Upper Patuxent River Watershed
Overall Summary Recommendation Report

Prepared for:

Anne Arundel County
Department of Public Works

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LimnoTech
Water | Environment | Scientists | Engineers

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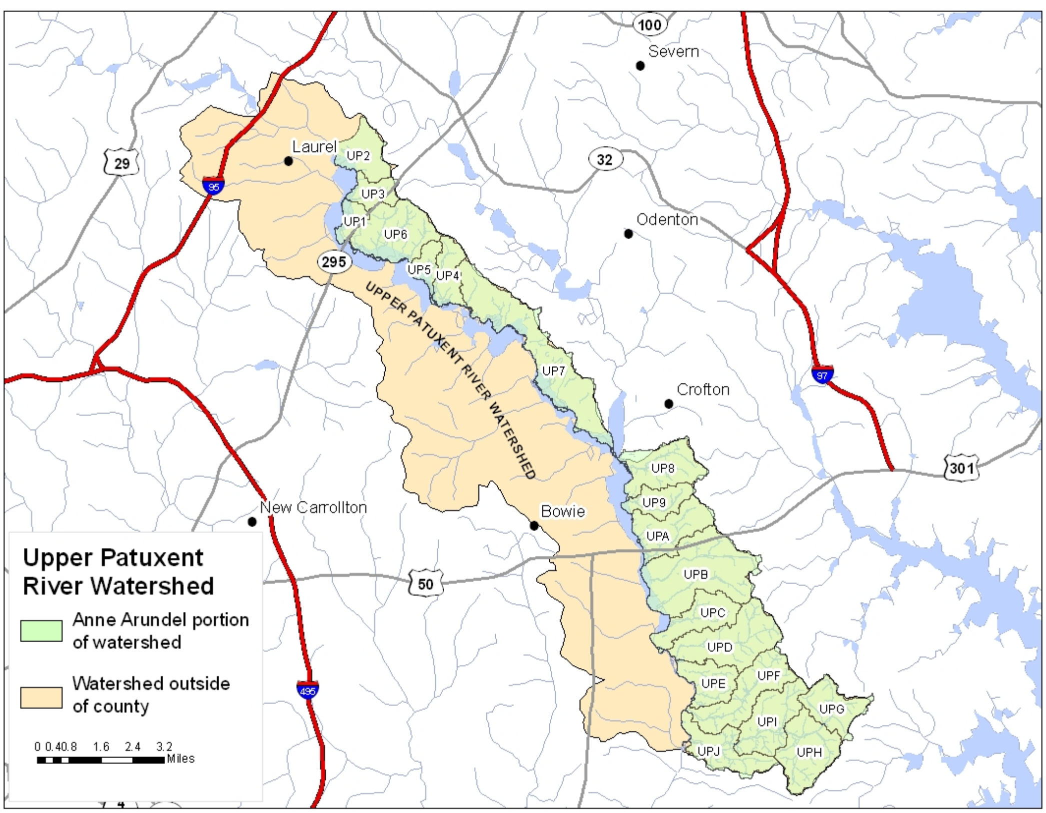
1. Introduction

The Upper Patuxent River Watershed is one of twelve major watersheds in Anne Arundel County, Maryland. It is a narrow watershed situated in the southwestern portion of the County along a border shared with Prince George's County. The portion of the watershed within Anne Arundel County drains approximately 22,500 acres, contains approximately 90 miles of perennial stream reaches, and is divided into 19 subwatersheds (See Figure 1).

In March 2007, the County Watershed and Ecosystem Services Division within the Department of Public Works initiated a watershed assessment study of the Upper Patuxent River Watershed. The main purpose of the study was to fulfill NPDES requirements and to support model applications and analysis that inform the County's capital improvement program with respect to the protection and restoration of aquatic resources within the watershed. Similar watershed studies have been initiated by the County in the Severn River Watershed and the South River Watershed and, more recently, in the Magothy River Watershed.

LimnoTech was awarded a contract with the County to assist with the collection of field and stream assessment data, as well as supporting GIS data, that would serve as inputs for the County's watershed assessment and modeling tools. LimnoTech also worked collaboratively with the County on its approaches and methods used to assess watershed and stream health and to set priorities for restoration and preservation.

Figure 1. Upper Patuxent River Watershed



This report is an executive summary of the work performed by LimnoTech and the County for the Upper Patuxent River watershed study. The report documents the County's assessment and modeling efforts as well as key findings and recommendations.

2. Subwatershed and Stream Assessment and Modeling

The County has developed a full suite of model applications and concomitant analyses to assess the relative health of streams and subwatersheds under its purview. These models and analyses, which include stream restoration assessments, subwatershed restoration and preservation assessments, and water quality modeling, are performed for each of the major watersheds in the County. The County's modeling approach and protocols were developed collaboratively and honed over the course of the three watershed studies conducted to date (Severn River, South River, and Upper Patuxent River). Data collection and specific assessment methods are discussed in more detail in the following subsections.

2.1 Data Collection

LimnoTech supported the County's assessment and modeling efforts by compiling and updating GIS data layers and collecting and recording chemical and physical data gathered in the field. This was performed under Tasks 2 and 3 of LimnoTech's contract with the County. The following represent the major datasets and products delivered to the County under these tasks.

- <u>Stream Reaches</u>
  LimnoTech constructed a stream reach GIS layer that accurately depicts the actual position, alignment, and character of all streams in the watershed. The stream reach GIS layer was segmented into reaches that reflect the changes in habitat conditions observed during field assessments. LimnoTech used a stream planimetric dataset along with drainage lines derived from a digital elevation model (DEM) as a guide for stream alignment verification efforts.

- <u>Rosgen Level I Classifications</u>
  LimnoTech gathered and created data to support the County's Rosgen Level I geomorphic characterization of single-threaded, perennial reaches in the watershed. This entailed generating Manning's roughness values for each eligible reach based on field observations and the Cowan method. Supporting photos, as well as GIS point locations and DEM-generated channel cross-sections and profiles, were also provided. The County utilized this information to classify each reach under the Rosgen Level I classification scheme.

- <u>Stream Crossing Geometry</u>

  LimnoTech performed field surveys of a set of selected older stream crossings with the potential for overtopping. The resulting crossing geometry information was used by the County to run the Army Corps of Engineers HY8 model for assessment and planning purposes. See Appendix A for the technical memorandum with a more detailed description of the crossing selection process.

- Urban Stormwater BMPs
  Using a combination of public primary and secondary data sources, LimnoTech developed a spatially accurate GIS inventory of all existing public and private stormwater BMPs located within the watershed. See Appendix B for the technical memorandum with a more detailed description of this work.

- Agricultural Conservation Methods and Runoff BMPs
  LimnoTech performed a windshield survey to collect data on agricultural land use practices in the watershed. This data was used to update the County's land use map. LimnoTech was unable to acquire site-specific information regarding agricultural practices, including BMPs as these data are protected by privacy laws and were unavailable. See Appendix C for the technical memorandum with a more detailed description of this work and some of the issues encountered.

- Base Flow Sampling
  LimnoTech collected dry weather flow grab samples within each subwatershed containing a perennial stream reach (20 total locations) to identify unusual pollutant loads and to characterize base flow loading. The measured parameters included dissolved oxygen, temperature, pH, total nitrogen, total Kjeldahl nitrogen, nitrate, nitrite, total phosphorus, total suspended solids, zinc, copper, lead, and bacteria. In addition, the cross-sectional geometry, stream velocity, field-observed Manning roughness, and local slope were recorded for each base flow location.

- Physical Habitat Condition Assessment
  LimnoTech performed a field assessment of the physical habitat conditions of approximately 90 perennial stream miles by observing and measuring various physical attributes. This work was completed in accordance with the Maryland Biological Stream Survey (MBSS) Stream Habitat Assessment field guidelines. The collected parameters and assessment scores were used to calculate a Maryland Physical Habitat Index (MPHI) score for each perennial stream reach in the watershed.

- Inventory of Infrastructure and Environmental Features
  LimnoTech compiled an inventory of infrastructure and significant environmental features located within each perennial reach. These features include confluences with ephemeral or intermittent channels, buffer deficiencies, excessive erosion, obstructions, stream crossings, utilities, dumpsites, head cuts, pipes, and drainage ditches. Each inventory point was scored in the field based on its impact to the environment and/or its restoration potential.

- Rosgen Level II Analysis
  LimnoTech's subcontractor, Biohabitats, conducted Rosgen Level II classifications for two perennial reaches (a potential restoration reach and a design reference reach). See Appendix D for the technical memorandum with a more detailed description of this work.

2.2 Assessment Methods

The County used the data generated and synthesized by LimnoTech, as well as previously collected data, for four primary assessment and modeling activities. Three of the assessment activities center on a rating process to assess the relative need for stream restoration, subwatershed restoration, and subwatershed protection among the stream reaches and subwatersheds within the Upper Patuxent River watershed. The fourth activity is a water quality modeling exercise used to examine loading under alternate scenarios.

The County's three assessment methods for restoration and preservation potential are based on a scoring or rating scheme that uses a series of indicators to characterize the conditions that contribute to the impairment or the sensitivity of the stream reach or subwatershed being assessed. Each indicator is given a rating score between 1 and 10 based on natural or fixed breaks in the underlying indicator data. The higher rating values represent good conditions while lower values represent poor or less desirable conditions. As a reflection of the relative importance of each indicator, the County weighs each one used in the rating process. The weighted indicator values are then combined to determine an overall rating for each stream reach or subwatershed. The overall ratings can be compared within the watershed (and with some modification, among all assessed watersheds) to identify those reaches and subwatersheds that are most in need of either restoration or protection.

The fourth assessment activity involves modeling nutrient loading under existing conditions and under future conditions with various levels of development and controls. The resulting nutrient loads can then be compared to a goal or goals for the watershed to help identify those future development and control scenarios that are most desirable for the County.

All of the County's assessment and modeling efforts were developed collaboratively with County staff and the various consultants that have assisted with the watershed studies conducted to date. LimnoTech provided peer review advice on the Upper Patuxent River Watershed assessments during a series of four professional management team meetings held in late 2007 and early 2008. This work was performed under Task 4 of LimnoTech's contract with the County. See Appendix E for the minutes and other memoranda from these meetings.

The following subsections describe each of the County's assessment and modeling efforts in more detail, including the specific indicators used and their relative weights. General findings for the Upper Patuxent River Watershed are also presented in each subsection.

2.2.1 Stream Restoration Assessment

The County's stream restoration assessment is intended to identify the impaired reaches in the watershed that warrant consideration for restoration activities. The stream restoration assessment is based on a suite of indicators that can be grouped into one of five categories: stream habitat, stream morphology, land cover, infrastructure, and hydrology and hydraulics. Each category is comprised of one to six different indicators. See Table 1 below for a summary of the indicators and their relative weighting.

Among the indicators for stream restoration, the Maryland Physical Habitat Index (MPHI) is utilized to represent the quality of physical stream habitat characteristics. Rosgen geomorphic (Level I) classifications are used in the assessments as an indicator of the degree of entrenchment of each stream reach. The percentage of imperviousness contributes to increased stormwater volumes and thermal and chemical pollutant loading. Deficient stream buffers, channel erosion, head cuts, dump sites, stream crossings, pipes and ditches, and obstructions are indicators of channel degradation, excessive pollution and sedimentation, and habitat impairment. Flooding and overtopping of road crossings pose an inconvenience and safety hazard to nearby residents. With the exception of the imperviousness indicator, all of the data underlying each of these indicators were generated by LimnoTech during the tasks described in the data collection section above.

Table 1. Stream Restoration Assessment Indicators

Category	Indicator	Weight
Stream Habitat	2003 MPHI score	31.6%
Stream Morphology	Rosgen Level I classifications	5.3%
Land Cover	Imperviousness (%)	5.3%
Infrastructure	Buffer impacts	5.3%
	Erosion impacts	10.5%
	Head cut impacts	5.3%
	Dump site impacts	5.3%
	Other infrastructure impacts (pipes, ditches, crossings, and obstructions)	15.8%
Hydrology and Hydraulics	Crossing flooding likelihood	15.8%

The stream reaches in the Upper Patuxent River Watershed were predominantly Good to Fair on the rating scale, while the other watersheds studied to date trended toward a mix of Good, Fair, Poor, and Very Poor ratings. See the Reach Restoration Assessment Fact Sheets in Appendix F for maps of the assessment results. See Table 2 for a breakdown of rating results by subwatershed. During the professional management team meetings, both LimnoTech and the County agreed that these ratings seemed appropriate given the more rural and hence less developed nature of the Upper Patuxent watershed compared to the others.

Table 2. Stream Restoration Assessment Results

Subwatershed	Number of Reaches with Rating			
	Very Poor	Poor	Fair	Good
UP1	No perennial reaches			
UP2	0	2	1	0
UP3	No perennial reaches			
UP4	0	0	0	1
UP5	0	0	1	2
UP6	1	1	1	18
UP7	1	3	4	10
UP8	1	8	7	6
UP9	0	1	3	5
UPA	1	7	9	13
UPB	2	5	13	10
UPC	0	5	6	5
UPD	2	6	9	3
UPE	1	3	5	17
UPF	5	8	21	12
UPG	1	5	10	12
UPH	2	1	7	23
UPI	5	8	14	10
UPJ	3	6	15	5

2.2.2 Subwatershed Restoration Assessment

The County's subwatershed restoration assessment is intended to identify those subwatersheds where conditions warrant consideration for restoration activities on a larger scale (e.g., BMP retrofitting). The subwatershed restoration assessment is based on a suite of indicators that can be grouped into one of seven categories: stream ecology, water quantity, water quality, landscape, BMPs, septics, and 303(d) list. Each category is comprised of one to four different indicators. See Table 3 for a summary of the indicators and their relative weighting.

Table 3. Subwatershed Restoration Assessment Indicators

Category	Indicator	Weight
Stream Ecology	Final habitat score	7.5%
	Bioassessment score	7.5%
303(d) List	No. of TMDL impairments	7.5%
Septics	Nitrogen load from septics (lbs)	9.3%
BMPs	Impervious area treated by BMPs (%)	6.6%
Water Quantity	Peak flow from 1-year storm (cfs/ac)	4.5%
	Peak flow from 2-year storm (cfs/ac)	4.5%
	Runoff volume from 1-year storm (in/ac)	5.8%
	Runoff volume from 2-year storm (in/ac)	5.8%
Water Quality	Nitrogen load from runoff (lbs/acre/yr)	6.9%
	Phosphorus load from runoff (lbs/acre/yr)	6.9%
Landscape	% Impervious cover	9.4%
	% Forest within the 100 ft stream buffer	10.3%
	% of existing wetlands to potential wetlands	9.4%
	Acres of developable Critical Area	5.3%

Among the indicators for the subwatershed restoration assessment, the final habitat and bioassessment scores are used as indicators of the quality of the physical and biological characteristics of stream reaches in the subwatershed. Changes in peak flow and runoff volume are indicators of hydrology changes due to increased development and urbanization. TMDL impairments, nitrogen loading from septics and runoff, and phosphorus loading from runoff are all indicative of water quality degradation in each subwatershed. Landscape indicators including percent imperviousness, percent BMP treatment, and percent forested buffer all influence stormwater volumes, peak flows, and pollutant loading. Potential wetland areas and acres of developable Critical Area serve as indicators of restoration potential. The data underlying these indicators were generated from various GIS datasets, County modeling efforts (including TR-20 and PLOAD), and LimnoTech's data collection efforts.

The results of the subwatershed restoration assessment revealed that the subwatersheds in the Upper Patuxent River Watershed received a reasonable mix of Good, Fair, Poor, and Very

Poor ratings. Three of the nineteen subwatersheds received a Good rating and two subwatersheds received a Very Poor rating. For the most part these ratings were well correlated with areas of urbanization and agricultural influences. See the Subwatershed Restoration Assessment Fact Sheets in Appendix F for maps of the assessment results. See Table 4 for a breakdown of rating results by subwatershed.

Table 4. Subwatershed Restoration Assessment Results

Rating	Subshed
Good	UP1, UP6, UP9
Fair	UP3, UP4, UP5, UP7, UP8, UPA, UPE, UPH, UPI, UPJ
Poor	UPC, UPD, UPF, UPG
Very Poor	UP2, UPB

2.2.3 Subwatershed Preservation Assessment

The County's subwatershed preservation assessment is intended to identify those subwatersheds where conditions warrant consideration for preservation activities (e.g., forest conservation). The subwatershed preservation assessment is based on a suite of indicators that can be grouped into one of five categories: stream ecology, future departure of water quality conditions, soils, landscape, and aquatic living resources. Each category is comprised of one to nine different indicators. See Table 5 for a summary of the indicators and their relative weighting.

Table 5. Subwatershed Preservation Assessment Indicators

Category	Indicator	Weight
Stream Ecology	Final habitat score	11.1%
Future Departure of Water Quality Conditions	Percent future departure of TN	7.4%
	Percent future departure of TP	7.4%
Soils	NRCS Erodibility Factor	11.1%
Landscape	Percent forest cover	11.1%
	Percent wetland cover	7.4%
	Density of headwater streams (ft/ac)	7.4%
	Percent of land within the Greenway Master Plan	3.7%
	Presence Sensitive Species Project Review Area (SSPRA)	3.7%
	Presence of bog wetlands	7.4%
	Acres of RCA lands within Critical Area	3.7%
	Percent of protected lands	3.7%
	Presence of Wellhead Protection Areas	3.7%
Aquatic Living Resources	Presence of trout spawning	4.4%
	Presence of anadromous spawning	6.7%

Among the indicators of the subwatershed preservation assessment, the final habitat scores are utilized as indicators of the quality of the physical characteristics of stream reaches in the subwatershed. The change in nutrient loading due to future development scenarios is an indicator of the need to protect a subwatershed based on pollutant considerations. The presence of sensitive environments like wetlands, bogs, threatened species habitat, spawning habitat, and other protected areas serve as further indicators of the need for preservation. The data underlying these indicators were generated from various GIS datasets, County modeling efforts, and LimnoTech's data collection efforts.

The results of the subwatershed preservation assessment revealed that the subwatersheds in the Upper Patuxent River Watershed received a reasonable mix of Good, Fair, Poor, and Very Poor ratings. About half of the subwatersheds were rated as Good to Fair candidates for preservation, while the other half were rated Poor to Very Poor candidates. See the Subwatershed Preservation Assessment Fact Sheets in Appendix F for maps of the assessment results. See Table 6 for a breakdown of rating results by subwatershed.

Table 6. Subwatershed Preservation Assessment Results

Rating	Subshed
Good	UP1, UP6, UP7
Fair	UP4, UP5, UP8, UP9, UPE, UPH, UPJ
Poor	UP2, UP3, UPA, UPC, UPD, UPF, UPI
Very Poor	UPB, UPG

2.2.4 Water Quality Modeling

In addition to the stream and subwatershed assessments, the County also performed water quality modeling to help assess existing and future development and pollutant control scenarios. This effort was intended to provide a sense of the potential for water quality improvements in the watershed and to satisfy permit and potential future TMDL requirements. Currently, the Upper Patuxent River Watershed is impaired due to nutrients and sediment. There is currently no TMDL in place for the watershed, but the County has suggested that one may be coming from the State in the future.

The County's water quality modeling is largely a GIS-driven accounting exercise. The modeling effort begins with a suite of intersected GIS layers (see Table 7) that are used in tandem with various assumptions about development and redevelopment potential and utilization of pollutant control practices. A series of existing and future scenarios (see Table 8) are created from these assumptions. Future development is assumed not to occur in floodplains, steep sloped areas, wetlands, certain stream buffers, schools and parks, cemeteries, and utility corridors. The County then performs a series of tests to determine whether and what type of new development can occur for a particular GIS polygon. This involves evaluating the land cover layer, zoning code, and potential redevelopment values. BMPs and environmental site design (ESD) retrofit opportunities are also identified in both public and private areas. Impervious cover assumptions are made for each future scenario, as well as assumptions about stormwater management and future septic loading.

Table 7. Water Quality Modeling GIS Layers

GIS Layer	Description	Purpose
Land cover	2004 delineation of land cover types (*e.g.*, industrial, commercial)	Helps determine runoff volumes and pollutant loading
Impervious cover	2004 delineation indicates presence or absence of impervious cover	Helps determine runoff volumes and pollutant loading
Hydrologic soil groups	Indicates NRCS soil groups A, B, C, or D	Defines areas eligible for BMP placement
Steep slopes	Derived from the digital elevation model (DEM)	Defines areas ineligible for development
Wetlands	Indicates presence or absence of wetlands	Defines areas ineligible for development
FEMA 100 year floodplains	Indicates presence or absence of floodplain	Defines areas ineligible for development
Critical areas	Includes Intense Development Areas, Limited Development Areas, and Resource Conservation Areas	Defines areas eligible or ineligible for development
Regulatory stream buffer	Buffer width varies depending on stream class	Defines areas ineligible for development
Redevelopment value and zone	Includes assessed value of land for a particular parcel plus improvements	Identifies new development or redevelopment likelihood
Schools and parks	Indicates presence or absence of schools or parks	Defines areas unlikely to be developed
Cemeteries	Indicates presence or absence of cemeteries	Defines areas unlikely to be developed
Ownership	Indicates private or public ownership	Guides BMP placement for future development scenarios
Greenways	Includes lands designated as such on the Greenways Master Plan	Defines areas ineligible for development
Expanded buffer	Includes a 300-foot stream buffer in areas with no public sewer service	Defines areas ineligible for development
Zoning codes	Includes County zoning codes (*e.g.*, commercial, low density residential, etc)	Defines areas eligible for specific development types
Sewer timing	Includes estimates for when and where future sewer systems will be installed	Helps determine septic pollutant loading
Septic delivery ratio	Septic pollutant delivery ration obtained from 2007 septic system study	Helps determine septic pollutant loading

For each scenario, the County uses BMP efficiencies and EMC values for the different land cover types to determine the resultant pollutant loading for a set of water quality parameters (*i.e.*, total nitrogen, total phosphorus, nitrates, fecal coliform, total suspended solids, and metals). Loading determinations are made for each of the typical TMDL categories (*i.e.*, urban, agricultural, and other). Loads are also calculated separately with and without BMPs or ESD retrofits.

Comparison of the loading results from each scenario can be used to focus the County's efforts for implementation and capital improvement projects. In the absence of a TMDL for the watershed, loading values were compared to those expected from a similar watershed with 10% impervious cover. The County previously suggested that they would prefer individual goals for each watershed, but as more watershed studies are completed they could consider moving towards a County-wide goal (which is important for determining County-wide spending priorities). In addition, the County utilized unit cost data associated with the BMPs or ESD retrofits to help determine which scenarios were most cost effective.

Table 8. Water Quality Modeling Scenarios

Control Scenario
• All forested conditions
Existing Condition Scenarios
• Existing conditions with fully maintained BMPs • Existing conditions with failed urban BMPs
Future Condition Scenarios
• Future conditions without protection of sensitive areas, implementation of future SWM regulations, and Sewer Master Plan • Future conditions without implementation of future SWM regulations and Sewer Master Plan • Future conditions with fully maintained BMPs and implementation of all future SWM regulations and Sewer Master Plan • Future conditions with public dry pond retrofit • Future conditions with expanded 300ft stream buffer in unsewered areas • Future conditions with preservation of the greenways • Future conditions with cluster developments for residential 1 and 2 acre developments • Future conditions with monthly street sweeping • Future conditions with recommended inlet cleaning • Future conditions with concrete and asphalt ditch retrofit • Future conditions with 100% ESD retrofit within county right of way • Future conditions with 25% ESD retrofit within county right of way • Future conditions with 100% ESD retrofit within private land • Future conditions with 25% ESD retrofit within private land • Future conditions with septic upgrades for nitrogen removal • Future conditions with the Onsite Sewage Discharge System (OSDS) study recommended retrofits • Future conditions with regenerative conveyance BMPs • Future conditions with all scenarios implemented

Within the Upper Patuxent River Watershed, for some subwatersheds and some water quality parameters, all of the current and future development scenarios were already well below the loading from the 10% impervious cover goal. In other instances, no future scenario met the loading goal. In general, the best opportunities for pollutant reductions were from implementation of ESD retrofits in the County right-of-way and select private lands.

3. Analysis and Recommendations

During the professional management team (PMT) meetings for the Upper Patuxent River Watershed study, LimnoTech and the County spent considerable time analyzing the County's methods, data inputs, and the assessment and modeling results. The following represents a summary of the major issues and recommendations discussed during these meetings, as well as those developed by LimnoTech in the ensuing months.

In general, LimnoTech found the County's assessment and modeling approaches to be well designed and reasonable. Discussions with the County during the PMT meetings suggested that the assessment and modeling approaches seem to be accurately identifying reaches and subwatersheds most in need of restoration or preservation. The County noted that overall the indicators used and the weighting schemes have generally served their needs and that adaptations made along way have improved the processes.

The large quantities of measured data and compiled watershed features and characteristics provides a substantial body of information that increases the County's understanding of the interactions between natural processes, anthropogenic stressors, and mitigative actions. However, the numerical precision of the extensive calculations performed in the data processing may inadvertently lead some reviewers and managers to an unsubstantiated faith in the accuracy of the results. LimnoTech urges the County to continue to maintain the proper perspective in relating admirable detail to end use and management objectives.

The remainder of this report provides specific recommendations on topics central to the County's assessment of watershed features and conditions.

3.1 Assessment and Modeling Data Inputs

LimnoTech reviewed a number of the inputs that the County was using and generally found them to be reasonable and in agreement with other published values, when available. Specifically, LimnoTech reviewed BMP efficiency, street sweeping removal rates, and event mean concentration (EMC) values that the County uses in their models. See Appendix E for the technical memorandum with LimnoTech's detailed analysis of these inputs.

- <u>BMPs and Stream Restoration Performance</u>
  The County revised their BMP pollutant removal efficiencies based on feedback received from LimnoTech and an internal comparison of those used by the Chesapeake Bay Program (CBP). It was noted during the PMT meetings that the revised BMP efficiencies suggest that there was not much efficiency gain between extended detention dry ponds and wet ponds, which is somewhat counter to the State's efforts to encourage the use of

wet ponds for efficiency purposes. As such, these new efficiencies will result in a loss of modeled benefits for wet ponds. It was also noted that the BMP efficiencies from the CBP included some practices that had failed (*i.e.*, negative efficiencies). Despite this, the County adopted these efficiencies to be consistent.

Going even further, the suite of BMPs and stream restoration practices in use in the mid-Atlantic states is expanding every year as more new and innovative technologies are implemented and tested. This includes the expanding use of green infrastructure practices that are becoming more effective and less costly. It also includes research like that provided by Dr. Sujay Kaushal of the University of Maryland Center for Environmental Science who has been among the first to associate and quantify the amount of nitrogen removed from an urban stream during environmental restoration. LimnoTech recommends a comprehensive review of the suite of BMPs used by the County in watershed planning. This would ensure that the range of BMPs and restoration practices is up to date and includes green infrastructure and leading edge research. It would also ensure that the flow attenuation and pollutant removal capabilities of BMPs and restoration practices used by the County in planning reflect advances in technology and performance.

- <u>Event Mean Concentrations</u>
  The County revised regional land cover EMCs based on feedback from LimnoTech. Specific changes included modifying the percent imperviousness for single row crops and open space from 0 to 1% and slight changes to the EMC values for metals in the open space and woods categories. The EMC values were assumed to account for air deposition and wash off.

3.2 Use of Break Points

With a few exceptions, the County employs natural breaks in indicator data to assign a rating score (e.g., 1, 4, 7, or 10). Using natural breaks minimizes the potential for having similar raw indicator data values grouped into different rating categories. LimnoTech noted during the PMT meetings that it may make sense to use finer discretization of indicator ranking scores than the grouped values of 1, 4, 7, or 10. This would help minimize the under- or over-valuation of certain raw indicator data points before arriving at a final rating score.
In addition, using natural breaks based on data from one watershed study could complicate comparisons made to another watershed with natural breaks based on its own dataset. Comparisons across watersheds could be accomplished by generating an entire new set of break points from the datasets from the combined watersheds. These break points would need to be recalculated following the completion of each new watershed study.

LimnoTech suggested that a weighted ranking scheme where indicators were assigned a value based on their relative ranking and then combined to obtain an overall rating score would eliminate the need to use break points entirely. This approach could yield superior data distribution across watersheds and would be more accurate than grouped or compartmentalized values. The County was concerned that this could result in some misrepresentation of values that are closely ranked but have vastly different raw values or vice versa. LimnoTech agreed that this would be a tradeoff and suggested that another alternative could be to look at scaled values instead of compartmentalized or ranked values. This would eliminate the need for break points, allow finer discretization of data, and would still keep the differences between values intact. These recommendations were briefly considered during the PMT meetings, but were not fully discussed. LimnoTech recommends that the concept of scaled indicator values be considered more fully during the PMT meetings for the next watershed study.

3.3 Normalization

Many of the indicator values are normalized by the reach length or subwatershed area to facilitate comparison. For one indicator in particular, total nitrogen and total phosphorus loading from runoff under the subwatershed restoration assessment, the indicator values were not normalized. The values were analyzed in terms of lbs per year and rather than lbs per year per acre. This approach unfairly penalized large watersheds. During the PMT meetings, the County expressed a desire to maintain dimensional consistency between the different scoring components. After further consideration following the PMT meetings, the County elected to change course and normalize all data sets to reach length or subwatershed area.

3.4 Indicator Weighting

During the course of the PMT dialogues, LimnoTech performed a statistical regression analysis of the weights used to combine indicators for preservation or restoration ratings. This analysis showed that the weights were appropriate and no changes were recommended. LimnoTech also performed a multi-linear regression analysis to determine the degree of correlation between MPHI scores and additional parameters that LimnoTech collected during field efforts. In this case, high correlation meant that a parameter is already in some way reflected in the County's assessments, while low correlation meant that the parameter could provide additional information. Several parameters had low correlation with MPHI scores: human intervention, riparian invasive species, barriers to fish movement, overall channel condition, and channel incision. LimnoTech suggests that these parameters be used as tie breakers should there be a need to differentiate between closely rated reaches.

3.5 Goal Development

Pollutant goals used by the County in water quality modeling are based on the 10 percent impervious cover level that the Center for Watershed Protection noted as the turning point for degradation of habitat, aquatic life and water quality. Exploration of other targets might be valuable. For example, it might be possible to use load allocations and waste load allocations from approved TMDLs to define new targets for pollutant loading. There will certainly be differences from one watershed TMDL to another, but the average loading targets on a per acre basis might be instructive and form a target that approximates regulatory expectations. Development of alternative pollutant goals would involve mining of allocations in approved watershed TMDLs from within Anne Arundel County and adjacent counties.

Alternately, the Water Environment Research Foundation (WERF) has recently released a research report that provides an assessment tool for characterizing stressor and biological gradients and defines the biological potential of urban streams in a context that is applicable in many parts of the United States. Review of this work and other methods that correlate water quality or physical habitat with macro-invertebrates and other biological measures may have value because of their ability to link current and future conditions to resources that are the object of protection and restoration.

3.6 Load Reduction Tracking

Future MS4 permits will have specific waste load allocation load reduction targets for storm sewer systems that are linked to approved TMDLs. In order to prepare for this eventuality, it might be prudent to establish a pollutant load reduction tracking system for nutrients. This would not be expected to be a major undertaking given the ample GIS coverages and other information available for watershed planning. It would likely require:

- Establishment of a base condition that becomes the point of reference for load reduction (i.e., the period during which Maryland collected water quality data and/or identified impaired water bodies to be listed).
- Alignment of County modeling practices and load estimates with Maryland procedures.
- Development of tracking procedures to account for load reductions associated with new control facilities and restoration projects.
- Implementation of regular updates to keep current.

3.7 Considering Global Climate Change Impacts

LimnoTech recommends consideration of global climate change projections into County analysis of protection priorities. Most of the global climate change models predict accelerated sea level rise. One ramification of this in the County might be the loss of tidal wetlands. In some instances, the loss will be offset by migration of tidal wetlands in an inland direction where permitted by the presence of appropriate undeveloped lowlands and the absence of barriers to migration. GIS and other modeling analyses would inform the County on the magnitude of this potential problem and the presence of appropriate land that might be purchased as a contingency for long term protection of tidal wetlands. Recently the Maryland Commission on Climate Change has recommended emphasis on identifying ecologically important lands including marsh migration corridors, targeting areas to buffer against sea level rise, increasing monitoring to detect changes due to climate change, and incorporating global climate change impacts into a watershed planning and management framework.

3.8 Leveraging Data to Understand Stressors and Mitigation

LimnoTech recommends that Anne Arundel County consider both the review of existing monitoring data and the design of future monitoring to identify "paired" stations whose contributing areas have similar characteristics with the exception of easily identifiable stressors or controls. Direct comparison of observed data at such stations can help to quantify the impact of stressors - such as presence/absence of septic systems - or the benefits of controls - such as presence/absence of wet ponds. Results of these comparisons may be useful for better identification of significant stressors as well as for demonstration of beneficial impacts of selected BMPs.

3.9 Continuous Monitoring

As a supplement to the periodic snapshots collected at monitoring points, LimnoTech suggests that the Country consider placing continuous monitors at selected locations - perhaps including "paired" stations as identified above - that collect certain parameters such as dissolved oxygen, pH, turbidity, or conductivity at a high frequency over an extended period of time. This high-frequency data record may be able to be correlated to parameters of direct interest, such as nutrient concentrations or habitat conditions. This would allow the County to better estimate annual totals and characterize uncertainty in both measured and correlated values, especially if data are collected in conjunction with continuous flow metering.

Bioassessment data may also be valuable in identifying stressors. There is increasing recognition that for biological monitoring programs to be most useful to managers there should be some link between the observed degradation and the cause of that degradation as a means to inform management and land use decisions. Several methodologies have been proposed to link degradation to specific stressor gradients, most notably the development of tolerance values and statistical risk assessment models, and the correlation of species assemblages to landcover and associated stressors. Continued refinement of these methods will allow managers to distinguish between different stressors, identify likely causes of degradation, and identify and model management changes on the biological community.

3.10 Aggregation of Data

LimnoTech also recommends that the County use aggregation of results to test for impacts from particular stressors or controls. For example, data from multiple sites (subwatersheds) with septic systems in their contributing areas can be averaged together and compared to data from sites (subwatersheds) without septic systems. Aggregating at a coarse level like this and comparing results with parallel base flow total nitrogen values could potentially identify an association between septic systems and elevated total nitrogen in base flow. Other informative analyses based on aggregation of data may prove useful.

Appendix A
Stream Crossing Technical Memorandum

- Stream Crossing Technical Memorandum – Delivered October 9, 2007

LimnoTech
Water | Environment | Scientists | Engineers

Technical Memorandum

DATE: 10/9/2007

FROM: Dan Herrema, P.E. and Zaneta Hough, LimnoTech

PROJECT: Upper Patuxent River Watershed Field Assessment and GIS Data Assembly

TO: Anne Arundel County Department of Watershed and Ecosystem Services

CC: Mary Searing, Hala Flores, Richard Fisher

SUBJECT: Upper Patuxent River HY8 Crossings Selection Procedure and Summary (Task 2.1.5)

Six stream crossings were selected by LimnoTech to be surveyed for selected hydraulic design information (as outlined in Task 2.1.5) for utilization by the County in HY8 modeling. Selection of these sites was performed using County GIS data along with crossings information collected during the Physical Habitat Condition Assessment (Task 3.2), and based on the criteria outlined by the County. In general, crossings were to be selected if they:

- crossed a road classified as freeway, arterial or collector;
- were likely to overtop (e.g., <20 from stream to crossing bed);
- were older than 5 years; and
- crossed a single access point to a community or business area and thus would isolate an area from emergency services.

Modifications to these criteria are discussed below.

Data utilized:

Site selection was conducted using County GIS data and crossings information collected during the Physical Habitat Condition Assessment (Task 3.2). An ArcMap file was created incorporating the following data:

- Stream reaches ("Upper_Pax_StreamReach_v2" *LimnoTech*)
- Crossings ("Crossings" *LimnoTech*)
- Roadway types ("Streets_Functional_layer" *County*)
- Upper Patuxent subwatershed boundaries ("subwatersheds" *County*)
- Aerial photography

Additional fields were added to the crossings layer for the HY8 crossings selection; these included:

- Name_Full: Street name from Streets_Functional_layer.

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STE 600
Washington, D.C. 20036
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- Func_Class: Roadway classification based on County Master Transportation Plan road classification system for roads within Anne Arundel County (Freeway, Principal Arterial, Minor Arterial, Collector, or Local) from Streets_Functional_layer.
- Map_Date: Date of culvert mapping from Upper Patuxent Crossings database provided by County.
- Type: Stream type (perennial, ephemeral, intermittent, wetland, underground), from Upper_Pax_StreamReach_v2 (based on Physical Habitat Condition Assessment streamwalks) generated by LimnoTech and approved by the County.
- Isolate_Single: Potential for roads, if overtopped individually, to completely isolate an area from emergency services where a stream crosses a single access point to a community or business area.
- Isolate_Mult: Potential for roads, if overtopped in combination, to completely isolate an area from emergency services where a stream crosses a single access point to a community or business area.
- HY8_Survey: Yes/No HY8 survey selection.

Selection Process:

The selection process was conducted as follows:

1. A subset of crossings inventoried during Subtask 3.2 (streamwalks) was selected if the road crossed was classified as Freeway, Principal Arterial, Minor Arterial, or Collector under the County Master Transportation Plan as provided in the Streets_Functional_layer shapefile, and crossed a perennial stream. Crossings on large interstate roads (Rt. 50 in this case) were not included as it is assumed that they are designed for large storm capacity. Foot trail crossings, culverts under interstates, driveway culverts, utility road culverts, SWM associated culverts, and farm field road culverts were eliminated from consideration. Out of 240 crossings assessed during Subtask 3.2, **18** met this criteria.
2. Crossings were selected if overtopping is likely, determined primarily by the height (less than 20 ft.) of the road surface above the channel. LimnoTech also visually assessed pertinent channel and floodplain characteristics, including culvert dimensions, embankment height, surrounding land use, and probable drainage area contribution. **14** of previous 18 crossings.
3. Crossings were to be selected if they were older than 5 years and not scheduled for replacement, as it is assumed that new stream crossings would be designed to flood infrequently. The County was unable to supply replacement schedule information. For culverts, date of mapping, provided by the County in the Upper Patuxent Crossings database was used as a surrogate for age. The County was unable to provide age information for bridge structures. All 14 remaining crossings remained following this evaluation**.**
4. Crossings were to be selected if there was potential that overtopped roads may completely isolate an area from emergency services. Aerial photography and county roads coverage were used to visually assess alternate routes to both sides of each crossing**.** No assessed crossings were determined to isolate an area if they were to flood

independently. We expanded this criterion to include crossings, that when flooded concurrently, could isolate an area. **6** of the 14 crossings remained following this evaluation.

Results:

Six crossings, located in subwatersheds UPB, UPC and UPD, were selected for collection of additional hydraulic design information:

Selected crossings:

Inventory ID	Street Name	Road Functional Class
UPD008.C001	PATUXENT RIVER RD	COLLECTOR
UPC010.C001	DOUBLE GATE RD	COLLECTOR
UPC006.C001	PATUXENT RIVER RD	COLLECTOR
UPB048.C002	PATUXENT RIVER RD	COLLECTOR
UPB007.C001	PATUXENT RIVER RD	COLLECTOR
UPD025.C001	MT AIRY RD	COLLECTOR

Selection elimination on subshed basis:

Subshed	Total crossings	Road Class Elimination	Other Criteria Elimination	Selected Sites
UP1	4	1	3	0
UP2	3	3	0	0
UP3	7	7	0	0
UP4	9	9	0	0
UP5	0	0	0	0
UP6	11	11	0	0
UP7	8	8	0	0
UP8	13	11	2	0
UP9	3	3	0	0
UPA	13	13	0	0
UPB	23	21	0	2
UPC	9	7	0	2
UPD	26	24	0	2
UPE	21	18	3	0
UPF	27	25	2	0
UPG	19	19	0	0
UPH	11	11	0	0
UPI	19	18	1	0
UPJ	14	13	1	0
Total	**240**	**222**	**12**	**6**

Appendix B
Urban Stormwater BMPs Technical Memorandum

- Urban Stormwater BMPs Technical Memorandum – Delivered April 7, 2008

URBAN BEST MANAGEMENT PRACTICES TECHNICAL MEMORANDUM

Subtask 2.2
Upper Patuxent River Watershed Study

April 2008

Prepared For:
Anne Arundel County Department of Public Works
Watershed Management Program
2664 Riva Road
Annapolis, Maryland 21401

Prepared by:
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Introduction

Under Subtask 2.2 of the Upper Patuxent Watershed study, LimnoTech was tasked by the Anne Arundel County Department of Public Works with developing a complete geospatial dataset of available urban stormwater best management practices (BMPs) within the Upper Patuxent River watershed. In summary, the effort to develop the dataset entailed:

- compiling existing data from multiple County and other sources,
- narrowing the dataset to eliminate those BMPs outside of the Upper Patuxent River watershed,
- confirming or updating the spatial locations of the remaining BMPs,
- removing duplicate records, and
- performing research to fill any data gaps.

This Technical Memorandum documents the steps and procedures LimnoTech performed to complete this task.

Compiling Existing Data

The first step in the process was to compile all of the existing BMP records for the Upper Patuxent watershed. Several sources were utilized in this process. The following is a list and brief description of the data sources:

- **Urban BMP Database:** The County provided this dataset to LimnoTech in the form of two point shapefiles. The dataset is derived from the Anne Arundel County Inspections and Permit urban stormwater management database. The dataset contains Anne Arundel County permitted public and private urban BMPs. Facilities permitted directly by other entities are not included in this dataset. The two shapefiles together contained 4,690 BMP records.

- **County's Public BMP Polygon Shapefile:** The County provided a second dataset containing a subset of public BMPs that had been digitized from operating maps and As-built plans. This dataset was provided as a polygon shapefile. The County noted that it is considered to be a spatially accurate, but incomplete inventory of the County-owned facilities. The County also noted that some of the records may be duplicates of those contained in the Urban BMP database. The polygon shapefile contained 19 BMP records.

- **SHA Highway Hydraulics BMP Database:** At the County's request, LimnoTech contacted the Maryland State Highway Administration (SHA) to obtain a list of SHA owned BMPs in the Upper Patuxent River watershed. SHA responded to the request and provided LimnoTech with an MS Access database of all BMPs in Anne Arundel County within its purview. The database contained spatial and attribute data for 461 BMP records.

- **Soil Conservation District Ponds:** At the County's request, LimnoTech contacted the Anne Arundel County Soil Conservation District (SCD) to obtain a list of MD-378 ponds in the Upper Patuxent River watershed. LimnoTech's contact at SCD was Jim Stein. LimnoTech was provided a spreadsheet containing attribute data for 1,210 ponds, but was informed that spatial information was only available on hard copy maps available for review at SCD offices.

LimnoTech also contacted the Patuxent Wildlife Refuge to inquire about the existence of BMPs located there. LimnoTech spoke with Mr. Holiday Obrecht at the Refuge and was informed there was no such list of BMPs on Refuge property.

Narrowing the Dataset to Eliminate BMPs Outside of the Watershed

With a draft dataset of BMP records compiled from the sources listed above, LimnoTech next worked to remove those BMP records known to be outside of the watershed. LimnoTech followed the protocols for this step as outlined in the County's draft Technical Memo dated June 7, 2007. As each BMP data source had different degrees of inherent spatial accuracy, the steps for eliminating records varied among the sources. The rationales for eliminating specific records are provided in the companion spreadsheet "UPBMPs_Data_Sources.xls." The code in the companion spreadsheet for removal rationale is provided in italicized parentheses following each data source or type. The procedures for each data source are provided below.

- **Urban BMP Database:** LimnoTech was informed that the data contained in this dataset is under review by the Department of Public Works' Infrastructure Management Division and that the spatial locations for many BMP records are inaccurate or unknown. To facilitate this analysis, LimnoTech defined a study area using a one-mile buffer of the Upper Patuxent River Watershed as an overlay layer. This helped eliminate the need to make close calls for BMPs located near the watershed boundary. The following steps defined in the County's draft protocol memo were taken:
    - All records with a XY_source value of "CPF", "CV", "MapOptix", or "Geocoded Address" that fell outside of the study area were removed from the draft dataset. *(Code: XY_Source is CPF, point outside buffer; XY_Source is CV, point outside buffer XY_Source is Geocoded Address, point outside buffer; XY_Source is MapOptix, point outside buffer)*
    - A spatial join was performed with the draft database and the County's Planning and Zoning zip code polygon shapefile. All BMP records (except those located at the County centroid) with matching zip codes that fell outside of the study area were removed from the draft dataset *(Code: Zip code matched, point outside buffer)*
    - A spatial join was performed with the draft database and the ADC map grid polygon shapefile. All BMP records (except those located at the County centroid) with matching ADC map grid values that fell outside of the study area were removed from the draft dataset. *(Code: Map grid matched, point outside buffer)*
    - Using a parcel map layer at the County offices, all BMP records (except those located at the County centroid) with matching tax accounts that fell outside of the study area were removed from the draft dataset. *(Code: BMP removed based on research using County resources)*
    - For the remaining records that plotted outside of the study area, including records with XY_source value of "County Centroid," LimnoTech performed two additional checks to determine if a particular record should be eliminated. The first was a check of the BMP name against the USGS Geographic Names Information System (GNIS) and

against the various index search categories within the ADC map (e.g., place names, airports, business parks, campsites, golf courses, parks, police stations, etc.). The second was a check of the street name or address against the County's street centerline file. If either of these approaches yielded a match outside of the study area, then the record was removed. *(Code: Address matched outside buffer; Place name matched outside buffer; XY_Source is centroid, address matched outside buffer; XY_Source is centroid, place name matched outside buffer)*

- For those records that still remained at this point, additional checks performed at the County offices eliminated another subset of BMP records. This entailed utilizing various County tools to positively identify a BMP record and determine its location. Specifically, LimnoTech used As-builts on CountyView, scanned grading and building permits, a search of archived electronic records, and the Google search engine. A record was considered positively identified if two pieces of identifying information matched a record in the draft dataset. This process eliminated 4,407 of the 4,690 BMP records and retained 283 records in the draft dataset for further study. *(Code: BMP removed based on research using County resources)*

- **County's Public BMP Polygon Shapefile:** The County's draft protocol memo dictated that the public BMP polygon was spatially accurate. As all 19 of the BMP polygons in this dataset were within the Upper Patuxent watershed, no BMP records were eliminated. All 19 BMPs were retained in the draft dataset for further study.

- **SHA Highway Hydraulics BMP Database:** The County's draft protocol memo assumed that the SHA database was also spatially accurate. As such, LimnoTech performed a spatial join with this dataset and the watershed boundary shapefile. Of the 461 BMP records in the database, 31 were located within the watershed boundaries and thus retained in the draft dataset for further study. *(Code: Point outside buffer, location assumed final)*

- **Soil Conservation District Ponds:** The primary identifying attributes of the MD-378 ponds in the SCD dataset were a unique ID number, a grading permit number, and a map number with grid coordinates. At the County SCD office, LimnoTech reviewed hard copy maps to determine the maps or portions of maps that lie within the Upper Patuxent River watershed. This was cross-checked with the map and grid coordinates to determine whether a pond should be retained or eliminated. Additionally, those ponds with valid grading permits were compared to the grading permits of previously eliminated BMPs to determine if there were any matches. Ponds with grading permits that match BMPs already established to be outside the study area were eliminated. Finally, all hard copy maps containing portions of the watershed were carefully examined in an attempt to identify any remaining ponds that may exist within the Upper Patuxent. Of the 1,210 ponds in the spreadsheet, 24 were positively identified within the watershed and retained in the draft dataset for further evaluation. *(Code: Grading permit match with BMP outside study area; Map includes part of UP, but point outside study area; Map outside study area; No grading permit match or map coordinates, pond not found on hard copy maps)*

Confirming or Updating Spatial Locations

A total of 286 records were ultimately retained in the draft dataset. For these records, LimnoTech worked to confirm or update the spatial location of the BMP using various record attributes. LimnoTech completed the majority of this step at the County offices during two visits in December 2007. Looking at each BMP record individually, LimnoTech used various County tools to first positively identify a BMP record from the draft dataset and second to confirm or update its location. Specifically, LimnoTech used the parcel layer, As-built records on CountyView, scanned grading and building permits, a search of archived electronic records, and the Google search engine to assist in this process. A record was considered positively identified if two pieces of identifying information (e.g., name, tax account ID, address) from the draft dataset matched the record or file from one of the County's resources.

Each positively identified record was then evaluated for spatial accuracy. The BMP record location in the draft dataset was compared to the location indicated in the County tool or resource where the record was positively identified. If the locations were within 500 feet (a value determined in consultation with the County program manager), then the BMP record was considered spatially accurate. A BMP in the draft dataset that was in the vicinity of, but over 500 feet from, the location suggested in the County tool or resource was moved to the new location only when aerial imagery, parcel maps, or facility drawings supported the move. This helped ensure that BMP points would only be relocated when enough evidence suggested a move was appropriate.

If the BMP record was located at the County centroid and the County tool or resource provided limited evidence of the correct location (which occurred in a few instances), LimnoTech used its best professional judgment to locate the BMP point as accurately as possible. Notes about relocating points and rationales for doing so are provided in the companion spreadsheet "UPBMPs_Data_Sources.xls." A total of 43 BMP records did not contain enough identifying information to be positively identified or spatially confirmed. These records are included separately in the companion spreadsheet under a separate tab called "BMPs Requiring More Research."

Resolving Duplicates
Given that data was compiled from multiple datasets, it is inevitable there may be some duplicate records. Note that the degree of identifying information available made it impossible to identify duplicates within an individual data source. As such, an effort to identify and remove duplicates was only performed between data sources. LimnoTech identified duplicate records by examining attributes and spatial locations. Only when points were co-located with matching identifying attributes and structure types were they considered to be redundant. Twenty MD-378 ponds were determined to be duplicates of records in the Urban BMP Database, while eight Public BMP polygons were found to be duplicates.

Researching Data Gaps
To perform the prioritization modeling using these BMPs, the County requires that the data attributes listed below be fully populated. LimnoTech performed the step to research data gaps concurrently with the step to confirm and update spatial locations at the County offices. Looking at each BMP

record individually, LimnoTech used County tools including As-builts on CountyView, scanned grading and building permits, and a search of archived electronic records to fill in data gaps.

- **Drainage Area (Drainage):** The County noted that all BMPs within the Upper Patuxent River were to be attributed with the drainage area. The drainage area for the majority of records was found in the existing Urban BMP database. For records with null or zero values, the scanned grading and building permits, archived records, and As-builts on CountyView were researched for the information. As a last resort, LimnoTech moved the BMP point to the appropriate flow direction grid and provided to the County for drainage area delineation. In those few instances where the drainage area for a private house infiltration drywell was missing from the Urban BMP database, an average value of 0.05 acres is to be used. This assumption was only used to populate missing information and not to override an existing data entry.

- **Structure Type (StrucType):** The County noted that all BMPs within the Upper Patuxent River were to be attributed with the Structure Type. The structure type was documented using structure codes in accordance with the WMT BMP master list. For records with missing structure type information, the scanned grading and building permits, archived records, and As-builts on CountyView were first researched for the information.

- **Ownership (Ownership):** This information was only to be compiled if it existed in the Urban BMP Database or if it was revealed during the record research for another required parameter.

- **Built Date (Built_Date):** This information was only to be compiled if it existed in the Urban BMP Database or if it was revealed during the record research for another required parameter.

- **Inspection Notes (Inspection):** This information was only to be compiled if it existed in the Urban BMP Database or if it was revealed during the record research for another required parameter.

Data Deliverables to County

In addition to this memo, the deliverable for this subtask also includes:

- a point shapefile (UPBMPs_final.shp) with all compiled, verified, and researched attributes;
- a point shapefile (UPBMPs_requiring_additional_research.shp) with the existing locations of BMPs requiring additional research; and
- a spreadsheet (UPBMPs_Data_Cources.xls) containing the final dataset, data requiring additional research,. eliminated records with rationales, and the original datasets.

Summary of Findings

Of the 286 BMPs whose information was confirmed in the BMP data search for the Upper Patuxent Study, 191 of them are located within the Upper Patuxent watershed boundary. The data for the 191 BMPs will be used in further analyses of the Upper Patuxent Study, including the evaluation of water quality.

The sum of the drainage areas for all 191 BMPs in the Upper Patuxent is 969 acres, while the entire watershed is approximately 22,600 acres in size.[1] Thus the area of the Upper Patuxent River watershed that is receiving water quality treatment through a BMP is just over four percent (4%).[2] The total impervious area in the Upper Patuxent River watershed is approximately 1,800 acres, equating to just under eight (8%) percent impervious. The BMP drainage areas range in size from 0.04 to 107.81 acres, with a mean drainage area of 5.07 acres, and a median drainage area of 0.48 acres. This indicates that many of the BMPs are very small in size. Seventy-five (75%) percent of the BMPs treat less than four (4) acres, but there are five (5) BMPs that treat drainage areas over sixty (60) acres.

Most of the BMPs are privately owned (61%), followed by publicly owned (31%), State Highway Administration (SHA) (6%) owned, and owned by a group termed "Other" (2%). However, when evaluated by the percent of the drainage area they treat in the Upper Patuxent Watershed, private BMPs treat 36% of the area, public BMPs treat 30%, "Other" BMPs treat 31%, and SHA BMPs treat 3%. It is recommended that the grouping of "Other" BMPs be further investigated since they treat a large BMP area, and are only four (4) in number. Further statistics on the BMPs by Ownership type can be found in Table 1.

Table 1. Statistics on BMPs by Ownership Type

Ownership	Quantity	Percent by Quantity	Drainage Area (ac)	Percent by Drainage Area	Mean Drainage Area (ac)	SD (ac)	Minimum Drainage Area (ac)	Maximum Drainage Area (ac)	Median Drainage Area (ac)
Public (DPW)	59	31%	288.66	30%	4.89	6.44	0.06	26.94	
Private	117	61%	351.84	36%	3.01	9.60	0.04	67.16	
SHA	11	6%	31.69	3%	2.88	3.39	0.39	10.72	
Other	4	2%	297.13	31%	74.28	35.93	13.85	107.81	
Total	191	100%	969.32	100%	5.07	14.15	0.04	107.81	0.48

The BMPs can be classified into six (6) categories: filtering practices, infiltration practices, dry detention practices, dry extended detention practices, wet ponds and wetlands, and other. The majority of the BMPs fall into the category of infiltration (59%) and this category also represents a good portion of the total BMP drainage area (32%). While wet ponds and wetlands only make up 12% of the BMPs by number, they cover 54% of the total BMP drainage area. In terms of how efficiently a BMP group removes pollutants from surface water runoff, infiltration BMPs have some of the highest reported efficiencies (CBPO, 2007), but they also require significant maintenance to keep them from failing (CWP, 2000). Further statistics on the BMPs by category can be found in Table 2.

[1] The statistics for the drainage areas of the BMPs were compiled from existing databases and research of the development plans. Actual drainage area boundaries have not been compiled using GIS methods.
[2] Some of the BMP drainage areas may overlap, meaning the same piece of land could be getting treated in a series of BMPs.

Table 2. Statistics on BMPs by BMP Classification

BMP Group	Quantity	Percent by Quantity	Sum of Drainage Area (acres)	Percent by Drainage Area
Total Filtering Practices	5	3%	6.26	1%
Total Dry Detention Practices	9	5%	56.64	6%
Total Infiltration Practices	113	59%	311.96	32%
Total Dry Extended Detention Practices	7	4%	64.49	7%
Total Wet Ponds and Wetlands	22	12%	520.63	54%
Total Other	35	18%	9.34	1%
Total of all BMPS	191	100%	969.32	100%

Further investigation into the fifty-nine (59) publicly owned BMPs indicates that the largest type in number is infiltration (75%), and these also treat 53% of the public BMP drainage area. The average drainage area for the public infiltration BMPs is less than four (4) acres. Further statistics on the publicly owned BMPs can be found in Table 3.

Table 3. Statistics on Publicly Owned BMPs

BMP Group	Quantity	Percent by Quantity	Drainage Area (ac)	Percent by Drainage Area	Mean Drainage Area (ac)	SD (ac)	Minimum Drainage Area (ac)	Maximum Drainage Area (ac)
Total Filtering Practices	2	3%	5.48	2%	2.74	1.46	1.28	4.20
Total Dry Detention Practices	1	2%	25.32	9%	25.32	0.00	25.32	25.32
Total Infiltration Practices	44	75%	152.51	53%	3.47	4.84	0.06	26.94
Total Dry Extended Detention Practices	4	7%	57.06	20%	14.27	8.28	2.01	23.16
Total Wet Ponds and Wetlands	5	8%	47.58	16%	9.52	4.49	3.90	17.40
Total Other	3	5%	0.71	0%	0.24	0.11	0.09	0.34
Total of all BMPS	59	100%	288.66	100%	4.89	6.44	0.06	26.94

Further investigation into the 117 privately owned BMPs indicates that the largest type in number is also infiltration (54%), and these treat 43% of the privately-owned BMP drainage area. While wet ponds only make up 8% of the total by number, they treat a significant part of the privately-owned BMP drainage area (43%). Further statistics on the privately owned BMPs can be found in Table 4.

Table 4. Statistics on Privately Owned BMPs

BMP Group	Quantity	Percent by Quantity	Drainage Area (ac)	Percent by Drainage Area	Mean Drainage Area (ac)	SD (ac)	Minimum Drainage Area (ac)	Maximum Drainage Area (ac)
Total Filtering Practices	3	3%	0.78	0%	0.26	0.22	0.10	0.57
Total Dry Detention Practices	7	6%	30.15	9%	4.31	3.28	0.24	10.14
Total Infiltration Practices	63	54%	152.62	43%	2.42	8.88	0.04	60.04
Total Dry Extended Detention Practices	3	3%	7.43	2%	2.48	2.13	0.11	5.28
Total Wet Ponds and Wetlands	9	8%	152.23	43%	16.91	20.23	3.44	67.16
Total Other	32	27%	8.63	2%	0.27	0.33	0.05	1.43
Total of all BMPS	117	100%	351.84	100%	3.01	9.60	0.04	67.16

Further investigation into the 11 BMPs owned by the State Highway Administration (SHA) indicates that the largest type in number is infiltration (55%), and these treat a significant portion of the SHA-owned BMP drainage area (22%). Four (4) of the BMPs are of the wet pond and wetland type, and these treat a large portion of the SHA-owned BMP drainage area (75%). Further statistics on the BMPs owned by the SHA can be found in Table 5.

Table 5. Statistics on BMPs Owned by SHA

BMP Group	Quantity	Percent by Quantity	Drainage Area (ac)	Percent by Drainage Area	Mean Drainage Area (ac)	SD (ac)	Minimum Drainage Area (ac)	Maximum Drainage Area (ac)
Total Filtering Practices	0	0%	0.00	0%	0.00	0.00	0.00	0.00
Total Dry Detention Practices	1	9%	1.17	4%	1.17	0.00	1.17	1.17
Total Infiltration Practices	6	55%	6.83	22%	1.14	0.53	0.39	1.74
Total Dry Extended Detention Practices	0	0%	0.00	0%	0.00	0.00	0.00	0.00
Total Wet Ponds and Wetlands	4	36%	23.69	75%	5.92	4.08	0.69	10.72
Total Other	0	0%	0.00	0%	0.00	0.00	0.00	0.00
Total of all BMPS	11	100%	31.69	100%	2.88	3.39	0.39	10.72

The four (4) BMPs with unknown ownership (“Other”) are all of the BMP category wet ponds and wetlands. As indicated earlier in this document, these BMPs treat 31% of the Upper Patuxent Watershed’s total BMP drainage area. Further statistics on the BMPs with unknown ownership can be found in Table 6.

Table 6. Statistics on BMPs with Unknown Ownership

BMP Group	Quantity	Percent by Quantity	Drainage Area (ac)	Percent by Drainage Area	Mean Drainage Area (ac)	SD (ac)	Minimum Drainage Area (ac)	Maximum Drainage Area (ac)
Total Filtering Practices	0	0%	0.00	0%	0.00	0.00	0.00	0.00
Total Dry Detention Practices	0	0%	0.00	0%	0.00	0.00	0.00	0.00
Total Infiltration Practices	0	0%	0	0%	0.00	0.00	0.00	0.00
Total Dry Extended Detention Practices	0	0%	0.00	0%	0.00	0.00	0.00	0.00
Total Wet Ponds and Wetlands	4	100%	297.13	100%	74.28	35.93	13.85	107.81
Total Other	0	0%	0.00	0%	0.00	0.00	0.00	0.00
Total of all BMPS	4	100%	297.13	100%	74.28	35.93	13.85	107.81

Figure 1 shows the Best Management Practices in the Upper Patuxent River Watershed by structure type and ownership. Table 7 contains additional detailed information on the urban BMPs in the Upper Patuxent River Watershed.

Figure 1. Best Management Practices in the Upper Patuxent River Watershed

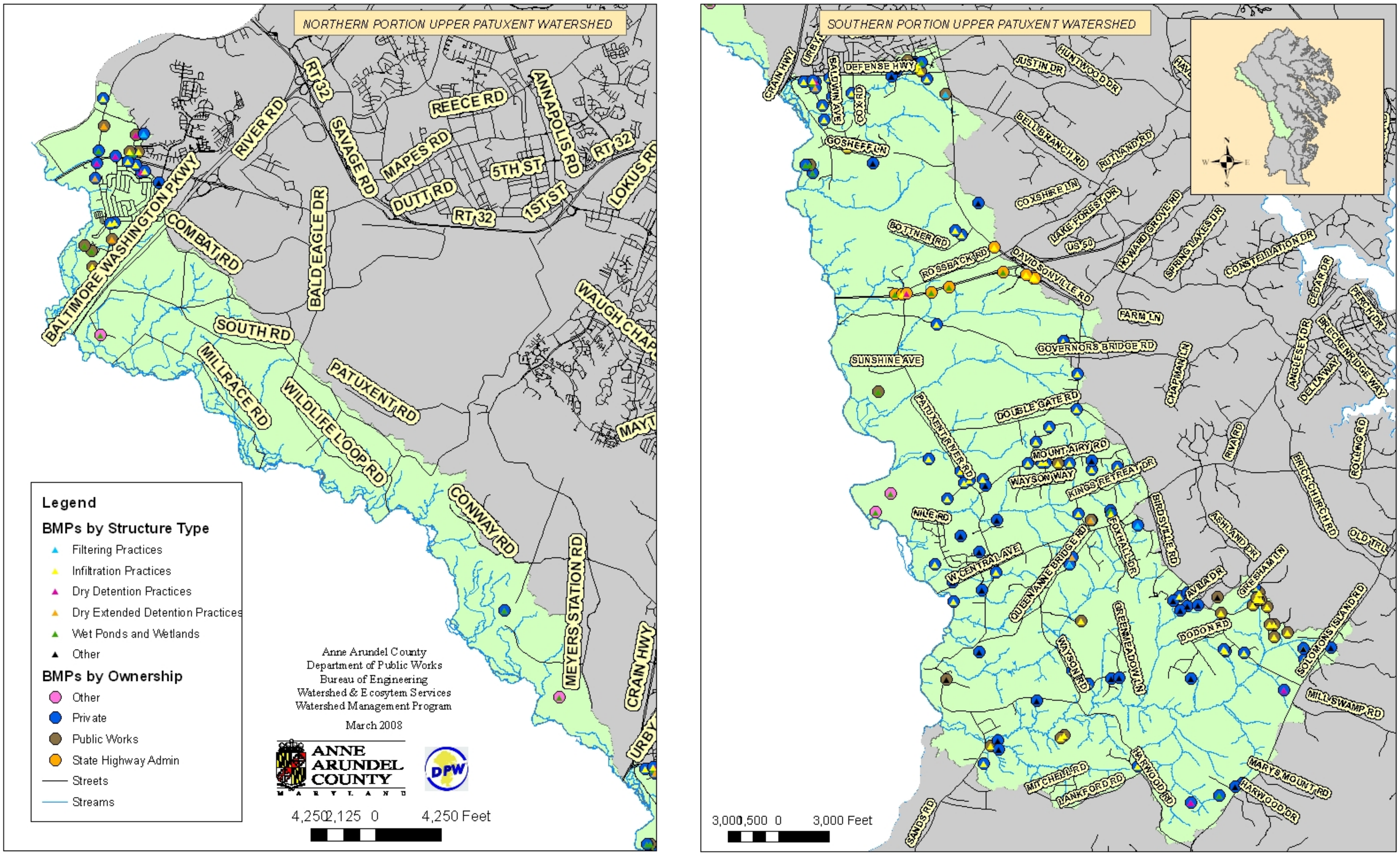

Table 7. Detailed Statistics on the Urban BMPs in the Upper Patuxent Watershed

STRU_TYPE	BMP Group	Quantity	Sum of Drainage Area (acres)	Mean DA	Std Dev	Min Area	Max Area	Median	# Public Ownership	# Private Ownership	# SHA Ownership	Other
ASCD	Filtering Practices	1	4.20	4.20	0.00	4.20	4.20		1	0	0	0
ATTENSWA	Filtering Practices	3	1.96	0.65	0.48	0.11	1.28		1	2	0	0
POSAND	Filtering Practices	1	0.10	0.10	0.00	0.10	0.10		0	1	0	0
Total Filtering Practices		**5**	**6.26**	**1.25**	**1.54**	**0.10**	**4.20**		**2**	**3**	**0**	**0**
DP	Dry Detention Practices	6	53.74	8.96	7.77	1.17	25.32		1	4	1	0
UGS	Dry Detention Practices	3	2.90	0.97	0.74	0.24	1.99		0	3	0	0
Total Dry Detention Practices		**9**	**56.64**	**6.29**	**7.39**	**0.24**	**25.32**		**1**	**7**	**1**	**0**
DW	Infiltration Practices	1	0.05	0.05	0.00	0.05	0.05		0	1	0	0
DWITCE	Infiltration Practices	11	1.14	0.10	0.13	0.05	0.50		1	10	0	0
DWITPE	Infiltration Practices	2	0.09	0.05	0.01	0.04	0.05		0	2	0	0
IB	Infiltration Practices	6	44.40	7.40	9.69	0.33	26.94		3	2	1	0
IT	Infiltration Practices	37	133.56	3.61	11.30	0.05	60.04		13	19	5	0
ITCE	Infiltration Practices	36	54.09	1.50	2.59	0.06	11.00		16	20	0	0
ITPE	Infiltration Practices	20	78.63	3.93	2.91	0.07	7.01		11	9	0	0
Total Infiltration Practices		**113**	**311.96**	**2.76**	**7.31**	**0.04**	**60.04**		**44**	**63**	**6**	**0**
ED	Dry Extended Detention Practices	2	43.53	21.77	1.40	20.37	23.16		2	0	0	0
EDSD	Dry Extended Detention Practices	5	20.96	4.19	4.02	0.11	11.52		2	3	0	0
Total Dry Extended Detention Practices		**7**	**64.49**	**9.21**	**8.66**	**0.11**	**23.16**		**4**	**3**	**0**	**0**
EDSW	Wet Ponds and Wetlands	7	79.55	11.36	9.95	3.76	35.23		3	4	0	0
EXPOND	Wet Ponds and Wetlands	1	17.94	17.94	0.00	17.94	17.94		0	1	0	0
WP	Wet Ponds and Wetlands	14	423.14	30.22	37.37	0.69	107.81		2	4	4	4
Total Wet Ponds and Wetlands		**22**	**520.63**	**23.67**	**31.58**	**0.69**	**107.81**		**5**	**9**	**4**	**4**
MC	Other	1	1.43	1.43	0.00	1.43	1.43		0	1	0	0
CRDT	Other	27	4.03	0.15	0.06	0.05	0.32		1	26	0	0
RD	Other	1	0.20	0.20	0.00	0.20	0.20			1		
PL	Other	2	0.34	0.17	0.11	0.06	0.28		1	1	0	0
BRT	Other	4	3.34	0.84	0.29	0.34	1.00		1	3	0	0
Total Other		**35**	9.34	0.27	0.32	0.05	1.43		3	32	0	0
Total of all BMPS		**191**	**969.32**	**5.07**	**14.15**	**0.04**	**107.81**	**0.48**	**59**	**117**	**11**	**4**

Appendix C
Agricultural Conservation Methods and Runoff BMPs Technical Memorandum

- Agricultural Conservation Methods and Runoff BMPs Technical Memorandum – Delivered April 8, 2008

AGRICULTURAL LAND USE AND BEST MANAGEMENT PRACTICES TECHNICAL MEMORANDUM

Subtask 2.3
Upper Patuxent River Watershed Study

April 2008

Prepared For:
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Introduction

Understanding the contribution of agricultural practices to the total nutrient loads within a watershed is important when developing watershed plans and performing watershed modeling activities. Pollution from agricultural sources includes nitrogen, phosphorus, sediment, bacteria and other agrochemicals like pesticides. These pollutants can be dissolved in or attached to soil particles suspended in runoff. Agricultural Best Management Practices (BMPs) are often applied to farm fields as part of watershed management to reduce non-point source pollution from agricultural runoff. The role BMPs play in reducing the generation of these pollutants in runoff is important at the site and watershed scale. Watershed planning and watershed modeling require accurate information on the extent and effectiveness of agricultural BMPs. The types of activities considered in watershed model development include: types of crops grown; farming practices including conservation practices (e.g. No-till, Strip, and Contour cropping, Nutrient Management); and types of BMPs employed (e.g. Grass Strip, Buffer, Grass Swale).

The purpose of this task was to assemble available data on agricultural practices in the Upper Patuxent River Watershed including information on farming practices such as crops grown and rotations, nutrient management, and conservation practices. Specifically, the scope of work required LimnoTech to obtain, check, and/or generate accurate georeferenced GIS datasets to develop a complete, georeferenced inventory of all agricultural BMPs (structural and non-structural) located within the watershed. This work was to be coordinated with the Soil Conservation District.

The deliverables originally requested by the County under this task included the following:

- A complete digital agricultural BMP point or polygon feature dataset for the Upper Patuxent River Watershed, including structural and non-structural BMPs listed by type and attributed with various fields such as location, ownership/easement type, and contributory drainage areas.

- Information from nutrient management plans along with methods to assess animal numbers and manure acres shall be investigated and reported in an ArcGIS Personal Geodatabase and written document.

- Additional hydraulic information (storage stage discharge) compiled from available design or asbuilt records for ponds identified by the Soil Conservation District as serving flood control functions.

Several of these deliverables were not able to be generated due to limited availability of data and information as described within this memo. This memorandum describes existing data; additional data requested and received from federal, state and local agencies; data obtained in a windshield survey; data processing and a summary of available information on agricultural BMPs in the Upper Patuxent River Watershed.

Existing Data

Existing data provided to LimnoTech consisted of the GIS layers provided by the County including:

- Watershed boundary shapefile
- 2004 County landcover shapefile
- County parcel shapefile
- Aerial orthophotography

Data Requested/Received

Several federal, state, and local agencies were contacted in an attempt to acquire information on agricultural practices within the watershed. In most cases, the information received was aggregated at the county or watershed level. A list of the agencies contacted, the data requested, and results of those requests are presented below.

National Resource Conservation Service (NRCS)

The NRCS is responsible for tracking, managing, and implementing federal cost-share conservation practices including the Conservations Reserve Enhancement Program (CREP), the Conservation Reserve Program, cover crops and others. The NRCS also retains information on current land ownership and cropping practices. The following data was requested from the NRCS:

- Maps (shapefile or hard copy) of the location of federal cost-share conservation practices within the Upper Patuxent watershed.
- List of agricultural farmlands in the Upper Patuxent River Watershed with data on soil conservation practices and BMPs.
    - Owner, operator, acres, farm, tract, map, parcel, practices planned, practices applied, plan date.
- Scanned copies of information on Code 378 Farm Ponds in the watershed including GIS files showing their locations.
- A marked-up Land-Use map that identifies current farmlands in the Upper Patuxent Watershed.

After talking with NRCS staff, a formal request letter was sent by the County to the Freedom of Information Officer at NRCS as privacy laws currently restrict the distribution of such information. The NRCS response to the letter is included as Appendix A of this document.

The NRCS's response stated that requested information including owner, operator, acres, farm, tract, map, parcel and practices planned/applied was not available for release, nor was the location of Code 378 Farm Ponds. It was also indicated that access to site-specific information on federal cost-share BMPs located within the watershed would also be denied, if requested.

Maryland Department of Agriculture (MDA)

The MDA has jurisdiction over Nutrient Management Plans (NMPs) in the state of Maryland. It is estimated that almost all farms in Anne Arundel County participate in an NMP. The MDA also tracks and manages the States cost-share program for conservation practices such as riparian buffers and cover crops. The following data were requested from the MDA for the Upper Patuxent Watershed:

- List of agricultural farmlands in the Upper Patuxent River Watershed with data on soil conservation practices and BMPs including:
  - Owner, operator, acres, farm, tract, map, parcel, practices planned, practices applied, plan date.
  - List of BMPs such as buffers, conservation tillage, cover crops etc. and their acreages.
- Scanned copies of information on Code 378 Farm Ponds in the watershed including GIS files showing their locations.
- A marked-up Land-Use map that identifies current farmlands in the Upper Patuxent Watershed, which can be cross-referenced with the practices.
- Data on nutrient application and management practices on farmlands.

In talking with MDA staff, it was determined that a formal request letter should be sent to MDA as privacy laws currently restrict the distribution of such information. No formal response was received.

The MDA was not able to provide specific information on nutrient management plans within the watershed due to confidentiality reasons, but was able to establish the number of acres in a NMP for the Upper Patuxent Watershed (Table 1). The agency also was not able to provide information on the amount of nutrients (fertilizer) applied to each crop. In terms of conservation practices, the MDA could only provide statistics on the acreage of winter cover crops paid for by the Maryland Agricultural Cost-Share (MACS) program, and SCWQ (Soil Conservation and Water Quality) Plan Acres. Soil Conservation and Water Quality Plans are a large part of Maryland's resource conservation and protection efforts. In general, the plans help farmers manage natural resources and identify and solve potential environmental problems while reaching optimal but sustainable production goals. The plans contain a menu of BMPs to help farmers prevent sediment, nutrients, and fertilizers from impacting nearby waterways. Specific information on what BMPs were being funded was not supplied.

The MDA was able to provide limited information on expected nutrient removal rates for nitrogen (N) and phosphorus (P) for each of the listed practices (Table 1). These numbers were used to estimate total nutrient removal by these practices within the watershed on an annual basis. While a majority of the nutrient removal seems to come from the implementation of NMPs, the actual removal rate is lower (3.11 lbs N/acre and 0.3 lbs P/acre) for NMPs than for winter cover crops (9.48 lbs N/acre and .013 lbs P/acre), however there are more acres in NMP in the watershed than in winter cover crop.

Table 1. Number of acres of conservation practices and nutrient removal rates for the Upper Patuxent Watershed*.

Conservation Practices	Extent	Lbs N/ac	Lbs P/ac	Lbs N/yr	Lbs P/yr
Nutrient Management Plan Acres	1,586	3.11	0.3	4,932	476
Winter Cover Crop Acres	134	9.48	0.13	1,270	17
SCWQ Plan Acres	1,430	0.93	0.14	1,330	200
			Total Nutrient Removal	**7,533**	**693**

Winter Cover Crop is acres paid by MACS program 2006-07.
Nutrient Management acres are calculated from county % implementation Dec. 2006.
Soil Conservation Water Quality Plan acres are 90% of acres listed in 2007 MOU to account for expiration of 10 yr old plans.
* Data provided in table by MDA via email.

Anne Arundel County Soil Conservation District (SCD)

The SCD maintains information on farming activities at the local scale including maps of current farm locations, active BMPs and conservation practices and nutrient management. The following data was requested from the SCD:

- A marked-up land use map identifying current farmland in the Upper Patuxent Watershed.
- Information on Code 378 Farm Ponds including a GIS map showing their locations.
- Information on farming practices within the watershed including crop rotation, fertilizer application and the amount of manure produced and applied within the watershed.

The County SCD was not able to provide data on farmlands or Code 378 Ponds within the Upper Patuxent River Watershed due to privacy laws. Due to similar laws preserving the confidentiality of farmers' activities, information on nutrient applications and production on the farm-level could not be obtained.

The information that was obtained from the County SCD is summarized in Table 2 and includes the total acreage of corn, soybean, wheat and pasture within the wathershed. While the amount of manure produced could not be obtained, the 'manure applied', as shown on the table, likely came from horses within the county, as a majority of the animal operations within the watershed are horse farms. Personal communications via email and phone calls with SCD and MDA staff also confirmed that very little manure is transported into the watershed for application to agricultural land so it is likely that the amount of manure applied is that which is produced within the watershed. Nutrient application rates were not provided by MDA for this study (in lbs/acre/yr). Nutrient application rates in Table 2 obtained from the South River Watershed Agricultural BMP task (provided by the County) were used to estimate the amount of each nutrient applied (lbs/yr). The South River Watershed is adjacent to the Upper Patuxent and it is assumed that application rates would be similar. The calculations indicate that the greatest amount of nutrient application occurs during the production of corn, accounting for 83% of total N and 90% of total P applied within the watershed per year.

Table 2. Summary of nutrient application in the Upper Patuxent River Watershed

		N*		P*		K*	
		lbs/yr	lbs/acre/yr	lbs/yr	lbs/acre/yr	lbs/yr	lbs/acre/yr
# of Operators	67						
Corn Acres (acres)	2,715	355,665	131	103,170	38	233,490	86
Soybean Acres (acres)	3,427	17,135	5	10,281	3	174,777	51
Wheat Acres (acres)	946	51,084	54	0	0	10,406	11
Pasture Acres (acres)	2,300	-	-	-	-	-	-
Other Acres	253	-	-	-	-	-	-
Tons of Manure Applied	8,432	-	-	-	-	-	-

*Nutrient application rates were obtained from the South River Watershed Agricultural BMP memo (Table 2) provided by the County, as this data could not be obtained through the agencies listed above. The total applications in lbs/yr were calculated from these rates. Dashes indicate no available data.

Windshield Survey

The County's landcover shapefile identifies the agricultural land in the Upper Patuxent River Watershed as either Pasture/Hay or Row Crop. In the absence of site-specific data on farming practices within the Upper Patuxent River Watershed, a windshield survey was conducted on October 22, 2007, to identify farming and conservation practices at the site-specific level. The landcover shapfile, watershed shapefile, and digital orthophotos provided by the County were overlain in GIS, and the landcover polygons in the landcover layer identified as Pasture/Hay and Row Crop were called out and highlighted. Hardcopy maps of each subwatershed were made from the overlay and taken into the field for the survey.

Where access was possible by public road, farms identified on the maps were verified as active farms in the field, or noted otherwise if the farmland was fallow. Many agricultural crops had already been harvested prior to the windshield survey, and it was therefore difficult to identify crop type in many cases. If it could be determined, the crop grown was documented and it was noted if a cover crop was visible. Multi-cropping practices within a landuse polygon were noted, when observed. In some cases, it was possible to identify if the land was under till or no-till operations. Conservation practices other than cover crops were not identified. It was not possible to access all of the farms labeled as Row Crop or Pasture/Hay within the subwatersheds and therefore several agricultural lands do not have updated information and are left with these pre-existing identifiers.

Data Processing

GIS Agricultural Layer Development

A dataset of all farmlands with agricultural activity were identified in the landcover shapefile provided by the County and updated with information obtained from the windshield survey. The parcel data provided by the county was not used to amend the polygon layer due to the fact that site specific information concerning the practices planned on each parcel could not be obtained. Instead, the data processing was limited to attribute changes and GIS polygon boundaries were not modified to reflect parcel information. Four fields were added to the attribute table: 1) Field Survey, 2) Crop/Animal, 3) Conservation Practice, and 4) BMP. The available fields for each of these attributes are presented in Table 3. During this survey, the Crop/Animal field data that could be observed was Corn, Soybean, Hay, Fallow, Cows, Horses, Flowers, and Strawberries, or a combination of such if multi-cropping existed (shaded in Table 3). Under the Conservation Practices field, No Till and Cover Crop were observed and listed when identified in the field (also shaded in Table 3). If cows or horses were identified, the number of animals was recorded and placed in the data table in parenthesis. LimnoTech was not able to identify any BMPs in the field. Two large-scale maps have been included (Figures 1 and 2, respectively) depicting the existing SRC and PAS coverage provided by the county, and additional landcover information obtained from the windshield survey, respectively.

Table 3. Available fields for attributes identified during the windshield survey

WMT master list of Crop/Animal Farm Activities, Conservation Practices, and BMPs		
Crop/Animal	**Conservation Practices**	**BMPs**
Corn	Strip Cropping	Grass Filter Strip
Fallow	No-Till	Grass Drainage Ditch
Garden	Contour Cropping	Pond
Strawberries	Cover Crop	Possible Manure Storage
Horse Farm	Rotation	Wooded Buffer
Open Space	Nutrient Management	Multi BMPs (List)
Pasture/Hay	Multi Practice (List)	
Row Crops		
Soybean		
Sod		
Wildlife		
Flowers		
Vegetables		

Summary of Data and Conclusions

Data obtained from the SCD and windshield survey results confirm that corn and soybean production account for the majority of the farming practices in the watershed. Pastureland for horses is the next most abundant farming practice in terms of total acreage. From the aggregated data provided by MDA, nutrient removal rates from conservation practices can be estimated for the Upper Patuxent River Watershed. A majority of the nutrient removal comes from the high number of acres in a NMP while the highest potential removal rates occur with winter cover crop implementation. There were no BMPs identified in the watershed in either the data received or during the windshield survey. The landuse map (shapefile), revised with the results of the windshield survey is provided electronically as part of the Subtask 2.3 deliverable.

Because site-specific data on where specific crops were grown was not made available, this document does not summarize total acreages of the various crops identified from the windshield survey, nor does it provide statistics on conservation practices, as very few conservation practices could be identified in the field. In total, MDA estimated 9,388 acres of farmland including row crops and pasture and hay while the landcover shapefile identified 3,608 acres of farmland within the watershed. The discrepancy is likely due to the fact that MDA does not sort out farms that sow two crops in one year, so in many instances, acreage might be counted more than twice for multi-cropping scenarios.

A more detailed landcover layer is deemed unnecessary for watershed modeling purposes given the County’s use of single row crop (SRC) and pasture (PAS) annotation along with published total nitrogen (TN) and total phosphorus (TP) event mean concentration (EMC) values within the updated 2004 landcover layer. For example, while there is an EMC value for pasture, there is no modified EMC value that takes into account the number of animals counted on a farm. Similarly, while the modified landcover layer has ‘verified’ the type of crop grown on a particular field, EMC values currently employed are not distinguished by the type of crop present. Furthermore, EMC values are likely to be influenced by factors other than crop type such as soil type, slope, and tillage. In order to address this issue, site- and practice-specific EMC values would be more effective in determining TN and TP from a particular field and would also allow the modified landcover layer to be utilized more effectively.

Data necessary to produce the primary deliverables described earlier in the memo could not be obtained in full due to confidentiality agreements regarding the information related to the details of farming practices. Neither LimnoTech nor the County was able to obtain data on planned and implemented BMPs or site specific information on field location, ownership/easement type, or nutrient management plans from any of the state or federal agencies due to these privacy laws. Confidentiality agreements were also cited by the SCD when trying to identify farm ponds functioning as flood control.

The ‘incomplete’ dataset is useful to the County in conjunction with windshield surveys conducted to define cropping practices as best as possible where the information is translated into site and practice-specific EMC values. Updating the landuse layer for incorporation of more site-specific data into the water quality model will only be useful if the EMC values the County currently uses are tailored to account for the refined scale of the data. However, if the County chooses to retain the more general EMC values, the updated landuse layer will have little impact except for tracking where agricultural land has shifted to residential areas or vice-versa. In this case, validating and updating the layer is useful, but detailing the difference between types of row crops and practices would not contribute to the overall water quality model.

Appendix D
Rosgen Level II Geomorphic Analysis Report

- Rosgen Level II Geomorphic Report – Delivered April 8, 2008

ROSGEN LEVEL II GEOMORPHIC REPORT

Subtask 3.3
Upper Patuxent River Watershed Study

April 2008

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1.0 INTRODUCTION

LimnoTech and its subcontractor Biohabitats, Inc. (Biohabitats) are assisting the Anne Arundel County Department of Public Works with assessing stream health and current conditions in the Upper Patuxent River watershed. As part of this work, Rosgen Level II classifications were conducted for two perennial reaches in the watershed. This report provides a summary of the methods used and the existing conditions data for the two selected reaches within the Upper Patuxent River Watershed.

1.1 REACH SELECTION

Originally, as described in the project scope of work, the County requested an impaired reach be selected based on potential candidacy for future restoration and that the reference reach be selected to establish physical design parameters for restoration of the impaired reach. Reaches were considered for these two designations during field work associated with the separate watershed-wide physical habitat assessment data collection efforts performed earlier in the project.

During the course of the project it was determined there were a limited number of reaches that would be good candidates for restoration, both in terms of need and accessibility. Similarly, the character of these impaired reaches and the similarly limited number of potential reference reaches to choose from made it difficult to find comparable reaches. As such, the County revised the requirements for reach selection such that the reference reach and impaired reach were to be generally representative of reaches within the watershed in good and poor condition, respectively in terms of physical habitat condition. This eliminated the requirement that streams be comparable in character for design purposes.

The two reaches upon which the Rosgen II classifications were performed have been subjected to numerous anthropogenic impacts, including agricultural runoff, poor stormwater management practices, tree removal, channel modifications, and residential development. The incised channel within the impaired reach and the resilient channel that serves as a reference reach represent the diverse range of conditions within the Upper Patuxent River watershed and reflect a complex interplay between anthropogenic impacts and geomorphic setting. With this new understanding, the two reaches described below were selected by Anne Arundel County with input from Biohabitats and LimnoTech.

1.2 PROJECT LOCATION

The two reaches are located in Anne Arundel County near the town of Davidsonville. The impaired reach (UPJ038) originates along Harwood Road just east of the intersection with Ivy Way and is a tributary to Stocketts Run. The reference reach (UPD003) is located at Renditions golf course, just east of the third fairway and is the mainstem of Kings Branch (Figure 1.1). The contributing watersheds to the impaired and reference reaches are approximately 0.02 and 2.35 square miles respectively and drain primarily agricultural land uses, along with some residential development.

1.3 OTHER AVAILABLE ASSESSMENT DATA

Prior to the initiation of the Rosgen Level II classification task, LimnoTech and Biohabitats collected physical habitat assessment and other data throughout the watershed. These data are used as input parameters in the County's preservation and restoration assessment modeling. The following represents a summary of the data collected for the two reaches of interest (UPD003 and UPJ038). See Table 1.1 for a tabular summary.

The reference reach (UPD003) scored 95 out of 100 in the County's reach assessment for restoration modeling and placed in the "Good" category. The physical habitat assessment for the reference reach scored 87 out of 100 for the Final Habitat Score (FHS) using the Maryland Biological Stream Survey (MBSS) scoring system. The impaired reach (UPJ038) scored 72 points out of 100 in the County's modeling and categorized as borderline "Very Poor" to "Poor". The MBSS FHS for the reach was 49 out of 100.

Table 1.1 Summary of Collected Physical Habitat Assessment Data

Assessment Parameters	Reference Reach, (UPD003)	Impaired Reach (UPJ038)
Water Quality	Clear, no odor	Clear, no odor
Sediment Quality	No odor	No odor
Fish Presence	Many, small (1-2 inches)	None
Aquatic Plants	None	None
Algae Cover (Slime)	Light, brown	Light, red
Algae Cover (Filamentous)	Light, green	None
Algae Cover (Floating)	None	None
Bacteria Presence	None	Light, iron floc
Dominant Landuse	Forest	Forest
Dominant Riparian Vegetation	Trees	Trees
Riparian Vegetation Width (ft)	>50	>50
Instream Habitat Score (1-20)	19	8
Epifaunal Substrate Score (1-20)	15	8
Shading (1-10)	10	10
Woody Debris (pieces)	18	12
Left Bank Erosion Severity, Percent	Minor, 30%	Moderate, 40%
Right Bank Erosion Severity, Percent	Minor, 30%	Minor, 50%
Pools (1-10)	10	1
Canopy Cover (1-10)	10	10
Fish Cover (1-10)	10	2
Riffle Embeddedness (1-10)	10	3
Human Intervention (1-10)	9	8
Riparian Invasive Species (1-10)	7	9
Barriers to Fish Movement (1-10)	10	4
Terrestrial Habitat (1-10)	10	10
Insect/Invertebrate Habitat (1-10)	10	9
Deficient Buffers	0	0
Crossings	1 (1 minor)	1 (1 minor)
Ditch/Pipes	0	0
Dumpsites	0	1 (1 minor)
Excessive Erosion	0	0
Obstructions	1 (1 minor)	10 (10 minor)

Figure 1.1 Locations of Rosgen Level II Geomorphic Characterizations

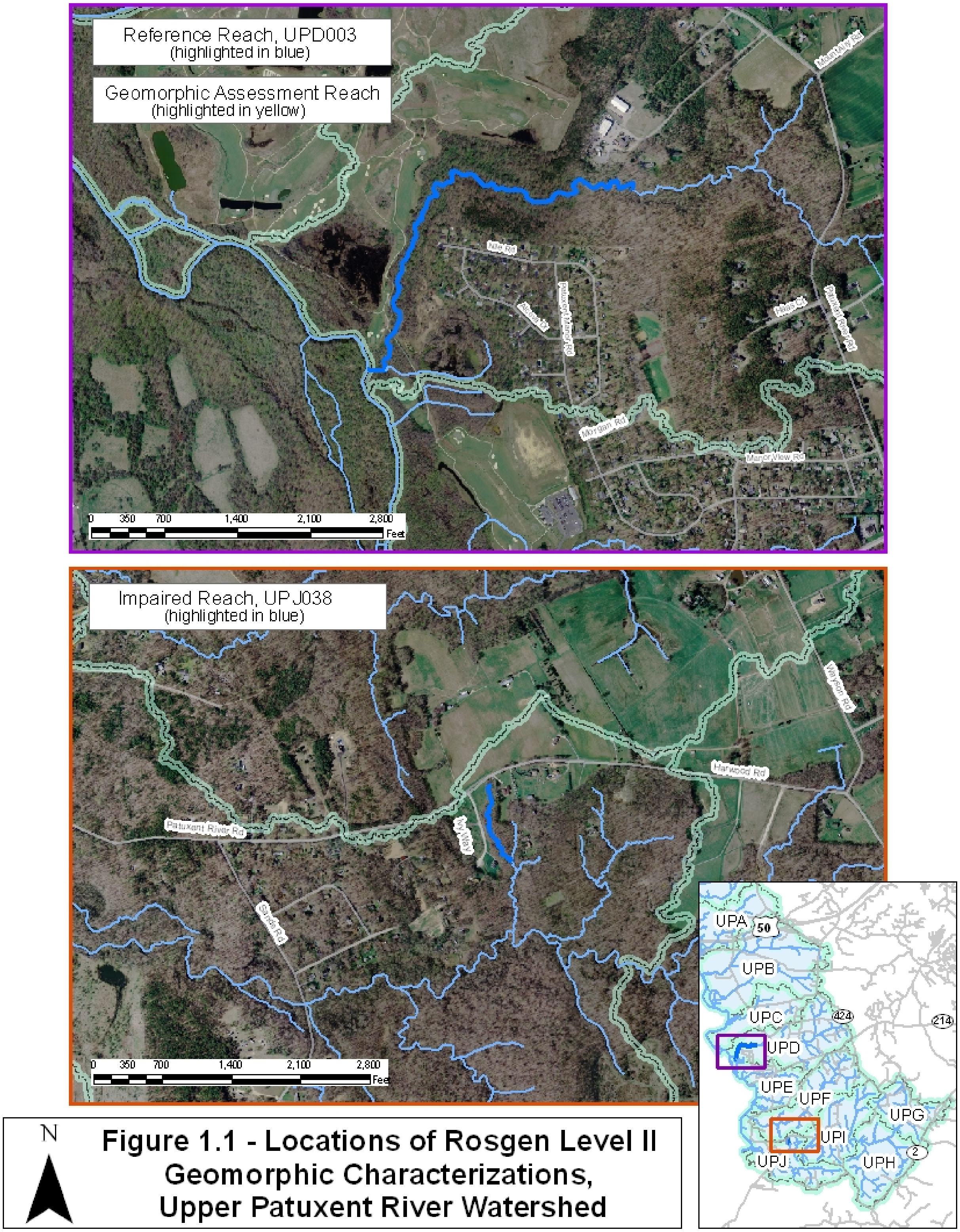


Figure 1.1 - Locations of Rosgen Level II Geomorphic Characterizations, Upper Patuxent River Watershed

2.0 METHODS

Conditions of the two reaches were documented through field investigation and review of aerial photography pertinent to the study area. This section outlines the methods used to collect the Rosgen II Classification data, perform the field survey, and analyze existing stream conditions.

2.1 DOCUMENT REVIEW

To document physical characteristics and anthropogenic impacts to the tributaries, Biohabitats evaluated maps and documents provided by the County specific to the Upper Patuxent River watershed including:

- Planimetric maps with stream lines and roadways
- 2004 2-foot topographic maps based on LIDAR
- 2005 6-inch orthophotographs

2.2 WATERSHED AND CHANNEL ASSESSMENT

The two reaches and immediate watershed were evaluated for several attributes including channel morphology, riparian vegetation, wetlands, and current land use. After review of topographic maps of the watersheds, a cursory investigation was conducted to verify the topography, stormwater routes, and land use.

Upon completion of the watershed survey, Biohabitats conducted a Rosgen Level II classification in accordance with the SHA's Baseline Study Field Methods dated February 17, 2005. The Baseline Study Field Methods protocol is based upon the Rosgen method of stream classification (Rosgen, 1994; Rosgen 1996; Rosgen reference reach field book). At each location, two cross sections, one riffle and one pool, were measured and a longitudinal profile was conducted that characterizes the geomorphic features. The following parameters were assessed:

- Flow regime
- Stream size/order
- Meander patterns
- Depositional features
- Stream channel debris blockages
- Riparian buffer composition
- Bank Erosion Hazard Index (BEHI)
- Total bank erosion calculation prediction
- Benchmarks
- Longitudinal curve

- Valley type
- Bankfull indicators
- Geometry data including measuring stream length, valley length, sinuosity, radius of curvature, belt width and meander wavelength
- Pebble count
- Survey cross sections including riffles and pool and/or run and glide
- Photo document each cross section and other strategic points

The measured data were collected and recorded using Pocket Rivermorph© on a Pocket PC for ease of data transfer. The longitudinal profile, cross sections, pebble counts, and BEHI were all recorded and collected through this method. Cross-sectional surveys were conducted using a stretched tape measure, survey rod, and site level. Cross sections were located to illustrate representative features of the channel based upon valley landforms, channel slope, and channel appearance. Riffle cross-sections were measured at representative crossover locations. These measurements included the stream invert, edge of water, maximum depth, bankfull depth, and floodprone level. Local channel slope at each cross section was measured using the survey rod and site level. The cross section locations were documented along the longitudinal profile and georeferenced. The surveyed cross sections were then marked in the field with labeled stakes and marked approximately on field topographic maps.

The team conducted pebble counts in each reach using the standard 100-particle Wolman pebble count procedure to characterize bed material and associated channel roughness (Wolman, 1954). The representative riffle versus pool transects models the ratio of riffle to pool through the evaluated reach. In addition to the above features, the location of culverts, storm drain outfalls, and sanitary sewers within each reach were noted on the field map. Other observations were made to document existing conditions, predict future channel changes, and to identify habitat features. These observations included channel modifications, debris dams, gravel bars, planform pattern, cross-sectional shape, eroding banks, and knick points.

2.3 RIPARIAN VEGETATION AND PRELIMINARY WETLAND ASSESSMENT

An assessment of the dominant and invasive riparian vegetation was conducted by dividing the forest into three layers: overstory, understory, and herbaceous species. The overstory vegetation included the largest trees that dominated the canopy. The understory included smaller species of trees and young specimens of overstory trees and shrubs. The herbaceous layer included all non-woody perennial and annual plants occupying the layer nearest the forest floor. Due to the season of the assessment (late December), it is likely that not all of the herbaceous plants existing within the study area were apparent and identifiable. The dominant species within each layer were identified, as well as forest development stage and recent disruptions. The general abundance of each species was qualitatively recorded by stream reach.

A preliminary wetland investigation was performed during the vegetation assessment. This survey identified possible wetland areas adjacent to the two reaches and is to be used only as additional insight for the review of the existing conditions. Wetland indicators included the identification of wetland vegetation and obvious signs of hydrology, such as buttressed/exposed tree roots and pools or standing water. The Army Corps of Engineers did not verify the investigation. A Jurisdictional Wetland delineation must be performed as a part of any restoration opportunity.

2.4 DATA ANALYSIS

All data and observations were recorded in the field within Pocket Rivermorph, on field data sheets, and on the field maps. The data was then exported to Rivermorph, a program that was developed in accordance with the Rosgen assessment and classification protocols. Rivermorph then allows the user to calculate numerous parameters including the following items that were calculated or determined from cross sections, profiles, and the field assessment:

- Bankfull cross-sectional area
- Bankfull water surface slope
- Bankfull discharge (using various methods and plotted for comparison)
- Bankfull velocity
- Bankfull mean depth
- Bankfull width/depth
- Bankfull wetted perimeter
- Bankfull hydraulic radius
- Floodprone width
- Entrenchment ratio
- Channel slope
- Median grain size (D50)
- D84 grain size
- Pfankuch stability rating
- Erosion rates from BEHI
- Mean radius of curvature
- Mean belt width
- Mean meander wavelength

These resulting morphologic values were summarized and interpreted to determine stream conditions, and helped to establish the bankfull discharge value for the streams.

2.5 CALCULATION OF BANKFULL AND PEAK DISCHARGES

"The bankfull stage corresponds to the discharge at which channel maintenance is the most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphologic characteristics of channels." *–Dunne and Leopold (1978)*

The calculation of a bankfull discharge provides an important technical basis for the assessment of the two reaches. The basis for the bankfull discharge is outlined below, followed by a description of the various methods used to estimate bankfull discharge.

In adjustable, alluvial, transport-limited rivers in temperate climates, flows of moderate frequency (e.g., the 1.5- to 2-year storm event) and magnitude perform most of the geomorphic work (Wolman and Miller, 1960). This concept of the "dominant discharge" provides a statistical index for the flow that corresponds with the peak volume of sediment transported. Dominant discharge is the maximum possible product, therefore, of the frequency of a flow occurrence and the amount of sediment transported by that flow event. Channel morphology is ultimately a result of all flows above a sediment transport threshold that do some geomorphic work. However, the dominant discharge is commonly used as a single-value estimate for a flow that may be largely responsible for resulting geomorphic form.

It is thought that, in many cases, the morphological feature of a bankfull elevation corresponds fairly well to the flow stage of the dominant discharge. This has led to the concept of bankfull elevation as a tool in stream restoration design. However, the concept should be applied cautiously in stream restoration design. It should be noted that as channel boundaries are more resistant or less adjustable (i.e., bedrock, hill slope constraints, or large bed material) or in more arid environments, the majority of geomorphic work is more likely to be performed by larger and less frequent flood events.

Bankfull elevations were identified in the field by Biohabitats personnel at each of the two reaches. The bankfull elevation at each cross section was derived from all available indications including depositional features, changes in bank angle, vegetation, scour lines, and storm debris lines. Bankfull discharge was estimated using the Cowan method to determine Manning's n and was then compared to the discharge calculated through several other methodologies and regional regressions.

2.6 STREAM CLASSIFICATION

Physical channel conditions were assessed using the procedures and methodologies for fluvial geomorphologic analysis as outlined in "A Classification of Natural Rivers" (Rosgen, 1994). As part of the field reconnaissance, the Rosgen classification system was used to categorize the stream channels into major, natural channel types. These channel types are determined on the basis of existing morphological features of the stream channels and valley. Key parameters and channel types used in the Rosgen classification system are presented in Table 2.1.

Table 2.1 Rosgen Stream Classification Parameters*

Channel Type	Entrenchment Ratio	Width/Depth Ratio	Sinuosity	Channel Gradient
A	< 1.4	< 12	Low (< 1.2)	4 to 10%
B	1.4 to 2.2	> 12	Moderate (> 1.2)	2 to 4%
C	> 2.2	> 12	Moderate to High (> 1.2)	< 2%
D	N/A	> 40	Very Low (<<1.2)	< 2%
E	> 2.2	< 12	High (> 1.5)	< 2%
F	< 1.4	> 12	Moderate (> 1.2)	< 2%
G	< 1.4	< 12	Moderate (> 1.2)	2 to 4%

*Adapted from Rosgen, 1994 and Rosgen, 1996.

Each major stream type identified in the field was further classified based upon the median particle size of the bed material. Numbers 1 through 6 correspond to different sediment size ranges as follows:

1 - Bedrock
2 - Boulder
3 - Cobble
4 - Gravel
5 - Sand
6 - Silt

Field measurements taken at each cross section were then compared with the parameters in the Rosgen classification system to determine channel types. The Rosgen classification system generally applies to channels that are in a state of "dynamic equilibrium" and generally stable. It should be noted that the impaired reach (UPJ038) is actively adjusting, as evidenced by severely eroding banks and downcutting. Identification of bankfull, therefore, was extremely difficult throughout the impaired reach (UPJ038).

3.0 EXISTING CONDITIONS

This section contains the results of the assessment of existing channel conditions, forest composition, and wetlands. Appendix A contains the study area photographs for both reaches. Impaired reach (UPJ038) field data and Rivermorph data are provided in Appendices B and C, respectively. Reference reach (UPD003) field data and Rivermorph data are provided in Appendices D and E, respectively. Electronic Rivermorph files, as well as a digital spreadsheet file of the fieldwork in the Mecklenberg format are also provided with this report.

3.1 PHYSIOGRAPHY, TOPOGRAPHY, AND GEOLOGY

Maryland is comprised of six physiographic provinces that extend in varying widths across the state in a northeasterly direction. Physiographic provinces, distinctive according to their geologic environments, play an important role in stream classification because the underlying geology influences the size and shape of watersheds. Underlying geology also affects the slope and shape of stream channels.

Anne Arundel County, Maryland lies completely within the Coastal Plain province. The study area associated with the two reaches lies within this province. The Coastal Plain is characterized by narrow stream divides, incised streams, and unconsolidated sands, silts, and clays (Woods et al. 1999).

3.2 SOILS

The watersheds of the two reaches contain soils belonging to the Collington/Wist/Westphalia, Widewater/Issue, Galestown, and Marr/Dodon series soils (USDA, 2008). The Collington/Wist/Westphalia, Widewater/Issue, and Galestown soils are located along the reference reach (UPD003), while the Marr/Dodon soils are located solely at the impaired reach (UPJ038). Descriptions of the individual soil series are as follows.

Collington/Wist/Westphalia (CSE)
These soils are typically found in ravines and divides and can be found along the side slopes leading from the upper terrace down to the floodplain along the reference reach (UPD003). The parent materials are loamy fluviomarine sediments which bear Glauconite. These soils are well drained with a moderate to high available water capacity. The limiting capacity for these soils is the potential for high flood events. The depth to the water table is generally 40 to 80 inches. The Collington/Wist/Westphalia soils are in the B hydrologic soil group.

Widewater/Issue (WBA)
These soils are found in the floodplain along the reference reach (UPD003) and can also be found throughout the area. The parent materials are loamy alluvium and consist of silt loams in the upper layers of soil, transitioning to loam and then fine sandy loam. The available water capacity ranges from high to low and the depth to the water table is from 0 to 20 inches. These soils are poorly to somewhat poorly drained and are frequently flooded. These soils are in the C hydrologic soil group.

Galestown loamy sand (GAB)
Galestown soils consist of very sandy soils that have a dark yellowish brown surface layer and a strong brown subsoil. These somewhat excessively drained soils have a very low available water capacity. Slopes of Galestown soils generally range from 0 to 5 percent and are located on divides and terraces within the coastal plain. They formed from eolian deposits and/or fluviomarine sediments. Galestown soils are in the A hydrologic soil group.

Marr and Dodon silt loam (MDE)
The Marr component makes up 45 percent of the map unit. Marr soils are typically on knolls and uplands. The parent material consists of loamy fluviomarine deposits with a root restriction depth of greater than 60 inches. The soil is well drained with a low shrink swell potential. This soil is not flooded, nor is it ponded. There is no zone of water saturation within a depth of 72 inches and the organic matter content in the surface horizon is about 4 percent. This soil does not meet hydric criteria and is in the B hydrologic soil group.

The Dodon component makes up 40 percent of the map unit. This component is on coastal plains, marine terraces and is made up of parent material which consists of loamy marine deposits of Miocene age containing diatomaceous earth. The depth to a root restrictive layer is greater than 60 inches and the soil is moderately well drained. Shrink-swell potential is low and the soil is not flooded or ponded. A seasonal zone of water saturation is at 24 inches during February and the organic matter content in the surface horizon is about 2 percent. This soil does not meet hydric criteria and is in the B hydrologic soil group.

3.3 HISTORIC LAND USE CHANGES

The tributary system has been indirectly affected by cumulative impacts that have occurred within the watershed throughout the last three centuries. Historical land use changes specific to the impaired and reference reaches are unknown. However, it is likely these reaches were subjected to regional influences in the historical past as recounted by Jacobsen and Coleman (1986). Prior to European settlement in about 1730, the stream was probably relatively undisturbed and in a regime relationship (generally stable). As settlement continued and agricultural land use accelerated, more sediment was supplied to streams. In addition, runoff moderately increased in response to altered land cover and drainage methods. These anthropogenic changes ultimately led to the deposition of thick, fine overbank and lateral sediment in the period 1730 to approximately 1930. In the post-1930 era, farm abandonment and introduction of soil conservation techniques slightly decreased overland run-off and substantially decreased sediment yield to streams. Jacobsen and Coleman point to stratigraphic evidence showing that streams accommodated these changes by altering the floodplain formation process to one of lateral accretion of sand and gravel while removing a larger volume of fine sediments from floodplain storage. Channel adjustments to these historical landscape changes included progressive channel deepening, as well as widening. These regional observations are consistent with stream morphology evident today along the impaired reach (UPJ038). In the absence of historical cross sections, photographs or other records, the causative relationship cannot be established and the rate and magnitude of change is unknown.

3.4 WATERSHED ASSESSMENT

Land use within the reference reach (UPD003) consists of a variety of uses ranging from open space to commercial development. The drainage area is approximately 10% impervious with the most dominant land use being residential development, which accounts for approximately 37% of the watershed. Approximately 30% of the drainage area is forested.

The dominant land use in the impaired reach (UPJ038) drainage area is pasture/hay, which accounts for 43% of the total watershed. Impervious surfaces account for approximately 10%. The next most dominant land use is residential development, which accounts for approximately 35% of the watershed. See Table 3.1 for a further breakdown of land uses for both reaches.

Table 3.1 Drainage Area Land Use

Land Use	UPD003 (acres)	UPD003 (% cover)	UPJ038 (acres)	UPJ038 (% cover)
Commercial	29.19	2.0%	-	-
Industrial	0.97	0.1%	-	-
Residential	550.19	36.5%	4.57	34.5%
Pasture/Hay	81.43	5.4%	5.66	42.7%
Row Crops	205.74	13.7%	-	-
Transportation	37.69	2.5%	1.49	11.2%
Open Space	151.08	10.0%	-	-
Woods	449.13	29.8%	1.55	11.7%
Water	1.54	0.1%	-	-
TOTAL	**1,506.97**	**100.0%**	**13.26**	**100.0%**
Impervious	*143.19*	9.5%	*1.41*	10.6%
Pervious	*1,363.78*	90.5%	*11.85*	89.4%

Initially the land use percentages may not indicate that UPD003 would be a likely candidate for use as a reference reach, nor that UPJ038 would be impaired, but when their geomorphic setting within the watershed is considered, some key factors in their physical differences become apparent. UPJ038 is a first-order tributary and relatively steep, thereby making it a source of sediment to the downstream watershed. In contrast, UPD003 is a higher order stream that has greater ability to store sediment and laterally and vertically adjust to incoming sediment loads. Additionally, the forest cover within the watershed above UPD003 is located primarily along the stream corridor, which provides a substantial buffer to the potential impact from the remaining land uses. In contrast, UPJ038 contains a smaller proportion of forested land, much of which does not serve as a sufficient buffer for the stream.

The contribution of impervious surface is similar between the two watersheds, which would eliminate impervious cover as a distinguishing factor between the two if it were not for the proximity of the impervious surfaces to the stream. The reference reach (UPD003) is located further away from negative upstream influences such as residential and commercial development and the associated impervious surfaces. This extended length provides a buffering capacity, which allows velocities to diminish as well as provide groundwater recharge and vegetative uptake. The impaired reach (UPJ038) begins at a culvert outfall from underneath Harwood Road. The proximity of the road and its uncontrolled runoff would presumably lead to a shorter time of concentration and flashier storm events as compared to UPD003.

As described in Section 1.3 of this report, a full watershed assessment was conducted during the course of this project. For further information please refer to the GIS deliverables provided from Subtasks 3.1 and 3.2.

3.5 RIPARIAN VEGETATION AND PRELIMINARY WETLAND ASSESSMENT

The riparian zone along both banks of the impaired reach (UPJ038) is mostly forested from the upstream road culvert outfall to the downstream extent of the reach; however, it is significantly narrower at the upstream end of the reach. The overstory forest composition is consistent throughout the project study area, as are the understory and herbaceous layers. The overstory layer is dominated by trees greater than 24" diameter at breast height such as American beech (*Fagus grandifolia*) and tulip poplar (*Liriodendron tulipifera*). This forest appears to be a mid-successional forest with evidence of regeneration and an overall healthy condition.

The riparian buffer in the impaired reach (UPJ038) is forested and is approximately 20 feet in width at the start of the reach and expands perpendicular to the stream in a downstream direction to approximately 100 feet on the right bank and greater than 200 on the left bank. Invasive species can be found at the margins of the forest.

The understory layer within the impaired reach (UPJ038) is dominated by black gum (*Nyssa sylvatica*), and juvenile beech. The diversity of the forest composition is limited, possibly due to the pioneering nature of the tulip poplars, but also due to the light-limiting nature of the American beech. Species tolerant of low light conditions such as strawberry bush (*Euonymus americana*) and several species of orchid (*Orchidaceae spp*) are found within the understory in limited quantities.

The dominant herbaceous species are Christmas fern (*Polystichium acrostichoides*) and moss (S*phagnum spp*). Due to the time of year the assessment was conducted, the species within the herbaceous layer were difficult to identify. Deer (*Odocoileus virgnianus*) browse does not appear to be of significance within this reach, whereas the downstream portions of this tributary near the confluence with Stocketts Run seem to be hampered by herbivory.

Table 3.2 Impaired Reach Vegetation

Common Name	Scientific Name	Dominant Species
Overstory Species Present		
Tulip poplar	*Lirodendron tulipifera*	√
American beech	*Fagus grandifolia*	√
Mixed Oak	*Quercus spp*	
Sweet Gum	*Liquidambar styraciflua*	
Red Maple	*Acer rubrum*	
Understory Species Present		
American beech	*Fagus grandifolia*	√
Black gum	*Nyssa sylvatica*	√
American holly	*Ilex opaca*	
Flowering dogwood	*Cornus florida*	
Red cedar	*Juniperus virginiana*	
Strawberry bush	*Euonymus americana*	
Herbaceous Species Present		
Moss	*Sphagnum spp*	√
Christmas fern	*Polystichium acrostichoides*	√
Japanese honeysuckle	*Lonicera japonica*	
Greenbrier	*Smilax spp*	√
Various orchids	*Orchidaceae spp*	

The steep erosive banks of the impaired reach (UPJ038) have led to the loss of numerous trees over the years. The excessive slopes, which are highly erodible, are not colonized well by vegetation and are therefore subject to continual losses until the stream bed and banks become stabilized.

The riparian zone along the reference reach (UPD003) is forested throughout the length of the reach and continues upstream and downstream of the reach for a significant distance. The forest structure is consistent throughout with well developed overstory and understory structure. The herbaceous layer is limited due to the forest canopy cover and does contain invasive species.

The width of the riparian forest is consistent along the length of the reach, approximately 50 feet along the right bank and nearly 200 feet along the left bank. Within the floodplain along the left bank, numerous pocket wetlands can be found with evidence of skunk cabbage (*Symplocarpus foetidus*). The forest along the reference reach (UPD003) can be classified as a mid-late successional forest with an overall healthy condition. In addition, the forest ecosystem is intermittently supplying woody debris to the stream channel, which is providing a diversity of habitat features to the local vertebrates and invertebrates.

Table 3.3 Reference Reach Vegetation

Common Name	Scientific Name	Dominant Species
Overstory Species Present		
Tulip poplar	*Liriodendron tulipifera*	√ √
Red maple	*Acer rubrum*	
American beech	*Fagus grandifolia*	
Mixed Oak	*Quercus spp*	
Sycamore	*Platanus occidentalis*	
Understory Species Present		
Spicebush	*Lindera benzoin*	√
Greenbrier	*Smilax spp*	√
Winterberry	*Ilex verticillata*	
Ironwood	*Carpinus caroliniana*	
Black gum	*Nyssa sylvatica*	
Paw paw	*Assimina triloba*	
Flowering dogwood	*Cornus florida*	
Herbaceous Species Present		
Stilt grass	*Microstegium vimineum*	√
Moss	*Sphagnum spp*	√
Christmas fern	*Polystichium acrostichoides*	
Japanese honeysuckle	*Lonicera japonica*	
Wild onion	*Allium canadense*	
Various grasses	*Poa spp*	√

The understory layer of the reference reach (UPD003) is well developed with shrub species and not dominated by juvenile tree species. Spicebush (*Lindera benzoin*), winter berry (*Ilex verticillata*), ironwood (Carpinus caroliniana) and paw paw (*Assimina triloba*) dominate with Christmas fern, various grasses (*Poa spp*) and sphagnum moss in the herbaceous layer. The presence of paw paw is an indicator of a healthy forest community as is the diversity of species within this forest. There seems to be an herbivory component to this forest; however, it is not significant. There is an invasive presence in the forest in the form of stilt grass (*Microstegium vimineum*) and greenbrier (*Smilax spp*). These species currently are not dominant within the forest; however, the potential for the stilt grass to dominate the herbaceous layer does exist. There is a human component within this forest in the form of an all terrain vehicle (ATV) trail that cuts through the floodplain along the left bank. The presence of this ATV trail could have serious effects on the local vegetation and the stream itself if the use of the trail increases.

3.6 CHANNEL ASSESSMENT

The conditions of the stream reaches are described in this section, and summaries are provided in Table 3.4. Photographs of typical reach cross sections are included (Appendix A). Appendices B and C contain the collected field data and Rivermorph calculations, respectively, for the impaired reach (UPJ038), while Appendices D and E provide the same information on the reference reach (UPD003). Graphic representations of riffle cross sections for each reach are presented as Figures 3.1 and 3.2. In addition, electronic data is provided for each reach in multiple formats and is included with this report.

In the incised condition, along the impaired reach (UPJ038), the flood flows conveyed through the mainstem do not overflow into rough flood plain areas that reduce flow velocities. In addition, the constrained width of the channel during flows exceeding bankfull causes water depths to be greater than if the flow were able to laterally expand. This increases the potential for erosion of the channel bottom and toe of the bank slope, promoting further instability.

Impaired Reach (UPJ038)

The impaired reach begins at a road culvert underneath of Harwood Road and extends approximately 900 feet downstream. Located along the impaired reach (UPJ038) is a small ephemeral tributary, which like the impaired reach is highly incised. Both channels are also distinguished by extreme headcutting and massive bank failures.

Typical View of the Impaired Reach

Within the surveyed profile along the mainstem, 20 headcuts were observed, ranging in height from 0.25 to 12 feet. The sinuosity of the reach is 1.12. Over the surveyed reach length of 900 feet the overall drop of the stream is nearly 47 feet resulting in an average gradient of 5.2% with bank heights averaging over 15 feet. A local slope of 2.7% was utilized for the determination of the discharge, because it hydraulically controls discharge in this steep setting. The discharge based upon the Cowan methodology was estimated to be 18.7 cubic feet per second (cfs). This result is higher than the predicted discharge of 2.8 cfs utilizing the 2007 US Fish and Wildlife Service regression. However, since the drainage area is an order of magnitude less than the smallest drainage area used to develop the regression, the applicability of the regression is questionable. The estimate of 18.7 cfs is similar to the 14 cfs discharge value obtained for the 2-year discharge as provided by Anne Arundel County's TR-20 calculations. Bankfull discharge values determined using the Colebrook-White variant equations (i.e., Leopold Wolman Miller and Hey 1979), and both Limerinos and Jarrett's equations were considerably higher than that calculated via the Cowan method. This is primarily attributed to limitations in the applicability of these methods to streams having characteristics similar to those used to develop the expressions. See Table 3.5 for a list of the methods used to estimate bankfull and their associated discharges. In addition, Appendix F contains comparisons of the estimated discharge with local regional regressions.

The dominant material of both the bed and banks of the stream is sand. The Rosgen Classification of the stream is that of an A5 stream type, indicative of the very steep and sandy nature of the stream. The conditions of the tributary are very similar with extremely large slopes and bank heights. Whereas the upstream elevation of the main tributary is held by a culvert outfall, the upstream end of the tributary is actively headcutting into the forested terrace. The extremely high banks of the impaired reach (UPJ038) are sparsely vegetated in some areas. It appears as though mass wasting is occurring on a regular basis, driven in large part by both seepage erosion, overland flow and tree topple. A BEHI survey was conducted to predict the potential sediment input to the stream and it was determined that approximately 1619.5 cubic yards of material may be entering the stream on an annual basis. In addition, the upper portions of the stream have been utilized by adjacent homeowners as a brush repository, and there is a considerable amount of trash as well. There were no utilities discovered during field assessment.

Reference Reach (UPD003)
The reference reach is located along the mainstem of Kings Branch within Renditions golf course. The reach flows parallel to the third fairway and has maintained a well developed floodplain. The floodplain throughout the area contains pocket wetlands (vernal pools). The reach starts near where Kings Branch makes a sharp, 90 degree turn to the left and extends downstream approximately 500 feet. The stream is stable through this reach and has an abundance of woody debris and excellent riffle/pool habitat. The reach is characterized by stable riffles and banks and well developed point bars. The rooting depth of most of the riparian vegetation extends to the water surface elevation which creates ideal conditions for the uptake of nutrients, bank stability and habitat. Numerous fish were noted during field assessment efforts. The immediate land use surrounding the reach is dominated by agricultural use with a fair amount of residential development. Forested areas can be found primarily along the stream corridor itself.

The sinuosity of the reach is 1.2 and the overall drop of the stream is only 2 feet. The overall slope of the stream is 0.4% with bank heights averaging 2.5 feet. The local slope utilized for the determination of the discharge is 0.33%. The discharge based upon the Cowan methodology was estimated to be 132.0 cubic feet per second (cfs). This result is very similar to the predicted discharge of 141 cfs utilizing Anne Arundel County's TR20 model, but much larger than the 47.2 cfs discharge value obtained for the 2-year discharge via the 2007 US Fish and Wildlife Service regression. While the computed method for discharge and bankfull width fall within the 95% prediction interval based upon the regional curve, the cross-sectional area of 52.9 square feet (sf) and bankfull mean depth of 2.28 feet are slightly higher than the 95% prediction interval. These results show that while the data appears to be higher than the predicted value based upon the USFWS regression, they are all within close proximity to the 95% prediction interval, showing a degree of precision. As before, bankfull discharge values determined using the Colebrook-White variant equations (i.e., Leopold Wolman Miller and Hey 1979), and both Limerinos and Jarrett's equations were considerably higher than that calculated via the Cowan method. See Table 3.5 for a list of the methodologies used to estimate bankfull and their associated discharges. In

Typical View of the Reference Reach

addition, Appendix F contains comparisons of the estimated discharge with local regional regressions.

The dominant material of both the bed and banks of the stream is a mixture of gravel and sand. The low banks of the reference reach allow frequent out of bank flooding. Small areas of erosion can be found within the reach, and a BEHI survey was conducted to predict the potential sediment input to the stream. It was determined that approximately 31.7 cubic yards of material may be entering the stream on an annual basis which is characteristic of a reference reach that is in an apparent state of equilibrium with the local flow regime. Although we did not expect to encounter a stable reference reach in such a highly utilized watershed adjacent to a golf course, all the data collected indicate that the selected reach is a stable and viable reference.

Table 3.4 Stream Reach Characteristics

Reach	Location	Conditions/Constraints
Impaired (UPJ038)	Harwood Road near Ivy Way.	• Entrenchment ratio = 1.4 • Drainage area = 0.02 square miles • Substrate (D50 = 0.2 mm) • Overall Slope = 0.052 ft/ft • Sinuosity = 1.1 • Width/Depth Ratio = 7.0 ft/ft • Stability Rating = 114 • Cross sectional area = 5.3 sq ft • Velocity = 3.5 ft/s • Bankfull Discharge = 18.7 cfs • Stream type = A5
Reference (UPD003)	Renditions golf course, parallel to the third fairway.	• Entrenchment ratio = 10.1 • Drainage Area = 2.35 square miles • Substrate (D50 = 7.23 mm) • Overall Slope = 0.004 ft/ft • Sinuosity = 1.2 • Width/Depth Ratio = 10.2 ft/ft • Stability Rating = 81 • Cross sectional area = 52.9 sq ft • Velocity = 2.5 ft/s • Bankfull Discharge = 132.0 cfs • Stream type = C4

Table 3.5 Comparison of Discharge Results

Methods		UPD003 Discharge (cfs)	UPJ038 Discharge (cfs)
Darcy Weisbach	Leopold Wolman Miller	311.3	68.2
	Hey 1979	320.0	70.1
	U/U*	291.7	61.5
Mannings Equations	Limerinos	249.0	51.9
	Jarrett's Equation	193.1	10.6
	Known n	126.6	18.4
	Cowan n	**132.0**	**18.7**
TR 20*	1 year	82	8
	2 year	141	14
Regression	USFWS 2007	47.2	2.8

Figure 3.1 Impaired Reach (UPJ038) Riffle Cross Section

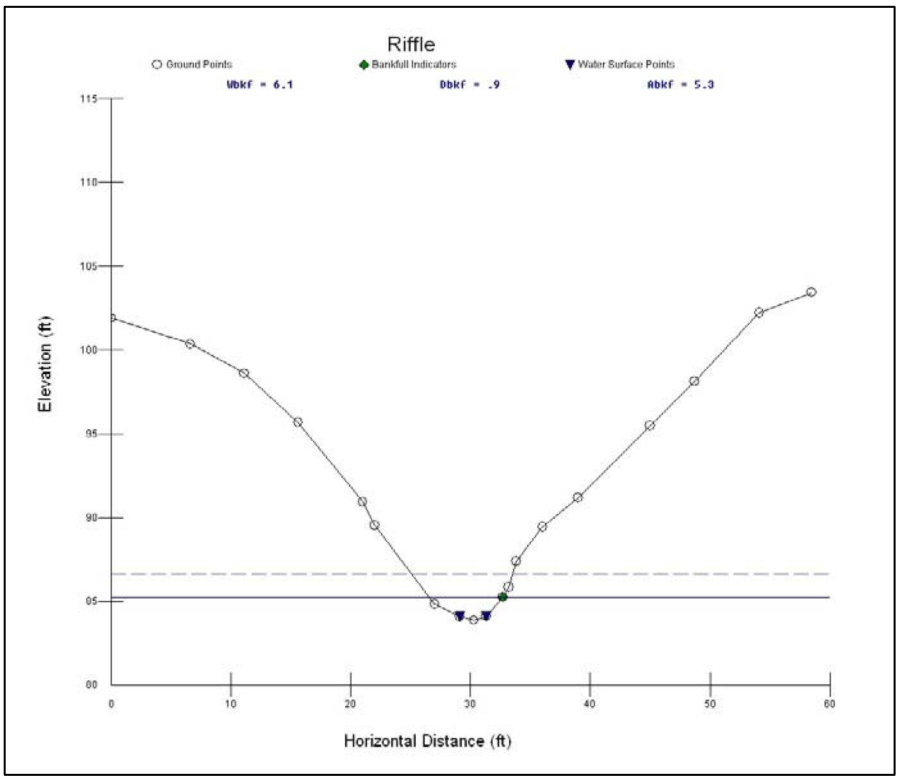
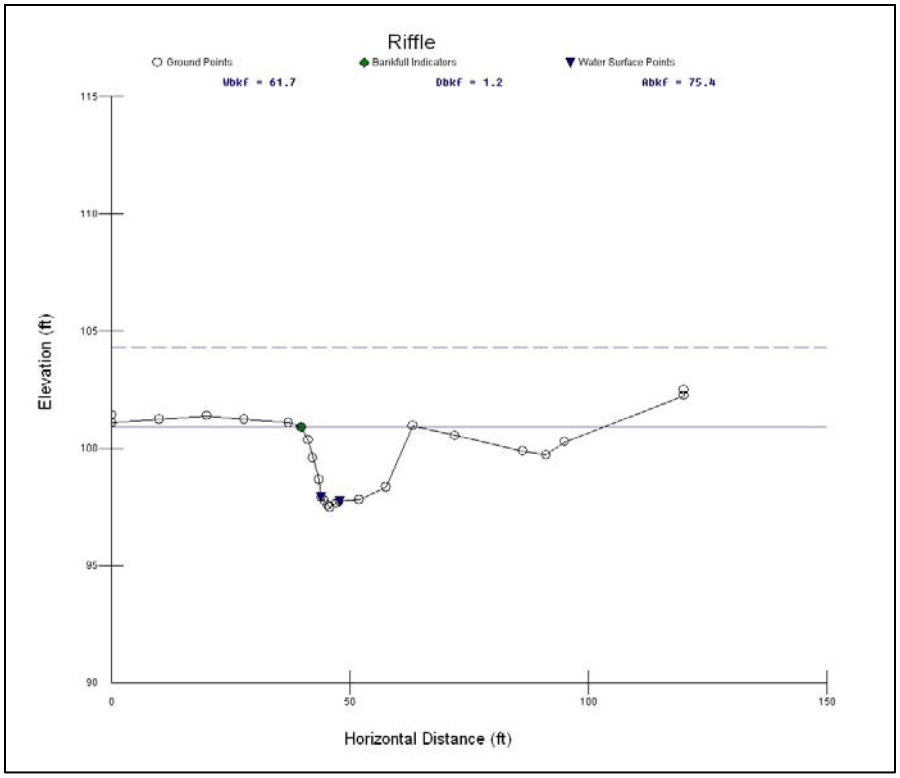


Figure 3.2 Reference Reach (UPD003) Riffle Cross Section



Further Studies
In addition to the data collected during the field assessment, it may be necessary in the future to collect additional data for permitting purposes or to gather preconstruction data to monitor the effectiveness of restoration efforts. In the event that restoration is to be performed on the impaired reach (UPJ038), it will be necessary to contact the Maryland Historic Trust and the Department of Natural Resources to provide necessary information on historic structures as well as rare, threatened and endangered species within the vicinity. Storm flow sampling may be warranted to develop a discharge curve for both the impaired and reference stream in order to verify bankfull elevations. A large tree survey may also be useful along the impaired reach (UPJ038) to determine what trees will be impacted in the event that a restoration project will be undertaken. It may also be beneficial to sample water quality at both sites to see what the best course of action may be to either maintain or improve water quality and habitat. Lastly, the collection of aquatic macroinvertebrates and vertebrates within the reference reach (UPD003) would provide an understanding of the type of fish community one could expect within a developed reference reach within the Coastal Plain physiographic province.

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STUDY AREA PHOTOGRAPHS

APPENDIX A

Photo 1. Impaired Reach. View of riffle cross section looking upstream

Photo 2. Impaired Reach. View of bank erosion looking upstream

Photo 3. Impaired Reach. View of small headcut looking upstream

Photo 4. Impaired Reach. View of erosion looking upstream

Photo 5. Impaired Reach. View showing incision looking upstream

Photo 6. Impaired Reach. View large headcut and debris looking upstream

Photo 7. Reference Reach. View of woody banks showing rooting depth looking upstream

Photo 8. Reference Reach. View of point bars and low bank heights looking upstream

Photo 9. Reference Reach. View of woody habitat looking downstream

Photo 10. Reference Reach. View of trees growing at water surface looking downstream

Photo 11. Reference Reach. View of riffle/pool sequence looking upstream

Photo 12. Reference Reach. View of trees and roots protecting banks looking upstream

STREAM MORPHOLOGY DATA PACKET

IMPAIRED REACH (UPJ038)

APPENDIX B

RIVERMORPH DATA

IMAPAIRED REACH (UPJ038)

APPENDIX C

STREAM MORPHOLOGY DATA PACKET

REFERENCE REACH (UPD003)

APPENDIX D

RIVERMORPH DATA

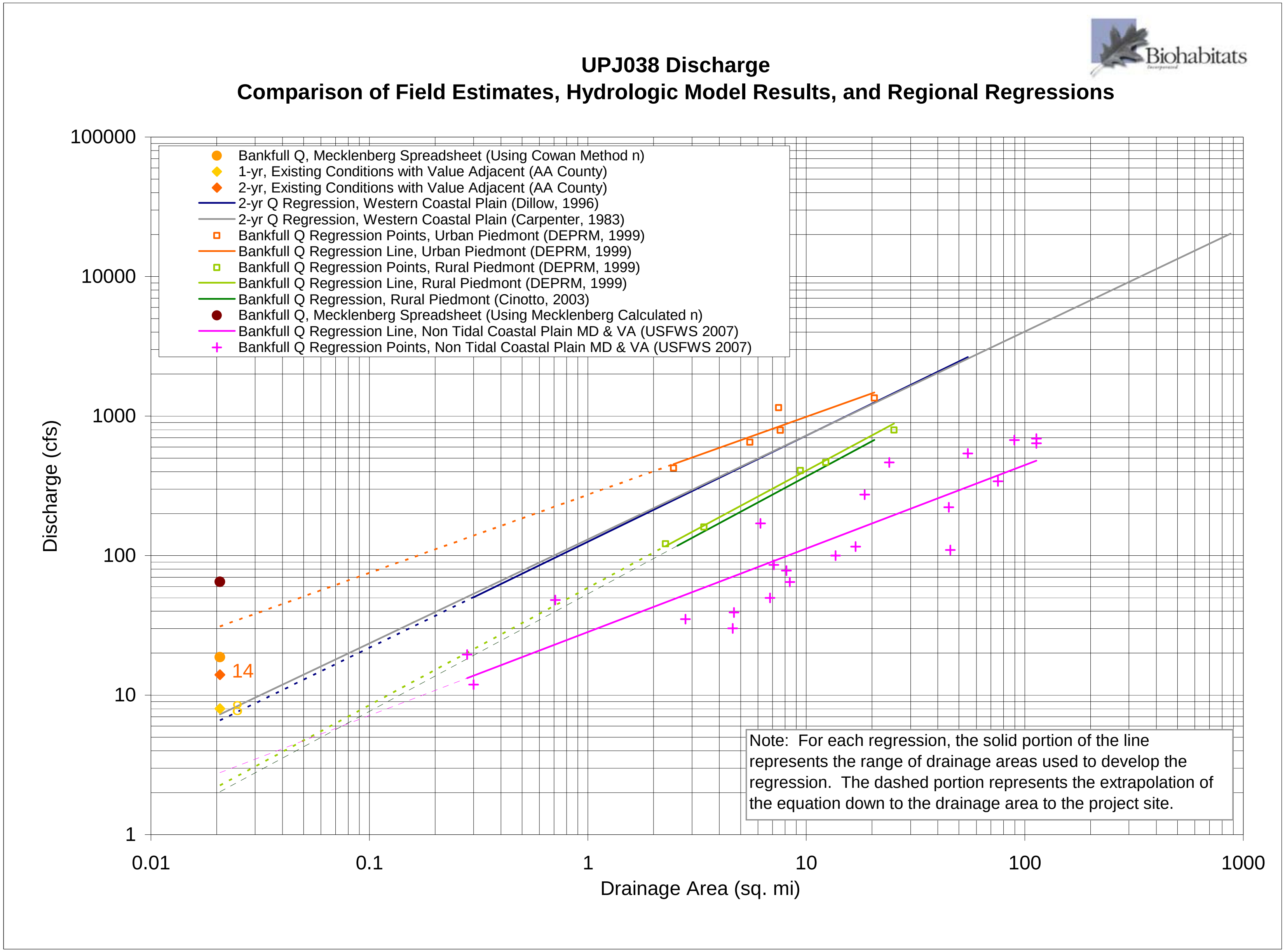
REFERENCE REACH (UPD003)

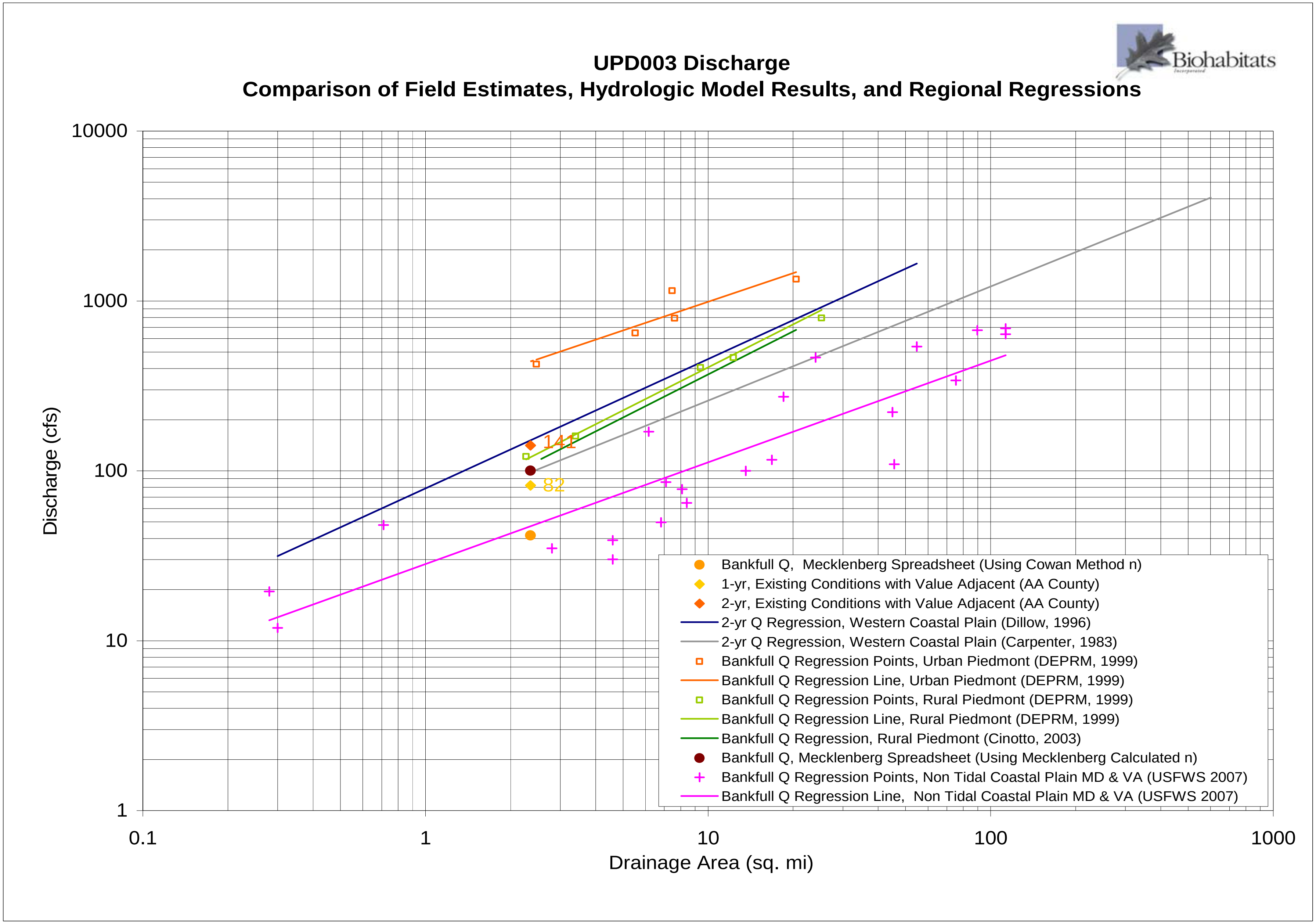
APPENDIX E

DISCHARGE ESTIMATE/

REGIONAL REGRESSION COMPARISON

APPENDIX F


UPJ038 Discharge
Comparison of Field Estimates, Hydrologic Model Results, and Regional Regressions
Biohabitats
Bankfull Q, Mecklenberg Spreadsheet (Using Cowan Method n)
1-yr, Existing Conditions with Value Adjacent (AA County)
2-yr, Existing Conditions with Value Adjacent (AA County)
2-yr Q Regression, Western Coastal Plain (Dillow, 1996)
2-yr Q Regression, Western Coastal Plain (Carpenter, 1983)
Bankfull Q Regression Points, Urban Piedmont (DEPRM, 1999)
Bankfull Q Regression Line, Urban Piedmont (DEPRM, 1999)
Bankfull Q Regression Points, Rural Piedmont (DEPRM, 1999)
Bankfull Q Regression Line, Rural Piedmont (DEPRM, 1999)
Bankfull Q Regression, Rural Piedmont (Cinotto, 2003)
Bankfull Q, Mecklenberg Spreadsheet (Using Mecklenberg Calculated n)
Bankfull Q Regression Line, Non Tidal Coastal Plain MD & VA (USFWS 2007)
Bankfull Q Regression Points, Non Tidal Coastal Plain MD & VA (USFWS 2007)
Discharge (cfs)
100000
10000
1000
100
10
1
14
8
0.01
0.1
1
10
100
1000
Drainage Area (sq. mi)
Note: For each regression, the solid portion of the line represents the range of drainage areas used to develop the regression. The dashed portion represents the extrapolation of the equation down to the drainage area to the project site.


Biohabitats
UPD003 Discharge
Comparison of Field Estimates, Hydrologic Model Results, and Regional Regressions
Discharge (cfs)
10000
1000
100
10
1
141
82
0.1
1
10
100
1000
Drainage Area (sq. mi)
Bankfull Q, Mecklenberg Spreadsheet (Using Cowan Method n)
1-yr, Existing Conditions with Value Adjacent (AA County)
2-yr, Existing Conditions with Value Adjacent (AA County)
2-yr Q Regression, Western Coastal Plain (Dillow, 1996)
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Bankfull Q Regression Line, Urban Piedmont (DEPRM, 1999)
Bankfull Q Regression Points, Rural Piedmont (DEPRM, 1999)
Bankfull Q Regression Line, Rural Piedmont (DEPRM, 1999)
Bankfull Q Regression, Rural Piedmont (Cinotto, 2003)
Bankfull Q, Mecklenberg Spreadsheet (Using Mecklenberg Calculated n)
Bankfull Q Regression Points, Non Tidal Coastal Plain MD & VA (USFWS 2007)
Bankfull Q Regression Line, Non Tidal Coastal Plain MD & VA (USFWS 2007)

Appendix E
Professional Management Team Meeting Minutes and Technical Memoranda

- PMT Meeting Minutes, First Meeting – Delivered January 18, 2008
- PMT Meeting Minutes, Second Meeting – Delivered February 28, 2008
- PMT Meeting Minutes, Third Meeting – Delivered April 7, 2008
- PMT Meeting Minutes, Fourth Meeting – Delivered May 14, 2008
- Memo, Review of Professional Management Team Items, First Meeting – Delivered February 6, 2008
- Memo, Review of Professional Management Team Items, Second Meeting – Delivered March 11, 2008
- Memo, Regression Analyses – Delivered March 11, 2008
- Memo, Additional Field Parameters – Delivered April 7, 2008

Memorandum

DATE: January 18, 2008

FROM: Dan Herrema, P.E.

TO: Mary Searing, P.E.
Watershed Management Program Administrator
Anne Arundel County Department of Public Works

CC: Brian Busiek, P.E. – LimnoTech
Richard Fisher – Anne Arundel County
Hala Flores, P.E. – Anne Arundel County
Tad Slawecki – LimnoTech
Michael Sullivan – LimnoTech

SUBJECT: Upper Patuxent River Watershed Study, Task 4 – Review of Professional Management Team Items from

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LimnoTech and Anne Arundel County, Department of Public Works staff met on December 27, 2007, for the first of four professional management team meetings to discuss the Upper Patuxent River Watershed Study. The purpose of these meetings is to collaborate on approaches and methods used to assess watershed and stream health and to set priorities for restoration and preservation. This first meeting served as a primer for the current assessment and prioritization practices that the County employs. The following goals were established for the meeting:

- Clarify outstanding issues and questions
- Review and discuss methodology (categories, indicators, and weights) for stream restoration prioritization for Upper Patuxent
- Review and discuss methodology (categories, indicators, and weights) for subwatershed restoration prioritization for Upper Patuxent
- Review and discuss methodology (categories, indicators, and weights) for subwatershed preservation prioritization for Upper Patuxent
- Introduce methods for water quality modeling for future discussion purposes

Mike Sullivan, Tad Slawecki, Dan Herrema, and Brian Busiek represented LimnoTech while Mary Searing and Hala Flores represented the County. The following represents the summary notes from the meeting. Specific action items and important consensus points are highlighted.

Review and Discuss Watershed Study Task List Coordination Items

The meeting opened with a brief discussion of the few remaining outstanding tasks related to the data collection component of the watershed study. These are presented briefly below.

Urban BMPs

The County had preliminarily reviewed LimnoTech's interim Urban BMP submittal. The County and LimnoTech agreed to schedule a follow-up visit to the County offices to complete the necessary research during the month of January 2008. The County noted that in addition to completing the BMP dataset, LimnoTech would need to develop a Technical Memo describing the procedures followed to develop the dataset. The County indicated that the final deliverable will be subjected to a QA/QC check, which will entail full assessment of 30 random facilities. If greater than 20% of the BMPs have errors, the deliverable would need to be corrected and resubmitted.

Action Item:
- Return to County offices to complete BMP research *[LimnoTech]*

Rosgen Level I and II

For the Rosgen Level I analysis, the County indicated that their preliminary assessment of LimnoTech's previous deliverable revealed several minor issues. The first was that some of the cross-sections do not extend far enough to allow for adequate analysis of bankfull conditions. The County agreed to provide a complete list of those reaches with inadequate cross-sections and LimnoTech will redraw them. The second issue was that it appeared that several perennial reaches may in fact be branches fed from the main stem of the Upper Patuxent River. LimnoTech and the County agreed that reaches of this nature should be excluded from the modeling analysis. The County will provide a dataset of reaches that appear to be branches of the main stem and LimnoTech will review it for concurrence. Lastly, the County requested that LimnoTech perform a check of reaches and drainage area delineations to ensure they concur with general field observations.

Action Items:
- Provide list of inadequate cross-sections *[County]*
- Redraw cross-sections *[LimnoTech]*
- Provide list of main stem branches *[County]*
- Review list of main stem branches *[LimnoTech]*
- Submit Rosgen Level II report *[LimnoTech]*

For the Rosgen Level II geomorphic analysis, LimnoTech provided an update of the task status. Completion of field work for this task occurred on December 27, 2007. LimnoTech noted that a report cataloging the assessment methods and classifications would be submitted to the County in January 2008.

Agriculture BMPs

LimnoTech submitted the technical memorandum and GIS shapefile associated with the Agricultural BMP task to the County on December 13, 2007. The County's review of this deliverable is pending. The County noted that agricultural BMPs or land-use are not currently a component of their modeling efforts. This is namely due to the fact that capital improvement projects funded by the County require a County source of impairment. The County did note interest in considering the incorporation of agricultural practices into modeling efforts and asked LimnoTech to consider possible approaches for a future meeting.

Action Item:
- Provide feedback on Agricultural BMP deliverable *[County]*

Watershed Fact Sheets

LimnoTech had previously submitted a two-page subwatershed fact sheet template for the County's review. The County had performed a cursory review of the fact sheet, but indicated that they would share it with other persons within the County and provide official feedback at a later date.

Action Item:
- Provide feedback on fact sheet template *[County]*

Upper Patuxent River Stream Restoration Prioritization Methodology

The County began the discussion of stream restoration prioritization with a brief comparison of preliminary results from the Upper Patuxent study with those from the South River and Severn River studies. It was noted that the results for the Upper Patuxent are to be considered draft and were only being shared at this point to help demonstrate how the data was being used. The County presented a map visualizing the reach rankings for each of the watersheds. The Upper Patuxent was comparable to the Severn River in terms of total stream miles and assessed stream miles and both were around 25% less than those of the South River. In general, the reaches in the Upper Patuxent appeared to be predominantly Good to Fair on the ranking scale, while the other watersheds trended toward a mix of Good, Fair, Poor, and Very Poor rankings. It was agreed that this general assessment seemed appropriate given the more rural and hence less developed nature of the Upper Patuxent watershed compared to the others.

Definition of Categories and Indicators
The County provided a detailed overview of the five categories that go into the stream restoration prioritization ranking calculations. Categories included Stream Habitat, Stream Morphology, Land Cover, Infrastructure, and Hydrology and Hydraulics. Each category was comprised of one to six different specific indicators. The Stream Habitat indicator is the 2003 Maryland Physical Habitat Index (MPHI) score. The Stream Morphology indicator is based on Rosgen Level I classifications, while the Land Cover indicator is based on the contributory percent imperviousness. The Infrastructure category contains six indicators, which include buffers, erosion, head cuts, dump sites, and others (pipes, ditches, crossings, and obstructions). Finally, the Hydrology and Hydraulics indicator is comprised of an overtopping analysis at road crossings. The County revealed that the Stream Morphology and Land Cover categories were added during the South River study based on consensus reached during similar professional management team meetings.

Review Indicator Weights
As a reflection of the relative importance of each indicator, the County has weighted each used in the ranking process. The Infrastructure and Stream Habitat categories receive the highest weighting as they comprise approximately 42% and 32% of the overall total ranking score, respectively. The Hydrology and Hydraulics category makes up approximately 16% of the ranking score, while Stream Morphology and Land Cover each comprise 5%. The County noted that the weights assigned to each indicator were the product of a collaborative approach during previous watershed studies.

LimnoTech questioned whether this process has served the County's needs in the past (i.e., are the correct stream reaches being prioritized?). The County felt that overall the indicators used and the weighting schemes have generally served their needs. They noted adaptations have been made along way (e.g., adding Stream Morphology and Land Cover categories and tweaking weights) that have improved the process. The County expressed a desire to achieve a balance between the right level of effort on a study versus getting satisfactory results in a timely and cost-effective manner.

LimnoTech inquired whether a statistical analysis has been performed as a check on weighting appropriateness. The County indicated that they had performed sensitivity analyses in the past with mixed results. LimnoTech noted that a multivariate statistical analysis might be helpful in providing input on the appropriateness of a given indicator or assigned weight. The County expressed interest in this approach and asked for more information. LimnoTech agreed to perform basic statistical analyses of a subset of indicators prior to the next meeting to demonstrate the type of analyses that may be done on a larger dataset. LimnoTech requested the current dataset to perform this work with the understanding that the data are in draft form.

Action Items:

- Provide draft data to LimnoTech for statistical analyses *[County]*
- Perform multivariate statistical analyses to evaluate indicators and weighting *[LimnoTech]*

Review Spreadsheet of Calculations

The County presented a series of tables for each of the indicators that included a breakdown of scoring and ranking categories and values for the Upper Patuxent and the combined watersheds. In general, each indicator was given a ranking score of 1, 4, 7, or 10 (with the exception of the Rosgen Level I indicator) based on natural or fixed breaks in the data. The higher values represent good conditions while lower values represent poor or less desirable conditions.

Ranking scores for the MPHI indicator are based on established Maryland Biological Stream Survey (MBSS) categories. Ranking scores for the Rosgen Level I indicator are assigned based on Rosgen classifications. A Rosgen classification of F or G merits a rank/score of 1, while all others receive a 10. The contributory percent imperviousness indicator is given a ranking score based on breaks established by the Center for Watershed Protection. The buffer and erosion indicator are assigned ranking scores based on the natural breaks of the products of the impact scores and the percentage of deficient buffers or erosion, respectively. Ranking scores for headcuts are assigned based on natural breaks of the sum of headcut heights per reach. Ranking scores for dump sites and all other infrastructure types are based on natural breaks of the sum of the impact scores. The County noted that for previous studies headcut heights, dump site impact scores, and all other impact scores were normalized by the reach length, but this is no longer the case. The final indicator, emergency road crossings, is assigned ranking scores based on fixed breaks.

LimnoTech questioned why natural breaks were utilized to define the categories for the ranking scores versus other breaking methods. The County noted that using natural breaks minimizes the potential for having raw ranking scores with similar values grouped into different ranking categories. LimnoTech agreed with the merit of this approach but offered to consider general applications and philosophies for calculating breaks for discussion at a future meeting.

Action Item:

- Consider merits of different breaking schemes for categorizing ranking scores *[LimnoTech]*

LimnoTech also inquired on the basis for the decision made to eliminate reach length normalization from several of the indicators. The County noted that it was the result of discussions at a previous professional management team meeting. One possible solution that LimnoTech posed was to sum the ranking scores first and then normalize them by reach length.

Compatibility of Prioritization Methods between Watersheds
Both the County and LimnoTech noted that using natural breaks based on data from one watershed could complicate comparisons made to another watershed with natural breaks based on its own dataset. It was noted and agreed by both parties that applying combined model breakpoints to the data from each watershed and evaluating the distribution of ranking scores would be a valuable exercise. LimnoTech also noted that finding watershed breakpoints that would yield similar distributions as the natural breaks in the combined model could also be useful. The County indicated that they would consider this further.

Upper Patuxent River Subwatershed Restoration Prioritization

The County began the discussion of subwatershed restoration prioritization with a brief comparison of results from the South River and Severn River studies. It was noted that the results for the Upper Patuxent have yet to be tabulated.

Definition of Categories and Indicators and Weights
The County provided a detailed overview of the four categories that make up the subwatershed restoration prioritization ranking calculations. These categories include Stream Habitat, Hydrology and Hydraulics, Water Quality, and Landscape. Each category was comprised of one to five indicators. The Stream Habitat category has one indicator that is based on the weighted average of Final Habitat Scores (FHS) for reaches in the subwatershed. The Hydrology and Hydraulics category is based on a comparison of discharge volumes modeled for current conditions versus pre-development conditions. The Water Quality category uses total nitrogen, total phosphorus, and copper loading as indicators. Finally, the Landscape category is comprised of five indicators (impervious cover, BMP coverage, forested buffers, wetland/hydric soils, and Limited Development Area (LDA)/Intensely Developed Area (IDA)). Weights for the various indicators ranged between 2 and 10% and were based on a consensus reached during previous professional management team meetings.

Review Spreadsheet of Calculations
The County presented a series of tables for each of the indicators that included a breakdown of scoring and ranking categories and values for the South River and Severn River models. In general, each indicator was given a ranking score of 1, 4, 7, or 10 based on various breaking schemes. Ranking scores were previously based on quartiles in many cases, but the County expressed an interest in moving towards natural breaks. Once again, the higher values represent good conditions while lower values represent poor or less desirable conditions.

The County noted that the approach for the Hydrology and Hydraulics category was newly proposed by the South River professional management team. Previously the category included both peak and cumulative discharge volumes, but as proposed only the cumulative discharge is used. Furthermore instead of looking solely at changes in peak or cumulative discharge from pre- to post-development, the new approach uses a slightly different method. When pre-development discharge is zero, the indicator value is equal to post-development discharge. In all other cases, the indicator value is equal to the ratio of post-development to pre-development discharge. This gives potentially much higher scores to subwatersheds where pre-development discharge is zero. LimnoTech generally agreed with the merit of this approach, but suggested that it might be beneficial to normalize the discharge values to the subwatershed area.

For the Water Quality category, the County explained that previously zinc was used as a surrogate for metals and other non-point toxics. However, in the most recent study, zinc was replaced by copper because the event mean concentrations (EMCs) used to calculate loading were better for copper than for zinc. The County asked LimnoTech to review the EMCs that are used for loading calculations to ensure that they are appropriate. LimnoTech agreed that this would be a useful exercise.

Action Items:

- Provide EMC values to LimnoTech *[County]*
- Review EMC values and provide feedback on appropriateness *[LimnoTech]*
- Provide BMP removal efficiencies to LimnoTech *[County]*
- Review values and provide feedback *[LimnoTech]*

Within the Landscape category, the County indicated that they were considering the incorporation of BMP removal efficiencies. LimnoTech noted that this sounded like a good idea. It was agreed that LimnoTech will review the existing inputs used by the County and provide feedback prior to the next meeting.

LimnoTech also suggested that wetland/hydric soil and LDA/IDA indicators be separated into their own category instead of being grouped under the Landscape category. LimnoTech noted that the first three indicators under the Landscape category (imperviousness, BMPs, and forested buffer) are reflective of current land-use conditions, while the wetland/hydric soil and LDA/IDA indicators are indicative of future potential conditions. The new category could be called Restoration Potential or something to that effect. LimnoTech noted that this wasn't critical and was more of a question of semantics. The County indicated that they would consider it.

Finally, LimnoTech noted that it may make sense to use finer discretization of indicator ranking scores than the grouped values of 1, 4, 7, or 10. This would help minimize the under- or over-valuation of certain interim indicator data points before arriving at a final ranking score. This approach could apply to all indicators for both stream and subwatershed prioritization. The County indicated that they would like to discuss this further in a future meeting.

The County also indicated that three additional indicators would be used in the subwatershed restoration prioritization process. These include the number of TMDLs in a subwatershed, septic systems, and bioassessment data. These indicators may be discussed in more detail in a future meeting.

Upper Patuxent River Subwatershed Preservation Prioritization

The County provided LimnoTech with a brief overview of the subwatershed prioritization approach currently being used. However, this method has not changed with respect to the Technical Memorandum, Problem Area Ranking, dated January 5, 2004. LimnoTech agreed to review the approach in the memo and provide feedback to the County at a future professional management team meeting.

Action Items:

- Review Subwatershed Preservation Prioritization approach and provide feedback *[LimnoTech]*

Water Quality Modeling Methods

The County introduced LimnoTech to modeling efforts that the County plans to perform on the Upper Patuxent River watershed to support its permit and TMDL requirements. The purpose of the introduction was to provide a general overview of the modeling approach used by the County in anticipation of future professional management team meetings where LimnoTech will collaborate with the County on specific modeling scenarios.

The County indicated that modeling will assess existing, future, and additional scenarios to develop a sense of the potential for water quality improvements in the watershed. Currently, the Upper Patuxent watershed is impaired due to nutrients and sediment. There is currently no TMDL in place for the Upper Patuxent, but the County noted that one may be coming from the State of Maryland in the future.

The County revealed that the State develops a current conditions scenario using the HSPF model, while the County utilizes models developed from the Center for Watershed Protection (e.g., Schueler, et. al.). The County utilizes different water quality data in many instances than the State. The goal for working collaboratively with LimnoTech on the modeling will be to give the County an independent, third party opinion on the appropriateness of watershed modeling efforts, and to correlate results with State-developed modeling results.

An example watershed model used by the County for Baltimore Harbor was briefly reviewed to provide a basis for explaining the general modeling approach. The model intersects land use conditions with various other water quality input parameters. The model begins by computing loads for each polygon (upwards of 60,000 in the example). Layers used in various scenarios include septic, BMPs, streams, subsheds, imperviousness, retrofits, new development, land use, zoning, cluster development, redevelopment, sensitive areas, and others. Many of these layers will also be available for the Upper Patuxent watershed, including buffers, ditches and ditch type, septic upgrades for nitrogen removal, and dry pond retrofits to wet ponds. The Baltimore Harbor example represents a generic approach that will be similar to that which will be used on the Upper Patuxent.

Miscellaneous

In addition to LimnoTech being provided the introduction to County approaches discussed above, the following miscellaneous items were also discussed in preparation for the next professional management team meeting.

- The County will provide previous Bioassessment data (benthic) as well as historical WRAS data for Upper Patuxent watershed (this was completed on December 31, 2007).
- The County requested that LimnoTech review County Stormwater Management Regulations, as well as State of Maryland Stormwater requirements. Specifically identified was House Bill 1141. The intent is to be aware of stormwater requirements prior to discussing modeling efforts in detail at the next professional management team meeting.
- The next PMT meeting is tentatively scheduled for February 13, 2008 at the County offices.

> Action Items:
> - Review local and State stormwater regulations and requirements *[LimnoTech]*

LimnoTech
Water | Environment | Scientists | Engineers

Memorandum

DATE: February 28, 2008

FROM: Brian Busiek, P.E.

TO: Mary Searing, P.E.
Watershed Management Program Administrator
Anne Arundel County Department of Public Works

CC: Richard Fisher – Anne Arundel County
Hala Flores, P.E. – Anne Arundel County
Dan Herrema, P.E. – LimnoTech
Tad Slawecki – LimnoTech
Michael Sullivan – LimnoTech

SUBJECT: Upper Patuxent River Watershed Study, Task 4 – Professional Management Team, Minutes from Second Professional Management Team Meeting, February 13, 2008

LimnoTech and Anne Arundel County Department of Public Works staff met on February 13, 2008, for the second of four professional management team meetings to discuss the Upper Patuxent River Watershed Study. The purpose of these meetings is to collaborate on approaches and methods used to assess watershed and stream health and to set priorities for restoration and preservation. This second meeting entailed a deeper look at the prioritization models that the County employs. The following goals were established for the meeting:

1. Review outstanding project tasks and follow-up from previous meeting
2. Provide progress update on Stream Restoration Prioritization efforts
3. Provide progress update on Subwatershed Restoration Prioritization efforts
4. Provide progress update on Subwatershed Preservation Prioritization efforts

Mike Sullivan, Tad Slawecki, Dan Herrema (via phone), and Brian Busiek represented LimnoTech while Mary Searing, Hala Flores, Richard Fisher, Jean Kapusnick, and Chris Victoria represented the County. The following represents the summary notes from the meeting. Specific action items are highlighted in call-out boxes.

Review Outstanding Project Tasks and Follow-up from Previous Meeting

The meeting opened with a discussion of the remaining outstanding tasks from the data collection and deliverables component of the project, and the minutes and action items from the previous professional management team meeting. These are presented briefly below.

Urban BMPs
Since the previous professional management team meeting in December, LimnoTech completed the data gathering and analysis for the Urban BMP task and submitted a complete draft deliverable (*i.e.*, technical memorandum, analysis spreadsheet, and GIS layer) on February 8, 2008. The County indicated that they were in the process of reviewing the deliverable, but had already provided some feedback to LimnoTech via email. The County discussed these comments briefly. The highlights included a request for a cover sheet on the analysis

spreadsheet, explanatory text for the codes used to indicate why a record was removed from the dataset, and a summary section detailing findings and statistics. These comments and others were included in an email from Mary Searing dated February 12, 2008.

> Action Items:
> - Provide final feedback to LimnoTech on Urban BMP deliverable *[County]*
> - Address County comments and submit final deliverable (including stage-storage-discharge relationships) *[LimnoTech]*

The County noted that they concurred with LimnoTech's assessment of the small subset of BMPs with limited identifying information. The County stated that they would consider internally what types of additional research if any could be completed to identify these BMPs. LimnoTech also requested clarification on the County's expectations for the compilation of stage-storage-discharge relationships, which is the final outstanding component of this subtask. LimnoTech noted that they expected to be able to research the historical records for a few BMPs, where available. The County indicated that this should be sufficient effort to satisfy the requirements of this task. The County requested that LimnoTech document the research steps and findings for this effort in the final version of the technical memorandum.

Agriculture BMPs

Prior to the meeting, the County provided comments via email on LimnoTech's previously submitted draft deliverable. The County and LimnoTech discussed these comments in detail. The County requested a standard report cover page, which should be used for all technical memorandum deliverables. The County also requested that the GIS metadata be updated (especially the process steps) and that the land use type categories be standardized. LimnoTech agreed to make these changes and the County indicated that they would provide a list of land use type categories to utilize.

> Action Items:
> - Provide list of preferred land use type categories to LimnoTech *[County]*
> - Address County comments and submit final deliverable *[LimnoTech]*

The landcover layer was projected for review during the meeting, and participants spent some time looking at agricultural land cover in various parts of the watershed. The County asked whether the parcel layer was used in any way to modify the agricultural land cover polygons, as it is generally thought to be more accurate than the actual land cover layer. LimnoTech responded that the parcel layer was available during the windshield survey, but that the degree of detail that could be observed from the road was not sufficient to warrant making modifications to the polygon boundaries using this layer. LimnoTech confirmed that changes that were made to the land cover layer were reclassifications of existing polygons. The County accepted this, but noted several areas where an overlay of the parcel layer, the land cover layer, and the orthophotography seemed to indicate that the landcover layer was incongruous with the other two. The County also revealed that during the creation of the layer, residential areas were often removed from the surrounding land cover using a buffering analysis.

Both LimnoTech and the County discussed the best way to resolve these incongruities save a manual search from one parcel or polygon to the next. LimnoTech suggested that focusing on the intersection of agricultural land cover and smaller sized parcels, where subdivision and redevelopment would be more likely, would be a good starting point. Aerial photographs could then be used to determine if changes need to be made on a targeted basis. LimnoTech also noted that an intersection of the impervious layer with the revised land cover layer would be useful to make sure that LimnoTech's modifications to residential land cover make sense.

LimnoTech observed that the use of published event mean concentrations (EMCs) in the County's modeling efforts introduces uncertainty to the model in much the same way as poorly delineated land cover polygons. The County agreed with this and noted that they have been pushing to obtain site specific EMCs, but to date have not had the resources to do so. The County also noted that using published EMCs for prioritization purposes is not problematic given the relative nature of the model analyses (e.g., comparing current scenarios with future scenarios). Both LimnoTech and the County agreed that with the use of published EMC values and their inherrent uncertainty, an effort at this point to refine the land cover polygons would not be necessary.

It was agreed that LimnoTech would modify the technical memorandum associated with this deliverable to include a discussion on the uses and limitations of the modified agricultural land cover layer. The County requested that LimnoTech include a discussion about future steps that the County could take to improve the dataset, including a parcel-by-parcel review of orthophotography and access to nutrient management plans and other data, which are currently unavailable. LimnoTech also agreed to revisit the modifications to the land cover layer made for the deliverable to the County to ensure that they were appropriate.

Rosgen Level I and II

The County noted during the last professional management team meeting that some of the cross-sections that LimnoTech previously delivered did not extend far enough to allow for adequate analysis of bankfull conditions. LimnoTech redrew the cross-sections and resubmitted them to the County on January 30, 2008. The County noted that the redelivered cross-sections appear to be drawn appropriately. The County suggested that they should be finishing up the Rosgen Level I classifications in the coming weeks and requested that LimnoTech review the results for general concurrence with field observations.

Action Items:
- Provide Rosgen Level I classifications *[County]*
- Review Rosgen classifications for concurrence with field sense *[LimnoTech]*
- Revise Rosgen Level II report and GIS deliverable according to County comments and resubmit *[LimnoTech]*

The County noted that they had a number of comments on the submitted Rosgen Level II draft deliverable. The County had provided several sets of comments to LimnoTech via email prior to the meeting. Comments included using the new version of the Mecklenberg spreadsheet and including all data required for analysis in the spreadsheet. The County surmised that some data was missing because the RiverMorph software performs many interim calculations and does necessarily provide interim outputs. The County noted that they do not have a copy of the RiverMorph software and could not verify all calculations due to omissions from the Mecklenberg spreadsheet.

County staff initially questioned reach selection and intent for the Rosgen II activities, as the impaired and reference reaches weren't comparable. Mary Searing of the County noted that during field discussions, when the reference reach and impaired reach were chosen, it was decided that it was appropriate for the reference reach to represent a typical reach in the Upper Patuxent and for the impaired reach to be typical of the worst reaches in Upper Patuxent. Mary acknowledged that the impaired reach and reference reach were not meant to be compared. Nevertheless, it was agreed that this understanding should be documented in the summary Rosgen II report. The County also noted that there were issues with the bankfull width calculation among a list of other issues. LimnoTech agreed with the County's assessment, and in lieu of a comment by comment discussion, agreed to work with Biohabitats, the primary author of the report, to address the County's comments. LimnoTech suggested that they would schedule a call with Biohabitats and the County at a future date to discuss the best approach for moving forward.

Watershed Fact Sheets

LimnoTech had previously submitted a two-page subwatershed fact sheet template for the County's review. The County indicated that they had gotten considerable internal feedback and would need to consolidate comments before they could be provided to LimnoTech.

Action Item:
- Provide feedback on fact sheet template *[County]*

First Professional Management Team Meeting Follow-up

In addition to those tasks above that are specifically articulated in the watershed study project plan, a number of additional action items were identified during the first professional management team meeting. LimnoTech performed these tasks and submitted an explanatory technical memorandum to the County on February 6, 2008. Going through this memo, the County expressed appreciation for LimnoTech's efforts to validate the reach ranking spreadsheet computations and to review the rankings for concurrence with field observations.

Action Items:
- Provide full EMC and BMP analysis spreadsheet *[LimnoTech]*
- Provide recommendation on terms of use related to the street sweeping removal rates *[LimnoTech]*
- Incorporate County comments on the statistical regression analyses and resubmit the memo *[LimnoTech]*

Another follow-up task that LimnoTech performed was to review the BMP efficiency and EMC values that the County uses in their models. LimnoTech compared the County values against other published values and provided a summary of the results in the above mentioned technical memorandum. Generally, there was agreement between County and published values; however some exceptions were noted in the memo. The County indicated that they were performing a sensitivity analysis across watersheds for the alternate BMP efficiencies and EMC values that LimnoTech had previously suggested. The County indicated that they would be prepared to discuss the results of this analysis at the next meeting. The County also requested a copy of the full BMP and EMC analysis spreadsheet, which LimnoTech agreed to provide.

The County and LimnoTech spent some time discussing the technical memorandum the County previously provided on removal rates from street sweeping and storm drain cleanout. In the February 6, 2008, technical memorandum and again at the meeting, LimnoTech noted general concurrence with the conceptual model and analysis presented in the street sweeping memo. The County expressed some concerns about the relatively low removal rates suggested in the street sweeping memo. LimnoTech explained that the values were obtained from the conceptual model rather than observed field measurements. There did seem to be some ambiguity about whether these removal rates should be used for the street area or the watershed area. LimnoTech agreed to look into this further and provide a final recommendation.

The County and LimnoTech also spent considerable time discussing the regression analyses that LimnoTech performed on two datasets. The first was a statistical regression analysis of the weights used to combine indicators for preservation or restoration rankings. This analysis showed that the weights were appropriate and no changes were recommended. The second analysis involved a multi-linear regression to determine the degree of correlation between MPHI scores and the added parameters that LimnoTech collected during field efforts. In this case, high correlation meant that a parameter is already in someway reflected in the County's assessments, while low correlation meant that the parameter could provide additional information. Several parameters had low correlation with MPHI scores: human intervention, riparian invasive species, barriers to fish movement, overall channel condition, and channel incision. LimnoTech suggested that these parameters could be used as tie breakers should there be a need to differentiate between closely ranked reaches.

The County appreciated the analyses and questioned what statistical program was used. LimnoTech responded that JMP from SAS was used. The County also requested that all the parameters be shown in Table 2 of the technical memorandum and that poorly correlated parameters be highlighted, rather than showing only the correlated parameters. LimnoTech agreed to revise the memo and resubmit.

Progress Update on Stream Restoration Prioritization Efforts

The County quickly noted that the stream restoration prioritization work is progressing smoothly and should be completed in the coming weeks.

Progress Update on Subwatershed Restoration Prioritization Efforts

The County reported that they are making changes to the modeling protocols based on the South River study. When the modeling is completed, the County requested that LimnoTech review the model results for concurrence with field observations. LimnoTech agreed to do so.

LimnoTech received an introduction to the indicators and weighting schemes for the subwatershed restoration prioritization efforts at the previous meeting. This time, the County briefly highlighted some of the major changes to the model from previous efforts. First, the County noted that they were considering replacing the final habitat score (FHS) with the stream reach ranks. The reason cited was the marked difference between FHS scores across watershed studies. These differences were primarily attributed to differences in scoring protocols between the 1999 MPHI and 2003 MPHI methods. The County was also considering the use of an available equation to relate 1999 MPHI values to 2003 values. The County indicated that they would consider these options further. LimnoTech noted that regardless of the ultimate choice, the decision to use consistent values was a good one.

<u>Action Items:</u>

- Review subwatershed restoration prioritization results for concurrence with field observations *[LimnoTech]*
- Test various reach ranking schemes and prepare to discuss results at the next meeting *[LimnoTech]*
- Create natural breaks macro for Excel and provide to County *[LimnoTech]*

The County also briefly discussed the three new indicators that they were adding: number of 303(d) list impairments, density of septic connections, and impervious surfaces treated by BMPs. With regard to the BMP treatment indicator, LimnoTech noted that as currently devised those areas with no impervious area may be artificially penalized. LimnoTech suggested modifying the approach to reflect impervious area minus treated area divided by total area. The County indicated that they would consider this approach.

At this point, LimnoTech made a general observation regarding the difficulty the County was having with the assignment of different breaking points for each watershed study. LimnoTech suggested that a weighted ranking scheme where indicators were assigned a value based on their relative ranking and then combined to obtain an overall ranking score would eliminate the need to use break points. It was noted that this could yield superior data distribution across watersheds. The County agreed that this approach would allow for finer discretization of indicator inputs, which would be more accurate than compartmentalized values, but could result in some misrepresentation of values that are closely ranked but have vastly different raw values or vice versa. LimnoTech agreed that this would be a tradeoff and suggested that another alternative could be to looking at scaled values instead of compartmentalized or ranked values. This would eliminate the need for break points, allow finer discretization of data, and would still keep the differences between values intact. In the end, the County was intrigued by these ideas in general and had pursued some of them independently before LimnoTech brought them up. LimnoTech volunteered to perform some experiments with various reach ranking schemes using draft data that the County had previously provided. LimnoTech also offered to provide the County with a macro that could be used to determine natural break points in Excel.

Continuing with the discussion of the subwatershed restoration prioritization indicators, the County indicated that they were going to use the newly proposed Hydrology and Hydraulics indicator discussed at the last meeting. For the Water Quality indicator, the County noted that the calculations as currently proposed actually use the natural log of the loads. The County had an internal debate on the merits of using the natural log of loads versus using unmodified load values. It was stated that the natural log of a load value was difficult to comprehend or explain to the public, but at the same time natural logs provide a wider distribution of values than load fractions. The County agreed to test both possibilities and that if natural log values were utilized, they would be converted back to unmodified load values when provided for public consumption. The County ended the discussion by noting that there were no proposed changes to the forested stream, wetland/hydric soil, or LDA/IDA indicators.

Progress Update on Subwatershed Preservation Prioritization Efforts

The County provided LimnoTech with an overview of the subwatershed preservation approach currently being used. The County started by noting that they were considering the same question for the Stream Habitat category as they were for the subwatershed restoration prioritization (*i.e.*, to replace the FHS with the stream reach ranks).

The County noted two new indicators were being considered: water quality and soil erodibility. The water quality indicator looks at future departure of water quality conditions from the current model to the ultimate model. Constituents of interest include changes in total nitrogen and total phosphorus. The County explained that the ultimate model is the implementation of all master plans and development plans on the books. LimnoTech suggested that the County consider percent departure in lieu of an absolute departure value. The County agreed to look at this possibility. For the soil erodibility indicator, the County was considering the use of NRCS data, which differentiates between potentially erodible or highly erodible soils. The issue that the County noted is that virtually all soils in the County are highly erodible. The County suggested K factors or erodibility factors as an alternative. The County indicated they would consider their options.

The County talked through the remainder of the indicators and noted that there were no changes from the methods established for the other watershed studies. These indicators included percent forest cover, percent wetland area, density of headwater streams, percent green ways, presence of sensitive species, presence of bogs, percent Critical Conservation Area, percent of protected lands according to DNR (including environmental easement protection areas), presence of wellhead protection areas, presence of trout spawning habitats, and presence of anadromous fish spawning habitats.

Next Meeting

At the close of the meeting, the County indicated that the next meeting would focus on discussions of the County's water quality modeling and BMP suggestions. The County also hoped to be able to discuss the Fact Sheets next time. The County agreed to provide the NPDES permit and Baltimore Harbor TMDL for LimnoTech to review prior to the next meeting. The tentative date for the meeting was set for March 12, 2008 at the County offices.

LimnoTech
Water | Environment | Scientists | Engineers

Memorandum

DATE: April 7, 2008

FROM: Brian Busiek, P.E.

TO: Mary Searing, P.E.
Watershed Management Program Administrator
Anne Arundel County Department of Public Works

CC: Richard Fisher – Anne Arundel County
Hala Flores, P.E. – Anne Arundel County
Dan Herrema, P.E. – LimnoTech
Tad Slawecki – LimnoTech
Michael Sullivan – LimnoTech

SUBJECT: Upper Patuxent River Watershed Study, Task 4 – Professional Management Team, Minutes from Third Professional Management Team Meeting, March 12, 2008

LimnoTech and Anne Arundel County Department of Public Works staff met on March 12, 2008, for the third of four professional management team meetings to discuss the Upper Patuxent River Watershed Study. The purpose of these meetings is to collaborate on approaches and methods used to assess watershed and stream health and to set priorities for restoration and preservation. This third meeting entailed a deeper look at the assumptions for the water quality model and the results from the prioritization modeling. The following agenda items were set for the meeting:

1. Review outstanding project tasks and follow-up from previous meeting
2. Discuss assumptions and draft results for modeling existing conditions
3. Discuss assumptions and draft results for modeling future conditions
4. Discuss assumptions and draft results for the various what-if scenarios
5. Share mapping and data products from Stream and Subwatershed Prioritization efforts

Mike Sullivan, Tad Slawecki, and Brian Busiek represented LimnoTech while Mary Searing, Hala Flores, Richard Fisher, and Jean Kapusnick represented the County. The following represents the summary notes from the meeting. Specific action items are highlighted in call-out boxes.

Review Outstanding Project Tasks and Follow-up from Previous Meeting

The meeting opened with a discussion of the remaining outstanding tasks from the data collection and deliverables component of the project, and the minutes and action items from the previous professional management team meeting. These are presented briefly below.

Rosgen I Classification
The County shared the results of the recently completed Rosgen Level I classifications. The County noted that an analysis of the distribution of channel types across the watershed revealed slightly more than one-third were “F” channels. This was significant because the County’s

prioritization modeling penalizes both "F" and "G" channels. A cursory analysis of the photos taken in the field of the Rosgen locations seems to support at least a borderline "F" classification in many cases. The County noted that "B" and "C" channels were predominant in the South and Severn rivers, although overall channel conditions are better in the Upper Patuxent River. The County indicated that they would evaluate the other channel condition parameters collected in the field and associated land cover to attempt to further verify and understand the Rosgen classifications. The County requested that LimnoTech perform a spot check of the results using photos and field notes to confirm the Rosgen Level I classifications.

> <u>Action Items:</u>
> - Provide Rosgen Level I classifications *[County]*
> - Review Rosgen classifications for concurrence with field sense *[LimnoTech]*

<u>Rosgen II Geomorphic Report</u>

The County had previously provided comments to LimnoTech on the draft Rosgen II Geomorphic Report that LimnoTech and Biohabitats submitted in January 2008. LimnoTech provided an update on the status of the revisions to the Geomorphic Report and indicated that a final version will be delivered in the coming weeks.

> <u>Action Items:</u>
> - Revise Rosgen Level II report and GIS deliverable according to County comments and resubmit *[LimnoTech]*

<u>Urban and Agricultural BMPs</u>

The County noted that they had completed the review of the Urban BMP deliverable that LimnoTech previously submitted. The deliverable contained 286 confirmed BMPs, of which 191 were actually within the Upper Patuxent River watershed. It was confirmed that there were fewer BMPs in the Upper Patuxent compared to previously studied watersheds and that this seemed appropriate based on the watershed size and associated land use. The County had summarized the BMPs by structure type and ownership and had provided tables with this information prior to the meeting. LimnoTech indicated that they had incorporated this information into the final Urban BMP technical memorandum.

The County noted that four of the BMPs had an ownership attribute designation of "Other." LimnoTech confirmed that the "Other" designation corresponded to the BMP records obtained from the Soil Conservation District's list of 378 ponds, for which ownership data was not available. After briefly looking at these BMP points and the underlying orthophotographs, it was confirmed that these were sizable ponds, but clues as to who owns them were not readily available. The County indicated that they would use in-house resources to research these further.

LimnoTech asked the County whether they intended to provide additional comments on the draft Urban BMP deliverable other than those received from Mary Searing on February 12, 2008, and March 4, 2008. The County responded that they had no additional comments other than suggesting that LimnoTech perform a final clip of the BMP GIS dataset with the watershed boundary to remove those BMPs outside of the watershed. LimnoTech noted that the comments and suggestions would be addressed and a final version of the Urban BMP deliverable would be submitted. For the Agricultural BMP task, LimnoTech asked the County if they would provide

> <u>Action Items:</u>
> - Provide list of preferred agricultural land use type categories to LimnoTech *[County]*
> - Address County comments and submit final Urban BMP deliverable [*LimnoTech]*
> - Address County comments and submit final Agricultural BMP deliverable *[LimnoTech]*

the list of standardized land use type categories that they had indicated were available during the previous professional management team meeting. The County agreed to do so.

BMP Pollutant Removal Efficiencies

The County provided a spreadsheet of revised BMP pollutant removal efficiencies based on feedback received from a previous professional management team meeting and a comparison of those used by the Chesapeake Bay Program. The master list of BMP structure types were grouped as follows: dry detention, extended dry detention, filtration, wet structures, and other.

The County pointed out that the revised BMP efficiencies suggest that there was not much efficiency gain between extended detention dry ponds and wet ponds, which is somewhat counter to the State's efforts to encourage the use of wet ponds for efficiency purposes. The County noted that these new efficiencies will result in a loss of modeled benefits for wet ponds. It was revealed that the BMP efficiencies from the CBP included some practices that had failed (*i.e.*, negative efficiencies). Despite this, the County adopted these efficiencies to be consistent.

Event Mean Concentrations

The County also provided a spreadsheet of revised regional event mean concentrations by land cover type. Revisions were made based on comments that LimnoTech had previously provided. Specific changes included modifying the percent imperviousness for single row crops and open space from 0 to 1% and slight changes to the EMC values for metals in the open space and woods categories.

The County noted that EMC land cover types presented in the spreadsheet were further grouped by terms used in Maryland TMDLs: non-point source agriculture, non-point source urban, and other non-point source. The County also remarked that the EMC values were assumed to account for air deposition and wash off.

Discuss Assumptions and Draft Results for Modeling Existing and Future Conditions and Various What-if Scenarios

The County began the discussion of the existing conditions modeling that they perform with a brief overview of the GIS data components that make up the model inputs. It was noted that the addition or intersection of each GIS layer creates successively smaller and smaller polygons that are tracked with a unique ID and that contain an attribute from every added layer. The GIS layers included in the existing condition modeling are described below.

GIS Layers

- *Subwatershed boundaries*
- *Land cover* – 2004 delineation of land cover types (e.g., industrial, commercial, residential, open space, etc.)
- *Impervious cover* – 2004 delineation; indicates presence or absence of impervious cover
- *Hydrologic soil groups* – A, B, C, or D
- *Steep slopes* – derived from the DEM; based on County ordinances, areas greater than 5,000 sf with slopes greater than 25% cannot be developed

- *Wetlands* – derived from DNR, NWI, and "wetlands of special state concern" datasets; indicates presence or absence of wetlands
- *FEMA 100 year floodplains* – indicates presence or absence of floodplain
- *Critical areas* – includes Intense Development Areas (IDA), Limited Development Areas (LDA), and Resource Conservation Areas (RCA); development is regulated based on requirements of the Anne Arundel County Critical Area Program
- *Regulatory stream buffer* – buffer width varies depending on stream class. Three buffer widths, 0-50, 50-75, and 75-100 feet, are used depending on the adjacent slope. In the Upper Patuxent most buffers fell within the 0-50 feet buffer, because the area is relatively flat.
- *Redevelopment value and zone* – includes assessed value of land for a particular parcel plus improvements. The County identifies commercial parcels where the improvement value is less than the assessed value. The purpose of this is to identify new development or redevelopment likelihood. This parameter is not as prevalent in the Upper Patuxent River watershed compared to other watersheds due to a relative dearth of commercial parcels.
- *Schools and parks* – indicates presence or absence of schools or parks. The rationale for the inclusion of this parameter is that schools and parks are thought to be less likely to be developed in the future. After looking at the GIS layer and its attributes, LimnoTech noted that some of the area includes non-school land owned by the Board of Education. It was proposed that Board of Education land not associated with a school would not necessarily be as immune to development as school property. The County indicated that they will investigate the layer to determine if it is appropriate to clean up the dataset to remove non-school polygons.
- *Cemeteries* - indicates presence or absence of cemeteries. Again, the rationale for inclusion is that cemeteries would be less likely to be developed in the future. The County noted that this layer was different from the parcel layer cemetery designation, as some churches have old plots on the premises that are not captured in the parcel layer. This layer was digitized from orthophotography.
- *Ownership* – includes ownership for public lands. The purpose of this layer is to guide BMP placement for future development scenarios.
- *Greenways* – includes lands designated as such on the Greenways Master Plan. The County noted that this layer is important for evaluating water quality.
- *Expanded buffer* – includes a 300 ft stream buffer in areas with no public sewer service. The County again noted that this parameter is important for evaluating water quality. This is a County proposed metric that will help keep future development away from areas where septic systems could short circuit directly to a waterbody.
- *Zoning codes* – differs from the land cover code, but can be translated to allow for comparisons between current and future scenarios.
- *Sewer timing* – this layer is used for long range planning purposes.
- *Septic delivery ratio* – obtained from 2007 septic system study, which considers distance from stream, soil type, and slope, and is based on permits and residences in the sewer service area that are not being billed. The County noted that the layer does not account for pollutant fate or whether the septic discharge is in headwater or tidal areas.

After the review of the GIS layers that they employ, the County briefly discussed the methods and rules for their modeling efforts. The County also showed the model template that they use to calculate loads for current and alternate future conditions. Loading parameters that the County uses include total nitrogen, total phosphorus, nitrogen oxides, fecal coliform, and metals. Loading determinations are made for each of the TMDL categories (*i.e.*, urban, agricultural, and other). Loads are also calculated separately with and without BMPs.

Future development conditions follow a number of assumptions that the County noted. Development is assumed not to occur in floodplains, steep sloped areas, wetlands, certain stream buffers, schools and parks, cemeteries, and utility corridors. The County then performs a series of tests to determine whether and what type of new development can occur for a particular polygon. This involves evaluating the land cover layer, zoning code, and potential redevelopment values. Bioretention retrofits opportunities are also identified in both public and private areas. Impervious cover assumptions are made for each future scenario, as well as assumptions about stormwater management and future septic loading.

The County shared the preliminary model results for the Upper Patuxent River watershed, which were presented separately for the northern section, the southern section, and overall. Scenarios, for which loading was calculated, included the addition of bioretention facilities, street sweeping, ditch retrofits, wet pond retrofits, septic upgrades, greenways, and various new developments. The County noted that the plan for the future is to be able to share this data with the public and other County entities.

In reviewing the GIS data, LimnoTech noted that some polygons didn't appear to represent a parcel or piece of land that could actually be developed. The County replied that much of this was an artifact of the residential buffering process that the County described previously. The County noted a need to rectify the land cover layer to the parcel layer before GIS processing for model inputs. The County revealed that the Upper Patuxent River watershed is the first study for which they had the parcel layer, which is why there are some disconnects between the parcel layer and other GIS layers. The County remarked that much of it boils down to an issue of scale. The assumptions and GIS processing associated with the modeling are appropriate for large scale watershed wide analysis, but become less appropriate for smaller sites or at neighborhood wide scales.

Mapping and Data Products from Stream and Subwatershed Prioritization Efforts

The County stated that the stream and subwatershed prioritization efforts were nearly complete. The County noted that they are making a fundamental shift in terminology. The terms "ranking" and "priority" will be eliminated and replaced by "rating" and "assessment," respectively. The rationale for this shift was that the County did not want there to be an expectation of priority associated with particular reaches or subwatersheds. LimnoTech agreed that this new terminology seemed appropriate.

For the subwatershed restoration modeling, the County remarked that they were still trying to decide whether to use the overall final habitat score (FHS) or the reach condition score as described during the last professional management team meeting. LimnoTech suggested potentially including both, with the worst of the two values actually being used in the assessment on a case by case basis. The County indicated that they would consider this. The County spoke internally about whether and how the bioassessment data should be used in its assessment modeling. There was some concern that at best there is only a single bioassessment point for each subwatershed. The County indicated that they will consider if and how to include bioassessment data in their modeling.

For the other indicators, the County noted that there were only a few changes since the last meeting. For the peak discharge indicator, the County stated that they were now using the peak discharge per acre as LimnoTech had suggested previously. For the nutrient and metal loading indicators, the County noted that there were no changes but that they needed to update the models based on the newly adopted EMC values. For the septics indicator, the County changed the parameter to be nitrogen load in pounds per acre rather than the number of connections per acre.

The subwatershed preservation modeling had a few similar modifications. Again, the County indicated that they needed to make a determination on whether to use FHS, reach conditions, or both. The County noted that the erodibility indicator is now the k factor, as previously suggested.

Miscellaneous

The County requested that LimnoTech make a final recommendation on how the additional parameters could be incorporated into the modeling efforts or otherwise used by the County. LimnoTech agreed to do so.

Action Items:
- Make recommendation on use of additional parameters *[LimnoTech]*

The tentative date for the next and last professional management team meeting was set for April 9, 2008, at the County offices.

DATE: May 14, 2008

Memorandum

FROM: Brian Busiek, P.E.

TO: Hala Flores, P.E.
Acting Watershed Management Program Administrator
Anne Arundel County Department of Public Works

CC: Richard Fisher – Anne Arundel County
Dan Herrema, P.E. – LimnoTech
Tad Slawecki – LimnoTech
Michael Sullivan – LimnoTech

SUBJECT: Upper Patuxent River Watershed Study, Task 4 – Professional Management Team, Minutes from Fourth Professional Management Team Meeting, April 9, 2008

LimnoTech and Anne Arundel County Department of Public Works staff met on April 9, 2008, for the fourth and final professional management team meeting to discuss the Upper Patuxent River Watershed Study. The purpose of these meetings is to collaborate on approaches and methods used to assess watershed and stream health and to set priorities for restoration and preservation. This fourth meeting entailed a final look at the water quality and assessment modeling results and wrap up of all deliverables. The following agenda items were set for the meeting:

1. Review project deliverables and follow-up from previous meeting
2. Discussion of water quality modeling results
3. Discussion of stream restoration assessment results
4. Discussion of subwatershed restoration assessment results
5. Discussion of subwatershed preservation assessment results
6. Expectations for Final Summary report

Mike Sullivan, Tad Slawecki, and Brian Busiek represented LimnoTech while Mary Searing, Hala Flores, and Richard Fisher represented the County. The following represents the summary notes from the meeting.

Review Project Deliverables and Follow-up from Previous Meeting

The meeting opened with a discussion of all project deliverables and the minutes and action items from the previous professional management team meeting. These are presented briefly below.

<u>Task 1 Deliverables</u>

The deliverables for Task 1 – Project Planning and Coordination included a detailed project plan, which was submitted at the beginning of the project in April 2007, and meeting minutes submitted following each of the monthly project status meetings. Both LimnoTech and the County agreed that all deliverables and contract requirements related to this task were complete.

Task 2 Deliverables

The deliverables for the various subtasks under Task 2 – GIS Data Collection and Acquisition were submitted over the course the project. The deliverables and their status are presented below.

- Stream reach GIS layer (Subtask 2.1) – completed
- Rosgen Level I GIS layer and Manning n spreadsheet (Subtask 2.1) – completed
- Stream crossing GIS layer and stream crossing geometry spreadsheet (Subtask 2.1) – completed
- Urban BMP GIS layer and explanatory technical memorandum (Subtask 2.2) – completed
- Ag BMP GIS layer and explanatory technical memorandum (Subtask 2.3) – completed
- Metadata for all GIS layers – submitted but still undergoing review by the County

Task 3 Deliverables

As with the Task 2 deliverables, those for the various subtasks under Task 3 – Physical Habitat Condition Assessment were submitted over the course the project. The deliverables and their status are presented below.

- Base flow sample GIS layer and laboratory results spreadsheet (Subtask 3.1) – completed
- Physical habitat condition and inventory GIS layer, populated SAT database template, and photos (Subtask 3.2) – completed
- Subshed specific maps and data summaries (Subtask 3.2) – the County noted that the factsheets proposed by LimnoTech for the northern and southern sections of the Upper Patuxent River watershed would replace any subshed specific maps or data summaries. These factsheets are currently in production and a draft version will be submitted to the County for review in the coming weeks.
- Rosgen Level II geomorphic report (Subtask 3.3) – completed
- Metadata for all GIS layers – completed

Task 4 Deliverables

The deliverable for Task 4 – Professional Management Team Meetings includes the meeting minutes for the four professional management team meetings. The minutes for the first three meetings have been submitted and were accepted by the County. The minutes for the fourth and final meeting are represented by this document. The only other deliverable associated with this task is the final summary recommendations report, which both LimnoTech and the County agreed to discuss in more detail at the end of the meeting.

Review of Previous Meeting Minutes

In reviewing the minutes from the third professional management team meeting, the County noted that LimnoTech had submitted and the County had accepted final versions of the Rosgen Level II geomorphic report, the agricultural BMP technical memorandum and GIS layer, and the urban BMP technical memorandum.

The County noted that since the last meeting they had reviewed and made revisions to their Rosgen Level I classifications. The County noted that an analysis of the channel types across the watershed and the photos of the Rosgen locations taken in the field seems to support most classifications. The County requested that LimnoTech perform a spot check of the results using photos and field notes to confirm the Rosgen Level I classifications.

Discussion of Water Quality Modeling Results

Since the previous professional management team meeting, the County completed the water quality modeling for a full suite of alternate future scenarios. The results were presented during the meeting in the form of oversized charts and a spreadsheet. The County walked LimnoTech through the results for each scenario. During this it was noted that the best opportunities for nutrient reductions were from implementation of bioretention in the County right-of-way and select private lands.

The County presented a second spreadsheet that showed the bioretention opportunities in the County. It was noted that such an analysis can be used to focus the County's efforts for implementation and capital improvement projects. The spreadsheet also showed additional opportunities related to street sweeping, ditch retrofits, public dry pond retrofits (which, as discussed previously, suffer somewhat from new downgraded efficiencies), septic system upgrades (which can include connecting to the sewer system, adding denitrification technology, or connecting to a clustered system), number of acres of greenways that can be preserved, and 300 foot forested buffers (which is not specified in County codes, but would be lobbied for with potential future development projects).

The County provided a third spreadsheet that focused on costs. The County noted that their bioretention unit costs were obtained from their experience in the Baltimore Harbor but admitted that they may require some additional refinement. LimnoTech asked whether these costs included O&M or future replacement costs. The County noted that they did not, but that they did include upfront design and contingency costs. LimnoTech revealed that they have ready access to unit costs and O&M costs related to bioretention from several sources that they would be happy to share with the County. The County indicated that they would be interested in this data.

The County went on to discuss costs related to dry to wet pond conversion, septic system upgrades, ditch retrofits, street sweeping, greenway preservation, and 300 foot forested buffers. The County noted that they would check with their capital improvement program to obtain better cost data related to septic system upgrades and ditch retrofits. It was stated that the greenway preservation and 300 foot buffer costs did include land acquisition costs and that the Severn River final report would be a good source for cost development methods.

The County noted the importance of goal development for their watershed modeling. The Severn River study consultants performed an analysis of the correlation of total phosphorus load per impervious acre and a "Good" bioassessment score. The result was a value of 0.35 lbs per acre. In this analysis, the County considered total nitrogen loading as well, but it was determined that septic system influences were skewing the results. Using this total phosphorus goal allows the County to determine which future scenarios would be the most beneficial to watershed health. The County suggested that they would like individual goals for each watershed, but as more watershed studies are completed they could consider moving towards a County-wide goal (which is important for determining County-wide spending priorities). The County indicated that they would perform the correlation analysis to determine the goal for the Upper Patuxent and requested that LimnoTech provide feedback when the analysis was available.

Both LimnoTech and the County spent some time reviewing large scale maps depicting many of the modeling elements discussed above (*e.g.*, septic and sewer system connections, greenways, BMPs, landcover, etc.)

Discussion of Stream Restoration Assessment Results

The County presented the results from the latest stream restoration assessment (formerly prioritization). The County revealed that there were no changes since the previous incarnation except that the modified Rosgen I classifications were now incorporated. During the presentation, the County noted that there was a previously unidentified issue with the way the assessment tool was processing MPHI data. The County stated that they would look into this further and provide corrected results to LimnoTech. With the assumption that LimnoTech's review of the Rosgen Level I classifications would not yield any further issues, the County indicated that the next revised data set will be considered final and can safely be referenced in the final report and fact sheets.

Discussion of Subwatershed Restoration Assessment Results

The County also presented results from the final subwatershed restoration assessment. The County indicated that there were only superficial changes since the previous incarnation. It was noted that the County chose to use the final habitat score (FHS) rather than overall rankings as was previously being considered.

It was also noted that total nitrogen and total phosphorus loading from runoff and from septic systems were analyzed in terms of lbs per year and rather than lbs per year per acre. LimnoTech objected that this approach would unfairly penalize large watersheds. The County indicated a desire to be consistent with the nitrogen loading from the septic systems. The County made a strong and convincing case that the septic component should **not** be area-normalized because this causes rankings to skew heavily towards smaller watersheds. LimnoTech agrees that this is reasonable. However, LimnoTech noted that similar treatment of the runoff components (i.e. not area-normalized) is inappropriate, as this skews rankings based on these components toward larger watersheds and reduces the value of the metric in terms of water quality. LimnoTech strongly recommends that the nitrogen and phosphorus model results be area-normalized when used in prioritization while continuing to express the septic component in terms of total watershed load.

The County noted a desire to maintain dimensional consistency between the different scoring components. While this is understandable, LimnoTech noted a few other components where dimensional consistency was not followed. For example, the flow and volume components of the subwatershed prioritization are area-normalized, so there are other components which are not dimensionally consistent.

LimnoTech also noted that septic systems are addressed on a point basis, so it makes sense from a mitigation standpoint to ignore area; one septic system in a 1,000-acre watershed will require about the same level and cost of treatment as a single septic system in a 10-acre watershed. LimnoTech further noted that surface runoff is diffuse, and treatment cost generally increases as treated area increases. From a mitigation standpoint, 1,000 pounds of nitrogen coming off of the landscape of a 1,000 acre watershed is likely to cost more to treat than 1,000 pounds of nitrogen coming off of a 100 acre watershed. This is because of the increased treatment volume from the larger watershed. Prioritization based on total watershed loads would give these two hypothetical watersheds equal scores when it is in fact more practical to work on the smaller watershed.

The County maintained their position and asked LimnoTech to document their objections in the final summary report.

Discussion of Subwatershed Preservation Assessment Results

The County briefly presented the results of the subwatershed preservation assessment. It was noted that the only change from the previous incarnation was the use of historical anadromous fish data, which is slightly more conservative than the previous data set.

Expectations for Final Summary Report

The County communicated their expectations regarding the final summary report requested under Task 4. The County suggested that the report serve as an executive summary of the work performed by LimnoTech and the County for the Upper Patuxent River watershed study. It was noted that the report should attempt to synthesize the summary findings from the various technical memorandums, meeting minutes, and County-produced modeling results and ratings. Each of these elements can be appendices to the summary report.

The County also requested that the report communicate findings and recommendations that may be of interest to both Maryland Department of the Environment (MDE) as well as the public. This should include any recommendations that came out of the professional management team meetings as well as any observations inspired by review of the County’s modeling and assessment results. Examples of possible recommendations include the need to rectify the County land cover layer with the parcel layer and LimnoTech’s suggestion that loading calculations be normalized by the subwatershed area. Examples of possible observations include the possibility of utilizing high indicators of erosion to help direct capital improvement work, noted areas with high development but limited BMPs, and any correlation with impervious areas, bioretention, and nutrient loads. The County also expressed an interest in letting MDE know of the issues that LimnoTech and the County have encountered surrounding privacy rules that limit the County’s access to important data related to agricultural land management practices. LimnoTech agreed that this type of summary report would be beneficial.

The County noted that there would be no draft review of this deliverable. The draft submitted by LimnoTech would be considered the final deliverable.

DATE: February 6, 2008

Memorandum

FROM: Michael Sullivan
Tad Slawecki
Dan Herrema, P.E.
Brian Busiek, P.E.

TO: Mary Searing, P.E.
Watershed Management Program Administrator
Anne Arundel County Department of Public Works

CC: Richard Fisher – Anne Arundel County
Hala Flores, P.E. – Anne Arundel County

SUBJECT: Upper Patuxent River Watershed Study, Task 4 – Review of Professional Management Team Items from Initial Task 4 meeting.

LimnoTech and Anne Arundel County, Department of Public Works staff met on December 27, 2007, for the first of four professional management team meetings to discuss the Upper Patuxent River Watershed Study. The purpose of these meetings was to review and collaborate on approaches and methods for assessing watershed and stream health and to setting priorities for restoration and preservation. This first meeting served as a primer for the current assessment and prioritization practices that the County employs. The following goals were established for the meeting:

- Clarify outstanding issues and questions
- Review and discuss methodology (categories, indicators, and weights) for stream restoration prioritization for Upper Patuxent
- Review and discuss methodology (categories, indicators, and weights) for subwatershed restoration prioritization for Upper Patuxent
- Review and discuss methodology (categories, indicators, and weights) for subwatershed preservation prioritization for Upper Patuxent
- Introduce methods for water quality modeling for future discussion purposes

Following that meeting, the County provided LimnoTech staff with several items for their review and comment. The purpose of this memo is to identify the materials reviewed by LimnoTech for the County, and LimnoTech comments on those items pertaining to our review. Specifically, the following materials were received from the County following the December 27th meeting:

- Zip folder (Reach Rank.zip) containing the AA County Stream Restoration Prioritization Spreadsheet, for LimnoTech to:
  - Validating the accuracy of the computations,
  - Learning if final prioritizations verify well with our field observations, and
  - Cursory review of statistical relationships that may exist and help with assigning weights more appropriately,

- BMPs_Bio_Clean.xls file containing BMP removal efficiencies for LimnoTech to review and comment on.
- EMCs_Clean.xls file containing event mean concentration data used for input by the County.
- A technical memorandum on street sweeping review and recommendations on appropriate pollution reduction values and use of modeling method. Also review and feedback on the memos discussion of storm drain and inlet cleanout benefits and values.

The following sections summarize LimnoTech's review of these items, along with any recommendations for revision or consideration.

AA County Stream Restoration Prioritization Spreadsheet Review

Spreadsheet Computations Validation

LimnoTech performed a thorough review of the underlying calculations, formulas, and links within the stream restoration prioritization spreadsheet provided by the County. LimnoTech looked for broken or inaccurate cell references and examined cell formulas, links and calculations to ensure consistency with those in the most recent version of the prioritization model discussed at the professional management team meeting. LimnoTech found that the spreadsheet was in good working order and consistent with current approaches.

Discussion of Results and correlations with LimnoTech Field Observations

LimnoTech reviewed field notes and photos of a subset of reaches having the highest and lowest preliminary rankings (Table 1). Based on our review and knowledge after having performed the field data collection effort, these rankings are consistent with our field sense of the best and poorest streams.

Cursory Statistical Relationships Review

LimnoTech used statistical tools to evaluate (1) the degree of correlation between MPHI scores and additional collected parameters in the Upper Patuxent watershed, and (2) the general appropriateness of weights used to combine indicators for preservation or restoration rankings. The evaluations, which are described in more detail in Appendix A, showed that:

1) The additional collected parameters Human Intervention, Riparian Invasive Plant Species, Barriers to Fish Movement, Overall Channel Condition, and Channel Incision are not highly correlated to MPHI score or components, and therefore may offer new information.

2) The weights assigned by the County to the different component indicators used in prioritization for preservation and restoration are consistent with coefficients developed in the analysis, and no changes to the weights are suggested.

Review of BMP Removal Efficiencies

LimnoTech reviewed the BMP removal efficiencies for individual BMP and pollutant categories provided by the County and compared the County values with other local and national literature sources. The sources included the Center for Watershed Protection (2007) and EPA (1999). This review and comparison revealed that the removal efficiencies (percent removal) used buy the County are generally in line with literature values for most of the BMP and pollutant categories for which we were able to make a comparison. However, we did note a few exceptions as follows:

- Literature values for detention structures/dry ponds were higher than County values for the removal of TN, copper, zinc and lead.
- Literature values for dry well/infiltration trenches were lower than County values for removal of TP.
- Literature values for infiltration basins were higher than County values for removal of copper, zinc and lead.
- Literature values for porous pavement were higher than County values for removal of copper and lead.
- Literature values for shallow marsh/constructed wetland were higher than County values for removal of lead.
- Literature values for bioretention facilities were higher than County values for removal of NOx.

Noted differences between County and literature values are provided in Table 2. The full spreadsheet comparison and analysis can also be provided upon request.

Review of Event Mean Concentration Values

LimnoTech reviewed the event mean concentration (EMC) values for individual land use categories provided by the County and compared the County values with other local and national literature sources. The sources included the Center for Watershed Protection (2005), Center for Watershed Protection and VA DCR (2007), and Robert Pitt, et. al. (2004). This review and comparison revealed that the EMC values used by the County are generally in line with literature values for most of the land use/EMC combinations for which we were able to make a comparison. However, we did note a few exceptions as follows:

- Literature values for fecal coliform EMCs were generally higher than County values for several land use categories.
- Literature values for TSS EMCs tended to be lower than County values for several land use categories.
- Literature values for zinc and lead EMCs for the Open Space land use category are lower than County values.

Noted differences between literature and County values are provided in Table 3. The full spreadsheet comparison and analysis can also be provided upon request.

Review of Street Sweeping Technical Memorandum

LimnoTech reviewed the technical memorandum on removal rates for street sweeping and storm drain cleanout. The analysis and conceptual model presented in the memorandum are sound, and LimnoTech agrees that the recommended interim removal rates for solids and nutrients are reasonable – as long as the contributing sources and associated loads are well matched with the BMP applied. In other words, the County should be careful to apply the indicated street sweeping removal rates only to that portion of the pollutant load which can actually be collected from the streets; street sweeping should not affect loads from other sources, such as runoff from agricultural lands.

LimnoTech also identified two projects that the County may already be aware of:

- *Deriving Reliable Pollutant Removal Rates for Municipal Street Sweeping and Storm Drain Cleanout Programs in the Chesapeake Bay Basin* – source of technical memorandum under review, monitoring and evaluation ongoing? (http://www.epa.gov/region3/chesapeake/grants/Progress/Workplan_CB97322201.pdf)

- *Evaluation of Street Sweeping as a Stormwater-Quality-Management Tool in Three Residential Basins in Madison, Wisconsin.* Data show little measurable impact from street sweeping activities, supporting the use of relatively low removal rates. (http://pubs.usgs.gov/sir/2007/5156/pdf/SIR_2007-5156.pdf).

LimnoTech also interviewed Roger Sutherland of Pacific Water Resources, a long-time promoter of the efficacy of street sweeping, who expressed his opinion that the removal rates in this memorandum are reasonable given the limits of data collection. He feels strongly, however, that detailed monitoring would demonstrate that the 90% collection efficiency of modern street sweeping technology can in fact translate into significantly higher net removal rates.

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EPA. 1999. *Preliminary Data Summary of Urban Storm Water Best Management Practices.* Office of Water, Washington, DC. EPA-821-R-99-012. Available at http://epa.gov/guide/stormwater/files/usw_a.pdf

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Watershed Protection, Ellicot City, MD. Available at:
http://www.cwp.org/NPDES_research_report.pdf;
http://rpitt.eng.ua.edu/Research/ms4/Paper/Mainms4paper.html

Table 1. Sample of Reach Subset Correlated with LimnoTech Field Observations

Reach	Normalized Ranking Score	Priority Ranking	Priority Category
UPI042	56	1	Very Poor
UPG017	57	2	Very Poor
UP8016	61	3	Very Poor
UPF026	62	4	Very Poor
UPF028	62	4	Very Poor
UPH008	62	4	Very Poor
UPJ025	62	4	Very Poor
UPJ038	62	4	Very Poor
UPB027	65	9	Very Poor
UPB069	65	9	Very Poor
UPD022	65	9	Very Poor
UPF025	65	9	Very Poor
UPH030	65	9	Very Poor
UPH003	100	358	Good
UPH005	100	358	Good
UPH010	100	358	Good
UPH011	100	358	Good
UPH017	100	358	Good
UPH021	100	358	Good
UPH022	100	358	Good
UPH031	100	358	Good
UPH036	100	358	Good
UPJ008	100	358	Good

Table 2. Differences Noted Between Literature and County BMP Removal Efficiency Values

	Removal Efficiency NOx	Removal Efficiency NOx
BMP category	**County**	**Literature**
Bioretention facility	0%	43%

	Removal Efficiency TN	Removal Efficiency TN
BMP category	**County**	**Literature**
Detention structure - dry pond	5%	15-45%

	Removal Efficiency TP	Removal Efficiency TP
BMP category	**County**	**Literature**
Dry well - infiltration trench	100%	15-45%

	Removal Efficiency Copper	Removal Efficiency Copper
BMP category	**County**	**Literature**
Detention structure - dry pond	10%	29-80%
Infiltration basin	30%	50-86%
Porous pavement	0%	50-80%

	Removal Efficiency Zinc	Removal Efficiency Zinc
BMP category	**County**	**Literature**
Detention structure - dry pond	5%	29-80%
Infiltration basin	21%	66-99%

	Removal Efficiency Lead	Removal Efficiency Lead
BMP category	**County**	**Literature**
Detention structure - dry pond	0%	50-80%
Infiltration basin	0%	50-98%
Porous pavement	0%	65-100%
Shallow marsh - constructed wetland	0%	63%

Table 3. Major Differences Between County EMCs and Literature Values

	Fecal Coliform (mpn/100 ml)	Fecal Coliform (mpn/100 ml)
Land Use	**County EMC**	**Pitt 2004**
Commercial	1262	4500
Open Space	500	3100
Residential	952-2309	7750

	TSS (mg/l)	TSS (mg/l)
Land Use	**County EMC**	**Range in Literature**
Commercial	400	43-56
Industrial	400	77-83
Residential	0-350	48-55
Transportation	400	99[1]

[1] Pitt 2004

	Zinc (mg/l)	Zinc (mg/l)
Land Use	**County EMC**	**Pitt 2004**
Open Space	0.195	0.039

	Lead (mg/l)	Lead (mg/l)
Land Use	**County EMC**	**Pitt 2004**
Open Space	0.03	0.005

DATE: March 11, 2008

Memorandum

FROM: Michael Sullivan
Tad Slawecki
Dan Herrema, P.E.
Brian Busiek, P.E.

TO: Mary Searing, P.E.
Watershed Management Program Administrator
Anne Arundel County Department of Public Works

CC: Richard Fisher – Anne Arundel County
Hala Flores, P.E. – Anne Arundel County

SUBJECT: Upper Patuxent River Watershed Study, Task 4 – Review of Professional Management Team Items from the second Task 4 meeting

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LimnoTech and Anne Arundel County, Department of Public Works staff met on February 13, 2008, for the second of four professional management team meetings to discuss the Upper Patuxent River Watershed Study. The minutes of that meeting are summarized in a memorandum submitted to the County electronically on February 28, 2008. The purpose of this memo is to provide follow-up reporting on certain items LimnoTech agreed to evaluate further during the course of that meeting.

The text below provides an update on where outstanding deliverables are at in terms of revisions or plans for submittal, as well as a summary of LimnoTech's further evaluation of certain topics discussed at the meeting.

Status of Documents:

- **Subtask 2.1.4 Rosgen Level I Cross-Sections and Profiles:** No additional items are outstanding from LimnoTech on this item.
- **Subtask 2.2 Urban BMPs:** Statistical and summary results of the BMP analysis were received from the County on March 4, 2008. LimnoTech has incorporated these and previously received comments on the draft deliverable. A revised submittal will be delivered one week following receipt of the County's full comments on the BMP dataset, which was submitted on February 7, 2008.
- **Subtask 2.3 Agricultural BMPs:** A revised memorandum addressing comments received from the County has been completed. Updates to the available GIS dataset are almost complete. LimnoTech is waiting for the County to provide preferred land use type categories before completing the GIS revisions. A revised report, GIS layer, and the previously requested poster-sized maps will be delivered one week following receipt of the land cover categories.
- **Subtask 3.1 Baseflow Sampling:** No additional items are outstanding from LimnoTech on this item.

- **Subtask 3.3 Rosgen Level II Geomorphic Report:** A discussion was held during the February 13, 2008, PMT meeting on the County's comments on the initial draft document submitted January 31, 2008. A revised report addressing those comments is anticipated to be submitted to the County by March 14, 2008.
- **Current Condition Subwatershed Factsheets:** A draft factsheet template was submitted to the County in December 2007. The County is planning to provide LimnoTech with comments during the week of March 17, 2008.
- **PMT Meeting Minutes:** Meeting minutes from the second PMT meeting were submitted to the County on February 28, 2008. LimnoTech is currently awaiting the County's review/acceptance of these minutes.
- **Statistical Regression Analysis and Task 4 – Review of PMT Items from Second Task 4 Meeting:** Some additional discussion and requested evaluations were requested of LimnoTech as a result of the second PMT meeting. Those evaluations are presented in the next section of this memorandum.

LimnoTech Review of Second PMT Meeting Items

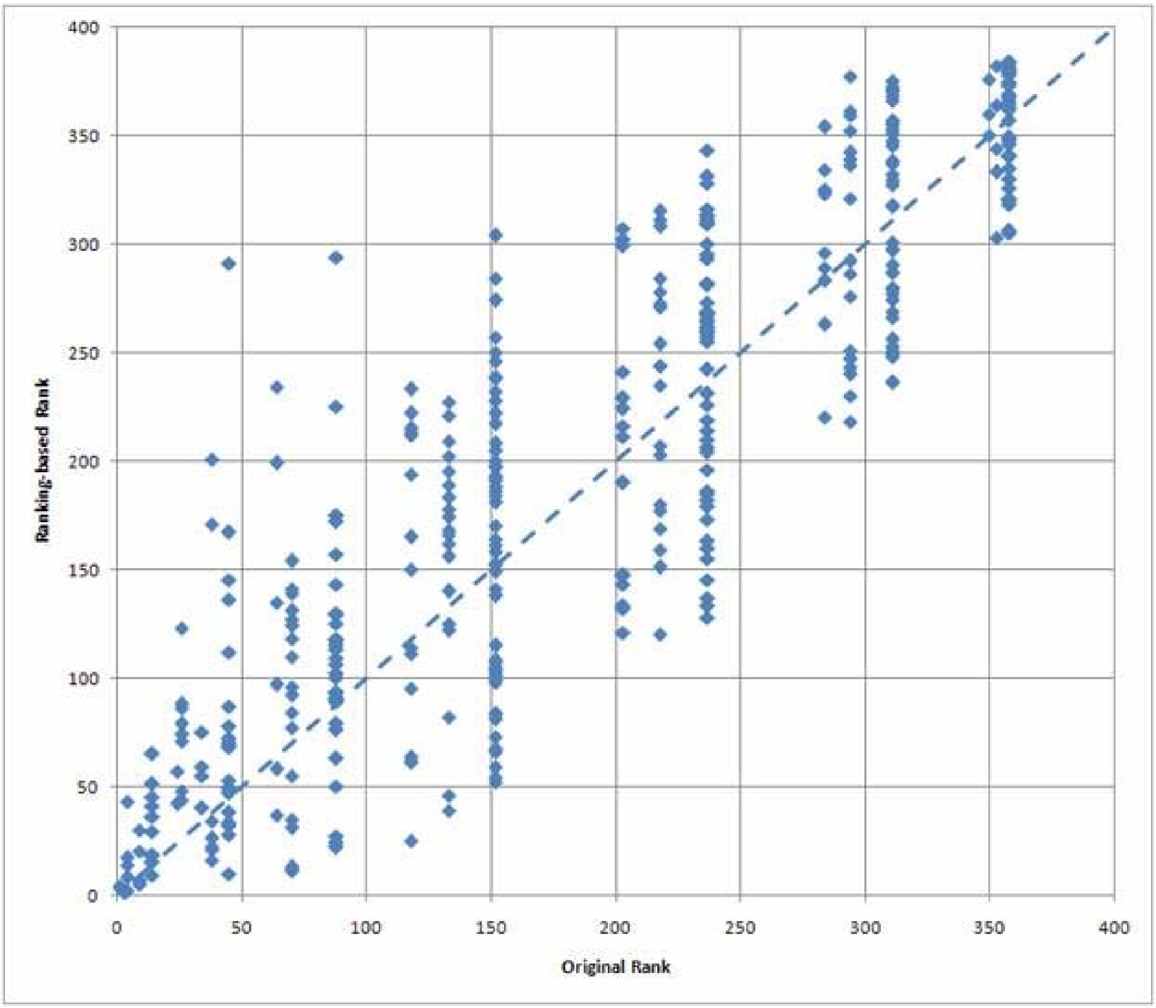
1. LimnoTech reviewed the question of appropriate contributing area for calculating loads affected by street sweeping BMPs. Although some arguments can be made for run-on from adjacent surfaces depositing on roadway surfaces and therefore being subject to removal by street sweeping operations, LimnoTech recommends that the load calculation be based strictly on the area of road surface. This is because the event-mean concentration being used in the load calculation is based on monitoring data collected from accrual roads that likely receive run-on from adjacent surfaces. Some allowance might be justifiable if the event-mean concentrations being used are known to come from studies where run-on was controlled or non-existent – e.g. an elevated roadway. However, LimnoTech would still recommend the conservative approach of using just the road surface area for this calculation in this case.

2. LimnoTech researched the availability of code, particularly in Excel, for the Jenks natural break classification scheme. A partial implementation for teaching purposes was found at http://web.archive.org/web/20011129093331/http://www.dartmouth.edu/~dbkarnes/jenks/jenks.html. An R (public domain statistics package) was discussed briefly at https://stat.ethz.ch/pipermail/r-sig-geo/2007-November/002830.html. An article (Cromley, R. G., 1996, A comparison of optimal classification strategies for choroplethic displays of spatially aggregated data. International Journal of Geographical Information - http://puck.ingentaconnect.com/vl=838771/cl=26/nw=1/rpsv/0269-3798^28^2910l.405[cw=1] (not acquired) is cited as a source of "useful optimal natural break variants" that could be useful to review for alternatives to the Fisher-Jenks algorithm. LimnoTech could implement the optimal solution for Jenks optimization in this article, but would need to discuss the County's needs and desired interface before developing cost estimates.

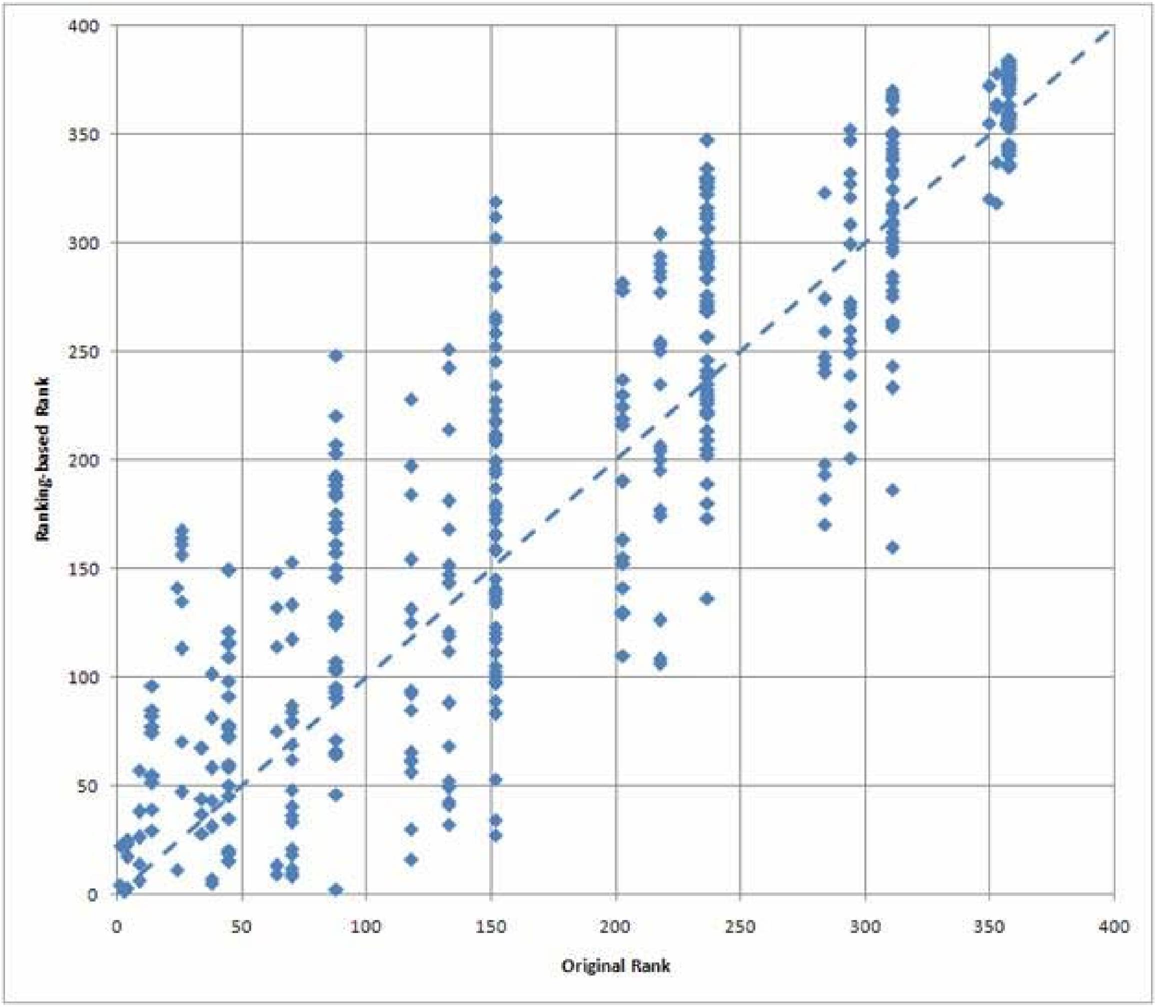
3. LimnoTech expanded the discussion of the statistical analysis of additional collected field parameters in response to comments from the County. The updated was provided to the County on March 11, 2008.

4. LimnoTech investigated the use of rank-based scoring for Upper Patuxent reaches. As an alternative to combining weighted translations of indicator scores to a lesser number of categories, LimnoTech combined the weighted rankings of indicator scores. Some difficulties were encountered with indicators that had only narrative descriptions and with indicators that had many scores of “na”. Rankings were done on the category scores for the former, and “na” values were set to either 384 (total number of reaches) or to the number of non-NA values for that indicator. The accompanying charts suggest that setting the rank of “na” scores to 384 gives a better result. However, the charts also show that although there is a strong overall trend, there is a lot of variation from the County’s original rankings. For example, the reaches ranked 150 by the County were ranked from 50 to 325 using the alternative approach. LimnoTech does not recommend further exploration of this alternative scheme for ranking.

1a) NA ranks set to n+1, where n = number of non-NA values



1b) NA ranks set to 384



LimnoTech
Water | Environment | Scientists | Engineers

DATE: March 11, 2008

Memorandum

FROM: Michael Sullivan
Tad Slawecki
Dan Herrema, P.E.
Brian Busiek, P.E.

TO: Mary Searing, P.E.
Watershed Management Program Administrator
Anne Arundel County Department of Public Works

CC: Richard Fisher – Anne Arundel County
Hala Flores, P.E. – Anne Arundel County

SUBJECT: Regression Analyses

Introduction

This memo summarizes the methods and results of statistical analyses used to evaluate the relationship of (1) additional parameters collected by LimnoTech during field stream surveys to the MPHI score calculated by other parameters and of (2) component indicators to subwatershed rankings for preservation.

For the analysis of additional collected parameters, LimnoTech first looked at the correlation coefficients between the calculated MPHI score and the additional parameters, which were:

- Human Interaction
- Terrestrial Habitat
- Riparian Invasive Species
- Canopy Cover
- Riffle Embeddedness
- Barriers to fish movement
- Instream fish cover (similar to the instream habitat parameter of the MPHI)
- Pools
- Insect/invertebrate habitat (similar to the MPHI epifaunal category)

Correlations of the MPHI scores and the new parameters thus summarize the strength of the linear relationships between each pair of variables.

LimnoTech also performed a multiple linear regression analysis to determine if changes in the additional parameters were reflected in changes in the MPHI score. This allows evaluation of whether the additional collected parameters are already reflected in the MPHI score.

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The difference between the correlation analysis and the multiple linear regression is that the correlation analysis only looks at individual relationships. Multiple linear regression measures the changes in MPHI score with respect to a linear combination of multiple variables that each contribute to changes in MPHI. Stepwise regression was used to determine the most significant parameters.

The second evaluation used multiple linear regression to examine how the prioritization ranking of subwatersheds were related to the unweighted indicators:

- MPHI 2003
- Rosgen Leve1
- Contributory Percent Imperviousness
- Buffer
- Erosion
- Head Cut
- Dumpsite
- Other Infrastructure
- Road Crossings
- Overall Channel Condition
- Channel Incision

Results from this analysis were used to confirm the importance of these variables and assess (at a crude level) whether the assigned indicator weights were appropriate.

Results

Additional Parameters versus MPHI

The correlation analysis of additional collected parameters to calculated MPHI score reveals the following high correlations (Table 1):

- MPHI score is most correlated to Instream Fish Cover and Insect/Invertebrates Habitat at the $p< 0.001$ significance level with r^2 values of 0.42 and 0.54 respectively. This makes sense since these variables are similar to other variables used to calculate the MPHI.
- Riffle Embeddeness ($r^2 = 0.41$) and possibly the presence of Pools ($r^{2=}$ 0.32) are correlated to MPHI score.

Strong correlations were also found between some of the additional collected parameters and the component scores for the MPHI, suggesting that the parameters may be functionally duplicative:

- MPHI component Shading is strongly correlated to the additional parameters Terrestrial Habitat ($r^2 = 0.65$) and Canopy Cover ($r^2 = 0.96$)

- MPHI components Instream Habitat and Epifaunal Substrate are highly correlated to additional parameters Riffle Embeddeness, Pools, Instream Fish Cover, and Insect/Invertebrate Habitat.
- The additional collected parameters Human Intervention, Terrestrial Habitat, Riparian Invasive Plant Species, and Barriers to Fish Movement are not highly correlated to MPHI score or components, and therefore may offer new information.

The multiple linear regression analysis performed with MPHI as the dependent (Y) variable, and the additional collected parameters (excluding Instream Fish Cover and Insect/Invertebrate Habitat, which are highly similar to MPHI component parameters) as the dependent variables (X). The analysis indicated that Human Intervention, Riparian Invasive Plant Species, Canopy Cover, Riffle Embeddedness, and Pools were the most important parameters in determining changes in MPHI score (Table 2). As discussed, Riffle Embeddedness, Canopy Cover, and Pools are highly correlated with the variables used to calculate MPHI score so they are expected to have higher estimates and be significant in the regression. Human Intervention and Riparian Invasive Plant Species contribute to the variability in MPHI when combined with the other variables in the regression, though their contribution is low, which suggests that there are some parameters in the MPHI calculation which contain surrogates for those parameters.

Table 1: Correlation analysis of MPHI versus additional parameters.

	Additional Parameters														MPHI Parameters				
	MPHI	Wtrshd. Area (acres)	Human	Terr. Habitat	Rip. Inv. Plant Sp.	Canopy Cover	Riffle Emb.	Barr. Fish Mvmt.	Instr. Fish Cvr.	Pools	Ins/Invert. Hab.	Overall Chan. Cond.	Channel Incision	Inst. Hab.	Epifaun. Sub.	Shading	Remote	Woody Debris	Bank Stabili
MPHI	1	-0.24	0.32	0.26	0.11	0.28	0.41	0.09	0.42	0.32	0.54	0.3	0.02	0.56	0.54	0.26	0.33	0.22	0.15
WatershedArea (acres)	-0.24	1	0.1	-0.06	0.13	0.05	-0.01	-0.15	0	0.11	0.09	0.05	0.06	0.02	0.12	0.05	0.14	0.06	0.09
Human Intervention	0.32	0.1	1	0.45	0.42	0.31	0.22	0.1	0.21	0.19	0.22	0.66	0.19	0.29	0.14	0.31	0.4	-0.02	-0.04
errestrial Habitat	0.26	-0.06	0.45	1	0.32	0.64	0.14	0.18	0.14	0.07	0.14	0.27	0.06	0.12	-0.09	0.65	0.09	-0.16	0.01
Riperian Invasive Plant Species	0.11	0.13	0.42	0.32	1	0.39	0.11	0	0.1	0.01	0.17	0.32	0.12	0.14	0.06	0.39	0	-0.08	0.01
Canopy Cover	0.28	0.05	0.31	0.64	0.39	1	0.15	0.04	0.03	-0.04	0.21	0.13	-0.01	0.03	-0.11	0.96	-0.07	-0.18	0.09
Riffle Embeddeness	0.41	-0.01	0.22	0.14	0.11	0.15	1	0.18	0.62	0.54	0.62	0.19	-0.01	0.64	0.6	0.12	-0.01	0.19	-0.13
Barriers to Fish Movement	0.09	-0.15	0.1	0.18	0	0.04	0.18	1	0.31	0.25	0.11	0.19	0.15	0.25	0.08	0.06	0.05	-0.05	-0.02
Instream Fish Cover	0.42	0	0.21	0.14	0.1	0.03	0.62	0.31	1	0.76	0.58	0.26	0.09	0.74	0.66	-0.02	0.1	0.27	-0.14
Pools	0.32	0.11	0.19	0.07	0.01	-0.04	0.54	0.25	0.76	1	0.5	0.16	0.05	0.67	0.64	-0.1	0.15	0.33	-0.2
sect/Invertebrate Habitat	0.54	0.09	0.22	0.14	0.17	0.21	0.62	0.11	0.58	0.5	1	0.19	0.03	0.65	0.68	0.17	-0.04	0.31	0.06
Overall Channel Condition	0.3	0.05	0.66	0.27	0.32	0.13	0.19	0.19	0.26	0.16	0.19	1	0.35	0.3	0.16	0.13	0.22	-0.02	0.16
Channel Incision	0.02	0.06	0.19	0.06	0.12	-0.01	-0.01	0.15	0.09	0.05	0.03	0.35	1	0.06	0.04	0	-0.01	-0.09	0.38
nstream Habitat	0.56	0.02	0.29	0.12	0.14	0.03	0.64	0.25	0.74	0.67	0.65	0.3	0.06	1	0.82	0	0.01	0.29	-0.06
pifaunal Substrate	0.54	0.12	0.14	-0.09	0.06	-0.11	0.6	0.08	0.66	0.64	0.68	0.16	0.04	0.82	1	-0.17	0.03	0.35	-0.05
Shading	0.26	0.05	0.31	0.65	0.39	0.96	0.12	0.06	-0.02	-0.1	0.17	0.13	0	0	-0.17	1	-0.05	-0.26	0.09
Remote	0.33	0.14	0.4	0.09	0	-0.07	-0.01	0.05	0.1	0.15	-0.04	0.22	-0.01	0.01	0.03	-0.05	1	-0.02	-0.13
Woody Debris	0.22	0.06	-0.02	-0.16	-0.08	-0.18	0.19	-0.05	0.27	0.33	0.31	-0.02	-0.09	0.29	0.35	-0.26	-0.02	1	-0.11
Bank Stability	0.15	0.09	-0.04	0.01	0.01	0.09	-0.13	-0.02	-0.14	-0.2	0.06	0.16	0.38	-0.06	-0.05	0.09	-0.13	-0.11	1

Table 2: Multiple linear regression with MPHI and additional collected parameters.

MPHI regression with new variables Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	56.98147	2.112873	26.97	<.0001
Human Intervention	0.347445	0.281167	1.24	0.2174
Riparian Invasive Plant Species	-0.41208	0.196902	-2.09	0.0371
Canopy Cover	1.107287	0.232181	4.77	<.0001
Riffle Embeddedness	0.963406	0.206171	4.67	<.0001
Pools	0.565894	0.20022	2.83	0.005
Terrestrial Habitat	Not found significant in analysis			
Barriers to Fish Movement	Not found significant in analysis			
Instream Fish Cover	Omitted – similar to MPHI component			
Insect/Invertebrate Habitat	Omitted – similar to MPHI component			

Terrestrial Habitat and Barriers to Fish Movement were the additional parameters not found significant in the regression and not correlated with MPHI. These two parameters may therefore provide additional information related to restoration priority not considered in the MPHI.

Rank Regressions

Stepwise regression was used to look at how the Reach Rank for restoration calculated by the County varies with respect to unweighted component indicators. In this way, the weights themselves can be re-assessed in terms of their importance ("Are the ranks correct?") by evaluating the magnitude of the coefficient (the higher the coefficient the more important the parameter). When performing stepwise regression, the inclusion of a parameter in the regression depends on how significant it is in predicting variability in rank. Since all of the variables were used to create the original rank, it is to be expected that the regressions with the unweighted variables will still be highly correlated to the rank. This is reflected in the results, where the significance of all of the parameters included in stepwise regression were <0.0001.

The stepwise regression results (Table 3) showed that MPHI had the highest predictive value across all of the datasets (Up, Severn, South, and Combined), meaning that it was most important or that it most strongly affects rank. Road Crossings and Other Infrastructure were the next most important in the rankings, which is consistent with the County's weighting system. In general, the weights used by the County are consistent with the regression coefficients from this analysis.

Table 3: Regressions of unweighted variables with Rank.

Variable	Old weight	UP New Estimate	UP Importance	Severn New Estimate	Severn Importance	South New Estimate	South Importance	Combined New Estimate	Combined Importance
MPHI	30	35.47	1	32.82	1	51.34	1	116.63	1
Rosgen Level 1	5	NA	9	4.98	8	10.53	5	18.3	6
Contributory Percent Imperviousness	5	7.03	5	5.5	7	9.3	6	20.14	5
Buffer	5	6.65	7	6.4	6	5.99	9	16.22	9
Erosion	10	11.38	4	7.4	5	15.4	3	29.87	4
Head Cut	5	5.28	8	7.4	4	8.7	8	17.75	7
Dumpsite	5	6.97	6	4.43	9	12.15	4	16.8	8
Other Infrastructure	15	19.54	3	13.42	2	28.5	2	59.65	2
Road Crossings	15	23.07	2	13.22	3	8.01	7	47.64	3

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Memorandum

DATE: April 7, 2008

FROM: Michael Sullivan
Tad Slawecki
Dan Herrema, P.E.
Brian Busiek, P.E.

TO: Mary Searing, P.E.
Watershed Management Program Administrator
Anne Arundel County Department of Public Works

CC: Richard Fisher – Anne Arundel County
Hala Flores, P.E. – Anne Arundel County

SUBJECT: Additional Field Parameters

Introduction

LimnoTech collected data on a group of additional field parameters as part of the physical habitat condition assessment in the Upper Patuxent Watershed. This memo summarizes our findings on the utility of these additional field parameters and contains recommendations on the use of these parameters in future watershed studies.

Findings

1. Several of the additional field parameters we collected were found to be highly correlated with their corresponding MPHI scores. Gathering additional data on these parameters (shown below) in future watershed studies would be redundant and is not recommended.

- Canopy Cover (shading)
- Riffle Embededness
- Instream Fish Cover
- Pools
- Insect/Invertabrate habitats

2. Several of the additional field parameters are not highly correlated with MPHI scores (*i.e.*, not redundant) and provide information that may be useful for purposes outside of scoring/ranking or assessment activities performed by the County (*i.e.*, as a supplement to on-going activities for the project). These parameters can be helpful in providing supplemental or explanatory information that can distinguish between closely scored reaches for the County. For example, human intervention or fish movement barriers may be able to assist in explaining a head cut or logjam. While field notes or comments can sometimes serve the same purpose, having a required field in our field forms allows for easy data capture and eliminates the risk of no comments being entered. In addition, the information collected for these additional field parameters in

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watersheds other than the Upper Patuxent River Watershed (*e.g.*, the Magothy) is likely to be quite different that what was collected in the Upper Patuxent. Consequently, gathering additional data on this group of parameters in future watershed studies is recommended.

- Human Intervention
- Terrestrial Habitat
- Riparian Invasive Species
- Barriers to Fish Movement

3. Several of the additional parameters provide supplemental information on reach characteristics that can be helpful in Rosgen classifications and other reach assessment activities. Gathering additional data on this group of parameters in future watershed studies is recommended.

- Overall channel condition (1-10)
- Bed Stability
- Channel incision
- Bedrock Control (presence and type if present)

4. Additional IDDE parameters were collected for pipes and drainage ditches. We did not identify many illicit discharges in the Upper Patuxent River Watershed, but it is possible that more will be observed in the Magothy River Watershed. Gathering additional data on this group of parameters in future watershed studies is recommended.

- Discharge type
- Presence of Deposits/Stains
- Presence of Floating Solids

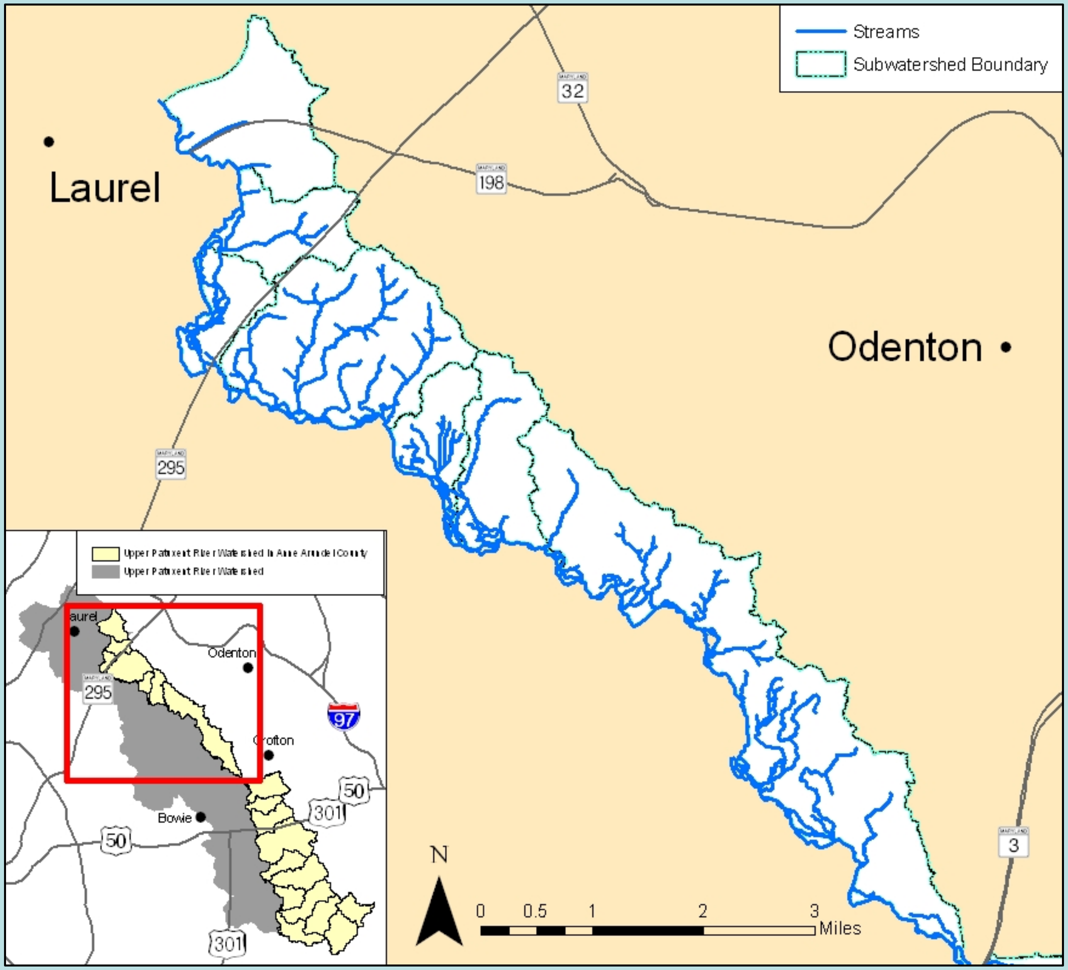
Conclusion

Most, but not all of the additional field parameters collected provide useful information. While we are prepared to collect information on all of the additional field parameters in the Magothy River Watershed, some of this data is redundant and may not be used by the County. LimnoTech can modify our plans accordingly for future data collection efforts should the County decide to act on the recommendations herein.

Appendix F
Watershed Fact Sheets

- Watershed Fact Sheet, Northern Section – Delivered June 26, 2008
- Watershed Fact Sheet, Southern Section – Delivered June 26, 2008

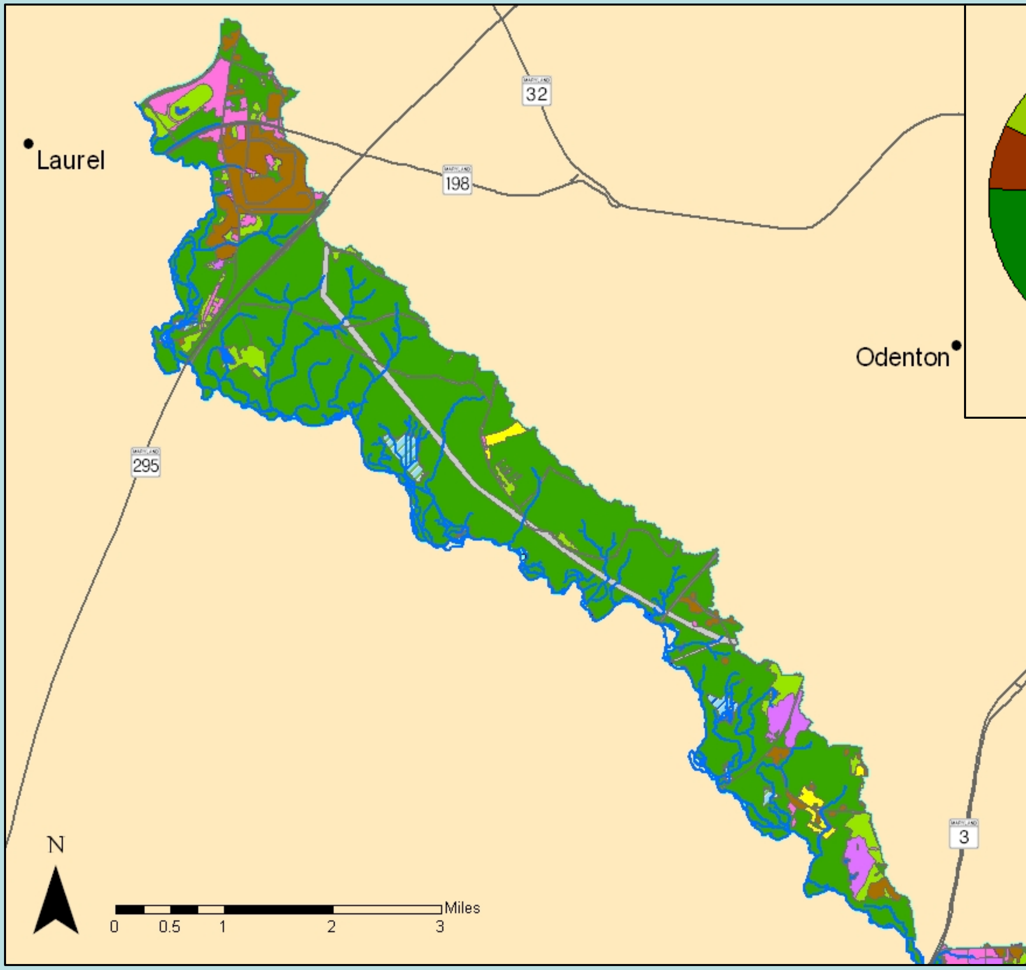
Upper Patuxent River Watershed: Northern Section

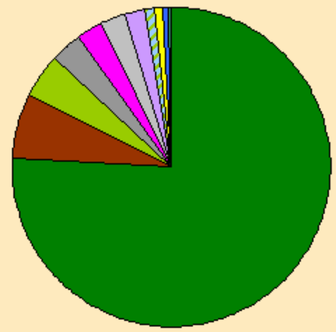


Overview

The Upper Patuxent River Watershed drains portions of Prince George’s, Howard, and Anne Arundel Counties. Forty percent (22,400 acres) of the watershed lies in Anne Arundel County to the east of the Upper Patuxent River. The Patuxent River continues south through Anne Arundel County to a confluence with the Chesapeake Bay at Solomons, MD; therefore, activities in the watershed have a direct impact on the Bay. The northern section of the Upper Patuxent River Watershed is approximately 7,100 acres in size and has 43.9 miles of northern section of the watershed is in the north surrounding the town of Laurel.

Upper Patuxent River Watershed: Northern Section



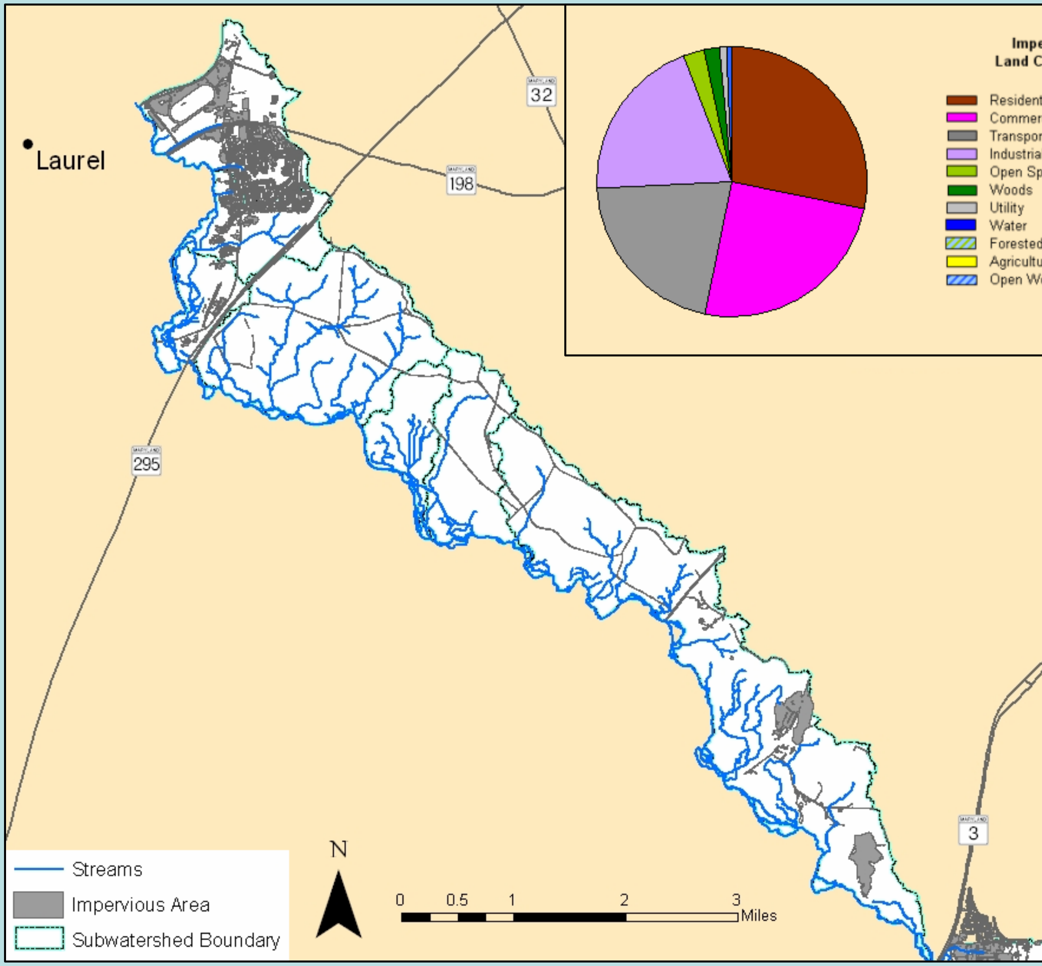


Land Cover	Acres	Percent
Woods	5366.0	76%
Residential	471.0	7%
Open Space	325.0	5%
Transportation	212.0	3%
Commercial/Airport	192.0	3%
Utility	177.0	3%
Industrial	139.0	2%
Forested Wetland	75.0	1%
Agricultural	65.0	1%
Water	30.0	0%
Open Wetland	24.0	0%

Land Cover

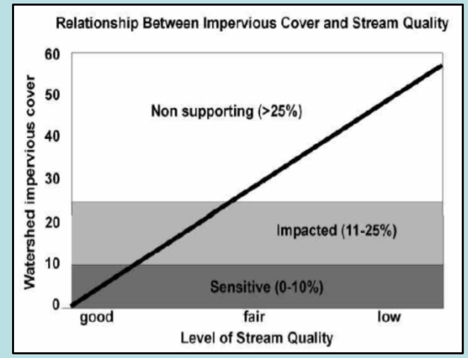
Land cover can play an important role in non-point source pollutant loading to streams. Agricultural and residential lawns may be sources of nutrients and bacteria, while urban development increases the potential for road runoff. Land cover can also affect pollutant removal. In a forested watershed, precipitation is absorbed by the tree canopy, lost to the air through evapotranspiration, and infiltrates into the ground to recharge ground water. Surface runoff is usually much higher in agricultural watersheds than in forested watersheds and even higher in urban watersheds, which leads to increased pollutant loads.   Land cover in the northern section of the Upper Patuxent River Watershed is dominated by forest and open space (81%), which have larger pollutant removal capabilities.

Upper Patuxent River Watershed: Northern Section



Impervious Area Land Cover Types

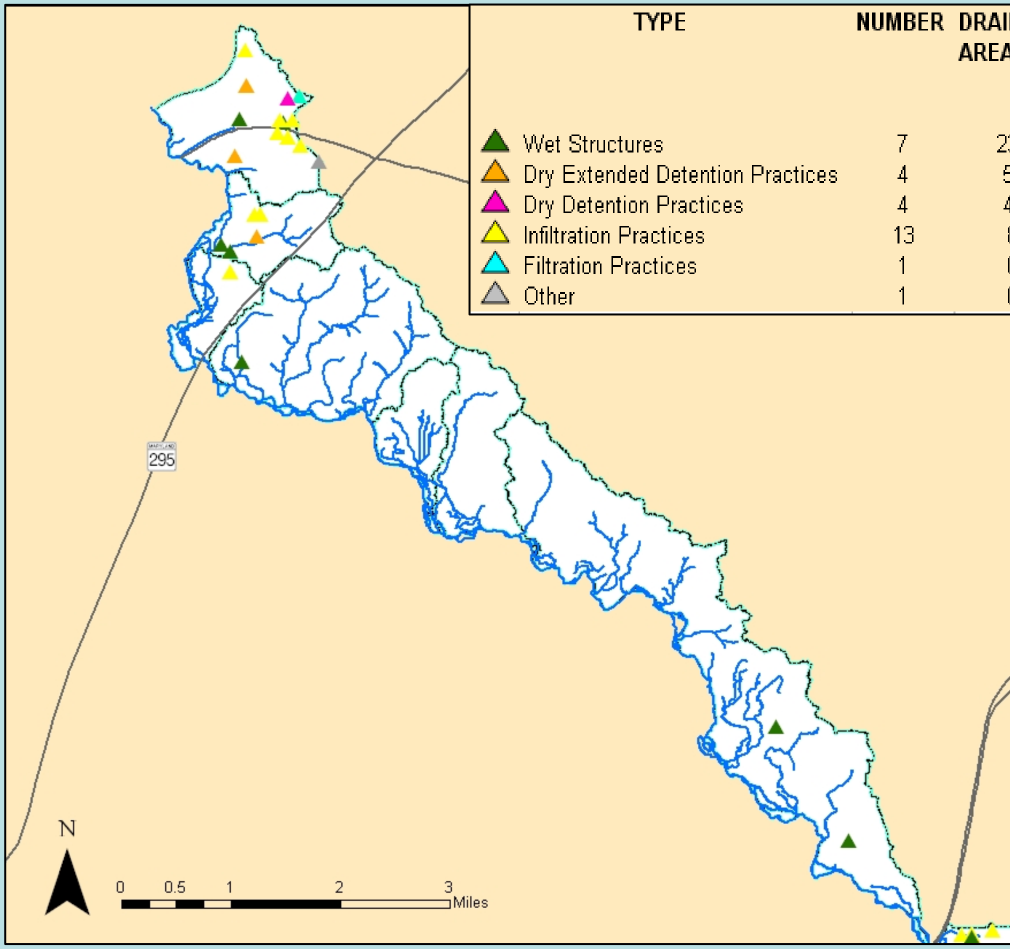
Land Cover	Acres	% of Impervious Cover
Residential	163.0	28%
Commercial/Airport	144.0	25%
Transportation	122.0	21%
Industrial	116.0	20%
Open Space	13.0	2%
Woods	12.0	2%
Utility	4.0	1%
Water	4.0	1%
Forested Wetland	0.0	0%
Agricultural	0.0	0%
Open Wetland	0.0	0%



Land Cover: Impervious Area

As a watershed undergoes development, impervious surfaces that prevent water from seeping into the ground, such as pavement, increase in area. This results in the potential for large volumes of water to run off more rapidly and more directly into streams. Pollutants carried with this runoff can reduce water quality and stream health. Research shows that as the impervious surface area in a watershed grows, the ecological integrity of streams decreases. Streams that receive large volumes of rapidly flowing water are also susceptible to flooding and channel erosion. Residential, commercial, transportation, and industrial land cover types make up the bulk of the impervious surface area in the northern section of the Upper Patuxent River watershed, but overall, this section of the watershed is only 8% impervious.

Upper Patuxent River Watershed: Northern Section



TYPE	NUMBER	DRAINAGE AREA (ac)	% OF NORTHERN UPPER PATUXENT WATERSHED TREATED
Wet Structures	7	236.5	3.3
Dry Extended Detention Practices	4	57.1	0.8
Dry Detention Practices	4	40.9	0.6
Infiltration Practices	13	8.6	0.1
Filtration Practices	1	0.6	<0.1
Other	1	0.2	<0.1

Stormwater Controls

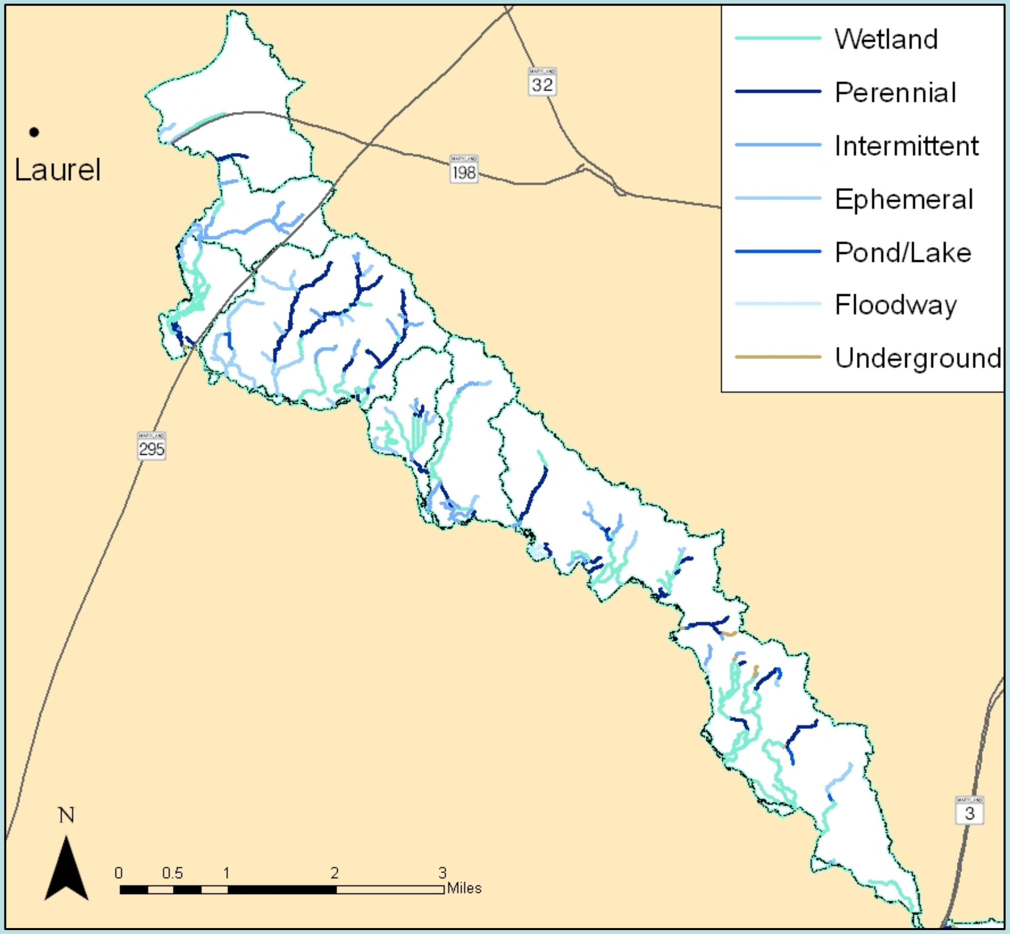
Stormwater controls are engineered structures or landscape enhancements that are used to manage local stormwater. They are important for controlling and minimizing the effects of excess stormwater runoff including flooding, erosion, and stream pollution.

Stormwater controls in the northern section of the Upper Patuxent River Watershed are predominately located in the more developed subwatersheds to the north. Infiltration practices and wet ponds/ wetlands are the most common controls.

Stormwater detention ponds are wet structures that are often used to capture stormwater runoff in residential areas.

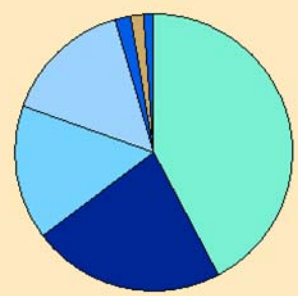
Infiltration practices capture stormwater and allow it to seep into the soil. This rain garden helps capture and filter runoff from a parking lot

Upper Patuxent River Watershed: Northern Section



Stream Reach Overview

The northern section of the Upper Patuxent River Watershed contains 43.9 miles of waterways. Wetlands are prevalent, totaling 42% of the waterway miles; while perennial streams (those with flowing water year round) make up only 22% of the total miles. Streams which may have flow only during portions of the year, intermittent (fed by groundwater) and ephemeral (flow in response to rain), make up most of the remaining waterway miles.



Stream Type	Miles	%
Wetland	18.5	42%
Perennial	9.8	22%
Intermittent	6.9	16%
Ephemeral	6.8	15%
Pond/Lake	0.8	2%
Floodway	0.6	1%
Underground	0.5	1%
Total	43.9	

Upper Patuxent River Watershed: Northern Section

Inventory of Infrastructure and Environmental Features

Infrastructure and significant physical features along the assessed streams were inventoried and scored based on their impact to stream integrity. In general, due to the fairly undeveloped nature of the northern section of the Upper Patuxent River Watershed there were few features significantly impacting the streams; however, there were two obstructions and one crossing determined to be having a severe impact, all located in the Patuxent Research Refuge.

Number of Features		Impact Score		
		Severe	Moderate	Minor
Deficient Buffer	9		9	
Crossing	42	1	4	37
Pipes and Ditches	6			6
Dumpsites	10		1	9
Erosion	14		14	
Obstruction	69	2	2	65

Dumpsite with moderate impact score located near town of Laurel

Deficient buffer with moderate impact score located in Patuxent Research Refuge

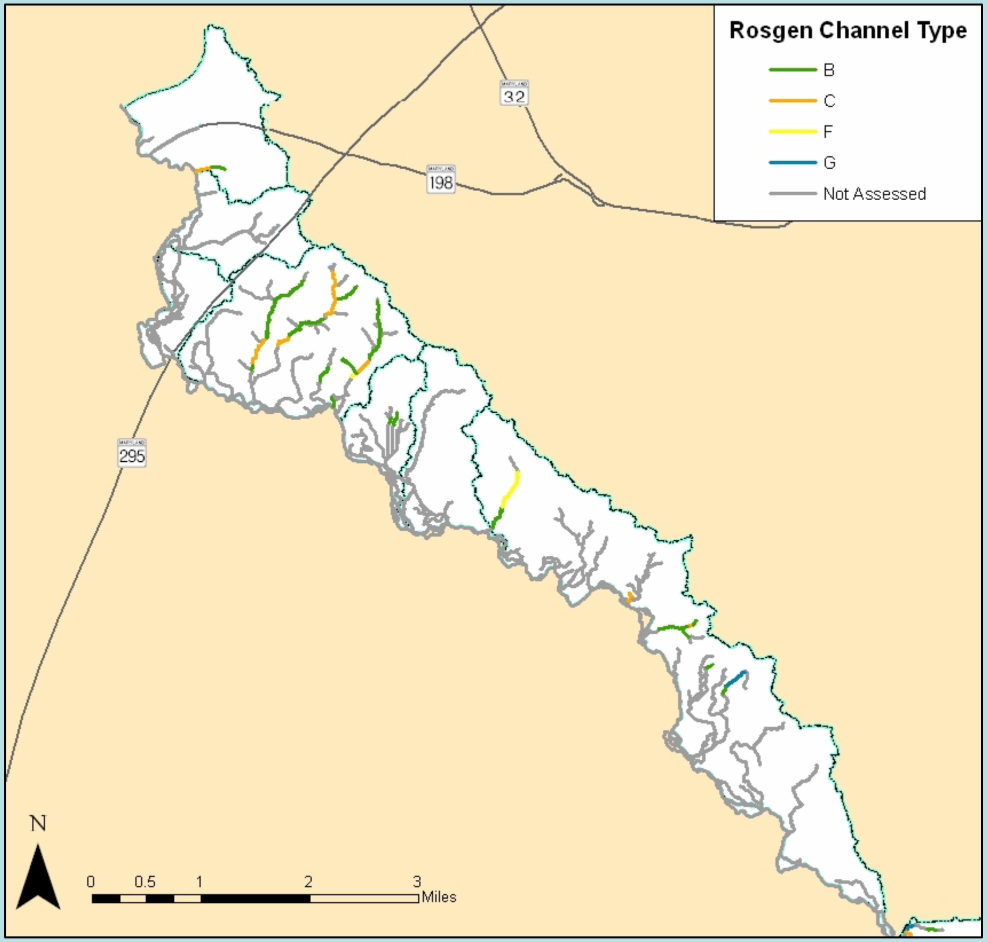
Obstruction with severe impact score located in Patuxent Research Refuge

Crossing with severe impact score located in Patuxent Research Refuge

Ditch with minor impact score located near Brock Bridge Road outside of Laurel

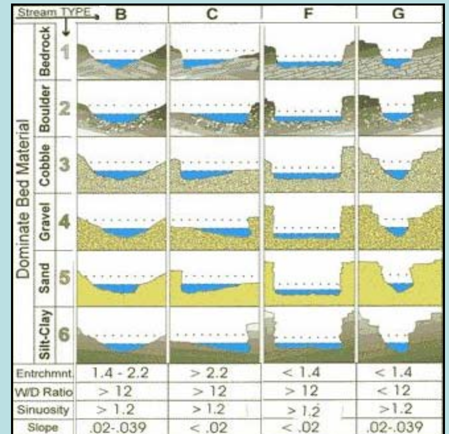
Erosion with moderate impact score located in Patuxent Research Refuge

Upper Patuxent River Watershed: Northern Section



Channel Morphology

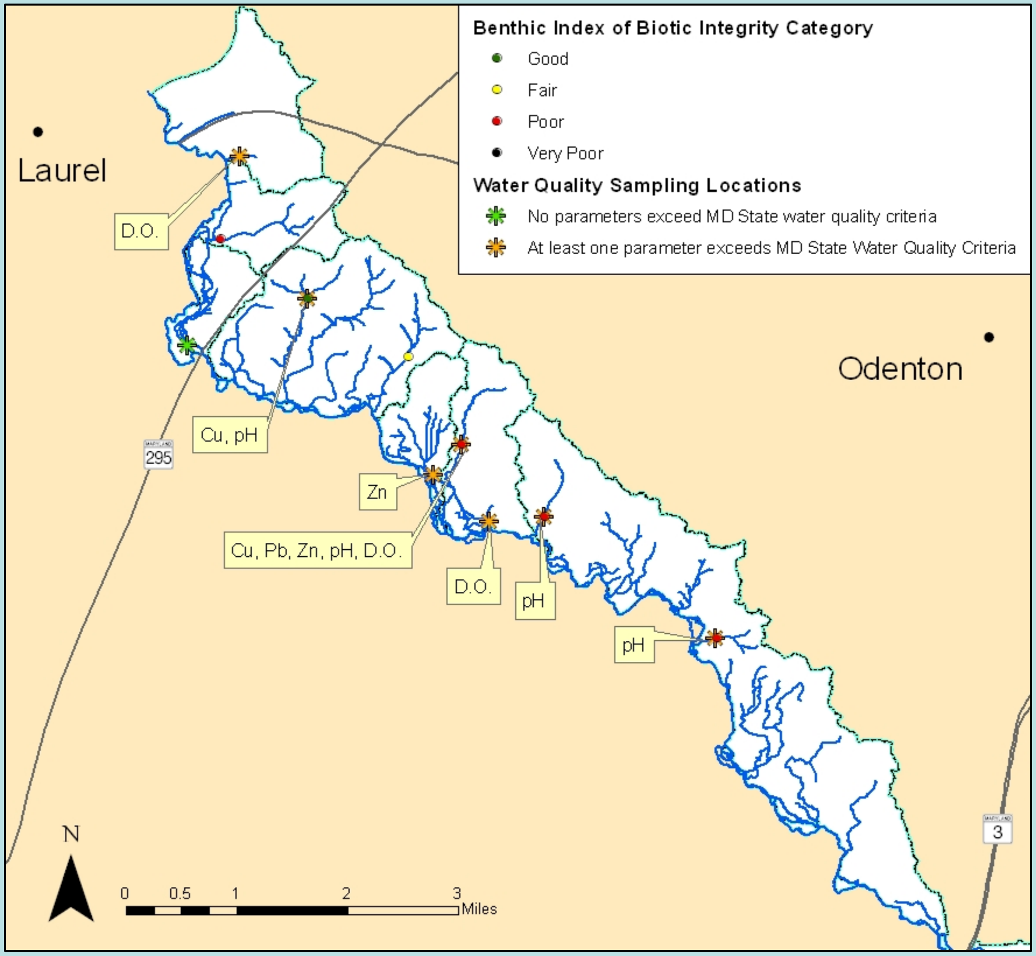
Rosgen classifications are a widely used method of classifying channel types based on similar morphological characteristics, with the goal of predicting hydrologic behavior. Nearly half (43%) of the assessed perennial streams in the northern section of the Upper Patuxent River Watershed were Type B channels, which are very stable, moderate gradient channels with low sinuosity and low erosion rates. 18% were Type C channels, which exhibit a well developed floodplain, higher sinuosity and susceptibility to de-stabilization when flow regimes are altered. The remainder were Type F and Type G channels, which are generally low gradient, entrenched channels with high erosion rates.



Rosgen Channel Type Definitions

Typical Type B Channel in northern section Upper Patuxent River watershed

Upper Patuxent River Watershed: Northern Section



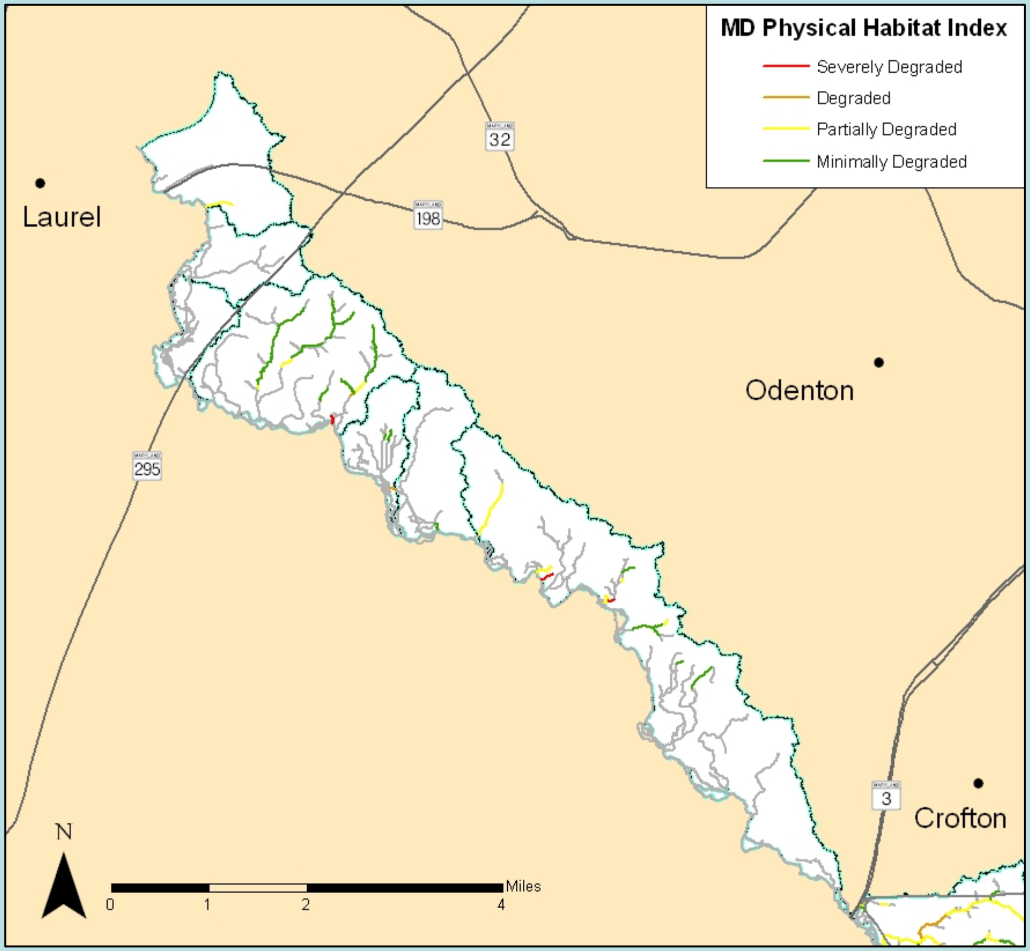
Water Quality and Bioassessment

The County assessed both the chemical water quality and biological integrity of streams in the watershed. Dry weather water quality samples were taken to characterize water quality and estimate potential pollutant loads. Samples from all but one site exceeded MD State Water quality criteria for at least one parameter. Dissolved oxygen and pH (which where primarily found with low flow/stagnant water conditions) and metals were the most common exceedances.

Parameter	Average concentration		MD State Water Quality Criteria
TKN	0.98	mg/l	
Nitrate & Nitrite	0.16	mg/l	
Total Phosphorus	0.13	mg/l	
Total Suspended Solids	496.57	mg/l	
Copper	15.39	ug/l	13 (acute) 9 (chronic)
Lead	23.82	ug/l	65 (acute) 2.5 (chronic)
Zinc	68.93	ug/l	120
Fecal coliform	720.14	col/100 ml	
pH	6.30		6.5-8.5
Temperature	15.37	C	
Dissolved Oxygen	5.95	mg/l	>5.0

The County also assessed the macroinvertebrates in the streams. Healthy streams usually contain a wide variety of macroinvertebrates, including those intolerant to pollution. As the quality of the water or habitat declines, the diversity and abundance of macroinvertebrates also typically declines, with pollution tolerant species becoming dominant. A Benthic Index of Biotic Integrity looks at these measures to assess a stream's health. Four of the six sites sampled were in the "poor" category.

Upper Patuxent River Watershed: Northern Section



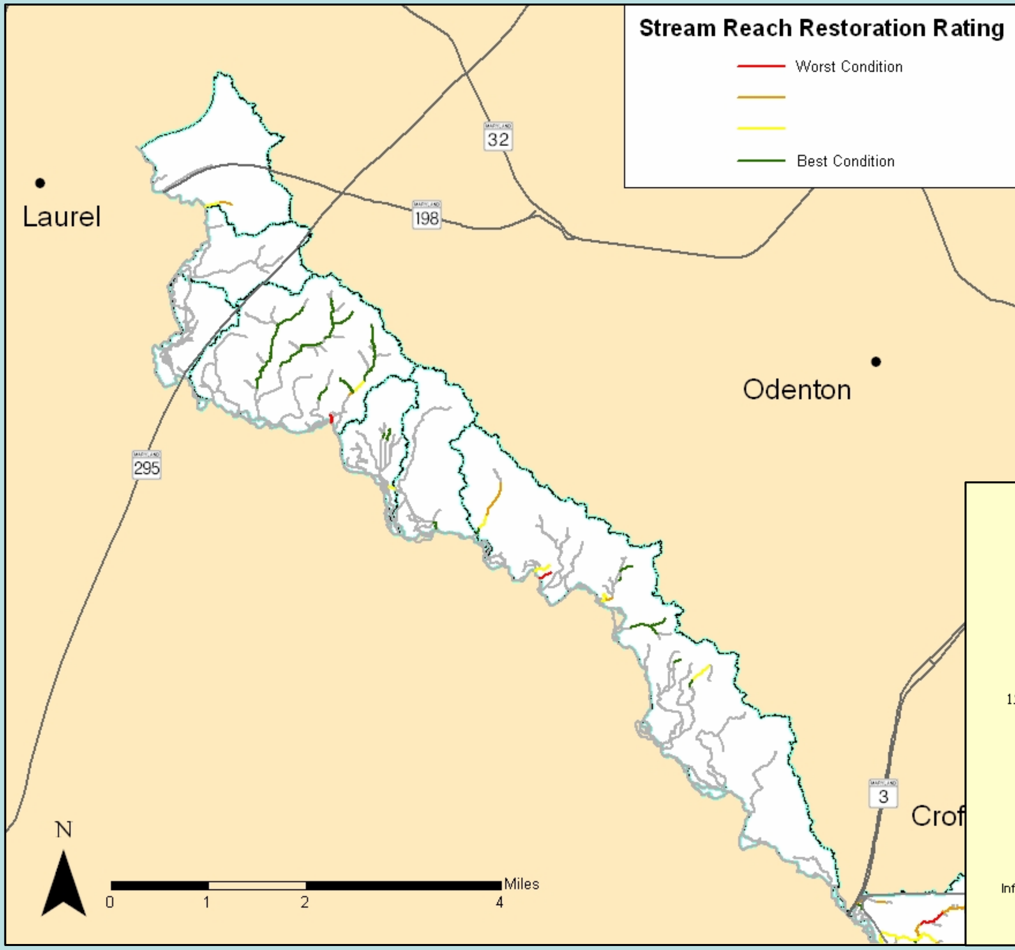
Habitat Assessment

The condition of stream habitat of perennial streams was assessed using the Maryland Physical Habitat Index (MPHI) which incorporated measures of fish and macroinvertebrate habitat, shading, remoteness and bank stability. The northern section of the Upper Patuxent River watershed had generally good habitat quality with 78% of the stream miles falling in the minimally degraded category, 17% partially degraded and only 5% being degraded or severely degraded.

Minimally degraded stream reach in the northern section of the Upper Patuxent River Watershed

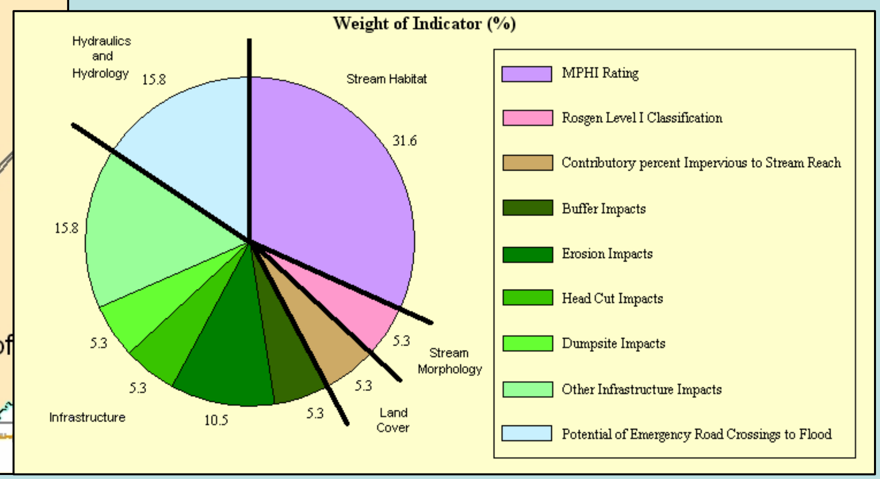
Partially degraded stream reach in the northern section of the Upper Patuxent River Watershed

Upper Patuxent River Watershed: Northern Section

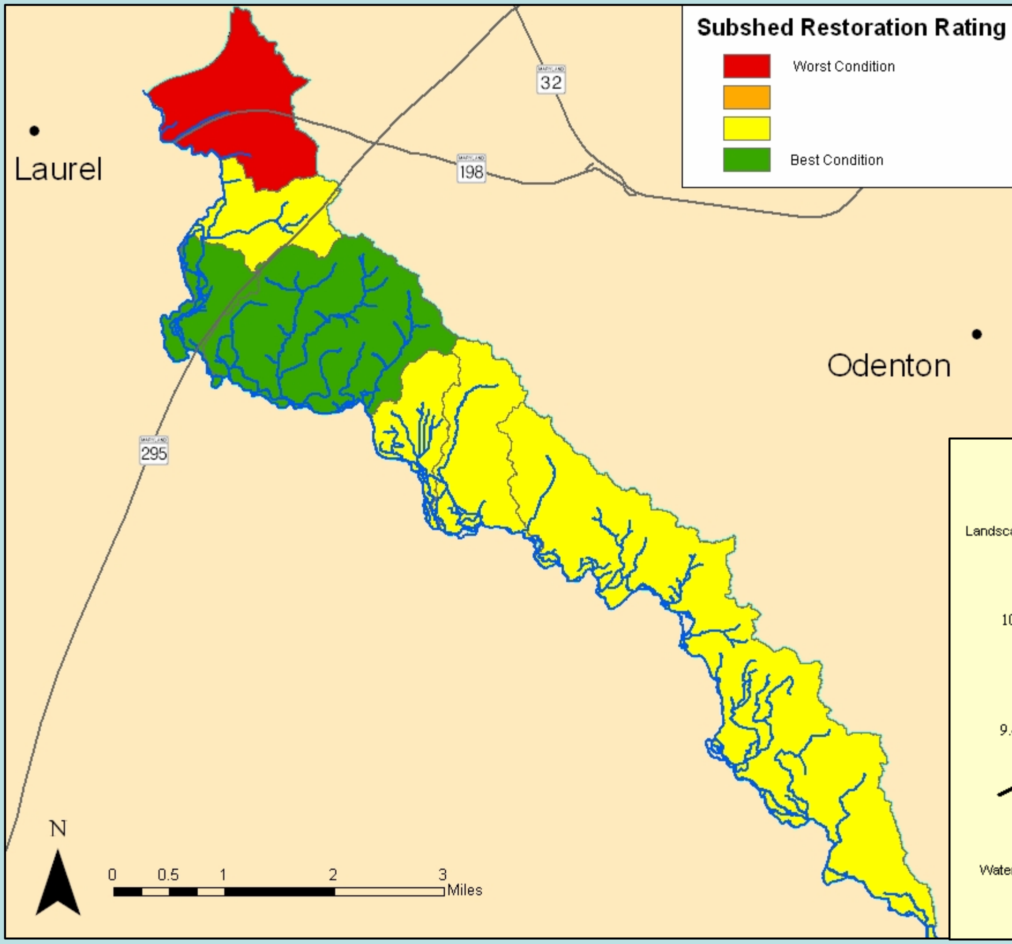


Reach Restoration Assessment

By looking at physical habitat quality, bank morphology, the amount of surrounding impervious land cover and the impact of infrastructure features such as dumpsites and deficient buffers, the County assessed individual stream reaches and rated them to help focus resources for restoring impaired stream reaches. Each indicator was weighted differently depending upon its impact on stream integrity. Approximately 20% of the assessed stream reaches in the northern section of the Upper Patuxent Watershed were determined to be good candidates for restoration ("worst condition").

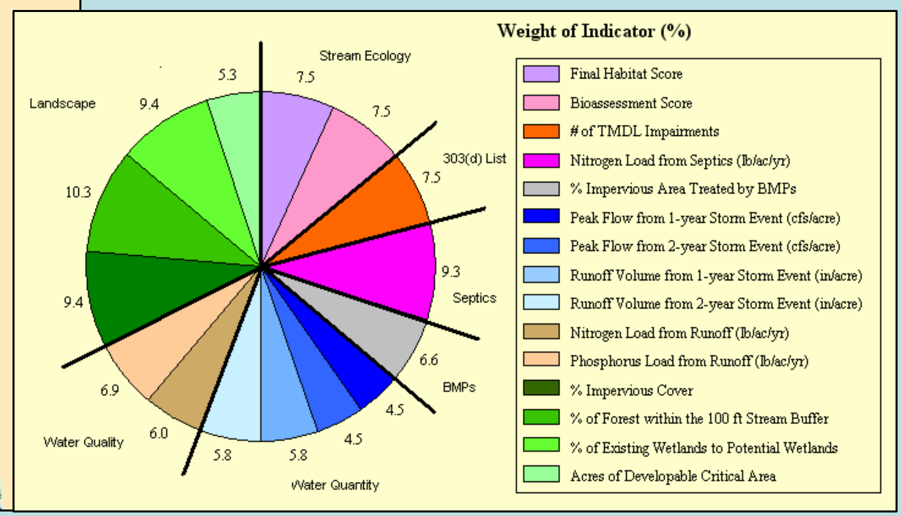


Upper Patuxent River Watershed: Northern Section



Subwatershed Restoration Assessment

By looking at stream habitat, hydrology and hydraulics, water quality, and landscape features such as impervious cover, stormwater control coverage, and forested buffers among others, the County assessed individual subwatersheds and rated them to help focus resources for restoring impaired subwatersheds. Two of subwatersheds in the northern Upper Patuxent River Watershed were rated highest for restoration, while one was rated in the lowest category.



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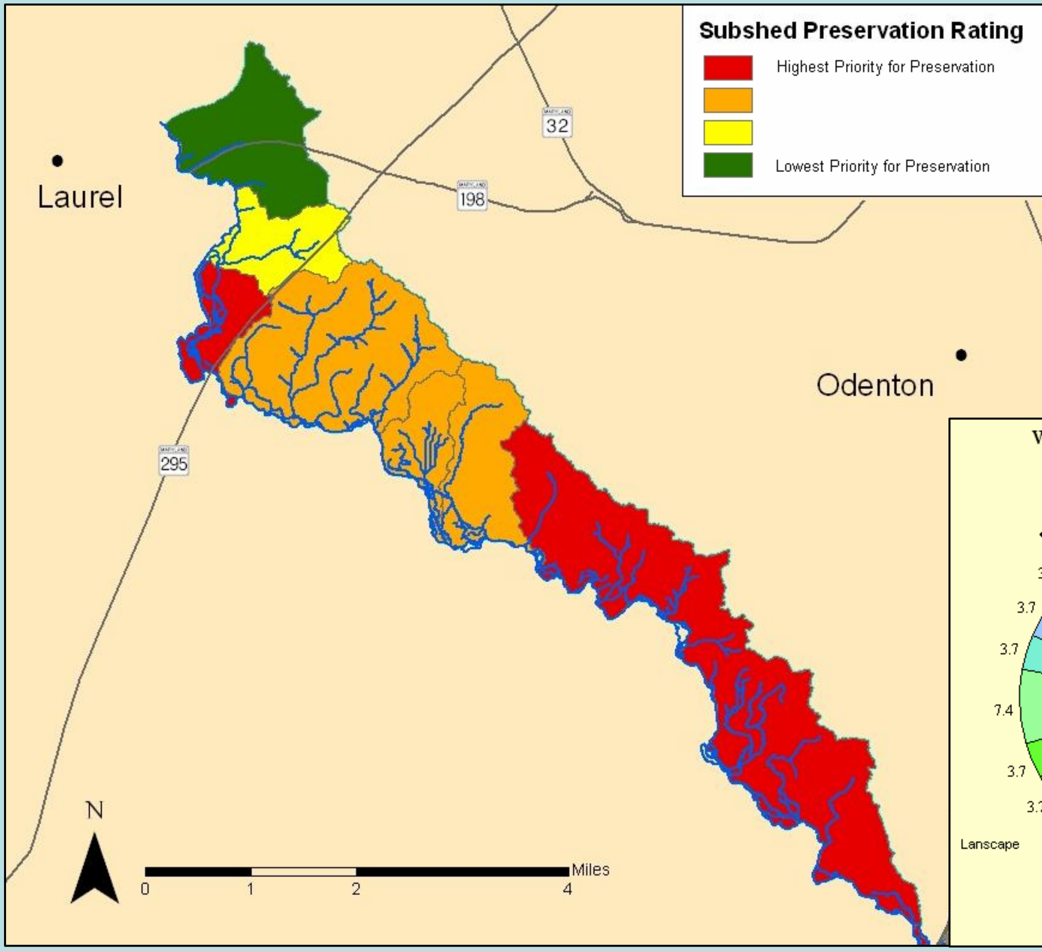
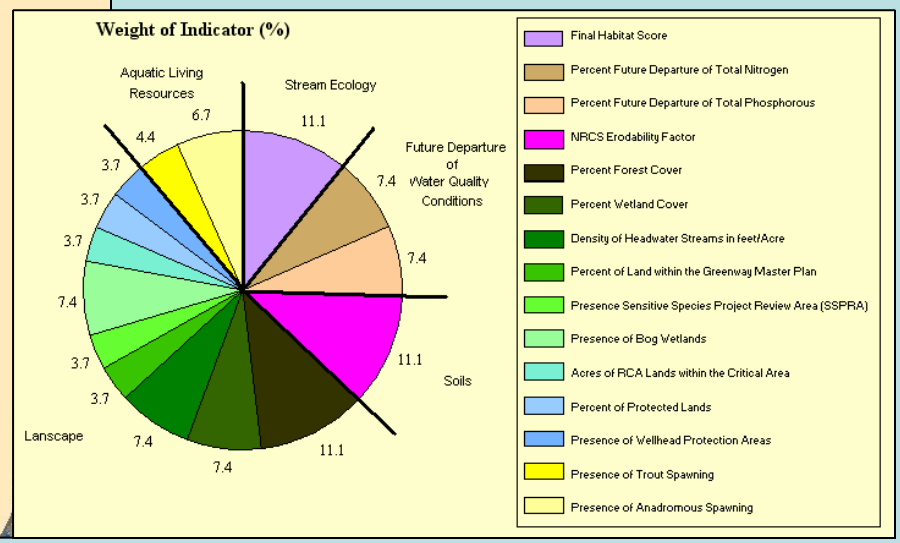
Upper Patuxent River Watershed: Northern Section



Subwatershed Preservation Assessment

By looking at stream habitat, water quality, and the presence of sensitive land types such as wetlands, greenways, and protected habitats among others, the County assessed individual subwatersheds and rated them to help focus resources for preserving those that are most sensitive. With the exception of two subwatersheds in the more urbanized north, the remainder of the northern Upper Patuxent River Watershed were rated high for preservation.



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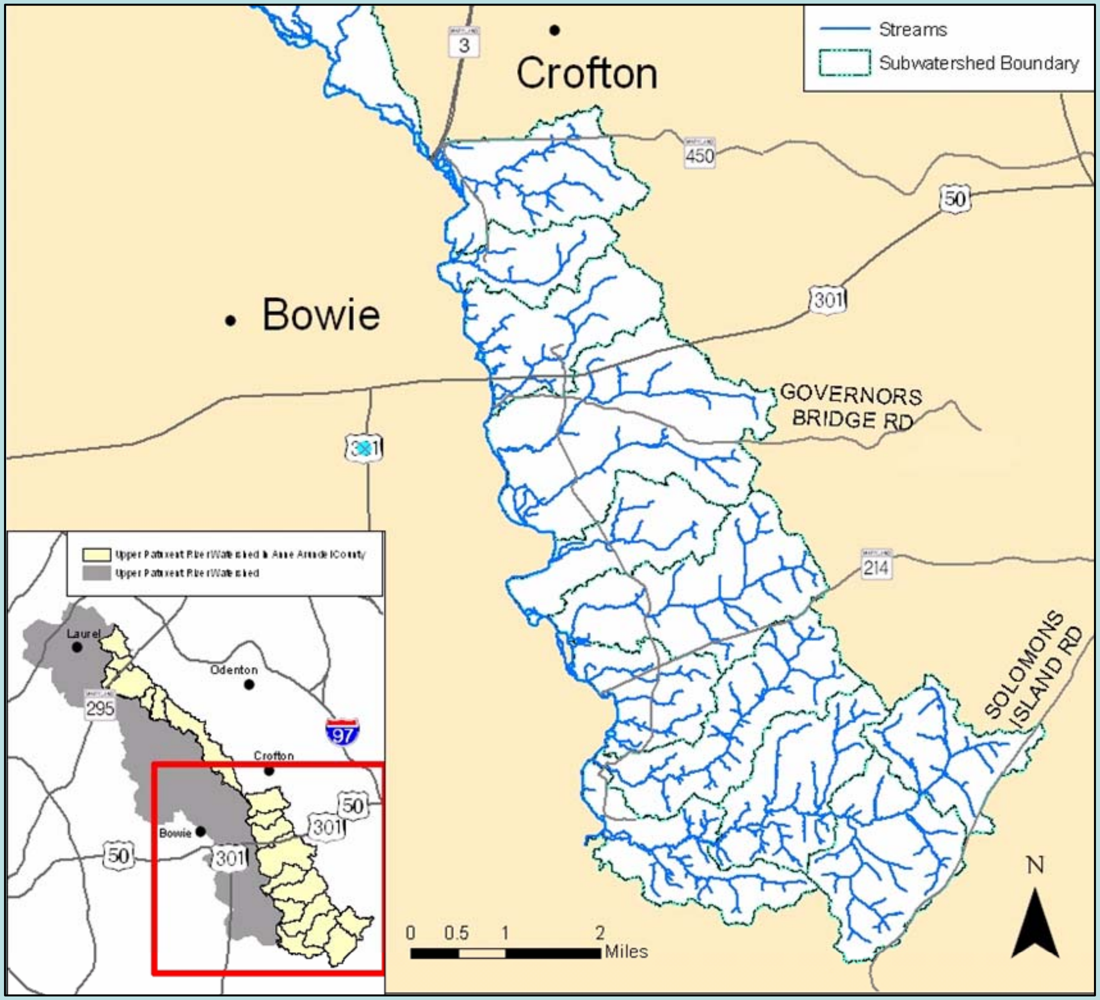
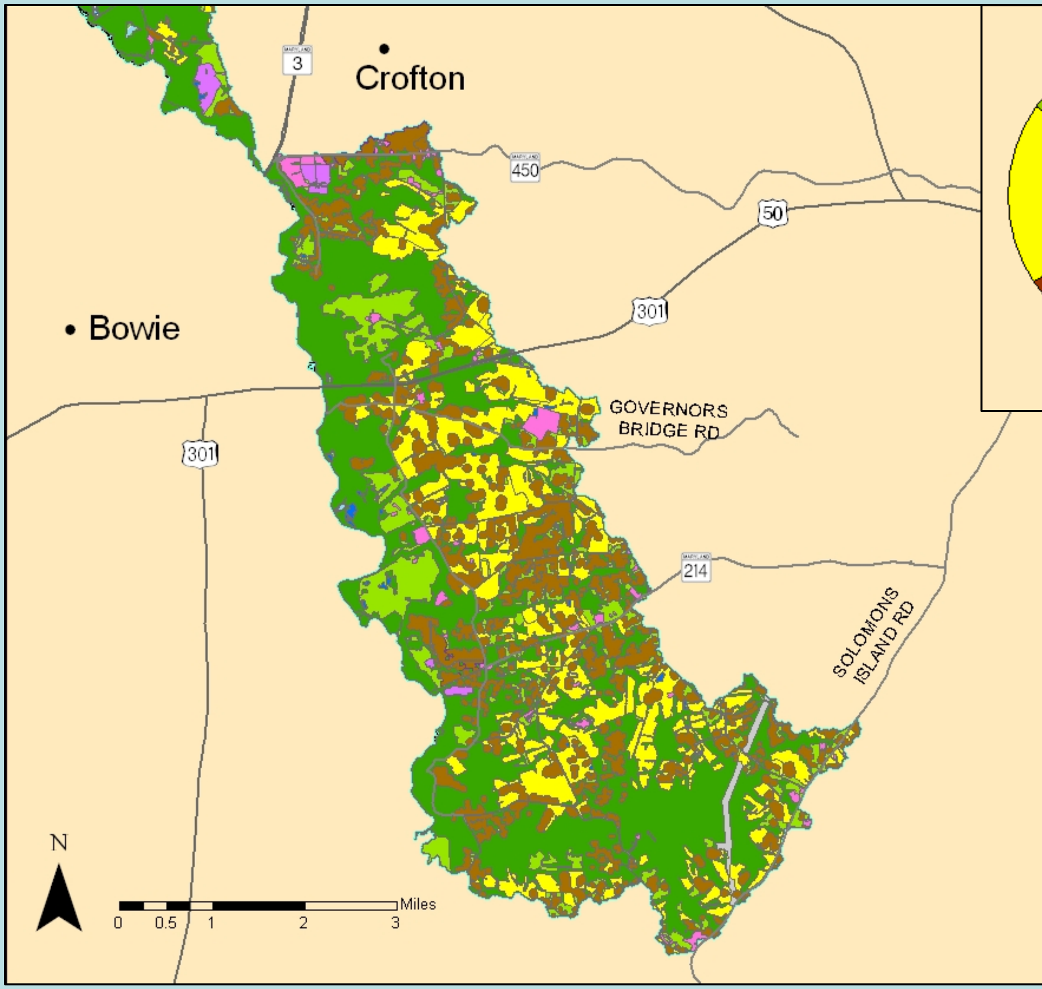
Upper Patuxent River Watershed: Southern Section

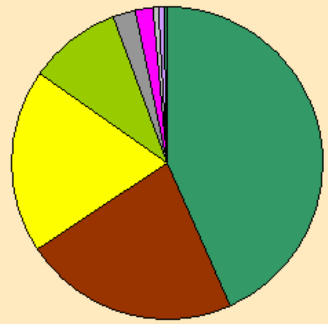


Overview

The Upper Patuxent River Watershed drains portions of Prince George's, Howard, and Anne Arundel Counties. Forty percent (22,400 acres) of the watershed lies in Anne Arundel County to the east of the Upper Patuxent River. The Patuxent River continues south through Anne Arundel County to a confluence with the Chesapeake Bay at Solomons, MD; therefore, activities in the watershed have a direct impact on the Bay.   The southern section of the Upper Patuxent River Watershed is approximately 15,275 acres in size and has 103 miles of waterways. It is highly agricultural with large areas of crop, pasture, and open space. Residential development is scattered throughout the watershed, with greater density around the outskirts of Crofton.

Upper Patuxent River Watershed: Southern Section



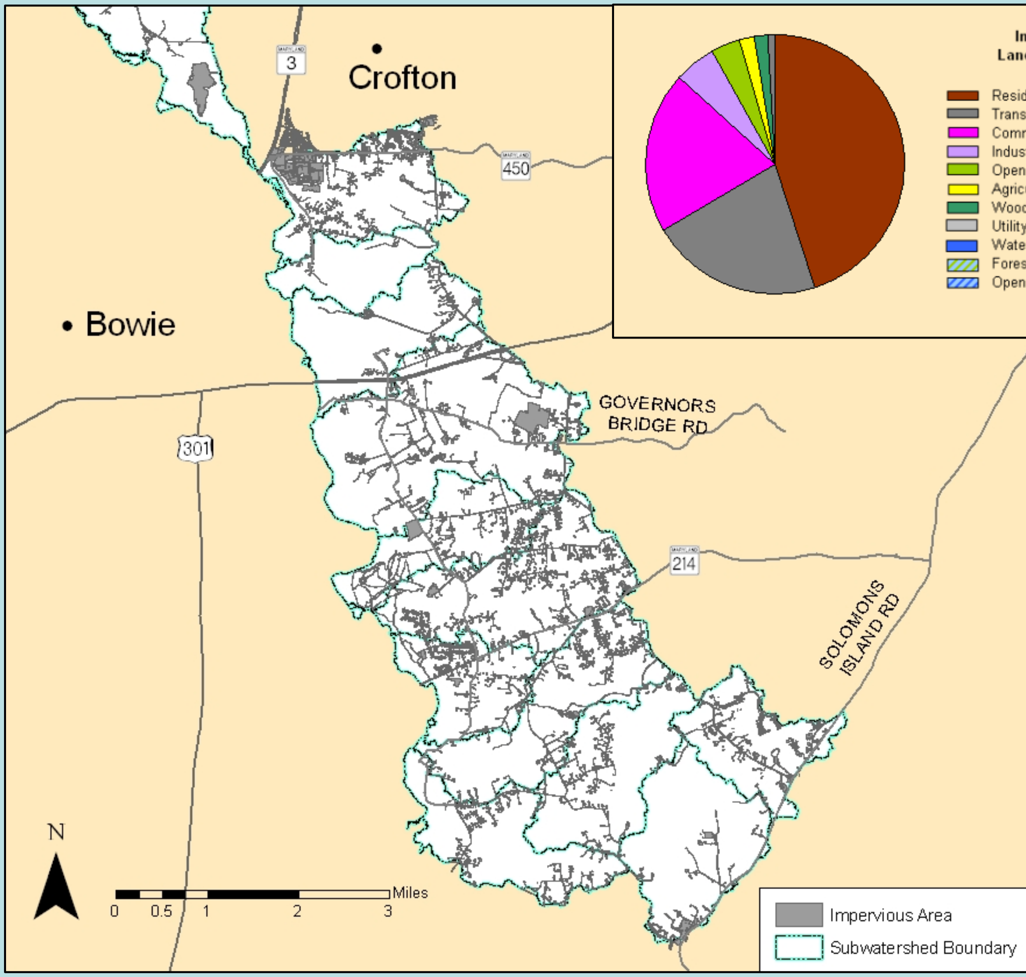


Land Cover	Acres	Percent
Woods	6616.0	43%
Residential	3384.0	22%
Agricultural	2950.0	19%
Open Space	1481.0	10%
Transportation	344.0	2%
Commercial	276.0	2%
Utility	98.0	1%
Industrial	72.0	<1%
Water	43.0	<1%
Forested Wetland	4.0	<1%
Open Wetland	4.0	<1%

Land Cover

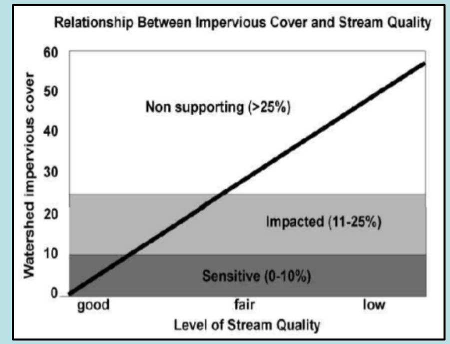
Land cover can play an important role in non-point source pollutant loading to streams. Agricultural and residential lawns may be sources of nutrients and bacteria, while urban development increases the potential for road runoff. Land cover can also affect pollutant removal. In a forested watershed, precipitation is absorbed by the tree canopy, lost to the air through evapotranspiration, and infiltrates into the ground to recharge ground water. Surface runoff is usually much higher in agricultural watersheds than in forested watersheds and even higher in urban watersheds, leading to increased pollutant loads. Land cover in the southern section of the Upper Patuxent River Watershed is nearly half forest which has larger pollutant removal capabilities. 22% of the watershed has residential cover and 19% has agricultural cover, which may contribute pollutants to the waterways.

Upper Patuxent River Watershed: Southern Section



Impervious Area Land Cover Types

Land Cover	Acres	% of Impervious Cover
Residential	436.0	45%
Transportation	206.0	21%
Commercial	196.0	20%
Industrial	49.0	5%
Open Space	36.0	4%
Agricultural	18.0	2%
Woods	17.0	2%
Utility	8.0	1%
Water	0.0	0%
Forested Wetland	0.0	0%
Open Wetland	0.0	0%



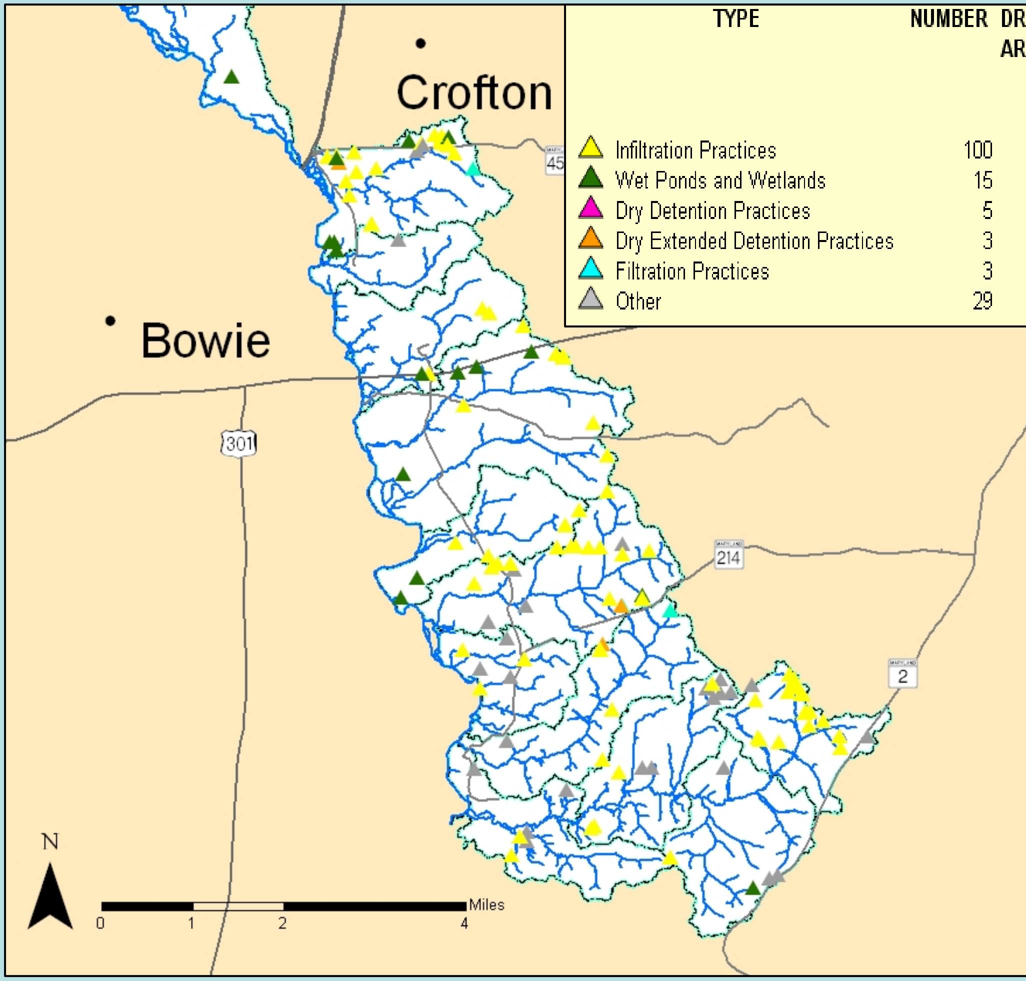
Land Cover: Impervious Area

As a watershed undergoes development, impervious surfaces that prevent water from seeping into the ground, such as pavement, increase in area. This results in the potential for large volumes of water to run off more rapidly and more directly into streams. Pollutants carried with this run off can reduce water quality and stream health. Research shows that as the impervious surface area in a watershed grows, the ecological integrity of streams decreases. Streams that receive large volumes of quickly flowing water are also susceptible to flooding and channel erosion. Residential, commercial, transportation, and industrial land cover types make up the bulk of the impervious surface area in the southern section of the Upper Patuxent River Watershed, but overall, this section of the watershed is only 6% impervious.

Upper Patuxent River Watershed: Southern Section

ANNE ARUNDEL COUNTY
M A R Y L A N D

DPW



TYPE	NUMBER	DRAINAGE AREA (ac)	% OF SOUTHERN UPPER PATUXENT WATERSHED TREATED
Infiltration Practices	100	303.4	2.0
Wet Ponds and Wetlands	15	284.1	1.9
Dry Detention Practices	5	15.8	0.1
Dry Extended Detention Practices	3	7.4	<0.1
Filtration Practices	3	5.6	<0.1
Other	29	4.4	<0.1

Stormwater Controls

Stormwater controls are engineered structures or landscape enhancements that are used to manage local stormwater. They are important for controlling and minimizing the effects of excess stormwater runoff including flooding, erosion, and stream pollution.

Stormwater controls in the southern section of the Upper Patuxent River Watershed are located throughout the area and treat approximately 4% of the land area. Infiltration and wet structures are the most common practices.

Stormwater detention ponds are wet structures that are often used to capture stormwater runoff in residential areas.

Infiltration practices capture stormwater and allow it to seep into the soil. This rain garden helps capture and filter runoff from a parking lot

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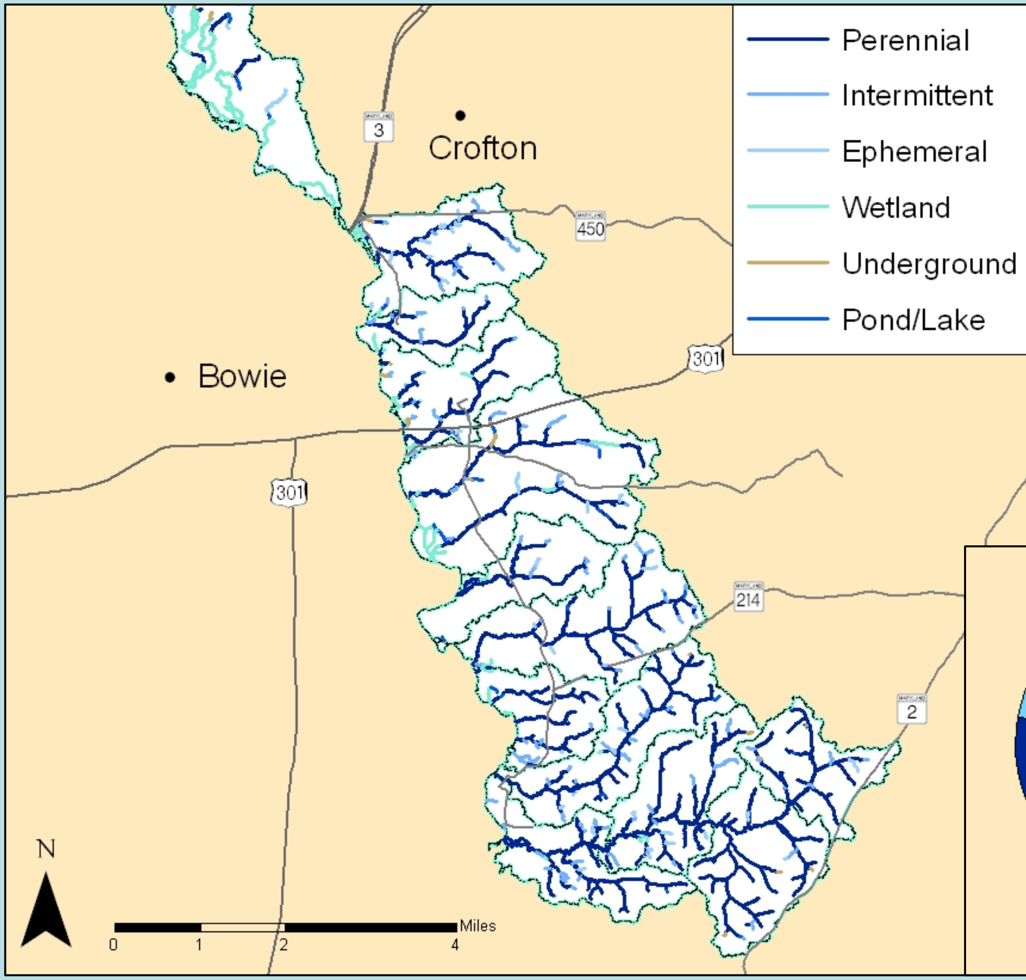
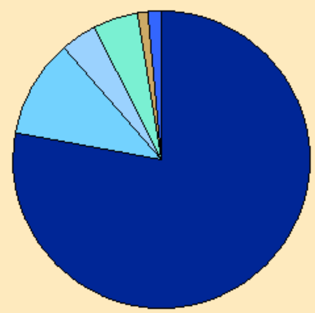
Upper Patuxent River Watershed: Southern Section



Stream Reach Overview

The southern section of the Upper Patuxent River Watershed contains 103 miles of waterways, comprised primarily of perennial streams (those with flowing water year round). Wetland and streams which may have flow only during portions of the year; intermittent (fed by groundwater) and ephemeral (flow in response to a rain event) streams, are less common than in the northern section of the watershed



Stream Type	Miles	%
Perennial	80	78%
Intermittent	11.4	11%
Ephemeral	3.9	4%
Wetland	5.2	5%
Underground	1.1	1%
Pond/Lake	1.4	1%
Total	103	

Upper Patuxent River Watershed: Southern Section

Inventory of Infrastructure and Environmental Features

Infrastructure and significant physical features along the assessed streams were inventoried and scored based on their impact to stream integrity. There were deficient buffers, crossings, pipes and ditches, dumpsites and erosion categorized as having a severe negative impact on the streams throughout the southern section of the Upper Patuxent Watershed.

Number of Features		Impact Score		
		Severe	Moderate	Minor
Deficient Buffer	67	4	63	
Crossing	197	6	48	143
Pipes and Ditches	65	1	7	57
Dumpsites	77	3	7	67
Erosion	86	10	76	
Obstruction	453		58	395

Dumpsite with severe impact score located south of Harwood Rd.

Deficient buffer with moderate impact score located near Double Gate Rd.

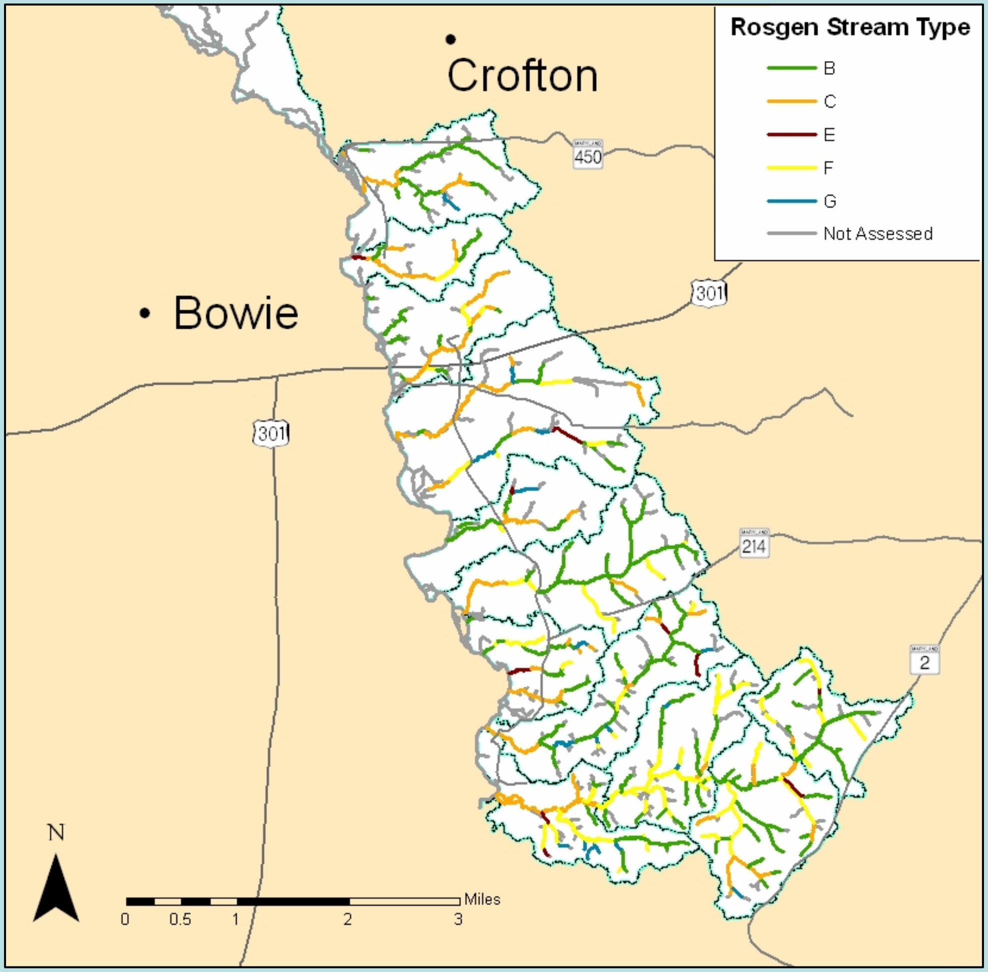
Obstruction with moderate impact score located near Foxhall Dr.

Crossing with severe impact score located south of Harwood Rd.

Roof drainage **pipe** with minor impact score south of Patuxent River Rd.

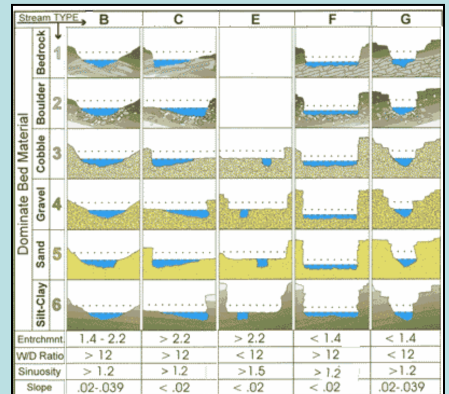
Erosion with severe impact score on stream between Harwood Rd. and Queen Anne Brige Rd.

Upper Patuxent River Watershed: Southern Section

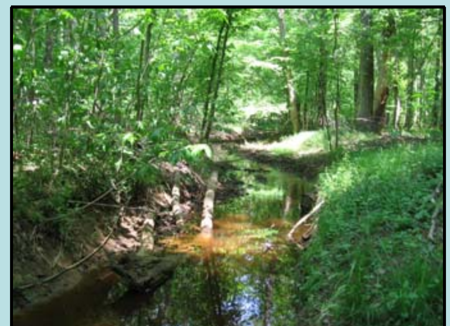


Channel Morphology

Rosgen classifications are a widely used method of classifying channel types based on similar morphological characteristics, with the goal of predicting hydrologic behavior. Nearly half (42%) of the assessed perennial streams in the northern section of the Upper Patuxent River Watershed were Type B channels, which are very stable, moderate gradient channels with low sinuosity and low erosion rates. 24% were Type C channels, which exhibit a well developed floodplain, higher sinuosity and susceptibility to de-stabilization when flow regimes are altered. The remainder were Type F and G channels, which are generally low gradient, entrenched channels with high erosion rates and Type E channels, which are low gradient, stable channels.

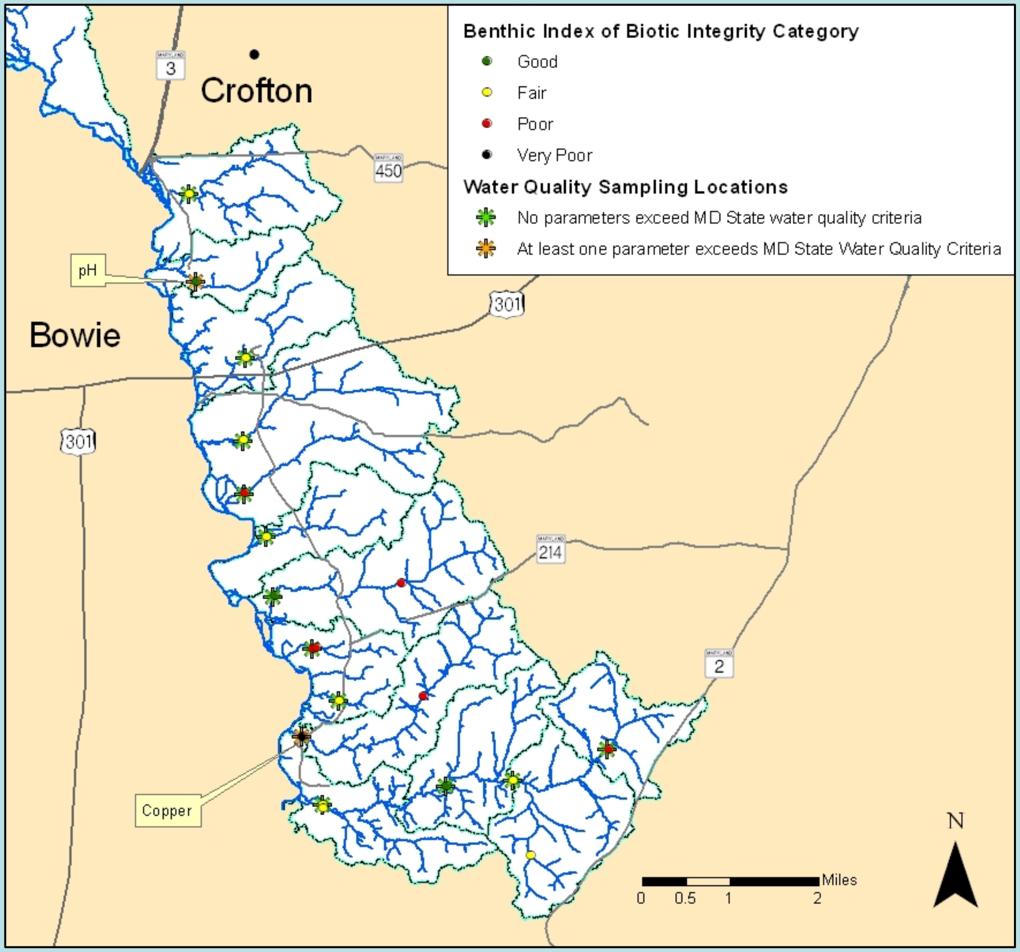


Rosgen Channel Type Definitions



Typical Type B Channel in southern section Upper Patuxent River watershed

Upper Patuxent River Watershed: Southern Section



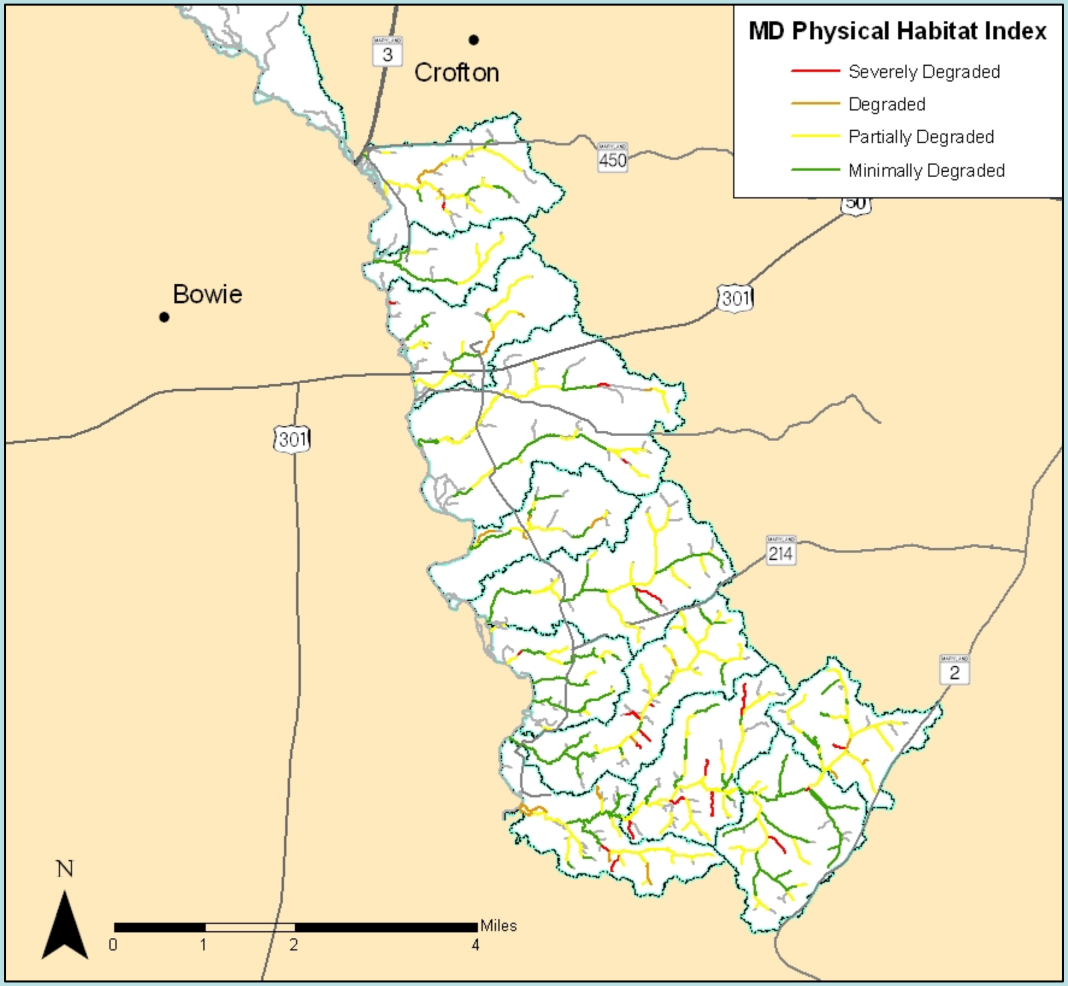
Water Quality and Bioassessment

The County assessed both the chemical water quality and biological integrity of streams in the watershed. Dry weather water quality samples were taken to characterize water quality and estimate potential pollutant loads. In general, water quality was good; however, there were two minor exceedances of MD State water quality criteria.

Parameter	Average concentration		MD State Water Quality Criteria
TKN	0.315	mg/l	
Nitrate & Nitrite	0.979	mg/l	
Total Phosphorus	3.399	mg/l	
Total Suspended Solids	71.61	mg/l	
Copper	5.464	ug/l	13 (acute) 9 (chronic)
Lead	4.35	ug/l	65 (acute) 2.5 (chronic)
Zinc	36.8	ug/l	120
Fecal coliform	4308	col/100 ml	
pH	7.36		6.5-8.5
Dissolved Oxygen	7.78	mg/l	> 5.0

The County also assessed the macroinvertebrates in the streams. Healthy streams usually contain a wide variety of macroinvertebrates, including those intolerant to pollution. As the quality of the water or habitat declines, the diversity and abundance of macroinvertebrates also typically declines, with pollution tolerant species becoming dominant. A Benthic Index of Biotic Integrity looks at these measures to assess a stream's health. Streams in the southern section of the Upper Patuxent River watershed varied widely in BIBI scores with three sites being in good condition, eight in fair condition, five in poor condition and one in very poor condition.

Upper Patuxent River Watershed: Southern Section



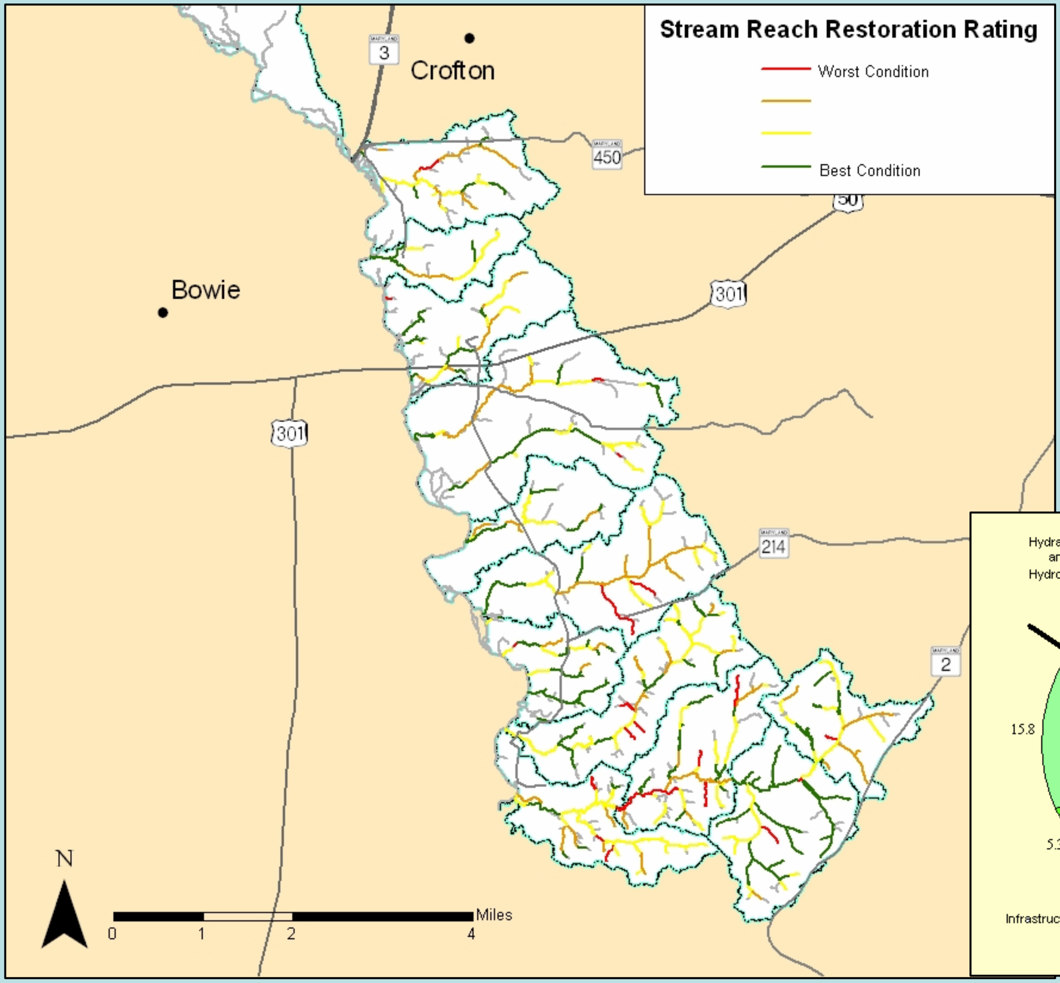
Habitat Assessment

The condition of stream habitat of perennial streams was assessed using the Maryland Physical Habitat Index (MPHI) which incorporated measures of fish and macroinvertebrate habitat, shading, remoteness, and bank stability. The southern section of the Upper Patuxent River watershed had generally acceptable habitat quality with 39% of the stream miles falling in the minimally degraded category and 52% partially degraded. Only 5% of the stream miles were determined to have severely degraded physical habitat.

Minimally degraded stream reach in the southern section Upper Patuxent River Watershed

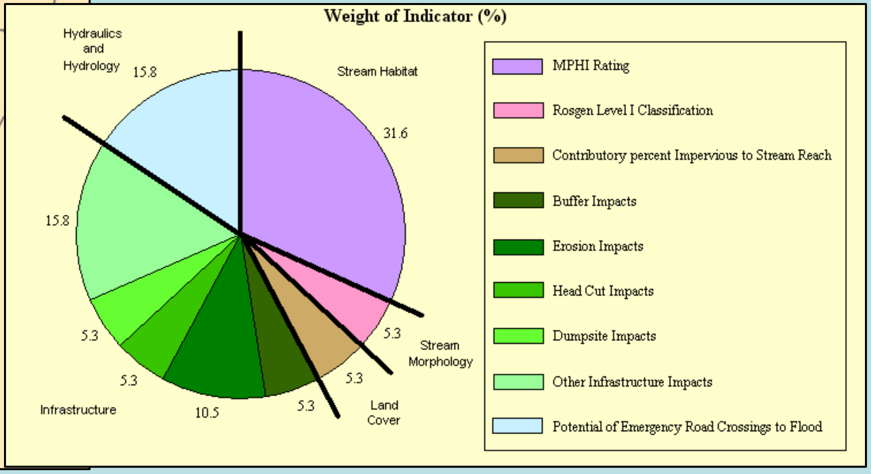
Severely degraded stream reach in the southern section Upper Patuxent River Watershed

Upper Patuxent River Watershed: Southern Section

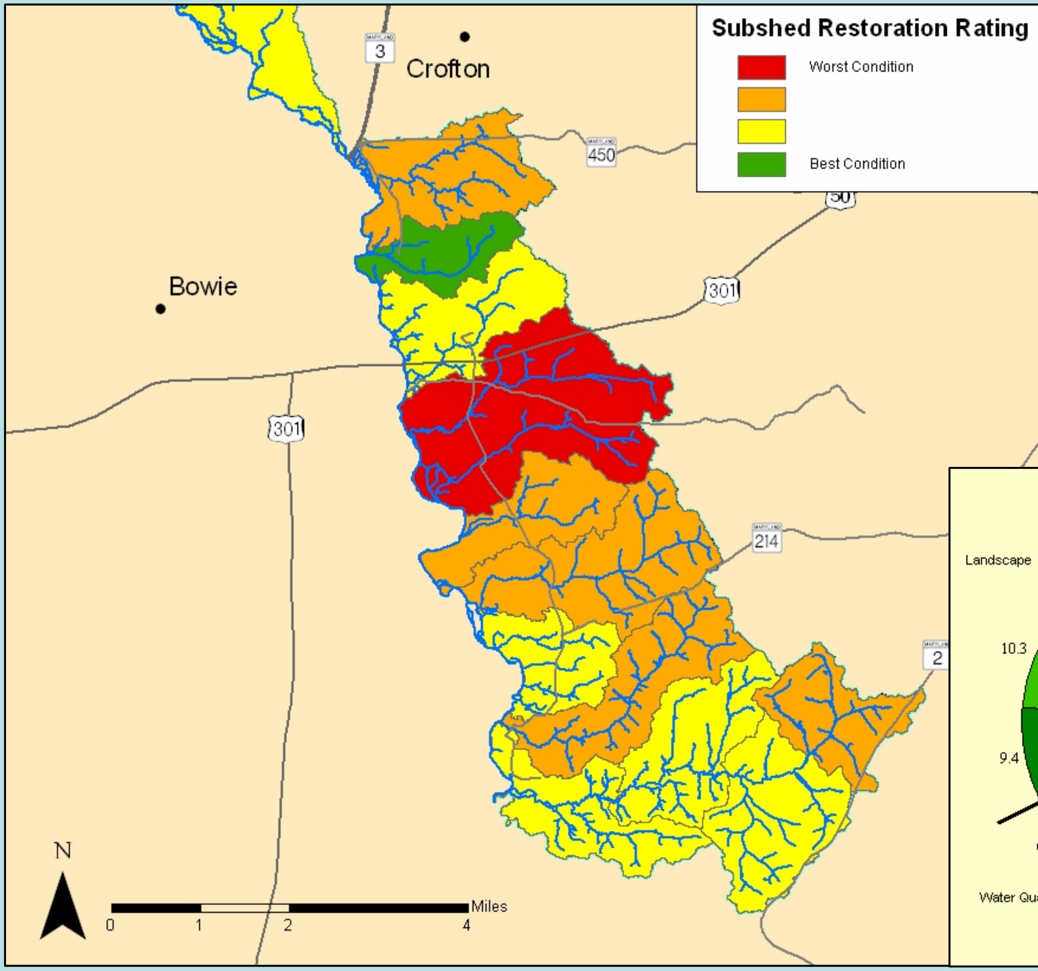


Reach Restoration Assessment

By looking at physical habitat quality, bank morphology, the amount of surrounding impervious land cover and the impact of infrastructure features such as dumpsites and deficient buffers, the County assessed individual stream reaches and rated them to help focus resources for restoring impaired stream reaches. Each indicator was weighted differently depending upon its impact on stream integrity. Approximately 2% of the streams in the southern section of the Upper Patuxent River Watershed were rated as being good candidates for restoration ("worst condition").

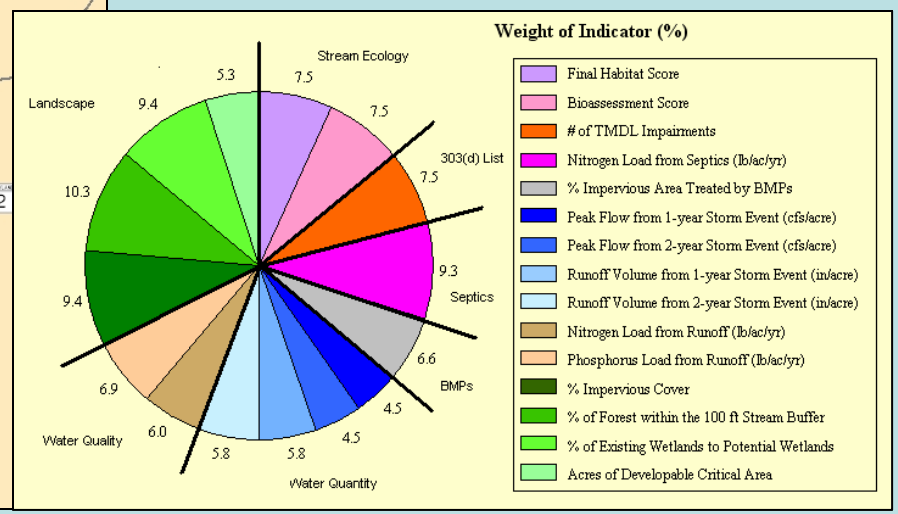


Upper Patuxent River Watershed: Southern Section

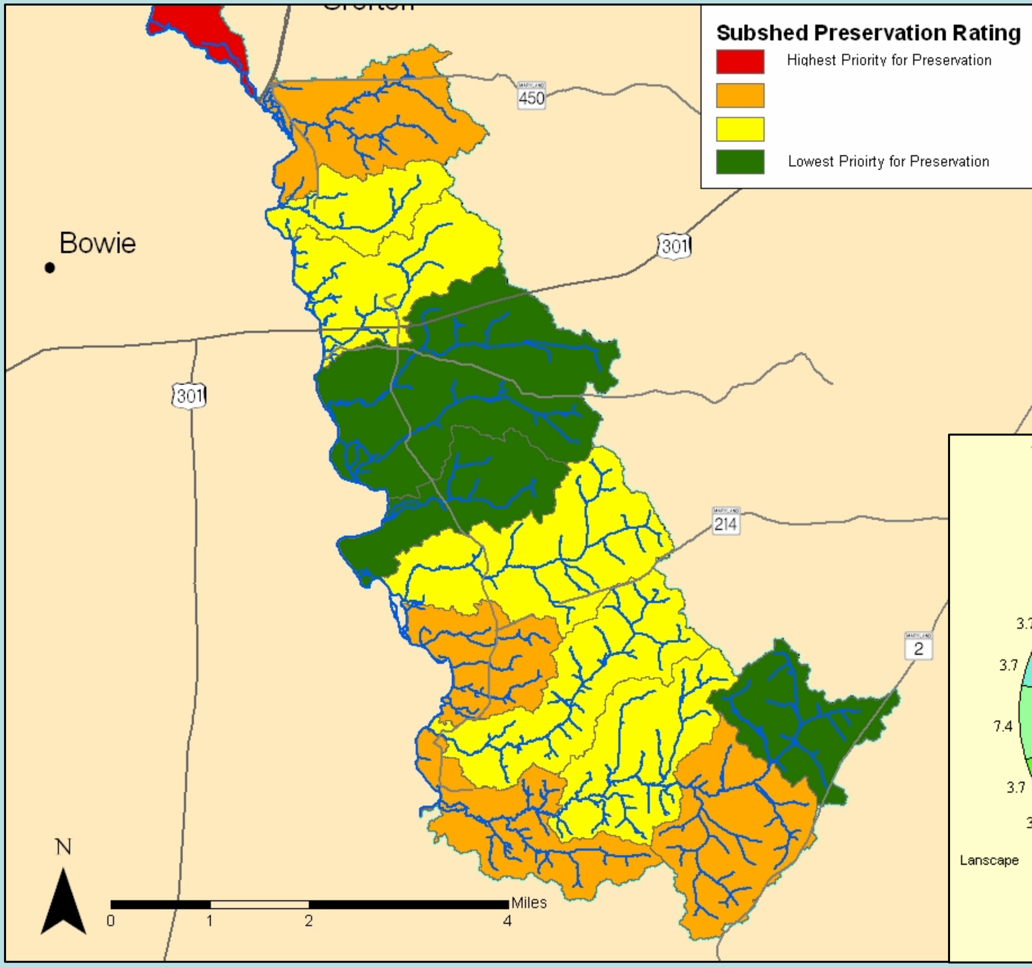


Subwatershed Restoration Assessment

By looking at stream habitat, hydrology and hydraulics, water quality, and landscape features such as impervious cover, BMP coverage, and forested buffers among others, the County assessed individual subwatersheds and rated them to help focus resources for restoring impaired subwatersheds. The southern section of the Upper Patuxent River Watershed had one subwatershed in the lowest and highest category for restoration priority.



Upper Patuxent River Watershed: Southern Section



Subwatershed Preservation Assessment

By looking at stream habitat, water quality, and the presence of sensitive land types such as wetlands, greenways, and protected habitats among others, the County assessed individual subwatersheds and rated them to help focus resources for preserving those that are most sensitive. None of the subwatersheds in the southern section of the Upper Patuxent River Watershed received the highest priority for preservation rating.