, so an alternative method was used to set the limit where aquatic integrity begins to be degraded. Using guidance from literature reviews, a threshold of 10% imperviousness was set as the limit to meeting the goal of "Good" bioassessment scores.

Total Phosphorus (TP) loads from runoff was used as a keystone indicator in this analysis. Anne Arundel County has regulations that require each new development to meet a 50% reduction in the TP load. Since TP is being used for new development review, it is the parameter that will be used for evaluating the watershed management plan alternatives.

Using the regression relationships as a guideline, 10% imperviousness cover would result in a TP load of 0.35 lb/ac/yr. This was the parameter set for determining whether watersheds in each scenario could meet the aquatic integrity the standards.

Evaluation of Alternatives

Preservation Alternatives

Preservation alternatives have been proposed to protect high-quality areas from degradation as the watershed develops. The BMPs proposed fall into two categories: Land Conservation, which identifies sensitive areas and protects them in their existing condition, and Site Design, which gives incentives to develop with designs that have a lower impact on aquatic resources than conventional development.

Land Conservation Scenarios

Greenways This alternative is a method of preserving important natural areas, which are important habitat and connecting corridors for terrestrial wildlife. Many of the proposed greenways follow stream valleys in the Severn River watershed.

Expanded Stream Buffer This alternative was represented by creating a 300 foot stream buffer in areas with no planned sewer service. The purpose for this buffer is to reduce the potential for septic systems to short circuit from the drainfield directly to streams without treatment.

Site Design Scenarios

Cluster Development Cluster development consists of developing 1- and 2-acre zoned lots so that buildings on these lots are placed more closely together than traditional zoning permits.

Higher Density Cluster A second alternative for cluster development (R11CD and R21CD) was also created to represent higher than zoned density. For this alternative, 30% of the area was reserved for woods and the remainder was assumed to be developed at the next higher density.

Restoration Alternatives

Restoration alternatives have been proposed to improve water quality and watershed conditions from areas that were developed before the most recent stormwater management regulations were in place. Two categories of BMPs are proposed: SWM Facilities, which treat stormwater runoff, and non-stormwater discharge BMPs, which reduce pollutants from other types of discharges from the watershed. The alternatives included the following:

Structural SWM Facilities

Wetland mitigation Anne Arundel County conducted a study of wetland mitigation sites in the Severn, South, and Magothy Rivers, which were included by changing the land use at the sites from the existing condition to Water.

Bioretention retrofits A distributed stormwater management alternative consisting of bioretention with an infiltration component was applied watershed-wide to commercial, industrial, 1/8 acre residential, and 1/4 acre residential land uses

Retrofit of dry ponds to wet ponds This alternative represents a reconstruction of an existing dry pond to one with better pollutant removal characteristics.

Non-Stormwater Discharges

Septic system upgrades This alternative consisted of reconstruction or upgrades to all existing septic systems to discharge 25% of the existing nitrogen load.

Watershed Guidelines

This section of the Watershed Plan serves two purposes. First, it gives an overview of watershed management scenarios as an integrated framework for managing the Severn River watershed, showing how preservation, controls on new development, and water quality retrofits can work together to meet watershed goals. Secondly, it establishes links to the more detailed recommendations which follow.

Four scenarios were modeled and the results were compared to the watershed improvement guidelines of "Good" biological condition and 0.35 lb/ac/yr TP to evaluate how well the goals were attained. The scenarios included existing conditions (Basemap 1), future conditions without controls (Basemap 2), future conditions with SWM and buffers designed to reduce post development TP loads by 50% (Modified Basemap 3), and a restoration scenario which added BMPs to existing developments within the watershed to reduce the total phosphorus load by 50%. The results were as follows:

- Existing conditions: The TP load was 0.45 lb/ac/yr, which exceeds the guidelines
- Future conditions: TP was 0.59 lb/ac/yr, which helps to quantify the case for controls on new development
- Future conditions with controls: TP was reduced to 0.51 lb/ac/yr, better than uncontrolled development but not back to existing conditions and not meeting the guidelines
- Retrofits: The overall watershed goal of 0.35 lb/ac/yr TP can be met if 38% of the existing development is retrofit with SWM controls.

Results of Preservation Alternatives

Water Quality

Water quality modeling showed that all of the preservation alternatives are effective at reducing runoff pollutant loads from future development. Greenways reduced nutrients by about four percent, while metals reductions varied from one to five percent. Reductions from buffers were about half this amount. Cluster development brought about an additional reduction of four percent of the nutrient and copper pollutant load, while having little effect on the other metals. The denser cluster scenario had a reduction of three percent instead of four, while allowing higher densities.

A comparison was made of TP loads on a subwatershed level. The combination of the two land conservation alternatives reduces future TP loads by 6% over the whole watershed, with the highest absolute reduction in Saltworks Creek (SWC) and the highest percentage reduction in Brewer's Pond (BWP). Similarly, cluster development shows a 4% reduction for the watershed compared with a base of greenway + buffer conservation, with the highest absolute reduction in Picture Spring Branch (PSB) and the highest percent reduction in Ringgold Cove (RGC).

Hydrology and Water Balance

Preservation scenarios were effective at reducing the amount of runoff from future development. Runoff volume increased by six percent with uncontrolled development, but by only three percent when the preservation measures were included, so the projected increase was reduced by half. The preservation alternative produces the largest change in evapotranspiration, due to the wooded area which is protected.

The preservation scenarios also reduced peak flows. Preservation reductions come from lower runoff parameters associated with wooded land use that does not become developed, and with reduced imperviousness from cluster development.

Results of Restoration Alternatives

Water Quality

Modeling results show that, except for the wetland mitigation alternative, the restoration alternatives are effective at reducing pollutant loads from existing development.

The most effective restoration alternative is bioretention retrofits for industrial and commercial areas, followed by the dry-to-wet pond retrofits. Removal efficiencies for bioretention are very high, and they appear to be very effective at reducing watershed loads. Retrofit of industrial and commercial areas alone will bring the phosphorus loads down to less than the existing loading, even after development.

The largest single change in nitrogen loads is from conversion of existing septic systems to low-nitrogen systems which removes 75% of the nitrogen load from this source and forty percent of the nitrogen from uncontrolled future development.

Hydrology and Water Balance

The restoration alternative, with its intensive bioretention / infiltration component, had a significant effect on water balance. It brought about the greatest reduction in direct runoff of the alternatives proposed, reducing it back to the levels of existing conditions.

The reductions in peak flows from the restoration scenario reflect the infiltration component of the bioretention BMPs included in that scenario. Conversion of dry ponds to wet ponds had no effect, since it was not designed to change flow characteristics, but only make improvements to runoff quality.

Implementation Plan

Capital Projects

Costs used in the analysis were life cycle costs including capital costs and amortized costs of annual maintenance. The total cost of all the improvements recommended in the Watershed Plan is $402,427,501 for the low cost and $529,761,601 for the high cost.

Pollutant Removal Effectiveness

Consistent with other County procedures, Total Phosphorus (TP) was used as the quantitative measure of benefits when comparing management alternatives. TP reductions from PLOAD modeling were used for the benefits. For the Severn River watershed as a whole, the results of the analysis are as follows.

Alternative	Low Cost	High Cost	TP Reduction (lb)	Cost / lb TP (Low) ($ / lb)	Cost / lb TP (high) ($ / lb)	Mid-Range Cost / Acre
Existing SWM Regs	$0	$0	1,271.3	$0	$0	$0
Existing Buffer Regs	$0	$19,984,300	771.2	$0	$44,762	$3,250
Wetland Mitigation	$5,088,837	$5,810,337	7.4	$689,473	$787,227	N/A
Bioretention COM/IND	$156,890,267	$156,890,267	3,940.1	$39,819	$39,819	$60,046
Bioretention R14/R18	$122,383,940	$122,383,940	2,442.5	$50,107	$50,107	$23,209
Pond Retrofit	$8,998,858	$8,998,858	563.4	$15,973	$15,973	$11,567
Greenways	$30,419,400	$84,799,100	846.4	$35,938	$100,184	$12,310
Expanded Buffer	$25,706,200	$77,954,800	319.1	$80,551	$244,274	$13,105
Cluster Development	$0	$0	757.6	$0	$0	$0
Denser Cluster	$0	$0	595.8	$0	$0	$0

The most cost-effective alternative for phosphorus removal is continuation of the existing SWM regulations, which have no cost to the County. The two cluster development alternatives also have no cost once the appropriate regulations have been drafted and are put into place.

The next most cost effective alternative is enforcement of the existing buffer regulations, which costs the County nothing if no easements need to be acquired. This alternative also has the effect of removing impervious area and reducing TP loads during redevelopment, which makes it more effective than the other land preservation alternatives of greenways and an expanded buffer.

Pond retrofits are the most cost effective structural controls, both in terms of cost per pound of TP and cost per acre of treatment. This is largely due to economies of scale. While bioretention is better at restoring the hydrologic regime at the source, the use of a single downstream facility to provide treatment is a lower cost solution.

The cost effectiveness of the wetland mitigation alternative is skewed high because the full benefits were not assessed during the modeling.

Non-Quantitative Criteria

Along with estimates of pollutant load reductions, non-quantitative evaluation criteria were also developed to reflect acceptability and the ease of implementation, operation and maintenance of each alternative.

The range of scores was from 13 to 20, with an average of 16.6. The lowest score of 13 was for residential bioretention retrofits, which scored low in 4 of the 8 criteria. Low ratings for public acceptance, reliability, ease of implementation, and ease of maintenance are all related to the requirements to maintain small, distributed systems that are owned privately.

The second lowest score, 14, was for dry pond retrofits to wet ponds. Public acceptability and health and safety concerns were rated low, primarily because of concern about creating mosquito habitat and accidents.

The highest scores were for enforcement of existing buffer regulations, and for bioretention in commercial and industrial areas.

The industrial / commercial bioretention alternative received moderately difficult ratings related to their characteristics as distributed systems. As with residential bioretention, there is a need to maintain privately owned systems; however, there would be fewer property owners to work with, and potentially fewer (and larger) systems.

Legislative Recommendations

Federal, State, and Regional

A thorough review of federal, state, and local regulations that influence watershed and stormwater management was undertaken to determine opportunities and constraints to implementation of the Severn River Watershed Management Plan. In addition to actions that can be taken by Anne Arundel County government, achieving the goals of the Severn Watershed study will require the cooperation and assistance of both federal and state governments, as follows:

- Identify all federal lands and federally controlled lands within the Severn watershed. Work with federal agencies and federal land managers, including those at the Naval Academy and Fort Meade to secure their cooperation in the Severn Water cleanup.
- Seek and use funding from the Chesapeake and Atlantic Coastal Bays Restoration Funds to support septic system upgrades in areas of the Severn Watershed outside the sewer service area; and seek funding and opportunities to extend sewer service to properties using septic systems within the current sewer service area.
- MDE should use the Severn River watershed management plan and model in any TMDL implementation plan prepared for the Severn or its subwatersheds.
- The recommendations of the Severn Watershed Study should be incorporated into the work plan for the Tributary Strategy Team, as appropriate.

Local

The implementation of some of the management options tested using the Watershed Management Tool (WMT) would require changes to existing Anne Arundel regulations at varying levels of complexity. Other options represent new initiatives that would require considerable discussion among the agencies of County government, the development community, and the public to determine their feasibility prior to proceeding.

Summary of Recommendations

Combining the results for cost effectiveness and non-quantitative criteria, along with recommendations from the legislative review, the priority for implementation of the alternatives is as follows:

1. Existing SWM Regulations The modeling showed this alternative to be an effective method of TP reduction with no additional cost to the County. The program should be continued.
2. Cluster Development (Both alternatives) These alternatives can be implemented with little or no additional cost to the County once the regulations are in place. They received the second highest rating in the non-quantifiable evaluation criteria. The legislative review determined that this would be the least complex alternative to implement.
3. Enhancement of existing buffer regulations This alternative had the lowest cost per pound of TP removed, and the lowest cost per acre of area treated. It also received the highest score for implementation and acceptability.

   The legislation review showed that current regulations provide for the stream and wetland buffers through provisions in the erosion and sediment control and the stormwater management manual. Most of the required buffer widths are less than the 100 feet tested through the watershed model. The current regulations also have no provisions to prevent the location of accessory structures building or activities on existing parcels or for smaller disturbances.
4. Dry-to-Wet Pond Retrofits This alternative was the second most cost-effective, but scored low in acceptability. The recommendation is to pursue this option where there are ponds that are at some distance from residential areas, to minimize health and safety concerns.
5. Commercial / Industrial Bioretention Retrofits This alternative was the fourth most cost effective in pollutant removal, and the most costly per acre treated, but ranked highest for acceptability and implementation.
6. Greenways Greenways were the second highest ranked in terms of acceptability, third for pollutant removal cost-effectiveness, and for cost per treated area. While not part of the scoring, they also provide habitat and recreational benefits beyond those for water quality improvements.

   The legislation review recommended that development of the implementation and management plan for the Severn Run 2 Greenway should be expanded to include all the greenways within the Severn watershed and should be linked to the goals of the Severn Watershed Study as well as the provisions of other County planning efforts. Consideration should be given to increasing the greenways set aside to approximately 25% of the total Severn watershed area
7. Residential Bioretention Retrofits This alternative ranked low for cost effectiveness for both TP removal and cost per treated area. It also scored the lowest for the non-quantitative criteria. To improve public acceptability, the recommendation is to construct these systems in areas where they can be installed as publicly owned and maintained systems in the right-of-way.
8. Expanded Buffers Expanded floodplain buffers scored relatively high, and expanded stream buffers in unsewered areas scored relatively low in the non-quantitative criteria. This was the least cost-effective alternative for pollutant removal.

   As discussed the legislative review, a more sophisticated approach would create a watershed overlay zone as an alternative to the stream buffer overlay ordinance. A watershed overlay ordinance would use the results of the watershed ranking exercise to create classifications of watersheds and impose development limitations within each classification that would achieve the appropriate level of water quality protection or restoration.

9. Septic System Upgrades This alternative was not prioritized using TP reduction as a measure; however, it is the most effective alternative for reducing nitrogen loads.

   Legislative recommendations for this alternative are to seek and use funding from the Chesapeake and Atlantic Coastal Bays Restoration Funds to support septic system upgrades in areas of the watershed outside the sewer service area; and seek funding and opportunities to extend sewer service to properties using septic systems within the current sewer service area. To reduce the impacts of septic systems in future years, all new development could be required to hook into the public sewer system or provide upgraded septic systems.

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1 Introduction

1.1 Purpose of Watershed Plan

As part of its MS4 National Pollutant Discharge Elimination System (NPDES) permit, Anne Arundel County has developed a comprehensive Watershed Management Master Plan for the Severn River. The Severn River watershed includes tidal and non-tidal surface water. It is located entirely within Anne Arundel County and flows southeast until joining the Chesapeake Bay to the east of Annapolis. The estuarine part of the River is currently on the 303(d) list for nutrients, sediment and bacteria. In addition, there are concerns about the buildup of toxic metals in the sediments. As a tributary to the Chesapeake Bay, the Severn River is also facing issues that are affecting aquatic resources Bay-wide. These include increases in nutrient loadings, algae growth, reduced dissolved oxygen (DO) and loss of submerged aquatic vegetation (SAV). The watershed is under pressure from continued residential and commercial development. Impacts of urbanization and pollution from existing sources need to be addressed. Land use must be managed properly to preserve and improve habitat quality, improve water quality, and reduce flooding. The Watershed Management Master Plan study has characterized the watershed's baseline conditions and resources, assessed existing and potential concerns, and addressed short- and long-term opportunities and improvements to provide a holistic, systematic watershed perspective to planning and plan review activities.

While the geographic location of this study is limited to the Severn River watershed, the County has presented a vision in the watershed master plan that calls for an implementable blueprint and tools to facilitate daily land use and infrastructure decisions by County staff and stakeholders to protect watershed resources countywide. Therefore, the Severn River Watershed Management Master Plan includes the development of a Watershed Management Tool (WMT) that will be integrated with the County's current business processes related to watershed management and will link watershed data and models to give County planners and development reviewers interactive information on how changes in land use, zoning, subdivision regulations, Best Management Practices (BMPs), and other watershed conditions affect the Severn River and its tributaries.

1.2 Phased Approach to the Scope

The Severn River Watershed Management Plan Study was undertaken in phases. In Phase I, the existing environmental studies and GIS coverages for the watershed were assessed and a data gap analysis was completed. A variety of watershed models were examined and selected for inclusion in the study. Initial public involvement activities were also performed during this phase. This was the basis for the work done in Phase II, which in general terms, included a characterization of the current condition of the watershed and the tributary streams to the tidal Severn. Phases III and IV focused on the future conditions within the watershed. Problems within the watershed were identified and a variety of management alternatives were analyzed as potential solutions. In addition, an evaluation of the County's current regulations related to watershed issues was performed and modifications and/or additions were suggested.

A variety of activities took place during Phase II in order to provide a current conditions assessment of the Severn. Many of the County's GIS layers were updated following the data gap analysis performed in Phase I. This allowed more accurate and up to date data to be used in the modeling portion of the study. Fieldwork was performed to allow for a baseline assessment of the watershed conditions. Fieldwork to understand the overall health of the Severn River and its tributaries included habitat assessments and bioassessments following MBSS protocols, infrastructure inventories, and geomorphic assessments following Rosgen Level I and Level II protocols. During the stream walks select cross sections were measured. In addition, cross sections were taken upstream and downstream of culverts and profiles through the culverts were determined. Dry weather base flow sampling was performed. The results of these field studies are discussed in more detail in the following sections.

To address the diverse issues and problems facing the Severn River, the next phase of work in this project included modeling. Modeling provides necessary tools for analyzing various alternatives for sustainable development without compromising environmental quality. Due to the complexity of the system and problems no single model can be used successfully to simulate the pollutant loads from various point and nonpoint sources, fate and transport of all the pollutants on land and in water body, and the impact on habitat quality. Time and spatial scale also play an important role.

The models used in this study were developed as part of the Anne Arundel County Watershed Management Tool, a set of GIS-based database and analytical tools used to assess watershed conditions and improvements. Water quality models focused on estimating pollutant loads generated from the watershed and not on determining the fate of pollutants in receiving waters. The models included the following:

- Two watershed models were used to simulate runoff quality (PLOAD and GWLF)
- A model was used to simulate soil erosion from the land surface (both PLOAD and GWLF can be used, but GWLF applies a more deterministic approach based on the Universal Soil Loss Equation - USLE)
- Hydrologic (TR-20) and hydraulic modeling tools (HEC-RAS) were used to address flooding and changes in flow regime
- GWLF was also used to examine the ground water and surface water interactions and overall watershed water budget
- A regression model was used to link stressors to habitat quality (WISE)
- Although not a true predictive model, the Stream Assessment Tool (SAT) allows for compilation, querying, and categorizing of stream assessment data

In addition to providing current conditions data, the fieldwork also captured data used in the modeling portion of the study. All cross section and profile information was used in the HECRAS modeling effort. The bioassessment data and habitat data were used to build the regressions in the WISE model. Data was compiled from the stream walks into the Stream Assessment Tool. These models, in addition to TR20, GWLF, and PLOAD, were utilized to determine additional information about the current conditions of the watershed.

Once the baseline conditions were established, the models were used with future land use to examine the expected future conditions of the watershed. Future pollutant loading, flooding of road crossings, stream erosion potential, and hydrology were analyzed.

Based on the previous field data gathering and modeling efforts, problem area ranking was performed. The problem area ranking task of the Severn River Watershed Management Master Plan is one of the first steps in integrating historical environmental data, stream assessment monitoring, and watershed-modeling results to begin identifying problems and determine which are the most significant. The purpose of this was to determine which subwatersheds and stream reaches are most in need of restoration or preservation. A variety of management alternatives were offered as potential solutions and modeling in PLOAD and GWLF was performed to see what effect the alternatives would have on the pollutant loading to the river.

1.3 Regulatory Framework

In addition to providing the County with the planning tools to look at its aquatic resources in a more holistic fashion, this project has also met many of the County’s current and pending regulation requirements. The initial driver for this project was the County’s MS4 NPDES permit. A minimum requirement of the permit's Section Part III F Watershed Assessment and Planning is "to develop watershed management plans for all watersheds in Anne Arundel County". This plan fulfills that requirement for the Severn River watershed. Information and work needed to fulfill additional sections of the permit, such as Section III Part G Watershed Restoration, will be provided by and streamlined by the Watershed Management Tool.

As mentioned previously, the estuarine part of the River is currently on the 303(d) list for nutrients, sediment and bacteria. Anne Arundel County's most recently updated NPDES permit (November 2004) contains components related to TMDLs, specifically that stormwater BMPs and programs implemented as part of the permit meet the waste load allocations under the TMDL. MDE has not assigned waste load allocations yet to the Severn River nor has it finalized requirements for an implementation strategy. The EPA published a draft TMDL/Watershed Rule (40CFR130.41) in the fall of 2004. MDE provided a portion of this (40CFR130.41: What elements are appropriate for a watershed plan designed to attain and maintain water quality standards?) to Anne Arundel County for their consideration as they complete watershed management plans on streams within their purview. The Severn River Watershed Management Plan will address the issues raised in the CFR and will meet these MDE requirements for the County.

In June 2000, Chesapeake Bay Program partners (the states of Virginia, Maryland, Pennsylvania, the District of Columbia, the Chesapeake Bay Commission and the U.S. Environmental Protection Agency) adopted the Chesapeake 2000 agreement, a strategic plan to achieve a vision for the future of the Chesapeake Bay. To restore an ecosystem as complex as the Chesapeake Bay requires work on many fronts. The agreement details nearly one hundred commitments important to Bay restoration, organized into five strategic focus areas: protecting and restoring living resources, protecting and restoring vital habitats, improving water quality, managing lands soundly, and engaging individuals and local communities. Enforcement of the provisions of Chesapeake 2000 is provided through the regulatory and legislative actions taken by each of the signatories. Chesapeake 2000 provides the major policy framework that guides the application of a variety of federal, state, and local programs, including their application in the Severn watershed. The details of some of these programs and their relevance to the Severn River Watershed Management Program is described in Section 7.6 and Appendix C. The data collected in this study provides the basis for the County to implement programs in the strategic areas identified as part of Chesapeake 2000.

2 Public Involvement

2.1 Objective

The Phase I public involvement activities focused on enhancing the data collection process. Stakeholders were introduced to the Severn River Watershed project and asked to identify environmental concerns and problems within the watershed, identify data sources that can help with various elements of the Phase II analysis, and identify additional stakeholders to participate in the project. In addition to strengthening the data collection and evaluation, the public involvement process helps to develop a better understanding of the issues involved in watershed management and the tradeoffs involved in watershed protection.

2.2 Approaches and Results

Two public stakeholder workshops and a survey distributed to over 3,500 residents of the Severn River watershed were used to achieve this objective. The survey was accompanied by a project fact sheet and map of the Severn River Watershed.

2.2.1 Workshop One

The first public stakeholder workshop on May 3, 2001 featured a presentation on the history of development in the watershed and various aspects of the watershed master planning process. Various potential functions of the GIS Management tool were also described. Participants at this meeting identified overall watershed issues and concerns and identified specific problems within the watershed. Stakeholders were given colored dots and were asked to identify specific problems by placing the dots on a large watershed GIS map. The dots were color coded according to category (water quality, flooding and erosion, impacted uses, and critical areas or special protection areas). Meeting attendees grouped the overall watershed concerns into six major categories. Meeting participants went through an exercise to prioritize their most important issues facing the Severn River Watershed.

2.2.2 Workshop Two

The second public stakeholder workshop on May 17, 2001 included a summary of the issues heard from the stakeholders at that previous meeting. The exercise of identifying specific problem areas using large-scale maps as reference points was continued to gain information from individuals who missed the first meeting. A listing of the data sources was handed out for the attendees to review. Additional studies were described by attendees and potential contact agencies were given. The public survey was discussed with several attendees offering to distribute surveys to their respective organizations. Workshop participants prioritized particular streams that they would like to see studied in detail. Both hydrologic and hydraulic models were discussed as well as the pollutant loading and estuary modeling to be performed in Phase II. It was later determined not to include estuary modeling for this study. Workshop participants identified and then prioritized a list of pollutants of concern that would be potentially modeled later on in the project. Attendees also identified outfalls where they have observed pollution in the receiving stream.

For more detailed information on the workshop results please review the meeting minutes, associated maps, and the list of invited stakeholders in Appendix A.

2.2.3 GIS Workshop

In addition to the external stakeholder workshops, a two-day workshop for County staff members was held to define the GIS based watershed management tool. This workshop focused on identifying the user groups, the tool's functional requirements, and the data needed to fulfill those requirements.

2.3 Survey Results

2.3.1 Objective

As determined in various meetings with the County, the most important use of the survey was to elicit specific information on the condition and problems residents saw with the tributaries and the River. It was hoped that this information would be utilized as reference during the field collection efforts of Phase 2. Some possibilities of how this data may be used would be to prioritize those areas in terms of schedule or focus or to aid the field teams in locating particular problems during field walks.

2.3.2 Approach

Surveys were mailed to 2500 randomly selected watershed residents. An additional approximately 400 heads of organizations received surveys as well. These organizations comprise the stakeholder list determined in earlier public involvement efforts and a list of neighborhood associations in the area. It was presumed that many of these people made copies and distributed the surveys throughout their organization. Unfortunately, it is not known how many surveys were distributed in addition to the 2900 original mailed surveys. Approximately 410 surveys were returned, for a maximum possible return rate of 14.1% (assuming that only 2900 surveys were distributed).

2.3.3 Watershed Survey Results

As stated earlier, the objective of the survey was to receive information regarding problems and resident concerns in the watershed. As a result, the information lends itself to being very anecdotal in nature. This information has been compiled and will be distributed to the field teams for use as reference in their field walks during Phase 2. While the data will not change the amount of or preclude any streams covered during the stream walks nor will monitoring stations be chosen solely on the basis of the survey results, the data will direct field crews to areas of interest during their stream walks and will provide an additional layer of possible reasons to choose a particular site for a monitoring station. Also, this information may feed into the ranking criteria later developed in Phase 2. In addition, some quantitative analysis was performed on particular questions that could aid in getting an overall picture of how the residents of Anne Arundel County perceive their watershed. Particulars on these questions are described below. Detailed pie charts and percent rankings, as well as compilation of some of the anecdotal information, are found in Appendix A.

Question 1 : residents' enjoyment of the County bodies of water

The majority of residents replied that their ability to enjoy the County bodies of water has increased or stayed the same over the past 5 years. Of those who responded that their enjoyment has decreased, the majority complained of too heavy boat traffic and pollution as being the main culprits. Several responded with concerns of sedimentation of the streams. Overall, the main reason the respondents use the County bodies of water is for boating. These responses were to be expected. The Severn River Watershed has many recreational bodies of water that are highly utilized. In addition, the Severn River Watershed residents tend to be highly educated and motivated by environmental concerns. Therefore, there is a contradiction of many responding that they use the waters for boating and at the same time many others seeing their enjoyment decreasing because of the increase boating and Jet Ski activities. Other activities that the County residents rated highly are fishing and swimming.

Question 2 : evidence of pollution

The majority (an overwhelming 73%) of respondents have found evidence of pollution in the County water bodies. The majority of those listed muddy water as the main evidence of pollution. Trash and litter were also frequently listed. Evidence of pollution was most frequently seen after rainfall events.

Question 3 : relative pollution of streams

Most of the people responding to this question answered “Don’t Know”. Clearly, respondents had difficulty making the relative comparison between streams intended by this question. There may be several reasons for this difficulty. Many respondents mentioned that streams within the watershed are bordered by private properties and are therefore inaccessible to most of the public. This may prevent people from developing a broader base of knowledge from which to make comparisons between streams. Perhaps also individuals are less likely to make relative comparisons unless they feel that they have specific data on the amount of pollution in particular streams. The response to this question in itself does not suggest a lack of awareness of environmental issues, rather a difficulty in making relative comparisons between water bodies. The stream that did receive the highest number of responses (other than “Don’t know”) was the Severn River. This is expected because of the high visibility of the river and all the activities that rely on it.

Question 4 : streams blocked by debris

In this question, residents were asked to give details on stream names and locations of where they had seen debris obstructions. Locations along Severn River and Severn Run were most frequently listed. The types of debris listed along the Severn River included trash, sandbar, beaver dam, fallen trees, crab pots, and construction fill. The types of debris listed along the Severn Run included trash, sandbar, and fallen trees. Trash was observed at almost every listed location along the Severn Run. Other streams listed multiple times included Clements Creek and Saltworks Creek.

Question 5 : flood prone areas

The majority of residents responded that they found roadways to be routinely flooded after a storm. A list of these areas will be used as reference in Phase 2 efforts and is included in Appendix A.

Question 6 : erosion and sediment transport

The results of this question showed an almost even split between County residents. That is, half of those responding had seen evidence of erosion or sediment transport within the watershed and half had not seen evidence. Residents were then asked to give details on stream names and locations of where they had seen evidence of erosion. Of the 93 people who responded to that question, 22.6% listed locations on Severn River and 21.5% listed locations on Severn Run. Other streams listed multiple times included Clements Creek, Forked Creek, Saltworks Creek, Spa Creek, Weems Creek, and Yantz Creek.

Free response question : overall degraded conditions

This question allowed the survey respondents to write any additional observations they had regarding degraded environmental conditions in the watershed. These responses were much too anecdotal for any type of quantitative analysis, but a compilation of the responses is included in Appendix A. A common theme in many of these responses was the concern over boat and Jet Ski traffic on the waterways. Concerns over development impacts on the environment were also echoed in several responses.

Preference question : preferred method of contact and information dissemination

Lastly, the respondents were asked to rate their preference of different methods techniques. This information will be invaluable as the Public Involvement effort enters Phase 2. Five different ways of being kept informed were evaluated: Anne Arundel County Website, Periodic Mailings, Telephone Calls and County Staff, Public Meetings, and Announcements in Local Newspapers. Survey respondents were asked to rank these methods 1 through 5. Because many people ranked more than one category as “1”, a pure percentage based comparison cannot be performed. However, the results have shown that the favored methods of information dissemination are periodic mailings, announcements in local newspapers, and the Anne Arundel County website.

2.3.4 Results of the Survey and Impacts to Future Outreach Efforts

The overall purpose of the survey was to elicit specific information on the current conditions and problems residents observe in the tributaries and the River. The survey met these objectives. It is risky to infer conclusions about public behavior beyond the specific objectives of the survey. For example, the survey did not try to capture data on the general environmental IQ of the watershed residents.

With these ground rules, however, some general observations can be made. The survey's return rate of 14.1%, was only slightly higher than average for this type of survey (approximately 10%). The project team had higher expectations for the return rate, due in part to the perceived high educational level and environmental interest of the watershed residents. From this low response we may conclude that broad, nearly random outreach efforts (like the survey) will be less effective for the Phase II public involvement program than more targeted communication to specific groups. We may also conclude, due to the difficulty people had in responding to the relative comparison in question 3, that impressions of stream and water quality are very localized. It may be difficult for area residents to evaluate watershed-wide programs and policies without understanding how a tool or management alternative will impact the water body with which they are most familiar.

3 Current Watershed Condition

3.1 Environmental Setting

In Phase I of the study, a data gap analysis was completed. The results can be found in the *Severn River Watershed Management Master Plan Phase I Final Report* (KCI 2002). In that report, existing environmental and watershed information was compiled, including reports on estuary hydrodynamics, toxicology, biological condition, water quality, pollutant loading, flow and gauge data, and GIS coverages of watershed parameters. A summary of the information compiled in Phase I is presented below to give a description of the existing physical and biological resources within the region and the Severn River Watershed specifically.

3.1.1 Physiography

The Severn River watershed is located within the Coastal Plain physiographic province. The Coastal Plain is the youngest province in the state, and is made up of unconsolidated sedimentary deposits. The layers of the Coastal Plain were deposited by streams flowing from the adjacent Piedmont Province and were also deposited in a shallow marine environment (MDNR 1987).

The topography within the watershed ranges from nearly level to very steep. Steep slopes (greater than 15%) border the headwater tributaries and downstream floodplains along the northern and southern shoreline of the Severn River (Glaser 1976). Deep V-shaped valleys have been formed where small streams have cut through the soft unconsolidated material of the Coastal Plain, and broad alluvial floodplains are located adjacent to both large and small streams (USDA-SCS 1973). Elevations range from sea level, along the shores of the Chesapeake Bay, to 300 feet.

3.1.2 Geology and Soils

Geology

The geology within the watershed is dominated by sand, gravel, silt, and clay of the Cretaceous age. Present in lesser quantities is sand, clay, silt, greensand, and diatomaceous earth of the Tertiary age, and sand, silt, gravel, clay, and peat of the Quaternary age. The Potomac Group, consisting of the Raritan and Patapsco Formations, Arundel Clay, and Patuxent Formation, is dominant along Severn Run and its tributaries. The Aquia Formation is the dominant geologic formation along the lower third and at the mouth of the Severn River. Lowland Deposits is present in moderate amounts at the mouth and within the southern shore of the upper third portion of the Severn River. Monmouth, Matawan, and Magothy Formations are located along and near the northern and southern shorelines within the middle third of the Severn River. The Calvert Formation and Upland Deposits are present within the watershed in minimal amounts and in isolated areas (MGS 2002). The associated rock types and formations within the watershed are briefly described below:

Aquia Formation – Characterized as dark green to gray-green, argillaceous, highly glauconite, well-sorted fine to medium-grained sand. Contains locally indurated shell beds. Thickness ranges from 0 to 100 feet.

Calvert Formation – The Plum Point Marls Member consists of fine-grained argillaceous sand and sandy clay that is dark green to dark bluish gray, and contains prominent shell beds and locally silica-cemented sandstones. The Fairhaven Member consists of greenish-blue diatomaceous clay that turns pale gray due to weathering. It also contains fine-grained sand that is pale brown to white in color, and greenish blue sandy clay. Thickness ranges from 0 to 150 feet.

Lowland Deposits – Consists of gravel, sand, silt, and clay. Sand and gravel is medium to coarse-grained, with cobbles and boulders near the base. Reworked Eocene glauconite is commonly found.

Contains varicolored silts and clays, dark gray lignitic silty clay. Remains of estuarine to marine fauna can be found in some areas. Thickness ranges from 0 to 150 feet.

Magothy Formation – Consists of loose, white, cross-bedded, lignitic sands and dark gray, laminated silty clays. In western Anne Arundel County it consists of white to orange-brown, iron stained, surrounded quartzose gravels. It is absent in the outcrop southwest of the Patuxent River. Thickness ranges from 0 to 60 feet.

Matawan Formation – Consists of sand and silt that is dark gray, micaceous, glauconitic, argillaceous, and fine-grained. Thickness ranges from 0 to 70 feet.

Monmouth Formation – Consists of micaceous, glauconitic, argillaceous, fine to coarse-grained sand that is dark gray to reddish brown in color. Thickness ranges from 0 to 100 feet.

Potomac Group – Consists of interbedded quartzose gravels, protoquartzitic to orthoquartzitic argillaceous sands, and silts and clays that are dark gray and multicolored. Thickness ranges from 0 to 800 feet. The Potomac Group is comprised of the Raritan and Patapsco, Arundel Clay, and Patuxent Formations.

Raritan and Patapsco Formations – Variegated silts and clays of gray, brown, and red colors. Lenticular, cross-bedded, argillaceous, sub rounded sands, and minor gravels. Thickness ranges from 0 to 400 feet.

Arundel Clay Formation – Consists of lignitic clays that are dark gray and maroon. Abundant siderite concretions are present. This soil formation is present only in the Baltimore-Washington area. Thickness ranges from 0 to 100 feet.

Patuxent Formation – Consists of angular sands and sub rounded quartz gravels that are moderately sorted, cross-bedded, argillaceous, and white or light gray to orange-brown in color. Silts and clays are subordinate and predominately pale gray in color. Thickness ranges from 0 to 250.

Upland Deposits – Consists of gravel and sand that is commonly orange-brown, and is locally limonite cemented. Minor silt and red, white, or gray clay. Consists of the lower gravel member and upper loam member in Southern Maryland. Thickness ranges from 0 to 50 feet.

Soils

According to the Soil Survey of Anne Arundel County, Maryland (USDA-SCS 1973), the Evesboro-Rumford-Sassafras association is the dominant soil association in the northwestern portion of the watershed, with the Loamy and clayey land-Muirkirk-Evesboro association present in minimal quantities. The Evesboro-Rumford-Sassafras association is described as gently sloping to moderately steep, consisting of excessively drained and well-drained sandy and loamy soils. The Loamy and clayey land-Muirkirk-Evesboro association is described as nearly level to steep, with well-drained loamy and clayey soils, and excessively drained sandy soils. The dominant soil association within the southeastern portion of the watershed is the Monmouth-Collington association, with the Elkton-Othello-Mattapex association present in minor quantities. The Monmouth-Collington association is described as being nearly level to moderately steep, with well-drained sandy and loamy soils. The Elkton-Othello-Mattapex association is described as being level to sloping, with poorly drained and moderately well drained loamy soils (USDA-SCS 1973).

All analytical work for the project requiring soils information was completed using digital soils data obtained in May 2002 from the Anne Arundel Soil Conservation District.

3.1.3 Aquifers

Within the Severn River watershed lie four geologic formations that are hydrologically characterized as aquifers. These formations consist of the Aquia, Magothy, Patapsco-Raritan, and Patuxent Formations.

The Patapsco-Raritan and Patuxent Formations consist of interchanging confining beds and aquifers throughout the profile. The Monmouth Formation is characterized as a poor aquifer in places throughout the area (Lucus 1976).

The Patuxent and Patapsco-Raritan Formations are the water bearing formations within the Potomac group and are the most heavily used aquifers in Maryland. The Patuxent Formation is a multi-aquifer unit and is a very productive water-bearing formation. Its transmissivity ranges from 130 sq. ft. per day to 10,700 sq. ft. per day, and has typical storage coefficients ranging from 0.001 to 0.00001. In Maryland, the best well yields for the Patuxent Formation range from a few hundred to 1,200 gallons per minute (gpm). The Patuxent formation has generally good natural water quality in most updip locations (up gradient in the aquifer) (MDNR 1987).

The Patapsco-Raritan Formation is also a multi-aquifer unit that is irregularly stratified, and a very productive ground water source. The transmissivity of the Patapsco-Raritan Formation ranges from 160 sq. ft. per day to 6,700 sq. ft. per day, and has typical storage coefficients ranging from 0.005 to 0.00005, but could be as much as 0.15. Wells in this formation have specific capacities that range from less than 1 to approximately 13 gallons per minute (gpm) per foot of drawdown. The natural water quality in most updip areas is good within the Patapsco-Raritan Formation (MDNR 1987).

The Magothy Aquifer is one of the most extensive aquifers in the Coastal Plain Area of Maryland. In general, the aquifer has the potential to yield moderate to large quantities of ground water. Its transmissivity ranges from 500 sq. ft. per day to over 12,000 sq. ft. per day, the highest values occurring in central Anne Arundel County. Storage coefficients for the formation average approximately 0.0001. Wells in this formation normally yield from 5 to 400 gpm, with drawdown capacities ranging from 1 to 7 gpm/ft. The Magothy aquifer has a natural water quality suitable for most uses (MDNR 1987).

The Aquia Formation acts as an aquifer over approximately 1,600 square miles. The transmissivity of the aquifer ranges from 100 to 5,500 sq. ft. per day, and the storage coefficient ranges from 0.001 to 0.004 and may be as high as 0.15. Generally, well yields range from 4 to 350 gpm, and has a drawdown capacity ranging from 1 to 20 gpm/ft. Overall, the natural water quality is good and is suitable for domestic use without treatment in most cases (MDNR 1987).

3.1.4 Unique Ecology

In 1971, the Severn River was designated as one of Maryland's Scenic Rivers. Many unique and ecologically important natural features can be found within the borders of its watershed.

Within the state of Maryland, Anne Arundel County possesses the highest quantity of bogs, which qualify as wetlands of special state concern. Bogs and wetlands of special state concern within the Severn River Watershed with unique habitat and flora, which may have carnivorous plants, include Dicus Mill and Gumbottom Complex (Arden Bog). Bogs and wetlands of special state concern that have Atlantic white cedar (*Chamaecyparis thyoides*) present include Arlington Echo, Cypress Creek, Lakewood, Carrollton, Forked Creek and Sullivan's Cove (SRA 2000). These areas are important as they serve as water filters, improving water quality within the watershed, and creating habitat for rare, threatened and endangered flora and fauna that depend on bog habitat.

During 2001, volunteers planted 1,000 Atlantic White Cedars in the Severn River Watershed. The trees were planted along Howard's Branch (BRC in this study), located adjacent to the Sherwood Forest and the Downs in the Crownsville, MD area (AACo 2002).

One state park is located in the Severn River watershed. Sandy Point State Park consists of 786 acres along the Chesapeake Bay that includes recreation facilities such as beaches, hiking trails, historic interests, and other recreational activities (MDNR 2002).

Greenways have been established and continue to be implemented in the watershed. The largest undeveloped forest tract is 300 acres and located in Crownsville, MD along the Severn River. This area has been put into a conservation easement through the Trust for Public Land (TPL 2000). The Severn Run Natural Environment Area is an area along Severn Run that is owned by the Maryland Department of Natural Resources (MDNR) and set aside for the protection of Severn Run.

Jabez Branch, the largest tributary to Severn Run, is the only Coastal Plain stream that supports a naturally reproducing population of brook trout. Jabez Branch has a series of springs and dense forest cover that provide the cool water necessary for brook trout reproduction (Vlavianos 2001).

Rare Threatened and Endangered Species

Information on current and historical Rare, Threatened and Endangered Species (RTE) present within the County is located in Table 3.1 and Table 3.2. This information was current as of November 7, 2002 and represents a compilation of information from the Department of Natural Resource's Wildlife and Heritage Service's Biological and Conservation Data system. The list includes 19 animal species and 108 plant species. The key for the State rank and status are located after Table 3.2. Four species on County RTE list also have federal status. These include the bald eagle (*Haliaeetus leucocephalus*), sensitive joint-vetch (*Aeschynomene virginica*), chaffseed (*Schwalbea Americana*) and swamp pink (*Helonias bullata*).

County GIS data includes a Sensitive Species Project Review Area (SSPRA) coverage (bb02830f.shp), which should be utilized in environmental review. SSPRAs give the general locations of documented RTE species. The coverage is created and updated by Wildlife and Heritage Service staff, and includes non-attributed, buffered polygons. The coverage does not specifically delineate habitats of RTE species. The coverage incorporates various types of regulated areas under the Critical Area Criteria and other areas of concern statewide, including: Natural Heritage Areas, Listed Species Sites, Other or Locally Significant Habitat Areas, Colonial Waterbird Sites, Waterfowl Staging and Concentration Areas, Nontidal Wetlands of Special State Concern, and Geographic Areas of Particular Concern. Therefore, the coverage provides an overview of all state-regulated and designated areas involving sensitive and listed species.

Although the SSPRA coverage contains the most complete single source of data on Maryland's rare, threatened, and endangered species and significant natural communities, it does not represent an exhaustive nor comprehensive inventory of these environmental elements throughout the state. Current field surveys by qualified biologists should be conducted to verify presence or absence. The SSPRA data layer contains dynamic information. Staff of the Wildlife and Heritage Service conduct field surveys and gather new information throughout the year. Thus, the SSPRA data layer will be revised regularly to incorporate the new information.

Table 3-1: Rare, Threatened, and Endangered Animal Species of Anne Arundel County

Common Name	Scientific Name	State Rank	State Status
Eastern tiger salamander	Ambystoma tigrinum	S2	E
Golden-banded skipper	Autochton cellus	S1	E
Glassy darter	Etheostoma vitreum	S1 S2	E
Peregrine falcon	Falco peregrinus	S1B	E
Spotfin killifish	Fundulus luciae	S2	
Common moorhen	Gallinula chloropus	S2B	I
Map turtle	Graptemys geographica	S1	E
Bald eagle	Haliaeetus leucocephalus	S2 S3B	T*
Hydrophilid beetle	Hydrochara occulta	SU	
Black rail	Laterallus jamaicensis	S2 S3B	I
Noctuid moth	Meropleon titan	SU	
Redbelly water snake	Nerodia erythrogaster erythrogaster	S2 S3	
Stripeback darter	Percina notogramma	S1	E
Northern pine snake	Pituophis melanoleucus	SR	
Pied-billed grebe	Podilymbus podiceps	S2B	

Common Name	Scientific Name	State Rank	State Status
Sora	Porzana Carolina	S1B	
A hydrophilid beetle	Sperchopsis tessellatus	S2	
Least tern	Sterna antillarum	S2B	T
Tidewater amphipod	Stygobromus indentatus	S1	

Table 3-2: Rare, Threatened, and Endangered Plant Species of Anne Arundel County

Common Name	Scientific Name	State Rank	State Status	Common Name	Scientific Name	State Rank	State Status
Sensitive joint-vetch	Aeschynomene virginica	S1	E*	Wild lupine	Lupinus perennis	S2	T
Thread-leaved gerardia	Agalinis setacea	S1	E	Climbing fern	Lygodium palmatum	S2	T
Small-fruited agrimony	Agrimonia microcarpa	SU		Anglepod	Matelea carolinensis	S1	E
Woodland agrimony	Agrimonia striata	S1	E	Climbing milkweed	Matelea obliqua	S1	E
Single-headed pussytoes	Antennaria solitaria	S2	T	Sweet pinesap	Monotropsis odorata	S1	E
Short's rockcress	Arabis shortii	S2	T	Thread-like naiad	Najas gracillima	SU	X
Curtiss' three-awn	Aristida curtissii	SU		Larger floating-heart	Nymphoides aquatica	S1	E
Woolly three-awn	Aristida lanosa	S1	E	One-sided pyrola	Orthilia secunda	SH	X
Giant cane	Arundinaria gigantea	S2		Roughish panicgrass	Panicum leucothrix	SU	
Silvery aster	Aster concolor	S1	E	White fringed orchid	Platanthera blephariglottis	S2	T
Bog aster	Aster nemoralis	SE		Crested yellow orchid	Platanthera cristata	S2	T
Willow aster	Aster praealtus	S1		Pale green orchid	Platanthera flava	S2	
Mosquito fern	Azolla caroliniana	SU		Marsh fleabane	Pluchea camphorata	S1	E
Small-fruited beggar-ticks	Bidens mitis	S1	E	Clammyweed	Polanisia dodecandra	S1	E
Grass-pink	Calopogon tuberosus	S1	E	Dense-flowered knotweed	Polygonum densiflorum	S1	E
Coast sedge	Carex exilis	S1	E	Bushy knotweed	Polygonum ramosissimu m	SH	X
Shoreline sedge	Carex hyalinolepis	S2 S3		Stout smartweed	Polygonum robustius	SH	X
Hop-like sedge	Carex lupuliformis	S1		Clasping-leaved pondweed	Potamogeton perfoliatus	S2	
Inflated sedge	Carex vesicaria	S1	T	Redheadgrass	Potamogeton richardsonii	SH	X
Velvety sedge	Carex vestita	S1	E	Spiral pondweed	Potamogeton spirillus	S1	
American chestnut	Castanea dentata	S2 S3		Beach plum	Prunus maritima	S1	E
Leatherleaf	Chamaedaphne calyculata	S1	T	Water-plantain spearwort	Ranunculus ambigens	SH	X
Red turtlehead	Chelone obliqua	S1	T	Hairy snoutbean	Rhynchosia tomentosa	S2	T
Wister's coralroot	Corallorhiza wisteriana	S1	E	Capitate beakrush	Rhynchospor a cephalantha	S1	E
Hazel dodder	Cuscuta coryli	SH	X	Grass-like	Rhynchospor	S1	E

Common Name	Scientific Name	State Rank	State Status	Common Name	Scientific Name	State Rank	State Status
				beakrush	a globularis		
Pretty dodder	Cuscuta indecora	SH		Clustered beakrush	Rhynchospora glomerata	S2	T
Smartweed dodder	Cuscuta polygonorum	S1	E	Spongy lophotocarpus	Sagittaria calycina	S2	
Rough cyperus	Cyperus retrofractus	S2		Dwarf prairie willow	Salix tristis	S1	
Trailing tick-trefoil	Desmodium humifusum	SH	X	Northern pitcher-plant	Sarracenia purpurea	S2	T
Few-flowered tick-trefoil	Desmodium pauciflorum	S1	E	Chaffseed	Schwalbea americana	SX	X**
Stiff tick-trefoil	Desmodium strictum	S1	E	Smith's clubrush	Scirpus smithii	SU	X
Glade fern	Diplazium pycnocarpon	S2	T	Water clubrush	Scirpus subterminalis	S1	E
White spikerush	Eleocharis albida	S1	E	Tall nutrush	Scleria triglomerata	S1 S2	
Pale spikerush	Eleocharis flavescens	S1		Snowy campion	Silene nivea	S1	E
Salt-marsh spikerush	Eleocharis halophila	S1	E	Halberd-leaved greenbrier	Smilax pseudochina	S2	T
Matted spikerush	Eleocharis intermedia	S1	E	Hairy goldenrod	Solidago hispida	SH	X
Beaked spikerush	Eleocharis rostellata	S2		Hard-leaved goldenrod	Solidago rigida	SH	X
Seven-angled pipewort	Eriocaulon aquaticum	S1	E	Showy goldenrod	Solidago speciosa	S2	T
Cluster fescue	Festuca paradoxa	SH	X	Long-leaved rushgrass	Sporobolus asper	S1	
Pumpkin ash	Fraxinus profunda	S2 S3		Hyssop-leaved hedge-nettle	Stachys hyssopifolia	SU	
Coast bedstraw	Galium hispidulum	S1	E	Featherbells	Stenanthium gramineum	S1	T
Box huckleberry	Gaylussacia brachycera	S1	E	Bog fern	Thelypteris simulata	S2	T
Striped gentian	Gentiana villosa	S1	E	Coastal false asphodel	Tofieldia racemosa	SX	X
Yellow avens	Geum aleppicum	S1	E	Pale mannagrass	Torreyochloa pallida	S1	E
Kentucky coffee-tree	Gymnocladus dioicus	S1		Climbing dogbane	Trachelospermum difforme	S1	E
Hoary frostweed	Helianthemum bicknellii	S1	E	Large marsh St. John's-wort	Triadenum tubulosum	S1	
Swamp pink	Helonias bullata	S2	E*	Narrow-leaved bluecurls	Trichostema setaceum	S1	
Crested coralroot	Hexalectris spicata	SH	X	Narrow-leaved horse-gentian	Triosteum angustifolium	S1	E
Dwarf iris	Iris verna	S1	E	Two-flowered bladderwort	Utricularia biflora	S1	E
New Jersey rush	Juncus caesariensis	S1	E	Horned bladderwort	Utricularia cornuta	SH	
Brown-fruited rush	Juncus pelocarpus	S1	E	Fibrous bladderwort	Utricularia fibrosa	S1	E
Potato dandelion	Krigia dandelion	S1	E	Northern blue violet	Viola septentrionalis	SU	
Narrow-leaved pinweed	Lechea tenuifolia	SH	X	Graybark	Vitis cinerea	SU	
Long-awned diplachne	Leptochloa fascicularis	SU		Small's yelloweyed-grass	Xyris smalliana	S1	E

State Rank

S1: Highly State Rare. Critically imperiled in Maryland because of extreme rarity (typically 5 or fewer estimated occurrences or very few remaining individuals or acres in the State) or because of some factor making it vulnerable to extirpation. MDNR's Natural Heritage Program actively tracks species with this rank.
S2: State Rare. Imperiled in Maryland because of rarity (typically 6-20 estimated occurrences or few remaining individuals or acres in the State) or because of some factor making it vulnerable to extirpation. MDNR's Natural Heritage Program actively tracks species with this rank.
S3: Rare to uncommon with the number of occurrences typically in the range of 21-100 in Maryland. It may have fewer occurrences but with a large number of individuals in some populations, and it may be susceptible to large-scale disturbances. MDNR's Natural Heritage Program does not actively track species with this rank.
SE: Established but not native to Maryland; it may be native elsewhere in North America.
SH: Historically known from Maryland, but not verified for an extended period (usually 20 or more years), with the expectation that it may be rediscovered.
SR: Reported from Maryland, but without persuasive documentation that would provide a basis for either accepting or rejecting the report.
SU: Possibly rare in Maryland, but of uncertain status for reasons including lack of historical records, low search effort, cryptic nature of the species, or concerns that the species may not be native to the State.
SX: Believed to be extirpated in Maryland with virtually no chance of rediscovery.
B: This species is migratory and the rank refers only to the breeding status of the species. Such a migrant may have a different rarity for non-breeding populations.

State Status

E: Endangered: a species whose continued existence as a viable component of the State's flora or fauna is determined to be in jeopardy.
T: Threatened: a species of flora or fauna which appears likely, within the foreseeable future, to become endangered in the State.
X: Endangered Extirpated; a species that was once a viable component of the flora or fauna of the State, but for which no naturally occurring populations are know to exist in the State.

Notes:

* Federal Status (LT)- Taxa listed as threatened: likely to become endangered within the foreseeable future throughout all or significant portion of their range

** Federal Status (LE)- Taxa listed as endangered; in danger of extinction throughout all or significant portion of their range

3.1.5 Forests

Three forest associations are found within the Severn River watershed, including the Chestnut-Post Oak-Blackjack Oak, Tulip Poplar, and River Birch-Sycamore Associations. The Tulip Poplar Association is the dominant association and can be found throughout the watershed. This association is dominated by the presence of red maple (*Acer rubrum*), flowering dogwood (*Cornus florida*), Virginia creeper (*Parthenocissus quinquefolia*), black gum (*Nyssa sylvatica*), white oak (*Quercus rubra*), and spicebush (*Lindera benzoin*). The Chestnut Oak-Post Oak-Blackjack Oak Association is present in moderate amounts and is located around the northern third of the Severn River. This association is dominated by the presence of red maple, black gum, white oak, sassafras (*Sassafras albidum*), greenbriers (*Smilax*), Japanese honeysuckle (*Lonicera japonica*), mountain laurel (*Kalmia latifolia*), and southern arrowwood (*Viburnum dentatum*). The River Birch-Sycamore Association is present in minor amounts and, where present, is located along the tributaries to the Severn River. The River Birch-Sycamore Association is dominated by the presence of red maple, poison ivy (*Toxicodendron radicans*), Virginia creeper, greenbriers, sweet gum (*Liquidambar styraciflua*), Japanese honeysuckle, and southern arrowwood (Brush et al. 1976).

3.1.6 Surface Water Resources

The Maryland Biological Stream Survey (MBSS) conducted by MDNR has rated the state of Maryland's streams. MBSS data is interpreted and applied to the statewide, basin, and county levels. The following highlights the results of MBSS data as it relates to Maryland's streams.

Maryland

In general, Maryland's streams are categorized as having poor habitat, poor to fair biological health, and elevated nutrients, while supporting a diversity of biological life. The following provides a description of MBSS data as it is related to the entire state of Maryland.

Within Maryland, only 20% of all stream miles have good physical habitat quality, 52% are in poor condition, and as much as 27% of Maryland's stream miles are poorly protected from stormwater runoff with no vegetated buffers (Boward et al. 1999). Based on a combined fish and benthic macroinvertebrate Index of Biotic Integrity (F-IBI and B-IBI), approximately 12% of Maryland's stream miles were rated to be in good condition, 42% were rated fair, and 46% were rated poor (Boward et al. 1999). The F-IBI and B-IBI are used statewide and focus on the response of biological indicators (fish and benthic macroinvertebrates) to stressors such as pollutants and habitat condition (Roth et al. 1997).

Land use plays a key role in the overall biological integrity within watersheds. When upstream imperviousness exceeded only 2%, pollution-sensitive brook trout were never found. Based on a combined F-IBI and B-IBI, stream health is not rated as good when watershed impervious area is greater than 15%. Watershed imperviousness greater than 25% yields conditions that allow only pollutant tolerant species to survive. Approximately 57% of Maryland's streams have unnaturally elevated levels of nutrients, which are generally higher in watersheds containing more agricultural land use (Boward et al. 1999).

West Chesapeake Basin

The MBSS data were analyzed at the basin level. The Severn River watershed is contained within the West Chesapeake basin, which includes parts of Anne Arundel County. In general, water quality within the West Chesapeake basin is good and does not continually exceed the required State water quality criteria (MDNR 1998, cited in Ostrowski et al. 1999).

Approximately 33% of the stream miles had high levels of nitrate (>1 mg/l) and dissolved oxygen levels were above the minimum Maryland State standard (5 ppm) within 82% of the stream miles (Ostrowski et al. 1999).

Twenty percent of the stream banks were rated as badly eroded, and 20% of the stream miles had trash and human refuse present in abundant amounts. Stream miles were rated as well shaded within 82% of the basin (Ostrowski et al. 1999).

In 1997, species diversity within the basin was low, including an overall density of 3,158 fish per stream mile. Six species collected in 1997 are not indigenous to the Chesapeake Bay. The MDNR F-IBI rated approximately 50% of the streams as Good or Fair and the remaining streams were rated as Poor or Very Poor (Ostrowski et al. 1999).

The MDNR B-IBI rated approximately 95% of the stream miles as Poor or Very Poor in their ability to support diverse benthic macroinvertebrate populations. Pollution tolerant species comprised a large amount of the benthic macroinvertebrates collected in 1997 (Ostrowski et al. 1999).

Anne Arundel County

The MBSS data has also been analyzed within the boundaries of Anne Arundel County. During 1994 to 1997, MBSS sampled 85 sites within Anne Arundel County, and an additional 42 sites in the county were qualitatively sampled for fish (Millard et al. 2001). In general, the overall ecological health of the streams within Anne Arundel County was rated as Poor.

Throughout the county the average F-IBI score was rated as Poor, just below the Fair range. Fish species such as American eel, eastern mudminnow, and black nose dace, considered to be pollution tolerant, were regularly collected. While no federally listed species were encountered, the glassy darter, listed as endangered in Maryland, was collected, and the American brook lamprey, a species of special interest, was found at 4% of the sites (Millard et al. 2001).

The average B-IBI within the county was rated as Poor. Benthic macroinvertebrate collections yielded 172 genera, while a single site was host to 30% of the taxa collected, and may be considered rare within the state (Millard et al. 2001).

The highest rated streams in the county considering F-IBI and B-IBI scores are Lyon's Run and Deep Run. Low rated streams include an unnamed tributary to Muddy Creek, Flat Creek, Gumbottom Branch, and unnamed tributary to the Patuxent River, a section of the Little Patuxent River, Bacon Ridge Branch, and an unnamed tributary to Smith Creek (Millard et al. 2001).

Overall, physical habitat in Anne Arundel County was rated as Fair (Millard et al. 2001). Values for nitrate (NO_3) averaged 1.0 mg/L, and no streams were above the limits set forth by the United States Environmental Protection Agency (EPA) for drinking water of 10 mg/L (Millard et al. 2001).

Severn River Watershed

MBSS data was collected at 15 sites throughout the Severn River watershed during 1997. These sites include 11 along Severn Run, and one site along Mill Creek, Jabez Branch, an Unnamed Tributary to Deep Ditch, and Schultz Run (ST2 in this study). The average Physical Habitat Index (PHI) score of the sampled sites was within the fair range, scoring very close to the good range. The average F-IBI and B-IBI scores were rated as Poor. The average F-IBI score was near the Fair range, while the average B-IBI score was in the middle of the Poor range.

3.2 GIS Data

3.2.1 Land Use and Development

Land use in the watershed is diverse. Portions are highly developed, containing the City of Annapolis, shopping centers, subdivisions, and industrial parks. The free-flowing section of Severn Run, however, is a Natural Resource Area managed by MDNR. Many of the south shore watersheds remain forested.

The single most dominant land use is single family residential, at all densities, at 38%. Forest is next, at 32%. When the 6% of open space maintained in turf is added to the forested areas, there is an equal amount of residential and vegetated land use.

Fifteen percent of the watershed is taken up with commercial and industrial property and the City of Annapolis. It should be noted that much of the city is residential, at similar densities to the County portion of the watershed, so this number is somewhat high.

Without good land use coverage of Annapolis, the exact imperviousness of the watershed cannot be calculated. However, if it is assumed to be 50%, which would represent a mix of commercial and residential properties, the watershed would be 18% impervious overall. Setting the 2,980 acres of Annapolis at 0% or 100% gives a range for the watershed of 15% to 22% impervious.

Other than the watersheds which drain the City of Annapolis (College Creek, Weems Creek, Spa Creek, and Back Creek), the most densely developed tributaries are Woolchurch Cove (50% impervious), Picture Spring Branch (33%), Pointfield Branch (32%), Bear Branch (30%), and Carr Creek (28%). These subwatersheds drain some parts of Odenton, the commercial areas along I-97, and the Naval Surface Warfare Center.

3.2.2 Sewered / Unsewered Areas

Twenty-six percent of the watershed is currently served by sanitary sewer systems. An additional 21% is planned to receive sewer service at some time in the future. This leaves over half of the watershed remaining with on-site sewage systems. Most of these areas are on the south shore, which is currently undeveloped or zoned for low-density residential development.

3.3 Stream Assessment

3.3.1 Stream Type

There were a total of 152 miles of stream assessed during the stream walk portion of the Watershed Study. GIS coverages of the data collected were delivered with the Stream Assessment Tool component of the WMT. Figure 3.1 and Table 3.3 present the stream miles per type and the percent of stream miles per type for the entire Watershed. Figure 3.2 displays the percent of each stream type in each subwatershed. It should be noted that Figure 3.2 shows the percent within each subwatershed and not the total number of stream miles.

Perennial streams are most abundant with 89.37 miles making up 58.8% of the total for the entire Watershed. Ephemeral streams comprise 19.5% of the channels with the remaining types making up the final 21%.

Figure 3-1: Stream Miles per Type

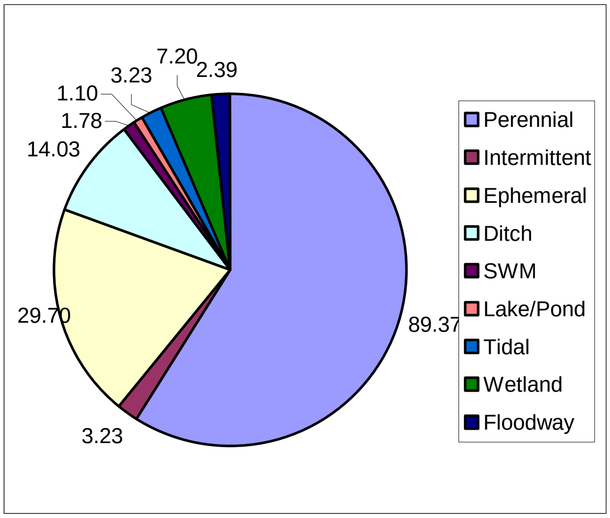


Table 3-3: Percent Stream Miles per Type

Type	Percent of Total
Perennial	58.8
Intermittent	2.1
Ephemeral	19.5
Ditch	9.2
SWM	1.2
Lake/Pond	0.7
Tidal	2.1
Wetland	4.7
Floodway	1.6

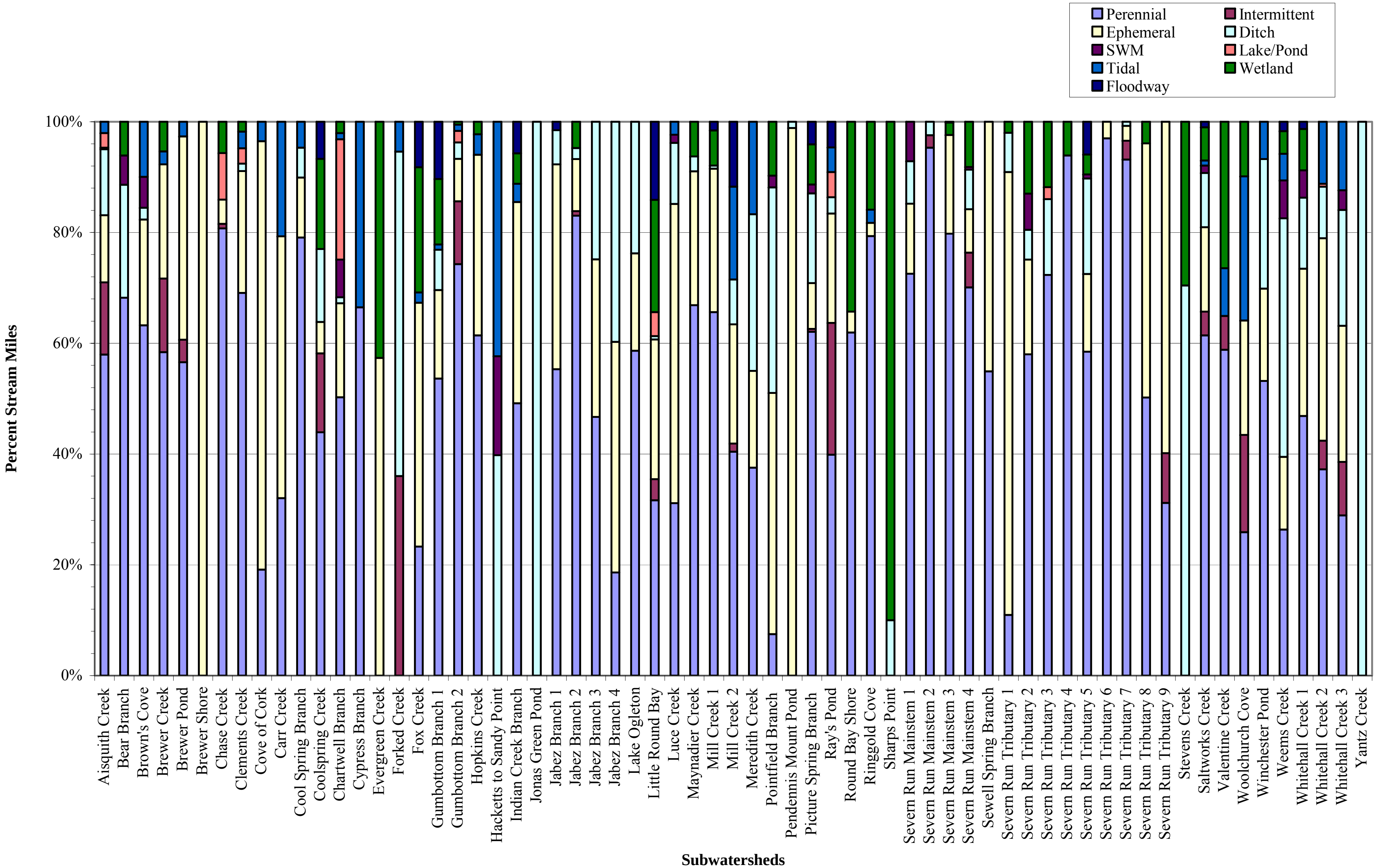


Figure 3-2: Stream Type Summary

3.3.2 Rosgen Classification

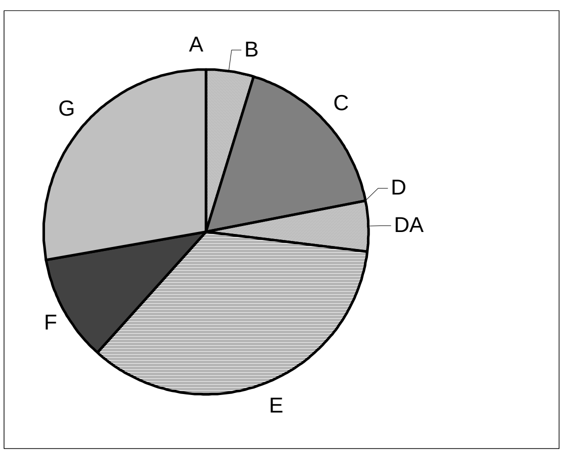
Stream classification systems provide a method for scientists and engineers to gain insight into how a stream system functions and how it might change over time. Streams are in constant adjustment with their watersheds, meandering, eroding, and filling with sediment as they seek a dynamically stable channel. The Rosgen classification system provides a well-established set of measurements to determine if a particular stream reach is stable or unstable, and to compare it with other streams in undisturbed watersheds to determine if its behavior is characteristic.

Section 3.4 describing the geomorphic assessment procedures provides more information on the details of the Rosgen classification system. A description of the fieldwork methodology is located in Appendix B.

For the Severn River watershed, Rosgen classification was conducted on 92.63 miles of 152 total miles of streams with 381 separate reaches and cross-sections conducted throughout the Watershed. Figure 3.3 presents the number of stream miles per Rosgen classification for the entire Watershed. Table 3.4 shows the miles and the percent of each classification as a percent of the Watershed total. Figure 3.4 displays the percent of each stream classification in each subwatershed. It should be noted that Figure 3.4 shows the percent within each subwatershed and not the total number of stream miles.

E type channels make up the majority of the stream miles throughout the Watershed, comprising 34.6% of the total. E channels are most prevalent in the downstream reaches of tributaries as they enter the floodplain of the subwatershed's main channel. G channels are also common and make up 27.9% of the total. Entrenched G type channels are typical of both mainstem channels and the upstream portions of tributaries as they flow out of steep, narrow headwater valleys with erodible materials. C type channels are most prevalent in the downstream mainstem reaches of Severn Run Mainstems 2 and throughout Severn Run Mainstem, 3 and 4.

Figure 3-3: Stream Miles per Rosgen Classification



Classification

Classification	Miles	Percent of Total
A	0.00	0.0
B	4.37	4.7
C	15.88	17.1
D	0.04	0.05
DA	4.68	5.1
E	32.09	34.6
F	9.76	10.5
G	25.81	27.9

Table 3-4: Stream Miles per Rosgen

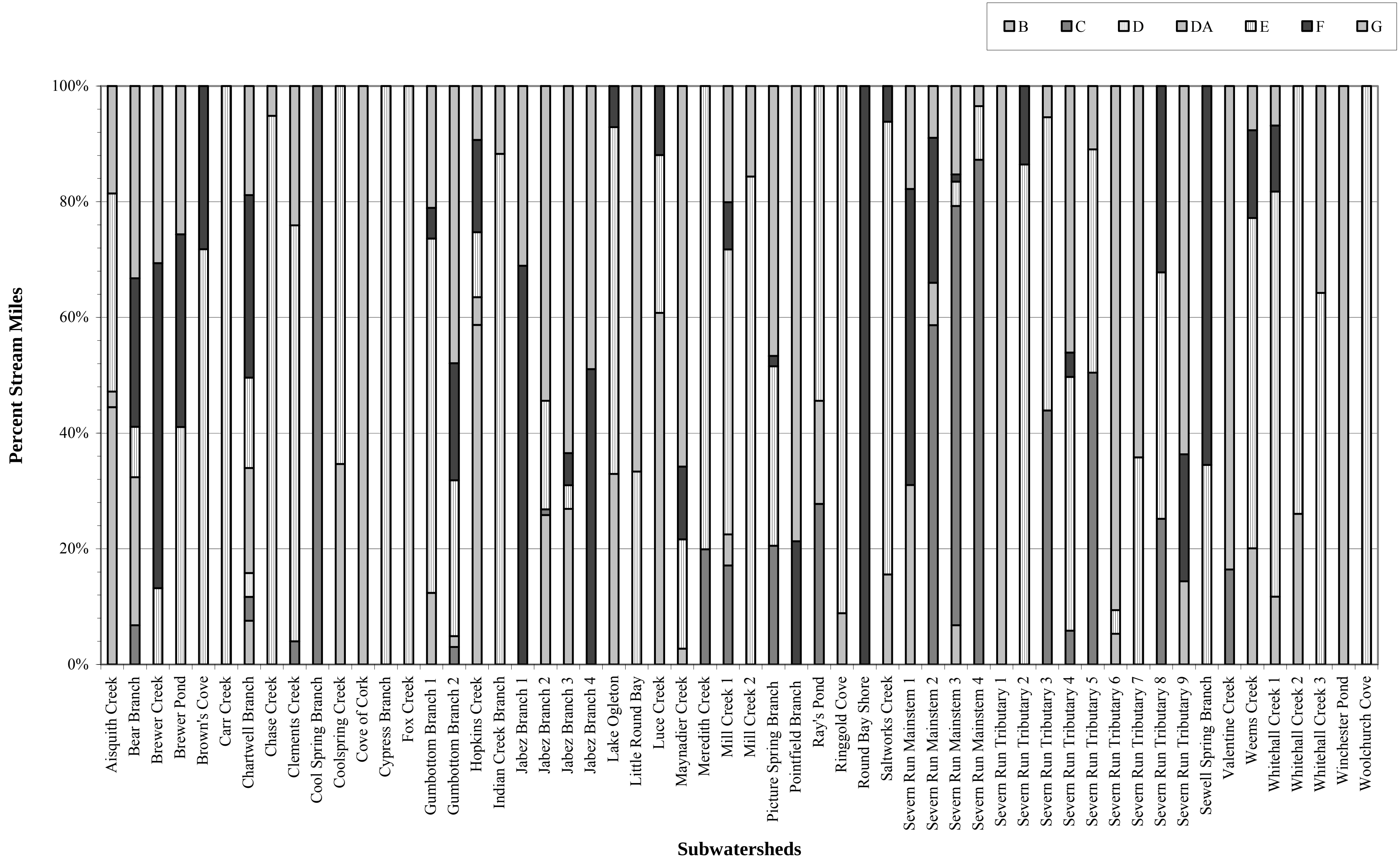


Figure 3-4: Rosgen Channel Classification Summary

3.3.3 MPHI and Final Habitat Scores

MPHI

Physical habitat is the living space for instream aquatic organisms, which is determined by the interaction of features of a stream channel and streamflow. Physical habitat is particularly critical for healthy fish communities. It is assessed with specific measurements of instream conditions, such as the diversity of pools, riffles, and runs, whether the substrate is fouled with silts and sands, bank stability, and other characteristics. Habitat scores give a summary of the overall ability of the stream reach to support aquatic life. Changes in physical habitat were used to determine breakpoints between the stream reaches and a habitat assessment was conducted for each reach. These habitat reaches are one of the major organizational units in the Stream Assessment Tool. Appendix B provides more detailed information on how the MPHI score was determined.

Habitat Assessments were conducted for a total of 89 miles of 152 total miles of perennial streams in the Watershed for 352 distinct reaches. The mean MPHI score for the entire Watershed is 44.05, Fair, while the median is 39.10, in the upper part of the Poor range. The stream length weighted MPHI score for the Watershed is in the Fair range with a score of 58.13.

Figure 3.5 presents the number of stream miles in each MPHI category. The higher quality streams are generally the longest reaches assessed and therefore tend to skew the results toward the Good range with 39.6% of the stream miles versus 39.1% in the Poor range. Figure 3.6 is also presented to show the number of reaches that were assessed with scores in each of the categories. Forty-five percent of the reaches are in the Poor range while 20.5% are in the Good range. The high number of small tributary channels assessed skews this distribution toward the Poor range.

Figure 3.9 shows the percentage of stream miles in each MPHI category for each subwatershed. It should be noted that Figure 3.9 shows the percent within each subwatershed and not the total number of stream miles.

Figure 3-5: Number of Stream Miles per MPHI Category

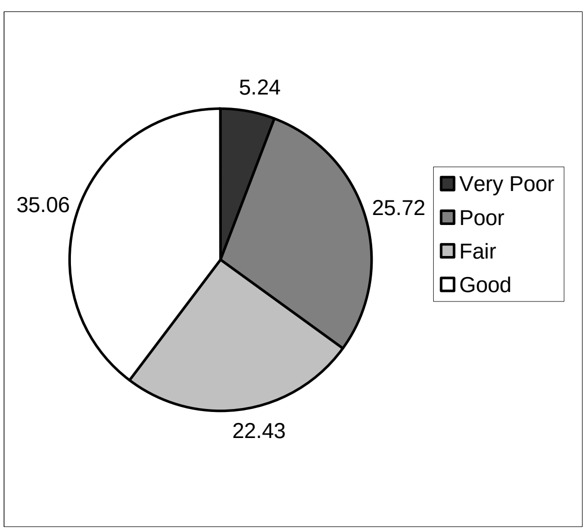
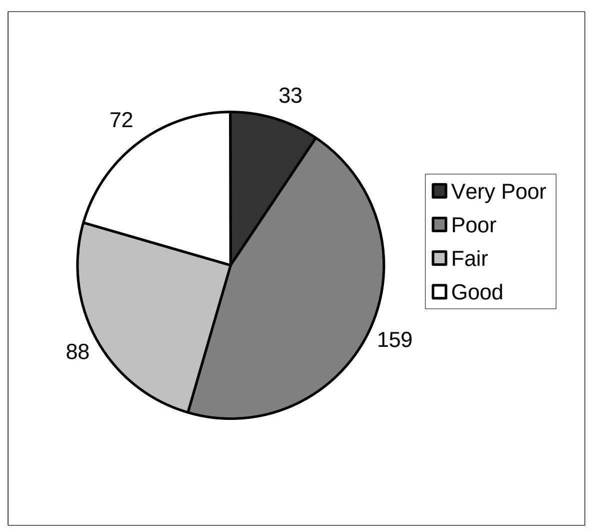


Figure 3-6: Number of Habitat Assessment Reaches per MPHI Category



Final Habitat Score

The mean FHS score for the entire Watershed was 40.1, Poor, while the median was 35.55, also in the Poor range. The stream length weighted FHS score for the Watershed was in the Fair range with a score of 53.98.

Table 3-5: MPHI and Final Habitat Summary

Category	Percent Stream Miles MPHI	Percent Reaches MPHI	Percent Stream Miles FHS	Percent Reaches FHS
Good	39.6	20.5	30.6	16.8
Fair	24.5	25.0	29.7	24.7
Poor	29.1	45.2	27.4	44.3
Very Poor	5.9	9.4	12.4	14.2

Figure 3.7 presents the number of stream miles in each FHS category. Like the MPHI results, the higher quality streams are generally the longest reaches and skew the results toward the Good range with 30.6% of the stream miles versus 27.4% in the Poor range. Figure 3.8 is shows the number of reaches that were assessed with scores in each of the categories. Forty-four percent of the reaches are in the Poor range while 16.8% are in the Good range. The high number of small tributary channels assessed skews this distribution toward the Poor range.

Figure 3.9 shows the percentage of stream miles in each MPHI category for each subwatershed. It should be noted that Figure 3.9 shows the percent within each subwatershed and not the total number of stream miles. Table 3.5 includes a summary of the MPHI and FHS percentages of each category.

Figure 3-7: Number of Stream Miles per FHS Category

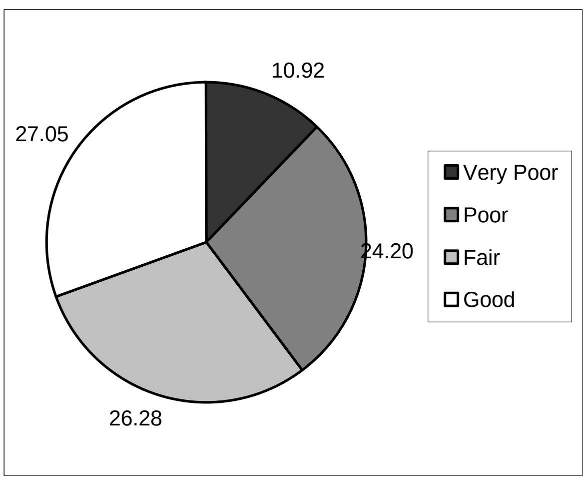
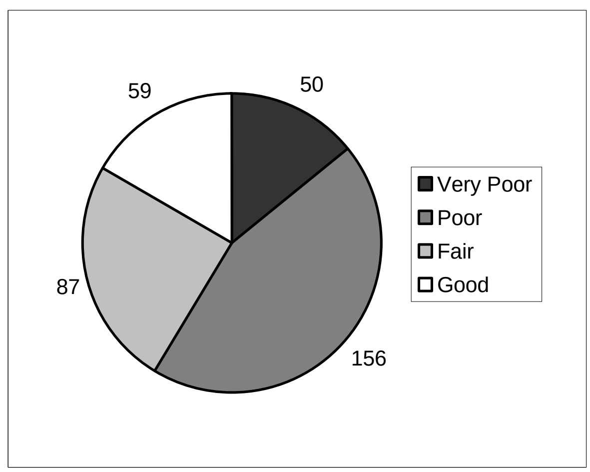


Figure 3-8: Number of Habitat Assessment Reaches per FHS Category



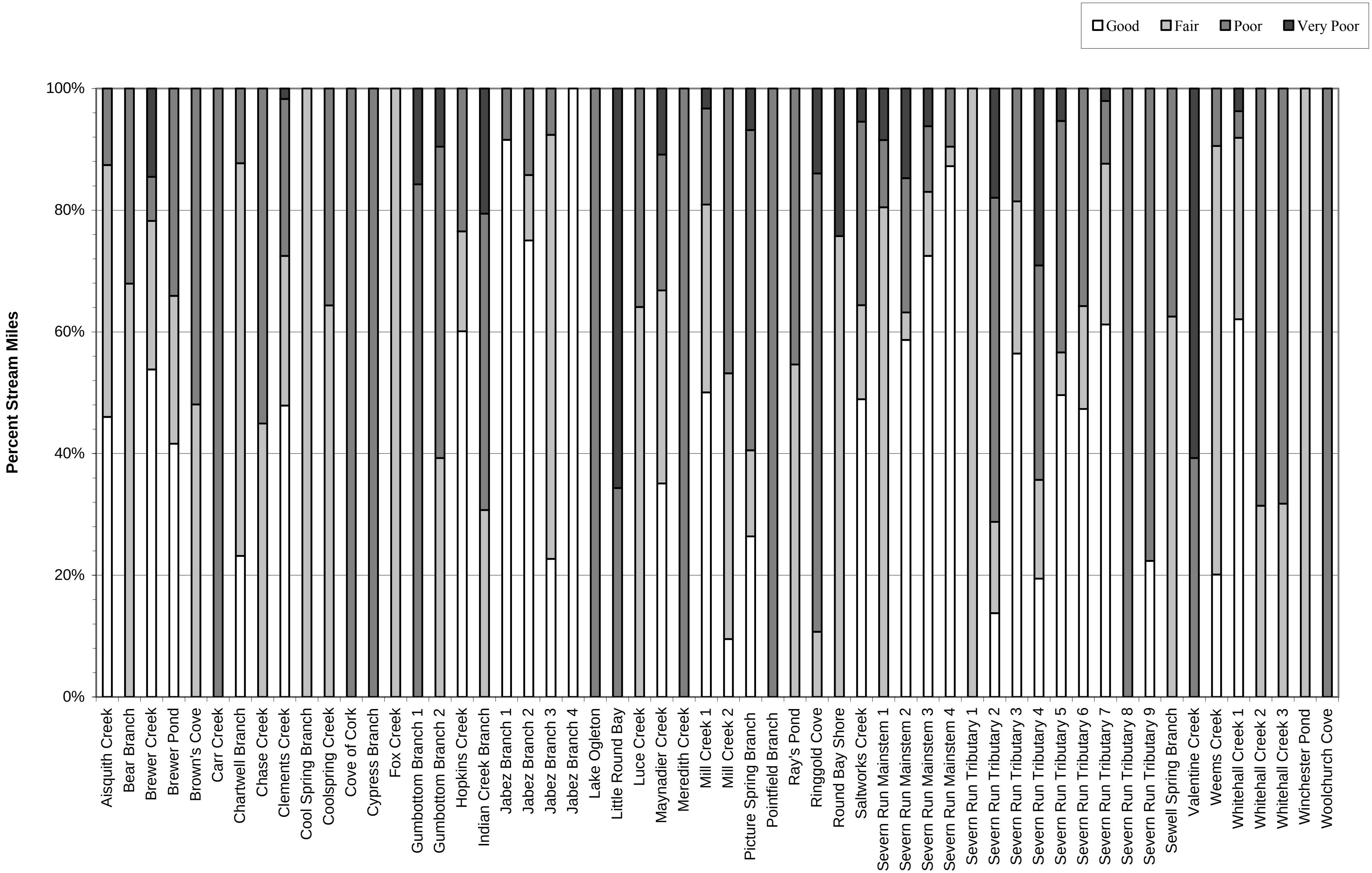


Figure 3.9 MPHI Summary

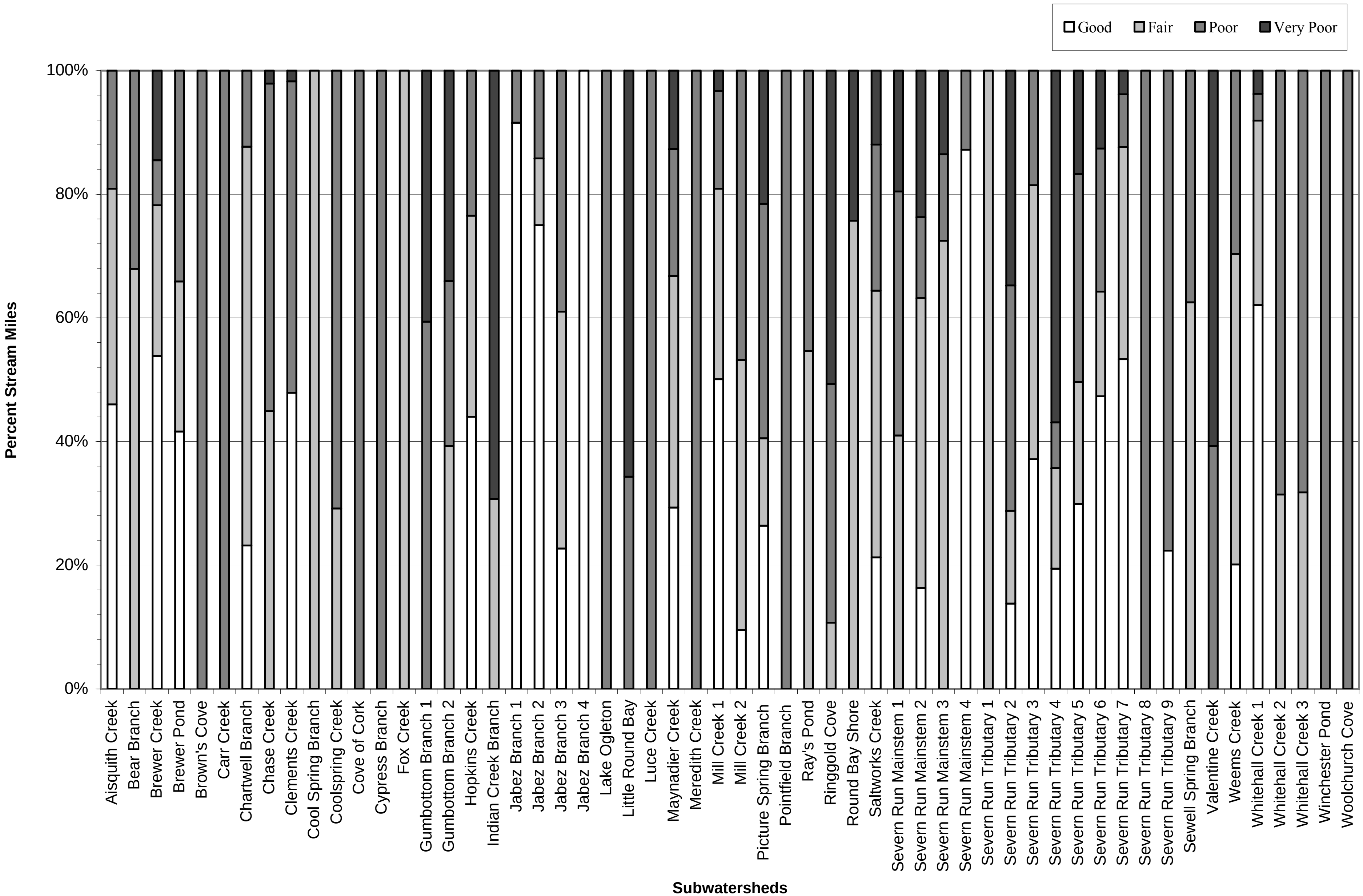


Figure 3.10 Final Habitat Summary

3.4 Geomorphic Assessment

3.4.1 Introduction

In Phases II and IV of the Severn River Watershed Study, geomorphic assessments were conducted at a total of 95 sites, providing Rosgen Level II classification for much of the watershed. The Level II stream classification is a useful tool for describing the current geometry of the Severn River tributaries and as a means of communication between scientists, engineers and planners. The empirical relationships developed between drainage area and channel geometry dimensions such as cross-sectional area, bankfull width and mean depth are useful in the identification of restoration sites and the development of stream restoration concept plans.

The classification system has limitations and the data should be used accordingly. The assessment provides a snapshot of the channel and was not repeated over time to develop trends or track changes in channel geometry. The assessment results should not be used for detailed design work. The relationships are dependent on several watershed factors including geology and land use. The results should only be applied to areas with similar hydrologic characteristics. The relationship between present land use within each drainage area and the channel dimensions was not conducted.

Under Phase II of the Severn River Watershed Study, a geomorphological characterization was performed during the winter and spring of 2002 to describe the stream types throughout the watershed. The Rosgen fluvial geomorphological assessment method was utilized. A Level I characterization was first conducted using available mapping. Mapping included orthophotography overlaid with 2-foot contours, County hydrography layer, soil type and delineated subwatershed boundaries. Valley type, sinuosity, planform and slope were all assessed and a Level I classification was assigned to each reach. During the stream walk fieldwork the Level I classification was field verified.

Verification was conducted by completing a modified Level II assessment. This assessment included a cross section, conducted at the bankfull level with depths recorded at equal intervals, and measurement of bankfull height, bankfull width, top of bank, wetted width and flood prone area. Bankfull height was based on field indicators. Slope and sinuosity were not assessed and dominant particle size was estimated. From the field measured values, mean depth, cross sectional area, width/depth ratios and entrenchment ratios were calculated and the Level II classification was given. The Level II classification was felt to be much more representative than the Level I, therefore the Level II results were used in all subsequent analyses.

Streams assessed were mainly comprised of perennial channels. Some ephemeral streams were characterized. These ephemeral streams were assessed because of their relatively large cross sectional area and signs that high storm flows were being conveyed. Teams characterized 380 individual reaches throughout the watershed.

To gather more watershed-wide information the Level II assessment was conducted in Phase II at 15 sites and in Phase IV at 72 sites that were assessed during the stream walk and eight new sites. The 95 total sites provided Level II classification for approximately one-fourth of the unique geomorphological stream reaches.

Data from previous tasks were used to select sites in three categories. Potential assessment sites were categorized based on the use of the data to be collected. Problem sites show evidence of degradation, where stream restoration could be effective. High Quality sites are in good condition and should represent stable geomorphology and habitat. Spatial sites are intended to provide more complete coverage at the watershed scale.

There are 52 Problem sites, 18 Spatial sites, and 10 High Quality sites throughout the Severn Watershed. Many of Severn's subwatersheds are small and do not have well formed stream systems, especially on the northern and southern shores. These small subwatersheds do not have Level II sites. Almost half (34) of the subwatersheds will not have further assessment. The majority of subwatersheds that were assessed have one or two sites. Only two subwatersheds, Severn River Mainstem 3 and Picture Spring Branch have 5 or more sites.

The sites were selected in an attempt to match the overall percentage of stream miles in each Rosgen stream type category throughout the Severn River Watershed while still addressing the problem areas. Table 3.6 shows the percent of stream length in each category and the percent of sites in each category. The percentage of F, B and C channel types closely match the percentages of stream length found in the watershed. The site frequency is shifted to cover more G type channels as they are typically more unstable and will provide greater information for restoration potential. E type channels, though found in 35 percent of the watershed are far more stable, with good floodplain access and stable geometry and therefore only about 19 percent of the sites will be on E channels.

A full description of the site selection process, field methodology and calculations is located in Appendix B.

Table 3-6: Percent of stream miles and sites per classification

Classification	Number of sites	Percent of length	Percent of sites	Difference in percent
G	39	27.8	48.8	+ 20
F	8	10.5	10.0	-0.5
B	2	4.7	2.5	-2.2
E	15	34.6	18.8	-15.8
C	14	17.3	17.5	+0.2
unclassified	2	NA	2.5	NA

3.4.2 Results

Table 3.7 provides the summary channel dimension and particle size statistics for the geomorphic assessment sites.

Table 3-7: Summary Data

Site	Dr. Area (mi^2)	Cross-sectional Bankfull Area (ft^2)	Width at Bankfull (ft)	Mean Bankfull Depth (ft)	Bankfull Discharge (cfs)	Width of Flood prone Area (ft)	Median Particle D_{50} (mm)	D_{84} (mm)
BRB003R201	0.18	1.27	3.60	0.35	4.55	10	2	9.2
BRB006R201	0.15	5.38	5.20	1.03	94.13	8	0.31	0.43
BRB007R201	0.17	6.46	7.80	0.83	75.80	11	0.25	0.4
BWC001R201	0.46	5.71	8.00	0.71	15.75	33	0.094	0.6
CHC005R201	0.08	1.44	4.00	0.36	15.23	23	0.25	0.4
CLC003R201	0.21	5.36	5.20	1.03	35.03	45	0.062	0.83
CLC012R201	0.18	2.36	4.80	0.49	7.85	10	0.13	0.43
CSB002R201	0.23	3.00	6.50	0.46	25.83	11	0.35	0.64
CWB002R201	0.27	14.21	10.90	1.30	106.30	13	0.33	0.44
GB1009R201	0.1	4.74	4.50	1.05	53.19	6	0.062	0.062
GB2001R201	0.62	26.47	15.70	1.69	108.88	200	0.33	0.44
GB2001R202	0.62	25.03	15.70	1.59	219.56	23	0.23	0.45
GB2015R201	0.1	3.24	5.50	0.59	17.67	8	0.31	4
HOC003R201	0.26	8.68	9.90	0.88	51.08	13	0.38	11
HOC006R201	0.07	5.90	7.00	0.84	116.26	9	0.062	0.062

Site	Dr. Area (mi^2)	Cross-sectional Bankfull Area (ft^2)	Width at Bankfull (ft)	Mean Bankfull Depth (ft)	Bankfull Discharge (cfs)	Width of Flood prone Area (ft)	Median Particle D_{50} (mm)	D_{84} (mm)
ICB002R201	1.56	2.21	2.90	0.76	5.68	100	1	1.6
ICB005R201	0.03	3.05	5.90	0.52	15.71	10	0.38	10
JZ1001R201	0.87	2.30	3.60	0.64	7.74	8	8.6	18
JZ1001R202	1.31	7.23	8.22	0.88	36.98	42	4.7	11
JZ1001R203	0.87	5.21	5.80	0.90	28.68	17	0.43	8.5
JZ1002R201	0.39	4.47	6.30	0.71	20.51	9	3.2	24
JZ2001R201	5.31	12.55	13.89	0.90	51.24	16	2.8	7.4
JZ2001R202	2.96	11.70	9.50	1.23	60.19	16	1.3	14
JZ2004R201	0.08	1.73	5.05	0.34	14.20	7	0.35	0.57
JZ2009R201	0.71	5.43	5.50	0.99	25.75	8	5.4	12
JZ2009R202	0.71	8.03	6.70	1.20	49.75	10	6.1	15
JZ3001R201	1.08	15.80	11.00	1.44	95.30	15	1.7	29
JZ3001R202	1.22	10.54	9.50	1.11	58.40	10	0.61	9.2
JZ3003R201	1.08	9.44	14.80	0.64	46.96	90	0.15	0.33
JZ3004R201	0.93	7.36	7.30	1.01	76.18	40	0.37	0.66
JZ3006R201	0.66	11.18	10.50	1.07	122.11	12	0.062	0.062
JZ4007R201	0.93	5.00	5.21	0.96	17.74	14	9	15
JZ4007R202	0.93	9.14	8.10	1.13	44.03	11	2.1	15
JZ4008R201	0.77	5.72	8.00	0.71	26.20	14	0.062	8.7
MAC005R201	0.42	7.93	8.50	0.93	54.52	12	0.1	0.25
MAC011R201	0.03	7.82	9.80	0.80	52.07	12	0.4	1.5
MAC017R201	0.04	2.86	3.70	0.77	16.80	10	0.41	4.2
MAC018R201	0.11	9.15	5.00	1.83	99.75	11	0.35	4.2
MC1009R201	0.47	15.69	28.06	0.56	111.85	100	0.29	0.46
MC1014R201	0.2	2.50	4.50	0.56	8.54	7	0.25	0.4
MC1019R201	0.41	8.31	6.40	1.30	65.14	50	0.29	0.46
MC1024R201	0.16	3.68	5.30	0.69	16.42	16	0.29	0.46
MC1026R201	0.17	2.84	3.20	0.89	15.65	8	0.29	0.46
MC2005R201	0.56	3.67	4.80	0.76	21.52	150	0.062	0.062
PFB002R201	0.11	4.63	6.40	0.72	29.92	8	2	17
PSB001R201	2.6	13.16	12.40	1.06	57.77	13	0.81	25
PSB007R201	1.17	7.96	7.90	1.01	60.57	10	0.39	0.97
PSB010R201	0.46	4.86	5.90	0.82	27.37	6	0.35	2
PSB015R201	0.53	9.13	8.50	1.07	33.10	11	0.25	5.4
PSB016R201	0.03	13.17	12.30	1.07	126.05	14	4	26
PSB018R201	0.1	1.85	3.80	0.49	11.16	5	0.062	4.5
PSB025R201	0.14	11.16	7.70	1.45	85.01	9	6	42
RAP002R201	0.01	3.76	4.90	0.77	51.56	6	0.11	0.3
RGC004R201	0.01	1.29	4.60	0.28	12.05	5	0.21	12
SM1002R201	1.55	15.68	11.50	1.36	74.21	110	0.47	14
SM1003R201	1.42	13.82	7.30	1.89	82.87	100	0.67	10

Site	Dr. Area (mi^2)	Cross-sectional Bankfull Area (ft^2)	Width at Bankfull (ft)	Mean Bankfull Depth (ft)	Bankfull Discharge (cfs)	Width of Flood prone Area (ft)	Median Particle D_{50} (mm)	D_{84} (mm)
SM1004R201	0.94	17.92	13.40	1.34	29.24	90	2.4	20
SM1005R201	0.64	6.13	8.00	0.77	14.09	12	2.9	19
SM2001R201	4.33	24.94	13.90	1.79	98.76	200	3.3	13
SM2004R201	0.02	6.48	7.00	0.93	39.06	12	0.35	8.8
SM2006R201	4.08	23.84	12.70	1.88	219.50	21	0.062	0.062
SM2007R201	3.93	23.88	14.95	1.60	105.91	30	0.49	25
SM3001R201	11.94	24.60	12.80	1.92	106.86	100	0.62	0.99
SM3002R201	0.21	1.77	4.00	0.44	5.28	6	0.24	14
SM3006R201	0.15	1.93	4.50	0.43	12.79	7	0.72	0.92
SM3007R201	6.89	31.21	17.91	1.74	251.16	60	0.41	0.95
SM3007R202	7.45	25.35	16.18	1.57	134.82	100	0.5	0.98
SM4001R201	24.14	42.96	19.00	2.26	154.91	350	1.1	29
SM4001R202	15.35	30.53	15.80	1.93	176.14	100	0.35	0.57
SM4008R201	0.1	3.10	6.10	0.51	11.47	6	0.5	41
ST2001R201	1.1	10.54	7.00	1.51	85.69	160	0.33	0.66
ST2006R201	0.21	6.88	6.30	1.09	36.78	18	0.29	0.46
ST2008R201	0.18	3.62	4.63	0.78	17.83	10	0.29	0.46
ST2010R201	0.2	3.39	6.00	0.56	14.62	300	0.31	0.47
ST3001R201	2.44	6.08	6.10	1.00	21.82	9	0.76	18
ST3001R202	2.22	7.06	6.30	1.12	23.38	100	0.54	12
ST4001R201	1.02	7.05	4.70	1.50	63.12	7	0.46	0.83
ST4003R201	0.74	7.66	7.30	1.05	54.94	10	0.26	0.47
ST4006R201	0.41	3.61	4.40	0.82	10.85	120	0.42	0.76
ST5004R201	0.26	4.14	5.50	0.75	28.90	8	0.32	0.44
ST5005R201	0.23	6.82	10.30	0.66	28.89	13	0.45	24
ST5007R201	1.62	8.37	9.40	0.89	45.08	12	0.062	0.43
ST5007R202	1.61	5.60	10.00	0.56	19.09	10	4.3	8.8
ST6002R201	0.23	1.03	2.00	0.51	24.67	4	0.062	0.062
ST7004R201	1.12	5.85	8.00	0.73	21.24	11	0.59	14
ST7012R201	0.76	5.16	6.50	0.79	30.69	45	0.44	0.8
ST8001R201	0.58	6.24	6.90	0.90	23.45	9	0.062	14
ST9003R201	0.54	10.96	8.30	1.32	123.91	13	0.36	0.45
SWC005R201	0.24	6.76	6.00	1.13	59.67	40	0.062	1.6
SWC012R201	0.06	4.91	5.90	0.83	41.57	7	0.38	12
SWC014R201	0.1	5.55	5.20	1.07	30.12	50	0.062	1.2
VTC004R201	0.05	1.76	2.90	0.61	15.18	13	0.21	0.6
WEC001R201	0.17	3.50	4.90	0.71	21.48	80	1.3	5.9
WEC009R201	0.09	4.85	5.50	0.88	24.42	7	0.17	0.34
WH1006R201	0.18	0.97	3.30	0.30	6.15	4	0.062	0.062

Table 3.8 displays the parameters used to determine the Level II type.

Table 3-8: Level II Parameters and Classification

Site	Entrenchment Ratio	Width Depth Ratio	Sinuosity	Channel Slope (%)	Channel Material	Valley Type	Type
BRB003R201	2.81	10.2	1.24	1.50	gravel	X	C4
BRB006R201	1.52	5.0	1.27	3.30	sand	II/VII	G5
BRB007R201	1.37	9.4	1.08	1.70	sand	II/VII	G5c
BWC001R201	4.08	11.2	1.44	0.11	sand	X	E5
CHC005R201	5.68	11.1	1.08	3.50	sand	X	E5b
CLC003R201	8.65	5.0	1.08	0.60	sand	II/VII	E5
CLC012R201	2.04	9.8	1.20	0.20	sand	II/VII	B5c
CSB002R201	1.66	14.1	1.07	1.90	sand	II/VII	B5c
CWB002R201	1.22	8.4	1.05	0.40	sand	II/VII	G5c
GB1009R201	1.24	4.3	1.03	0.85	sand	II/VII	E5
GB2001R201	12.74	9.3	1.03	0.09	sand	X	C5c-
GB2001R202	1.43	9.8	1.15	0.42	sand	X	G5c
GB2015R201	1.42	9.3	1.17	1.20	sand	II/VII	G5c
HOC003R201	1.29	11.3	1.03	1.10	sand	X	F5
HOC006R201	1.27	8.3	1.04	3.00	sand	II/VII	G5
ICB002R201	34.48	3.8	1.09	0.17	sand	X	E5
ICB005R201	1.75	11.4	1.21	1.70	sand	II/VII	G5
JZ1001R201	2.28	5.6	1.51	0.96	gravel	X	E4
JZ1001R202	5.11	9.4	1.14	0.85	gravel	X	E4
JZ1001R203	3.00	6.5	1.42	0.97	sand	X	E5
JZ1002R201	1.41	8.9	1.21	1.40	gravel	II/VII	G4c
JZ2001R201	1.16	15.4	1.25	0.42	gravel	X	F4
JZ2001R202	1.63	7.7	1.14	0.63	sand	X	B5c
JZ2004R201	1.47	14.7	1.22	2.40	sand	II/VII	G5
JZ2009R201	1.45	5.6	1.21	0.85	gravel	X	G4c
JZ2009R202	1.42	5.6	1.23	1.10	gravel	X	G4c
JZ3001R201	1.33	7.7	1.16	1.00	sand	X	G5c
JZ3001R202	1.03	8.6	1.09	0.68	sand	X	G5c
JZ3003R201	6.08	23.2	1.41	0.39	sand	X	DA5
JZ3004R201	5.48	7.3	1.10	1.20	sand	E	E5
JZ3006R201	1.10	9.9	1.16	0.58	sand	II/VII	G5c
JZ4007R201	2.64	5.4	1.12	0.51	gravel	X	E4
JZ4007R202	1.33	7.2	1.34	0.70	gravel	II/VII	G4c
JZ4008R201	1.76	11.2	1.08	0.80	sand	II/VII	B5c
MAC005R201	1.35	9.1	1.20	0.41	sand	X	G5c
MAC011R201	1.17	12.3	1.14	0.73	sand	II/VII	F5
MAC017R201	2.70	4.8	1.06	1.20	sand	II/VII	E5
MAC018R201	2.10	2.7	1.09	2.00	sand	II/VII	B5
MC1009R201	3.56	50.2	1.09	0.90	sand	X	DA5
MC1014R201	1.56	8.1	1.50	0.21	sand	II/VII	G5c
MC1019R201	7.81	4.9	1.27	0.51	sand	X	E5

Site	Entrenchment Ratio	Width Depth Ratio	Sinuosity	Channel Slope (%)	Channel Material	Valley Type	Type
MC1024R201	2.96	7.6	1.09	0.28	sand	X	E5
MC1026R201	2.40	3.6	1.23	0.45	sand	X	E5
MC2005R201	31.25	6.3	1.05	0.30	sand	X	E5
PFB002R201	1.25	8.8	1.06	2.20	gravel	II/VII	G4
PSB001R201	1.07	11.7	1.05	0.69	sand	II/VII	F5
PSB007R201	1.20	7.8	1.31	0.72	sand	II/VII	G5c
PSB010R201	1.03	7.2	1.09	0.63	sand	II/VII	G5c
PSB015R201	1.32	7.9	1.16	0.25	sand	II/VII	G5c
PSB016R201	1.13	11.5	1.17	3.40	gravel	II/VII	G4
PSB018R201	1.24	7.8	1.15	1.60	sand	II/VII	G5c
PSB025R201	1.16	5.3	1.12	2.10	gravel	II/VII	G4
RAP002R201	1.31	6.4	1.17	2.40	sand	X	G5
RGC004R201	1.09	16.4	1.16	13.00	silt/clay	I	A6
SM1002R201	9.57	8.4	1.16	0.43	sand	II/VII	C5
SM1003R201	13.70	3.9	1.28	0.54	sand	II/VII	C5
SM1004R201	6.72	10.0	1.15	0.07	gravel	X	C4c-
SM1005R201	1.50	10.4	1.14	0.27	gravel	II/VII	G4c
SM2001R201	14.39	7.7	1.06	0.21	gravel	X	C4
SM2004R201	1.66	7.6	1.15	1.10	sand	II/VII	G5c
SM2006R201	1.61	6.8	1.44	0.26	sand	X	B5c
SM2007R201	2.01	9.4	1.12	0.40	sand	X	C5
SM3001R201	7.81	6.7	1.41	0.11	sand	X	C5
SM3002R201	1.38	9.0	1.14	0.96	sand	II/VII	G5c
SM3006R201	1.53	10.5	1.11	1.50	sand	II/VII	G5c
SM3007R201	3.35	10.3	1.22	0.36	sand	X	C5
SM3007R202	6.18	10.3	1.27	0.18	sand	X	C5
SM4001R201	18.42	8.4	2.82	0.18	sand	X	C5
SM4001R202	6.33	8.2	1.48	0.15	sand	X	C5
SM4008R201	1.05	12.0	1.18	1.60	sand	II/VII	G5c
ST2001R201	22.86	4.6	1.14	0.50	sand	X	E5
ST2006R201	2.93	5.8	1.05	0.28	sand	X	E5
ST2008R201	2.12	5.9	1.07	0.36	sand	X	E5
ST2010R201	50.00	10.6	1.17	0.62	sand	X	E5
ST3001R201	1.44	6.1	1.08	0.57	sand	X	G5c
ST3001R202	15.87	5.6	1.33	0.35	sand	X	E5
ST4001R201	1.57	3.1	1.20	0.79	sand	II/VII	G5c
ST4003R201	1.30	7.0	1.17	0.50	sand	II/VII	G5c
ST4006R201	27.27	5.4	1.13	0.17	sand	X	E5
ST5004R201	1.42	7.3	1.03	0.70	sand	II/VII	G5c
ST5005R201	1.24	15.6	1.14	1.30	sand	II/VII	G5c
ST5007R201	1.26	10.6	1.41	0.31	sand	X	C5
ST5007R202	1.04	17.9	1.52	0.59	gravel	II/VII	F4

Site	Entrenchment Ratio	Width Depth Ratio	Sinuosity	Channel Slope (%)	Channel Material	Valley Type	Type
ST6002R201	1.85	3.9	1.08	9.80*	silt/clay	II/VII	E6b
ST7004R201	1.35	10.9	1.49	0.67	sand	II/VII	G5c
ST7012R201	6.92	8.2	1.28	0.52	sand	II/VII	E5
ST8001R201	1.29	7.6	1.14	0.54	sand	II/VII	G5c
ST9003R201	1.51	6.3	1.01	0.95	sand	II/VII	G5c
SWC005R201	6.67	5.3	1.40	1.10	sand	X	E5
SWC012R201	1.10	7.1	1.16	2.80	sand	II/VII	G5
SWC014R201	9.62	4.9	1.16	0.45	sand	II/VII	E5
VTC004R201	4.34	4.8	1.19	1.80	sand	X	E5
WEC001R201	16.33	6.9	1.23	1.40	sand	X	E5
WEC009R201	1.25	6.2	1.34	0.29	sand	II/VII	G5c
WH1006R201	1.24	11.2	1.01	1.00	sand	II/VII	G5c

*slope for ST6002R201 is artificially high due to headcut

Topography in the Severn River Watershed ranges from nearly level along the open floodplains to very steep slopes and stream valleys in the dissected headwaters. Deep V-shaped valleys have been formed where small streams have cut through the soft unconsolidated material of the Coastal Plain, and broad alluvial floodplains are located adjacent to both large and small streams (USDA-SCS 1973). These conditions contribute to place the Severn River stream valleys generally into two Valley Type (Rosgen, 1996) categories.

The headwater tributaries are similar to the Type II and Type VII and have been listed with both types as they have characteristics of both. Type II have moderate relief, are relatively stable and have soils developed from alluvial parent material. Type VII also have moderate steep landforms and highly dissected slopes. Streams in these valleys are deeply incised in the alluvium and the channels have moderate to steep gradients, are confined and may be entrenched. A majority of these valleys have streams classified as Type G, which is true of the Severn.

The downstream reaches are in broader Type X valleys. These valleys are characteristic of the coastal plain, have gentle relief, and are developed in alluvial material. The low relief provides area for wetlands and the C, E and DA channels are commonly found. The E channel is most widely distributed in the Severn in the Type X valley and most of the mainstem Type C channels are in Type X valleys.

Figure 3.11 below displays the bankfull discharge in cubic feet per second (cfs) plotted against the drainage area to each of the sites. Each channel type is displayed separately with the power function trend line.

Table 3-9 provides the sample size N for each of the channel types with the power function equations and the R^2 value. The R^2 Squared value is the square of the r value which represents the goodness-of-fit of a linear model (the regression equation). It is the proportion of variation in the dependent variable explained by the regression. It ranges in value from 0 to 1. Small values indicate that the model does not fit the data well. The C channel type tended to have the strongest relationship with drainage area when looking at the individual channel types. The entire data set has a moderate goodness of fit. The G channels and E channels appear to have low goodness of fit. G type channels are typically found in areas of the watershed with high impervious levels and intense land use, in which the drainage area itself may be less important than the land cover. This may explain some of the variability in the G type distribution.

Figure 3-11: Bankfull discharge and drainage area for each channel type

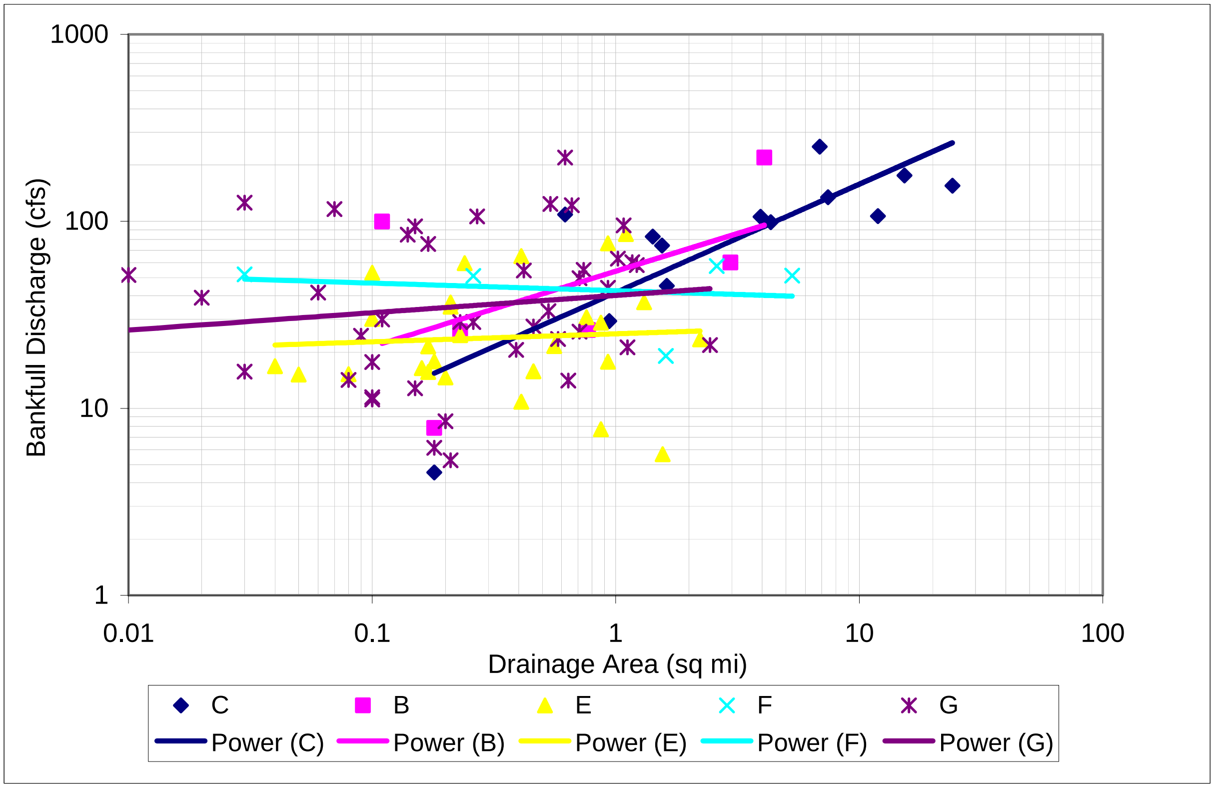


Table 3-9: Bankfull Discharge and Drainage Area

Type	N	Power equation*	R^2
A	1	na	na
B	6	$y=54.093x^{0.4032}$	0.27
C	13	$y=41.611x^{0.5792}$	0.64
DA	2	na	na
E	27	$y=25.035x^{0.0428}$	0.0048
F	5	$y=42.581x^{0.0406}$	0.034
G	41	$y=40.164x^{0.0926}$	0.0168
All sites	95	$y=41.611x^{0.5792}$	0.6377

*In the power equations above, y represents Bankfull Discharge in cfs and x represents Drainage Area in square miles.

Table 3-10: Cross-section Dimension and Drainage Area

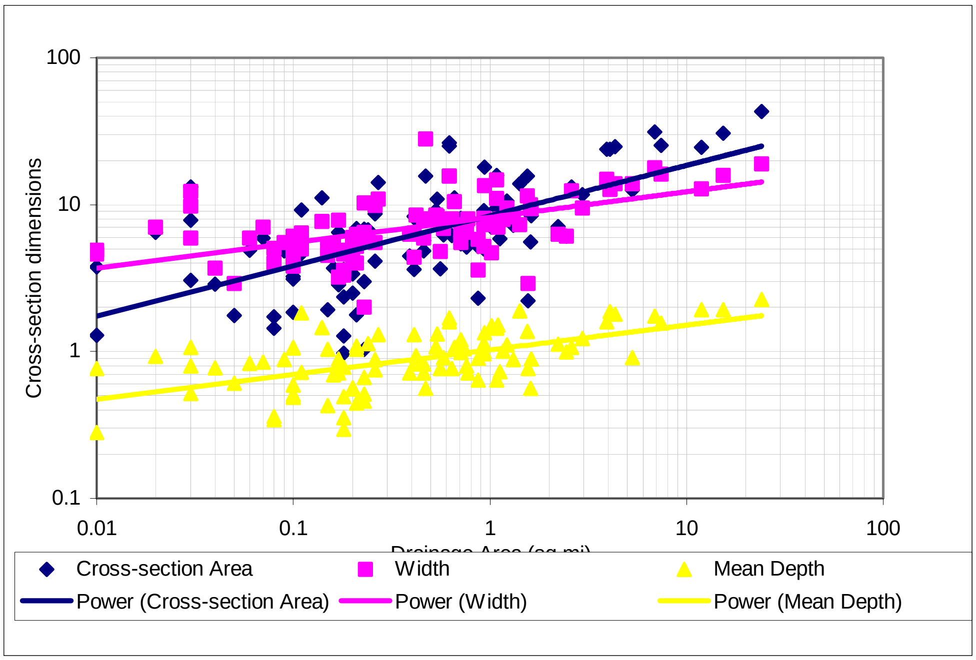
	Type	N	Power equation*	R^2	r**
All sites	Bankfull Cross-sectional Area (ft^2)	95	$y=8.4264x^{0.3418}$	0.4143	0.76
	Bankfull Width (ft)	95	$y=8.2041x^{0.1737}$	0.3125	0.53
	Mean Depth (ft)	95	$y=1.0271x^{0.168}$	0.337	0.596
Sites over 1.5 square miles	Bankfull Cross-sectional Area (ft^2)	17	$y=5.132x^{0.7362}$	0.625	0.82
	Bankfull Width (ft)	17	$y=6.527x^{0.3783}$	0.453	0.66
	Mean Depth (ft)	17	$y=0.7862x^{0.3579}$	0.5968	0.75

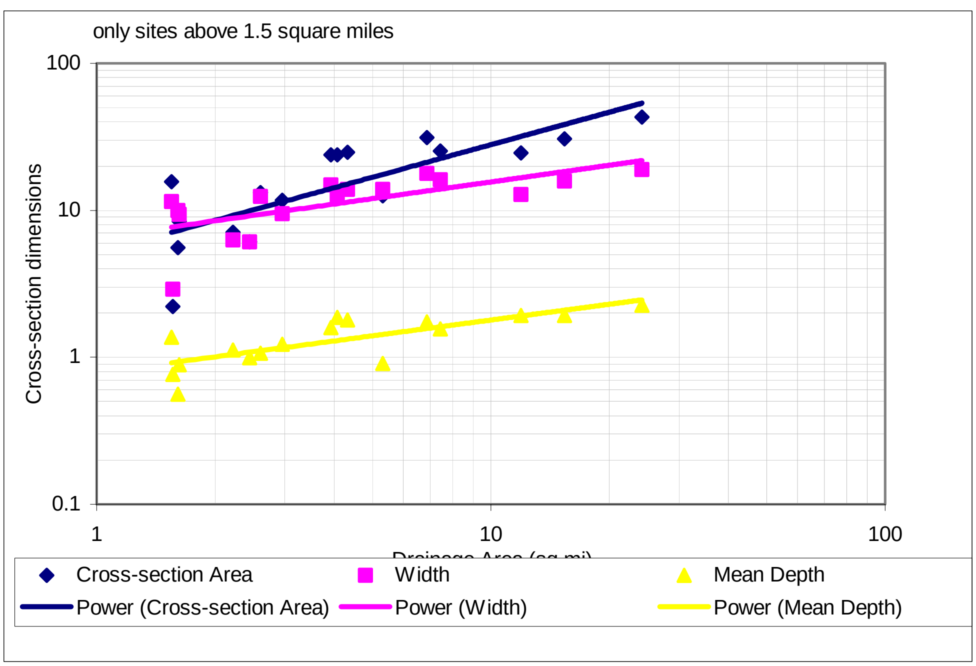
*In the power equations above, y represents the parameter in the Type column in the corresponding row and x indicates the drainage area in square miles.

**The r value is the Pearson correlation coefficient. Ranges from –1 to +1, which represent strong negative and positive correlation

The various channel dimensions are plotted below in Figure 3.12 and the equation data is presented in Table 3.10. In all of the relationships, the goodness of fit of the data appears to go up as the drainage area increases. The scatter of the plots decreases past one square mile. Most of the sites in the Severn were on smaller channels less than one square mile. The mean area is 1.4 square miles and the median is 0.46 square miles. Figure 3.12 and Table 3.10 show the relationship between the bankfull channel dimensions an drainage are for site with drainage areas over 1.5 square miles. The R^2 values and correlation coefficients both increase as the overall sample's drainage area increases. Smaller catchments are likely more flashy and have less consistent flow regimes and channel dimensions.

Figure 3-12: Cross-section Dimension and Drainage Area





3.5 Bioassessment

3.5.1 Introduction

In Phase IV of the Severn River Watershed Study, a comprehensive bioassessment was conducted, providing biological assessment for much of the watershed and supporting WISE model development. Fifteen sites were sampled in 2002 and 48 sites were sampled in 2004. Each site was assessed for water quality, benthic macroinvertebrates and physical habitat assessment.

Under Phase II of the Severn River Watershed Study, bioassessments were conducted at 15 stations in 6 subwatersheds in 2002. Those subwatersheds included Severn Run Tributary 2 (4 sites), Mill Creek 1 (4 sites), Jabez Branch 1 (2 sites), Jabez Branch 2 (2 sites), Jabez Branch 3 (2 sites), and Jabez Branch 4 (1 site). The purpose of the assessment was to support the WISE model data requirements and to begin characterizing the Severn's tributaries. The watersheds were selected based on their overall condition, imperviousness, land use and their predicted ability to support varying levels of aquatic biota. The intent was to select sites that would yield Index of Biotic Integrity (IBI) scores ranging from Very Poor and Poor classifications, to Fair and Good classifications. Results were skewed towards the lower end of the IBI range with 13 of the 15 sites scoring Poor and Very Poor and no sites in the Good range. Therefore, more and varied IBI data, specifically higher IBI scores were required to support a more robust regression for the WISE model.

In addition to the WISE model requirements, the Anne Arundel County Office of Environmental and Cultural Resources designed a comprehensive biological assessment program for all of the County's watersheds, divided into 24 primary sampling units. The goals were to characterize the current status and trends in the health of the County's watersheds, identify possible stressors, and provide support to the County's resource management decisions. The sampling units and goals are described in the *Design of the Biological Monitoring and Assessment Program for Anne Arundel County, Maryland* (Hill and Stribling, 2004).

A total of 63 sites were assessed for water quality, macroinvertebrates and physical habitat in 30 of the Severn's subwatersheds. Twenty-four of the 63 sites were in subwatersheds that drain directly to the Severn River while 39 of the sites were in the Severn Run drainage area. The random site selection identified 85 percent of the sites on 1st order streams, 10 percent on 2nd order, and 5 percent on 3rd order. With all of the sites complete, the sites sampled were on 84 percent 1st order, 11 percent on 2nd order and 5 percent on 3rd order. Four duplicate samples were collected in the Severn River Watershed.

Table 3.11 below shows the breakdown of sites. Within the Random sites, four alternate sites were sampled, two in the Severn River PSU and two in the Severn Run PSU.

Table 3-11: Site Summary

Type	Sites	Duplicates	Total
Random (Severn Run) 2004	10	1	11
Random (Severn River) 2004	10	1	11
Targeted 2004 Sites	28	2	30
Targeted 2002 Sites	15	0	15
Total	63	4	67

Table 3.12 provides the entire list of sites. Also shown are the percent of impervious surface and percent of stream miles with forested buffer in the subwatershed that the site was sampled. The AA County Code can be used to cross-reference the site identification with the codes used in the Countywide Assessment Program.

Table 3-12: Site Information

Site	Type[1]	PSU	Stream Order	Drainage Area (acres)	Subwatershed Impervious Percent	Subwatershed Forested Stream Percent	AA Co Code	Date Sampled
BRB001G001	R	SRI	1	582	30.0	20.46	10-08	03/12/04
BWC001G001	T	SRI	1	439	6.8	48.14	na	05/06/04
BWP001G001	T	SRI	1	224	1.0	85.61	na	03/29/04
BWP001G201	T (D)	SRI	1	224	1.0	85.61	na	03/29/04
CLC001G001	T	SRI	1	535	6.0	54.85	na	03/29/04
CSB001G001	T	SRI	1	348	17.9	16.18	na	05/06/04
CWB004G001	R	SRI	1	589	12.8	7.73	10-10	03/12/04
GB2001G001	R	SRI	1	589	3.8	79.98	10-11A	03/23/04
GB2002G001	R	SRI	1	379	3.8	79.98	10-04	03/23/04
GB2010G001	R	SRI	1	127	3.8	79.98	10-06	03/12/04
HOC001G001	T	SRI	1	482	2.7	70.52	na	05/06/04
ICB001G001	T	SRI	1	1447	8.1	44.89	na	05/06/04
JZ1001G001	T	SRU	1	555	9.9	48.63	na	05/30/02
JZ1001G002	T	SRU	1	839	9.9	48.63	na	05/30/02
JZ1001G003	T	SRU	1	555	9.9	48.63	na	03/26/04
JZ1001G004	T	SRU	1	839	9.9	48.63	na	03/26/04
JZ2001G001	T	SRU	2	2399	9.9	57.90	na	05/31/02
JZ2001G002	T	SRU	2	2399	9.9	57.90	na	04/16/04
JZ2009G001	T	SRU	1	469	9.9	57.90	na	05/31/02
JZ2009G002	R	SRU	1	394	9.9	57.90	09-01	03/09/04
JZ2009G003	T	SRU	1	469	9.9	57.90	na	03/26/04
JZ2010G001	R	SRU	1	242	9.9	57.90	09-07	03/12/04
JZ3001G001	T	SRU	1	782	25.4	27.51	na	05/06/04
JZ3003G001	T	SRU	1	689	25.4	27.51	na	05/29/02
JZ3004G001	T	SRU	1	593	25.4	27.51	na	05/31/02
JZ4007G001	T	SRU	1	597	8.4	35.90	na	05/30/02
LUC001G001	R	SRI	1	98	12.9	55.32	10-20A	03/24/04
LUC001G002	T	SRI	1	227	12.9	55.32	na	03/29/04
MAC006G001	R	SRI	1	139	4.3	73.98	10-01	03/17/04
MAC006G002	R	SRI	1	230	4.3	73.98	10-03	03/23/04
MAC006G003	R	SRI	1	210	4.3	73.98	10-09	03/17/04
MAC006G203	R (D)	SRI	1	210	4.3	73.98	10-09dup	03/17/04
MAC015G001	R	SRI	1	225	4.3	73.98	10-02	03/17/04
MC1009G001	T	SRI	1	298	14.8	55.31	na	06/04/02
MC1019G001	T	SRI	1	183	14.8	55.31	na	06/04/02
MC1023G001	T	SRI	1	108	14.8	55.31	na	06/04/02
MC1024G001	T	SRI	1	104	14.8	55.31	na	06/04/02
PSB001G001	T	SRU	2	1567	32.8	25.07	na	04/06/04
PSB014G001	T	SRU	1	427	32.8	25.07	na	04/06/04
PSB023G001	R	SRU	1	293	32.8	25.07	09-11A	03/09/04
SM1001G001	T	SRU	1	601	22.6	15.96	na	04/06/04
SM1001G002	T	SRU	2	1190	22.6	15.96	na	05/06/04
SM1005G001	T	SRU	1	344	22.6	15.96	na	04/06/04
SM2001G001	R	SRU	2	2768	18.3	45.96	09-09	03/08/04
SM2005G001	R	SRU	2	2677	18.3	45.96	09-08	03/08/04
SM3006G001	T	SRU	1	119	7.4	59.94	na	04/16/04
SM3007G001	T	SRU	3	6597	7.4	59.94	na	04/20/04

Site	Type[1]	PSU	Stream Order	Drainage Area (acres)	Subwatershed Impervious Percent	Subwatershed Forested Stream Percent	AA Co Code	Date Sampled
SM4001G001	R	SRU	3	11994	10.2	80.68	na	04/16/04
SM4001G002	R	SRU	3	10408	10.2	80.68	09-10	03/24/04
SM4001G202	T (D)	SRU	3	10408	10.2	80.68	09-10dup	03/24/04
SSB001G001	T	SRI	1	476	2.8	65.10	na	04/07/04
ST2001G001	T	SRU	1	702	25.1	33.09	na	05/28/02
ST2001G002	R	SRU	1	698	25.1	33.09	09-02	03/08/04
ST2001G003	R	SRU	1	702	25.1	33.09	09-06	03/08/04
ST2006G001	T	SRU	1	131	25.1	33.09	na	05/29/02
ST2008G001	T	SRU	1	72	25.1	33.90	na	05/29/02
ST2010G001	T	SRU	1	126	25.1	33.09	na	05/28/02
ST3001G001	T	SRU	1	1562	17.0	33.96	na	05/06/04
ST4001G001	T	SRU	1	650	7.0	55.40	na	04/20/04
ST4001G201	T (D)	SRU	1	650	7.0	55.40	na	04/20/04
ST4003G001	R	SRU	1	360	7.0	55.40	09-12A	03/24/04
ST5005G001	T	SRU	1	130	14.3	31.00	na	04/20/04
ST5007G001	T	SRU	2	1527	14.3	31.00	na	04/07/04
ST7002G001	T	SRU	1	866	25.9	44.40	na	05/06/04
ST9003G001	R	SRU	1	280	15.8	61.90	09-05	03/09/04
SWC005G001	T	SRI	1	135	14.3	50.30	na	04/07/04
WEC009G001	T	SRI	1	148	27.0	6.34	na	04/20/04

[1] R - Random site, T – Targeted, D - Duplicate

3.5.2 Water Quality Sampling

Field water quality measurements were collected in-situ at upstream, midstream and downstream locations at all monitoring stations so that an average for the reach could be calculated. All in-situ parameters were measured with a HydroLab MiniSonde® probe and Surveyor® 4 data storage device. Field tested parameters included the pH, temperature, dissolved oxygen (DO), conductivity, total dissolved solids (TDS), and turbidity. Refer to Appendix B for the full description if water quality methods.

The Maryland Department of the Environment (MDE) has established acceptable standards for several of the above-described parameters for each designated Stream Use Designation. These standards are listed in the *Code of Maryland Regulations (COMAR) 26.08.02.01-.03 - Water Quality* (MDE 1994). The Severn River watershed, which is in the West Chesapeake Bay Area (Sub-Basin 02-13-10) includes four use designations (I, II, III and IV) however no waters are considered public water supply.

Table 3.13 shows the average value for each parameter for each of the sites along with the designated use for that stream segment. The cells **in bold** represent values that fall outside the COMAR limits, which are included in a table in Appendix B. Water quality sampling was not conducted at the duplicate sites.

Table 3-13: Water Quality Results

Site	Designated Use	pH	Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	Total Dissolved Solids (mg/L)	Turbidity (NTU)
BRB001G001	Use I	7.0	8.84	8.40	362.2	231.7	9.2
BWC001G001	Use I	7.1	19.97	5.75	169.4	108.4	11.3
BWP001G001	Use I	7.0	10.00	7.95	57.0	36.5	3.0
BWP001G201	Use I	na	na	na	na	na	na

Site	Designated Use	pH	Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	Total Dissolved Solids (mg/L)	Turbidity (NTU)
CLC001G001	Use I	6.9	10.19	8.38	242.8	155.4	6.1
CSB001G001	Use I	6.8	15.56	6.08	247.4	158.3	7.1
CWB004G001	Use I	6.8	9.53	9.26	256.7	164.2	3.3
GB2001G001	Use I	**6.1**	9.80	8.59	162.6	104.1	6.7
GB2002G001	Use I	**5.9**	7.36	9.26	169.9	108.0	6.0
GB2010G001	Use I	7.0	5.45	9.08	203.6	130.3	6.9
HOC001G001	Use I	**6.4**	15.66	7.06	199.8	127.9	11.6
ICB001G001	Use I	**6.0**	15.79	6.52	74.1	47.4	13.4
LUC001G002	Use I	6.9	9.96	8.00	164.2	105.0	2.8
LUC001G001	Use I	6.7	12.13	7.44	137.5	88.0	9.2
MAC006G001	Use I	6.7	6.78	8.87	279.6	179.5	4.7
MAC006G002	Use I	na	3.14	9.33	211.0	134.9	3.0
MAC006G003	Use I	6.6	6.38	9.07	235.3	150.7	3.5
MAC006G203	Use I	na	na	na	na	na	na
MAC015G001	Use I	6.6	5.42	9.37	118.9	76.2	4.8
MC1009G001	Use I	7.4	20.47	5.41	110.4	70.3	15.6
MC1019G001	Use I	6.8	15.77	6.60	164.4	105.6	6.5
MC1023G001	Use I	6.9	17.38	9.01	39.2	25.1	6.8
MC1024G001	Use I	6.8	17.56	8.22	152.6	97.7	4.1
SSB001G001	Use I	**5.1**	11.14	7.50	48.3	30.9	3.0
SWC005G001	Use I	7.5	8.66	6.68	282.6	180.9	5.1
WEC009G001	Use I	7.2	15.40	6.64	229.9	168.4	9.8
JZ1001G001	Use III	6.6	16.31	9.22	261.7	167.5	0.0
JZ1001G002	Use III	7.1	15.80	9.11	194.1	124.2	0.9
JZ1001G003	Use III	6.7	12.79	7.91	166.0	106.3	3.9
JZ1001G004	Use III	6.9	12.14	8.81	142.1	91.0	1.5
JZ2001G001	Use III	7.5	16.93	9.88	212.6	206.9	4.3
JZ2001G002	Use III	**5.7**	8.40	7.14	107.2	68.7	7.8
JZ2009G001	Use III	7.4	18.45	9.56	137.8	88.2	5.8
JZ2009G002	Use III	7.1	7.19	8.95	139.8	89.2	5.6
JZ2009G003	Use III	na	9.51	8.94	131.0	83.8	3.8
JZ2010G001	Use III	7.0	7.16	9.11	174.5	111.6	15.8
JZ3001G001	Use III	7.5	16.44	7.07	348.3	223.0	9.2
JZ3003G001	Use III	7.5	18.14	8.31	405.5	259.8	2.4
JZ3004G001	Use III	7.4	16.76	7.84	696.2	445.5	11.8
JZ4007G001	Use III	**6.3**	15.86	9.56	80.5	51.5	3.5
PSB001G001	Use IV	7.3	6.40	8.44	402.4	257.5	4.8
PSB014G001	Use IV	7.2	7.28	8.27	250.4	160.2	12.0
PSB023G001	Use IV	6.9	8.83	8.50	329.9	211.0	4.1
SM1001G001	Use IV	7.3	10.27	8.56	263.1	168.5	12.5
SM1001G002	Use IV	7.4	11.87	6.91	220.9	141.6	7.9
SM1005G001	Use IV	7.4	14.54	7.99	303.2	194.1	5.9
SM2001G001	Use IV	7.2	8.12	8.69	311.7	199.4	26.0
SM2005G001	Use IV	7.3	8.54	8.57	266.4	170.4	19.9
SM3006G001	Use IV	7.2	14.76	7.58	192.6	123.3	8.9
SM3007G001	Use IV	7.7	18.32	7.39	242.4	155.2	7.4
SM4001G001	Use IV	7.0	9.54	8.14	192.6	123.3	26.6
SM4001G002	Use IV	6.5	5.60	9.15	228.7	146.3	8.3
SM4001G202	Use IV	na	na	na	na	na	na
ST2001G001	Use IV	7.3	17.63	6.76	181.0	115.7	4.5
ST2001G002	Use IV	7.3	9.25	8.14	362.3	262.5	27.4

Site	Designated Use	pH	Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	Total Dissolved Solids (mg/L)	Turbidity (NTU)
ST2001G003	Use IV	7.2	9.34	8.03	350.0	224.0	37.8
ST2006G001	Use IV	6.9	14.22	**3.53**	293.3	187.5	9.5
ST2008G001	Use IV	7.8	16.78	6.71	330.8	212	6.8
ST2010G001	Use IV	7.2	18.05	6.62	518.1	331.5	1.9
ST3001G001	Use IV	7.1	12.94	6.80	224.9	144.0	1.9
ST4001G001	Use IV	na	na	na	na	na	na
ST4001G201	Use IV	6.9	9.88	9.05	237.6	152.1	15.8
ST4003G001	Use IV	7.5	18.97	6.98	143.0	91.5	3.9
ST5005G001	Use IV	7.7	16.88	8.12	380.5	243.4	7.6
ST5007G001	Use IV	**6.4**	13.34	8.36	205.8	131.7	11.0
ST7002G001	Use IV	7.6	14.42	7.02	202.9	129.9	11.6
ST9003G001	Use IV	7.3	3.77	8.88	225.9	144.5	19.8

The water quality samples were generally within the COMAR limits and typical of coastal plain streams. The averages and summary statistics are provided below in Table 3.14. The pH levels had a study wide average of 7.0. Eight sites fell below the lower limit of 6.5, the lowest being 5.1 in Sewell Spring Branch. Temperature values were all within acceptable levels. The highest temperature was recorded in the 2002 sample in Mill Creek 1. Dissolved oxygen levels averaged 7.99 mg/L and only 1 site fell below the acceptable minimum, in Severn Run Tributary 2 in 2002. The conductivity and total dissolved solids levels were within normal levels for most of the watershed. Higher levels, above 300µS/cm for conductivity and above 200mg/L for total dissolved solids, were recorded in many of the Severn Run tributaries including SM1, SM2, ST2, ST5, PSB, and JZ3. These subwatersheds are in more intensely developed areas with high levels of commercial and transportation land use. Turbidity levels were within COMAR limits throughout the watershed. The lowest values, indicating good clarity, were in JZ1, while the highest values were in SM2 and ST2.

Table 3-14: Water Quality Summary

	pH	Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	Total Dissolved Solids (mg/L)	Turbidity (NTU)
N	61	63	63	63	63	63
Mean	7.0	12.22	7.99	228.2	148.0	8.6
Standard Deviation	0.51	4.52	1.19	111.8	72.7	7.1
Maximum Value	7.8	20.5	9.9	696.2	445.5	37.8
Minimum Value	5.1	3.1	3.5	39.2	25.1	0.0
Below COMAR limits	8	na	1	na	na	na
Above COMAR limits	0	0	na	na	na	0

3.5.3 Macroinvertebrate Sampling

The Severn River Watershed Study and the County's biological monitoring program are designed to be consistent with methodologies developed by the Maryland Department of Natural Resources (DNR) in their Maryland Biological Stream Survey (MBSS). The County has adopted the MBSS methodology to be consistent with statewide monitoring programs and programs adopted by other Maryland counties. The methods have been developed locally and are calibrated to Maryland's physiographic regions and stream types.

Benthic macroinvertebrate collection followed procedures described in the *Maryland Biological Stream Survey Sampling Manual* (Kazyak, 2001). Data were analyzed using methods developed by MBSS as outlined in the *Development of a Benthic Index of Biotic Integrity for Maryland Streams* (Stribling et al., 1998). The Benthic Index of Biotic Integrity (BIBI) approach involves statistical analysis using metrics that have a predictable response to water quality and/or habitat impairment. A BIBI score from 1 to 5 was generated for each site based on the metrics scoring. The BIBI developed for the coastal plain region was used. Refer to Appendix B for the full methods description.

Table 3-15: BIBI Scores

BIBI Score	Narrative Rating
4.0 – 5.0	Good
3.0 – 3.9	Fair
2.0 – 2.9	Poor
1.0 – 1.9	Very Poor

There were a total of 158 genera collected in the 63 sites throughout the Severn River watershed, just below the 172 genera collected by DNR in 85 sites throughout Anne Arundel County from 1994-1997 (Millard, et. al, 2001). Table 3.16 shows the top 50 final identification taxa listed in order of percent occurrence or the percentage of sites that the taxa occurred. Also given is the overall percent abundance for the taxa. The Chironomidae genera were the most prevalent throughout the watershed. Other common genera include *Caloteryx sp*. (damsel-fly larvae), which was present at 49 percent of the sites, *Crangonyx sp*. (a freshwater amphipod), which was present at 64 percent of the sites and made up almost 8 percent of the total number of organisms, and *Caecidotea sp.* (an isopod), which made up more than 5 percent of the total. EPT taxa were less common, however the stonefly *Leuctra sp.* was present in 28 percent of the samples and made up over 5 percent of the total.

Table 3-16: Abundance and Occurrence of Macroinvertebrates

Final Identification	Order	Family	Functional Feeding Group	Habit	Tolerance Value	Percent Occurrence	Percent Abundance
Chironomidae	Diptera	Chironomidae	Collector	na	7	74.63	3.12
Crangonyx	Amphipoda	Crangonyctidae	Collector	sp	4	64.18	7.88
Polypedilum	Diptera	Chironomidae	Shredder	cb, cn	6	59.70	3.85
Larsia	Diptera	Chironomidae	Predator	sp	6	59.70	2.60
Thienemannimyia	Diptera	Chironomidae	Predator	sp	7	56.72	5.19
Calopteryx	Odonata	Calopterygidae	Predator	cb	6	49.25	1.80
Lumbriculidae	Lumbriculida	Lumbriculidae	Collector	bu	10	49.25	1.76
Sphaeriidae	Veneroida	Sphaeriidae	Filterer	bu	8	47.76	2.20
Parametriocnemus	Diptera	Chironomidae	Collector	sp	5	43.28	4.29
Brillia	Diptera	Chironomidae	Shredder	bu, sp	5	43.28	1.70
Orthocladius	Diptera	Chironomidae	Collector	sp, bu	6	41.79	4.08
Cheumatopsyche	Trichoptera	Hydropsychidae	Filterer	cn	5	35.82	4.68
Tubificidae	Tubificida	Tubificidae	Collector	cn	10	35.82	1.57
Bezzia/Palpomyia	Diptera	Chironomidae	Predator	bu	6	35.82	0.97
Caecidotea	Isopoda	Asellidae	Collector	sp	8	34.33	5.27
Hydrobaenus	Diptera	Chironomidae	Scraper	sp	8	34.33	2.28
Phaenopsectra	Diptera	Chironomidae	Scraper	cn	7	34.33	1.28
Tipula	Diptera	Tipulidae	Shredder	bu	4	31.34	0.74
Simulium	Diptera	Simuliidae	Filterer	cn	7	29.85	4.42
Tanytarsus	Diptera	Chironomidae	Filterer	cb, cn	6	29.85	1.37
Anchytarsus	Coleoptera	Ptilodactylidae	Shredder	cn	4	29.85	1.21
Diplectrona	Trichoptera	Hydropsychidae	Filterer	cn	2	29.85	1.01
Leuctra	Plecoptera	Leuctridae	Shredder	cn	0	28.36	5.34

Final Identification	Order	Family	Functional Feeding Group	Habit	Tolerance Value	Percent Occurrence	Percent Abundance
Diptera	Diptera	Diptera	na	na	na	28.36	0.32
Lumbricidae	Haplotaxida	Lumbricidae	Collector	bu, sp	10	26.87	0.57
Hexatoma	Diptera	Tipulidae	Predator	bu, sp	4	26.87	0.30
Nigronia	Megaloptera	Corydalidae	Predator	cn, cb	0	25.37	0.37
Dicranota	Diptera	Tipulidae	Predator	sp, bu	4	23.88	0.31
Naididae	Tubificida	Naididae	Collector	bu	10	23.88	0.27
Sialis	Megaloptera	Sialidae	Predator	bu, cb, cn	4	23.88	0.25
Hydroporus	Coleoptera	Dytiscidae	Predator	sw, cb	5	22.39	0.49
Prodiamesa	Diptera	Chironomidae	Collector	bu, sp	3	19.40	1.51
Physidae	Basommatophora	Physidae	Scraper	cb	8	19.40	1.41
Cordulegaster	Odonata	Cordulegastridae	Predator	bu	3	19.40	1.18
Pycnopsyche	Trichoptera	Limnephilidae	Shredder	sp, cb, cn	4	19.40	0.53
Boyeria	Odonata	Aeshnidae	Predator	cb, sp	2	19.40	0.32
Leptophlebia	Ephemeroptera	Leptophlebiidae	Collector	sw, cn,sp	4	17.91	1.63
Stenelmis	Coleoptera	Elmidae	Scraper	cn	6	17.91	0.36
Helichus	Coleoptera	Dryopidae	Scraper	cn	5	17.91	0.30
Limnephilidae	Trichoptera	Limnephilidae	Shredder	cb, sp, cn	4	16.42	0.68
Chironomus	Diptera	Chironomidae	Collector	bu	10	14.93	2.74
Chrysops	Diptera	Tabanidae	Collector	sp, bu	7	14.93	1.12
Stenochironomus	Diptera	Chironomidae	Shredder	bu	5	14.93	0.30
Lype	Trichoptera	Psychomyiidae	Scraper	cn	2	14.93	0.28
Dineutus	Coleoptera	Gyrinidae	Predator	sw, dv	4	14.93	0.22
Molophilus	Diptera	Tipulidae	na	bu	4	14.93	0.20
Polycentropus	Trichoptera	Polycentropodidae	Predator	cn	5	13.43	0.56
Ironoquia	Trichoptera	Limnephilidae	Shredder	sp	3	13.43	0.37
Eccoptura	Plecoptera	Perlidae	Predator	cn	2	13.43	0.26
Hoplonemertea	Hoplonemertea	na	Predator	sp	na	13.43	0.16

Table 3.17 provides the metric calculation results for each of the sampled sites.

Table 3-17: Macroinvertebrate Metric Calculation Results

Site	Total Taxa	EPT Taxa	Percent Ephemeroptera	Percent Tanytarsini	Beck's Biotic Index	Number of Scraper Taxa	Percent Clingers
BRB001G001	16	3	0.0	47.5	3	3	44.9
BWC001G001	10	0	0.0	0.0	3	0	0.0
BWP001G001	19	2	26.2	6.9	8	1	57.4
BWP001G201	19	5	26.3	0	10	3	47.9
CLC001G001	19	3	0.0	10.5	7	1	13.8
CSB001G001	17	1	0.0	0.0	6	3	4.3
CWB004G001	15	2	0.0	35.9	2	1	74.0
GB2001G001	16	2	0.7	0.0	3	1	57.8
GB2002G001	25	5	15.4	2.9	9	3	51.7
GB2010G001	23	3	0.8	1.4	11	2	22.7
HOC001G001	24	4	0.6	6.7	11	0	45.2
ICB001G001	25	9	0.0	11.8	11	0	61.3

Site	Total Taxa	EPT Taxa	Percent Ephemeroptera	Percent Tanytarsini	Beck's Biotic Index	Number of Scraper Taxa	Percent Clingers
JZ1001G001	25	7	0.0	2.6	12	1	60.0
JZ1001G002	19	6	0.9	1.6	8	3	56.0
JZ1001G003	32	10	0.0	4.6	17	3	70.4
JZ1001G004	38	12	2.9	34.0	20	4	70.8
JZ2001G001	19	3	0.0	0.0	7	1	48.0
JZ2001G002	34	10	11.4	17.9	12	3	63.8
JZ2009G001	26	3	0.0	1.4	12	1	39.0
JZ2009G002	24	10	7.0	7.7	16	1	80.6
JZ2009G003	30	11	7.9	7.3	16	3	54.7
JZ2010G001	17	2	0.0	0.0	7	1	30.1
JZ3001G001	22	4	0.0	22.6	10	0	36.4
JZ3003G001	17	0	0.0	34.0	3	2	4.8
JZ3004G001	10	0	0.0	4.5	1	0	10.4
JZ4007G001	17	1	0.0	12.5	6	0	61.5
LUC001G001	17	1	0.0	0.0	5	0	9.4
LUC001G002	23	6	7.0	3.8	6	3	26.6
MAC006G001	28	6	3.5	1.6	18	1	34.3
MAC006G002	30	7	16.0	0.0	14	3	44.3
MAC006G003	18	4	3.7	0.0	10	1	39.3
MAC006G203	23	4	5.2	1.4	11	2	33.9
MAC015G001	23	6	4.5	0.9	8	3	14.1
MC1009G001	17	1	0.0	0.0	5	1	6.3
MC1019G001	18	1	0.0	0.0	6	0	9.2
MC1023G001	17	3	0.0	0.0	14	0	49.0
MC1024G001	22	1	0.0	0.0	9	2	15.0
PSB001G001	24	3	4.8	1.7	7	3	24.1
PSB014G001	23	4	0.0	5.1	5	1	17.4
PSB023G001	21	4	0.0	0.0	7	1	7.7
SM1001G001	13	2	0.0	0.0	1	1	11.4
SM1001G002	18	0	0.0	5.7	5	0	19.6
SM1005G001	16	1	0.0	0.0	2	3	48.8
SM2001G001	29	1	0.0	20.0	9	5	22.5
SM2005G001	24	1	0.0	30.1	5	5	48.9
SM3006G001	27	5	0.8	2.2	9	5	40.8
SM3007G001	26	4	12.2	3.3	6	2	78.0
SM4001G001	28	9	6.4	64.9	11	5	77.1
SM4001G002	27	5	5.6	3.7	12	2	45.1
SM4001G202	26	5	2.6	35.0	9	6	79.3
SSB001G001	29	6	0.0	23.1	11	2	67.8
ST2001G001	34	0	0.0	6.6	11	6	31.8
ST2001G002	20	1	0.0	22.2	3	3	43.0
ST2001G003	20	1	0.0	25.9	4	5	50.5
ST2006G001	13	0	0.0	0.0	2	0	2.4
ST2008G001	12	0	0.0	0.0	3	1	0.0
ST2010G001	17	0	0.0	0.0	6	1	6.3

Site	Total Taxa	EPT Taxa	Percent Ephemeroptera	Percent Tanytarsini	Beck's Biotic Index	Number of Scraper Taxa	Percent Clingers
ST3001G001	28	6	5.0	8.7	11	3	25.0
ST4001G001	26	2	0.0	0.0	7	1	26.6
ST4001G201	24	4	0.0	1.4	10	2	37.2
ST4003G001	16	2	0.0	9.1	1	5	33.9
ST5005G001	19	1	0.0	0.0	3	3	17.5
ST5007G001	27	6	0.0	9.1	14	6	39.1
ST7002G001	36	7	0.0	11.1	14	4	51.1
ST9003G001	19	5	0.8	0.0	10	1	38.3
SWC005G001	12	0	0.0	0.0	1	1	17.6
WEC009G001	12	1	0.0	0.0	1	1	28.6

The high values for total taxa, EPT taxa and Beck's biotic index were all a result of one site in Jabez Branch (JZ1001G004). Conversely the Brewer Creek site (BWC001G001) had the fewest taxa and low values for EPT taxa, percent ephemeroptera, percent tanytarsini, number of scraper taxa and percent clingers.

Table 3-18: Macroinvertebrate Summary

	Total Taxa	EPT Taxa	Percent Ephemeroptera	Percent Tanytarsini	Beck's Biotic Index	Number of Scraper Taxa	Percent Clingers
N	63	63	63	63	63	63	63
Mean	21.7	3.5	2.2	8.0	7.9	2.0	36.4
Std Deviation	6.44	3.08	4.84	11.42	4.67	1.71	22.40
Maximum Value	38.0	12.0	26.2	47.5	20.0	6.0	80.6
Minimum Value	10.0	0.0	0.0	0.0	1.0	0.0	0.0

Duplicate sites were sampled in four locations. Table 3.19 provides the results of those sites. The results show a high level of precision in the sampling methodology. Two of the sites have identical scores, while the others vary by only 0.3. None of the duplicate sites were in a category different from the study site.

Table 3-19: Duplicate Sites

Site	Subshed	Score	Rating	Difference	Rating Change
SM4001G002	SM4	4.1	Good	0.3	0
SM4001G202	SM4	4.4	Good		
MAC006G03	MAC	2.7	Poor	0	0
MAC006G203	MAC	2.7	Poor		
BWP001G001	BWP	3.0	Fair	0	0
BWP001G201	BWP	3.0	Fair		
ST4001G001	ST4	2.1	Poor	0.3	0
ST4001G201	ST4	2.4	Poor		

3.5.4 Physical Habitat Assessment

Habitat assessments were completed at all of the monitoring sites to evaluate the reach's ability to support aquatic life. DNR's Provisional Physical Habitat Index (PHI) (Hall et. al, 1999) was used for the 15 sites assessed in 2002. The 2004 sampling employed both the PHI (Paul et. al, 2003) and the Environmental Protection Agency's Rapid Bioassessment Protocol (RBP) habitat assessment (Barbour et. al, 1999). Both methods were used in 2004 so that a comparison could be made between the results and applicability of the two assessment techniques. The methods use a series of habitat parameters with scoring that increases as the quality of instream habitat increases.

The RBP method uses a reference site to develop the final percent comparability. A reference reach was identified in Severn Run Tributary 3 (site ST3001G037) with the highest score of 187. The percent comparability was then calculated based on 187 as the highest attainable score.

Tables 3.20 and 3.22 provide the results for the PHI and RBP habitat assessments. Summary statistics are given in tables 3.21 and 3.23.

Table 3-20: PHI Results

Site	Instream Habitat	Velocity Depth Diversity	Pool Quality	Percent Embeddedness	Maximum Depth (cm)	Aesthetics/ Trash Rating
BRB001G001	17	15	17	35	100	13
BWC001G001	15	9	12	35	55	20
BWP001G001	16	14	15	15	74	20
BWP001G201	na	na	na	na	na	na
CLC001G001	14	14	15	45	62	20
CSB001G001	14	14	12	80	70	9
CWB004G001	17	14	13	20	75	15
GB2001G001	11	8	8	20	35	17
GB2002G001	12	9	10	30	58	20
GB2010G001	11	9	9	85	15	20
HOC001G001	14	9	10	30	45	20
ICB001G001	18	15	17	30	60	20
JZ1001G001	17	15	15	40	35	20
JZ1001G002	16	15	15	30	40	19
JZ1001G003	17	14	10	25	58	18
JZ1001G004	18	15	13	25	74	15
JZ2001G001	17	17	17	40	25	20
JZ2001G002	13	10	12	80	130	12
JZ2009G001	15	13	13	30	15	20
JZ2009G002	17	10	10	20	61	16
JZ2009G003	16	13	11	10	56	14
JZ2010G001	12	8	7	70	50	18
JZ3001G001	14	12	11	60	60	20
JZ3003G001	15	15	15	70	64	20
JZ3004G001	14	14	14	65	101	18
JZ4007G001	15	14	14	45	41	19
LUC001G001	6	10	7	95	55	16
LUC001G002	7	13	9	90	74	1
MAC006G001	17	13	14	85	33	17
MAC006G002	12	12	12	80	74	18
MAC006G003	17	13	11	35	89	17
MAC006G203	na	na	na	na	na	na
MAC015G001	4	8	9	80	40	19
MC1009G001	14	14	14	65	27	19
MC1019G001	13	14	14	60	80	19
MC1023G001	14	14	14	40	25	20
MC1024G001	10	8	8	55	37	18
PSB001G001	14	15	15	70	74	15

Site	Instream Habitat	Velocity Depth Diversity	Pool Quality	Percent Embeddedness	Maximum Depth (cm)	Aesthetics/ Trash Rating
PSB014G001	10	9	8	60	56	11
PSB023G001	13	9	8	70	25	17
SM1001G001	14	15	14	85	74	3
SM1001G002	16	15	14	70	50	12
SM1005G001	13	14	14	70	89	4
SM2001G001	17	14	15	35	142	12
SM2005G001	15	14	14	30	60	13
SM3006G001	5	8	2	45	10	10
SM3007G001	17	16	16	15	100	18
SM4001G001	18	16	16	35	140	14
SM4001G002	18	17	19	30	180	19
SM4001G202	na	na	na	na	na	na
SSB001G001	16	11	13	15	56	20
ST2001G001	11	12	12	50	69	18
ST2001G002	7	6	8	80	50	10
ST2001G003	8	10	8	70	75	14
ST2006G001	7	7	7	75	30	10
ST2008G001	9	9	9	65	40	16
ST2010G001	13	10	10	75	49	18
ST3001G001	19	18	18	50	90	20
ST4001G001	12	8	9	40	55	19
ST4001G201	na	na	na	na	na	na
ST4003G001	10	10	9	40	55	17
ST5005G001	10	10	8	40	50	6
ST5007G001	16	15	15	25	89	7
ST7002G001	18	16	14	70	50	20
ST9003G001	9	12	8	80	45	17
SWC005G001	13	14	13	100	95	9
WEC009G001	7	6	7	70	55	16

Table 3-21: PHI Summary

	Instream Habitat	Velocity Depth Diversity	Pool Quality	Percent Embeddedness	Maximum Depth	Aesthetics/ Trash Rating
N	63	63	63	63	63	63
Mean	13.4	12.2	11.9	52.1	62.6	15.7
Std Deviation	3.68	3.02	3.40	23.84	31.44	4.72
Maximum Value	19	18	19	100	180	20
Minimum Value	4	6	2	10	10	1

Table 3-22: RBP Habitat Results

Site	Epifaunal Substrate	Pool Substrate	Pool Variability	Sediment Deposition	Channel Flow Status	Channel Alteration	Channel Sinuosity	Bank Stability	Vegetative Protection	Riparian Vegetation
BRB001G001	15	18	16	17	17	20	14	20	18	20
BWC001G001	14	12	12	10	17	20	14	20	19	20
BWP001G001	18	13	15	8	16	20	15	20	16	20
BWP001G201	na	na	na	na	na	na	na	na	na	na
CLC001G001	17	16	15	15	17	20	8	14	17	20
CSB001G001	15	9	12	8	13	12	9	13	14	20
CWB004G001	15	16	16	16	20	20	16	20	18	20
GB2001G001	13	14	5	17	19	20	14	20	18	20
GB2002G001	11	10	9	9	12	20	10	4	16	20
GB2010G001	6	8	3	6	15	20	13	18	16	20
HOC001G001	18	14	10	13	17	20	12	18	16	20
ICB001G001	19	17	17	12	18	20	17	18	20	20
JZ1001G001	na	na	na	na	na	na	na	na	na	na
JZ1001G002	na	na	na	na	na	na	na	na	na	na
JZ1001G003	18	14	10	15	15	20	16	18	16	20
JZ1001G004	18	13	13	14	15	20	13	17	16	20
JZ2001G001	na	na	na	na	na	na	na	na	na	na
JZ2001G002	10	10	12	4	14	20	13	8	11	20
JZ2009G001	na	na	na	na	na	na	na	na	na	na
JZ2009G002	16	14	8	18	15	18	15	5	16	20
JZ2009G003	18	18	11	15	14	20	10	12	13	20
JZ2010G001	11	12	5	10	18	20	11	20	18	20
JZ3001G001	15	14	12	11	15	20	6	13	16	20
JZ3003G001	na	na	na	na	na	na	na	na	na	na
JZ3004G001	na	na	na	na	na	na	na	na	na	na
JZ4007G001	na	na	na	na	na	na	na	na	na	na
LUC001G001	2	7	7	5	16	20	11	18	17	20
LUC001G002	12	7	9	4	16	20	11	16	16	20
MAC006G001	12	7	9	12	12	20	14	9	10	20
MAC006G002	10	10	14	7	15	20	14	5	13	20
MAC006G003	13	14	10	16	15	20	11	18	18	20
MAC006G203	na	na	na	na	na	na	na	na	na	na
MAC015G001	4	4	8	6	13	19	14	4	11	20
MC1009G001	na	na	na	na	na	na	na	na	na	na
MC1019G001	na	na	na	na	na	na	na	na	na	na
MC1023G001	na	na	na	na	na	na	na	na	na	na
MC1024G001	na	na	na	na	na	na	na	na	na	na
PSB001G001	13	13	15	6	18	20	12	6	19	20
PSB014G001	13	11	8	4	14	20	14	12	9	20
PSB023G001	12	10	4	13	15	19	10	16	18	20
SM1001G001	16	13	14	15	12	20	12	16	16	19
SM1001G002	15	14	10	12	18	20	7	20	18	16
SM1005G001	3	9	14	16	8	20	13	8	7	20
SM2001G001	15	17	17	12	18	20	9	14	16	19
SM2005G001	15	12	16	11	18	17	13	16	12	20
SM3006G001	9	9	2	11	14	20	11	18	13	20

Site	Epifaunal Substrate	Pool Substrate	Pool Variability	Sediment Deposition	Channel Flow Status	Channel Alteration	Channel Sinuosity	Bank Stability	Vegetative Protection	Riparian Vegetation
SM3007G001	17	14	16	15	17	20	15	10	19	20
SM4001G001	na	na	na	na	na	na	na	11	13	20
SM4001G002	18	16	16	12	18	20	16	12	15	20
SM4001G202	19	13	16	13	18	20	16	na	na	na
SSB001G001	18	17	13	18	20	20	17	20	20	20
ST2001G001	na	na	na	na	na	na	na	na	na	na
ST2001G002	7	5	10	15	17	15	7	16	16	14
ST2001G003	9	6	15	11	18	18	15	10	14	20
ST2006G001	na	na	na	na	na	na	na	na	na	na
ST2008G001	na	na	na	na	na	na	na	na	na	na
ST2010G001	na	na	na	na	na	na	na	na	na	na
ST3001G001	19	18	19	16	20	20	15	20	20	20
ST4001G001	13	9	9	7	17	20	15	14	20	20
ST4001G201	na	na	na	na	na	na	na	na	na	na
ST4003G001	5	7	9	6	17	20	11	14	14	20
ST5005G001	11	8	8	9	7	20	12	14	12	20
ST5007G001	15	12	15	13	14	20	14	17	10	20
ST7002G001	18	16	15	13	18	20	9	19	20	20
ST9003G001	4	8	7	7	10	12	3	8	13	14
SWC005G001	0	12	13	11	18	20	13	16	12	20
WEC009G001	11	10	7	8	18	20	12	18	16	20

Table 3-23: RBP Habitat Summary

	Epifaunal Substrate	Pool Substrate	Pool Variability	Sediment Deposition	Channel Flow Status	Channel Alteration	Channel Sinuosity	Bank Stability	Vegetative Protection	Riparian Vegetation
N	48	48	48	48	48	48	48	48	48	48
Mean	12.8	11.9	11.4	11.3	15.8	19.4	12.3	14.4	15.4	19.6
Std Deviation	4.97	3.68	4.11	4.03	2.86	1.81	3.02	4.89	3.20	1.33
Maximum Value	19	18	19	18	20	20	17	20	20	20
Minimum Value	0	4	2	4	7	12	3	4	7	14

3.5.5 Summary

The BIBI, PHI and RBP habitat final scores and ratings are shown in Table 3.24. Summary Statistics are provided below in Table 3.25.

Table 3-24: Final Scores and Ratings

Site	BIBI Score	BIBI Rating	PHI Score	PHI Rating	RBP Score	RBP Percent Comparability	RBP Rating
BRB001G001	2.7	Poor	94.59	Good	175	93.58	Comparable

Site	BIBI Score	BIBI Rating	PHI Score	PHI Rating	RBP Score	RBP Percent Comparability	RBP Rating
BWC001G001	1.0	Very Poor	78.90	Good	158	84.49	Supporting
BWP001G001	3.0	Fair	93.94	Good	161	86.10	Supporting
BWP001G201	3.0	Fair	na	na	na	na	na
CLC001G001	2.4	Poor	88.67	Good	159	85.03	Supporting
CSB001G001	1.9	Very Poor	69.49	Fair	125	66.84	Partially Supporting
CWB004G001	2.7	Poor	90.97	Good	177	94.65	Comparable
GB2001G001	1.9	Very Poor	52.67	Fair	160	85.56	Supporting
GB2002G001	3.6	Fair	70.18	Fair	121	64.71	Partially Supporting
GB2010G001	2.4	Poor	39.08	Poor	125	66.84	Partially Supporting
HOC001G001	2.4	Poor	71.77	Fair	158	84.49	Supporting
ICB001G001	3.0	Fair	95.13	Good	178	95.19	Comparable
JZ1001G001	3.3	Fair	90.51	Good	na	na	na
JZ1001G002	2.7	Poor	90.51	Good	na	na	na
JZ1001G003	3.9	Fair	87.02	Good	162	86.63	Supporting
JZ1001G004	4.4	Good	92.16	Good	159	85.03	Supporting
JZ2001G001	2.4	Poor	93.00	Good	na	na	na
JZ2001G002	4.1	Good	75.00	Good	122	65.24	Partially Supporting
JZ2009G001	3.0	Fair	81.52	Good	na	na	na
JZ2009G002	3.9	Fair	80.85	Good	145	77.54	Supporting
JZ2009G003	3.9	Fair	84.75	Good	151	80.75	Supporting
JZ2010G001	1.9	Very Poor	44.43	Fair	145	77.54	Supporting
JZ3001G001	2.4	Poor	77.01	Good	142	75.94	Supporting
JZ3003G001	2.1	Poor	88.33	Good	na	na	na
JZ3004G001	1.3	Very Poor	88.55	Good	na	na	na
JZ4007G001	2.1	Poor	85.45	Good	na	na	na
LUC001G001	1.6	Very Poor	26.99	Poor	123	65.48	Partially Supporting
LUC001G002	2.7	Poor	28.99	Poor	131	70.05	Partially Supporting
MAC006G001	3.3	Fair	77.59	Fair	125	66.84	Partially Supporting
MAC006G002	3.9	Fair	71.55	Fair	128	68.45	Partially Supporting
MAC006G003	2.7	Poor	88.89	Good	155	82.89	Supporting
MAC006G203	2.7	Poor	na	na	na	na	na
MAC015G001	2.7	Poor	25.92	Poor	103	55.08	Non-supporting
MC1009G001	1.9	Very Poor	78.34	Good	na	na	na
MC1019G001	1.6	Very Poor	85.99	Good	na	na	na
MC1023G001	2.4	Poor	83.12	Good	na	na	na
MC1024G001	1.9	Very Poor	42.26	Fair	na	na	na
PSB001G001	2.7	Poor	85.18	Good	142	75.94	Supporting
PSB014G001	2.4	Poor	39.34	Poor	125	66.84	Partially Supporting
PSB023G001	2.1	Poor	44.43	Fair	137	73.26	Partially Supporting
SM1001G001	1.6	Very Poor	69.25	Fair	153	81.82	Supporting
SM1001G002	1.9	Very Poor	80.67	Good	150	80.21	Supporting
SM1005G001	1.9	Very Poor	72.66	Good	118	63.10	Partially Supporting
SM2001G001	3.0	Fair	94.97	Good	157	83.96	Supporting
SM2005G001	3.0	Fair	85.99	Good	150	80.21	Supporting
SM3006G001	3.3	Fair	10.41	Very Poor	127	67.91	Partially Supporting

Site	BIBI Score	BIBI Rating	PHI Score	PHI Rating	RBP Score	RBP Percent Comparability	RBP Rating
SM3007G001	3.9	Fair	96.63	Good	163	87.17	Supporting
SM4001G001	3.3	Fair	96.97	Good	160	85.56	Supporting
SM4001G002	4.1	Good	99.08	Good	162	86.63	Supporting
SM4001G202	4.4	Good	na	na	na	na	na
SSB001G001	3.6	Fair	87.98	Good	183	97.86	Comparable
ST2001G001	2.7	Poor	74.79	Good	na	na	na
ST2001G002	2.4	Poor	19.22	Poor	122	65.24	Partially Supporting
ST2001G003	3.0	Fair	43.07	Fair	136	72.73	Partially Supporting
ST2006G001	1.3	Very Poor	16.78	Poor	na	na	na
ST2008G001	1.6	Very Poor	40.39	Poor	na	na	na
ST2010G001	1.9	Very Poor	59.18	Fair	na	na	na
ST3001G001	3.0	Fair	97.42	Good	187	100.00	Comparable
ST4001G001	2.1	Poor	60.76	Fair	144	77.01	Supporting
ST4001G201	2.1	Poor	na	na	na	na	na
ST4003G001	2.1	Poor	58.11	Fair	123	65.78	Partially Supporting
ST5005G001	1.6	Very Poor	39.08	Poor	121	64.71	Partially Supporting
ST5007G001	3.6	Fair	89.93	Good	150	80.21	Supporting
ST7002G001	3.6	Fair	90.03	Good	168	89.84	Supporting
ST9003G001	2.1	Poor	44.43	Fair	86	45.99	Non-supporting
SWC005G001	1.6	Very Poor	70.64	Fair	135	72.19	Partially Supporting
WEC009G001	1.6	Very Poor	25.92	Poor	140	74.87	Partially Supporting

Table 3-25: Final Score Summary

	BIBI Score	PHI Score	RBP Percent Comparability
N	63	63	48
Mean	2.6	70.0	77.2
Std Deviation	0.82	24.37	11.40
Maximum Value	4.4	99.1	100
Minimum Value	1.0	10.4	45.99

The BIBI scores ranged from a low of 1.0 in Brewer Creek at site BWC001G001 to a high of 4.4 in Jabez Branch 1 at site JZ1001G004. These are the same sites that had most of the high and low individual metric values. The mean BIB score is 2.6, which would indicate a Poor condition. As depicted in Table 3.26 and Figures 3.13 and 3.14, the range of BIBI scores is skewed toward the Poor and Very Poor categories. Forty of the 63 sites were in the Poor to Very Poor range and only three sites scored in the Good range. As mentioned in section 3.1.6, DNR data in the Severn River Watershed from 1994-1997 also generated an average BIBI value in the Poor range (Millard, et. al, 2001). Similar to their results, sites in the upper reaches of Severn Run (SM1 and ST2) were Poor and Very Poor. Scores increase as the drainage area increases from SM2 in the Fair range to SM4 in the Good category. Site along the north and south shores of the Severn were generally Poor and Very Poor, with the exception of a few sites in Gumbottom Branch 2 and Maynadier Creek (MAC) that had some Fair sites sampled.

Table 3-26: BIBI, PHI and RBP Summary

	Very Poor	Poor	Fair	Good
BIBI	18	22	20	3
PHI	1	10	16	36
	Non-supporting	**Partially Supp.**	**Supporting**	**Comparable to Ref**
RBP	2	18	23	5

Figure 3-13: BIBI Frequency distribution

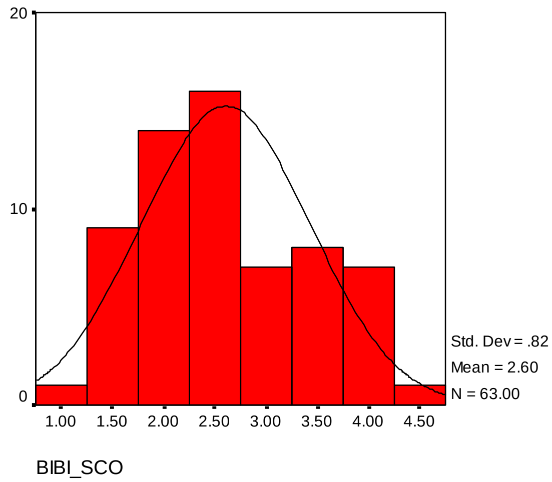
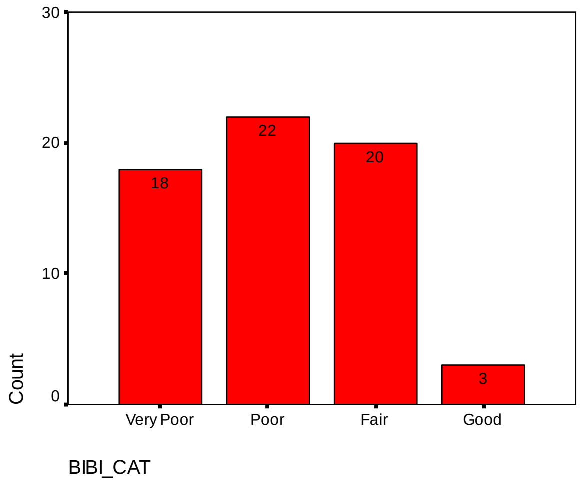


Figure 3-14: BIBI sites per rating classification



Habitat data generated an average value of 70, which is at the top of the Fair range. Thirty-six of the 63 sites were in the Good range. The RBP habitat scores, however show a somewhat more normal distribution across the four categories.. Figures 3.15 to 3.18 show the frequency distributions and the number of sites in each of the assessment categories. The PHI scoring system is developed so that a reference reach is not required and sites are measured against a scoring system developed across the coastal plain region. The RBP scores however, use a reference reach, in this case a reach from the same watershed and assessed in the same study period. This difference may be a factor in the varying distributions of the PHI and RBP scores.

Figure 3-15: PHI Frequency distribution

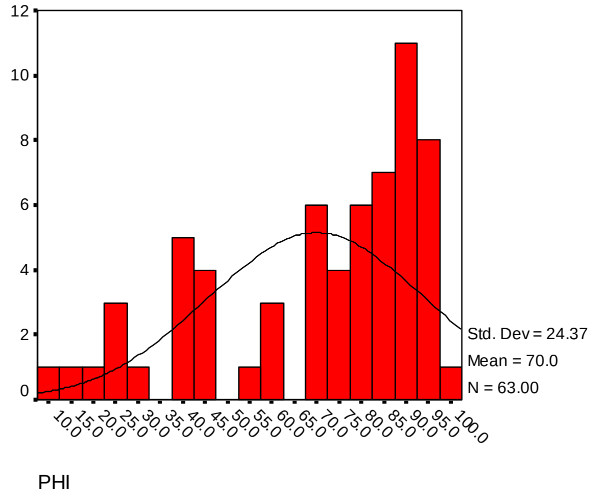


Figure 3-17: RBP Frequency Distribution

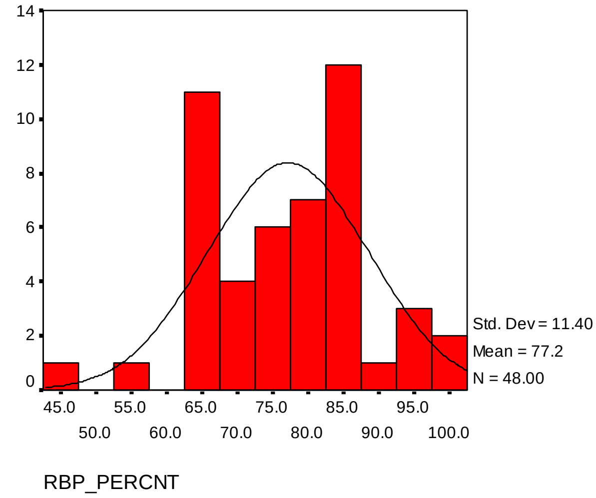


Figure 3-16: PHI sites per rating classification

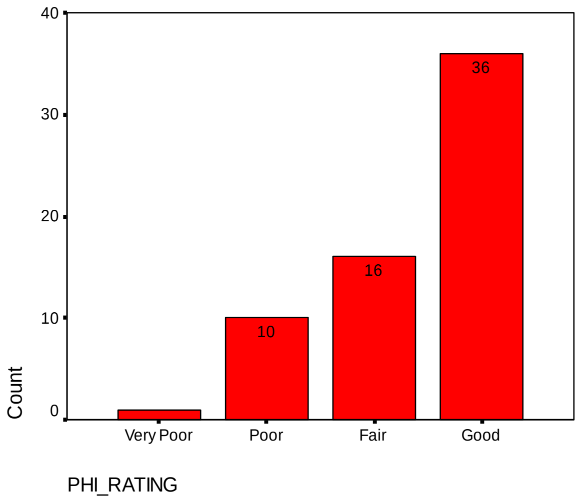
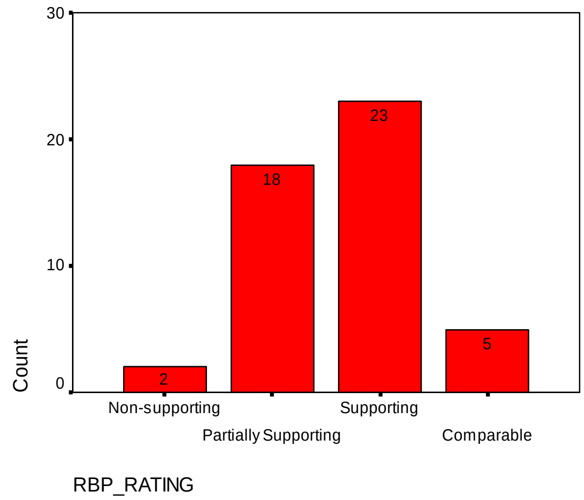


Figure 3-18: RBP sites per rating classification



3.6 WISE Modeling

Prediction is an important component of any management plan to determine the effect of changes in the landscape on aquatic integrity. In regression and correlation analyses attempts are made to discern the association relationship between potential stressors (e.g., land uses) and stream degradation (habitat and biota). Being empirical in nature, a regression model does not represent a functional relationship. Thus, it should not be inferred as a cause-and-effect relationship. In complex systems such as watershed hydrologic modeling exact functional relationships are not known, hence in most cases empirical relationships are used. Therefore, the results of these regression assessments can be used for predictive modeling to develop future management scenarios and establish appropriate goals and success criteria.

The purpose of this analysis is to identify meaningful relationships between in-stream biological conditions (which represent stream health) and subbasin conditions (including habitat and pollutant loadings) in Anne Arundel County's watersheds. The load or concentration of each parameter was quantified using the PLOAD model (see Section 3.7). Also quantified was the aquatic integrity rating of the streams and creeks in the study areas. Aquatic integrity was based on the measures of biotic community structure (such as numbers of sensitive species present) and physical habitat (see Sections 3.3 and 3.5). In this section, regression and correlation analysis, with two variables (dependent and independent), are used to integrate the pollutant levels with stream integrity information to identify key associations for establishing management goals. The correlation and regression analysis is based on the assumption that good biological conditions depend on both good water quality and adequate habitat.

3.6.1 Methods

The WISE analysis consists of a series of correlation, significance, and regression analyses. These analyses were performed using biological, habitat, and pollutant loading data from the study areas. In-stream biological conditions (macroinvertebrate scores) were classified as dependent variables, and subbasin characteristics (including pollutant loadings and habitat scores) were classified as independent variables.

Independent Variables

Independent variables are those that can influence or limit the dependent variables (i.e., in-stream biological conditions). The following parameters were evaluated as independent variables for each monitoring point in the study:

- Stream habitat score (raw score)
- Subbasin area effective imperviousness (percent)
- Annual pollutant loading rates for each of the following pollutants of interest (in pounds per acre per year):
  - Total P
  - Total N
  - Nitrate Plus Nitrite
  - Fecal Coliform
  - Total Copper
  - Total Lead
  - Total Zinc

The PLOAD model was used to determine pollutant loading rates for the Severn River watershed. Detailed information about the development of this PLOAD model can be found in *the Severn River Watershed Management Master Plan Current Conditions Report*, KCI and CH2M HILL, December 2002.

Dependent Variables

There are two basic dependent variables that can be considered in this analysis: *fish score* and *macroinvertebrate score*. The fish score is an aggregate of several fish metrics. Development of the macroinvertebrate score, or Index of Biotic Integrity (IBI), followed the procedures outlined by the Maryland Department of Natural Resources' MBSS method in the Development of a Benthic Index of Biotic Integrity for Maryland Streams December 1998. After identification and enumeration of collected samples to the genus level, the index for the Coastal Plain was used to develop a final IBI score. The Coastal Plain IBI includes seven metrics, or statistical measures, that showed the highest efficiency to classify streams as impacted or non-impacted for Maryland's Coastal Plain streams. The metrics included measures of diversity, tolerance to degradation and abundance of sensitive species. There was no fish data available for this study hence the analysis relied on the macroinvertebrate score for analysis.

Macroinvertebrate data was collected in the field at two different times – Spring 2002 and Spring 2004.

Results

Based on the correlation and significance analysis discussed in more detail in Appendix B, Table 3.27 provides the results using the County's data for the parameters listed above.

Several conclusions can be drawn from Table 3.27:

- Habitat conditions indicate a fair correlation with strong significance with the macroinvertebrate conditions. The correlation results indicate that good habitat is necessary factor needed to achieve higher levels of in-stream biological conditions.
- Macroinvertebrate conditions appear to have inversely proportional relationships with all pollutants of concerns. This stands to reason as increasing amounts of pollutants within a water body can have adverse impacts on the aquatic integrity that resides within the stream. This is further validated by a show of strong significance between most parameters of concern and the macroinvertebrates.
- Percent effective imperviousness appears strongly related to the condition of most pollutants. It also shows inverse relationships with habitat and the macroinvertebrate community. The pollutant loading inputs to the WISE model came from PLOAD which has an inherent dependent relationship on imperviousness as one of the parameters used in the Simple Method equation. However, it is important to note that the WISE results holds true because increased percent effective imperviousness leads to increased sediment and pollution loadings in the streams and elevates stream velocities, which in turn has a negative impact on in-stream biological conditions.

The above paragraphs describe overall conclusions that can be drawn from the statistical data presented in the WISE model determined based on the number of samples collected. This information, as well as guidance from the Center for Watershed Protection, was used to create watershed guidelines for the Severn River. The guideline derivation can be found in Section 5.2 while specific recommendations for the Severn River and its subwatersheds based on the WISE analysis can be found in Section 6.

Table 3-27: Correlation and Significance Analysis

Independent Variable	Dependent Variable	Correlation Coefficient (r value)	Number of Obser-vations	Degree of Freedom	Calculated t-value	Critical t-value	p-value	Correlation Relationship	Relationship Significance
% Effective Imperviousness	TP (lb/ac/yr)	0.97	67	65	30.72	2	0	Strong	Strong
% Effective Imperviousness	TN (lb/ac/yr)	0.99	67	65	57.06	2	0	Strong	Strong
% Effective Imperviousness	NO2+NO3-N (lb/ac/yr)	0.98	67	65	41.18	2	0	Strong	Strong
% Effective Imperviousness	Fecal Coliform (MPN/ac/yr)	0.94	67	65	21.56	2	0	Strong	Strong
% Effective Imperviousness	Total Copper (lb/ac/yr)	0.92	67	65	18.46	2	0	Strong	Strong
% Effective Imperviousness	Total Lead (lb/ac/yr)	0.45	67	65	4.06	2	0	Fair	Strong
% Effective Imperviousness	Total Zinc (lb/ac/yr)	0.89	67	65	15.97	2	0	Strong	Strong
% Effective Imperviousness	Benthic Raw Score	-0.36	67	65	-3.16	2	0	Weak	Strong
% Effective Imperviousness	Habitat Raw Score	-0.19	67	65	-1.52	2	0.13	Weak	Little or None
TP (lb/ac/yr)	Benthic Raw Score	-0.34	67	65	-2.94	2	0	Weak	Strong
TN (lb/ac/yr)	Benthic Raw Score	-0.39	67	65	-3.45	2	0	Weak	Strong
NO2+NO3-N (lb/ac/yr)	Benthic Raw Score	-0.39	67	65	-3.46	2	0	Weak	Strong
Fecal Coliform (MPN/ac/yr)	Benthic Raw Score	-0.43	67	65	-3.8	2	0	Fair	Strong
Total Copper (lb/ac/yr)	Benthic Raw Score	-0.34	67	65	-2.96	2	0	Weak	Strong
Total Lead (lb/ac/yr)	Benthic Raw Score	-0.13	67	65	-1.04	2	0.3	Weak	Little or None
Total Zinc (lb/ac/yr)	Benthic Raw Score	-0.27	67	65	-2.25	2	0.03	Weak	Moderate
Habitat Raw Score	Benthic Raw Score	0.44	67	65	3.97	2	0	Fair	Strong

NOTES:

This correlation matrix is based on strictly linear correlations.

Correlation coefficients range between -1 and 1.

A correlation coefficient value of 0 indicates that there is no correlation between the variables.

Correlation coefficient values of -1 and 1 indicate full correlation between the variables.

A positive correlation coefficient indicates that there is positive correlation between the variables (as one increases, the other increases).

A negative correlation coefficient indicates that there is an inverse correlation between the variables (as one increases, the other decreases).

The Correlation Coefficient (r value) is used to predict the correlation relationship in column L. If the r value is greater than I0.8I, it is deemed to be a strong correlation, if it is greater than I0.4I then it is deemed to be a fair correlation, else it is deemed to be a weak correlation.

The p-value is used to predict the whether the relationship is significant in column M. If p-val<= 0.01 then the significance of the relationship is deemed Strong, if 0.01<p-val<=0.05 it is deemed Moderate, if 0.05<p-val<=0.1 it is deemed Suggestive, else it is deemed Little or None.

3.7 PLOAD Modeling

3.7.1 Pollutant Load Analysis Results

The total pollutant loads discharged from the Severn River Watershed are presented by subwatershed in Tables 3.28 and Table 3.29.

The City of Annapolis was not included in this study – land use information, imperviousness ratings, and BMP information were not obtained. An imperviousness rate of 0% was applied to the land use category “CIT” that represents the City of Annapolis. In addition, the EMCs CIT was zero for all parameters. Therefore, the City of Annapolis was not modeled and no pollutant runoff was calculated for the area. College Creek is contained wholly within the City, therefore, the pollutant loads from College Creek are zero. Spa Creek, Weems Creek, and Back Creek are contained mainly in the City with a small portion in Anne Arundel County. Lake Ogleton, Chase Pond, and Severn River Tidal are contained mainly in Anne Arundel County with small portions located within the city limits. In all of these 6 subwatersheds, the pollutant loads shown are the loads that run off from Anne Arundel County lands only. Although the following figures show the load over the whole subwatershed, it is really only being delivered by the areas within the County.

The subwatershed titled Severn River Tidal (SRT) is actually composed of 31 non-contiguous subwatersheds bordering the Severn River. Unlike Jabez Branch, which was divided into four subwatersheds with unique names (JZ1, JZ2, etc), all of these 31 subwatersheds were given the subwatershed code of SRT. Many of these are very small, and lumping them together creates an overall SRT subwatershed of approximately 1500 acres. PLOAD calculates the total load for the aggregated SRT and displays it across all the pieces.

Table 3-28: Current Conditions 2002 PLOAD Results - Nutrients and Fecal Coliform Annual Loads

		Non-point Source Loads (lbs/yr)				Point Source Loads (lbs/yr)				Non-point Source Loads (lbs/acre/yr)			
Code	Subwatershed Name	TN	NOx	TP	Fecal Coliform (counts/ yr)	TN	NOx	TP	Fecal Coliform (counts/ yr)	TN	NOx	TP	Fecal Coliform (counts/ acre/yr)
AQC	Aisquith Creek	816	275	94	3.07E+12					2.93	0.99	0.34	1.10E+10
ARP	Arden Pond	931	312	109	3.48E+12					4.18	1.40	0.49	1.56E+10
BKC	Back Creek[1]	373	126	48	1.10E+12					0.44	0.15	0.06	1.29E+09
BRB	Bear Branch	3977	1251	519	1.35E+13					6.07	1.91	0.79	2.06E+10
BRC	Browns Cove	775	186	107	2.32E+12					4.16	1.00	0.57	1.25E+10
BWC	Brewer Creek	1045	362	125	3.68E+12					2.38	0.82	0.29	8.38E+09
BWP	Brewer Pond	282	118	44	6.57E+11					0.70	0.29	0.11	1.64E+09
BWS	Brewer Shore	169	56	20	6.44E+11					3.91	1.30	0.46	1.49E+10
CGC	College Creek	0	0	0	0.00E+00					0.00	0.00	0.00	0.00E+00
CHC	Chase Creek	932	330	110	3.25E+12					2.09	0.74	0.25	7.29E+09
CLC	Clements Creek	1654	587	194	5.81E+12					2.18	0.77	0.26	7.67E+09
COC	Cove of Cork	538	176	65	1.91E+12					4.95	1.62	0.60	1.75E+10
CPO	Chase Pond[1]	455	162	48	1.62E+12					5.30	1.88	0.55	1.88E+10
CRC	Carr Creek	2191	752	293	5.52E+12	0	1773.9	6205	1.93E+10	5.49	1.88	0.73	1.38E+10
CSB	Cool Spring Branch	1639	549	193	6.03E+12					4.71	1.58	0.56	1.73E+10
CSC	Cool Spring Creek	237	86	32	6.62E+11					2.07	0.75	0.28	5.79E+09
CWB	Chartwell Branch	3049	1034	351	1.09E+13					3.74	1.27	0.43	1.33E+10
CYB	Cypress Branch	546	191	77	1.51E+12					2.01	0.70	0.28	5.54E+09
EVC	Evergreen Creek	290	113	37	1.13E+12					3.59	1.39	0.46	1.40E+10
FRC	Forked Creek	1071	355	119	3.91E+12					4.31	1.43	0.48	1.57E+10
FXC	Fox Creek	446	147	51	1.68E+12					3.82	1.26	0.44	1.44E+10
GB1	Gumbottom Branch 1	1580	552	216	5.40E+12					1.95	0.68	0.27	6.67E+09
GB2	Gumbottom Branch 2	813	309	105	2.30E+12					1.33	0.51	0.17	3.77E+09
HLA	Heron Lake	340	121	37	1.05E+12					5.65	2.02	0.62	1.74E+10
HOC	Hopkins Creek	607	228	78	1.92E+12					1.26	0.47	0.16	3.97E+09
HSP	Hacketts to Sandy Pt.	2748	922	409	6.56E+12					5.01	1.68	0.74	1.20E+10
ICB	Indian Creek Branch	3386	1117	497	1.03E+13					2.34	0.77	0.34	7.10E+09
JGP	Jonas Green Pond	245	79	31	8.43E+11					4.19	1.35	0.53	1.44E+10
JZ1	Jabez Branch 1	2316	767	316	7.81E+12					2.76	0.91	0.38	9.30E+09
JZ2	Jabez Branch 2	3007	983	440	8.87E+12					2.55	0.83	0.37	7.52E+09
JZ3	Jabez Branch 3	4269	1313	625	1.23E+13					5.46	1.68	0.80	1.57E+10
JZ4	Jabez Branch 4	1350	428	225	4.15E+12					2.26	0.72	0.38	6.95E+09
LKO	Lake Ogleton[1]	1663	552	191	6.22E+12					3.42	1.14	0.39	1.28E+10

		Non-point Source Loads (lbs/yr)				Point Source Loads (lbs/yr)				Non-point Source Loads (lbs/acre/yr)			
Code	Subwatershed Name	TN	NOx	TP	Fecal Coliform (counts/ yr)	TN	NOx	TP	Fecal Coliform (counts/ yr)	TN	NOx	TP	Fecal Coliform (counts/ acre/yr)
LRB	Little Round Bay	1052	356	122	3.79E+12					2.53	0.86	0.29	9.12E+09
LUC	Luce Creek	1148	386	137	3.76E+12					2.98	1.00	0.36	9.78E+09
MAC	Maynadier Creek	1589	588	204	4.76E+12					1.49	0.55	0.19	4.45E+09
MC1	Mill Creek 1	4877	1669	614	1.59E+13					3.41	1.17	0.43	1.11E+10
MC2	Mill Creek 2	3987	1391	522	1.35E+13					2.52	0.88	0.33	8.56E+09
MEC	Meredith Creek	2061	667	354	6.11E+12					2.12	0.69	0.36	6.29E+09
MRP	Martins Pond	41	18	5	9.95E+10					0.70	0.30	0.09	1.71E+09
PFB	Pointfield Branch	651	190	88	2.29E+12					6.23	1.82	0.85	2.19E+10
PMP	Pendennis Mount Pond	498	161	65	1.70E+12					5.39	1.75	0.70	1.84E+10
PSB	Picture Spring Branch	9498	2893	1081	3.91E+13					6.06	1.85	0.69	2.49E+10
RAP	Ray's Pond	318	116	37	1.07E+12					1.64	0.59	0.19	5.51E+09
RBS	Round Bay Shore	495	166	58	1.87E+12					3.97	1.33	0.46	1.50E+10
RGC	Ringgold Cove	403	135	47	1.53E+12					3.33	1.11	0.39	1.26E+10
SHP	Sharps Point	255	78	43	9.44E+11					1.91	0.58	0.32	7.07E+09
SM1	Severn Run Mainstem 1	4799	1561	531	1.92E+13					5.43	1.77	0.60	2.18E+10
SM2	Severn Run Mainstem 2	2261	700	262	8.86E+12					4.26	1.32	0.49	1.67E+10
SM3	Severn Run Mainstem 3	3131	1105	451	9.72E+12					2.13	0.75	0.31	6.60E+09
SM4	Severn Run Mainstem 4	1944	591	234	7.20E+12					2.30	0.70	0.28	8.52E+09
SPC	Spa Creek[1]	375	125	50	1.19E+12					0.24	0.08	0.03	7.71E+08
SRT	Severn River Tidal[1]	4368	1475	506	1.58E+13	0.02	0		3.87E+10	3.72	1.26	0.43	1.35E+10
SSB	Sewell Spring Branch	621	221	95	1.93E+12					1.31	0.46	0.20	4.05E+09
ST1	Severn Run Trib. 1	744	254	99	2.32E+12					2.43	0.83	0.32	7.59E+09
ST2	Severn Run Trib. 2	3658	1145	379	1.38E+13					5.21	1.63	0.54	1.96E+10
ST3	Severn Run Trib. 3	6320	2061	731	2.61E+13					4.05	1.32	0.47	1.67E+10
ST4	Severn Run Trib. 4	1477	514	179	5.25E+12					2.27	0.79	0.28	8.08E+09
ST5	Severn Run Trib. 5	6311	2079	801	2.23E+13					3.61	1.19	0.46	1.28E+10
ST6	Severn Run Trib. 6	1353	434	159	4.14E+12					3.94	1.26	0.46	1.20E+10
ST7	Severn Run Trib. 7	4678	1576	590	1.43E+13					5.40	1.82	0.68	1.65E+10
ST8	Severn Run Trib. 8	1567	491	199	5.42E+12					4.19	1.31	0.53	1.45E+10
ST9	Severn Run Trib. 9	1194	415	162	3.15E+12					3.47	1.21	0.47	9.17E+09
STC	Stevens Creek	540	183	59	2.11E+12					3.61	1.22	0.39	1.41E+10
SVC	Sullivan Cove	760	256	89	2.78E+12					4.63	1.56	0.55	1.69E+10
SWC	Saltworks Creek	3106	1018	355	1.20E+13					3.27	1.07	0.37	1.27E+10
VTC	Valentine Creek	833	284	97	3.09E+12					3.05	1.04	0.35	1.13E+10
WCC	Woolchurch Cove	2648	902	344	6.90E+12					9.82	3.34	1.28	2.56E+10

Code	Subwatershed Name	Non-point Source Loads (lbs/yr) TN	NOx	TP	Fecal Coliform (counts/yr)	Point Source Loads (lbs/yr) TN	NOx	TP	Fecal Coliform (counts/yr)	Non-point Source Loads (lbs/acre/yr) TN	NOx	TP	Fecal Coliform (counts/acre/yr)
WCP	Winchester Pond	286	94	43	7.70E+11					2.66	0.88	0.39	7.15E+09
WEC	Weems Creek[1]	7683	2400	998	2.32E+13					5.00	1.56	0.65	1.51E+10
WH1	Whitehall Creek 1	3371	1112	465	1.06E+13					4.56	1.50	0.63	1.43E+10
WH2	Whitehall Creek 2	1664	543	292	5.37E+12					1.82	0.60	0.32	5.89E+09
WH3	Whitehall Creek 3	1099	360	174	3.13E+12					2.64	0.86	0.42	7.51E+09
YZC	Yantz Creek	1181	394	143	4.15E+12					5.79	1.93	0.70	2.04E+10
TOTAL (Average for lb/ac/yr)		**138585**	**45645**	**17666**	**4.71E+14**	**164969**	**126312**	**68255**	**2.13E+11**	**3.41**	**1.13**	**0.43**	**1.15E+10**

Notes:
[1]These subwatersheds lie in both Anne Arundel County and the City of Annapolis. The pollutant loads shown are the loads that runs off from the Anne Arundel County lands only.

Table 3-29: Current Conditions 2002 PLOAD Results – Metals Annual Loads

Code	Subwatershed Name	Non-point Source Loads (lbs/yr) Zn	Cu	Pb	Point Source Loads (lbs/yr) Zn	Cu	Pb	Non-point Source Loads (lbs/acre/yr) Zn	Cu	Pb
AQC	Aisquith Creek	34	6.7	5.2				0.12	0.02	0.02
ARP	Arden Pond	36	7.8	5.5				0.16	0.03	0.02
BKC	Back Creek[1]	23	3.2	3.1				0.03	0.00	0.00
BRB	Bear Branch	279	47.2	205.1				0.43	0.07	0.31
BRC	Browns Cove	86	13.7	107.8				0.46	0.07	0.58
BWC	Brewer Creek	55	8.4	8.3				0.13	0.02	0.02
BWP	Brewer Pond	36	1.6	5.5				0.09	0.00	0.01
BWS	Brewer Shore	6	1.4	0.9				0.13	0.03	0.02
CGC	College Creek	0	0.0	0.0				0.00	0.00	0.00
CHC	Chase Creek	54	7.3	8.3				0.12	0.02	0.02
CLC	Clements Creek	94	12.9	14.3				0.12	0.02	0.02
COC	Cove of Cork	27	5.0	10.4				0.25	0.05	0.10
CPO	Chase Pond[1]	16	3.6	2.3				0.18	0.04	0.03
CRC	Carr Creek	164	19.0	22.1				0.41	0.05	0.06
CSB	Cool Spring Branch	67	13.7	9.9				0.19	0.04	0.03

		Non-point Source Loads (lbs/yr)			Point Source Loads (lbs/yr)			Non-point Source Loads (lbs/acre/yr)		
Code	Subwatershed Name	Zn	Cu	Pb	Zn	Cu	Pb	Zn	Cu	Pb
CSC	Cool Spring Creek	25	2.6	13.6				0.22	0.02	0.12
CWB	Chartwell Branch	137	25.1	20.6				0.17	0.03	0.03
CYB	Cypress Branch	42	4.3	6.0				0.16	0.02	0.02
EVC	Evergreen Creek	14	2.5	2.3				0.17	0.03	0.03
FRC	Forked Creek	44	9.1	6.5				0.18	0.04	0.03
FXC	Fox Creek	18	3.8	2.8				0.16	0.03	0.02
GB1	Gumbottom Branch	87	12.1	13.3				0.11	0.01	0.02
GB2	Gumbottom Branch	76	6.4	18.2				0.12	0.01	0.03
HLA	Heron Lake	16	2.7	2.3				0.27	0.05	0.04
HOC	Hopkins Creek	47	4.3	7.3				0.10	0.01	0.02
HSP	Hacketts Pt to Sandy Pt.	254	37.2	212.4				0.46	0.07	0.39
ICB	Indian Creek Branch	266	37.4	160.9				0.18	0.03	0.11
JGP	Jonas Green Pond	16	2.8	11.1				0.28	0.05	0.19
JZ1	Jabez Branch 1	146	21.9	56.3				0.17	0.03	0.07
JZ2	Jabez Branch 2	279	37.7	197.5				0.24	0.03	0.17
JZ3	Jabez Branch 3	407	65.4	397.5				0.52	0.08	0.51
JZ4	Jabez Branch 4	100	12.9	43.8				0.17	0.02	0.07
LKO	Lake Ogleton[1]	72	14.0	10.8				0.15	0.03	0.02
LRB	Little Round Bay	55	8.5	8.6				0.13	0.02	0.02
LUC	Luce Creek	71	9.2	11.7				0.18	0.02	0.03
MAC	Maynadier Creek	128	12.0	19.0				0.12	0.01	0.02
MC1	Mill Creek 1	349	49.1	152.9				0.24	0.03	0.11
MC2	Mill Creek 2	243	35.1	79.4				0.15	0.02	0.05
MEC	Meredith Creek	149	21.5	91.4				0.15	0.02	0.09
MRP	Martins Pond	5	0.2	0.8				0.09	0.00	0.01
PFB	Pointfield Branch	57	9.3	63.5				0.54	0.09	0.61
PMP	Pendennis Mount Pond	30	5.7	21.2				0.32	0.06	0.23
PSB	Picture Spring Branch	681	104.5	359.1	0	58.	0	0.43	0.07	0.23
RAP	Ray's Pond	23	2.4	3.5				0.12	0.01	0.02
RBS	Round Bay Shore	19	4.1	2.9				0.15	0.03	0.02
RGC	Ringgold Cove	15	3.4	2.3				0.12	0.03	0.02
SHP	Sharps Point	8	1.7	1.4				0.06	0.01	0.01
SM1	Severn Run Mainstem 1	182	40.6	28.9				0.21	0.05	0.03
SM2	Severn Run Mainstem 2	130	21.1	40.2				0.24	0.04	0.08
SM3	Severn Run Mainstem 3	199	24.5	29.4				0.14	0.02	0.02

		Non-point Source Loads (lbs/yr)			Point Source Loads (lbs/yr)			Non-point Source Loads (lbs/acre/yr)		
Code	Subwatershed Name	Zn	Cu	Pb	Zn	Cu	Pb	Zn	Cu	Pb
SM4	Severn Run Mainstem 4	200	23.4	99.7				0.24	0.03	0.12
SPC	Spa Creek[1]	20	3.1	2.8				0.01	0.00	0.00
SRT	Severn River Tidal[1]	196	36.9	36.4	0	0.019178	0	0.17	0.03	0.03
SSB	Sewell Spring Branch	44	4.5	8.0				0.09	0.01	0.02
ST1	Severn Run Trib. 1	47	6.0	7.3				0.15	0.02	0.02
ST2	Severn Run Trib. 2	214	36.4	119.2				0.30	0.05	0.17
ST3	Severn Run Trib. 3	291	53.5	42.1				0.19	0.03	0.03
ST4	Severn Run Trib. 4	78	11.6	12.1				0.12	0.02	0.02
ST5	Severn Run Trib. 5	317	54.1	75.8				0.18	0.03	0.04
ST6	Severn Run Trib. 6	81	10.8	14.2				0.23	0.03	0.04
ST7	Severn Run Trib. 7	293	39.9	41.3				0.34	0.05	0.05
ST8	Severn Run Trib. 8	128	18.7	82.9				0.34	0.05	0.22
ST9	Severn Run Trib. 9	87	9.9	12.0				0.25	0.03	0.03
STC	Stevens Creek	19	4.2	3.3				0.13	0.03	0.02
SVC	Sullivan Cove	30	6.3	4.5				0.18	0.04	0.03
SWC	Saltworks Creek	203	26.9	27.1				0.21	0.03	0.03
VTC	Valentine Creek	38	6.8	5.7				0.14	0.03	0.02
WCC	Woolchurch Cove	179	23.0	23.7				0.66	0.09	0.09
WCP	Winchester Pond	32	4.4	28.7				0.30	0.04	0.27
WEC	Weems Creek[1]	551	86.1	341.4				0.36	0.06	0.22
WH1	Whitehall Creek 1	263	41.3	198.3				0.36	0.06	0.27
WH2	Whitehall Creek 2	83	11.5	12.6				0.09	0.01	0.01
WH3	Whitehall Creek 3	82	11.3	42.7				0.20	0.03	0.10
YZC	Yantz Creek	51	10.0	7.3				0.25	0.05	0.04
TOTAL (Average for lb/ac/yr)		**8891**	**1347**	**3757**	**0**	**58.4**	**0**	**0.21**	**0.03**	**0.09**

Notes:
[1] These subwatersheds lie in both Anne Arundel County and the City of Annapolis. The pollutant loads shown are the loads that run off from the Anne Arundel County lands only.

In order to determine the overall effectiveness of the over 1400 BMPs in the Severn River watershed, a PLOAD model scenario was run assuming that no BMPs existed. It was found that BMPs treat runoff from approximately 14 percent of the land, producing the overall pollutant reductions presented in Table 3.30.s

Table 3-30: Annual Percent Reduction of Non-point Source Pollutants from Existing BMPs

	TN (lb/yr)	NOx (lb/yr)	TP (lb/yr)	Zn (lb/yr)	Cu (lb/yr)	Pb (lb/yr)	Fecal Coliform (Counts/yr)
Without BMPS	145,097	48,191	19,030	9,383	1,416	3,758	4.71E+14
With BMPS	138,585	45,645	17,666	8,891	1,347	3,757	4.71E+14
Total Load Reduced	6,512	2,546	1,364	491	69	1	1.25E+11
Percent Reduction	4.5%	5.3%	7.2%	5.2%	4.8%	0.0%	0.0%

A forested condition model run scenario was performed to provide a baseline for activities in the County. While this could be construed as a baseline condition, it is important to keep in mind that this assumes that the whole watershed is entirely composed of forest (with the exception of the City of Annapolis) to which it will never return. The results are included in the following two tables – nutrients and fecal coliform data are shown in Table 3.31 and metals data are shown in Table 3.32.

Table 3-31: Forested Condition PLOAD Results – Nutrients and Fecal Coliform Annual Loads

		Non-point Source Loads (lbs/yr)				Non-point Source Loads (lbs/acre/yr)			
Code	Subwatershed Name	TN	NOx	TP	Fecal Coliform (counts/yr)	TN	NOx	TP	Fecal Coliform (counts/acre/yr)
AQC	Aisquith Creek	137	65	18	2.70E+11	0.49	0.23	0.06	9.69E+08
ARP	Arden Pond	109	52	14	2.16E+11	0.49	0.23	0.06	9.69E+08
BKC	Back Creek[1]	27	13	4	5.33E+10	0.03	0.01	0.00	6.24E+07
BRB	Bear Branch	322	152	42	6.35E+11	0.49	0.23	0.06	9.69E+08
BRC	Browns Cove	92	43	12	1.80E+11	0.49	0.23	0.06	9.69E+08
BWC	Brewer Creek	216	102	28	4.26E+11	0.49	0.23	0.06	9.69E+08
BWP	Brewer Pond	197	93	26	3.88E+11	0.49	0.23	0.06	9.69E+08
BWS	Brewer Shore	21	10	3	4.18E+10	0.49	0.23	0.06	9.69E+08
CGC	College Creek	0	0	0	0.00E+00	0.00	0.00	0.00	0.00E+00
CHC	Chase Creek	219	104	29	4.32E+11	0.49	0.23	0.06	9.69E+08
CLC	Clements Creek	372	176	49	7.34E+11	0.49	0.23	0.06	9.69E+08
COC	Cove of Cork	53	25	7	1.05E+11	0.49	0.23	0.06	9.69E+08
CPO	Chase Pond[1]	39	18	5	7.61E+10	0.45	0.21	0.06	8.85E+08
CRC	Carr Creek	196	93	26	3.86E+11	0.49	0.23	0.06	9.69E+08
CSB	Cool Spring Branch	171	81	22	3.37E+11	0.49	0.23	0.06	9.69E+08
CSC	Cool Spring Creek	56	27	7	1.11E+11	0.49	0.23	0.06	9.69E+08
CWB	Chartwell Branch	401	189	52	7.91E+11	0.49	0.23	0.06	9.69E+08
CYB	Cypress Branch	134	63	17	2.64E+11	0.49	0.23	0.06	9.69E+08
EVC	Evergreen Creek	40	19	5	7.83E+10	0.49	0.23	0.06	9.69E+08
FRC	Forked Creek	122	58	16	2.41E+11	0.49	0.23	0.06	9.69E+08
FXC	Fox Creek	57	27	7	1.13E+11	0.49	0.23	0.06	9.69E+08
GB1	Gumbottom Branch 1	398	188	52	7.85E+11	0.49	0.23	0.06	9.69E+08
GB2	Gumbottom Branch 2	300	142	39	5.92E+11	0.49	0.23	0.06	9.69E+08
HLA	Heron Lake	30	14	4	5.83E+10	0.49	0.23	0.06	9.69E+08
HOC	Hopkins Creek	237	112	31	4.67E+11	0.49	0.23	0.06	9.69E+08
HSP	Hacketts Pt to Sandy Pt	270	127	35	5.32E+11	0.49	0.23	0.06	9.69E+08
ICB	Indian Creek Branch	711	336	93	1.40E+12	0.49	0.23	0.06	9.69E+08
JGP	Jonas Green Pond	29	14	4	5.66E+10	0.49	0.23	0.06	9.69E+08
JZ1	Jabez Branch 1	413	195	54	8.14E+11	0.49	0.23	0.06	9.69E+08
JZ2	Jabez Branch 2	580	274	76	1.14E+12	0.49	0.23	0.06	9.69E+08
JZ3	Jabez Branch 3	384	181	50	7.58E+11	0.49	0.23	0.06	9.69E+08
JZ4	Jabez Branch 4	294	139	38	5.79E+11	0.49	0.23	0.06	9.69E+08

		Non-point Source Loads (lbs/yr)				Non-point Source Loads (lbs/acre/yr)			
Code	Subwatershed Name	TN	NOx	TP	Fecal Coliform (counts/yr)	TN	NOx	TP	Fecal Coliform (counts/acre/yr)
LKO	Lake Ogleton[1]	235	111	31	4.63E+11	0.48	0.23	0.06	9.52E+08
LRB	Little Round Bay	204	96	27	4.03E+11	0.49	0.23	0.06	9.69E+08
LUC	Luce Creek	189	89	25	3.73E+11	0.49	0.23	0.06	9.69E+08
MAC	Maynadier Creek	526	248	69	1.04E+12	0.49	0.23	0.06	9.69E+08
MC1	Mill Creek 1	703	332	92	1.39E+12	0.49	0.23	0.06	9.69E+08
MC2	Mill Creek 2	777	367	101	1.53E+12	0.49	0.23	0.06	9.69E+08
MEC	Meredith Creek	478	225	62	9.42E+11	0.49	0.23	0.06	9.69E+08
MRP	Martins Pond	29	13	4	5.63E+10	0.49	0.23	0.06	9.69E+08
PFB	Pointfield Branch	51	24	7	1.01E+11	0.49	0.23	0.06	9.69E+08
PMP	Pendennis Mount Pond	45	21	6	8.95E+10	0.49	0.23	0.06	9.69E+08
PSB	Picture Spring Branch	770	364	100	1.52E+12	0.49	0.23	0.06	9.69E+08
RAP	Ray's Pond	96	45	12	1.88E+11	0.49	0.23	0.06	9.69E+08
RBS	Round Bay Shore	61	29	8	1.21E+11	0.49	0.23	0.06	9.69E+08
RGC	Ringgold Cove	59	28	8	1.17E+11	0.49	0.23	0.06	9.69E+08
SHP	Sharps Point	66	31	9	1.29E+11	0.49	0.23	0.06	9.69E+08
SM1	Severn Mainstem 1	435	205	57	8.57E+11	0.49	0.23	0.06	9.69E+08
SM2	Severn Mainstem 2	261	123	34	5.15E+11	0.49	0.23	0.06	9.69E+08
SM3	Severn Mainstem 3	724	342	94	1.43E+12	0.49	0.23	0.06	9.69E+08
SM4	Severn Mainstem 4	415	196	54	8.19E+11	0.49	0.23	0.06	9.69E+08
SPC	Spa Creek[1]	38	18	5	7.51E+10	0.02	0.01	0.00	4.85E+07
SRT	Severn River Tidal[1]	572	270	75	1.13E+12	0.49	0.23	0.06	9.61E+08
SSB	Sewell Spring Branch	234	110	30	4.61E+11	0.49	0.23	0.06	9.69E+08
ST1	Severn Run Trib. 1	151	71	20	2.97E+11	0.49	0.23	0.06	9.69E+08
ST2	Severn Run Trib. 2	345	163	45	6.81E+11	0.49	0.23	0.06	9.69E+08
ST3	Severn Run Trib. 3	768	363	100	1.51E+12	0.49	0.23	0.06	9.69E+08
ST4	Severn Run Trib. 4	319	151	42	6.30E+11	0.49	0.23	0.06	9.69E+08
ST5	Severn Run Trib. 5	858	405	112	1.69E+12	0.49	0.23	0.06	9.69E+08
ST6	Severn Run Trib. 6	169	80	22	3.33E+11	0.49	0.23	0.06	9.69E+08
ST7	Severn Run Trib. 7	425	201	55	8.39E+11	0.49	0.23	0.06	9.69E+08
ST8	Severn Run Trib. 8	184	87	24	3.62E+11	0.49	0.23	0.06	9.69E+08
ST9	Severn Run Trib. 9	169	80	22	3.33E+11	0.49	0.23	0.06	9.69E+08
STC	Stevens Creek	74	35	10	1.45E+11	0.49	0.23	0.06	9.69E+08
SVC	Sullivan Cove	81	38	11	1.59E+11	0.49	0.23	0.06	9.69E+08
SWC	Saltworks Creek	467	220	61	9.20E+11	0.49	0.23	0.06	9.69E+08

Code	Subwatershed Name	Non-point Source Loads (lbs/yr) TN	NOx	TP	Fecal Coliform (counts/yr)	Non-point Source Loads (lbs/acre/yr) TN	NOx	TP	Fecal Coliform (counts/acre/yr)
VTC	Valentine Creek	134	63	17	2.64E+11	0.49	0.23	0.06	9.69E+08
WCC	Woolchurch Cove	133	63	17	2.61E+11	0.49	0.23	0.06	9.69E+08
WCP	Winchester Pond	53	25	7	1.04E+11	0.49	0.23	0.06	9.69E+08
WEC	Weems Creek[1]	417	197	54	8.21E+11	0.27	0.13	0.04	5.34E+08
WH1	Whitehall Creek 1	363	172	47	7.16E+11	0.49	0.23	0.06	9.69E+08
WH2	Whitehall Creek 2	449	212	59	8.84E+11	0.49	0.23	0.06	9.69E+08
WH3	Whitehall Creek 3	205	97	27	4.04E+11	0.49	0.23	0.06	9.69E+08
YZC	Yantz Creek	100	47	13	1.98E+11	0.49	0.23	0.06	9.69E+08
TOTAL (Average for lb/ac/yr)		**19,456**	**9,187**	**2,538**	**3.84E+13**	**0.49**	**0.23**	**0.06**	**9.69E+08**

Notes:
[1]These subwatersheds lie in both Anne Arundel County and the City of Annapolis. The pollutant loads shown are the loads that run off from the Anne Arundel County lands only.

Table 3-32: Forested Condition PLOAD Results – Metals Annual Loads

Code	Subwatershed Name	Non-point Source Loads (lbs/yr) Zn	Cu	Pb	Non-point Source Loads (lbs/acre/yr) Zn	Cu	Pb
AQC	Aisquith Creek	23	0.7	3.6	0.08	0.00	0.01
ARP	Arden Pond	19	0.6	2.9	0.08	0.00	0.01
BKC	Back Creek[1]	5	0.1	0.7	0.01	0.00	0.00
BRB	Bear Branch	55	1.7	8.4	0.08	0.00	0.01
BRC	Browns Cove	16	0.5	2.4	0.08	0.00	0.01
BWC	Brewer Creek	37	1.1	5.6	0.08	0.00	0.01
BWP	Brewer Pond	33	1.0	5.1	0.08	0.00	0.01
BWS	Brewer Shore	4	0.1	0.6	0.08	0.00	0.01
CGC	College Creek	0	0.0	0.0	0.00	0.00	0.00
CHC	Chase Creek	37	1.1	5.7	0.08	0.00	0.01
CLC	Clements Creek	63	1.9	9.7	0.08	0.00	0.01
COC	Cove of Cork	9	0.3	1.4	0.08	0.00	0.01
CPO	Chase Pond[1]	7	0.2	1.0	0.08	0.00	0.01
CRC	Carr Creek	33	1.0	5.1	0.08	0.00	0.01
CSB	Cool Spring Branch	29	0.9	4.5	0.08	0.00	0.01

Code	Subwatershed Name	Non-point Source Loads (lbs/yr)			Non-point Source Loads (lbs/acre/yr)		
		Zn	Cu	Pb	Zn	Cu	Pb
CSC	Cool Spring Creek	10	0.3	1.5	0.08	0.00	0.01
CWB	Chartwell Branch	68	2.1	10.5	0.08	0.00	0.01
CYB	Cypress Branch	23	0.7	3.5	0.08	0.00	0.01
EVC	Evergreen Creek	7	0.2	1.0	0.08	0.00	0.01
FRC	Forked Creek	21	0.6	3.2	0.08	0.00	0.01
FXC	Fox Creek	10	0.3	1.5	0.08	0.00	0.01
GB1	Gumbottom Branch 1	68	2.1	10.4	0.08	0.00	0.01
GB2	Gumbottom Branch 2	51	1.6	7.8	0.08	0.00	0.01
HLA	Heron Lake	5	0.2	0.8	0.08	0.00	0.01
HOC	Hopkins Creek	40	1.2	6.2	0.08	0.00	0.01
HSP	Hacketts Pt to Sandy Pt	46	1.4	7.0	0.08	0.00	0.01
ICB	Indian Creek Branch	121	3.7	18.6	0.08	0.00	0.01
JGP	Jonas Green Pond	5	0.1	0.7	0.08	0.00	0.01
JZ1	Jabez Branch 1	70	2.2	10.8	0.08	0.00	0.01
JZ2	Jabez Branch 2	98	3.0	15.1	0.08	0.00	0.01
JZ3	Jabez Branch 3	65	2.0	10.0	0.08	0.00	0.01
JZ4	Jabez Branch 4	50	1.5	7.7	0.08	0.00	0.01
LKO	Lake Ogleton[1]	40	1.2	6.1	0.08	0.00	0.01
LRB	Little Round Bay	35	1.1	5.3	0.08	0.00	0.01
LUC	Luce Creek	32	1.0	4.9	0.08	0.00	0.01
MAC	Maynadier Creek	89	2.7	13.7	0.08	0.00	0.01
MC1	Mill Creek 1	119	3.7	18.3	0.08	0.00	0.01
MC2	Mill Creek 2	132	4.1	20.3	0.08	0.00	0.01
MEC	Meredith Creek	81	2.5	12.5	0.08	0.00	0.01
MRP	Martins Pond	5	0.1	0.7	0.08	0.00	0.01
PFB	Pointfield Branch	9	0.3	1.3	0.08	0.00	0.01
PMP	Pendennis Mount Pond	8	0.2	1.2	0.08	0.00	0.01
PSB	Picture Spring Branch	131	4.0	20.1	0.08	0.00	0.01
RAP	Ray's Pond	16	0.5	2.5	0.08	0.00	0.01
RBS	Round Bay Shore	10	0.3	1.6	0.08	0.00	0.01
RGC	Ringgold Cove	10	0.3	1.6	0.08	0.00	0.01
SHP	Sharps Point	11	0.3	1.7	0.08	0.00	0.01
SM1	Severn Mainstem 1	74	2.3	11.3	0.08	0.00	0.01
SM2	Severn Mainstem 2	44	1.4	6.8	0.08	0.00	0.01

		Non-point Source Loads (lbs/yr)			Non-point Source Loads (lbs/acre/yr)		
Code	Subwatershed Name	Zn	Cu	Pb	Zn	Cu	Pb
SM3	Severn Mainstem 3	123	3.8	18.9	0.08	0.00	0.01
SM4	Severn Mainstem 4	70	2.2	10.8	0.08	0.00	0.01
SPC	Spa Creek[1]	6	0.2	1.0	0.00	0.00	0.00
SRT	Severn River Tidal[1]	97	3.0	14.9	0.08	0.00	0.01
SSB	Sewell Spring Branch	40	1.2	6.1	0.08	0.00	0.01
ST1	Severn Run Trib 1	26	0.8	3.9	0.08	0.00	0.01
ST2	Severn Run Trib 2	59	1.8	9.0	0.08	0.00	0.01
ST3	Severn Run Trib 3	130	4.0	20.0	0.08	0.00	0.01
ST4	Severn Run Trib 4	54	1.7	8.3	0.08	0.00	0.01
ST5	Severn Run Trib 5	146	4.5	22.4	0.08	0.00	0.01
ST6	Severn Run Trib 6	29	0.9	4.4	0.08	0.00	0.01
ST7	Severn Run Trib 7	72	2.2	11.1	0.08	0.00	0.01
ST8	Severn Run Trib 8	31	1.0	4.8	0.08	0.00	0.01
ST9	Severn Run Trib 9	29	0.9	4.4	0.08	0.00	0.01
STC	Stevens Creek	12	0.4	1.9	0.08	0.00	0.01
SVC	Sullivan Cove	14	0.4	2.1	0.08	0.00	0.01
SWC	Saltworks Creek	79	2.4	12.2	0.08	0.00	0.01
VTC	Valentine Creek	23	0.7	3.5	0.08	0.00	0.01
WCC	Woolchurch Cove	22	0.7	3.5	0.08	0.00	0.01
WCP	Winchester Pond	9	0.3	1.4	0.08	0.00	0.01
WEC	Weems Creek[1]	71	2.2	10.9	0.05	0.00	0.01
WH1	Whitehall Creek 1	62	1.9	9.5	0.08	0.00	0.01
WH2	Whitehall Creek 2	76	2.3	11.7	0.08	0.00	0.01
WH3	Whitehall Creek 3	35	1.1	5.3	0.08	0.00	0.01
YZC	Yantz Creek	17	0.5	2.6	0.08	0.00	0.01
TOTAL	**(Average for lb/ac/yr)**	**3,299**	**101.5**	**507.6**	**0.08**	**0.00**	**0.01**

Notes:
1These subwatersheds lie in both Anne Arundel County and the City of Annapolis. The pollutant loads shown are the loads that runs off from the Anne Arundel County lands only.

The PLOAD results represent total loads and as loads per acre for the watershed for runoff pollutants. Without completing a receiving water analysis, it is not possible to determine the relationship of pollutant loading to the overall health of the estuarine Severn River. Other conclusions can be inferred from the model results, however.

For nutrients, annual loads from point sources were higher than runoff loads. The sources were the U.S. Naval Academy discharging to Carr Creek and the Annapolis Water Reclamation FC discharging to the tidal Severn. These two sources represented 79% of the total phosphorus (TP), 73% of the nitrate-nitrite (NOx), and 54% of the total nitrogen loads from the model.

Fecal coliform loads were more than 2,000 times higher from runoff than from point sources. Again, the same two point sources were the sources of the discharges.

When runoff loads are normalized by area, loads are within the typical range for residential and commercial land uses. TN loads are 3.4 lb/ac/yr, TP loads are 0.43 lb/ac/yr, and NOx loads are 1.13 lb/ac/yr. By way of comparison, if the Severn River watershed was completely forested, loading rates in lb/ac/yr would be 0.49 for TN, 0.23 for NOx, and 0.06 for TP.

Other than the subwatersheds draining the City of Annapolis, Woolchurch Cove had the highest runoff loads per acre for both TN and TP. Bear Branch, Pointfield Branch, Yantz Creek, Carr Creek, Jabez Branch 3, and Picture Spring Branch are also among the highest areas for runoff loads. They are also among the subwatersheds with the highest imperviousness.

For metals, the highest annual loads were from runoff. The only significant point source was from is the International Paper facility in Picture Spring Branch, which draws groundwater for its cooling systems. The groundwater is naturally high in copper, with concentrations that are acceptable by drinking water standards. Point source copper loads were 58 lb/yr from this source, versus 1,347 lb/yr from runoff, or 4% of the total loads.

Normalized loads for zinc, copper, and lead were 0.21, 0.03, and 0.09 lb/ac/yr, respectively, within the typical range for residential land uses. They are 2 to 8 times higher than the loads from equivalent forested areas.

In order to determine the overall effectiveness of the over 1400 BMPs in the Severn River watershed, a scenario was run assuming that no BMPs existed. It was found that BMPs treat runoff from approximately 14 percent of the land, producing the overall pollutant reductions of 5 to 7 percent.

3.8 TR20 Modeling

TR-20 modeling was conducted to provide estimates of runoff volume and streamflow for rainfall events with return periods of 1-, 2-, 5-, 10-, 50-, and 100-years. The model results presented in table 3.33 represent runoff from each subwatershed, but not the flows routed from upstream. This allows comparisons of the severity of runoff effects among different subwatersheds.

Information on how the model was developed and the data used can be found in Appendix B.

Results from the current conditions TR-20 modeling were used as input to the hydraulic analysis of four subwatersheds discussed in Section 3.10. In this case, routed streamflows were used as input to the hydraulic models.

Table 3-33: TR-20 Results

Code	Subwatershed Name	Area (ac)	1 Year (cfs)	2 Year (cfs)	5 Year (cfs)	10 Year (cfs)	50 Year (cfs)	100 Year (cfs)
AQC	Aisquith Creek	278.1	64	122	390	508	614	784
ARP	Arden Pond	222.5	37	75	253	331	403	513
BRB	Bear Branch	655.8	185	261	592	741	873	1085
BRC	Browns Cove	186.2	82	135	356	446	530	658
BWC	Brewer Creek	439.1	142	236	618	776	913	1130
BWP	Brewer Pond	400.9	80	142	425	544	652	818
BWS	Brewer Shore	43.1	54	81	184	224	258	306
CHC	Chase Creek	446.3	88	166	503	648	776	979
CLC	Clements Creek	757.3	107	175	496	642	778	993
COC	Cove of Cork	108.8	66	108	264	327	381	460
CPO	Chase Pond	86.0	89	126	254	303	345	409
CRC	Carr Creek	398.8	299	399	732	856	968	1133
CSB	Cool Spring Branch	348.1	1	7	109	176	243	360
CSC	Cool Spring Creek	114.4	10	32	155	212	264	346
CWB	Chartwell Branch	815.9	29	77	384	542	692	938
CYB	Cypress Branch	272.0	18	38	135	179	219	283
EVC	Evergreen Creek	80.8	1	2	28	60	87	127
FRC	Forked Creek	248.3	55	114	368	477	579	735
FXC	Fox Creek	116.7	29	60	195	256	305	389
GB1	Gumbottom Branch 1	810.0	58	116	403	529	661	856
GB2	Gumbottom Branch 2	610.5	22	60	275	382	482	643
HLA	Heron Lake	60.2	68	98	204	244	277	331
HOC	Hopkins Creek	482.4	117	208	568	717	849	1053
HSP	Hacketts Pt to Sandy Pt	548.5	313	446	898	1071	1220	1445
ICB	Indian Creek Branch	1,447.0	117	243	849	1124	1375	1770
JGP	Jonas Green Pond	58.4	23	44	130	166	197	248
JZ1	Jabez Branch 1	839.5	148	266	773	993	1189	1492
JZ2	Jabez Branch 2	1,179.8	146	292	993	1317	1605	2064
JZ3	Jabez Branch 3	782.1	183	312	825	1057	1301	1638
JZ4	Jabez Branch 4	597.2	110	185	488	615	728	903
LKO	Lake Ogleton	486.1	203	331	806	1004	1170	1427
LRB	Little Round Bay	415.7	110	190	516	652	775	967
LUC	Luce Creek	384.8	75	150	488	635	768	976
MAC	Maynadier Creek	1,069.8	137	258	799	1047	1251	1601
MC1	Mill Creek 1	1,430.2	383	658	1746	2217	2626	3260
MC2	Mill Creek 2	1,581.9	436	744	1946	2454	2897	3590
MEC	Meredith Creek	971.7	240	358	783	950	1098	1321
MRP	Martins Pond	58.1	4	11	53	73	92	121
PFB	Pointfield Branch	104.4	54	82	189	231	268	325
PMP	Pendennis Mount Pond	92.4	73	117	278	341	397	482
PSB	Picture Spring Branch	1,566.7	387	654	1,796	2,286	2,709	3,374
RAP	Ray's Pond	194.4	82	143	375	471	555	684
RBS	Round Bay Shore	124.7	49	97	301	388	466	589
RGC	Ringgold Cove	121.0	4	21	134	190	242	324

Code	Subwatershed Name	Area (ac)	1 Year (cfs)	2 Year (cfs)	5 Year (cfs)	10 Year (cfs)	50 Year (cfs)	100 Year (cfs)
SHP	Sharps Point	133.6	98	143	309	384	442	530
SM1	Severn Mainstem 1	884.1	64	146	574	776	960	1256
SM2	Severn Mainstem 2	531.4	28	61	234	315	391	510
SM3	Severn Mainstem 3	1,472.6	30	86	424	601	770	1045
SM4	Severn Mainstem 4	845.0	38	73	261	358	451	600
SSB	Sewell Spring Branch	475.6	34	70	246	328	403	521
ST1	Severn Run Tributary 1	306.4	31	59	185	239	288	371
ST2	Severn Run Tributary 2	702.5	33	81	349	478	597	786
ST3	Severn Run Tributary 3	1,562.2	22	68	418	608	790	1092
ST4	Severn Run Tributary 4	649.9	3	9	65	100	134	194
ST5	Severn Run Tributary 5	1,746.7	38	83	378	552	716	987
ST6	Severn Run Tributary 6	343.5	61	74	147	216	257	319
ST7	Severn Run Tributary 7	865.7	223	347	891	1125	1344	1690
ST8	Severn Run Tributary 8	373.6	69	119	329	422	505	637
ST9	Severn Run Tributary 9	344.1	75	129	343	434	513	636
STC	Stevens Creek	149.8	1	5	57	87	117	166
SVC	Sullivan Cove	164.2	39	76	234	302	361	455
SWC	Saltworks Creek	949.4	78	156	487	630	754	954
VTC	Valentine Creek	272.9	54	117	402	528	637	817
WCC	Woolchurch Cove	269.7	384	528	1001	1179	1330	1559
WCP	Winchester Pond	107.7	37	70	205	263	316	400
WH1	Whitehall Creek 1	739.1	165	262	727	924	1100	1371
WH2	Whitehall Creek 2	912.6	373	583	1352	1658	1926	2336
WH3	Whitehall Creek 3	417.0	125	193	440	537	622	751
YZC	Yantz Creek	204.0	33	75	269	356	432	554

With TR-20, it is not as easy to determine if the results are within the range of other similar watersheds as it is with pollutant loading models. Because the input data are more complex, there are no simple methods of normalization (such as by watershed area). Results of the modeling are within the range of other hydrologic model results, however. Tests with a set of subwatersheds using the TR-55, and GIS-HYDRO showed results to be within a factor of 2. Rational Method tests gave considerably higher peaks.

The results show, unsurprisingly, that the subwatersheds with the largest area tend to have the largest peak flows. These include Mill Creek (MC1 and MC2), Picture Spring Branch (PSB), and Whitehall Creek 2 (WH2), which have the four highest flows for both the 2-year and 100-year events and are in the top 15 for drainage area.

The watersheds with the largest departure from forested conditions (largest change in peak flows due to development) for the 2-year event, are Picture Spring Branch, Bear Branch, Woolchurch Cove, Mill Creek, Whitehall Creek 2, and Carr Creek. Four of these watersheds (all except Mill Creek and Whitehall Creek) are among the top five in imperviousness as well. This information is summarized in Chapter 5.

3.9 GWLF Modeling

3.9.1 Water Balance

The GWLF model was run to develop information on rainfall-runoff relationships using twenty-five years worth of rainfall data. The model uses TR-20 relationships to determine the amount of direct runoff, then uses evaporation rates based on location and vegetation to calculate evapotranspiration. The remaining portion of rainfall is assumed to be infiltrated.

Infiltrated water can remain as shallow groundwater or be lost to deep aquifer recharge. For the purposes of this study, no recharge was assumed and all shallow groundwater was assumed to flow to streams. As a result, in the following table, it can be seen that streamflow is equal to groundwater plus direct runoff.

Table 3-34: Existing Conditions Results - Water Balance

Subwatershed	Precip (in)	ET (in)	GW (in)	DRO (in)	Stream (in)
AQC	43.05	9.13	32.40	1.62	34.01
ARP	43.05	8.77	32.77	1.60	34.37
BKC	43.05	1.03	1.42	40.76	42.18
BRB	43.05	7.50	32.48	3.16	35.65
BRC	43.05	7.90	31.64	3.61	35.24
BWC	43.05	9.18	31.56	2.40	33.96
BWP	43.05	9.24	31.78	2.12	33.90
BWS	43.05	9.16	30.42	3.56	33.99
CGC	43.05	0.00	0.16	43.05	43.21
CHC	43.05	9.18	31.98	1.98	33.96
CLC	43.05	9.26	32.39	1.49	33.88
COC	43.05	8.33	31.36	3.45	34.81
CPO	43.05	7.90	24.98	10.28	35.26
CRC	43.05	7.66	29.23	6.25	35.49
CSB	43.05	8.69	33.78	0.67	34.45
CSC	43.05	9.33	32.51	1.31	33.82
CWB	43.05	8.81	32.75	1.59	34.34
CYB	43.05	8.79	32.32	2.04	34.36
EVC	43.05	8.66	32.75	1.73	34.48
FRC	43.05	8.82	31.78	2.54	34.33
FXC	43.05	8.89	32.56	1.70	34.26
GB1	43.05	8.99	32.69	1.47	34.16
GB2	43.05	9.22	32.73	1.19	33.92
HLA	43.05	8.39	26.62	8.14	34.76
HOC	43.05	9.26	31.53	2.35	33.88
HSP	43.05	7.57	26.64	8.94	35.58
ICB	43.05	8.81	32.34	1.99	34.33
JGP	43.05	8.79	32.02	2.34	34.36
JZ1	43.05	8.66	32.05	2.43	34.48
JZ2	43.05	8.71	32.25	2.18	34.43
JZ3	43.05	7.55	31.18	4.42	35.60
JZ4	43.05	8.34	31.63	3.18	34.80
LKO	43.05	8.87	30.89	3.38	34.27
LRB	43.05	9.00	32.19	1.95	34.14
LUC	43.05	8.69	32.05	2.40	34.45
MAC	43.05	9.18	31.99	1.98	33.96
MC1	43.05	8.50	31.43	3.22	34.65
MC2	43.05	8.96	31.54	2.64	34.19
MEC	43.05	8.54	30.51	4.09	34.60
MRP	43.05	9.34	32.78	1.02	33.80
PFB	43.05	6.98	31.17	4.99	36.16
PMP	43.05	8.53	31.13	3.49	34.61
PSB	43.05	7.21	31.95	3.98	35.93

Subwatershed	Precip (in)	ET (in)	GW (in)	DRO (in)	Stream (in)
RAP	43.05	9.36	31.40	2.39	33.79
RBS	43.05	9.05	32.52	1.58	34.10
RGC	43.05	9.19	33.15	0.80	33.95
SHP	43.05	8.08	30.02	5.05	35.07
SM1	43.05	8.21	33.66	1.27	34.93
SM2	43.05	8.26	32.88	2.00	34.88
SM3	43.05	8.74	32.93	1.47	34.40
SM4	43.05	8.67	32.78	1.69	34.48
SPC	43.05	0.81	1.17	41.22	42.39
SSB	43.05	9.06	32.56	1.53	34.08
ST1	43.05	8.61	32.15	2.38	34.53
ST2	43.05	7.91	33.23	2.01	35.24
ST3	43.05	8.40	33.63	1.12	34.75
ST4	43.05	8.99	33.48	0.68	34.16
ST5	43.05	8.44	33.28	1.43	34.71
ST6	43.05	7.98	30.14	5.03	35.17
ST7	43.05	7.59	30.56	5.00	35.56
ST8	43.05	7.85	32.17	3.13	35.29
ST9	43.05	8.34	31.01	3.79	34.81
STC	43.05	8.97	32.81	1.37	34.18
SVC	43.05	8.67	32.32	2.16	34.48
SWC	43.05	8.51	31.29	3.35	34.63
VTC	43.05	8.97	32.71	1.46	34.17
WCC	43.05	6.29	26.30	10.56	36.86
WCP	43.05	8.86	31.56	2.73	34.29
WEC	43.05	1.40	17.48	24.30	41.77
WH1	43.05	7.95	31.24	3.96	35.20
WH2	43.05	8.72	30.72	3.71	34.43
WH3	43.05	8.35	30.04	4.76	34.80
YZC	43.05	8.31	32.94	1.90	34.84
Average	43.05	7.66	29.12	6.37	35.49

Discounting the subwatersheds draining Annapolis, the results showed that twenty percent of the rainfall was returned to the atmosphere through evaporation or transpiration by plants. Seventy-four percent infiltrated to shallow groundwater and six percent ran off into streams. Deep aquifer recharge was not modeled.

Since the shallow groundwater component represents baseflow to the streams, the modeling shows that on average, over the watershed, about ninety-two percent of streamflow comes from baseflow, and eight percent from storm runoff.

3.9.2 Pollutant Loading

GWLF reports pollutant loading in two different output tables. The first is by type of pollutant. Erosion and sediment are calculated for rural (undeveloped) land using the Universal Soil Loss Equation. Watersheds with no erosion are those which had no agricultural land use and very little forest or open space. Nitrogen and phosphorus are reported for both the total and dissolved fractions. Table 3.35 shows the results of the analysis.

The second method of reporting loads is for nitrogen and phosphorus by source, shown in Table 3.36. Loads are reported for septic systems, groundwater, and runoff. Runoff loads can be either dissolved, coming from urban runoff and agricultural sources, or solid, which are pollutants attached to sediment coming from rural land uses. Groundwater loads are all dissolved and represent loads from constant concentrations measured in groundwater.

Table 3-35: Existing Conditions Results - Pollutants

Subwatershed	Erosion (lb/yr)	Sediment (lb/yr)	DissN (lb/yr)	TotalN (lb/yr)	DissP (lb/yr)	TotalP (lb/yr)
AQC	62,861	16,344	3,237	3,243	101	105
ARP	24,470	6,362	15,856	15,954	148	160
BKC	7,480	1,945	4,000	4,058	98	107
BRB	133,480	34,705	12,573	12,624	573	592
BRC	20,495	5,329	3,039	3,073	172	181
BWC	56,564	14,707	7,688	7,746	189	197
BWP	497,559	129,365	1,684	1,694	113	114
BWS	-	-	1,229	1,234	26	27
CGC	-	-	10	10	1	1
CHC	74,602	19,396	7,858	7,873	187	195
CLC	86,222	22,418	12,667	12,712	287	303
COC	19,106	4,968	5,151	5,160	100	104
CPO	16,822	4,374	3,322	3,408	97	108
CRC	241,012	62,663	4,311	4,468	403	427
CSB	-	-	5,723	5,756	132	137
CSC	-	-	674	681	45	47
CWB	239,897	62,373	20,184	20,238	352	372
CYB	283,376	73,678	3,605	3,632	121	125
EVC	4,598	1,196	1,812	1,814	40	41
FRC	719	187	1,927	2,012	114	124
FXC	3,298	857	5,719	5,745	73	77
GB1	1,096,127	284,993	15,065	15,081	319	324
GB2	121,404	31,565	4,107	4,122	173	178
HLA	5,895	1,533	1,013	1,066	57	64
HOC	267,550	69,563	3,409	3,417	154	157
HSP	470,581	122,351	7,530	7,830	789	842
ICB	1,999,185	519,788	16,534	16,632	664	683
JGP	-	-	1,932	1,944	40	42
JZ1	548,542	142,621	15,427	15,489	510	543
JZ2	907,509	235,952	11,508	11,596	558	597
JZ3	750,119	195,031	15,110	15,262	834	873
JZ4	1,379,544	358,681	5,298	5,330	383	618
LKO	91,872	23,887	3,780	3,853	275	294
LRB	4,905	1,275	11,982	11,998	216	222
LUC	20,360	5,294	6,722	6,734	198	204
MAC	346,821	90,173	9,195	9,229	363	372
MC1	43,734	11,371	22,395	22,499	854	975
MC2	956,333	248,647	27,173	27,262	755	862
MEC	1,133,259	294,647	11,808	11,886	715	735
MRP	-	-	226	227	13	13
PFB	120,824	31,414	2,802	2,810	141	146
PMP	-	-	4,085	4,132	94	101
PSB	367,592	95,574	30,397	30,527	1,413	1,501
RAP	27,436	7,118	1,657	1,667	74	75
RBS	11,074	2,818	1,308	1,316	70	71
RGC	44,209	11,494	1,814	1,815	34	34
SHP	394,078	102,460	1,686	1,689	109	110
SM1	136,287	35,435	7,102	7,129	405	418
SM2	177,755	46,216	7,846	7,871	336	345
SM3	399,643	103,907	15,392	15,425	559	572
SM4	83,563	21,726	5,604	5,639	401	414
SPC	60,693	15,780	3,075	3,113	196	204
SSB	231,634	60,225	3,923	3,938	142	145
ST1	286,479	74,485	2,901	2,908	143	146
ST2	36,870	9,586	5,193	5,219	376	391
ST3	320,602	83,356	43,076	43,112	739	756
ST4	93,753	24,376	4,880	4,887	170	174
ST5	566,559	147,305	38,852	38,903	751	845

Subwatershed	Erosion (lb/yr)	Sediment (lb/yr)	DissN (lb/yr)	TotalN (lb/yr)	DissP (lb/yr)	TotalP (lb/yr)
ST6	25,141	6,537	5,301	5,320	270	285
ST7	27,825	7,235	24,471	24,587	844	1,128
ST8	93,241	24,243	5,989	6,009	245	477
ST9	105,597	27,455	3,171	3,304	234	255
STC	79	20	1,407	1,409	44	45
SVC	5,173	1,345	1,942	2,035	130	145
SWC	100,206	26,053	16,164	16,236	615	644
VTC	6,911	1,797	13,505	13,520	173	176
WCC	42,703	11,103	5,651	5,991	382	428
WCP	73,224	19,038	927	949	64	67
WEC	70,924	18,440	33,321	33,736	1,476	1,620
WH1	160,276	41,672	12,507	12,572	646	734
WH2	2,016,906	524,396	11,695	11,818	605	625
WH3	705,946	183,546	4,397	4,433	326	341
YZC	41,237	10,721	1,702	1,755	148	156
TOTAL	18,750,743	4,875,116	636,223	640,365	23,596	25,716

Table 3-36: Existing Conditions Results - Nutrients by Source

Subwatershed	SepticN (lb/yr)	SepticP (lb/yr)	GW N (lb/yr)	GW P (lb/yr)	RO N (lb/yr)	RO P (lb/yr)
AQC	1,922	2	807	47	514	56
ARP	14,140	15	653	38	1,162	107
BKC	3,061	3	109	6	888	98
BRB	6,005	7	1,908	111	4,711	474
BRC	970	1	527	31	1,576	149
BWC	5,353	6	1,241	72	1,151	119
BWP	197	-	1,141	66	356	48
BWS	933	1	117	7	184	19
CGC	-	-	10	1	(0)	0
CHC	5,541	6	1,278	74	1,054	114
CLC	9,006	10	2,195	128	1,511	166
COC	4,051	4	306	18	803	82
CPO	2,172	2	192	11	1,043	95
CRC	-	-	1,044	61	3,424	366
CSB	4,007	4	1,053	61	696	72
CSC	71	-	333	19	277	27
CWB	15,763	17	2,393	139	2,081	216
CYB	2,187	2	787	46	658	77
EVC	1,337	1	237	14	241	26
FRC	314	-	707	41	991	83
FXC	4,894	5	340	20	511	52
GB1	11,287	12	2,371	138	1,423	175
GB2	1,646	2	1,788	104	688	72
HLA	268	-	143	8	655	55
HOC	1,393	2	1,362	79	662	76
HSP	137	-	1,309	76	6,385	765
ICB	8,681	10	4,190	244	3,761	429
JGP	1,464	2	167	10	313	31
JZ1	9,885	11	2,409	140	3,195	392
JZ2	4,421	5	3,407	198	3,768	393
JZ3	5,954	7	2,184	127	7,124	740
JZ4	1,743	2	1,691	98	1,895	518
LKO	234	-	1,344	78	2,276	216
LRB	9,406	10	1,198	70	1,394	143
LUC	4,305	5	1,105	64	1,324	135
MAC	4,454	5	3,064	178	1,711	189
MC1	11,381	12	4,026	234	7,093	729

Subwatershed	SepticN (lb/yr)	SepticP (lb/yr)	GW N (lb/yr)	GW P (lb/yr)	RO N (lb/yr)	RO P (lb/yr)
MC2	17,937	19	4,468	260	4,857	583
MEC	5,465	6	2,655	155	3,766	575
MRP	28	-	171	10	28	3
PFB	1,279	1	292	17	1,239	128
PMP	3,077	3	258	15	797	83
PSB	12,809	14	4,483	261	13,235	1,226
RAP	714	1	546	32	406	43
RBS	485	1	363	21	468	49
RGC	1,346	1	359	21	110	12
SHP	954	1	359	21	375	88
SM1	1,542	2	2,665	155	2,923	261
SM2	3,933	4	1,565	91	2,373	250
SM3	8,514	9	4,343	253	2,569	310
SM4	453	0	2,481	144	2,705	269
SPC	1,944	2	163	9	1,006	192
SSB	2,119	2	1,387	81	433	62
ST1	1,237	1	882	51	789	94
ST2	1	-	2,090	122	3,128	269
ST3	34,295	37	4,704	274	4,113	445
ST4	2,328	3	1,948	113	611	57
ST5	29,401	31	5,205	303	4,296	510
ST6	2,161	2	927	54	2,232	229
ST7	15,328	16	2,369	138	6,890	973
ST8	2,863	3	1,076	63	2,070	412
ST9	570	1	955	56	1,779	198
STC	710	1	440	26	259	19
SVC	483	1	475	28	1,077	116
SWC	8,844	10	2,659	155	4,734	479
VTC	11,610	13	799	47	1,111	117
WCC	1,201	1	635	37	4,155	390
WCP	145	-	304	18	500	50
WEC	16,895	18	2,406	140	14,435	1,462
WH1	5,096	6	2,067	120	5,409	608
WH2	6,721	7	2,510	146	2,587	472
WH3	1,448	2	1,121	65	1,864	274
YZC	23	-	602	35	1,130	121
TOTAL	362,539	384	109,871	6,398	167,955	18,934

Loads from septic systems can be a large part of the nutrient load for a low-density watershed, especially for nitrogen. Septic systems can be a significant source of loads even if they are working properly. The modeling showed that for nitrogen, septic systems were the major source in the Severn River, producing 57% of the annual load, with runoff providing 26% and groundwater 17%. This was not the case for phosphorus, where runoff was the primary source at 74%, with groundwater contributing 25% of the load and septic systems just 1 %.

3.9.3 Comparison of Pollutant Loading Models

Runoff pollutant loads from urban land uses are estimated by both PLOAD and GWLF. The two models use completely different calculation methods: for example, PLOAD estimates runoff and loads based on a single annual rainfall total, while GWLF runs a continuous simulation of daily rainfall events.

In order to verify that the two models were producing similar results, an analysis was made of runoff loads, comparing TN and TP loads calculated by PLOAD with those generated by GWLF. Both loads included reductions from BMPs. General observations were as follows:

- For the watershed as a whole, GWLF estimated TN loads to be 124% of PLOAD, and estimated TP loads to be 106% of PLOAD.

- There were 50 out of 70 subwatersheds where GWLF estimated higher TN loads than PLOAD and 38 out of 70 subwatersheds where GWLF estimated higher TP loads.
- There is a weak trend for GWLF to estimate higher loads for both nutrients than PLOAD as imperviousness increases.
- For each subwatershed, the ratios for TN and TP were consistent. Both were low or high with similar magnitude.
- The subwatersheds where GWLF reported higher TP loads than PLOAD had a large portion of agricultural land use (Whitehall Creek, Meredith Creek, Jabez Branch 4). The trend was similar, but not as pronounced for TN loads.

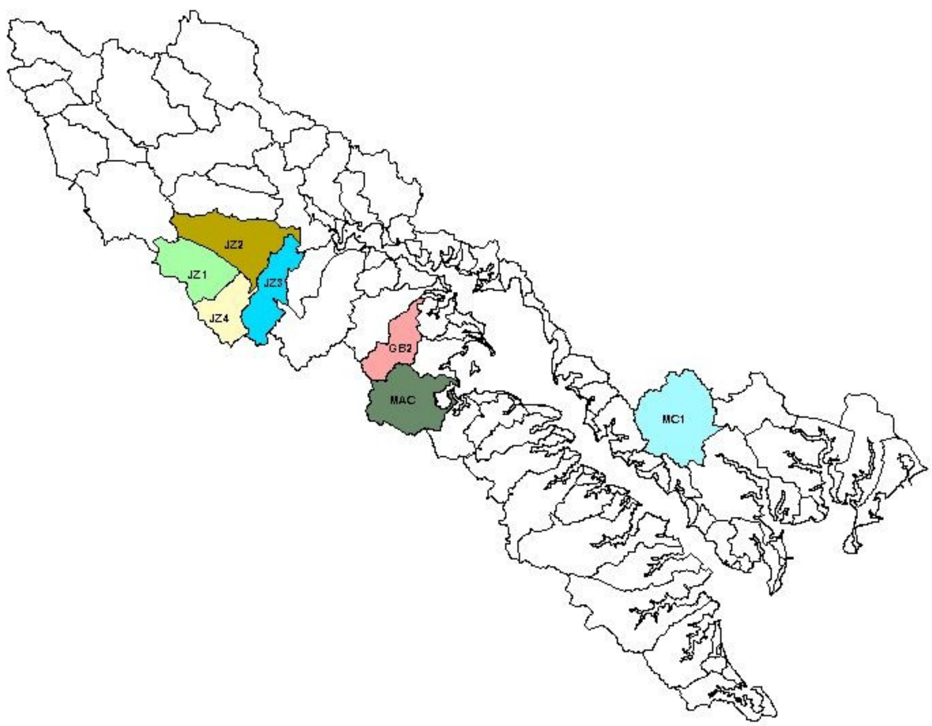
3.10 HECRAS Modeling

3.10.1 Introduction

This section presents the results of hydraulic models using HEC-RAS for approximately 20 miles of stream and HY-8/HEC-RAS for 50 stream crossings within the Severn River Watershed. This analysis was completed to identify areas of stream erosion and flood-prone stream crossings.

The project Scope of Work called for modeling a subset of twenty miles of the streams in the watershed. The approach taken was to model all of the streams in three subwatersheds instead of isolated stream reaches throughout the entire watershed. Stream systems included in this study were those contained in the Jabez Branch, Gumbottom 2, Mill Creek 1, and Maynadier subwatersheds. Figure 3.19 shows the subwatersheds that were assessed.

Figure 3-19: Modeled Subwatersheds



3.10.2 Existing Conditions

Stream Hydraulics

The primary purpose of the hydraulic modeling for this project was to identify stream reaches that may be at risk for erosion. To assess erosion, KCI compared tractive forces computed by HEC-RAS to critical shear stresses for the bed materials. The tractive force is proportional to the shear stress of the water acting on the bed and bank materials.

Critical shear stress is the maximum shear force per unit area (stress) that will not cause serious erosion of the material forming the channel bed on a level surface. Critical shear stress computations were performed using a two-step process using the following formulas:

1. $\tau^*_{ci} = 0.0384\ (d_i/d_{50})^{-0.887}$, where

τ^*_{ci} = dimensionless critical shear stress
d_{50} = diameter of the grain size constituting 50 percent of the bed material
d_i = diameter of the grain size fraction of concern

2. $\tau_c = \tau^*_{ci} (\gamma_b - \gamma_w) d_i$, where

τ_c = critical shear stress
γ_b = bulk unit weight of sediment (165 lb/ft^3)
γ_w = unit weight of water (62.4 lb/ ft^3)
d_i = diameter of the soil fraction of concern

Site-specific data regarding bed material was available from the geomorphic assessment performed in 2004. The Team used values for the mean bed material diameter which were estimated from 95 pebble counts performed during the assessment. To identify stream reaches where erosion would be likely, modeled tractive forces were compared to the average critical shear stress; erosion was assumed to occur if the modeled shear stress exceeded the average critical shear stress.

The reasonableness of these results was assessed by comparing the average critical shear stress to tractive force data computed by HEC-RAS for cross-sections located nearest to erosion points identified by the Team during the stream assessment phase. Figures 3.20 and 3.21 show the locations of these erosion points. Table 3.37 presents the results of this analysis for the 1- and 2-year return period floods only. These flows are assumed to bracket bankfull conditions, which are generally considered to be the most erosive flows.

Results of this comparison indicate that the HEC-RAS model predicted the potential for erosion at every erosion point identified in the field. Erosion problems are denoted by negative values in the column entitled "Critical Stress minus Tractive Force," where the critical stress corresponds to the value estimated from the median (d_{50}) grain size. Therefore, negative numbers indicate a high potential for the bed and bank materials to erode. However, based on the bed materials, flows throughout the four subwatersheds appear to be erosive everywhere except wetlands and tidal areas.

- Mill Creek Bed materials at all locations in the subwatershed were medium sands of 0.25 to 0.29 mm, corresponding to a critical shear stress of 0.004 lb/sq ft. Tractive forces for the 1- and 2-year events exceeded this level everywhere except reach 3547.041, a wide flat area with a flow velocity less than 0.5 fps.
- Gumbottom 2 Bed materials in this subwatershed were medium sands (0.23 to 0.33 mm) with a critical shear stress of 0.003 to 0.004 lb/sq ft. Tractive forces for the 1- and 2-year events exceeded this level everywhere except reach 1062, which was stable only for the 1-year event, with a flow velocity less than 0.2 fps.
- Maynadier Creek Channel materials are fine to medium sands (0.1 to 0.41 mm) with a critical shear stress of 0.001 to 0.005 lb/sq ft. This was exceeded everywhere in the watershed except for reaches 2738.776, 1453.863, 1602.659, all flat and wide, and 379.270, which was tidally influenced.
- Jabez Branch Bed materials in this subwatershed are found in a wide range of sizes, from silts to medium gravels (0.062 to 9.0 mm), corresponding to critical shear stresses of 0.000 to 0.12 lb/sq ft. These were exceeded in every location.

Figure 3-20: Erosion Points Observed in the Field, Jabez Branch

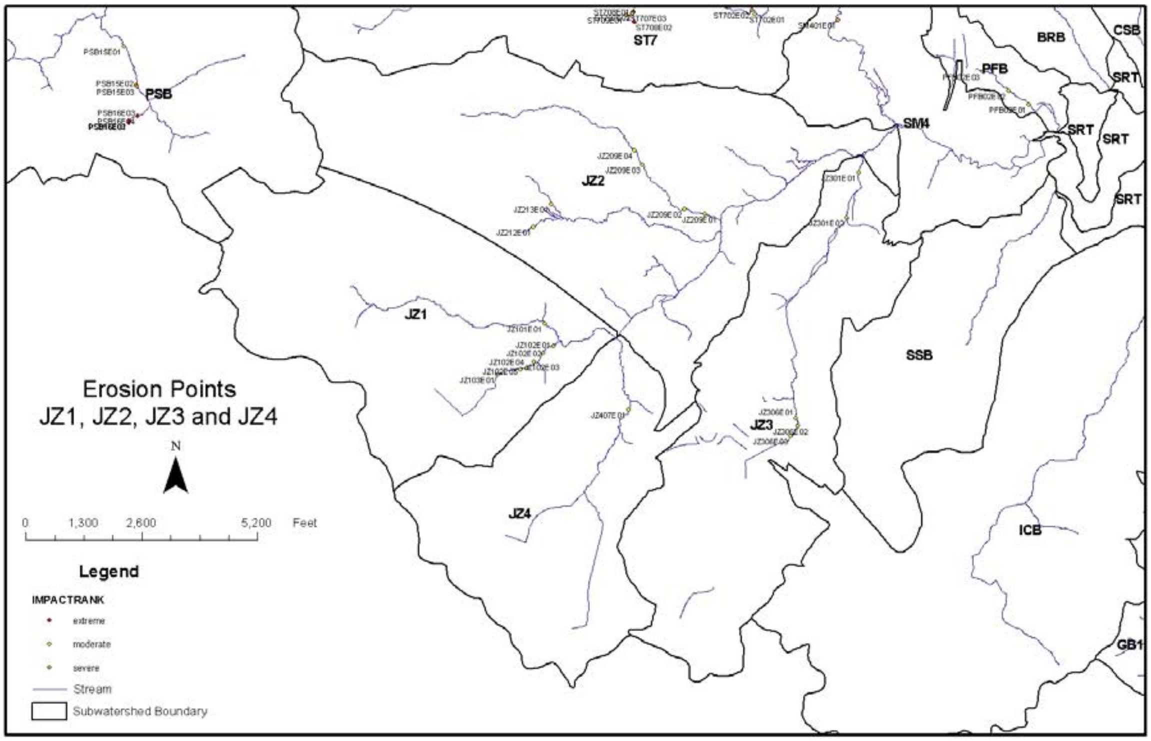


Figure 3-21: Erosion Points Observed in the Field, Gumbottom 2 Branch and Maynadier Creek

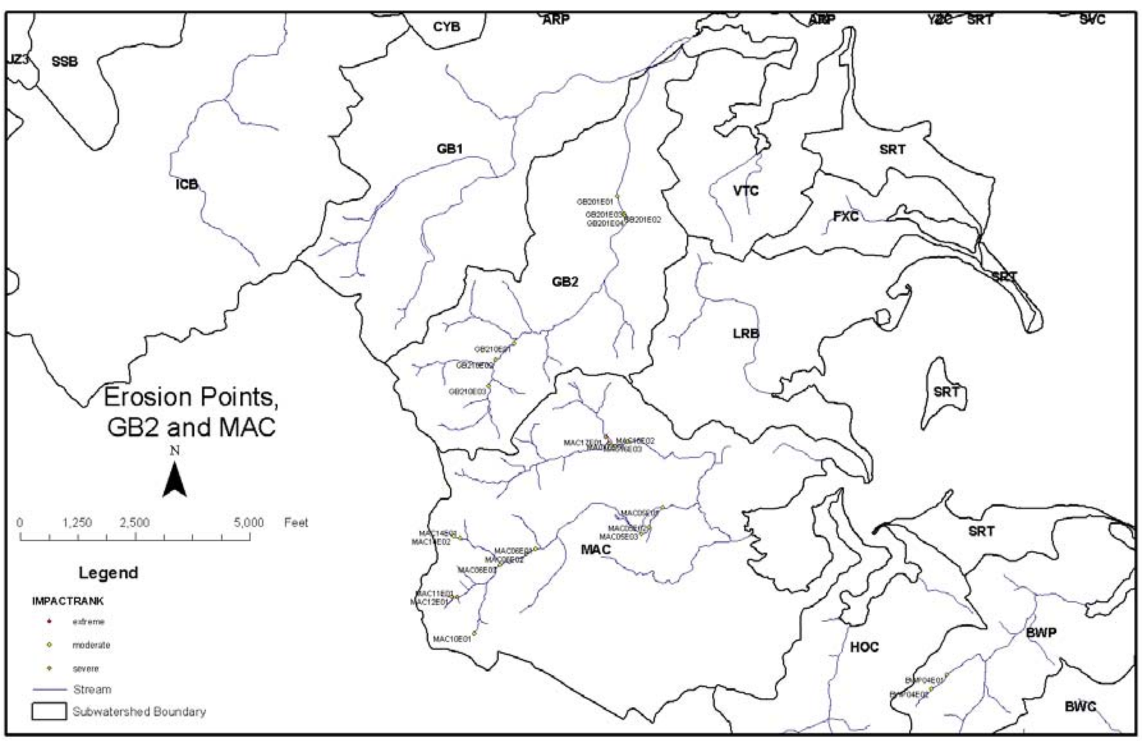


Table 3-37: Shear Stress Comparisons at Erosion Points

Erosion Point	Sediment Sample Point	River Station	d50 (mm)	Critical Shear Stress	Return Period	Tractive Force	Critical Stress Minus Tractive Force
MAC10E01	MAC011R201	1013.262	0.40	0.005	1-Year	1.01	-1.01
			0.40	0.005	2-Year	1.13	-1.13
MAC12E01	MAC011R201	8650.144	0.40	0.005	1-Year	0.83	-0.83
			0.40	0.005	2-Year	1.25	-1.25
MAC11E01	MAC011R201	8324.05	0.40	0.005	1-Year	1.78	-1.78
			0.40	0.005	2-Year	2.37	-2.37
MAC14E02, MAC14E01	MAC011R201	998.585	0.40	0.005	1-Year	0.36	-0.36
			0.40	0.005	2-Year	0.55	-0.55
MAC06E03	MAC011R201	7876.632	0.40	0.005	1-Year	0.62	-0.62
			0.40	0.005	2-Year	0.78	-0.78
MAC06E01, MAC06E02	MAC011R201	7076.136	0.40	0.005	1-Year	0.64	-0.64
			0.40	0.005	2-Year	0.82	-0.82
MAC05E02, MAC05E03	MAC005R201	3822.745	0.10	0.001	1-Year	0.22	-0.22
			0.10	0.001	2-Year	0.35	-0.35
MAC05E01	MAC005R201	2686.03	0.10	0.001	1-Year	2.03	-2.03
			0.10	0.001	2-Year	2.58	-2.58
MAC17E01, MAC16E03	MAC017R201	399.779	0.41	0.005	1-Year	0.63	-0.63
			0.41	0.005	2-Year	0.84	-0.84
MAC16E02, MAC16E01	MAC018R201	3531.236	0.35	0.005	1-Year	0.29	-0.29
			0.35	0.005	2-Year	0.42	-0.42
GB210E03	GB2015R201	8367	0.33	0.004	1-Year	0.32	-0.32
			0.33	0.004	2-Year	0.40	-0.40
GB210E02	GB2015R201	7550	0.33	0.004	1-Year	0.33	-0.33
			0.33	0.004	2-Year	0.46	-0.46
GB210E01	GB2015R201	7102	0.33	0.004	1-Year	1.12	-1.12
			0.33	0.004	2-Year	1.49	-1.49
GB201E04, GB201E03,	GB2001R202	2408	0.23	0.003	1-Year	2.38	-2.38
			0.23	0.003	2-Year	0.42	-0.42
GB201E01	GB2001R201	2116	0.31	0.004	1-Year	0.26	-0.26
			0.31	0.004	2-Year	0.27	-0.27
JZ103E01	JZ1002R201	1768.391	3.2	0.041	1-Year	1.23	-1.19
			3.2	0.041	2-Year	1.42	-1.38
JZ102E05, JZ102E04	JZ1002R201	1145.158	3.2	0.041	1-Year	1.07	-1.03
			3.2	0.041	2-Year	1.21	-1.17
JZ102E03, JZ102E02,	JZ1002R201	583.97	3.2	0.041	1-Year	0.49	-0.45
JZ102E01			3.2	0.041	2-Year	0.63	-0.59
JZ407E01	JZ4007R202	1862.705	2.1	0.027	1-Year	0.98	-0.95
			2.1	0.027	2-Year	1.11	-1.08
JZ306E03, JZ306E02,	JZ3006R201	5932.935	0.06	0.001	1-Year	1.18	-1.18
JZ306E01			0.06	0.001	2-Year	1.28	-1.28
JZ301E02	JZ3001R201	1380.181	1.7	0.022	1-Year	1.38	-1.36
			1.7	0.022	2-Year	3.13	-3.11

Erosion Point	Sediment Sample Point	River Station	d50 (mm)	Critical Shear Stress	Return Period	Tractive Force	Critical Stress Minus Tractive Force
JZ301E01	JZ3001R202	377.712	0.61	0.008	1-Year	0.31	-0.30
			0.61	0.008	2-Year	0.29	-0.28
JZ212E01, JZ213E01	JZ2009R202	4246.718	6.1	0.079	1-Year	0.33	-0.25
			6.1	0.079	2-Year	0.50	-0.42
JZ209E04	JZ2009R202	2622.096	6.1	0.079	1-Year	1.00	-0.92
			6.1	0.079	2-Year	1.75	-1.67
JZ209E03	JZ2009R202	2622.096	6.1	0.079	1-Year	1.00	-0.92
			6.1	0.079	2-Year	1.75	-1.67
JZ209E02, JZ209E01	JZ2001R202	1727.284	1.3	0.017	1-Year	0.56	-0.54
			1.3	0.017	2-Year	0.88	-0.86
MC101E01	MC1024R201	209.109	0.29	0.004	1-Year	0.01	-0.01
			0.29	0.004	2-Year	0.01	-0.01

Stream Crossings

The HY-8 and HEC-RAS analyses for stream crossings generated a return interval in which floodwaters will overtop the crossing. Flows for this analysis were obtained from TR-20 analyses performed under a separate task. Results of the stream crossing analysis are presented below in Table 3.38.

Table 3-38: Stream Crossing Modeling Results

Road	Site	100-Yr WSE	Water Surface	Overtopping Flow	Overtopping Frequency (OF)
Gambrills Rd.	1160001	25.7	3.7	13.9	<1-year
Blue Water Blvd.	1300003	20.5	2.6	134.1	>100-year
Reece Rd.	1290005B	22.7	7.8	1299.0	>100-year
Disney Rd.	1300037B	20.9	4.8	1058.7	>100-year
Reece Rd.	**1310012B**	**25.8**	**10.6**	**209.9**	**>100 year**
MD 170	2010015B				
Jacobs Rd	**2060025B**	**23.8**	**6.6**	**231.8**	**2<OF<10**
Charter Oaks Blvd.	2080011B	4.2	2.6	471.4	>100-year
Burns Crossing Rd.	2120006B	25.6	6.4	75.6	2-<OF<10-year
WB&A Rd.	**2120011B**	**25.6**	**11.5**	**460.5**	**>100 year**
MD 170	**2120017B**	**27.0**	**6.8**	**92.8**	**25<OF<50**
Sandy Hill Rd.	2150034B	19.6	4.8	59.2	>100-year
Quarterfield Rd.	**2180016B**	**18.0**	**2.2**	**89.0**	**>100-year**
MD 170	2190012A	21.7	5.6	88.4	>100-year
New Cut Rd.	**2200023B**	**26.3**	**6.3**	**135.3**	**25<OF<50**
MD 175	2200027A	17.2	3.0	16.5	<1-year
MD 175	2200029A	25.7	11.2	134.4	2-<OF<10-year
Murray Rd.	2200031A	25.2	6.1	63.9	
Upton Rd.	2210034B	25.7	5.3	42.7	2-<OF<10-year
Stehlils Dr.	**2210050A**	**25.5**	**9.9**	**191.8**	**>100 year**
Quarterfield Rd.	**2210057B**	**25.8**	**3.0**	**12.3**	**25<OF<50**
Gambrills Rd.	**2280013A**	**25.6**	**6.1**	**268.3**	**>100 year**
Gambrills Rd.	**2280029B**	**15.4**	**7.6**	**128.5**	**1<OF<2**

Road	Site	100-Yr WSE	Water Surface	Overtopping Flow	Overtopping Frequency (OF)
Gambrills Rd.	**3070008A**	**26.4**	**10.6**	**289.4**	**>100 year**
New Cut Rd.	3070022B	23.2	3.2	161.3	>100-year
Millersville Rd.	**3080008A**	**25.4**	**6.3**	**105.3**	**>100 year**
River Rd.	**3110043A**	**17.3**	**6.6**	**189.8**	**10<OF<25**
Plum Creek Dr.	**3120011B**	**26.9**	**6.6**	**107.0**	**10<OF<25**
Plum Creek Dr.	**3150014B**	**26.3**	**4.4**	**46.8**	**2<OF<10**
Old Herald Harbor Rd.	**3150024B**	**26.1**	**6.4**	**108.8**	**50<OF<100**
Benfield Rd.	**3190005A**	**124.7**	**108.4**	**210.9**	**10 year**
Generals Hwy.	3210043B	23.8	6.6	231.8	>100-year
Saint Ives St.	3250052B	22.6	3.7	115.1	>100-year
River Rd.	**3270004A**	**16.3**	**2.8**	**13.0**	**2<OF<10**
River Rd.	3270008A	374.4	363.5	16.5	<1-year
River Rd.	**3270046A**	**16.5**	**4.9**	**35.7**	**>100 year**
River Rd.	**3280009A**	**14.5**	**2.1**	**1.5**	**1 year**
Dogwood Trail	3290021B	14.8	4.9	172.5	>100-year
Dogwood Trail	**3290023B**	**27.1**	**14.4**	**36.4**	**50<OF<100**
Herald Harbor Rd.	**4010009B**	**25.7**	**3.7**	**16.0**	**10-year**
Old Herald Harbor Rd.	**4010016B**	**24.6**	**2.4**	**9.5**	**25<OF<50**
Admiral Dr.	**4020035A**	**25.3**	**9.7**	**261.5**	**<1-year**
Holly Rd.	4150036A	25.1	41.5	184.3	100-year
MD 179	4150054B	27.1	4.8	44.0	2<OF<10
Asquith View Lane.	**4190024A**	**26.4**	**10.6**	**289.4**	**>100 year**
MD 2	**4190033B**	**19.9**	**7.7**	**48.8**	**2<OF<10**
Hillcrest Rd.	**4240004A**	**24.3**	**1.2**	**0.7**	**2 year**
Old River Rd.	4290029B	19.9	0.5	48.8	2<OF<10
Disney Rd.	6280001B	23.0	6.3	390.2	>100-year
Disney Rd.	6280002B	23.5	4.9	295.5	>100-year
Broadneck Rd.	P1160027	25.1	4.5	184.3	100-year

A review of Table 3.38 indicates the following probability of flooding during any particular year:

- 5 crossings — 100 percent
- 7 crossings — at least 50 percent
- 18 crossings — at least 10 percent
- 28 crossings — at least 1 percent
- 20 crossings — less than 1

Of particular interest, are the crossings that when flooded isolate commercial or residential developments, shown in **bold** in the table above. According to the results, 16 of the crossings have a high risk of isolating developments when flooded, and of those crossings 4 exhibit a chance of flooding during any year greater than 50 percent.

3.10.3 Conclusions

Hydraulic analyses with HEC-RAS and HY-8 have been used to identify stream reaches with potential erosion problems and to estimate the probability of flooding at stream crossings, respectively. A combination of digital topography and field surveying was used to generate the input files for these models. After running the models, the Team compared the computed results to photographs of some of the stream reaches and stream crossings to evaluate the adequacy of the HEC-RAS and HY-8 models in predicting erosion potential.

Results of the HEC-RAS model indicate that most stream reaches in the four modeled subwatersheds exhibit potential erosion problems. Comparisons with field data corroborate this conclusion.

4 Future Watershed Condition

4.1 Introduction

The purpose of modeling future conditions is to determine the degree of impact that proposed development will have on watershed conditions such as pollutant loads and stream flows. From this point, the effect of proposed projects and improvements can be measured. For the Severn River watershed plan, future conditions were based on land use scenarios developed from the County's zoning map.

Three scenarios were created representing future conditions. The first was a scenario with none of the existing stormwater regulations (Basemap 1). The County was interested in determining the effectiveness of existing stormwater management regulations and stream buffer regulations, so scenarios were developed to assess these measures. The scenarios were named Basemap2 and Basemap3, respectively.

4.2 Scenarios

4.2.1 Future Land Use (Base Map 1)

The County's 2001 zoning map was used as the basis for future (ultimate) land use conditions. The procedure was to recode the zoning map based on the relationships between the codes in Table 4-1.

Table 4-1: Future Land Use / Zoning Codes

Code	Land Use Type	Zoning Codes
COM	Commercial	C1, C2, C3, C4, MA1, MA2, MA3, MB, MCSB, TC
IND	Industrial	W1, W2, W3
OPS	Open Space	OS
R11	Residential 1 Acre lots	R2
R12	Residential 1/2 Acre lots	R5
R14	Residential 1/4 Acre lots	R10
R18	Residential 1/8 Acre lots	R15
R21	Residential 2 Acre lots	R1
RWD	Residential Woods	RLD
SRC	Single Row Crop	RA
TRN	Transportation	N/A Included in other zoning categories
WAT	Water	N/A
WDS	Woods	N/A All open space assumed to be turf
CIT	City	All land uses within the City of Annapolis

The next step in creating the future land use map was to compare the current land use map with zoning. There were a number of areas where land use became less intensive in the future, i.e. the zoning of the area was for a less intense use than what was mapped from the current orthophotography. This situation is not considered likely to occur, so the future land use map was developed to take it into account by assuming the most intense land use governs, whether it is existing or zoned.

The map was developed by intersecting the zoning-based land use with the existing land use, then assigning the most intensive land use for each polygon. Intensity was ranked according to Table 4-2, which is roughly equivalent to imperviousness. Stormwater management techniques applied to this new future land use layer were the same set of BMPs as applied to the current land use layer.

Table 4-2: Development Intensity used to Code Future Land Use

Code	Land Use	Rank
CIT	Annapolis City	13
TRN	Transportation	12
WAT	Water	11
IND	Industrial	10
COM	Commercial	9
R18	Residential, 1/8 acre	8
R14	Residential, 1/4 acre	7
R12	Residential, 1/2 acre	6
R11	Residential, 1 acre	5
R21	Residential, 2 acre	4
OPS	Open Space, Turf	3
SRC	Single Row Crop	2
RWD	Residential Wooded	1
WDS	Woods	0

4.2.2 Future Land Use with Stormwater Management (Base Map 2)

To determine the effectiveness of existing stormwater management regulations, additional BMPs were added to the future land use depicted in Base Map 1. Ideally, future conditions BMPs should simulate the stormwater controls that would occur under the current regulations, with recharge, peak shaving, and water quality treatment components. For this study, however, recharge was not modeled.

These future BMPs were represented as lumped parameter systems; that is, individual BMPs were not modeled, but the pollutant reduction expected from BMPs meeting the stormwater management regulations was applied to an entire area of new development.

PLOAD Modeling of Future BMPs

For PLOAD modeling, areas greater than 1-acre slated for development to Industrial, Commercial, Residential ⅛-Acre, Residential ¼-Acre, Residential ½-Acre and Residential 1-Acre were assumed to receive stormwater treatment. Each such area was modeled so that it would drain to a single BMP with the structure type of *GBMP* (Generic BMP). Reduction efficiencies were intended to represent the type of systems most likely to be built. Two removal rates are specified in the Maryland Stormwater Manual. Any systems designed to these criteria are presumed to achieve reductions of 80% for TSS and 40% for TP. Reductions for other pollutants were chosen (conservatively) based on the data in Table 4-3.

Table 4-3: Removal Efficiency Used for Future BMPs

Pollutant	TP	TN	NOx	Cu	Zn
MDE General Performance Stds	40				
Wet Ponds	51	33	43	57	66
Wetlands	49	30	67	40	44
Filters	59	38	-14	49	88
Infiltration	65	83			99
Swales	34	84	31	51	71
Average	52	54		49	74
Proposed Removal Efficiencies	40	30	0	40	70

Forty percent removal for TP was chosen based on the assumptions of the Maryland Stormwater Manual. TN was chosen to be 30%, representing the lowest average efficiency of the BMPs in the table. It is conservative, given that in is unlikely that many on-site stormwater wetlands will be built. For NOx, removal efficiencies vary widely. Nitrates are exported by filter systems. Since there is a potential for a large number of filters / bioretention systems to be built with new development, the typical removal will be low. For Cu, 40% is the lowest average efficiency in the table. Finally, the removal efficiency of 70% for Zn is the only one where the percentage chosen is higher than the lowest one in the table. The reasoning was that more filters and swales are projected to be installed than wetlands, so it is important to reflect the most likely mix of BMPs. Also, for all the BMPs the removal efficiency of Zn is higher than Cu, so this should also be reflected in the assumptions.

TR20 Modeling of Future BMPs

Twenty SWM ponds were modeled, chosen in the largest contiguous areas where future land use changed to COM, IND or R18. These were located in the following subwatersheds:

Table 4-4: Location of Ponds Modeled for Future Conditions

Code	Subwatershed	No. of Ponds
PSB	Picture Spring Branch	6
SM2	Severn Run Mainstem 2	3
SM4	Severn Run Mainstem 2	1
ST2	Severn Run Trib 2	3
ST3	Severn Run Trib 3	1
ST5	Severn Run Trib 5	2
ST8	Severn Run Trib 8	1
SWC	Saltworks Creek	1
WEC	Weems Creek	2

The existing catchment layer was subdivided and drainage areas were delineated to the ponds. TR20 requires an elevation-storage-discharge table to model the routing through ponds. For the current conditions modeling KCI staff searched County records and put together elevation-storage-discharge tables based on the stormwater comps and design data that were found. This approach obviously could not be duplicated for future conditions, so an alternative method was attempted to find representative tables from the existing ponds which could be used for any future BMP.

The most difficult part of the modeling was developing the information for these two tables, which essentially govern the outflow characteristics from the future conditions BMPs, which were modeled individually. These tables ideally would be based on CN, drainage area, impervious area, or other parameters. However, after plotting different stage discharge tables for different ponds there was no simple way to create a generic table for future BMPs in TR-20.

As an alternative, the twenty ponds were divided into four categories based on the drainage area. Pond volumes were estimated using calculations for WQ_v and Cp_v. Other parameters for pond shape, depth, and outflow were estimated and rating curves were developed for each of the four categories. The future BMPs were assigned a structure type of MDE in the BMP database

GWLF Modeling of Future BMPs

The GWLF interface, which incorporated BMP modeling using RUNQUAL subroutines, models all the BMP structure types in the County database with a mixture of treatment processes. RUNQUAL modeled up to four different types of BMPs (filter strips, infiltration, dry ponds, and wet ponds) by modeling the physical processes involved. These include infiltration, dead storage, dry detention, and filtration.

Additional processes of extended detention and nutrient uptake were added while creating the interface in order to more accurately estimate the effectiveness of bioretention and wetland systems.

Future BMPs were modeled as a combination infiltration / bioretention system that included the processes of infiltration, dead storage, extended detention, and uptake. This data was included in the attribute table of the *GBMP* structure type.

The water quality volume (WQv) and the channel protection volume (Cpv) were used to model the BMP's design. All BMPs were sized following MDE regulations to estimated WQv by using the equations described in Appendix B.

$$WQ_v = \frac{\mathrm{P}(0.05 + 0.009\mathrm{I})\mathrm{DA} * 43{,}560}{12}$$

Where,

WQv = the water quality volume in cubic feet
P = 1 inch of precipitation
DA = BMP drainage area in Acres.

MDE manual design criteria suggest that Cpv has to be calculated based on the ratio between peak flows from the existing conditions at the time when ponds were constructed and the post-development conditions which are unknown for most of the BMPs. CPv is estimated by the use of a regression equation that estimates the ratio between the required storage volume and the developed total volume of runoff from the ratio between existing and future discharge as independent variable. It was found that the ratios of peak flows for the 12 and 24-hour release time were almost constant for the flows under analyses; this ratio was approximated by 0.65. The runoff volume was estimated by using a similar approach (Simple Method equation) as used in estimating the water quality volume but using a precipitation of 2.67 inches (2 year storm event).

4.2.3 Future Land Use with SWM and Riparian Buffers (Base Map 3)

To estimate the water quality improvements associated with current buffer regulations, an overlay to Base Map 2 was prepared that reflected existing county regulations. The county regulations included were those described in Ordinance 2-2A-14. Preservation of stream, wetland and floodplain:

<u>100-foot perennial stream buffer</u> This buffer is based on KCI field-collected stream data. All sections of stream designated as perennial, wetlands and ponds (as part of the stream system), and tidal were buffered. Those portions of stream field designated as ditch, ephemeral, intermittent and stormwater management were not buffered.

<u>100-foot tidal and 25-foot nontidal wetland buffer</u> This buffer is based on the DNR wetland coverage. Using class codes within the table, all wetlands within the Severn Watershed that were designated as Estuarine or Palustrine with tidal water regime received a 100-foot buffer. All remaining wetlands were buffered 25 feet.

<u>100-foot tidal and 25-foot nontidal floodplain buffer</u> These buffers were combined with a 100-foot tidal shoreline buffer for Chesapeake Bay Critical Area (CBCA) regulations. The floodplain buffers are based on FEMA layers, and the tidal shoreline buffer is based on the shoreline layer provided by Anne Arundel County.

It was assumed that areas within these buffers slated for development would be returned to open space under future conditions. Although these buffer areas will ultimately return to forest, open space was selected as the land use because it was assumed that forest regeneration would not occur within the time horizon of this planning study. Open space also gives a more conservative estimate of pollutant load and runoff. An exception was made for areas that were slated for development to residential wooded or for areas that were already woods.

The overlay changed the future land use in the buffer areas as follows:

Existing	Zoned	Future
Open Space	Developed	Open Space
Woods	Developed	Woods
Developed	Developed	Woods

In the last case in thelist, the assumption was made that any development that occurred where there was already existing development would be a situation of redevelopment. In this case, it was assumed that the developer would restore the stream buffer as a condition of development.

PLOAD, TR20, and GWLF Modeling

The Basemap3 scenario changes land use through the inclusion of the additional buffers, but does not change any of the BMPs utilized in the Basemap 2 scenario. For PLOAD, this results in changes in imperviousness and EMCs. For TR20 and GWLF, CN and Tc will change, and for GWLF, pollutant build-up factors may change. Because this scenario involved a change in land use rather than a change in BMPs, modeling was performed for PLOAD, TR20, and GWLF just by the inclusion of this new land use layer in the model run.

4.3 Model Results

4.3.1 PLOAD

Model results are taken from PLOAD, using the NPS loads only, under the assumption that point sources will remain the same, with reductions from BMPs, for each subwatershed. The table below summarizes the results for each pollutant for the entire watershed in lb/yr.

Table 4-5: Pollutant Loads for Future Scenarios (lb/yr)

	FC	TP	NOx	TN	Cu	Pb	Zn
Existing	4.71E+14	17,666	45,645	138,585	1,347	3,757	8,891
BaseMap 1	6.52E+14	21,955	59,326	181,407	1,748	3,968	10,748
BaseMap 2	6.52E+14	20,684	59,063	173,485	1,647	3,968	9,733
BaseMap 3	6.21E+14	19,913	56,828	166,359	1,584	3,933	9,458

The pollutant load reductions attributed to the current SWM program are calculated using the difference in the loads from BaseMap 2 and Basemap1. The reductions attributable to the current buffer regulations are calculated using the difference between BaseMap3 and BaseMap2.

The PLOAD results show the SWM program appears to be more effective at reducing metals and phosphorus from new development than the buffer regulations. The model is probably underestimating the effectiveness of the buffers, however, since the filtering capability of the buffers is not included as a BMP pollutant reduction. The only reduction effect is the change of loading by using an EMC for open space or forest instead of developed land. For the SWM program, no reduction is shown for lead (Pb) or fecal coliform (FC) because there were no removal rates for these pollutants found for use in the lookup table.

A comparison was made of TP loads on a subwatershed level, shown in the Table 4-6. The SWM program reduces future TP loads by 6% over the whole watershed, with the highest absolute reduction in Picture Spring Branch (PSB) and the highest percentage reduction in Severn Run Trib 9 (ST9). Similarly, the buffer regulations show a 4% reduction for the watershed with the highest absolute reduction in Picture Spring Branch (PSB) and the highest percent reduction in Ringgold Cove (RGC).

Table 4-6: TP Comparison for Future Scenarios

Shed Code	Area	Existing Conditions	Base Map1	Base Map2	Base Map3	Base Map3	Existing To BM1 Increase	Existing To BM1 Increase	TP Reduction (lb/yr)		TP Reduction (%)	
	acres	lb/yr	lb/yr	lb/yr	lb/yr	lb/ac/yr	lb/yr	(%)	SWM	Buffers	SWM	Buffers
AQC	278.1	94	125.5	125.5	116.2	0.42	31.5	34%	0.0	9.2	0%	7%
ARP	222.2	109	124.6	119.2	116.6	0.52	15.6	14%	5.4	2.6	4%	2%
BKC	854.2	48	20.1	20.0	19.6	0.02	-27.9	-58%	0.0	0.4	0%	2%
BRB	655.8	519	647.5	616.9	598.8	0.91	128.5	25%	30.6	18.1	5%	3%
BRC	186.2	107	155.0	155.0	152.9	0.82	48.0	45%	0.0	2.2	0%	1%
BWC	439.1	125	203.6	200.0	186.9	0.43	78.6	63%	3.5	13.1	2%	7%
BWP	400.9	44	94.2	89.8	83.5	0.21	50.2	114%	4.4	6.2	5%	7%
BWS	43.1	20	19.7	19.7	19.7	0.46	-0.3	-2%	0.0	0.0	0%	0%
CGC	732.0	0	0.0	0.0	0.0	0.00	0.0		0.0	0.0	n/a	n/a
CHC	446.3	110	150.4	144.4	134.4	0.30	40.4	37%	6.0	10.0	4%	7%
CLC	757.2	194	249.8	249.6	231.8	0.31	55.8	29%	0.2	17.7	0%	7%
COC	108.8	65	75.5	73.0	69.5	0.64	10.5	16%	2.5	3.5	3%	5%
CPO	86.0	48	22.3	22.1	22.0	0.26	-25.7	-54%	0.2	0.1	1%	1%
CRC	398.8	293	397.3	397.3	360.9	0.90	104.3	36%	0.0	36.5	0%	9%
CSB	348.1	193	193.9	191.0	189.0	0.54	0.9	0%	3.0	2.0	2%	1%
CSC	114.4	32	21.8	21.8	21.8	0.19	-10.2	-32%	0.0	0.0	0%	0%
CWB	815.9	351	376.3	364.2	359.1	0.44	25.3	7%	12.1	5.1	3%	1%
CYB	272.0	77	85.2	83.9	83.2	0.31	8.2	11%	1.3	0.7	2%	1%
EVC	80.8	37	50.6	50.6	48.5	0.60	13.6	37%	0.0	2.0	0%	4%
FRC	248.3	119	129.6	125.5	122.2	0.49	10.6	9%	4.1	3.2	3%	3%
FXC	116.7	51	58.5	57.0	51.7	0.44	7.5	15%	1.4	5.3	2%	9%
GB1	810.0	216	230.0	230.0	224.6	0.28	14.0	6%	0.0	5.4	0%	2%
GB2	610.5	105	146.6	144.6	134.3	0.22	41.6	40%	2.0	10.3	1%	7%
HLA	60.2	37	38.5	37.6	36.9	0.61	1.5	4%	1.0	0.7	3%	2%
HOC	482.4	78	101.0	101.0	96.5	0.20	23.0	29%	0.0	4.5	0%	4%
HSP	548.5	409	370.9	365.5	320.2	0.58	-38.1	-9%	5.5	45.3	1%	12%
ICB	1447.0	497	525.6	525.3	523.1	0.36	28.6	6%	0.2	2.3	0%	0%
JGP	58.4	31	23.4	23.4	23.2	0.40	-7.6	-25%	0.0	0.2	0%	1%
JZ1	839.5	316	318.0	300.0	297.3	0.35	2.0	1%	18.0	2.7	6%	1%
JZ2	1179.8	440	414.2	414.2	407.7	0.35	-25.8	-6%	0.0	6.5	0%	2%
JZ3	782.1	625	694.4	692.0	688.8	0.88	69.4	11%	2.4	3.2	0%	0%
JZ4	597.2	225	274.6	272.0	270.4	0.45	49.6	22%	2.6	1.6	1%	1%
LKO	486.0	191	221.9	210.1	196.6	0.40	30.9	16%	11.8	13.5	5%	6%
LRB	415.7	122	168.1	159.4	153.6	0.37	46.1	38%	8.6	5.8	5%	4%
LUC	384.8	137	205.7	187.6	175.3	0.46	68.7	50%	18.1	12.3	9%	7%
MAC	1069.8	204	243.8	243.8	232.4	0.22	39.8	20%	0.0	11.4	0%	5%
MC1	1430.2	614	753.7	731.2	717.7	0.50	139.7	23%	22.5	13.5	3%	2%
MC2	1581.9	522	583.9	580.2	553.6	0.35	61.9	12%	3.7	26.6	1%	5%
MEC	971.7	354	386.3	386.3	362.3	0.37	32.3	9%	0.0	24.0	0%	6%
MRP	58.1	5	25.0	25.0	19.8	0.34	20.0	400%	0.0	5.2	0%	21%
PFB	104.4	88	111.4	92.3	90.6	0.87	23.4	27%	19.1	1.8	17%	2%
PMP	92.4	65	62.8	62.4	61.4	0.66	-2.2	-3%	0.4	1.0	1%	2%
PSB	1566.7	1081	1823.1	1586.2	1503.0	0.96	742.1	69%	236.9	83.2	13%	5%
RAP	194.4	37	47.1	47.1	45.3	0.23	10.1	27%	0.0	1.8	0%	4%
RBS	124.5	58	51.1	51.1	48.9	0.39	-6.9	-12%	0.0	2.2	0%	4%
RGC	121.0	47	62.7	62.7	47.4	0.39	15.7	33%	0.0	15.3	0%	24%
SHP	133.6	43	37.9	37.9	36.6	0.27	-5.1	-12%	0.0	1.2	0%	3%

Shed Code	Area	Existing Conditions	Base Map1	Base Map2	Base Map3	Base Map3	Existing To BM1 Increase	Existing To BM1 Increase	TP Reduction (lb/yr)		TP Reduction (%)	
	acres	lb/yr	lb/yr	lb/yr	lb/yr	lb/ac/yr	lb/yr	(%)	SWM	Buffers	SWM	Buffers
SM1	884.1	531	626.7	600.0	595.0	0.67	95.7	18%	26.7	5.0	4%	1%
SM2	531.4	262	426.9	358.4	346.8	0.65	164.9	63%	68.5	11.6	16%	3%
SM3	1472.6	451	592.4	566.2	557.8	0.38	141.4	31%	26.2	8.4	4%	1%
SM4	845.0	234	286.5	277.7	276.8	0.33	52.5	22%	8.8	0.9	3%	0%
SPC	1549.3	50	4.5	4.5	4.5	0.00	-45.5	-91%	0.0	0.0	0%	-1%
SRT	1172.4	506	576.1	571.3	526.8	0.45	70.1	14%	4.8	44.5	1%	8%
SSB	475.6	95	111.6	111.3	110.9	0.23	16.6	17%	0.3	0.4	0%	0%
ST1	306.4	99	176.7	149.4	146.6	0.48	77.7	78%	27.4	2.8	15%	2%
ST2	702.5	379	757.0	655.0	611.7	0.87	378.0	100%	102.0	43.2	13%	7%
ST3	1562.2	731	876.3	731.2	712.5	0.46	145.3	20%	145.2	18.7	17%	3%
ST4	649.9	179	273.1	238.3	226.9	0.35	94.1	53%	34.9	11.4	13%	5%
ST5	1746.7	801	1105.7	934.5	902.1	0.52	304.7	38%	171.2	32.5	15%	3%
ST6	343.5	159	206.1	206.1	203.5	0.59	47.1	30%	0.0	2.6	0%	1%
ST7	865.6	590	654.6	654.1	650.1	0.75	64.6	11%	0.5	4.0	0%	1%
ST8	373.6	199	296.2	247.0	237.1	0.63	97.2	49%	49.2	9.9	17%	4%
ST9	344.1	162	268.2	216.2	210.5	0.61	106.2	66%	52.0	5.6	19%	3%
STC	149.8	59	64.0	62.2	58.3	0.39	5.0	8%	1.8	3.9	3%	6%
SVC	164.2	89	94.5	92.3	80.6	0.49	5.5	6%	2.2	11.8	2%	13%
SWC	949.3	355	549.6	534.3	502.0	0.53	194.6	55%	15.3	32.3	3%	6%
VTC	272.9	97	102.7	102.1	99.6	0.36	5.7	6%	0.5	2.6	1%	3%
WCC	269.7	344	367.8	367.8	366.5	1.36	23.8	7%	0.0	1.3	0%	0%
WCP	107.7	43	51.2	51.2	49.8	0.46	8.2	19%	0.0	1.4	0%	3%
WEC	1537.5	998	1216.2	1164.3	1124.3	0.73	218.2	22%	51.9	39.9	4%	3%
WH1	739.1	465	499.0	482.7	476.9	0.65	34.0	7%	16.3	5.8	3%	1%
WH2	912.5	292	336.9	315.1	298.5	0.33	44.9	15%	21.8	16.6	6%	5%
WH3	416.9	174	152.7	138.0	134.9	0.32	-21.3	-12%	14.7	3.2	10%	2%
YZC	204.0	143	159.1	157.5	145.8	0.71	16.1	11%	1.6	11.7	1%	7%
TOTAL	43304.1	17666	21955.2	20683.8	19912.6	0.46	4285.4	24%	1271.4	771.2	6%	4%

4.3.2 TR20

The results of peak discharge in cfs are taken from TR20 output files summary table 3, or from the tables in the mdb where the results are written by the interface. Table 4-7 below summarizes the results for the 2-year and 100-year storm events for some of the subwatersheds with larger values.

All of the subwatersheds shown in the table below showed significant increases in peak flows as future development (Basemap 1)occurred. Some SWM facilities were modeled in Basemap 2 for drainage areas larger than 10 acres in PSB and SM2, and these showed a reduction in the peak, but not back to the level of existing conditions. Future conditions for MC2 did not include SWM facilities in Basemap 2, and this is reflected in the fact that peak flows did not change.

Incorporating stream buffer regulations in Basemap 3 provided additional reduction in peak flows due to the lower CN values associated with the buffer land uses.

Table 4-7: TR20 Peak Flow Results for Selected Subwatersheds

	Maximum peak flow (cfs)							
Storm event	2 yr				100 yr			
Scenario/Subshed	PSB	MAC	ST7	SWC	PSB	MAC	ST7	SWC
Existing	654	744	61	156	3,374	3,590	510	954
Basemap1	1,563	1,137	272	1,013	5,821	5,227	1,254	4,060
Basemap2	1,483	1,137	211	1,011	5,773	5,227	1,238	4,048
Basemap3	1,247	1,046	177	908	5,482	4,815	1,161	3,794

Peak flow reduction and total direct runoff reduction are calculated using the difference in the loads from BaseMap 2 and Basemap1. The reductions attributable to the current buffer regulations are calculated using the difference between BaseMap3 and BaseMap2.

Tables 4.8 and 4.9 show peak discharge results by subwatershed for the 2-yr and 100-yr events.

Table 4-8: 2 yr Storm Peak Flows

		Area	2-yr Peak Flow (cfs)				Percent Change		
Code	Subwatershed Name	(acres)	Existing	BM 1	BM 2	BM 3	Future	SWM	Buffers
AQC	Aisquith Creek	278.1	122	198	198	168	62%	0%	-15%
ARP	Arden Pond	222.5	75	116	116	108	55%	0%	-7%
BRB	Bear Branch	655.8	261	376	376	340	44%	0%	-10%
BRC	Browns Cove	186.2	135	200	200	197	48%	0%	-2%
BWC	Brewer Creek	439.1	236	446	446	409	89%	0%	-8%
BWP	Brewer Pond	400.9	142	308	308	267	117%	0%	-13%
BWS	Brewer Shore	43.1	81	81	81	81	0%	0%	0%
CHC	Chase Creek	446.3	166	375	375	315	126%	0%	-16%
CLC	Clements Creek	757.3	175	234	234	215	34%	0%	-8%
COC	Cove of Cork	108.8	108	147	147	124	36%	0%	-16%
CPO	Chase Pond	86.0	126	189	189	187	50%	0%	-1%
CRC	Carr Creek	398.8	399	619	619	494	55%	0%	-20%
CSB	Cool Spring Branch	348.1	7	10	10	9	43%	0%	-10%
CSC	Cool Spring Creek	114.4	32	35	35	35	9%	0%	0%
CWB	Chartwell Branch	815.9	77	94	94	93	22%	0%	-1%
CYB	Cypress Branch	272.0	38	39	39	38	3%	0%	-3%
EVC	Evergreen Creek	80.8	2	6	6	4	200%	0%	-33%
FRC	Forked Creek	248.3	114	167	167	151	46%	0%	-10%
FXC	Fox Creek	116.7	60	106	106	85	77%	0%	-20%
GB1	Gumbottom Branch 1	810.0	116	104	104	100	-10%	0%	-4%
GB2	Gumbottom Branch 2	610.5	60	102	102	86	70%	0%	-16%
HLA	Heron Lake	60.2	98	107	107	104	9%	0%	-3%
HOC	Hopkins Creek	482.4	208	285	285	250	37%	0%	-12%
HSP	Hacketts Pt to Sandy Pt	548.5	446	456	456	372	2%	0%	-18%
ICB	Indian Creek Branch	1,447.0	243	256	256	251	5%	0%	-2%
JGP	Jonas Green Pond	58.4	44	49	49	46	11%	0%	-6%
JZ1	Jabez Branch 1	839.5	266	412	412	397	55%	0%	-4%
JZ2	Jabez Branch 2	1,179.8	292	349	349	327	20%	0%	-6%
JZ3	Jabez Branch 3	782.1	312	393	393	389	26%	0%	-1%
JZ4	Jabez Branch 4	597.2	185	266	266	272	44%	0%	2%
LKO	Lake Ogleton	486.1	331	455	454	426	37%	0%	-6%

		Area	2-yr Peak Flow (cfs)				Percent Change		
Code	Subwatershed Name	(acres)	Existing	BM 1	BM 2	BM 3	Future	SWM	Buffers
LRB	Little Round Bay	415.7	190	331	332	308	74%	0%	-7%
LUC	Luce Creek	384.8	150	321	321	279	114%	0%	-13%
MAC	Maynadier Creek	1,069.8	258	409	409	351	59%	0%	-14%
MC1	Mill Creek 1	1,430.2	658	1135	1135	1042	72%	0%	-8%
MC2	Mill Creek 2	1,581.9	744	1137	1137	1046	53%	0%	-8%
MEC	Meredith Creek	971.7	358	382	382	337	7%	0%	-12%
MRP	Martins Pond	58.1	11	58	58	42	427%	0%	-28%
PFB	Pointfield Branch	104.4	82	168	168	154	105%	0%	-8%
PMP	Pendennis Mount Pond	92.4	117	126	126	120	8%	0%	-5%
PSB	Picture Spring Branch	1,566.7	654	1563	1483	1247	139%	-5%	-16%
RAP	Ray's Pond	194.4	143	212	212	195	48%	0%	-8%
RBS	Round Bay Shore	124.7	97	99	99	95	2%	0%	-4%
RGC	Ringgold Cove	121.0	21	44	44	23	110%	0%	-48%
SHP	Sharps Point	133.6	143	135	135	124	-6%	0%	-8%
SM1	Severn Mainstem 1	884.1	146	177	177	169	21%	0%	-5%
SM2	Severn Mainstem 2	531.4	61	272	211	177	346%	-22%	-16%
SM3	Severn Mainstem 3	1,472.6	86	95	95	92	10%	0%	-3%
SM4	Severn Mainstem 4	845.0	73	127	123	121	74%	-3%	-2%
SSB	Sewell Spring Branch	475.6	70	82	82	81	17%	0%	-1%
ST1	Severn Run Tributary 1	306.4	59	186	186	174	215%	0%	-6%
ST2	Severn Run Tributary 2	702.5	81	314	252	198	288%	-20%	-21%
ST3	Severn Run Tributary 3	1,562.2	68	201	197	169	196%	-2%	-14%
ST4	Severn Run Tributary 4	649.9	9	18	18	16	100%	0%	-11%
ST5	Severn Run Tributary 5	1,746.7	83	172	159	152	107%	-8%	-4%
ST6	Severn Run Tributary 6	343.5	74	89	89	82	20%	0%	-8%
ST7	Severn Run Tributary 7	865.7	347	496	496	478	43%	0%	-4%
ST8	Severn Run Tributary 8	373.6	119	260	256	242	118%	-2%	-5%
ST9	Severn Run Tributary 9	344.1	129	334	334	316	159%	0%	-5%
STC	Stevens Creek	149.8	5	13	13	9	160%	0%	-31%
SVC	Sullivan Cove	164.2	76	96	96	80	26%	0%	-17%
SWC	Saltworks Creek	949.4	156	1013	1011	908	549%	0%	-10%
VTC	Valentine Creek	272.9	117	174	174	153	49%	0%	-12%
WCC	Woolchurch Cove	269.7	528	600	599	594	14%	0%	-1%
WCP	Winchester Pond	107.7	70	104	104	98	49%	0%	-6%
WH1	Whitehall Creek 1	739.1	262	376	376	382	44%	0%	2%
WH2	Whitehall Creek 2	912.6	583	651	651	622	12%	0%	-4%
WH3	Whitehall Creek 3	417.0	193	351	350	317	82%	0%	-9%
YZC	Yantz Creek	204.0	75	94	93	80	25%	-1%	-14%

Table 4-9: 100-yr Storm Peak Flows

		Area	100-yr Peak Flow (cfs)				Percent Change		
Code	Subwatershed Name	(acres)	Existing	BM 1	BM 2	BM 3	Future	SWM	Buffers
AQC	Aisquith Creek	278.1	784	1087	1087	974	39%	0%	-10%
ARP	Arden Pond	222.5	513	738	738	705	44%	0%	-4%
BRB	Bear Branch	655.8	1085	1625	1624	1486	50%	0%	-8%
BRC	Browns Cove	186.2	658	916	916	898	39%	0%	-2%

		Area	100-yr Peak Flow (cfs)				Percent Change		
Code	Subwatershed Name	(acres)	Existing	BM 1	BM 2	BM 3	Future	SWM	Buffers
BWC	Brewer Creek	439.1	1130	2046	2046	1862	81%	0%	-9%
BWP	Brewer Pond	400.9	818	1566	1566	1398	91%	0%	-11%
BWS	Brewer Shore	43.1	306	306	306	306	0%	0%	0%
CHC	Chase Creek	446.3	979	1892	1891	1659	93%	0%	-12%
CLC	Clements Creek	757.3	993	1522	1522	1356	53%	0%	-11%
COC	Cove of Cork	108.8	460	594	593	517	29%	0%	-13%
CPO	Chase Pond	86.0	409	508	508	494	24%	0%	-3%
CRC	Carr Creek	398.8	1133	2002	2002	1532	77%	0%	-23%
CSB	Cool Spring Branch	348.1	360	422	422	402	17%	0%	-5%
CSC	Cool Spring Creek	114.4	346	361	361	361	4%	0%	0%
CWB	Chartwell Branch	815.9	938	1094	1093	1081	17%	0%	-1%
CYB	Cypress Branch	272.0	283	351	350	344	24%	0%	-2%
EVC	Evergreen Creek	80.8	127	191	191	164	50%	0%	-14%
FRC	Forked Creek	248.3	735	942	942	882	28%	0%	-6%
FXC	Fox Creek	116.7	389	551	551	479	42%	0%	-13%
GB1	Gumbottom Branch 1	810.0	856	940	940	893	10%	0%	-5%
GB2	Gumbottom Branch 2	610.5	643	1001	1001	892	56%	0%	-11%
HLA	Heron Lake	60.2	331	350	350	343	6%	0%	-2%
HOC	Hopkins Creek	482.4	1053	1462	1462	1334	39%	0%	-9%
HSP	Hacketts Pt to Sandy Pt	548.5	1445	1470	1469	1274	2%	0%	-13%
ICB	Indian Creek Branch	1,447.0	1770	2036	2036	2008	15%	0%	-1%
JGP	Jonas Green Pond	58.4	248	259	259	253	4%	0%	-2%
JZ1	Jabez Branch 1	839.5	1492	2487	2487	2381	67%	0%	-4%
JZ2	Jabez Branch 2	1,179.8	2064	2753	2753	2490	33%	0%	-10%
JZ3	Jabez Branch 3	782.1	1638	2195	2194	2159	34%	0%	-2%
JZ4	Jabez Branch 4	597.2	903	1310	1310	1358	45%	0%	4%
LKO	Lake Ogleton	486.1	1427	1817	1817	1717	27%	0%	-6%
LRB	Little Round Bay	415.7	967	1690	1689	1563	75%	0%	-7%
LUC	Luce Creek	384.8	976	1602	1602	1485	64%	0%	-7%
MAC	Maynadier Creek	1,069.8	1601	2336	2335	2098	46%	0%	-10%
MC1	Mill Creek 1	1,430.2	3260	5076	5076	4760	56%	0%	-6%
MC2	Mill Creek 2	1,581.9	3590	5227	5227	4815	46%	0%	-8%
MEC	Meredith Creek	971.7	1321	1461	1460	1315	11%	0%	-10%
MRP	Martins Pond	58.1	121	301	301	252	149%	0%	-16%
PFB	Pointfield Branch	104.4	325	592	590	544	82%	0%	-8%
PMP	Pendennis Mount Pond	92.4	482	504	504	491	5%	0%	-3%
PSB	Picture Spring Branch	1,566.7	3374	5821	5773	5482	73%	-1%	-5%
RAP	Ray's Pond	194.4	684	956	956	898	40%	0%	-6%
RBS	Round Bay Shore	124.7	589	596	596	585	1%	0%	-2%
RGC	Ringgold Cove	121.0	324	437	437	341	35%	0%	-22%
SHP	Sharps Point	133.6	530	603	603	566	14%	0%	-6%
SM1	Severn Mainstem 1	884.1	1256	1520	1520	1485	21%	0%	-2%
SM2	Severn Mainstem 2	531.4	510	1254	1238	1161	146%	-1%	-6%
SM3	Severn Mainstem 3	1,472.6	1045	1349	1349	1337	29%	0%	-1%
SM4	Severn Mainstem 4	845.0	600	818	806	801	36%	-1%	-1%
SSB	Sewell Spring Branch	475.6	521	712	712	708	37%	0%	-1%
ST1	Severn Run Tributary 1	306.4	371	871	871	821	135%	0%	-6%
ST2	Severn Run Tributary 2	702.5	786	1768	1723	1574	125%	-3%	-9%

Code	Subwatershed Name	Area (acres)	100-yr Peak Flow (cfs) Existing	BM 1	BM 2	BM 3	Percent Change Future	SWM	Buffers
ST3	Severn Run Tributary 3	1,562.2	1092	2128	2131	1959	95%	0%	-8%
ST4	Severn Run Tributary 4	649.9	194	383	383	340	97%	0%	-11%
ST5	Severn Run Tributary 5	1,746.7	987	1852	1883	1609	88%	2%	-15%
ST6	Severn Run Tributary 6	343.5	319	495	495	445	55%	0%	-10%
ST7	Severn Run Tributary 7	865.7	1690	2400	2401	2333	42%	0%	-3%
ST8	Severn Run Tributary 8	373.6	637	1233	1229	1159	94%	0%	-6%
ST9	Severn Run Tributary 9	344.1	636	1392	1392	1331	119%	0%	-4%
STC	Stevens Creek	149.8	166	251	251	218	51%	0%	-13%
SVC	Sullivan Cove	164.2	455	526	526	472	16%	0%	-10%
SWC	Saltworks Creek	949.4	954	4060	4048	3794	326%	0%	-6%
VTC	Valentine Creek	272.9	817	1119	1119	1011	37%	0%	-10%
WCC	Woolchurch Cove	269.7	1559	1733	1732	1717	11%	0%	-1%
WCP	Winchester Pond	107.7	400	554	554	523	39%	0%	-6%
WH1	Whitehall Creek 1	739.1	1371	1859	1859	1772	36%	0%	-5%
WH2	Whitehall Creek 2	912.6	2336	2613	2614	2538	12%	0%	-3%
WH3	Whitehall Creek 3	417.0	751	1313	1312	1202	75%	0%	-8%
YZC	Yantz Creek	204.0	554	638	633	577	15%	-1%	-9%

4.3.3 GWLF

The results of the GWLF modeling are shown as annual average of the water balance (precipitation, evapotranspiration, ground water flow, direct runoff and streamflow), pollutants (Erosion, sediment, dissolved N, Total N, dissolved P, total P, and nutrients by source (septic systems, groundwater, runoff. These results are taken from the GWLF/RUNQUAL output files. Model runs were performed for a 25-year historic rainfall record.

The results show that water balance is not changed a great deal by the alternatives. In all of the scenarios, most of the precipitation infiltrates, then flows as groundwater to streams (Table 4.10).

Table 4-10: Water Balance

Subshed	Precip (in)	ET (in)	GW (in)	DRO (in)	Stream (in)
Existing	43.05	7.66	29.12	6.37	35.49
BaseMap 1	43.05	7.53	28.86	6.76	35.62
BaseMap 2	43.05	7.51	28.94	6.70	35.64
BaseMap 3	43.05	7.54	28.98	6.62	35.61
Future	0.00	(0.13)	(0.26)	0.40	0.14
SWM	0.00	(0.02)	0.08	(0.06)	0.02
Buffers	0.00	0.04	0.04	(0.08)	(0.04)

Future development has the effect of reducing evapotranspiration and infiltration to groundwater, while increasing direct runoff flows. SWM regulations modeled in Basemap 2 help restore natural hydrology somewhat by increasing infiltration and decreasing direct runoff compared to future conditions. Adding the effect of existing buffer regulations in Basemap 3 increases evapotranspiration and infiltration.

Table 4-11 shows that all of the scenarios except Basemap2 (existing SWM regulations) reduce erosion and sediment yield. Since these pollutants are from rural land uses and SWM is only applied to urban land uses, this result is consistent with the model procedures. Future conditions result in less erosion and sediment because of the conversion of agricultural land to urban development. The existing buffer scenario is also effective at reducing erosion by converting open space to woods.

Table 4-11: Pollutants by Type

Subshed	Erosion (lb/yr)	Sediment (lb/yr)	DN (lb/yr)	TN (lb/yr)	DP (lb/yr)	TP (lb/yr)
Existing	18,750,743	4,875,116	636,223	640,365	23,596	25,716
BaseMap 1	13,039,740	3,390,320	537,015	542,396	25,995	28,739
BaseMap 2	13,040,954	3,390,635	532,668	535,982	24,903	27,052
BaseMap 3	9,798,109	2,547,409	517,544	520,593	24,067	26,501
Future	(5,711,003)	(1,484,796)	(99,207)	(97,970)	2,399	3,024
SWM	1,214	316	(4,347)	(6,414)	(1,092)	(1,687)
Buffers	(3,242,845)	(843,226)	(15,124)	(15,389)	(836)	(552)

Table 4-12 shows that for future development, nutrient loads decrease from every source except direct runoff. Referring back to Table 4-11, it can be seen that nitrogen loads show an absolute decrease with uncontrolled future development, while phosphorus increases. The source of the decrease is septic systems, which are reduced because many areas now on septic systems will be put on sanitary sewers under the County's sewer service plan.

Runoff loads increase significantly with development, with nitrogen increasing by 22% and phosphorus by 17%. Existing SWM and buffer regulations mitigate against the increase, with the result that nitrogen and phosphorus loads in Basemap 3 are 13% and 5% higher than existing loads, respectively

Table 4-12: Nutrients by Source

Subshed	Septic N (lb/yr)	Septic P (lb/yr)	GW N (lb/yr)	GW P (lb/yr)	RO N (lb/yr)	RO P (lb/yr)
Existing	362,539	384	109,871	6,398	167,955	18,934
BaseMap 1	227,970	242	108,897	6,341	205,529	22,156
BaseMap 2	227,972	242	109,218	6,341	198,792	20,469
BaseMap 3	221,154	232	109,348	6,341	190,091	19,928
Future	(134,569)	(142)	(974)	(57)	37,573	3,222
SWM	2	(1)	321	0	(6,737)	(1,687)
Buffers	(6,818)	(10)	130	0	(8,701)	(542)

5 Analysis, Problem Identification, and Ranking

5.1 Procedure

The problem area ranking task (Task 5) of the Severn River Watershed Management Master Plan is one of the first steps in integrating historical environmental data, stream assessment monitoring, and watershed-modeling results to begin identifying problems and determine which are the most significant. The purpose of this task is to determine which subwatersheds and stream reaches are most in need of restoration or protection and serve as a guide to future project implementation to make improvements.

This section briefly describes the procedure used to determine how problems were defined and ranked, and presents the ranking and prioritization results. The approach to the task was collaborative. A series of meetings was held with a small group of County staff, stakeholders, and consultants to discuss the approach. The approach would have to

1. Choose a set of ranking criteria or indicators to characterize condition with a minimum of duplication.
2. Quantify or score each indicator, preferably in a normalized fashion so that, for instance, one subwatershed's score could be directly compared with that of another.
3. Weight the indicators against each other so that the ones that are most important in establishing watershed health or vulnerability would have the highest consideration.
4. Develop two sets of indicators to identify the priorities for watershed restoration and preservation.

Ultimately the ranking procedure for subwatersheds involved establishing two sets of indicators in two ranking scenarios. The first ranked the subwatersheds in terms of their need for Restoration, while the second ranked subwatersheds by their need for Preservation. The indicator values were scored based on natural breaks, quartiles or previously established breaks, depending on the type of data. Scores ranges from 1 to 10 such that Good-10, Fair-7, Poor-4 and Very Poor-1. The indicators were then weighted such that the ones that were most important in establishing watershed health or vulnerability would be given the highest consideration. The scores for each subwatershed were then totaled, normalized on a 1 to 100 scale and then ranked. The stream ranking was conducted in a similar fashion, except that only one set of indicators, Restoration, was used. More detailed procedures with the full description of each indicator and how it was scored is located in Appendix B.

In some cases, a certain piece of indicator data may have been missing for a particular subwatershed or reach. Each case was handled individually because the impact the individual indicator might have on the score and the reason behind the missing data could be very different. The following are several examples of the decisions made by the group on how to proceed with missing data:

<u>Missing Reach Data</u>

- For various reasons, some stream reaches have no MPHI (habitat) score for ranking. These reaches were not ranked. All the field data on them is available in the Stream Assessment Tool, however, so they can be reviewed for restoration opportunities in parallel with the ranking process.
- Those reaches that were missing both MPHI (habitat) scores and infrastructure scores were also taken out of the ranking procedure.
- Not every reach has a major road crossing, so those without crossings would rank the same as a reach with a road crossing that is not experiencing flooding. Both situations would cause a reach to rank lower on the need for restoration than one with a road crossing that has a flooding problem. The reach was ranked with a score of zero for that indicator.

- HECRAS analyses were not performed for all reaches. In the cases that the data was missing, that indicator was left out of the weighting and ranking procedure.

Missing Subwatershed Data

- Not every subwatershed has a major road crossing, so those without crossings would rank the same as a subwatershed with a road crossing that is not experiencing flooding. Both situations would cause a subwatershed to rank lower on the need for restoration than one with a road crossing that has a flooding problem.
- If there is no FHS data within the watershed, meaning that there are no inventoried streams, the subwatershed would receive a score of zero for that inventory within the scoring and ranking procedure.
- Under the restoration ranking, if the subwatershed did not have any hydric soils, it received a score of 10 for that indicator meaning that it was not in need of restoration.

Tables 5.1, 5.3 and 5.5 summarize the indicators and weights that were used to develop the Restoration and Preservation scores for each of the 70 subwatersheds and Restoration ranking for the 401 reaches.

5.2 Subwatershed Restoration Ranking

For subwatershed restoration, the landscape indicators were weighted the most important, with the amount of forested stream buffer as the single highest weighted indicator. Impervious cover and wetlands scored almost as highly. Modeled water quality and quantity together were weighted equally with the landscape indicators.

Table 5-1: Summary of Subwatershed Restoration Indicator Weighting

Category	Indicator	No. of Indicators	Category Weight	Indicator Weight	Percent Indicator of Category	Percent Indicator of Total	Percent Category of Total
Stream habitat	FHS	1	20	20	100	9.1	9.1
Modeled Water quantity	Peak, 1-year	4	50	11	22	5.0	22.7
	Peak, 2-year			11	22	5.0	
	Volume, 1-year			14	28	6.4	
	Volume, 2-year			14	28	6.4	
Modeled Water quality	Total nitrogen	4	50	15	30	6.8	22.7
	Total phosphorus			15	30	6.8	
	Total zinc			5	10	2.3	
	Total suspended solids			15	30	6.8	
Landscape	Impervious cover	5	100	23	23	10.5	45.5
	BMPs			16	16	7.3	
	Forested stream buffer			25	25	11.4	
	Wetlands/ hydric soils			23	23	10.5	
	LDA/IDA			13	13	5.9	
Total		14	220	220	400	100	100

The result should show that the watersheds with the highest priority for restoration are those with few remaining high quality natural features, and those where runoff characteristics lead to high flows and pollutant loads. The results, shown in Table 5-2, are in basic agreement with this hypothesis. The table presents the results of scoring each of the indicators and the weighted scores for the 70 Severn River subwatersheds. The results are sorted in order of priority for restoration. Low scores indicate poor conditions and thus a higher priority for restoration. These scores have been normalized to 100 so the highest score attainable is 100

In general, subwatersheds with high landscape ranking are low in priority (Brewer Pond, Rays Pond, Hopkins Creek, for example). Those with low landscape ranking tend to be higher priority (Woolchurch Cove, Picture Spring Branch, Jabez Branch 3). The seven highest priority watersheds all had the lowest possible water quality score. This trend was not as noticeable with the H&H ranking, however.

Table 5-2: Summary of Subwatershed Restoration Category Scoring and Priority

Code	Subwatershed	Streams	Habitat Score	H & H Score	Water Quality Score	Landscape Score	Total	Normalized Score	Priority
WCC	Woolchurch Cove	Y	80	134	35	247	496	23	1
PSB	Picture Spring Branch	Y	140	50	35	273	498	23	2
JZ3	Jabez Branch 3	Y	140	125	35	210	510	23	3
WEC	Weems Creek	Y	140	0	35	364	539	25	4
HSP	Hacketts to Sandy Point	N	0	92	35	524	651	30	5
CRC	Carr Creek	Y	80	134	35	436	685	31	6
ST7	Severn Run Tributary 7	Y	140	134	35	381	690	31	7
YZC	Yantz Creek	N	0	383	50	269	702	32	8
BRB	Bear Branch	Y	140	134	35	436	745	34	9
SM1	Severn Run Mainstem 1	Y	80	233	50	423	786	36	10
HLA	Heron Lake	N	0	434	35	347	816	37	11
WH1	Whitehall Creek 1	Y	140	167	80	439	826	38	12
ST2	Severn Run Tributary 2	Y	80	233	80	444	837	38	13
BRC	Brown's Cove	Y	80	401	80	277	838	38	14
ST9	Severn Run Tributary 9	Y	80	317	140	375	912	41	15
PMP	Pendennis Mount Pond	N	0	434	35	446	915	42	16
ST8	Severn Run Tributary 8	Y	80	317	125	402	924	42	17
PFB	Pointfield Branch	Y	80	401	35	421	937	43	18
ST5	Severn Run Tributary 5	Y	140	233	155	423	951	43	19
CSB	Cool Spring Branch	Y	140	500	95	238	973	44	20
RBS	Round Bay Shore	Y	80	467	155	277	979	45	21
LKO	Lake Ogleton	Y	80	317	245	361	1003	46	22
MC1	Mill Creek 1	Y	140	92	185	622	1039	47	23
SVC	Sullivans Cove	N	0	467	110	476	1053	48	24
WH2	Whitehall Creek 2	Y	80	92	350	535	1057	48	25
JZ4	Jabez Branch 4	Y	200	200	290	369	1059	48	26
MEC	Meredith Creek	Y	80	125	290	568	1063	48	27
MC2	Mill Creek 2	Y	140	92	245	607	1084	49	28
CPO	Chase Pond	N	0	500	110	476	1086	49	29
FRC	Forked Creek	N	0	350	155	584	1089	50	30
WH3	Whitehall Creek 3	Y	80	317	230	466	1093	50	31
ARP	Arden Pond	N	0	467	155	476	1098	50	32
RGC	Ringgold Cove	Y	80	458	260	307	1105	50	33
SWC	Saltworks Creek	Y	140	134	230	622	1126	51	34
ICB	Indian Creek Branch	Y	80	167	245	643	1135	52	35
ST3	Severn Run Tributary 3	Y	140	299	140	567	1146	52	36
JZ1	Jabez Branch 1	Y	200	200	245	519	1164	53	37
BWS	Brewer Shore	N	0	467	170	545	1182	54	38
JZ2	Jabez Branch 2	Y	200	167	230	588	1185	54	39
JGP	Jonas Green Pond	N	0	500	125	584	1209	55	40
COC	Cove of Cork	Y	80	434	50	649	1213	55	41

Code	Subwatershed	Streams	Habitat Score	H & H Score	Water Quality Score	Landscape Score	Total	Normalized Score	Priority
FXC	Fox Creek	Y	140	467	155	451	1213	55	41
VTC	Valentine Creek	Y	20	401	245	565	1231	56	43
SM2	Severn Run Mainstem 2	Y	140	383	140	588	1251	57	44
CWB	Chartwell Branch	Y	140	383	155	580	1258	57	45
EVC	Evergreen Creek	N	0	500	155	641	1296	59	46
LUC	Luce Creek	Y	80	317	245	661	1303	59	47
ST6	Severn Run Tributary 6	Y	140	350	140	684	1314	60	48
CLC	Clements Creek	Y	140	317	350	532	1339	61	49
WCP	Winchester Pond	Y	80	467	215	580	1342	61	50
ST1	Severn Run Tributary 1	Y	140	383	290	540	1353	62	51
STC	Stevens Creek	N	0	500	215	641	1356	62	52
SM3	Severn Run Mainstem 3	Y	140	266	335	636	1377	63	53
GB1	Gumbottom Branch 1	Y	80	317	350	637	1384	63	54
SM4	Severn Run Mainstem 4	Y	200	350	275	561	1386	63	55
LRB	Little Round Bay	Y	80	317	305	688	1390	63	56
CSC	Coolspring Creek	Y	80	500	320	514	1414	64	57
MRP	Martins Pond	N	0	500	350	572	1422	65	58
AQC	Aisquith Creek	Y	140	434	260	607	1441	66	59
SHP	Sharps Point	N	0	359	350	737	1446	66	60
BWC	Brewer Creek	Y	140	317	305	703	1465	67	61
CYB	Cypress Branch	Y	80	500	335	601	1516	69	62
ST4	Severn Run Tributary 4	Y	80	500	350	588	1518	69	63
SSB	Sewell Spring Branch	Y	140	383	350	649	1522	69	64
MAC	Maynadier Creek	Y	140	317	350	787	1594	72	65
CHC	Chase Creek	Y	140	434	350	688	1612	73	66
GB2	Gumbottom Branch 2	Y	80	500	350	778	1708	78	67
HOC	Hopkins Creek	Y	140	434	350	787	1711	78	68
RAP	Ray's Pond	Y	140	467	350	790	1747	79	69
BWP	Brewer Pond	Y	140	467	350	856	1813	82	70

5.3 Subwatershed Preservation Ranking

To prioritize subwatershed protection, the landscape indicators were weighted much higher than the other two categories. This is in part because so many individual indicators which showed whether there was high quality habitat within the subwatershed. The indicators

Stream habitat, impervious cover, forest cover, wetlands, headwater streams, and freshwater bogs were the highest weighted indicators, and all given the same weight. The aquatic living resources category was given an equivalent weight.

Table 5-3: Summary of Subwatershed Preservation Indicator Weighting

Category	Indicator	No. of Indicators	Category Weight	Indicator Weight	Percent Indicator of Category	Percent Indicator of Total	Percent Category of Total
Stream habitat	FHS	1	15	15	100.0	11.5	11.5
Landscape	Impervious cover (change)	10	100	15	15.0	11.5	76.9
	Forest cover			15	15.0	11.5	
	Wetlands			15	15.0	11.5	

Category	Indicator	No. of Indicators	Category Weight	Indicator Weight	Percent Indicator of Category	Percent Indicator of Total	Percent Category of Total
	Headwater streams			15	15.0	11.5	
	Greenway			5	5.0	3.8	
	SSPRA			5	5.0	3.8	
	Bog			15	15.0	11.5	
	RCA			5	5.0	3.8	
	Protected lands			5	5.0	3.8	
	Wellhead protection			5	5.0	3.8	
Aquatic living resources	Trout spawning	2	15	6	40.0	4.6	11.5
	Anadromous spawning			9	60.0	6.9	
Total		14	220	220	400	100	100

The highest priority areas, given the indicators and weights, should be those with the least urbanization, and those with unique habitat or natural resources. The results bear this out, with the highest priority watersheds in the undeveloped areas of the South Shore or the Severn Run Natural Resources Area. Table 5.4 presents the results of scoring each of the indicators and the weighted scores for the 70 Severn River subwatersheds. The results are sorted in order of priority. High scores indicate better condition and thus a higher priority for preservation. These scores have been normalized to 100 so the highest score attainable is 100.

The results show the effect of the high weight for the landscape score, with the top seven landscape scores also the top seven priority subwatersheds. Subwatersheds with the highest habitat scores tended to rank high in priority, but it was not as close a relationship. A similar result was found with the scores for the aquatic resources category.

Table 5-4: Summary of Subwatershed Preservation Category Scoring and Priority

Code	Subwatershed	Streams	Habitat Score	Landscape Score	Aquatic Resources	Total	Normalized Score	Priority
MAC	Maynadier Creek	Y	140	820	96	1056	81	1
SM4	Severn Run Mainstem 4	Y	200	665	96	961	74	2
GB2	Gumbottom Branch 2	Y	80	760	15	855	66	3
ICB	Indian Creek Branch	Y	80	625	96	801	62	4
BWP	Brewer Pond	Y	140	640	15	795	61	5
HOC	Hopkins Creek	Y	140	640	15	795	61	5
GB1	Gumbottom Branch 1	Y	80	685	15	780	60	7
JZ2	Jabez Branch 2	Y	200	425	150	775	60	8
SM3	Severn Run Mainstem 3	Y	140	515	96	751	58	9
RAP	Ray's Pond	Y	140	535	15	690	53	10
MEC	Meredith Creek	Y	80	595	15	690	53	10
MC1	Mill Creek 1	Y	140	505	15	660	51	12
SSB	Sewell Spring Branch	Y	140	505	15	660	51	12
VTC	Valentine Creek	Y	20	625	15	660	51	12
ST6	Severn Run Tributary 6	Y	140	485	15	640	49	15
BWC	Brewer Creek	Y	140	475	15	630	48	16
CHC	Chase Creek	Y	140	475	15	630	48	16
ST4	Severn Run Tributary 4	Y	80	530	15	625	48	18
JZ1	Jabez Branch 1	Y	200	350	69	619	48	19
LUC	Luce Creek	Y	80	520	15	615	47	20
MC2	Mill Creek 2	Y	140	445	15	600	46	21
WH1	Whitehall Creek 1	Y	140	445	15	600	46	21
JZ4	Jabez Branch 4	Y	200	320	69	589	45	23

Code	Subwatershed	Streams	Habitat Score	Landscape Score	Aquatic Resources	Total	Normalized Score	Priority
JZ3	Jabez Branch 3	Y	140	380	69	589	45	23
AQC	Aisquith Creek	Y	140	430	15	585	45	25
PFB	Pointfield Branch	Y	80	490	15	585	45	25
ST5	Severn Run Tributary 5	Y	140	410	15	565	43	27
ST7	Severn Run Tributary 7	Y	140	410	15	565	43	27
CLC	Clements Creek	Y	140	400	15	555	43	29
COC	Cove of Cork	Y	80	460	15	555	43	29
HSP	Hacketts to Sandy Point	N	0	535	15	550	42	31
SWC	Saltworks Creek	Y	140	385	15	540	42	32
LRB	Little Round Bay	Y	80	445	15	540	42	32
WCC	Woolchurch Cove	Y	80	445	15	540	42	32
WH2	Whitehall Creek 2	Y	80	445	15	540	42	32
WH3	Whitehall Creek 3	Y	80	445	15	540	42	32
SM2	Severn Run Mainstem 2	Y	140	380	15	535	41	37
ST8	Severn Run Tributary 8	Y	80	440	15	535	41	37
FXC	Fox Creek	Y	140	370	15	525	40	39
PSB	Picture Spring Branch	Y	140	365	15	520	40	40
ST3	Severn Run Tributary 3	Y	140	365	15	520	40	40
WEC	Weems Creek	Y	140	355	15	510	39	42
CRC	Carr Creek	Y	80	415	15	510	39	42
ST1	Severn Run Tributary 1	Y	140	335	15	490	38	44
BRB	Bear Branch	Y	140	325	15	480	37	45
CSC	Coolspring Creek	Y	80	385	15	480	37	45
CYB	Cypress Branch	Y	80	385	15	480	37	45
SHP	Sharps Point	N	0	460	15	475	37	48
WCP	Winchester Pond	Y	80	370	15	465	36	49
ST2	Severn Run Tributary 2	Y	80	365	15	460	35	50
ST9	Severn Run Tributary 9	Y	80	365	15	460	35	50
BRC	Brown's Cove	Y	80	355	15	450	35	52
SM1	Severn Run Mainstem 1	Y	80	335	15	430	33	53
SVC	Sullivans Cove	N	0	415	15	430	33	53
CWB	Chartwell Branch	Y	140	265	15	420	32	55
LKO	Lake Ogleton	Y	80	325	15	420	32	55
MRP	Martins Pond	N	0	400	15	415	32	57
JGP	Jonas Green Pond	N	0	385	15	400	31	58
PMP	Pendennis Mount Pond	N	0	385	15	400	31	58
BWS	Brewer Shore	N	0	370	15	385	30	60
RGC	Ringgold Cove	Y	80	280	15	375	29	61
CSB	Cool Spring Branch	Y	140	205	15	360	28	62
RBS	Round Bay Shore	Y	80	265	15	360	28	62
HLA	Heron Lake	N	0	340	15	355	27	64
EVC	Evergreen Creek	N	0	325	15	340	26	65
FRC	Forked Creek	N	0	295	15	310	24	66
ARP	Arden Pond	N	0	280	15	295	23	67
STC	Stevens Creek	N	0	280	15	295	23	67
CPO	Chase Pond	N	0	265	15	280	22	69
YZC	Yantz Creek	N	0	190	15	205	16	70

5.4 Stream Restoration Ranking

The stream indicators in table 5-5 below are intended to identify which reaches are in the poorest condition and most in need of restoration. Two elements of the stream assessment are included as categories: physical habitat, and infrastructure, which represent specific types of degradation in the stream. A third category, H&H, was included to indicate whether there was flooding potential at road crossings within the reach. Stream habitat was the single highest weighted indicator.

Table 5-5: Summary of Stream Reach Restoration Indicator Weighting

Category	Indicator	No. of Indicators	Category Weight	Indicator Weight	Percent Indicator of Category	Percent Indicator of Total	Percent Category of Total
Stream habitat	MPHI	1	35	35	100.0	37	37
Infrastructure	Buffer	5	45	5	11	5	47
	Erosion			10	22	11	
	Head cut			5	11	5	
	Dump site			5	11	5	
	Other			20	44	21	
Hydrology and hydraulics	Road crossings	1	15	15	100	16	16
Total		7	95	95	300	100	100

The results of the ranking show very little correlation between the H&H score and the priority, which is primarily due to the low number of road crossings where data was available: 50 crossings out of over 400 stream reaches. Correlation with habitat scores was somewhat better, as the eight highest priority stream reaches scored lowest or second lowest in habitat ranking. The two highest priority reaches had the lowest infrastructure scores, but again, there was not a close correlation. For the stream reach ranking, more so than the subwatersheds, it requires a poor score in more than one indicator to put a reach in the high priority list.

Table 5.6 presents the results of the Reach Ranking. The results are have been prioritized—low scores indicating poor conditions and thus a higher priority for restoration. These scores have been normalized to 100 so the highest score attainable is 100.

Table 5-6: Stream Reach Ranking

Reach	Habitat	Infra-struc-ture	H&H	Total	Normal-ized Score	Priority
ST6006	70	125	15	210	22	1
MAC011	35	105	150	290	31	2
RGC004	70	190	30	290	31	2
ST5018	70	225	30	325	34	4
SM3006	35	155	150	340	36	5
MAC010	70	135	150	355	37	6
PSB010	70	255	30	355	37	6
ST7009	35	180	150	365	38	8
ST9002	70	265	30	365	38	8
WEC001	105	235	30	370	39	10
CWB002	70	155	150	375	39	11
SM2004	70	160	150	380	40	12
ST5005	105	125	150	380	40	12
CLC009	35	200	150	385	41	14
ST7005	70	180	150	400	42	15
ST7008	70	180	150	400	42	15
PSB024	70	290	45	405	43	17
BRB001	105	290	15	410	43	18
HOC007	105	290	15	410	43	18
ICB005	35	225	150	410	43	18
PSB019	35	230	150	415	44	21
LUC002	70	215	150	435	46	22
PSB012	35	250	150	435	46	22
SM4008	105	180	150	435	46	22
ST7007	105	180	150	435	46	22
SM3003	70	220	150	440	46	26

Reach	Habitat	Infra-struc-ture	H&H	Total	Normal-ized Score	Priority
ST5009	35	255	150	440	46	26
ST6005	70	220	150	440	46	26
WCP001	105	185	150	440	46	26
PSB006	105	190	150	445	47	30
SM3002	105	190	150	445	47	30
ST3003	105	310	30	445	47	30
SWC008	70	225	150	445	47	30
GB2016	35	265	150	450	47	34
PSB003	35	265	150	450	47	34
WH3001	70	230	150	450	47	34
LRB003	na	270	15	285	48	37
PSB016	na	135	150	285	48	37
RGC003	35	270	150	455	48	39
SM1005	105	200	150	455	48	39
SM2011	35	270	150	455	48	39
BRB006	70	240	150	460	48	42
MC2006	70	240	150	460	48	42
ST4005	35	275	150	460	48	42
GB2001	70	380	15	465	49	45
SM2006	105	210	150	465	49	45
ST4003	70	245	150	465	49	45
WH2002	70	245	150	465	49	45
PSB015	na	145	150	295	49	49
BRB003	70	250	150	470	49	50
BRC003	70	250	150	470	49	50
SM1001	70	250	150	470	49	50
ST4009	70	250	150	470	49	50
GB1003	35	290	150	475	50	54
GB1009	70	255	150	475	50	54
GB2019	35	290	150	475	50	54
GB2020	35	290	150	475	50	54
MC1010	35	290	150	475	50	54
MC1014	70	255	150	475	50	54
SM1003	35	290	150	475	50	54
SWC013	70	255	150	475	50	54
AQC004	105	225	150	480	51	62
WH1006	na	155	150	305	51	63
BRB007	70	270	150	490	52	64
CHC001	70	270	150	490	52	64
CHC007	70	270	150	490	52	64
CHC015	70	270	150	490	52	64
CLC004	70	270	150	490	52	64
CSB001	105	235	150	490	52	64
CSC003	70	270	150	490	52	64
GB1010	70	270	150	490	52	64
HOC008	70	270	150	490	52	64
HOC009	70	405	15	490	52	64
LKO002	70	270	150	490	52	64

Reach	Habitat	Infra-struc-ture	H&H	Total	Normal-ized Score	Priority
MC2013	70	270	150	490	52	64
SM1004	105	235	150	490	52	64
ST2005	70	270	150	490	52	64
WEC012	70	270	150	490	52	64
CYB001	70	275	150	495	52	79
GB1006	35	310	150	495	52	79
PSB002	70	275	150	495	52	79
WH2001	70	275	150	495	52	79
WH3003	105	245	150	500	53	83
CSB002	105	250	150	505	53	84
CWB008	105	250	150	505	53	84
JZ4009	na	290	30	320	53	86
CLC002	70	290	150	510	54	87
GB2006	70	290	150	510	54	87
MEC001	70	290	150	510	54	87
MEC002	70	290	150	510	54	87
PSB025	70	290	150	510	54	87
SM2010	70	290	150	510	54	87
ST2006	70	290	150	510	54	87
ST2010	70	290	150	510	54	87
ST5014	70	290	150	510	54	87
ST8001	70	290	150	510	54	87
WEC003	70	290	150	510	54	87
LRB005	35	450	30	515	54	98
PSB008	105	265	150	520	55	99
ST3002	70	405	45	520	55	99
AQC010	105	270	150	525	55	101
BRC001	105	270	150	525	55	101
MAC015	105	270	150	525	55	101
PSB009	105	270	150	525	55	101
SM1002	105	270	150	525	55	101
SM3010	105	270	150	525	55	101
WEC008	105	270	150	525	55	101
WH3004	105	270	150	525	55	101
CLC005	70	310	150	530	56	109
CLC015	70	310	150	530	56	109
GB2015	70	310	150	530	56	109
JZ3003	105	275	150	530	56	109
LUC004	70	310	150	530	56	109
MAC007	70	310	150	530	56	109
MAC018	105	275	150	530	56	109
MC1001	105	275	150	530	56	109
MC2012	70	310	150	530	56	109
PSB023	70	310	150	530	56	109
ST5017	70	310	150	530	56	109
ST8007	70	310	150	530	56	109
WH2003	70	310	150	530	56	109
WH3005	70	310	150	530	56	109

Reach	Habitat	Infra-struc-ture	H&H	Total	Normal-ized Score	Priority
FXC004	na	310	30	340	57	123
PSB011	na	310	30	340	57	123
MAC005	70	320	150	540	57	125
MAC019	35	360	150	545	57	126
RBS003	35	360	150	545	57	126
WEC010	105	290	150	545	57	126
WH2004	105	290	150	545	57	126
GB1001	70	450	30	550	58	130
JZ2013	70	340	150	560	59	131
CWB004	105	310	150	565	59	132
FXC001	105	310	150	565	59	132
GB2009	105	310	150	565	59	132
GB2010	105	310	150	565	59	132
JZ2002	105	310	150	565	59	132
MC2011	105	310	150	565	59	132
PSB013	105	310	150	565	59	132
WEC005	105	310	150	565	59	132
WH1002	105	310	150	565	59	132
MAC017	105	315	150	570	60	141
MAC012	70	360	150	580	61	142
CHC009	105	450	30	585	62	143
GB2002	105	450	30	585	62	143
MAC020	70	365	150	585	62	143
BWP004	70	370	150	590	62	146
GB2021	70	370	150	590	62	146
MAC013	35	405	150	590	62	146
MAC016	105	335	150	590	62	146
MC1020	70	370	150	590	62	146
WH1008	35	405	150	590	62	146
RAP002	na	225	150	375	63	152
LKO001	70	375	150	595	63	153
ST4002	35	410	150	595	63	153
ST2011	35	415	150	600	63	155
VTC004	35	415	150	600	63	155
JZ1003	na	240	150	390	65	157
CWB006	70	405	150	625	66	158
MC2001	70	405	150	625	66	158
LKO003	na	245	150	395	66	160
ICB002	70	410	150	630	66	161
JZ2017	70	410	150	630	66	161
GB1008	na	250	150	400	67	163
BWC007	35	450	150	635	67	164
GB1004	35	450	150	635	67	164
GB1005	70	415	150	635	67	164
GB1007	35	450	150	635	67	164
HOC002	350	270	15	635	67	164
ST4004	35	450	150	635	67	164
ST4010	35	450	150	635	67	164

Reach	Habitat	Infra-struc-ture	H&H	Total	Normal-ized Score	Priority
ST7002	105	380	150	635	67	164
SWC011	35	450	150	635	67	164
VTC002	70	415	150	635	67	164
WEC009	105	380	150	635	67	164
WEC002	na	255	150	405	68	175
JZ1006	na	265	150	415	69	176
CSC001	105	405	150	660	69	177
JZ2004	105	405	150	660	69	177
BRC006	na	270	150	420	70	179
BWP003	105	410	150	665	70	179
FXC003	na	270	150	420	70	179
JZ3004	105	410	150	665	70	179
LRB002	na	270	150	420	70	179
PMP002	na	270	150	420	70	179
ST4006	105	410	150	665	70	179
AQC003	70	450	150	670	71	186
AQC008	70	450	150	670	71	186
BRC004	70	450	150	670	71	186
BRC005	70	450	150	670	71	186
BWC006	70	450	150	670	71	186
BWP002	70	450	150	670	71	186
CHC003	70	450	150	670	71	186
CHC004	70	450	150	670	71	186
CHC006	70	450	150	670	71	186
CHC008	70	450	150	670	71	186
CHC010	70	450	150	670	71	186
CHC011	70	450	150	670	71	186
CHC012	70	450	150	670	71	186
CHC013	70	450	150	670	71	186
CHC018	70	450	150	670	71	186
CHC019	70	450	150	670	71	186
CLC007	70	450	150	670	71	186
CLC008	70	450	150	670	71	186
CLC013	70	450	150	670	71	186
CLC016	70	450	150	670	71	186
COC001	70	450	150	670	71	186
CRC001	70	450	150	670	71	186
GB1002	70	450	150	670	71	186
GB2003	70	450	150	670	71	186
GB2004	70	450	150	670	71	186
GB2007	70	450	150	670	71	186
GB2012	70	450	150	670	71	186
GB2013	70	450	150	670	71	186
JZ1005	70	450	150	670	71	186
JZ2003	70	450	150	670	71	186
JZ2005	70	450	150	670	71	186
JZ2006	70	450	150	670	71	186
JZ2016	70	450	150	670	71	186

Reach	Habitat	Infra-struc-ture	H&H	Total	Normal-ized Score	Priority
JZ2018	70	450	150	670	71	186
JZ2019	70	450	150	670	71	186
JZ3002	70	450	150	670	71	186
LRB004	70	450	150	670	71	186
LUC001	105	415	150	670	71	186
MAC008	70	450	150	670	71	186
MC1003	70	450	150	670	71	186
MC1015	70	450	150	670	71	186
MC1024	105	415	150	670	71	186
MC1026	70	450	150	670	71	186
MC1027	70	450	150	670	71	186
MC2008	70	450	150	670	71	186
MC2014	70	450	150	670	71	186
MC2016	70	450	150	670	71	186
MC2017	70	450	150	670	71	186
PFB001	70	450	150	670	71	186
PSB014	70	450	150	670	71	186
PSB018	70	450	150	670	71	186
PSB022	70	450	150	670	71	186
RAP001	70	450	150	670	71	186
RAP005	70	450	150	670	71	186
RGC001	70	450	150	670	71	186
RGC005	70	450	150	670	71	186
SM3008	70	450	150	670	71	186
SM3009	70	450	150	670	71	186
SM4002	70	450	150	670	71	186
SM4006	70	450	150	670	71	186
SM4007	70	450	150	670	71	186
SM4010	70	450	150	670	71	186
SSB002	70	450	150	670	71	186
ST1002	105	415	150	670	71	186
ST2001	70	450	150	670	71	186
ST3006	70	450	150	670	71	186
ST5002	70	450	150	670	71	186
ST5011	70	450	150	670	71	186
ST5019	70	450	150	670	71	186
ST6003	70	450	150	670	71	186
ST7011	70	450	150	670	71	186
ST7015	70	450	150	670	71	186
ST8005	70	450	150	670	71	186
ST9005	70	450	150	670	71	186
ST9006	70	450	150	670	71	186
SWC006	70	450	150	670	71	186
SWC009	70	450	150	670	71	186
SWC016	70	450	150	670	71	186
WCC001	70	450	150	670	71	186
WH1009	70	450	150	670	71	186
ST5007	350	180	150	680	72	266

Reach	Habitat	Infra-struc-ture	H&H	Total	Normal-ized Score	Priority
PFB002	na	285	150	435	73	267
JZ1004	350	310	30	690	73	268
MAC014	350	190	150	690	73	268
SM2005	350	190	150	690	73	268
CLC018	na	290	150	440	73	271
CWB003	na	290	150	440	73	271
ST8008	na	290	150	440	73	271
AQC005	350	200	150	700	74	274
AQC006	105	450	150	705	74	275
BRB002	105	450	150	705	74	275
BWC004	105	450	150	705	74	275
BWC005	105	450	150	705	74	275
CHC005	105	450	150	705	74	275
CLC003	105	450	150	705	74	275
CSC002	105	450	150	705	74	275
GB2008	105	450	150	705	74	275
GB2011	105	450	150	705	74	275
GB2017	105	450	150	705	74	275
ICB001	105	450	150	705	74	275
JZ2015	105	450	150	705	74	275
JZ3005	105	450	150	705	74	275
MAC004	105	450	150	705	74	275
MC1013	105	450	150	705	74	275
MC1018	105	450	150	705	74	275
MC1019	105	450	150	705	74	275
MC1023	105	450	150	705	74	275
MC2005	105	450	150	705	74	275
MC2007	105	450	150	705	74	275
PSB027	105	450	150	705	74	275
RAP003	105	450	150	705	74	275
RBS002	105	450	150	705	74	275
RGC006	105	450	150	705	74	275
SSB001	105	450	150	705	74	275
ST2008	105	450	150	705	74	275
ST3007	105	450	150	705	74	275
ST6002	105	450	150	705	74	275
ST7010	105	450	150	705	74	275
ST7012	105	450	150	705	74	275
SWC002	105	450	150	705	74	275
WH1005	105	450	150	705	74	275
WH1011	105	450	150	705	74	275
HOC003	350	225	150	725	76	308
SM2001	350	225	150	725	76	308
MC1006	na	310	150	460	77	310
WEC004	na	310	150	460	77	310
JZ1002	350	230	150	730	77	312
SWC005	350	230	150	730	77	312
PSB005	350	235	150	735	77	314

Reach	Habitat	Infra-struc-ture	H&H	Total	Normal-ized Score	Priority
SWC012	na	315	150	465	78	315
ST7006	350	375	15	740	78	316
HOC006	350	245	150	745	78	317
WH1004	350	250	150	750	79	318
BWC001	350	255	150	755	79	319
CWB001	350	255	150	755	79	319
JZ3006	na	330	150	480	80	321
SM2007	350	270	150	770	81	322
ST5001	350	270	150	770	81	322
SM2008	350	275	150	775	82	324
PSB007	350	290	150	790	83	325
SM2009	350	290	150	790	83	325
ST2003	350	290	150	790	83	325
SWC014	350	290	150	790	83	325
ST3001	350	415	30	795	84	329
CLC006	na	360	150	510	85	330
AQC001	350	310	150	810	85	331
AQC002	350	310	150	810	85	331
CLC010	350	310	150	810	85	331
JZ2008	350	310	150	810	85	331
MAC009	350	310	150	810	85	331
MC1007	350	310	150	810	85	331
MC1009	350	310	150	810	85	331
MC1012	350	310	150	810	85	331
MC1017	350	310	150	810	85	331
PSB001	350	310	150	810	85	331
SM2003	350	310	150	810	85	331
SM3001	350	310	150	810	85	331
SM3007	350	310	150	810	85	331
HOC001	350	450	15	815	86	344
MAC001	350	450	30	830	87	345
ST5008	350	450	30	830	87	345
WH1010	na	380	150	530	88	347
JZ2014	na	405	150	555	93	348
MC2010	na	405	150	555	93	348
JZ2009	350	380	150	880	93	350
JZ2012	350	380	150	880	93	350
JZ3001	350	380	150	880	93	350
MAC006	350	380	150	880	93	350
ST7004	350	380	150	880	93	350
ST5004	na	410	150	560	93	355
ICB003	na	415	150	565	94	356
MC1025	na	415	150	565	94	356
VTC003	na	415	150	565	94	356
WH1012	na	415	150	565	94	356
BWC003	350	410	150	910	96	360
AQC007	350	450	150	950	100	361
BWP001	350	450	150	950	100	361

Reach	Habitat	Infra-struc-ture	H&H	Total	Normal-ized Score	Priority
CLC001	350	450	150	950	100	361
CLC012	350	450	150	950	100	361
CLC014	na	450	150	600	100	361
COC002	na	450	150	600	100	361
CSB003	na	450	150	600	100	361
GB1011	na	450	150	600	100	361
HOC004	350	450	150	950	100	361
HOC005	350	450	150	950	100	361
JZ1001	350	450	150	950	100	361
JZ2001	350	450	150	950	100	361
JZ2010	350	450	150	950	100	361
JZ2011	350	450	150	950	100	361
JZ4007	350	450	150	950	100	361
JZ4008	na	450	150	600	100	361
LRB007	na	450	150	600	100	361
MAC002	350	450	150	950	100	361
MAC021	na	450	150	600	100	361
MC1004	na	450	150	600	100	361
MC1016	350	450	150	950	100	361
MC1022	na	450	150	600	100	361
MC2004	350	450	150	950	100	361
MC2018	na	450	150	600	100	361
PMP001	na	450	150	600	100	361
PSB021	350	450	150	950	100	361
SM4001	350	450	150	950	100	361
SM4011	350	450	150	950	100	361
ST2007	na	450	150	600	100	361
ST3005	350	450	150	950	100	361
ST4001	350	450	150	950	100	361
ST6001	350	450	150	950	100	361
ST7001	350	450	150	950	100	361
ST7014	350	450	150	950	100	361
ST9003	na	450	150	600	100	361
ST9004	350	450	150	950	100	361
SWC001	350	450	150	950	100	361
WEC007	350	450	150	950	100	361
WH1001	350	450	150	950	100	361
WH1007	350	450	150	950	100	361
WH3002	na	450	150	600	100	361

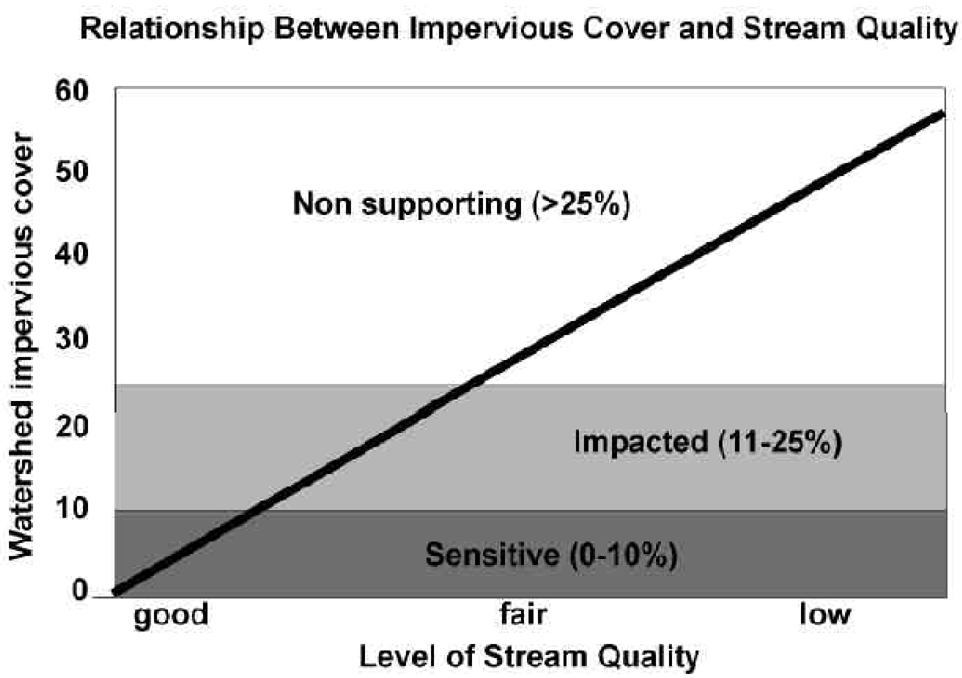
5.5 Development of Watershed Guidelines for TP

The purpose of the watershed management guidelines is to provide a mechanism to protect relatively unimpaired systems and/or restore impaired systems to a level of quality that is acceptable to meet designated uses and goals of the governing bodies. The guidelines are flexible so that a range of restoration and protection programs can be established that are reasonable for a desired outcome of meeting and sustaining designated uses.

As seen in the relationships presented previously in Chapter 3, the r^2 values for the regressions do not indicate strong relationships among the water quality and biological variables. There are many factors that cause the variance among environmental data, however, the lack of data from "pristine" watersheds does add to weak relationships seen. Given the situation, it is still important to put guidelines in place in order to gauge a watershed management plan when evaluating alternatives, identifying scenarios, and estimating costs. However, as the County moves forward with this approach, it is imperative that an adaptive management strategy be implemented for watershed management. This will allow for the guidelines to be revised as more data becomes available and provide the flexibility to enhance the management strategies by implementing the scenarios that work while re-evaluating those that do not.

Due to the lack of strong relationships, the project team reverted to guidance from the Center of Watershed Protection (CWP) to be used as the basis for the initial draft guidelines. Figure 5.1 presents the relationships provided by CWP (1999) that illustrate the relationships between aquatic integrity and watershed imperviousness. The CWP advises that a threshold of 10% imperviousness is where the aquatic integrity within an urban watershed begins to degrade.

Figure 5-1: Impervious Area and Watershed Health



Total Phosphorus (TP) is one of the pollutants that was modeled in this study. Anne Arundel County does have New Development Criteria within their regulations that require each new development to meet a 50% reduction in the TP load. Since TP is being used for new development review, it is the parameter that will be used for evaluating the watershed management plan alternatives, and in order to do this, it will be the parameter for which the guidelines are based. The project team evaluated the relationship between Imperviousness and TP. Figure 5.2 presents the results.

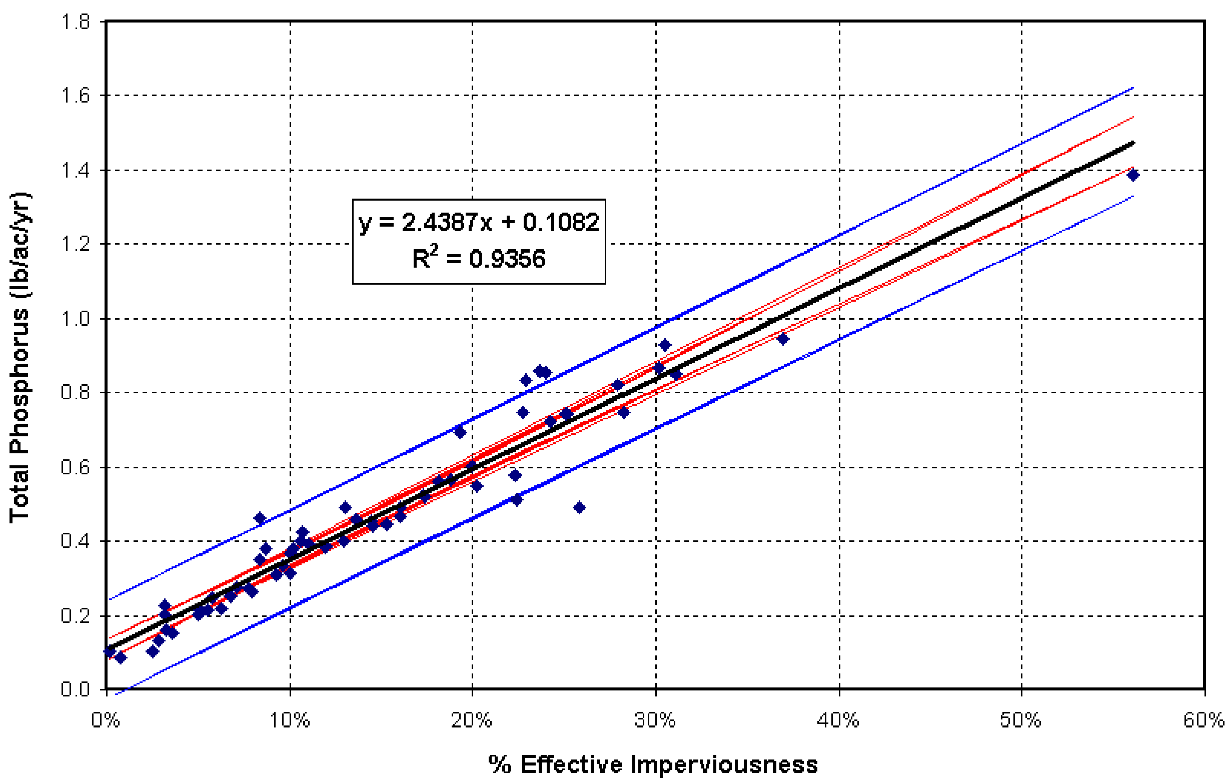


Figure 5-2: Total Phosphorus as a function of Percent Effective Imperviousness

Figure 5.2 indicates that there is a strong relationship between imperviousness and TP. Using this initial relationship as a guideline, 10% imperviousness cover would result in a TP load of 0.35 lb/ac/yr. Draft guidelines are presented within Table 5.7. These values will be used as a method to evaluate watershed management alternatives in the next Chapter.

Table 5-7: Draft Watershed Management Guidelines

Parameter	Guideline
Macroinvertebrate (Watershed goal)[1]	Good
Percent Effective Imperviousness[1]	10%
TP loading rate (lb/ac/yr)[2]	0.35

Notes:
1 - Using relationships from Center of Watershed Protection between Imperviousness and Watershed Health
2 - Using relationship presented in Figure 5-2 between Total Phosphorus and Percent Effective Imperviousness

6 Evaluation of Alternatives

6.1 Introduction

This section of the Watershed Plan serves two purposes. First, it gives an overview of watershed management scenarios as an integrated framework for managing the Severn River watershed, showing how preservation, controls on new development, and water quality retrofits can work together to meet watershed goals. Secondly, it establishes links to the more detailed recommendations which follow. Note that this work was done in parallel to the ranking of the indicators described in Section 5.0, and is complementary to that process.

Sections 6.3 and 6.4 describe the alternatives for improvements that were selected by the Project Team for evaluation, along with measures of benefits that will be used in Section 7.0 to prioritize projects for implementation.

6.2 Management Scenarios

6.2.1 Overview

Four scenarios were modeled in WISE to complement the components of the watershed management plan. These scenarios were then compared to the Draft Watershed Improvement Guidelines to evaluate attainment of goals. Scenarios 2 through 4 were only run on Total Phosphorus as it is the parameter chosen to evaluate the effectiveness of the plan. The following is a description of each scenario:

Scenario 1: Existing Land Use Conditions

Existing land use projections were used to determine the modeled water quality rates in the study area. The approach used for simulating the existing water quality conditions, using PLOAD, involved applying the current land use data, EMC, and rainfall data for computing pollutant loads and applying existing BMPs to reduce pollutants in the runoff. Detailed information about the development of this PLOAD model can be found in Section 3.7.

Scenario 2: Future Land Use Conditions with No Control on New Developments

Future land use projections were used to determine the impacts associated with changes in land use on modeled water quality rates in the study area. The approach used for simulating the future water quality conditions, using PLOAD, involved applying the future land use data, EMC, and rainfall data for computing pollutant loads. The projected loads from the future land use conditions model assumes growth in Anne Arundel County with neither additional watershed management regulations on new development nor implementation of any stream restoration or BMP retrofits.

Scenario 3: Future Land Use Conditions with Water Quality Requirements on New Developments

Anne Arundel County has development review regulations that require all new developments to reduce the post development Total Phosphorus load exiting the site by 50%. In Scenario 3, an approach similar to Scenario 2 was applied, however total phosphorus loads from all new development occurring between existing and the future land use conditions were reduced by 50%. More detail regarding the creation of these scenarios is discussed in Appendix B.

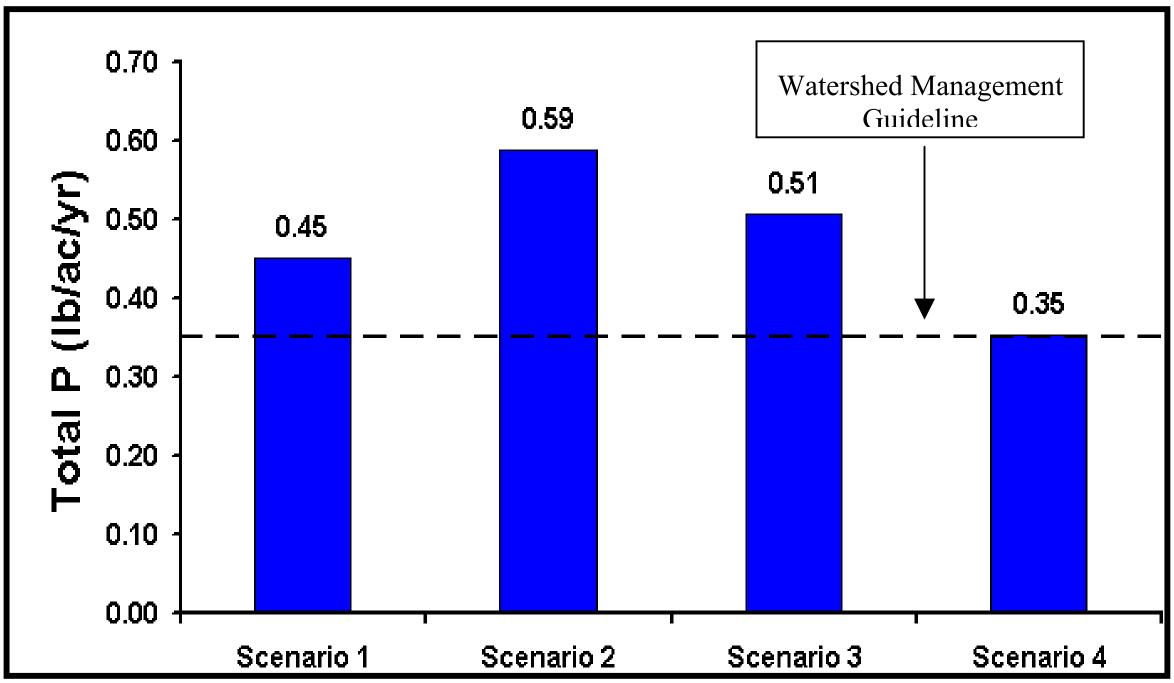
Scenario 4: Future Land Use Conditions with Water Quality Requirements on New Developments along with Retrofitting of Existing Developments

Scenario 4 builds on the previous one. For watersheds that do not meet the Draft Watershed Management Guidelines after implementation of new development requirements, this scenario evaluates the amount of retrofitting needed within already developed areas in order to achieve the guidelines. All retrofits assume that BMPs will be added to existing developments within the watershed to reduce the total phosphorus load by 50%. More detail regarding the creation of these scenarios is discussed in Appendix B.

Results

Figure 6.1 presents the results for each scenario for the entire study area.

Figure 6-1: Watershed Management Scenario Results



Scenario 1: Existing Land Use
Scenario 2: Future Land Use Conditions with No Control on New Developments
Scenario 3: Future Land Use Conditions with Water Quality Requirements on New Developments
Scenario 4: Future Land Use Conditions with Water Quality Requirements on New Developments along with Retrofitting of Existing Developments

The figure illustrates that the overall watershed is already exceeding the guidelines during existing conditions. Scenario 2 qualifies the argument for controls on new developments. Scenario 3 does add some control however does not meet the guidelines. Additional retrofits will need to implemented to achieve the goals. Based on Scenario 4, 38% of the entire watershed area will need to be retrofitted to attain the goals.

Table 6.1 breaks down the results by individual sub-watersheds under the four scenarios. There are 3 groups of watersheds within the data presented:

- Group 1 - Sub-Watersheds that meet the guidelines under Scenario 3
- Group 2 - Sub-Watersheds that meet the guidelines under Scenario 4
- Group 3 - Sub-Watersheds that do not meet the guidelines under any scenario.

Table 6-1: Watershed Management Scenarios for Subwatersheds (TP Loads, lb/ac/yr)

Sub-Watershed	Scenario 1	Scenario 2	Scenario 3	Scenario 4	% of Total Area Needed for Retrofits to Attain the Guideline
Group 1 - Sub-Watersheds that meet the guidelines under Scenario 3					
Cool Spring Creek	0.28	0.54	0.33	NA	0%
Little Round Bay	0.29	0.39	0.33	NA	0%
Severn Run Trib 4	0.28	0.42	0.33	NA	0%
Clements Creek	0.26	0.45	0.33	NA	0%
Sharps Point	0.32	0.33	0.32	NA	0%
Severn Mainstem 3	0.31	0.40	0.32	NA	0%
Maynadier Creek	0.19	0.33	0.30	NA	0%
Cypress Branch	0.28	0.33	0.29	NA	0%
Severn Mainstem 4	0.28	0.33	0.29	NA	0%
Chase Creek	0.25	0.36	0.29	NA	0%
Gumbottom Branch 1	0.27	0.31	0.27	NA	0%
Ray's Pond	0.19	0.28	0.23	NA	0%
Martins Pond	0.09	0.42	0.22	NA	0%
Sewel Spring Branch	0.20	0.27	0.22	NA	0%
Hopkins Creek	0.16	0.25	0.20	NA	0%
Gumbottom Branch 2	0.17	0.25	0.19	NA	0%
Brewer Pond	0.11	0.25	0.16	NA	0%
Group 2 - Watersheds that meet the guidelines under Scenario 4					
Cove of Cork	0.60	0.66	0.62	0.35	74%
Severn Mainstem 1	0.60	0.66	0.62	0.35	70%
Cool Spring Branch	0.56	0.61	0.57	0.35	68%
Sullivan Cove	0.55	0.63	0.57	0.35	68%
Heron Lake	0.62	0.69	0.62	0.35	63%
Whitehall Creek 1	0.63	0.70	0.65	0.35	59%
Forked Creek	0.48	0.55	0.50	0.35	55%
Jonas Green Pond	0.53	0.59	0.54	0.35	51%
Round Bay Shore	0.46	0.48	0.47	0.35	51%
Arden Pond	0.49	0.54	0.51	0.35	51%
Evergreen Creek	0.46	0.58	0.51	0.35	50%
Fox Creek	0.44	0.56	0.49	0.35	49%
Brewer Shore	0.46	0.46	0.46	0.35	48%
Severn River Tidal	0.43	0.53	0.48	0.35	45%
Severn Run Trib 3	0.47	0.61	0.52	0.35	45%
Severn Run Trib 5	0.46	0.62	0.51	0.35	43%
Ringgold Cove	0.39	0.51	0.44	0.35	42%
Mill Creek 1	0.43	0.59	0.49	0.35	40%
Lake Ogleton	0.40	0.52	0.45	0.35	36%
Chartwell Branch	0.43	0.48	0.45	0.35	34%
Stevens Creek	0.39	0.46	0.42	0.35	33%
Saltworks Creek	0.37	0.60	0.46	0.35	29%

Sub-Watershed	Scenario 1	Scenario 2	Scenario 3	Scenario 4	% of Total Area Needed for Retrofits to Attain the Guideline
Whitehall Creek 3	0.42	0.54	0.47	0.35	28%
Severn Run Trib 6	0.46	0.52	0.49	0.35	25%
Winchester Pond	0.39	0.50	0.44	0.35	20%
Meredith Creek	0.36	0.46	0.43	0.35	20%
Jabez Branch 4	0.38	0.50	0.43	0.35	18%
Jabez Branch 1	0.38	0.48	0.42	0.35	18%
Luce Creek	0.36	0.54	0.42	0.35	18%
Aisquith Creek	0.34	0.44	0.38	0.35	15%
Jabez Branch 2	0.37	0.42	0.40	0.35	15%
Severn Run Trib 1	0.32	0.55	0.41	0.35	14%
Mill Creek 2	0.33	0.48	0.38	0.35	13%
Indian Creek Branch	0.34	0.41	0.38	0.35	11%
Whitehall Creek 2	0.32	0.41	0.36	0.35	7%
Valentine Creek	0.35	0.40	0.37	0.35	6%
Brewer Creek	0.29	0.47	0.36	0.35	4%
Group 3 - Watersheds that do not meet the guidelines under any scenario.					
Spa Creek	0.65	1.93	1.10	0.97	*
Back Creek	0.87	1.48	1.07	0.74	*
Woolchurch Cove	1.28	1.37	1.31	0.69	*
Weems Creek	1.18	1.35	1.25	0.68	*
Chase Pond	0.61	1.08	0.69	0.55	*
Pointfield Branch	0.85	1.08	0.92	0.54	*
Picture Spring Branch	0.69	1.03	0.85	0.52	*
Carr Creek	0.73	0.98	0.84	0.49	*
Bear Branch	0.79	0.92	0.84	0.46	*
Jabez Branch 3	0.80	0.85	0.82	0.44	*
Severn Run Trib 7	0.68	0.80	0.77	0.44	*
Hacketts Point to S	0.74	0.75	0.68	0.43	*
Severn Run Trib 2	0.54	0.84	0.68	0.42	*
Yantz Creek	0.70	0.78	0.73	0.39	*
Severn Run Trib 9	0.47	0.78	0.59	0.39	*
Severn Mainstem 2	0.49	0.76	0.59	0.39	*
Severn Run Trib 8	0.53	0.74	0.62	0.38	*
Browns Cove	0.57	0.72	0.64	0.36	*
Pendennis Mount Pond	0.70	0.72	0.71	0.36	*

Scenario 1: Existing Land Use
Scenario 2: Future Land Use Conditions with No Control on New Developments
Scenario 3: Future Land Use Conditions with Water Quality Requirements on New Developments
Scenario 4: Future Land Use Conditions with Water Quality Requirements on New Developments along with Retrofitting of Existing Developments

* Note: All land available for retrofits in scenario 4 was used in the model but these watersheds still did not meet the guideline

6.2.2 Preservation Scenario

Alternatives for watershed preservation have been proposed for the Severn River Watershed Management Plan as a method to protect high-quality areas from degradation as the watershed develops. The BMPs proposed fall into two categories: Land Conservation, which identifies sensitive areas and protects them in their existing condition, and Site Design, which gives incentives to develop with designs that have a lower impact on aquatic resources than conventional development.

All of the preservation measures proposed will provide benefits compared to conventional development, to some degree. The major benefit is to reduce the changes on the hydrologic regime, keeping baseflow closer to pre-development conditions, and reducing peak flows and flashiness. This benefit, along with an expected reduction in runoff pollutant loads, will also help to preserve aquatic habitat and reduce streambank erosion and other geomorphological changes.

Land Conservation Scenarios

Greenways This alternative is a method of preserving important natural areas, which are important habitat and connecting corridors for terrestrial wildlife. Many of the proposed greenways follow stream valleys in the Severn River watershed.

A Countywide coverage of greenways was provided by the County which provided the basis for the analysis. Much of the greenway area is already owned by public entities, based on a Countywide coverage showing schools, County parks, State parks and natural resource areas, Federal parks, and Conservation Fund properties. To identify which greenway area in private hands could be preserved, public lands (except for property owned by the County Board of Education) were removed from the greenways to be preserved leaving the final scenario coverage of greenway lands currently not in public ownership.

This alternative made the following changes to the areas of change in the future land use map which are in greenway preservation areas:

In areas where no change in development occurs between present and future land use, there is no change. Greenways are not added and the preservation land use is the same as future conditions.

In areas where the existing land use is not equal to WDS, land use is changed to OPS, indicating acquisition of land or easements for greenways during redevelopment and conversion to open space, which will undergo reforestation over time.

In areas where the existing land use is WDS, the future (preservation) land use is changed to WDS, indicating acquisition of land or easements for greenways during development.

Expanded Stream Buffer This alternative was represented by creating a 300-foot stream buffer in areas with no planned sewer service. The purpose for this buffer is to reduce the potential for septic systems to short circuit from the drain field directly to streams without treatment. Similarly to greenways, it is assumed that if no development occurs, the buffer will not be created, but if a property develops, the County will have the opportunity to reclaim the buffer.

As with the greenways, the buffer areas already in public ownership were removed in order to focus on the areas in private ownership that would be affected by the alternative. Greenway areas were removed from the buffers to eliminate overlap in the two alternatives.

The proposed land use of the buffer areas was determined in the same way as the greenways, by comparing present and future land use in the buffers and changing it as described above.

Site Design Scenarios

Cluster Development Cluster development consists of developing 1- and 2-acre zoned lots so that buildings on these lots are placed more closely together than traditional zoning permits. Controlling placement of homes in such a manner allows for larger sections of contiguous open space or woods. Furthermore, the clustered areas of buildings exhibit pollutant runoff values (EMCs) more closely resembling residential lots with half the density. For cluster development, model input parameters were recalculated based on reserving half the area as woods and developing the other half as residential at twice the nominal density.

The cluster development scenario was created by changing future R11 and R21 land uses to R11C and R21C with imperviousness, EMCs, and CNs as described in the table below.

Higher Density Cluster A second alternative for cluster development (R11CD and R21CD) was also created to represent higher than zoned density. For this alternative, 30% of the area was reserved for woods and the remainder was assumed to be developed at the next higher density.

Table 6-2: Characteristics of Cluster Development

Land Use Code	Land Use Description	Percent Impervious			EMC	CN for hydrologic soil type			
		Imperv	Woods	Lawn	(TP)	A	B	C	D
R11	Residential with 1-ac lots	11	0	89	0.32	45	65	77	82
R11C	R11 / Cluster Development	8	50	42	0.24	35	58	72	79
R11CD	R11/ Cluster w/ Add'l Density	10	30	60	0.27	40	62	74	80
R21	Residential with 2-ac lots	11	0	89	0.32	45	65	77	82
R21C	R21 / Cluster Development	6	50	44	0.24	38	60	73	80
R11CD	R11/ Cluster w/ Add'l Density	8	30	62	0.27	39	61	74	80

6.2.3 Restoration Alternatives

Alternatives for watershed restoration have been proposed for the Severn River Watershed Management Plan as a method to improve water quality and watershed conditions from areas that were developed before the most recent stormwater management regulations were in place. Two categories of BMPs are proposed: SWM Facilities, which treat stormwater runoff, and non-stormwater discharge BMPs, which reduce pollutants from other types of discharges from the watershed.

Watershed benefits from these alternatives are primarily related to water quality, with some secondary benefits of flow reduction and restoration of the natural hydrologic regime resulting from the proposed structural benefits.

Structural SWM Facilities

Wetland mitigation Anne Arundel County conducted a study of wetland mitigation sites in the Severn, South, and Magothy Rivers. To include these in pollutant load modeling, sites on publicly owned lands in the Severn River watershed were overlaid on the Base Map 3 land use map. They were not modeled as BMPs providing treatment or detention storage for the upstream area, but only as a change in the land use from the existing category (usually commercial or open space) to water. The change affected runoff characteristics in the subwatershed, since water is modeled as 100% impervious, but with no pollutant loading benefit modeled.

Bioretention retrofits A distributed stormwater management alternative consisting of bioretention with an infiltration component was applied watershed-wide to commercial, industrial, 1/8 acre residential, and 1/4 acre residential land uses. For this alternative, locations of individual facilities were not researched, assuming that the entire site area can be treated. The alternative was modeled by changing the treated land areas as shown in the table below and giving them a suffix of B in the land use code.

Table 6-3: Land Use Characteristics of Bioretention BMPs

Land Use Code	Land Use Description	Percent Impervious	CN for hydrologic soil type			
			A	B	C	D
R14	Residential with 1/4-ac lots	20	51	68	79	84
R14B	R14 with Bioretention	17	46	66	78	83
R18	Residential with 1/8-ac lots	34	59	74	82	86
R18B	R18 with Bioretention	30	51	70	81	86

Land Use Code	Land Use Description	Percent Impervious	CN for hydrologic soil type A	B	C	D
COM	Commercial	85	89	92	94	95
COMB	COM with bioretention	74	70	84	92	94
IND	Industrial	72	81	88	91	93
INDB	IND with Bioretention	63	65	81	89	92

For each of the treated areas, a new structure type (BRT) was added to the BMP percent removal efficiencies (Table 6-4) using data reported by the Center for Watershed Protection. A point was digitized in the BMP file for each one with attributes for structure type and drainage area.

Table 6-4: Pollutant Removal Efficiency of Bioretention BMPs

Pollutant	TP	TN	NOx	Cu	Zn
Bioretention	65	49	16	97	95

For TR-20 and GWLF modeling, bioretention is assumed to have an infiltration component. This was modeled by adjusting the drainage area characteristics to reduce the volume of runoff, specifically by reducing the CN to account for the recharge volume calculated according to the Maryland Stormwater Manual and reducing the percent impervious to account for infiltration. The adjustment calculations are summarized in Table 6-3, with a comparison to the values for the same land uses without bioretention.

For each drainage area, an estimate of infiltration potential was made based on an assumption about soils, such as the predominant soil type in the vicinity or a mix of soil properties. Event mean concentrations (EMCs) for areas with bioretention did not change and are identical to those without bioretention.

<u>Retrofit of dry ponds to wet ponds</u> This alternative represents a reconstruction of an existing dry pond to one with better pollutant removal characteristics. It is the only site-specific BMP in the scenario. Sites were selected by choosing ponds with the attribute *EDSD* (Extended Detention Structure Dry) or *DP* (Dry Pond) in the field describing the type of structure (*STRU_TYPE*). There were a total of 170 ponds to be retrofitted, 98 EDSD and 72 DP. The retrofit was modeled by converting the structure type to the equivalent wet pond (EDSW and WP, respectively), which had the effect of changing removal efficiencies in PLOAD. Removal efficiencies were obtained from the Center for Watershed Protection as shown in Table 6-5. For each retrofit removal efficiencies were revised from dry ponds to wet ponds. This alternative was selected watershed-wide, without consideration of whether a particular subwatershed was a high priority or not.

Table 6-5: Dry-to-Wet Pond Pollutant Removal

Pollutant	TP	TN	NOx	Cu	Zn
Dry Ponds	5	9	19	10	5
Wet Ponds	51	33	43	57	66

Non-Stormwater Discharges

<u>Septic system upgrades</u> Septic systems are modeled in GWLF using per capita nitrogen and phosphorus loads and uptake from vegetation over the drain field. The model also treats functioning and failing systems separately, with the primary result that nutrients are discharged directly rather than subject to uptake.

Septic system upgrades were modeled in GWLF by changing the loading rates for nitrogen to show the results of retrofitting or replacing conventional systems with low-nitrogen systems. Based on information from the County Health Department, a low-nitrogen system should remove about 75% of the nitrogen discharged from a conventional system. Model inputs for septic system loads were taken from the GWLF manual. For phosphorus, the data incorporating low-phosphate detergents were used. Per capita loads used for the modeling are shown in Table 6-6.

Table 6-6: Septic System Upgrade Parameters (grams/day)

Pollutant	TP	TN
Normal System	2.5	12.0
Upgraded System	2.5	3.0

6.3 Results of Analysis

6.3.1 Preservation

PLOAD

Table 6-7 below summarizes the PLOAD modeling results for each pollutant for the entire watershed in lb/yr. The upper section shows the totals and the lower section shows the reduction resulting from each of the management alternatives.

Table 6-7: PLOAD Results for Preservation Alternatives

	FC lb/yr	TP lb/yr	NOx lb/yr	TN lb/yr	Cu lb/yr	Pb lb/yr	Zn lb/yr
Basemap3	6.21E+14	19,913	56,828	166,359	1,584	3,933	9,458
Greenway	6.00E+14	19,066	55,202	159,601	1,521	3,901	9,003
Greenway + Buffer	5.86E+14	18,747	54,239	156,514	1,494	3,885	8,879
Cluster	5.50E+14	17,989	51,942	149,265	1,427	3,891	8,906
Denser Cluster	5.57E+14	18,151	52,501	150,880	1,442	3,899	8,943
Greenway	-2.06E+13	(846)	(1,626)	(6,758)	(63)	(31)	(455)
Buffer	-1.40E+13	(319)	(962)	(3,086)	(27)	(16)	(124)
Cluster	-3.59E+13	(758)	(2,298)	(7,249)	(67)	6	26
Denser Cluster	-2.87E+13	(596)	(1,739)	(5,634)	(53)	14	63

Model runs were made by adding each alternative to the one preceding it, with the exception of the higher density cluster development alternative. Both the cluster development results show the cumulative total of all the earlier alternatives. The pollutant load reductions attributed to greenways are calculated using the difference in the loads from Greenway and Basemap3. The reductions attributable to expanded buffers in the non-sewered areas are calculated using the difference between Greenway + Buffer and Greenway. Improvements from cluster development and higher density clustering are measured using Greenway + Buffer as a base.

The PLOAD results show all of the preservation alternatives are effective at reducing pollutant loads from future development. It is likely that the buffer and cluster development alternatives, if tested individually and not in addition to the greenways, would show more reduction because some of the area where these alternatives were applied was already reserved as greenways. A similar situation holds for cluster development in comparison with buffer areas.

The cluster development alternatives showed higher metal loads instead of reductions, when compared to the land area as it would have been developed in the conservation scenario. This result is not expected – development with more forest and less lawn and imperviousness should show an improvement in water quality. The reason appears to be related to EMC values for WDS, which are lower than the values for residential land for all of the pollutants except the metals. Changing land use from R11 to R11C or R11CD would therefore give higher than expected modeled results.

A comparison was made of TP loads on a subwatershed level, shown in Table 6-8. The combination of the two land conservation alternatives reduces future TP loads by 6% over the whole watershed, with the highest absolute reduction in Saltworks Creek (SWC) and the highest percentage reduction in Brewer's Pond (BWP). Similarly, cluster development shows a 4% reduction for the watershed compared with a base of greenway + buffer conservation, with the highest absolute reduction in Picture Spring Branch (PSB) and the highest percent reduction in Ringgold Cove (RGC).

Table 6-8: PLOAD Results for Preservation Alternatives (TP by Subwatershed)

		TP (lb/yr)					TP Reduction (lb/yr)			
Shed Code	Area (ac)	Basemap3	Greenway	+Buffer	Cluster	Dense Cluster	Greenway	Buffer	Cluster	Dense Cluster
AQC	278.1	116.2	110.1	106.0	97.0	99.5	(6.2)	(4.0)	(9.0)	(6.5)
ARP	222.2	116.6	116.6	116.6	111.6	112.3	(0.0)	0.0	(5.0)	(4.3)
BKC	854.2	19.6	19.6	19.6	19.5	19.5	0.0	(0.0)	(0.2)	(0.2)
BRB	655.8	598.8	587.3	585.7	569.3	572.6	(11.4)	(1.6)	(16.4)	(13.2)
BRC	186.2	152.9	145.4	140.7	135.5	137.0	(7.5)	(4.6)	(5.2)	(3.8)
BWC	439.1	186.9	133.1	128.0	124.4	125.1	(53.8)	(5.1)	(3.6)	(2.9)
BWP	400.9	83.5	46.6	46.5	37.3	38.7	(37.0)	(0.0)	(9.3)	(7.9)
BWS	43.1	19.7	19.7	19.7	19.7	19.7	(0.0)	(0.0)	0.0	0.0
CGC	732.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CHC	446.3	134.4	123.0	120.5	109.7	112.1	(11.4)	(2.5)	(10.7)	(8.4)
CLC	757.2	231.8	192.9	179.0	169.7	172.2	(38.9)	(14.0)	(9.3)	(6.7)
COC	108.8	69.5	69.5	69.5	67.5	67.8	0.0	(0.0)	(2.0)	(1.7)
CPO	86.0	22.0	22.0	22.0	22.0	22.0	0.0	(0.0)	0.0	0.0
CRC	398.8	360.9	303.6	298.9	266.4	275.3	(57.3)	(4.7)	(32.5)	(23.6)
CSB	348.1	189.0	189.0	189.0	186.3	186.7	(0.0)	0.0	(2.7)	(2.3)
CSC	114.4	21.8	21.4	21.4	21.0	21.1	(0.3)	0.0	(0.4)	(0.3)
CWB	815.9	359.1	356.4	356.4	341.5	344.1	(2.8)	(0.0)	(14.9)	(12.3)
CYB	272.0	83.2	77.6	77.6	77.3	77.4	(5.6)	(0.0)	(0.2)	(0.2)
EVC	80.8	48.5	43.4	43.4	38.7	40.0	(5.1)	0.0	(4.7)	(3.4)
FRC	248.3	122.2	120.0	120.0	117.9	118.5	(2.2)	(0.0)	(2.1)	(1.5)
FXC	116.7	51.7	50.4	48.7	46.7	47.2	(1.3)	(1.7)	(2.0)	(1.4)
GB1	810.0	224.6	208.7	201.6	201.6	201.6	(15.9)	(7.0)	(0.1)	(0.1)
GB2	610.5	134.3	110.4	103.4	103.4	103.4	(23.8)	(7.0)	(0.0)	(0.0)
HLA	60.2	36.9	36.9	36.9	36.2	36.3	(0.0)	(0.0)	(0.7)	(0.6)
HOC	482.4	96.5	77.7	75.7	75.7	75.7	(18.8)	(2.0)	(0.0)	(0.0)
HSP	548.5	320.2	313.0	313.0	313.0	313.0	(7.2)	(0.0)	0.0	0.0
ICB	1447.0	523.1	509.6	506.5	504.0	504.7	(13.5)	(3.1)	(2.5)	(1.8)
JGP	58.4	23.2	23.2	23.2	22.9	23.0	(0.0)	(0.0)	(0.2)	(0.2)
JZ1	839.5	297.3	287.4	283.0	271.1	272.9	(9.9)	(4.4)	(11.9)	(10.1)
JZ2	1179.8	407.7	402.4	393.3	393.3	393.3	(5.3)	(9.1)	0.0	0.0
JZ3	782.1	688.8	666.0	660.2	648.8	652.0	(22.8)	(5.8)	(11.3)	(8.2)
JZ4	597.2	270.4	250.9	235.8	227.3	229.7	(19.5)	(15.0)	(8.5)	(6.2)
LKO	486.0	196.6	196.6	196.6	185.4	187.1	0.0	(0.0)	(11.2)	(9.5)
LRB	415.7	153.6	141.4	138.4	133.1	133.9	(12.2)	(3.1)	(5.3)	(4.5)
LUC	384.8	175.3	155.7	151.4	125.6	131.5	(19.6)	(4.3)	(25.8)	(20.0)
MAC	1069.8	232.4	212.7	203.2	203.2	203.2	(19.7)	(9.5)	(0.0)	(0.0)
MC1	1430.2	717.7	648.5	646.9	615.3	623.3	(69.2)	(1.6)	(31.7)	(23.6)
MC2	1581.9	553.6	527.7	500.0	466.7	475.5	(25.9)	(27.7)	(33.3)	(24.5)
MEC	971.7	362.3	333.5	333.4	326.8	328.6	(28.8)	(0.1)	(6.6)	(4.8)
MRP	58.1	19.8	13.8	13.8	7.2	9.0	(6.0)	(0.0)	(6.6)	(4.8)

Shed Code	Area (ac)	TP (lb/yr) Basemap3	Greenway	+Buffer	Cluster	Dense Cluster	TP Reduction (lb/yr) Greenway	Buffer	Cluster	Dense Cluster
PFB	104.4	90.6	98.0	82.8	81.8	81.9	7.5	(15.2)	(1.1)	(0.9)
PMP	92.4	61.4	61.8	61.3	61.3	61.3	0.4	(0.5)	0.0	0.0
PSB	1566.7	1503.0	1503.5	1503.5	1493.4	1494.9	0.5	0.0	(10.2)	(8.7)
RAP	194.4	45.3	45.0	43.1	42.4	42.6	(0.3)	(2.0)	(0.7)	(0.5)
RBS	124.5	48.9	48.9	48.9	48.9	48.9	(0.0)	(0.0)	0.0	0.0
RGC	121.0	47.4	47.4	46.1	45.8	45.9	0.0	(1.3)	(0.3)	(0.2)
SHP	133.6	36.6	36.6	36.2	36.2	36.2	(0.0)	(0.5)	0.0	0.0
SM1	884.1	595.0	587.0	587.0	577.3	579.3	(8.1)	(0.0)	(9.7)	(7.7)
SM2	531.4	346.8	340.0	340.0	330.4	331.9	(6.8)	(0.0)	(9.6)	(8.1)
SM3	1472.6	557.8	500.8	489.5	413.7	432.0	(57.0)	(11.3)	(75.8)	(57.5)
SM4	845.0	276.8	265.6	245.2	244.1	244.3	(11.2)	(20.5)	(1.1)	(0.9)
SPC	1549.3	4.5	2.7	2.7	2.7	2.7	(1.8)	(0.0)	0.0	0.0
SRT	1172.4	526.8	508.7	508.7	494.0	497.8	(18.0)	(0.0)	(14.7)	(11.0)
SSB	475.6	110.9	91.0	91.0	91.0	91.0	(19.9)	0.0	0.0	0.0
ST1	306.4	146.6	124.5	124.5	94.2	100.5	(22.1)	0.0	(30.4)	(24.0)
ST2	702.5	611.7	610.9	610.9	610.5	610.6	(0.8)	0.0	(0.4)	(0.3)
ST3	1562.2	712.5	711.8	711.8	664.6	671.7	(0.7)	(0.0)	(47.2)	(40.1)
ST4	649.9	226.9	210.7	206.5	177.8	182.9	(16.2)	(4.2)	(28.7)	(23.6)
ST5	1746.7	902.1	884.4	854.2	764.9	780.2	(17.7)	(30.1)	(89.3)	(74.0)
ST6	343.5	203.5	197.5	195.8	195.8	195.8	(6.0)	(1.7)	0.0	0.0
ST7	865.6	650.1	629.6	626.2	610.4	614.7	(20.5)	(3.4)	(15.8)	(11.5)
ST8	373.6	237.1	225.8	224.9	205.4	208.9	(11.3)	(0.9)	(19.5)	(16.0)
ST9	344.1	210.5	191.1	191.1	170.6	175.1	(19.5)	(0.0)	(20.5)	(16.0)
STC	149.8	58.3	57.0	56.7	54.0	54.6	(1.2)	(0.3)	(2.7)	(2.1)
SVC	164.2	80.6	80.6	80.6	79.2	79.4	(0.0)	0.0	(1.4)	(1.2)
SWC	949.3	502.0	465.6	430.1	393.8	403.8	(36.5)	(35.5)	(36.2)	(26.3)
VTC	272.9	99.6	94.0	94.0	93.7	93.8	(5.5)	(0.0)	(0.3)	(0.2)
WCC	269.7	366.5	341.0	339.8	328.6	331.7	(25.5)	(1.2)	(11.3)	(8.2)
WCP	107.7	49.8	49.5	47.5	47.2	47.2	(0.2)	(2.1)	(0.3)	(0.2)
WEC	1537.5	1124.3	1131.9	1109.5	1104.8	1105.6	7.6	(22.3)	(4.7)	(3.9)
WH1	739.1	476.9	476.8	460.7	452.6	454.2	(0.2)	(16.0)	(8.1)	(6.6)
WH2	912.5	298.5	300.7	291.6	267.4	271.1	2.2	(9.1)	(24.1)	(20.5)
WH3	416.9	134.9	136.4	133.3	126.0	127.1	1.6	(3.1)	(7.3)	(6.2)
YZC	204.0	145.8	145.8	145.8	145.8	145.8	0.0	0.0	0.0	0.0
TOTAL	43304.1	19912.6	19066.1	18747.0	17989.4	18151.2	(846.4)	(319.1)	(757.6)	(595.8)

TR20

TR-20 model runs were made for all subwatersheds to estimate peak flows coming from each subwatershed, without routing flows through the stream network between subwatersheds. The table below summarizes the results of the peak flow modeling for the 2-year storm events.

Model runs were performed on all the detailed preservation alternatives combined, and not for individual alternatives. The results showed that preservation scenarios were effective at reducing peak flow many of the watersheds.

Preservation reductions come from lower CN values and Tc associated with wooded land use that does not become developed, and with reduced imperviousness from cluster development. As would be expected, the highest reduction comes in subwatersheds with a large amount of existing wooded land which is zoned for development: Brewer Pond, Brewer Creek, Gumbottom Branch 2, and Maynadier

Creek on the South Shore; Pointfield Branch and Severn Run Mainstem 4 surrounding the Severn Run Natural Resource Area.

Table 6-9: TR20 Results for Preservation Scenario (2-Yr Peak Flow in cfs)

Code	Subwatershed	Area(ac)	Existing	Base map 3	Preser-vation	Change	% Change
AQC	Aisquith Creek	278.1	122	168	158	(10)	-6.0%
ARP	Arden Pond	222.5	75	108	107	(1)	-0.9%
BRB	Bear Branch	655.8	261	340	332	(8)	-2.4%
BRC	Brown's Cove	186.2	135	197	170	(27)	-13.7%
BWC	Brewer Creek	439.1	236	409	244	(165)	-40.3%
BWP	Brewer Pond	400.9	142	267	147	(120)	-44.9%
BWS	Brewer Shore	43.1	81	81	81	0	0.0%
CHC	Chase Creek	446.3	166	315	234	(81)	-25.7%
CLC	Clements Creek	757.3	175	215	189	(26)	-12.1%
COC	Cove of Cork	108.8	108	124	124	0	0.0%
CPO	Chase Pond	86.0	126	187	187	0	0.0%
CRC	Carr Creek	398.8	399	494	475	(19)	-3.8%
CSB	Cool Spring Branch	348.1	7	9	9	0	0.0%
CSC	Coolspring Creek	114.4	32	35	35	0	0.0%
CWB	Chartwell Branch	815.9	77	93	93	0	0.0%
CYB	Cypress Branch	272.0	38	38	32	(6)	-15.8%
EVC	Evergreen Creek	80.8	2	4	4	0	0.0%
FRC	Forked Creek	248.3	114	151	151	0	0.0%
FXC	Fox Creek	116.7	60	85	78	(7)	-8.2%
GB1	Gumbottom Branch 1	810.0	116	100	90	(10)	-10.0%
GB2	Gumbottom Branch 2	610.5	60	86	59	(27)	-31.4%
HLA	Heron Lake	60.2	98	104	104	0	0.0%
HOC	Hopkins Creek	482.4	208	250	206	(44)	-17.6%
HSP	Hacketts to Sandy Point	548.5	446	372	356	(16)	-4.3%
ICB	Indian Creek Branch	1,447.0	243	251	235	(16)	-6.4%
JGP	Jonas Green Pond	58.4	44	46	46	0	0.0%
JZ1	Jabez Branch 1	839.5	266	397	338	(59)	-14.9%
JZ2	Jabez Branch 2	1,179.8	292	327	273	(54)	-16.5%
JZ3	Jabez Branch 3	782.1	312	389	344	(45)	-11.6%
JZ4	Jabez Branch 4	597.2	185	272	219	(53)	-19.5%
LKO	Lake Ogleton	486.1	331	426	426	0	0.0%
LRB	Little Round Bay	415.7	190	308	250	(58)	-18.8%
LUC	Luce Creek	384.8	150	279	253	(26)	-9.3%
MAC	Maynadier Creek	1,069.8	258	351	266	(85)	-24.2%
MC1	Mill Creek 1	1,430.2	658	1042	820	(222)	-21.3%
MC2	Mill Creek 2	1,581.9	744	1046	906	(140)	-13.4%
MEC	Meredith Creek	971.7	358	337	318	(19)	-5.6%
MRP	Martins Pond	58.1	11	42	42	0	0.0%
PFB	Pointfield Branch	104.4	82	154	97	(57)	-37.0%
PMP	Pendennis Mount Pond	92.4	117	120	117	(3)	-2.5%
PSB	Picture Spring Branch	1,566.7	654	1247	1245	(2)	-0.2%
RAP	Ray's Pond	194.4	143	195	182	(13)	-6.7%

Code	Subwatershed	Area(ac)	Existing	Base map 3	Preser-vation	Change	% Change
RBS	Round Bay Shore	124.7	97	95	95	0	0.0%
RGC	Ringgold Cove	121.0	21	23	20	(3)	-13.0%
SHP	Sharps Point	133.6	143	124	120	(4)	-3.2%
SM1	Severn Run Mainstem 1	884.1	146	169	156	(13)	-7.7%
SM2	Severn Run Mainstem 2	531.4	61	177	147	(30)	-16.9%
SM3	Severn Run Mainstem 3	1,472.6	86	92	78	(14)	-15.2%
SM4	Severn Run Mainstem 4	845.0	73	121	83	(38)	-31.4%
SSB	Sewell Spring Branch	475.6	70	81	69	(12)	-14.8%
ST1	Severn Run Tributary 1	306.4	59	174	155	(19)	-10.9%
ST2	Severn Run Tributary 2	702.5	81	198	198	0	0.0%
ST3	Severn Run Tributary 3	1,562.2	68	169	164	(5)	-3.0%
ST4	Severn Run Tributary 4	649.9	9	16	14	(2)	-12.5%
ST5	Severn Run Tributary 5	1,746.7	83	152	133	(19)	-12.5%
ST6	Severn Run Tributary 6	343.5	74	82	74	(8)	-9.8%
ST7	Severn Run Tributary 7	865.7	347	478	457	(21)	-4.4%
ST8	Severn Run Tributary 8	373.6	119	242	226	(16)	-6.6%
ST9	Severn Run Tributary 9	344.1	129	316	315	(1)	-0.3%
STC	Stevens Creek	149.8	5	9	9	0	0.0%
SVC	Sullivans Cove	164.2	76	80	80	0	0.0%
SWC	Saltworks Creek	949.4	156	908	765	(143)	-15.7%
VTC	Valentine Creek	272.9	117	153	125	(28)	-18.3%
WCC	Woolchurch Cove	269.7	528	594	583	(11)	-1.9%
WCP	Winchester Pond	107.7	70	98	89	(9)	-9.2%
WH1	Whitehall Creek 1	739.1	262	382	332	(50)	-13.1%
WH2	Whitehall Creek 2	912.6	583	622	612	(10)	-1.6%
WH3	Whitehall Creek 3	417.0	193	317	293	(24)	-7.6%
YZC	Yantz Creek	204.0	75	80	80	0	0.0%

GWLF

The results are shown as annual average of the water balance (precipitation, evapotranspiration, ground water flow, direct runoff and streamflow), pollutants (Erosion, sediment, dissolved N, Total N, dissolved P, total P, and nutrients by source (septic systems, groundwater, runoff). These results are taken from the GWLF/RUNQUAL output files.

Water balance is not changed a great deal by the preservation alternatives. Similarly to the existing and future scenarios, most of the precipitation infiltrates, then flows as groundwater to streams (Table 6.10).

Table 6-10: Water Balance

	Precip (in)	ET (in)	GW (in)	DRO (in)	Stream flow (in)
Existing	43.05	7.66	29.12	6.37	35.49
BaseMap 3	43.05	7.54	28.98	6.62	35.61
Preservation	43.05	7.61	28.97	6.57	35.54
Preservation Change	0.00	0.07	(0.01)	(0.05)	(0.07)
Preservation Change %	0.0%	0.9%	0.0%	-0.8%	-0.2%

The preservation alternatives are relatively effective at reducing sediment and nutrient pollutant loads, however, as shown in Table 6.11.

Table 6-11: Pollutants by Type

	Erosion (lb/yr)	Sediment (lb/yr)	DN (lb/yr)	TN (lb/yr)	DP (lb/yr)	TP (lb/yr)
Existing	18,750,743	4,875,116	636,223	640,365	23,596	25,716
BaseMap 3	9,798,109	2,547,409	517,544	520,593	24,067	26,501
Preservation	8,821,711	2,293,546	477,049	479,247	22,870	24,981
Preservation Change	(976,398)	(253,864)	(40,496)	(41,346)	(1,197)	(1,520)
Preservation Change %	-10.0%	-10.0%	-7.8%	-7.9%	-5.0%	-5.7%

Table 6-12 shows that the single best method to reduce pollutant loads is to minimize development in unsewered areas with the land conservation alternatives of greenways and expanded buffers, both of which are found to a large extent in areas of the watershed that would be served with septic systems.

Table 6-12: Nutrients by Source

Subshed	Septic N (lb/yr)	Septic P (lb/yr)	GW N (lb/yr)	GW P (lb/yr)	RO N (lb/yr)	RO P (lb/yr)
Existing	362,539	384	109,871	6,398	167,955	18,934
BaseMap 3	221,154	232	109,348	6,341	190,091	19,928
Preservation	190,385	201	109,293	6,341	179,568	18,438
Preservation Change	(30,769)	(31)	(55)	0	(10,522)	(1,489)
Preservation Change %	-13.9%	-13.3%	-0.1%	0.0%	-5.5%	-7.5%

6.3.2 Restoration

PLOAD

PLOAD model runs were made by successively adding restoration alternatives to the previous run in the order shown above. The final run shows the benefits of all the restoration alternatives combined. Wetland mitigation was modeled using the revised wetland land use and future BMPs . The bioretention alternatives were modeled using the revised land use layers discussed above with a BMP coverage that included bioretention.

Table 6-13 below summarizes the results for each pollutant for the entire watershed in lb/yr. The upper section shows the totals and the lower section shows the reduction resulting from each of the management alternatives.

Table 6-13: PLOAD Results for Restoration Alternatives

	FC MPN/yr	TP lb/yr	NOx lb/yr	TN lb/yr	Cu lb/yr	Pb lb/yr	Zn lb/yr
Basemap3	6.21E+14	19,913	56,828	166,359	1,584	3,933	9,458
Wetland	6.21E+14	19,905	57,010	166,684	1,585	3,933	9,459
Wetland + Bio-IC	6.07E+14	15,965	53,238	141,232	1,145	3,893	6,898
Wetland + Bio-ICR	5.87E+14	13,154	50,453	122,471	832	3,785	5,190
All Restoration	5.87E+14	12,590	48,226	120,448	791	3,785	4,796
Wetland	5.02E+11	(7)	182	325	1	0	1
Bio-IC	-1.44E+13	(3,940)	(3,771)	(25,452)	(440)	(39)	(2,561)
Bio-R	-1.93E+13	(2,812)	(2,786)	(18,761)	(313)	(109)	(1,708)
Dry Pond Retrofit	0.00E+00	(563)	(2,227)	(2,023)	(41)	0	(395)
All Restoration	-3.32E+13	(7,322)	(8,602)	(45,911)	(793)	(148)	(4,663)

The load reductions attributed to the wetland mitigation alternative are calculated using the difference between the wetland model run and Basemap3. Reductions attributable to bioretention retrofits in industrial and commercial areas are based on a comparison with the wetland results. Reductions from bioretention retrofits in residential areas are based on comparison with the previous run with industrial and commercial retrofits. Finally, the benefits of dry-to-wet pond retrofits are found by comparing the reductions from all the restoration measures together with the run showing results from wetlands and bioretention.

The PLOAD results show that, except for the wetland mitigation alternative, the restoration alternatives are effective at reducing pollutant loads from existing development. Wetlands were modeled as a change of land use and not a BMP, which would cause an underestimate of benefits. Negative or very low removals for nutrients and metals are explained with a comparison of imperviousness and EMC values between the most common pre-existing condition (OPS) and the wetland itself (WAT), shown in the Table 6-14. The combination of a higher effective imperviousness for water and higher (in some cases) EMCs results in higher loads.

Table 6-14: Comparison of EMCs for Wetland Mitigation Sites

LU CODE	IMPERV	FC	TP	NOX	TN	CU	PB	ZN
	%	MPN/100ml	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
OPS	0	500	0.15	0.54	1.15	0.006	0.030	0.195
WAT	100	500	0.03	0.60	1.20	0.005	0.003	0.023

The most effective restoration alternative is bioretention retrofits for industrial and commercial areas, followed by the dry-to-wet pond retrofits. Removal efficiencies for bioretention are very high, and combined with the higher loading from commercial and industrial land uses, they appear to be very effective at reducing watershed loads.

A comparison was made of TP loads on a subwatershed level, shown Table 6-15. The combination of the two bioretention alternatives reduces future TP loads by 21% over the whole watershed. The highest absolute reduction was in Picture Spring Branch (PSB) and the highest percentage reduction in Yantz Creek (YZC) at 62%.

Similarly, the dry-to-wet pond retrofit gives a 4% reduction for the watershed compared against the base of bioretention retrofits, with the highest absolute reduction in Severn Run Tributary 3 (ST3) and the highest percent reduction in Chase Pond (CPO) at 35%.

Table 6-15: PLOAD Results for Restoration Alternatives (TP by Subwatershed)

		TP (lb/yr)					TP Reduction (lb/yr)			
Shed Code	Area	Basemap3	Wetland	Wetland +Bio_IC	Wetland +Bio_ICR	All	Wetland	Bio_IC	Bio_R	Dry-to-Wet
AQC	278.1	116.2	116.2	115.3	115.4	115.4	(0.0)	(0.9)	0.1	0.0
ARP	222.2	116.6	116.6	58.0	0.0	0.0	(0.0)	(58.6)	(58.0)	0.0
BKC	854.2	19.6	19.6	18.0	18.0	18.0	0.0	(1.6)	(0.0)	0.0
BRB	655.8	598.8	598.8	369.9	206.4	205.1	(0.0)	(228.9)	(163.5)	(1.3)
BRC	186.2	152.9	152.9	152.8	152.8	152.8	0.0	(0.0)	0.0	0.0
BWC	439.1	186.9	186.9	184.3	184.5	184.5	0.0	(2.6)	0.2	0.0
BWP	400.9	83.5	83.5	83.5	83.5	83.5	0.0	(0.1)	(0.0)	0.0
BWS	43.1	19.7	19.7	19.7	19.7	19.7	(0.0)	0.0	(0.0)	0.0
CGC	732.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CHC	446.3	134.4	134.4	133.7	133.8	133.8	0.0	(0.7)	0.1	0.0
CLC	757.2	231.8	231.8	231.8	232.0	232.0	0.0	(0.0)	0.2	0.0
COC	108.8	69.5	69.5	56.6	48.3	48.3	0.0	(12.9)	(8.3)	0.0
CPO	86.0	22.0	22.0	21.0	20.0	12.9	0.0	(1.0)	(1.0)	(7.0)

Shed Code	Area	TP (lb/yr) Basemap3	Wetland	Wetland +Bio_IC	Wetland +Bio_ICR	All	TP Reduction (lb/yr) Wetland	Bio_IC	Bio_R	Dry-to-Wet
CRC	398.8	360.9	358.0	256.4	253.6	253.6	(2.8)	(101.6)	(2.8)	0.0
CSB	348.1	189.0	189.0	90.3	-4.4	-4.4	(0.0)	(98.7)	(94.8)	0.0
CSC	114.4	21.8	21.8	21.8	21.8	21.8	0.0	(0.0)	(0.0)	0.0
CWB	815.9	359.1	359.1	302.8	265.0	265.0	(0.0)	(56.3)	(37.9)	0.0
CYB	272.0	83.2	83.2	70.3	65.1	65.1	0.0	(12.9)	(5.1)	0.0
EVC	80.8	48.5	48.5	40.6	35.8	35.8	(0.0)	(8.0)	(4.8)	0.0
FRC	248.3	122.2	122.2	89.2	61.5	61.5	(0.0)	(33.0)	(27.7)	0.0
FXC	116.7	51.7	51.7	38.6	30.3	30.3	(0.0)	(13.1)	(8.3)	0.0
GB1	810.0	224.6	224.6	204.7	187.1	187.1	(0.0)	(19.9)	(17.6)	0.0
GB2	610.5	134.3	134.3	129.9	129.4	129.4	(0.0)	(4.3)	(0.5)	(0.0)
HLA	60.2	36.9	36.9	31.8	31.8	29.5	(0.0)	(5.1)	(0.0)	(2.2)
HOC	482.4	96.5	96.5	96.5	96.5	96.5	0.0	(0.0)	0.0	0.0
HSP	548.5	320.2	320.8	306.9	307.5	307.5	0.6	(13.9)	0.6	0.0
ICB	1447.0	523.1	522.9	504.8	498.8	498.8	(0.2)	(18.1)	(5.9)	0.0
JGP	58.4	23.2	23.2	23.2	23.2	15.4	0.0	(0.0)	(0.0)	(7.8)
JZ1	839.5	297.3	297.3	254.5	228.0	228.0	0.0	(42.8)	(26.5)	0.0
JZ2	1179.8	407.7	407.7	394.9	393.3	393.1	(0.0)	(12.7)	(1.6)	(0.2)
JZ3	782.1	688.8	689.0	657.5	658.1	658.1	0.2	(31.5)	0.6	0.0
JZ4	597.2	270.4	269.6	252.7	252.2	252.2	(0.7)	(16.9)	(0.5)	0.0
LKO	486.0	196.6	196.6	192.2	190.7	169.5	0.0	(4.4)	(1.5)	(21.3)
LRB	415.7	153.6	153.6	137.3	124.3	120.1	0.0	(16.4)	(13.0)	(4.1)
LUC	384.8	175.3	175.3	148.0	139.5	139.5	(0.0)	(27.3)	(8.6)	0.0
MAC	1069.8	232.4	232.4	220.5	221.4	221.4	(0.0)	(11.9)	0.9	0.0
MC1	1430.2	717.7	717.7	611.6	562.4	529.5	(0.0)	(106.2)	(49.2)	(32.9)
MC2	1581.9	553.6	553.6	534.5	524.4	427.6	(0.0)	(19.1)	(10.1)	(96.8)
MEC	971.7	362.3	363.8	355.7	354.3	354.3	1.4	(8.1)	(1.4)	0.0
MRP	58.1	19.8	19.8	19.8	19.8	19.8	(0.0)	0.0	(0.0)	0.0
PFB	104.4	90.6	90.6	80.2	80.1	78.3	0.0	(10.4)	(0.0)	(1.9)
PMP	92.4	61.4	61.4	60.6	60.6	55.2	0.0	(0.8)	(0.0)	(5.4)
PSB	1566.7	1503.0	1503.0	923.1	350.1	285.4	(0.0)	(579.9)	(573.1)	(64.6)
RAP	194.4	45.3	45.3	45.3	45.4	45.4	(0.0)	0.0	0.0	0.0
RBS	124.5	48.9	48.9	41.1	35.9	35.9	0.0	(7.8)	(5.2)	0.0
RGC	121.0	47.4	47.4	47.4	47.4	47.4	0.0	(0.0)	(0.0)	0.0
SHP	133.6	36.6	36.6	36.6	36.6	35.9	(0.0)	0.0	(0.0)	(0.7)
SM1	884.1	595.0	595.0	322.0	55.4	5.8	0.0	(273.1)	(266.6)	(49.6)
SM2	531.4	346.8	346.8	259.5	89.6	89.6	(0.0)	(87.3)	(169.9)	0.0
SM3	1472.6	557.8	557.0	505.4	487.3	487.3	(0.7)	(51.6)	(18.1)	0.0
SM4	845.0	276.8	276.8	255.4	252.3	244.8	0.0	(21.4)	(3.1)	(7.5)
SPC	1549.3	4.5	4.5	4.5	4.6	4.6	0.0	(0.0)	0.0	0.0
SRT	1172.4	526.8	526.8	410.1	305.3	305.3	(0.0)	(116.7)	(104.8)	0.0
SSB	475.6	110.9	110.9	110.6	110.6	110.6	(0.0)	(0.3)	(0.0)	0.0
ST1	306.4	146.6	146.6	128.5	123.5	118.5	0.0	(18.1)	(4.9)	(5.0)
ST2	702.5	611.7	611.7	360.8	62.4	33.5	0.0	(251.0)	(298.4)	(28.9)
ST3	1562.2	712.5	712.5	530.8	368.3	293.1	0.0	(181.7)	(162.5)	(75.2)
ST4	649.9	226.9	226.9	207.3	191.9	191.9	(0.0)	(19.6)	(15.4)	0.0
ST5	1746.7	902.1	902.1	627.4	367.1	345.4	(0.0)	(274.7)	(260.3)	(21.7)
ST6	343.5	203.5	203.5	160.6	160.6	151.2	(0.0)	(42.9)	(0.0)	(9.3)
ST7	865.6	650.1	650.1	457.4	408.6	408.6	0.0	(192.7)	(48.8)	0.0
ST8	373.6	237.1	237.1	200.3	172.6	121.0	0.0	(36.8)	(27.8)	(51.5)
ST9	344.1	210.5	210.5	168.0	163.7	163.7	0.0	(42.5)	(4.3)	0.0

Shed Code	Area	TP (lb/yr) Basemap3	Wetland	Wetland +Bio_IC	Wetland +Bio_ICR	All	TP Reduction (lb/yr) Wetland	Bio_IC	Bio_R	Dry-to-Wet
STC	149.8	58.3	58.3	52.8	49.4	49.4	0.0	(5.5)	(3.4)	0.0
SVC	164.2	80.6	80.6	40.7	3.6	3.6	0.1	(39.9)	(37.1)	0.0
SWC	949.3	502.0	502.0	439.9	437.0	437.0	0.0	(62.1)	(2.9)	0.0
VTC	272.9	99.6	99.6	67.2	37.7	37.7	0.0	(32.3)	(29.5)	0.0
WCC	269.7	366.5	362.5	206.1	202.1	202.0	(4.0)	(156.3)	(4.0)	(0.1)
WCP	107.7	49.8	49.8	49.8	49.8	49.8	(0.0)	0.0	(0.0)	0.0
WEC	1537.5	1124.3	1124.3	871.0	778.1	778.1	(0.0)	(253.3)	(92.9)	0.0
WH1	739.1	476.9	476.9	391.3	345.8	279.1	0.0	(85.6)	(45.5)	(66.7)
WH2	912.5	298.5	298.5	287.6	278.3	276.8	(0.0)	(10.9)	(9.2)	(1.6)
WH3	416.9	134.9	134.2	124.3	123.6	123.6	(0.7)	(9.8)	(0.7)	0.0
YZC	204.0	145.8	145.3	59.7	-17.6	-17.6	(0.5)	(85.6)	(77.3)	0.0
TOTAL	43304.1	19912.6	19905.2	15965.1	13153.5	12590.1	(7.4)	(3940.1)	(2811.5)	(563.4)

TR20

The results, amount of runoff in cubic feet and peak discharge in cfs, are taken from TR20 output files summary tables 1 and 3 respectively. Table 6-16 below summarizes the results for the 2-tear storm event.

TR-20 model runs were made for all subwatersheds to estimate peak flows coming from each subwatershed, without routing flows through the stream network between subwatersheds. The table below summarizes the results of the peak flow modeling for the 2-year storm events.

Model runs were performed on all the detailed restoration alternatives combined, and not for individual alternatives. The results showed that restoration scenarios were effective at reducing peak flow many of the watersheds. Reductions in peak flow from restoration alternatives come from the increased infiltration which is part of the bioretention alternative. Infiltration reduces the CN value and subsequently reduces both the volume and the peak flows.

The highest reduction comes in subwatersheds with a large amount of high density residential and commercial development: Severn Run Mainstem 1 and 2, Severn Run Tributary 5, and Picture Spring Branch in the northern part of the watershed; and Cool Spring Branch, Bear Branch, Severn Run Tributary 8, and Yantz Creek, Evergreen Creek, and Chartwell Branch around Severna Park.

Table 6-16: TR20 Results for Restoration Scenario (2-Yr Peak Flow in cfs)

Code	Subwatershed	Area(ac)	Existing	Base map 3	Restor-ation	Change	% Change
AQC	Aisquith Creek	278.1	122	168	167	(1)	-0.6%
ARP	Arden Pond	222.5	75	108	88	(20)	-18.5%
BRB	Bear Branch	655.8	261	340	264	(76)	-22.4%
BRC	Brown's Cove	186.2	135	197	197	0	0.0%
BWC	Brewer Creek	439.1	236	409	407	(2)	-0.5%
BWP	Brewer Pond	400.9	142	267	266	(1)	-0.4%
BWS	Brewer Shore	43.1	81	81	81	0	0.0%
CHC	Chase Creek	446.3	166	315	314	(1)	-0.3%
CLC	Clements Creek	757.3	175	215	215	0	0.0%
COC	Cove of Cork	108.8	108	124	118	(6)	-4.8%
CPO	Chase Pond	86.0	126	187	183	(4)	-2.1%
CRC	Carr Creek	398.8	399	494	459	(35)	-7.1%
CSB	Cool Spring Branch	348.1	7	9	2	(7)	-77.8%
CSC	Coolspring Creek	114.4	32	35	35	0	0.0%

Code	Subwatershed	Area(ac)	Existing	Base map 3	Restor-ation	Change	% Change
CWB	Chartwell Branch	815.9	77	93	79	(14)	-15.1%
CYB	Cypress Branch	272.0	38	38	34	(4)	-10.5%
EVC	Evergreen Creek	80.8	2	4	3	(1)	-25.0%
FRC	Forked Creek	248.3	114	151	129	(22)	-14.6%
FXC	Fox Creek	116.7	60	85	79	(6)	-7.1%
GB1	Gumbottom Branch 1	810.0	116	100	98	(2)	-2.0%
GB2	Gumbottom Branch 2	610.5	60	86	84	(2)	-2.3%
HLA	Heron Lake	60.2	98	104	102	(2)	-1.9%
HOC	Hopkins Creek	482.4	208	250	250	0	0.0%
HSP	Hacketts to Sandy Point	548.5	446	372	377	5	1.3%
ICB	Indian Creek Branch	1,447.0	243	251	251	0	0.0%
JGP	Jonas Green Pond	58.4	44	46	46	0	0.0%
JZ1	Jabez Branch 1	839.5	266	397	377	(20)	-5.0%
JZ2	Jabez Branch 2	1,179.8	292	327	320	(7)	-2.1%
JZ3	Jabez Branch 3	782.1	312	389	382	(7)	-1.8%
JZ4	Jabez Branch 4	597.2	185	272	271	(1)	-0.4%
LKO	Lake Ogleton	486.1	331	426	426	0	0.0%
LRB	Little Round Bay	415.7	190	308	301	(7)	-2.3%
LUC	Luce Creek	384.8	150	279	259	(20)	-7.2%
MAC	Maynadier Creek	1,069.8	258	351	346	(5)	-1.4%
MC1	Mill Creek 1	1,430.2	658	1042	987	(55)	-5.3%
MC2	Mill Creek 2	1,581.9	744	1046	1040	(6)	-0.6%
MEC	Meredith Creek	971.7	358	337	354	17	5.0%
MRP	Martins Pond	58.1	11	42	42	0	0.0%
PFB	Pointfield Branch	104.4	82	154	145	(9)	-5.8%
PMP	Pendennis Mount Pond	92.4	117	120	122	2	1.7%
PSB	Picture Spring Branch	1,566.7	654	1247	1043	(204)	-16.4%
RAP	Ray's Pond	194.4	143	195	195	0	0.0%
RBS	Round Bay Shore	124.7	97	95	92	(3)	-3.2%
RGC	Ringgold Cove	121.0	21	23	23	0	0.0%
SHP	Sharps Point	133.6	143	124	124	0	0.0%
SM1	Severn Run Mainstem 1	884.1	146	169	87	(82)	-48.5%
SM2	Severn Run Mainstem 2	531.4	61	177	151	(26)	-14.7%
SM3	Severn Run Mainstem 3	1,472.6	86	92	87	(5)	-5.4%
SM4	Severn Run Mainstem 4	845.0	73	121	104	(17)	-14.0%
SSB	Sewell Spring Branch	475.6	70	81	81	0	0.0%
ST1	Severn Run Tributary 1	306.4	59	174	153	(21)	-12.1%
ST2	Severn Run Tributary 2	702.5	81	198	198	0	0.0%
ST3	Severn Run Tributary 3	1,562.2	68	169	164	(5)	-3.0%
ST4	Severn Run Tributary 4	649.9	9	16	14	(2)	-12.5%
ST5	Severn Run Tributary 5	1,746.7	83	152	101	(51)	-33.6%
ST6	Severn Run Tributary 6	343.5	74	82	80	(2)	-2.4%
ST7	Severn Run Tributary 7	865.7	347	478	444	(34)	-7.1%
ST8	Severn Run Tributary 8	373.6	119	242	191	(51)	-21.1%
ST9	Severn Run Tributary 9	344.1	129	316	301	(15)	-4.7%
STC	Stevens Creek	149.8	5	9	8	(1)	-11.1%
SVC	Sullivans Cove	164.2	76	80	69	(11)	-13.8%
SWC	Saltworks Creek	949.4	156	908	900	(8)	-0.9%

Code	Subwatershed	Area(ac)	Existing	Base map 3	Restor-ation	Change	% Change
VTC	Valentine Creek	272.9	117	153	136	(17)	-11.1%
WCC	Woolchurch Cove	269.7	528	594	552	(42)	-7.1%
WCP	Winchester Pond	107.7	70	98	98	0	0.0%
WH1	Whitehall Creek 1	739.1	262	382	369	(13)	-3.4%
WH2	Whitehall Creek 2	912.6	583	622	619	(3)	-0.5%
WH3	Whitehall Creek 3	417.0	193	317	323	6	1.9%
YZC	Yantz Creek	204.0	75	80	45	(35)	-43.8%

GWLF

The results are shown as annual average of the water balance (precipitation, evapotranspiration, ground water flow, direct runoff and streamflow), pollutants (Erosion, sediment, dissolved N, Total N, dissolved P, total P, and nutrients by source (septic systems, groundwater, runoff). These results are taken from the GWLF/RUNQUAL output files.

The output shows the improvements resulting from the infiltration component of bioretention. Groundwater flows are increased by roughly the same amount that the direct runoff is reduced, amounting to a four percent change from future conditions (Basemap 3). Evapotranspiration is also increased from vegetative uptake (Table 6-17). These alternatives reduce direct runoff back to the levels of existing conditions.

Table 6-17: Water Balance

	Precip (in)	ET (in)	GW (in)	DRO (in)	Stream (in)
Existing	43.05	7.66	29.12	6.37	35.49
BaseMap 3	43.05	7.54	28.98	6.62	35.61
Restoration	43.05	7.57	29.23	6.36	35.59
Restoration (Low N)	43.05	7.57	29.23	6.36	35.59
Restoration Change	0.00	0.02	0.24	(0.27)	(0.02)
Restoration Change %	0.0%	0.3%	0.8%	-4.0%	-0.1%
Restoration Change (Low N)	0.00	0.02	0.24	(0.27)	(0.02)
Restoration Change (Low N) %	0.0%	0.3%	0.8%	-4.0%	-0.1%

The restoration scenario results in some reduction in erosion and sediment, and a significant reduction in phosphorus. There is a very large reduction in nitrogen loads from the watershed, however, primarily from dissolved nitrogen.

Table 6-18: Pollutants by Type

	Erosion (lb/yr)	Sediment (lb/yr)	DN (lb/yr)	TN (lb/yr)	DP (lb/yr)	TP (lb/yr)
Existing	18,750,743	4,875,116	636,223	640,365	23,596	25,716
BaseMap 3	9,798,109	2,547,409	517,544	520,593	24,067	26,501
Restoration	9,703,969	2,522,933	497,035	499,861	21,939	24,501
Restoration (Low N)	9,703,969	2,522,933	317,118	319,943	21,939	24,501
Restoration Change	(94,140)	(24,477)	(20,509)	(20,732)	(2,128)	(1,999)
Restoration Change %	-1.0%	-1.0%	-4.0%	-4.0%	-8.8%	-7.5%
Restoration Change (Low N)	(94,140)	(24,477)	(200,427)	(200,649)	(2,128)	(1,999)
Restoration Change (Low N) %	-1.0%	-1.0%	-38.7%	-38.5%	-8.8%	-7.5%

The largest single change in nutrient loads is from conversion of existing septic systems to low-nitrogen systems. The bioretention facilities and dry pond conversions provide about a 10 percent reduction in runoff nitrogen and phosphorus.

Table 6-19: Nutrients by Source

	Septic N (lb/yr)	Septic P (lb/yr)	GW N (lb/yr)	GW P (lb/yr)	RO N (lb/yr)	RO P (lb/yr)
Existing	362,539	384	109,871	6,398	167,955	18,934
BaseMap 3	221,154	232	109,348	6,341	190,091	19,928
Restoration	221,118	232	110,268	6,341	168,475	17,928
Restoration (Low N)	41,205	232	110,268	6,341	168,471	17,928
Restoration Change	(37)	0	920	0	(21,616)	(1,999)
Restoration Change %	0.0%	0.0%	0.8%	0.0%	-11.4%	-10.0%
Restoration Change (Low N)	(179,950)	0	920	0	(21,620)	(1,999)
Restoration Change (Low N) %	-81.4%	0.0%	0.8%	0.0%	-11.4%	-10.0%

7 Implementation Plan

7.1 Introduction

In this section, the costs and benefits of implementing the capital project alternatives proposed earlier are presented. The objective is to provide evaluation criteria that should allow alternatives to be compared economically on the basis of a cost/benefit ratio.

The cost information presented below represents the range of costs anticipated from the perspective of the County, but not from all perspectives. For example, costs to developers or private homeowners are not as easily identified. Therefore, non-quantitative evaluation criteria were also developed to reflect the ease of implementation, operation and maintenance of each alternative. These implementation, operation and maintenance criteria capture indirectly the cost to all parties and include the following:

- Public Acceptability
- Acceptability to Anne Arundel County
- Acceptability to Regulators (MDE and DNR)
- Public Health and Safety Concerns
- Ease of Construction and Implementation (for Stakeholders and/or County)
- Reliability
- Ease of Maintenance

Cost estimates are presented below, followed by an alternatives assessment based on pollutant reduction and the implementation and operation criteria. The section concludes with a discussion of legislative recommendations for watershed improvements.

7.2 Capital Cost Estimates

Cost estimates were developed for the management alternatives that are part of the future land use, preservation and restoration scenarios as follows:

Future
    Existing buffer regulations
    Wetland mitigation
Restoration
    Commercial / Industrial bioretention
    Residential bioretention
    Dry-to-wet pond retrofits
    Septic system upgrades
Preservation
    Land preservation (greenways, buffers)

These estimates are discussed for each scenario below. Capital cost estimates were developed for structural BMPs in the form of unit costs, so that an estimate of the cost of retrofitting a large area can be derived from the size of the systems needed to provide treatment. The costs for structural BMPs include design, permitting, and construction, but not land or right-of way acquisition.

Two of the alternatives are presented with no costs: Current SWM regulations for future development and cluster development for the preservation scenario. There was no additional cost to the County anticipated for implemening either of these alternatives. The County will incur costs for program administration, but these will be continuing costs, not new program costs.

Costs for land preservation were prepared on a per acre basis.

Unless otherwise noted, all cost information is from the fact sheets developed by the EPA for NPDES permitting which can be found on the EPA website at http://cfpub.epa.gov/npdes/stormwater/menuofbmps/post_27.cfm.

All costs are in 2003 dollars, adjusted as necessary using the Consumer Price Index (CPI-W).

7.2.1 Existing Buffer Regulations

The land use map for future conditions makes the assumption that existing buffer regulations will be enforced as development and redevelopment occurs. If all costs are borne by the developers, there is no cost to the County for this management measure. For purposes of comparison, a high-range cost was developed that includes coordination with the property owner and payment for an easement for the buffer. These costs were estimated per acre both within and outside the Critical Area, and are shown below in Section 7.2.6 Land Preservation.

Costs were summarized by subwatershed and are given in the attached spreadsheet. For the 3,074 acres of buffer identified, the low range cost is zero, the high range is $19,984,300, of which $6,149,100 represents coordination with property owners and $18,385,200 represents easement acquisition.

7.2.2 Wetland Mitigation

Wetland mitigation sites were identified by the County in September 2003 in a paper assessing potential sites in the Severn, South, and Magothy River watersheds. The County provided the area of each wetland mitigation site. Wetland volume was computed by assuming an average depth of 2 feet. Several methods for estimating wetland construction costs were reviewed. The results were somewhat variable. The current equation originally developed by Brown and Schueler (1997) provided an estimate that was at the high end of the range, but still within the range of other estimates. This was also one of the most recently published methodologies. It was selected to be somewhat conservative and use the most recent data available. The estimating equation is provided below.

$$C = 30.6V^{0.705}$$

Where C = Capital cost
V = Wetland volume in cf

This cost equation was developed in 1997, therefore costs were escalated to 2003 dollars using a factor of 116.6%. The final equation used for retrofits is:

$$C = (1.166)(30.6)V^{0.705}$$

In addition to capital costs, wetland mitigation will likely require either property acquisition, or at a minimum a construction and maintenance easement. These costs were estimated using the same methodology summarized under Land Preservation.

The overall high cost estimate of $5,810,300 includes capital costs, property owner coordination, easement plat, land acquisition, amortized costs of maintenance as described in Section 7.3. The overall low cost estimate of $5,088,800 includes the same costs without land acquisition. Costs are summarized in with other restoration alternatives in Table 7.5 below.

7.2.3 Bioretention Retrofits

Commercial, industrial and residential (R14 and R18) land areas were considered to be eligible for bioretention retrofits if the property was expected to remain the same in future land use projections areas (coded COMB, INCB, R14B and R18B in the restoration land use scenario).

Costs were estimated by determining the size of bioretention systems required to treat the area of each land use by subwatershed. Systems were sized according to the criteria for WQ_v and Re_v in the Maryland Stormwater Manual, using the following equation:

$$A_f = \frac{(WQ_v)(d_f)}{9 \times [k \times (h_f + d_f) \times t_f]}$$

Where A_f = Bioretention area in SY
WQ_v = water quality volume in cf
d_f = filter bed depth in ft,
k = permeability in ft/day
h_f = ponding depth in ft
t_f = time to drain in days

For the purposes of this study, assumptions were made for the design of the systems:

d_f = 2.5 ft
k = 0.5 ft/day
h_f = 0.5 ft
t_f = 2.0 days

The systems proposed for this project are assumed to have an infiltration component as well. To size this part of the facility, the recharge volume (Re_v) was determined, using the following equation from the Maryland Stormwater Manual.

$$Re_v = (S)(R_v)(A)$$

Where Re_v = Recharge volume in cf
S = soil-specific recharge factor, dimensionless
R_v = runoff coefficient, dimensionless
A = drainage area, acres

The bioretention retrofit areas are primarily in the areas of the watershed, with predominantly A and B soils, so the soil-specific recharge factor was set at 0.32, reflecting 50% A and 50% B soils.

The volume to be treated by bioretention (BRT_v) is the difference between WQ_v and Re_v. This is the volume used to size the surface area of bioretention systems which is used for the cost estimate. Recharge volume is constructed below this surface area and is included in the unit cost estimate. The results by subwatershed are given with other restoration alternatives in Table 7.5.

Cost estimates for bioretention systems were developed using Maryland State Highway Administration (MSHA) bid prices for the items needed to construct a unit sized system, corresponding to a size of 1 square yard (SY) of surface area with a volume of 2.08 cubic yard (CY). Unit costs were developed by the square yard because the calculations above give the size of facility by area. The results, shown in Table7-1, are approximately \$210 / SY for residential systems and \$190 / SY for commercial or industrial areas, which includes construction costs for demolition, construction of the bioretention cell, underdrain, recharge area, planting, and restoration. The unit cost also includes 5% design costs and a 20% contingency. The cost differential comes from the need to remove and replace sidewalk for residential areas, assuming systems are constructed in the utility strip.

Table 7-1: Unit Cost Estimate for Bioretention Systems

	Description	Unit Price	Unit	Qty	Resi-	Qty	Comm /
Demolition	Curb-Gutter Removal	\$5.00	LF	3.00	\$15.00	3.0	\$15.00
	Sidewalk Removal	\$30.00	CY	0.4	\$13.20	0.0	\$0.00

	Description	Unit Price	Unit	Qty	Resi-	Qty	Comm /
Underdrain	Class 2 Excavation, 15"	$10.00	CY	0.42	$4.17	0.42	$4.17
	Gravel Jacket 15" Deep	$40.00	CY	0.42	$16.67	0.42	$16.67
	6" PVC Perforated Pipe	$10.00	LF	3.0	$30.00	3.0	$30.00
	Geotextile Filter Fabric	$1.00	SY	1.0	$1.00	1.0	$1.00
Bioretention	Class 2 Excavation, 42"	$10.00	CY	1.17	$11.67	1.17	$11.67
Cell	Fine Aggregate/Sand, 4"	$35.00	CY	0.11	$3.89	0.11	$3.89
	No. 57 Stone, 8"	$35.00	CY	0.22	$7.78	0.22	$7.78
	Bioretention Soil, 30"	$20.00	CY	0.83	$16.67	0.83	$16.60
Recharge Cell	Class 2 Excavation, 18"	$10.00	CY	0.50	$5.00	0.50	$5.00
	No. 2 Stone	$30.00	CY	0.5	$15.00	0.5	$15.00
	Geotextile Filter Fabric	$1.00	SY	1.0	$1.00	1.0	$1.00
Planting and	Seed	$0.75	SY	1.0	$0.75	1.0	$0.75
Restoration	Tree	$200.00	EA	0.0	$0.00	0.0	$0.00
	Shrubs	$22.00	EA	1.0	$22.00	1.0	$22.00
	Hardwood Bark Mulch	$1.75	SY	1.0	$1.75	1.0	$1.75
	Construct Sidewalk	$5.00	SF	0.67	$3.33		$0.00
Subtotal	Construction Cost				$168.87		$152.27
	Contingency @ 20%				$33.77		$30.45
	Design @ 5%				$8.44		$7.61
TOTAL				SY	$211.08	SY	$190.33

The estimated capital cost of bioretention is $159,793,000, with a breakdown among land uses shown in Table 7.2: Life cycle costs of bioretention come to $156,890,000 for commercial and industrial systems and $122,384,000 for residential systems. Section 7.3 describes the procedure used to develop life cycle costs.

Table 7-2: Capital Cost of Bioretention by Land Use

Land Use	Acres	Impervious Acres	Capital Cost	Cost / Imp Acre
COM	2,081	1,696	$73,633,000	$43,400
IND	532	372	$16,135,000	$43,400
R14	3,320	764	$36,649,000	$48,000
R18	1,953	695	$33,376,000	$48,000
TOTAL	7,886	3,527	$159,793,000	$45,306

7.2.4 Dry-to-Wet Pond Conversion

Because conversion of dry ponds to wet ponds is a relatively new practice, and because costs can vary widely, cost estimating methods for planning studies have not been widely published. For the purposes of this budget-level estimate, the costs were assumed to be 75 percent of the cost of constructing a wet pond. This estimate is based on the assumption that costs for the purchase and installation of a new riser and plant material would be similar to building a new wet pond. The only cost savings would result from a reduction in the amount of grading and excavation.

There are several equations available for estimating the cost of designing and constructing a wet pond. These methods were reviewed, producing similar results. The current equation recommended on the EPA website (http://cfpub.epa.gov/npdes/stormwater/menuofbmps/post_26.cfm) was used.

$$C = 24.5V^{0.705}$$

Where C = Capital cost
V = Pond volume in cf

This cost equation was developed in 1997, therefore costs were escalated to 2003 dollars using a factor of 116.6%. The final equation used for retrofits is:

$$C = (1.166)(0.75)(24.5)V^{0.705}$$

Pond volume is not part of the BMP database, but information is available for the drainage area. To determine size of the retrofit facilities, an estimate was made using criteria from the Maryland Stormwater Manual for the water quality volume (WQ_v) and channel protection volume (Cp_v). WQ_v is a function of the impervious area in the drainage area. This was estimated based on the average imperviousness for the land use types in the subwatershed containing each pond and used to find the runoff coefficient.

$$WQ_v = \frac{43{,}560(P)(R_v)(A)}{12}$$

Where WQ_v = water quality volume in cf
P = rainfall depth in inches (1.0 for Anne Arundel County)
R_v = runoff coefficient, dimensionless
A = drainage area in acres

Cp_v is based on detention of the 1-year 24-hour rainfall event for post development conditions abd a ratio of outflow to inflow which is a function of the unit peak discharge. With this information, the storage volume (V_s) is found as a function of runoff volume (V_r). Review of the methodology in the design manual shows that for drainage areas and outflow in the range found for the ponds proposed for retrofits, a ratio of $V_s / V_r = 0.65$ is a close approximation.

$$Cp_v = \frac{0.65 \times 43{,}560 \times (P)(R_v)(A)}{12}$$

Where Cp_v = channel protection volume in cf
P = rainfall depth of the 1-yr 24-hr event in inches (2.7 for Anne Arundel County)
R_v = runoff coefficient, dimensionless
A = drainage area in acres

Retrofit volume, V, used in the cost equation is the sum of WQ_v and Cp_v.

A summary of costs by subwatershed are shown in Table 7.5. The capital cost of the retrofits is $6,005,000, and the life cycle cost including maintenance is $8,999,000. The average cost per impervious acre is $7,700. The table shows the summary by subwatershed.

7.2.5 Septic System Upgrades

Septic systems are modeled in GWLF using per capita nitrogen and phosphorus loads and uptake from vegetation over the drain field. The model also treats functioning and failing systems separately, with the primary result that nutrients are discharged directly rather than subject to uptake.

For systems that are installed as new, the cost with installation is approximately $5,000. These systems can achieve 75% removal of nitrogen.

Costs were determined by estimating the number of people per subwatershed on septic systems, based on an estimate of residential units per land use category in each. With the assumption of 2.4 persons per household, an estimate of the number of septic systems was derived, and the total cost was estimated at $5,000 each for installation. . Table 7.6 shows all costs. The total cost for all septic system upgrades across the watershed is $52,940,000.

7.2.6 Land Preservation

The cost of land preservation varies depending on the level of protection placed on the land. The County could either purchase the land outright, obtain an easement on the land, or institute development restrictions through regulations which limit activities within stream buffers. The cost of protecting land through regulation is limited to the one time cost of developing the regulation and is negligible, given that most of these regulations are already in place (which does not mean this approach would be politically acceptable and easy to implement, as measured by these evaluation criteria in Table 7-10). The cost of purchasing the land or obtaining an easement will be a combination of four elements:

- the time involved in coordinating with the property owner,
- the cost of obtaining a plat to define the easement or land purchase,
- payment to the land owner for easement rights, and/or
- the cost of purchasing the land.

For this analysis, the unit cost assumed for each of these elements is summarized in Table 7.3.

Table 7-3: Land Acquisition Unit Costs

Cost Element	Unit Cost		Source and Assumptions
Property Coordination	$2,000	per acre	Assumes 40 hrs of staff time at $50/hr
Cost of Easement Plat	$480	per acre	Assumes 1 survey team 4 hrs at $120/hr
Compensation for easement	$4,000	per acre	Assumes $200 per year per acre, for 20 yrs
Compensation for Land Area (outside Critical Area)	$10,000	per acre	Survey of Realtors provided range of $5000-$25,000 per acre for unimproved land
Compensation for Land Area (in Critical Area)	$20,000	per acre	Survey of Realtors provided range of $5000-$25,000 per acre for unimproved land

It was assumed to be highly unlikely for the County to purchase the land protected under existing buffer and critical area regulations. The most protection provided in these areas would be a possible property easement.

It was assumed to be more likely for the County to need to purchase some of the land within the greenways and potential 300-foot buffers in unsewered areas. It is unlikely these areas could be protected through regulation alone, therefore a range of cost is presented. The lowest cost would require obtaining an easement, and the highest, purchasing the land.

The area of land to be preserved was limited to areas that were expected to be developed in future land use projections. As a result of the current ordinance, in addition to preserving existing buffers, developers are required to restore deficient buffers as part of development. As a result, the entire buffer area was assumed to be intact, without need for restoration.

Costs for greenway preservation range from $30,419,400 to $84,799,100, with the difference coming from outright purchase of the land, as opposed to simply acquiring easements. Costs of extended buffer preservation range from $25,706,200 to $77,954,800 for the same reason.

7.3 Maintenance and Life Cycle Costs

Annual costs of operations and maintenance have been estimated for the management alternatives proposed for this project, based on information obtained from literature review and discussions with County staff. The values used in the cost analysis are discussed below.

7.3.1 Existing Buffer Regulations

Stream buffers will be maintained by private landowners and there is no anticipated annual maintenance cost to be borne by the County. Additional inspection and enforcement may be required, but this cost is not included in the analysis.

7.3.2 Wetland Mitigation

Maintenance costs generally range from 3% to 5% of construction costs. An average value of 4% was selected for this analysis.

For the purpose of life cycle cost analysis, a Net Present Value calculation was performed using a discount rate of 5% and an expected life of 20 years before substantial reconstruction.

7.3.3 Commercial / Industrial / Residential Bioretention

Costs for maintenance of bioretention systems were estimated at 5% to 7% of construction costs from an EPA study (Urban Stormwater Best Management Practices Study (EPA-821-R-99-012, August 1999) An average value of 6% was selected for this analysis.

For the purpose of life cycle cost analysis, a Net Present Value calculation was performed using a discount rate of 5% and an expected life of 20 years before substantial reconstruction.

7.3.4 Dry-to-Wet Pond Retrofits

The annual cost of routine maintenance for wet ponds is typically estimated at about 3 to 5 percent of the construction cost. An average value of 4% was selected for this analysis.

For the purpose of life cycle cost analysis, a Net Present Value calculation was performed using a discount rate of 5% and an expected life of 20 years before substantial reconstruction.

7.3.5 Septic System Retrofits

It is anticipated that septic systems will remain in private hands and will be maintained by landowners. Additional inspection and enforcement may be required, but this cost is not included in the analysis.

7.3.6 Land Preservation (Greenway and 300-foot buffer)

Greenways and buffers will be maintained by private landowners and there is no anticipated annual maintenance cost to be borne by the County. Additional inspection and enforcement may be required, but this cost is not included in the analysis.

7.4 Summary of Costs for Alternatives

The total cost of all the improvements recommended in the Watershed Plan is $402,427,501 for the low cost and $529,761,601 for the high cost. Several breakdowns of the costs are presented in the tables below.

- Tables 7-4 and 7-5 show summaries of cost by subwatershed for the preservation and restoration alternatives. For reasons discussed in Section 7.3, both low and high cost estimates are provided.
- Table 7-6 shows an estimate of costs for septic system upgrades by subwatershed, along with the estimated population on septic systems used to derive the costs.
- Tables 7-7 and 7-8 show the total costs for preservation and restoration scenarios, along with a columns showing the costs normalized by subwatershed area.

Table 7-4: Summary of Buffer and Greenway Costs

	Existing Buffer Regulations		Greenway		300 ft Buffer	
Subwatershed	Low Cost	High Cost	Low Cost	High Cost	Low Cost	High Cost
AQC	$0	$188,500	$0	$0	$441,600	$1,710,500
ARP	$0	$49,500	$1,300	$5,500	$1,200	$4,700
BKC	$0	$11,400	$1,900	$4,700	$0	$0
BRB	$0	$359,400	$9,200	$23,300	$187,700	$476,500

Subwatershed	Existing Buffer Regulations		Greenway		300 ft Buffer	
	Low Cost	High Cost	Low Cost	High Cost	Low Cost	High Cost
BRC	$0	$101,800	$0	$0	$376,900	$1,407,400
BWC	$0	$220,900	$1,131,600	$3,069,200	$492,400	$1,547,200
BWP	$0	$324,600	$1,865,100	$5,505,000	$7,100	$18,200
BWS	$0	$0	$0	$0	$58,200	$236,900
CGC	$0	$0	$0	$0	$0	$0
CHC	$0	$402,000	$687,700	$2,161,200	$267,400	$1,048,900
CLC	$0	$573,900	$1,116,600	$2,962,800	$1,078,400	$3,247,800
COC	$0	$73,000	$0	$0	$177,200	$714,000
CPO	$0	$52,100	$0	$0	$0	$0
CRC	$0	$593,100	$0	$0	$0	$0
CSB	$0	$35,400	$0	$0	$0	$0
CSC	$0	$0	$0	$0	$1,000	$4,000
CWB	$0	$99,800	$0	$0	$0	$0
CYB	$0	$47,100	$311,100	$960,400	$20,100	$81,800
EVC	$0	$33,600	$0	$0	$0	$0
FRC	$0	$57,300	$0	$0	$0	$0
FXC	$0	$66,000	$0	$0	$226,800	$756,600
GB1	$0	$388,400	$1,237,500	$3,246,900	$1,053,000	$2,756,800
GB2	$0	$529,000	$1,908,800	$4,900,200	$942,300	$2,423,100
HLA	$0	$11,700	$0	$0	$0	$0
HOC	$0	$517,100	$1,550,000	$5,032,900	$816,100	$2,148,500
HSP	$0	$449,400	$421,900	$1,427,600	$290,200	$1,133,200
ICB	$0	$359,900	$1,255,200	$3,470,500	$507,600	$1,324,600
JGP	$0	$7,400	$0	$0	$16,200	$65,800
JZ1	$0	$219,800	$1,002,300	$2,544,200	$560,400	$1,422,600
JZ2	$0	$658,700	$705,000	$1,789,700	$1,534,200	$3,894,500
JZ3	$0	$140,700	$287,900	$730,700	$1,053,200	$2,673,500
JZ4	$0	$118,900	$783,200	$1,988,100	$774,200	$1,965,400
LKO	$0	$199,300	$0	$0	$0	$0
LRB	$0	$222,400	$932,700	$2,478,400	$247,300	$850,600
LUC	$0	$343,600	$0	$0	$252,600	$880,400
MAC	$0	$1,342,000	$3,415,000	$9,313,500	$1,463,800	$4,068,500
MC1	$0	$709,200	$2,159,200	$5,481,100	$278,400	$706,700
MC2	$0	$633,500	$136,200	$529,300	$2,031,600	$6,850,100
MEC	$0	$807,600	$1,618,800	$5,380,600	$336,400	$1,344,900
MRP	$0	$97,900	$0	$0	$0	$0
PFB	$0	$32,300	$0	$0	$354,600	$1,074,200
PMP	$0	$55,500	$0	$0	$232,700	$795,600
PSB	$0	$609,000	$24,400	$61,900	$0	$0
RAP	$0	$119,000	$0	$0	$437,900	$1,678,800
RBS	$0	$8,400	$0	$0	$115,500	$470,900
RGC	$0	$98,500	$0	$0	$117,300	$478,000
SHP	$0	$79,000	$0	$0	$171,000	$697,000
SM1	$0	$373,800	$664,600	$1,687,000	$0	$0
SM2	$0	$479,100	$537,300	$1,364,000	$0	$0
SM3	$0	$258,600	$848,000	$2,152,700	$628,100	$1,594,400
SM4	$0	$103,400	$707,600	$1,841,400	$405,000	$1,113,700

Subwatershed	Existing Buffer Regulations Low Cost	Existing Buffer Regulations High Cost	Greenway Low Cost	Greenway High Cost	300 ft Buffer Low Cost	300 ft Buffer High Cost
SPC	$0	$4,500	$46,100	$116,900	$0	$0
SRT	$0	$714,900	$763,700	$3,063,600	$43,800	$172,300
SSB	$0	$26,300	$887,600	$2,257,000	$5,900	$16,400
ST1	$0	$98,100	$174,300	$442,500	$0	$0
ST2	$0	$482,600	$4,600	$11,600	$0	$0
ST3	$0	$699,400	$374,000	$949,400	$3,300	$8,400
ST4	$0	$386,800	$1,024,700	$2,601,100	$209,600	$532,100
ST5	$0	$759,100	$389,300	$988,100	$355,200	$901,600
ST6	$0	$163,200	$490,100	$1,244,100	$277,000	$703,100
ST7	$0	$336,300	$106,000	$269,100	$582,800	$1,479,400
ST8	$0	$78,600	$221,700	$562,800	$69,800	$177,100
ST9	$0	$134,900	$15,900	$40,300	$0	$0
STC	$0	$63,700	$0	$0	$61,400	$249,600
SVC	$0	$63,900	$0	$0	$0	$0
SWC	$0	$641,100	$0	$0	$1,529,000	$4,294,600
VTC	$0	$249,600	$599,400	$2,134,900	$123,400	$355,600
WCC	$0	$27,900	$0	$0	$121,500	$495,100
WCP	$0	$66,900	$0	$0	$104,000	$423,900
WEC	$0	$266,100	$0	$0	$804,000	$3,044,300
WH1	$0	$311,300	$0	$0	$1,537,900	$4,160,400
WH2	$0	$753,400	$0	$0	$1,417,600	$5,259,200
WH3	$0	$346,400	$1,900	$4,900	$504,400	$2,015,400
YZC	$0	$46,800	$0	$0	$0	$0
Grand Total	$0	$19,984,300	$30,419,400	$84,799,100	$25,706,200	$77,954,800

Table 7-5: Summary of Bioretention Retrofits, Pond Retrofits, and Wetland Mitigation Costs

Subwatershed Code	Bioretention Retrofits (Commercial/ Industrial) LCC	Bioretention Retrofits (Residential) LCC	Dry to Wet Pond Retrofits LCC	Wetland Mitigation ‡ Low Cost	Wetland Mitigation ‡ High Cost
AQC	$140,810	$0	$0	$0	$0
ARP	$95,876	$3,132,705	$0	$0	$0
BKC	$378,555	$43,664	$0	$0	$0
BRB	$5,277,574	$4,779,416	$42,660	$0	$0
BRC	$3,711	$0	$0	$0	$0
BWC	$301,854	$0	$0	$0	$0
BWP	$17,320	$0	$0	$0	$0
BWS	$0	$0	$0	$0	$0
CGC	$0	$0	$0	$0	$0
CHC	$91,546	$0	$0	$0	$0
CLC	$9,278	$0	$0	$0	$0
COC	$480,617	$360,791	$0	$0	$0
CPO	$0	$319,492	$319,962	$0	$0
CRC	$8,064,711	$0	$0	$583,291	$667,191
CSB	$523,915	$4,894,213	$0	$0	$0
CSC	$0	$0	$0	$0	$0
CWB	$2,150,095	$2,332,985	$0	$0	$0

Subwatershed Code	Bioretention Retrofits (Commercial/ Industrial) LCC	Bioretention Retrofits (Residential) LCC	Dry to Wet Pond Retrofits LCC	Wetland Mitigation ‡ Low Cost	Wetland Mitigation ‡ High Cost
CYB	$1,154,841	$482,341	$0	$0	$0
EVC	$322,885	$235,189	$0	$0	$0
FRC	$611,750	$1,479,049	$0	$0	$0
FXC	$116,288	$686,660	$0	$0	$0
GB1	$355,669	$1,899,843	$0	$0	$0
GB2	$547,421	$116,919	$2,216	$0	$0
HLA	$495,462	$0	$58,859	$0	$0
HOC	$0	$0	$0	$0	$0
HSP	$1,457,768	$0	$0	$394,344	$443,144
ICB	$1,636,695	$469,607	$0	$699,138	$806,838
JGP	$0	$0	$158,741	$0	$0
JZ1	$2,000,142	$2,013,878	$0	$0	$0
JZ2	$1,419,294	$181,098	$20,472	$0	$0
JZ3	$2,490,918	$0	$0	$193,729	$211,929
JZ4	$2,074,967	$0	$0	$690,357	$796,257
LKO	$429,277	$142,149	$414,868	$0	$0
LRB	$405,153	$1,016,388	$84,684	$0	$0
LUC	$2,181,022	$489,169	$0	$0	$0
MAC	$1,540,200	$322,975	$0	$0	$0
MC1	$6,060,595	$3,787,620	$822,508	$0	$0
MC2	$1,244,531	$772,923	$955,547	$0	$0
MEC	$663,709	$221,298	$0	$761,489	$882,689
MRP	$0	$0	$0	$0	$0
PFB	$642,810	$0	$59,100	$0	$0
PMP	$68,041	$0	$82,081	$0	$0
PSB	$19,925,963	$8,685,904	$894,474	$0	$0
RAP	$0	$0	$0	$0	$0
RBS	$0	$505,107	$0	$0	$0
RGC	$1,856	$0	$0	$0	$0
SHP	$0	$386	$28,365	$0	$0
SM1	$595,049	$15,855,580	$683,979	$0	$0
SM2	$2,155,635	$3,655,579	$0	$0	$0
SM3	$4,448,643	$1,333,382	$0	$502,376	$570,576
SM4	$3,347,225	$0	$271,349	$0	$0
SPC	$0	$0	$0	$0	$0
SRT	$1,399,788	$7,078,504	$0	$0	$0
SSB	$81,649	$0	$0	$0	$0
ST1	$1,500,613	$259,237	$79,940	$0	$0
ST2	$2,472,362	$9,608,475	$484,716	$0	$0
ST3	$5,121,333	$15,453,733	$1,345,975	$0	$0
ST4	$657,523	$1,359,512	$0	$0	$0
ST5	$5,787,721	$11,613,715	$281,780	$0	$0
ST6	$4,365,138	$0	$91,971	$0	$0

Subwatershed Code	Bioretention Retrofits (Commercial/ Industrial) LCC	Bioretention Retrofits (Residential) LCC	Dry to Wet Pond Retrofits LCC	Wetland Mitigation ‡ Low Cost	High Cost
ST7	$13,176,145	$2,000,413	$0	$0	$0
ST8	$3,256,312	$127,724	$756,476	$0	$0
ST9	$3,571,533	$254,136	$0	$0	$0
STC	$107,628	$281,880	$0	$0	$0
SVC	$263,504	$2,062,874	$0	$105,719	$113,519
SWC	$6,562,326	$135,280	$0	$0	$0
VTC	$0	$2,424,051	$0	$0	$0
WCC	$9,342,644	$0	$3,697	$297,001	$329,901
WCP	$0	$0	$0	$0	$0
WEC	$16,755,638	$3,458,110	$0	$0	$0
WH1	$3,817,099	$2,135,889	$993,722	$0	$0
WH2	$248,659	$768,272	$60,714	$0	$0
WH3	$1,420,819	$0	$0	$748,535	$866,935
YZC	$1,052,161	$3,145,825	$0	$112,858	$121,358
Grand Total	$156,890,267	$122,383,940	$8,998,858	$5,088,837	$5,810,337

Table 7-6: Estimated Cost of Septic System Upgrades

Subwatershed	Population	Systems	Cost
AQC	44	19	$95,000
ARP	1,685	703	$3,515,000
BKC	-	-	
BRB	0	1	$5,000
BRC	152	64	$320,000
BWC	843	352	$1,760,000
BWP	200	84	$420,000
BWS	107	45	$225,000
CGC	-	-	
CHC	76	32	$160,000
CLC	1,271	530	$2,650,000
COC	8	4	$20,000
CPO	17	8	$40,000
CRC	161	68	$340,000
CSB	-	-	
CSC	8	4	
CWB	9	4	$20,000
CYB	280	117	$585,000
EVC	-	-	
FRC	-	-	
FXC	611	255	$1,275,000
GB1	1,297	541	$2,705,000
GB2	241	101	$505,000
HLA	40	17	$85,000
HOC	160	67	$335,000

Subwatershed	Population	Systems	Cost
HSP	16	7	$35,000
ICB	1,010	421	$2,105,000
JGP	172	72	$360,000
JZ1	1,201	501	$2,505,000
JZ2	448	187	$935,000
JZ3	751	313	$1,565,000
JZ4	252	105	$525,000
LKO	50	22	$110,000
LRB	1,244	519	$2,595,000
LUC	76	32	$160,000
MAC	515	215	$1,075,000
MC1	69	29	$145,000
MC2	2,301	959	$4,795,000
MEC	298	125	$625,000
MRP	42	18	$90,000
PFB	25	11	$55,000
PMP	357	149	$745,000
PSB	18	8	$40,000
RAP	24	11	$55,000
RBS	53	22	$110,000
RGC	8	4	$20,000
SHP	110	46	$230,000
SM1	-	-	
SM2	-	-	
SM3	1,162	485	$2,425,000
SM4	50	21	$105,000
SPC	-	-	
SSB	243	102	$510,000
ST1	-	-	
ST2	-	-	
ST3	203	85	$425,000
ST4	81	34	$170,000
ST5	29	13	$65,000
ST6	248	104	$520,000
ST7	1,711	713	$3,565,000
ST8	-	-	
ST9	-	-	
STC	-	-	
SVC	59	25	$125,000
SWC	748	312	$1,560,000
VTC	1,351	563	$2,815,000
WCC	163	69	$345,000
WCP	24	10	$50,000
WEC	1,250	521	$2,605,000
WH1	556	232	$1,160,000
WH2	1,135	473	$2,365,000

Subwatershed	Population	Systems	Cost
WH3	91	38	$190,000
YZC	-	-	
TOTAL	25,353	10,592	$52,940,000

Table 7-7: Summary of Preservation Costs

Code		Area	Low Cost	High Cost	Cost per Acre Low	Cost per Acre High
AQC	Aisquith Creek	278.1	$441,600	$1,899,000	$1,588	$6,828
ARP	Arden Pond	222.5	$2,500	$59,700	$11	$268
BKC	Back Creek	854.2	$1,900	$16,100	$2	$19
BRB	Bear Branch	655.8	$196,900	$859,200	$300	$1,310
BRC	Brown's Cove	186.2	$376,900	$1,509,200	$2,024	$8,105
BWC	Brewer Creek	439.1	$1,624,000	$4,837,300	$3,698	$11,015
BWP	Brewer Pond	400.9	$1,872,200	$5,847,800	$4,670	$14,587
BWS	Brewer Shore	43.1	$58,200	$236,900	$1,350	$5,495
CGC	College Creek	732.0	$0	$0	$0	$0
CHC	Chase Creek	446.3	$955,100	$3,612,100	$2,140	$8,094
CLC	Clements Creek	757.3	$2,195,000	$6,784,500	$2,899	$8,959
COC	Cove of Cork	108.8	$177,200	$787,000	$1,629	$7,234
CPO	Chase Pond	86.0	$0	$52,100	$0	$606
CRC	Carr Creek	398.8	$0	$593,100	$0	$1,487
CSB	Cool Spring Branch	348.1	$0	$35,400	$0	$102
CSC	Coolspring Creek	114.4	$1,000	$4,000	$9	$35
CWB	Chartwell Branch	815.9	$0	$99,800	$0	$122
CYB	Cypress Branch	272.0	$331,200	$1,089,300	$1,218	$4,004
EVC	Evergreen Creek	80.8	$0	$33,600	$0	$416
FRC	Forked Creek	248.3	$0	$57,300	$0	$231
FXC	Fox Creek	116.7	$226,800	$822,600	$1,943	$7,049
GB1	Gumbottom Branch 1	810.0	$2,290,500	$6,392,100	$2,828	$7,891
GB2	Gumbottom Branch 2	610.5	$2,851,100	$7,852,300	$4,670	$12,863
HLA	Heron Lake	60.2	$0	$11,700	$0	$194
HOC	Hopkins Creek	482.4	$2,366,100	$7,698,500	$4,905	$15,959
HSP	Hacketts to Sandy Point	548.5	$712,100	$3,010,200	$1,298	$5,488
ICB	Indian Creek Branch	1447.0	$1,762,800	$5,155,000	$1,218	$3,563
JGP	Jonas Green Pond	58.4	$16,200	$73,200	$277	$1,253
JZ1	Jabez Branch 1	839.5	$1,562,700	$4,186,600	$1,861	$4,987
JZ2	Jabez Branch 2	1179.8	$2,239,200	$6,342,900	$1,898	$5,376
JZ3	Jabez Branch 3	782.1	$1,341,100	$3,544,900	$1,715	$4,533
JZ4	Jabez Branch 4	597.2	$1,557,400	$4,072,400	$2,608	$6,819
LKO	Lake Ogleton	486.0	$0	$199,300	$0	$410
LRB	Little Round Bay	415.7	$1,180,000	$3,551,400	$2,839	$8,543
LUC	Luce Creek	384.8	$252,600	$1,224,000	$656	$3,181
MAC	Maynadier Creek	1069.8	$4,878,800	$14,724,000	$4,560	$13,763
MC1	Mill Creek 1	1430.2	$2,437,600	$6,897,000	$1,704	$4,822
MC2	Mill Creek 2	1581.9	$2,167,800	$8,012,900	$1,370	$5,065

					Cost per Acre	
Code		Area	Low Cost	High Cost	Low	High
MEC	Meredith Creek	971.7	$1,955,200	$7,533,100	$2,012	$7,752
MRP	Martins Pond	58.1	$0	$97,900	$0	$1,685
PFB	Pointfield Branch	104.4	$354,600	$1,106,500	$3,395	$10,595
PMP	Pendennis Mount Pond	92.4	$232,700	$851,100	$2,518	$9,211
PSB	Picture Spring Branch	1566.7	$24,400	$670,900	$16	$428
RAP	Ray's Pond	194.4	$437,900	$1,797,800	$2,253	$9,248
RBS	Round Bay Shore	124.7	$115,500	$479,300	$926	$3,844
RGC	Ringgold Cove	121.0	$117,300	$576,500	$969	$4,764
SHP	Sharps Point	133.6	$171,000	$776,000	$1,280	$5,810
SM1	Severn Run Mainstem 1	884.1	$664,600	$2,060,800	$752	$2,331
SM2	Severn Run Mainstem 2	531.4	$537,300	$1,843,100	$1,011	$3,469
SM3	Severn Run Mainstem 3	1472.6	$1,476,100	$4,005,700	$1,002	$2,720
SM4	Severn Run Mainstem 4	845.0	$1,112,600	$3,058,500	$1,317	$3,619
SPC	Spa Creek	1549.4	$46,100	$121,400	$30	$78
SRT	Severn River Tidal	1172.9	$807,500	$3,950,800	$688	$3,368
SSB	Sewell Spring Branch	475.6	$893,500	$2,299,700	$1,879	$4,835
ST1	Severn Run Tributary 1	306.4	$174,300	$540,600	$569	$1,764
ST2	Severn Run Tributary 2	702.5	$4,600	$494,200	$7	$704
ST3	Severn Run Tributary 3	1562.2	$377,300	$1,657,200	$242	$1,061
ST4	Severn Run Tributary 4	649.9	$1,234,300	$3,520,000	$1,899	$5,416
ST5	Severn Run Tributary 5	1746.7	$744,500	$2,648,800	$426	$1,516
ST6	Severn Run Tributary 6	343.5	$767,100	$2,110,400	$2,233	$6,143
ST7	Severn Run Tributary 7	865.6	$688,800	$2,084,800	$796	$2,408
ST8	Severn Run Tributary 8	373.6	$291,500	$818,500	$780	$2,191
ST9	Severn Run Tributary 9	344.1	$15,900	$175,200	$46	$509
STC	Stevens Creek	149.8	$61,400	$313,300	$410	$2,091
SVC	Sullivans Cove	164.2	$0	$63,900	$0	$389
SWC	Saltworks Creek	949.4	$1,529,000	$4,935,700	$1,611	$5,199
VTC	Valentine Creek	272.9	$722,800	$2,740,100	$2,649	$10,042
WCC	Woolchurch Cove	269.7	$121,500	$523,000	$450	$1,939
WCP	Winchester Pond	107.7	$104,000	$490,800	$966	$4,558
WEC	Weems Creek	1537.6	$804,000	$3,310,400	$523	$2,153
WH1	Whitehall Creek 1	739.1	$1,537,900	$4,471,700	$2,081	$6,050
WH2	Whitehall Creek 2	912.5	$1,417,600	$6,012,600	$1,553	$6,589
WH3	Whitehall Creek 3	417.0	$506,300	$2,366,700	$1,214	$5,676
YZC	Yantz Creek	204.0	$0	$46,800	$0	$229
Grand Total (Average for per-acre costs)			$56,125,600	$182,738,200	$1,303	$4,474

Table 7-8: Summary of Restoration Costs

					Cost per Acre	
Code		Area	Low Cost	High Cost	Low	High
AQC	Aisquith Creek	278.1	$235,810	$235,810	$848	$848
ARP	Arden Pond	222.5	$6,743,581	$6,743,581	$30,303	$30,303
BKC	Back Creek	854.2	$422,219	$422,219	$494	$494
BRB	Bear Branch	655.8	$10,104,651	$10,104,651	$15,409	$15,409

					Cost per Acre	
Code		Area	Low Cost	High Cost	Low	High
BRC	Brown's Cove	186.2	$323,711	$323,711	$1,739	$1,739
BWC	Brewer Creek	439.1	$2,061,854	$2,061,854	$4,695	$4,695
BWP	Brewer Pond	400.9	$437,320	$437,320	$1,091	$1,091
BWS	Brewer Shore	43.1	$225,000	$225,000	$5,219	$5,219
CGC	College Creek	732.0	$0	$0	$0	$0
CHC	Chase Creek	446.3	$251,546	$251,546	$564	$564
CLC	Clements Creek	757.3	$2,659,278	$2,659,278	$3,512	$3,512
COC	Cove of Cork	108.8	$861,407	$861,407	$7,918	$7,918
CPO	Chase Pond	86.0	$679,454	$679,454	$7,902	$7,902
CRC	Carr Creek	398.8	$8,988,002	$9,071,902	$22,536	$22,746
CSB	Cool Spring Branch	348.1	$5,418,128	$5,418,128	$15,565	$15,565
CSC	Coolspring Creek	114.4	$0	$0	$0	$0
CWB	Chartwell Branch	815.9	$4,503,079	$4,503,079	$5,519	$5,519
CYB	Cypress Branch	272.0	$2,222,181	$2,222,181	$8,169	$8,169
EVC	Evergreen Creek	80.8	$558,075	$558,075	$6,909	$6,909
FRC	Forked Creek	248.3	$2,090,799	$2,090,799	$8,419	$8,419
FXC	Fox Creek	116.7	$2,077,948	$2,077,948	$17,806	$17,806
GB1	Gumbottom Branch 1	810.0	$4,960,512	$4,960,512	$6,124	$6,124
GB2	Gumbottom Branch 2	610.5	$1,171,556	$1,171,556	$1,919	$1,919
HLA	Heron Lake	60.2	$639,321	$639,321	$10,623	$10,623
HOC	Hopkins Creek	482.4	$335,000	$335,000	$694	$694
HSP	Hacketts to Sandy Pt	548.5	$1,887,112	$1,935,912	$3,440	$3,529
ICB	Indian Creek Branch	1447.0	$4,910,440	$5,018,140	$3,394	$3,468
JGP	Jonas Green Pond	58.4	$518,741	$518,741	$8,883	$8,883
JZ1	Jabez Branch 1	839.5	$6,519,020	$6,519,020	$7,765	$7,765
JZ2	Jabez Branch 2	1179.8	$2,555,865	$2,555,865	$2,166	$2,166
JZ3	Jabez Branch 3	782.1	$4,249,647	$4,267,847	$5,434	$5,457
JZ4	Jabez Branch 4	597.2	$3,290,324	$3,396,224	$5,510	$5,687
LKO	Lake Ogleton	486.0	$1,096,294	$1,096,294	$2,256	$2,256
LRB	Little Round Bay	415.7	$4,101,225	$4,101,225	$9,866	$9,866
LUC	Luce Creek	384.8	$2,830,191	$2,830,191	$7,355	$7,355
MAC	Maynadier Creek	1069.8	$2,938,175	$2,938,175	$2,746	$2,746
MC1	Mill Creek 1	1430.2	$10,815,723	$10,815,723	$7,562	$7,562
MC2	Mill Creek 2	1581.9	$7,768,001	$7,768,001	$4,911	$4,911
MEC	Meredith Creek	971.7	$2,271,496	$2,392,696	$2,338	$2,462
MRP	Martins Pond	58.1	$90,000	$90,000	$1,549	$1,549
PFB	Pointfield Branch	104.4	$756,910	$756,910	$7,247	$7,247
PMP	Pendennis Mount Pond	92.4	$895,122	$895,122	$9,687	$9,687
PSB	Picture Spring Branch	1566.7	$29,546,342	$29,546,342	$18,859	$18,859
RAP	Ray's Pond	194.4	$55,000	$55,000	$283	$283
RBS	Round Bay Shore	124.7	$615,107	$615,107	$4,933	$4,933
RGC	Ringgold Cove	121.0	$21,856	$21,856	$181	$181
SHP	Sharps Point	133.6	$258,751	$258,751	$1,937	$1,937
SM1	Severn Run Mainstem 1	884.1	$17,134,608	$17,134,608	$19,382	$19,382

Code		Area	Low Cost	High Cost	Cost per Acre Low	Cost per Acre High
SM2	Severn Run Mainstem 2	531.4	$5,811,214	$5,811,214	$10,936	$10,936
SM3	Severn Run Mainstem 3	1472.6	$8,709,400	$8,777,600	$5,914	$5,961
SM4	Severn Run Mainstem 4	845.0	$3,723,574	$3,723,574	$4,407	$4,407
SPC	Spa Creek	1549.4	$0	$0	$0	$0
SRT	Severn River Tidal	1172.9	$8,478,293	$8,478,293	$7,229	$7,229
SSB	Sewell Spring Branch	475.6	$591,649	$591,649	$1,244	$1,244
ST1	Severn Run Tributary 1	306.4	$1,839,790	$1,839,790	$6,004	$6,004
ST2	Severn Run Tributary 2	702.5	$12,565,553	$12,565,553	$17,888	$17,888
ST3	Severn Run Tributary 3	1562.2	$22,346,040	$22,346,040	$14,305	$14,305
ST4	Severn Run Tributary 4	649.9	$2,187,036	$2,187,036	$3,365	$3,365
ST5	Severn Run Tributary 5	1746.7	$17,748,216	$17,748,216	$10,161	$10,161
ST6	Severn Run Tributary 6	343.5	$4,977,109	$4,977,109	$14,489	$14,489
ST7	Severn Run Tributary 7	865.6	$18,741,558	$18,741,558	$21,650	$21,650
ST8	Severn Run Tributary 8	373.6	$4,140,511	$4,140,511	$11,084	$11,084
ST9	Severn Run Tributary 9	344.1	$3,825,668	$3,825,668	$11,119	$11,119
STC	Stevens Creek	149.8	$389,508	$389,508	$2,600	$2,600
SVC	Sullivans Cove	164.2	$2,557,097	$2,564,897	$15,577	$15,624
SWC	Saltworks Creek	949.4	$8,257,606	$8,257,606	$8,698	$8,698
VTC	Valentine Creek	272.9	$5,239,051	$5,239,051	$19,201	$19,201
WCC	Woolchurch Cove	269.7	$9,988,341	$10,021,241	$37,031	$37,153
WCP	Winchester Pond	107.7	$50,000	$50,000	$464	$464
WEC	Weems Creek	1537.6	$22,818,748	$22,818,748	$14,840	$14,840
WH1	Whitehall Creek 1	739.1	$8,106,710	$8,106,710	$10,968	$10,968
WH2	Whitehall Creek 2	912.5	$3,442,645	$3,442,645	$3,773	$3,773
WH3	Whitehall Creek 3	417.0	$2,359,355	$2,477,755	$5,658	$5,942
YZC	Yantz Creek	204.0	$4,310,843	$4,319,343	$21,129	$21,170
Grand Total (Average for per-acre costs)			$346,301,901	$347,023,401	$8,127	$8,144

7.5 Cost / Benefit Analysis for Preservation and Restoration Alternatives

7.5.1 Pollutant Reduction

In earlier work, the decision was made to use Total Phosphorus (TP) as the quantitative measure of benefits when comparing management alternatives. Appendix B contains several worksheets which were used to determine the cost per pound of phosphorus reduction for each of the alternatives described above. Costs used in the analysis were life cycle costs including capital costs and amortized costs of annual maintenance. The worksheets include:

- Summary of low and high cost estimates for each alternative by subwatershed.
- TP reductions by subwatershed from PLOAD modeling described in Section 6.0.
- Cost per pound of TP removed.

For the Severn River watershed as a whole, the results of the analysis are shown in Table 7.9 below. The most cost-effective alternative for phosphorus removal is continuation of the existing SWM regulations, which have no cost to the County. The two cluster development alternatives also have no cost once the appropriate regulations have been drafted and are put into place.

The next most cost effective alternative is enforcement of the existing buffer regulations, which costs the County nothing if no easements need to be acquired. This alternative also has the effect of removing impervious area and reducing TP loads during redevelopment, which makes it more effective than the other land preservation alternatives of greenways and an expanded buffer.

Pond retrofits are the most cost effective structural controls, both in terms of cost per pound of TP and cost per acre of treatment. This is largely due to economies of scale. While bioretention is better at restoring the hydrologic regime at the source, the use of a single downstream facility to provide treatment is a lower cost solution.

The cost effectiveness of the wetland mitigation alternative is skewed low low (highest cost per pound TP) because the full benefits were not assessed during the modeling.

Table 7-9: Results of C/B Analysis for Management Alternatives

Alternative	Low Cost	High Cost	TP Reduction (lb)	Cost / lb TP (Low) ($ / lb)	Cost / lb TP (high) ($ / lb)	Mid-Range Cost / Acre
Existing SWM Regs	$0	$0	1,271.3	$0	$0	$0
Existing Buffer Regs	$0	$19,984,300	771.2	$0	$44,762	$3,250
Wetland Mitigation	$5,088,837	$5,810,337	7.4	$689,473	$787,227	N/A
Bioretention COM/IND	$156,890,267	$156,890,267	3,940.1	$39,819	$39,819	$60,046
Bioretention R14/R18	$122,383,940	$122,383,940	2,442.5	$50,107	$50,107	$23,209
Pond Retrofit	$8,998,858	$8,998,858	563.4	$15,973	$15,973	$11,567
Greenways	$30,419,400	$84,799,100	846.4	$35,938	$100,184	$12,310
Expanded Buffer	$25,706,200	$77,954,800	319.1	$80,551	$244,274	$13,105
Cluster Development	$0	$0	757.6	$0	$0	$0
Denser Cluster	$0	$0	595.8	$0	$0	$0

7.5.2 Non-Quantitative Evaluation Criteria

Table 7-10 presents the results of a review of the evaluation criteria discussed in the introduction to this chapter. They were rated with a score from 1 to 3, from difficult to easy implementation.

Table 7-10: Summary of Non-Quantitative Evaluation Criteria

Alternatives	Public Acceptability	Acceptability to Local Govt.	Acceptability to Regulators (MDE/DNR)	Ease of Construction/ Implementation (for Stakeholders and/or County)	Reliability	Ease of Maintenance	Public Health and Safety Concerns	Total Score (All Factors Being Equal)
Existing Buffer Regulations	3	3	3	2	3	2	3	19
Bioretention Commercial / Industrial	3	3	3	2	3	2	3	19
Bioretention Residential	1	3	3	1	1	1	3	13
Dry-to-Wet Pond Retrofit	1	2	3	2	3	2	1	14
Greenways	3	2	3	1	3	3	3	18
Expanded Floodplain 50 Ft Buffer	2	2	3	2	3	2	3	17
Expanded Buffer in Unsewered Areas	2	1	3	1	3	2	3	15
Cluster Development	2	3	3	1	3	3	3	18

Legend: 1 = Hard to Implement, 2 = Moderately difficult to implement, 3 = Easy to Implement

The range of scores was from 13 to 19 with an average of 16.6. The lowest score of 13 was for residential bioretention retrofits, which scored low in 4 of the 8 criteria. Low ratings for public acceptance, reliability, ease of implementation, and ease of maintenance are all related to the requirements to maintain small, distributed systems that are owned privately.

The second lowest score, 14, was for dry pond retrofits to wet ponds. Public acceptability and health and safety concerns were rated low, primarily because of concern about creating mosquito habitat and accidents.

The highest scores were for enforcement of existing buffer regulations, and for bioretention in commercial and industrial areas. Each of these alternatives was given a moderate rating for two of the criteria, and easy ratings for all other criteria.

Buffer regulations were considered moderately difficult to implement, because of perceived resistance from the development community. Additional buffers would also bring about the need for more maintenance activities by County staff and some inspection and enforcement action to prevent encroachment or dumping of yard waste.

The industrial / commercial bioretention alternative received moderately difficult ratings related to their characteristics as distributed systems. As with residential bioretention, there is a need to maintain privately owned systems; however, there would be fewer property owners to work with, and potentially fewer (and larger) systems.

7.6 Legislative Recommendations

A thorough review of federal, state, and local regulations that influence watershed and stormwater management was undertaken to determine opportunities and constraints to implementation of the Severn River Watershed Management Plan. The entire report can be found in Appendix C. A summary of the recommendations is given in this section.

7.6.1 Federal / State/ Regional

In addition to actions that can be taken by Anne Arundel County government, achieving the goals of the Severn Watershed study will require the cooperation and assistance of both federal and state governments.

Federal Lands

Identify all federal lands and federally controlled lands with the Severn watershed. Work with federal agencies and federal land managers, including those at the Naval Academy and Fort Meade to secure their cooperation in the Severn Water cleanup.

Chesapeake and Atlantic Coastal Bays Restoration Fund

Seek and use funding from the Chesapeake and Atlantic Coastal Bays Restoration Funds to support septic system upgrades in areas of the Severn Watershed outside the sewer service area; and seek funding and opportunities to extend sewer service to properties using septic systems with the current sewer service area.

TMDL Implementation Plans

MDE should use the Severn River watershed management plan and model in any TMDL implementation plan prepared for the Severn or its subwatersheds.

Tributary Strategy Teams

The recommendations of the Severn Watershed Study should be incorporated into the work plan for the Tributary Strategy Team, as appropriate.

7.6.2 Local

The implementation of some of the management options tested using the Watershed Management Tool (WMT) would require changes to existing Anne Arundel regulations at varying levels of complexity. A few changes could be incorporated into the current round of amendments to the zoning ordinance and subdivision regulations under consideration by the Department of Planning and Zoning. Other options represent new initiatives that would require considerable discussion among the agencies of County government, the development community, and the public before detailed ordinance language could be finalized. The legislative concepts described below are generally listed in order from least to most complex or challenging to implement.

Cluster Development

The model has been used to evaluate the effects of cluster development, developing 1- and 2-acre zoned lots so that buildings on these lots are placed more closely together than traditional zoning permits. Controlling placement of homes in such a manner allows for larger sections of contiguous open space or woods. One cluster development management alternative recalculates pollutant runoff values (EMCs and CNs) based on reserving half the area as woods and developing the other half as residential at twice the nominal density.

A second alternative for cluster development reserves 30% of the site area for woods while the remainder is developed at the next higher density.

The provisions of the subdivision and zoning codes will provide much of the effect of the second alternative tested. Several additional changes would enhance the protection offered to watersheds:

- Expand the definition of "net area" to exclude the most sensitive bog overlay areas and stream buffers.
- Require that floodplains and their buffers be included in the open space parcel.
- In the R5 district, allow the same side lot yards (7 ft each, 20 total) in a cluster project that are permitted in a conventional project.
- Reduce the side yard requirement for single-family lots at the boundary line of the cluster project in R2 and R5 zones. If a conventional single-family house would be only 7-10 feet from the property line, a cluster unit at the project boundary on a conventionally sized lot (required) should be able to be a similar distance from the project boundary.

Septic System Upgrades

Septic systems have been modeled in this study in GWLF using per capita nitrogen and phosphorus loads and uptake from vegetation over the drain field. The model also treats functioning and failing systems separately, with the primary result that nutrients are discharged directly rather than subject to uptake. Upgraded systems for nitrogen removal were assumed to discharge 25% of the nitrogen load, based on discussions with Rich Piluk of Anne Arundel County's Health Department.

To reduce the impacts of septic systems in future years, all new development could be required to hook into the public sewer system or provide upgraded septic systems. Replacement and repair situations could be required to include nitrogen upgrades. Grants and low interest loans could be provided for existing residential units to hook into the sewer system. If this strategy is selected, a team from the affected agencies could develop a comprehensive program addressing both existing and new septic systems.

Reducing Impervious Surface

<u>Parking Regulations</u> Parking regulations are an area, not tested directly by the model but important to the area of impervious surface and overall watershed health. Table 7-11 below compares the parking ratios in

the Anne Arundel County zoning ordinance with the recommended standards of the Center for Watershed Protection (CWP).

Table 7-11: Comparison of County Parking Requirements with CWP Recommendations

Use	Anne Arundel County	CWP
Office and professional uses	5/1000 sq. ft.	3/1000 sq. ft.
Shopping Centers	6.25/1000 sq. ft. (<50,000 sq. ft.) 5.5/1000 sq. ft. (50,000 – 600,000 sq. ft.) 5.0/1000 sq. ft. (>600,000 sq. ft.)	4.5/1000 sq. ft.

Additional changes to parking requirements that could reduce impervious areas include:

- Establishing a maximum parking ratio for commercial and employment uses
- Permit the use of shared parking arrangements for uses on separate lots that would permit parking requirements to be reduced by a fraction of the combined minimum
- Allow overflow-parking areas that would be used on a limited basis each year to be constructed from a pervious material.
- Require that a 20-30 percent of the spaces in lots of more that 25 parking spaces meet the compact space definition, with appropriate signage.

<u>Road Construction Standards</u> Review the subdivision and road construction standards to consider changes similar to those proposed for Frederick County including:

- Change the current road design standards to reflect average daily trips (ADT) instead of density, and reduce the minimum required road width as shown in Table 7-12. This recommended change to ADT as the basis for road width should not serve to support widening existing residential streets in the future.

Table 7-12 Recommended Standards for Closed Section Roads, Frederick County

Minimum Road Width	Parking	Average Daily Trips (ADT)	# of Dwelling Units
20’	Parking on both sides*	< 200	20
22’	Parking on one side*	200-400	20-40
26’	Parking on both sides	400-2000	40-200
26’	Parking on one side	> 2000	> 200
32’	Parking on both sides	> 2000	> 200

* Restrict parking to one side during snow emergency. No parking permitted if road is a designated fire lane.

Source: Recommended Model Development Principles for Frederick County, MD, Center for Watershed Protection, January 2000

- Consider reduced pavement widths for streets with no required parking. The required ROW width could be directly related to the road width.
- Reduce the current ROW standard from 50' to 40'. In environmentally sensitive areas, ROW width could only extend to back of curb or edge of pavement. For wider streets, either widen the ROW or place sidewalks in an easement when they fall outside of the ROW.
- If road is less than 1300' long (1/4 mile), *do not* size a cul-de-sac or other turnaround based on school bus turning radius. Allow hammerheads (T-turnarounds) to be constructed if a road has eight or fewer lots, and do not allow driveways to be placed on the end of the “T.”

- Setbacks on loop-de-lanes (horseshoe-shaped turnarounds with vegetated open areas in the center) could be from the centerline of the center island, and setbacks on eyebrows could be from the centerline of the main road.

Buffer Regulations

The management scenarios tested using the model included establishing stream and wetland buffers on newly developed or redeveloped sites, described in earlier in Section 4.2.3.

The scenario tested assumed that areas within these buffers slated for development would be returned to open space under future conditions. Areas that are slated for development to residential wooded or for areas containing existing woods were assumed to be wooded in the future.

The scenario assumed that any development that occurs where there is existing development would be a situation of redevelopment and the stream buffer would be restored as a condition of redevelopment.

Current regulations provide for the stream and wetland buffers through provisions in the erosion and sediment control ordinance (Article 21, Section 2-301(j)) and the stormwater management manual. These regulations are applied to new development that requires erosion and sediment control (generally over 5000 sq. ft in disturbance) or stormwater management. However, most of the required buffer widths are less than the 100 feet tested through the watershed model. The current regulations also have no provisions to prevent the location of accessory structures building or activities on existing parcels or for smaller disturbances.

There are specific buffer provisions applicable in bog protection zones that apply to a broad range of permits and disturbance activities.

Stream and Wetland Buffer Widening A stream buffer overlay zone would establish a variable width buffer a minimum of 100 feet along all perennial streams. The basic width of the buffer would be 100-feet, with variation depending upon adjacent steep slopes and the presence of adjacent wetlands. The buffer area would be retained in natural vegetation except to provide access roads and utilities. Land uses in buffer areas would be restricted to minimize impervious surface and maximize the presence of natural vegetation. Examples of buffer requirements can be drawn from numerous local jurisdictions in Maryland and other states.

The stream and wetlands buffer overlay would be administered through the stormwater management program and through zoning and subdivision codes in much the same way that the bog overlay is currently administered. Cross-references to the buffer overlay zones could add additional restrictions to new developments through the subdivision, forest conservation, grading and sediment control, and stormwater management ordinances.

Greenways

This management alternative tests the effects of preserving important natural areas. The County supplied a map of potential greenway areas that are important habitat and connecting corridors for terrestrial wildlife. These areas were assumed to be open space under this alternative unless already designated as woods. The land use for all areas to be developed was changed to open space.

Greenway Dedication Development of the implementation and management plan for the Severn Run 2 Greenway should be expanded to include all the greenways within the Severn watershed and should be linked to the goals of the Severn Watershed Study as well as the provisions of other County planning efforts. Consideration should be given to increasing the greenways set aside to approximately 25% of the total Severn watershed area. With a well-developed greenways plan, the management alternative tested in the watershed model could be implemented by requiring developers to dedicate greenway land to public use during subdivision and site plan review (Section 26-3-403). The dedicated greenway could be credited toward the required open space and recreation area for residential projects if it is transferred to the county at no charge. The language of Section 26-3-403 may need to be modified when used to secure dedication of a greenways parcel to account for dedication of land that may be subject to little or no capital improvement given its function as a greenway. Fee in lieu of open space and recreation set-asides could be used for the purchase of greenway dedications when necessary.

7.6.3 Watershed Protection Zoning

This alternative was tested as a 300-foot stream buffer in areas with no planned sewer service. The model assumed that no development would occur and that ultimately the county would reclaim the buffer. These areas were assumed open space under this alternative unless already designated as woods.

The effect of the management alternative used in the model could be achieved by including a 300-foot stream buffer for areas not planned for sewer service in the stream buffer overlay ordinance.

A more sophisticated approach would create a watershed overlay zone as an alternative to the stream buffer overlay ordinance. A watershed overlay ordinance would use the results of the watershed ranking exercise to create classifications of watersheds and impose development limitations within each classification that would achieve the appropriate level of water quality protection or restoration.

Development of the specific provisions of watershed protection zones would most likely require collaboration among a broad cross-section of stakeholders over an extended period – probably 6 –12 months. Once established for the Severn Watershed however, the same watershed protections could be applied to the subwatersheds of other major water bodies once the field data for each is collected and analyzed using the WMT.

7.7 Summary of Recommendations

Combining the results for cost effectiveness and non-quantitative criteria, along with recommendations from the legislative review, the priority for implementation of the alternatives is as follows:

1. <u>Existing SWM Regulations</u> The modeling showed this alternative to be an effective method of TP reduction with no additional cost to the County. The program should be continued and programmatically reinforced.
2. <u>Cluster Development (Both alternatives)</u> These alternatives can be implemented with little or no additional cost to the County once the regulations are in place. They received the second highest rating in the non-quantifiable evaluation criteria. The legislative review determined that this would be the least complex alternative to implement.
3. <u>Enhancement of existing buffer regulations</u> This alternative had the lowest cost per pound of TP removed, and the lowest cost per acre of area treated. It also received the highest score for implementation and acceptability.

   The legislation review showed that current regulations provide for the stream and wetland buffers through provisions in the erosion and sediment control and the stormwater management manual. Most of the required buffer widths are less than the 100 feet tested through the watershed model. The current regulations also have no provisions to prevent the location of accessory structures building or activities on existing parcels or for smaller disturbances.
4. <u>Dry-to-Wet Pond Retrofits</u> This alternative was the second most cost-effective, but scored low in acceptability. The recommendation is to pursue this option where there are ponds that are at some distance from residential areas, to minimize health and safety concerns.
5. <u>Commercial / Industrial Bioretention Retrofits</u> This alternative was the fourth most cost effective in pollutant removal, and the most costly per acre treated, but ranked highest for acceptability and implementation.

6. Greenways Greenways were the second highest ranked in terms of acceptability, third for pollutant removal cost-effectiveness, and for cost per treated area. While not part of the scoring, they also provide habitat and recreational benefits beyond those for water quality improvements.

   The legislation review recommended that development of the implementation and management plan for the Severn Run 2 Greenway should be expanded to include all the greenways within the Severn watershed and should be linked to the goals of the Severn Watershed Study as well as the provisions of other County planning efforts. Consideration should be given to increasing the greenways set aside to approximately 25% of the total Severn watershed area

7. Residential Bioretention Retrofits This alternative ranked low for cost effectiveness for both TP removal and cost per treated area. It also scored the lowest for the non-quantitative criteria. To improve public acceptability, the recommendation is to construct these systems in areas where they can be installed as publicly owned and maintained systems in the right-of-way.

8. Expanded Buffers Expanded floodplain buffers scored relatively high, and expanded stream buffers in unsewered areas scored relatively low in the non-quantitative criteria. This was the least cost-effective alternative for pollutant removal.

   As discussed the legislative review, a more sophisticated approach would create a watershed overlay zone as an alternative to the stream buffer overlay ordinance. A watershed overlay ordinance would use the results of the watershed ranking exercise to create classifications of watersheds and impose development limitations within each classification that would achieve the appropriate level of water quality protection or restoration.

9. Septic System Upgrades This alternative was not prioritized using TP reduction as a measure; however, it is the most effective alternative for reducing nitrogen loads.

   Legislative recommendations for this alternative are to seek and use funding from the Chesapeake and Atlantic Coastal Bays Restoration Funds to support septic system upgrades in areas of the watershed outside the sewer service area; and seek funding and opportunities to extend sewer service to properties using septic systems within the current sewer service area. To reduce the impacts of septic systems in future years, all new development could be required to hook into the public sewer system or provide upgraded septic systems.