THE ALEXAUKEN CREEK
WATERSHED PROTECTION PLAN
319(h) Grant # RP05-084

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Executive Summary

The Alexauken Creek Watershed Protection Plan is the culmination of efforts on the part of West Amwell Township, other watershed municipalities including Delaware Township, East Amwell Township, and the City of Lambertville, environmental groups, and perhaps most importantly watershed residents to prepare a scientifically-based document that outlines the steps to protect, preserve, and improve the water quality and environmental resources of the Alexauken Creek Watershed. This document is two-parted. The first part is the Characterization and Assessment component based on extensive in-field sampling of water quality, volunteer visual assessment of stream corridor condition, and hydrology/hydraulics. The in-field sampling was paired with various water quality and land use models to effectively identify, characterize, and quantify environmental resources and impairments within the watershed. The second component is the Protection Plan which addresses characterized impairments both in general and on site specific basis. This includes the identification and development of an extended list of Restoration Sites which are ranked by priority based on various criteria. The two primary goals of this plan are:

- To accurately and extensively characterize surface water quality, biological condition, and potential sources of pollutant loading in the Alexauken Creek watershed.
- To ensure protection from negative measurable changes in water quality and, where feasible, enhance surface water quality in the Alexauken Creek watershed.

Alexauken Creek is designated a FW-2 Trout Maintenance (TM) Category One (C1) Stream, meaning in general that it is a freshwater capable of supporting trout, but not trout reproduction. The stream is also subject to Category One anti-degradation status providing for no negative changes in water quality and protected primarily by a 300 foot stream buffer. The designation of Alexauken Creek as both a TM and C1 waterway indicates the relatively high quality of the system. This quality is largely a function of the rural watershed land uses, primarily agricultural and forested, albeit with increases in developed land uses and continuing development pressure. Despite the general indication of quality in the State designation of Alexauken Creek as a TM and C1 waterbody, the stream also has documented water quality impairments. These include designation on the 303(d) list for non-attainment of aquatic life uses related to temperature impairments, moderate impairment of benthic infauna at stations according to AMNET reports, and elevated *Enterococcus* in a Delaware River Basin Commission study from 2001. These conflicting classifications indicate that water quality metrics for the watershed are mixed.

The various field surveys and modeling efforts largely confirm some of these issues. The following list includes some of the more pertinent issues affecting the integrity of the watershed.

- The volunteer visual assessment effort, overseen by project partner Delaware Riverkeeper Network which pooled volunteers from concerned residents in the watershed, noted buffer impairments and bank encroachment as some of the primary issues affecting the stream, as well as channel erosion and the ubiquity of invasive plants throughout the tributary network.

- Temperature impairments were observed at various sites throughout the stream and were noted in both continuous and discrete temperature monitoring; this type of impairment negatively affects aquatic organism community composition.
- Total Phosphorus (TP), which is the nutrient of greatest concern in promoting excessive algae and aquatic plant growth, was shown to be greatly elevated during storms indicating the need for better stormwater management.
- Total Suspended Solids, similar to TP, were elevated during storm sampling and indicate erosion both in the channel and overland.
- Nitrate was generally acceptable, but showed very high concentrations at one of the headwater stations.
- *E. coli*, a fecal bacterium, was shown to be well in excess of water quality standards and represents a significant threat to contact uses like swimming, and is in part related to agricultural land use and septic effluent.
- The macroinvertebrate community was generally good, but showed some impairment, particularly in the composition which tended to be somewhat pollution and thermally tolerant.
- The visual habitat assessment, which looks at stream condition, was generally optimal to sub-optimal throughout the sampled sites, but bank stability and erosion tended to be the issues of greatest concern.

The characterization and documentation of impairments in the watershed fostered the development of solutions to mitigate these issues. The rural nature of the watershed presents a challenge in rectifying these issues. In more densely developed watersheds achieving control can be easier because many impairments tend to be concentrated, be it through stormwater outfalls, wastewater treatment plants, known areas of contamination, or other such scenarios. The situation in the Alexauken is different in the sense that the identified pollutant loading and stormwater runoff is diffuse and ubiquitous, and thus not easily tackled with discrete or concentrated measures. Mitigation of these problems will therefore require widespread implementation throughout the watershed which will hinge on public and municipal buy-in and participation. Therefore, this plan has been developed to be both achievable and realistic with a full understanding of limitations including funding and public holdings. Many of the solutions offered in this Watershed Protection Plan are of relatively low-intensity requiring minimal expenditure, consulting, or earth moving in an effort to more widely implement these designs in order to protect and improve the aquatic function of the watershed.

The following list identifies some of the management measures that are discussed within the body of the report to affect positive changes in the watershed.

- Existing regulations are among the strongest protections afforded the water quality of the watershed including State regulations and rules such as the Surface Water Quality Standards, Stormwater Management Rules, Flood Hazard Area Rules, Freshwater Wetland Protection Act Rules, as well as local environmental ordinances from the constituent municipalities including Stream Corridor

Protection, Stream Buffers, Steep Slopes, and Groundwater Protection. All of these work in concert to limit the types of development or land use activities that could potentially significantly impair the environmental function of the watershed.

- Riparian Buffer Enhancements were identified as the most efficacious techniques to implement in improving water quality in the watershed by providing increased shading, pollutant removal, bank stability, and habitat improvements. These are among the most cost effective techniques to be utilized, and are low intensity, taking the form of no-mow zones and buffer plantings to restore a functional riparian buffer.
- Cultural Best Management Practices (BMPs) are also extremely useful and will focus on cultural practices that can promote better stream function by examining fertilizer use, septic management, water conservation, waterfowl control, yard waste, and structural BMP maintenance.
- Structural BMPs are also recommended at specific sites throughout the watershed, and will focus on the use of newer designs, including vegetation components and infiltration, to target specific areas where better performance is required to control stormwater, both for quality and quantity, and pollutant loading in general. Some of the specific structural BMPs include wet ponds, bioretention and infiltration systems, water quality swales, and manufactured treatment devices.
- Bed and bank stabilization techniques will be employed to address problem areas in the watershed where erosion related impacts are most severe. This will include bank stabilization techniques, toe protection, flow deflection, and grade control to not only fix problems, but improve habitat as well as hydraulics and hydrology
- Other solutions to be utilized include manure management, invasive species management, open space preservation to protect sensitive areas, agricultural BMPS, and others.
- In total, 38 candidate restoration sites are included in the report with conceptual solutions that include estimated costs, design and permit requirements, and associated benefits.

Finally, this plan also includes a variety of technical and planning information to guide the implementation of this plan. This type of information includes:

- Technical and financial assistance to design, construct, and implement mitigation solutions.
- Information and education components to inform interested parties about the need for implementation as well as project progress.
- Implementation schedule based on ranking of specific projects.
- Milestones for tracking implementation.
- Monitoring criteria and reporting requirements to document water quality changes and to inform further implementation.

1.0 Background

The Alexauken Creek is a tributary to the lower Delaware River located in the southern portion of Hunterdon County, New Jersey and its watershed encompasses portions of four municipalities: West Amwell Township, Delaware Township, East Amwell Township, and the City of Lambertville. The creek, and by extension the watershed, is an outstanding natural resource of these predominantly rural communities and is recognized for its ecological function, habitat value, aesthetic beauty, recreational opportunities, and unique geology, landscapes, and hydrology. These qualities have been preserved due to a variety of factors including the preservation of open spaces, such as intact contiguous forest and wetlands, sustained active agriculture, statutory and regulatory protections, and low level development. The headwater portions of the Alexauken Creek drain approximately 10% of Sourland Mountain, a geologic sill of diabase or trap rock characterized by high gradients, exposed rock fields, and poor infiltration which have limited onsite wastewater treatment and development in general. Similarly, the lower portions of the watershed adjacent to the major tributaries along the western slopes of the watershed continue to be used for agriculture or remain forested. The watershed is inhabited by a variety of sensitive plant and wildlife communities including threatened and endangered species and other species that merit special protection, such as trout.

Despite the quality of the watershed and the stream the Alexauken Creek is not pristine and has documented impairments in function as listed by the State of New Jersey Department of Environmental Protection (NJDEP) and the United States Environmental Protection Agency (EPA). For the most part, the impairments in the stream are related to the generation of nonpoint source (NPS) pollution in stormwater runoff, although increased hydraulic loading to the streams from impervious services, such as roadways, also implicates the effects of bank erosion and sediment deposition. More specifically, Alexauken Creek is listed on the 303(d) List of Water Quality Limited Waters and Sublist 5 for non-attainment of designated uses, aquatic life (trout) and aquatic life (general). The noted deficiency for the listing is temperature impairment as defined by the New Jersey Surface Water Quality Standards (SWQS, N.J.A.C. 7:9B).

Alexauken Creek is designated in the SWQS as a FW2-TM(C1). More plainly, the stream is a Freshwater 2 Trout Maintenance stream with Category One (C1) antidegradation standard. FW2-TM refers to its classification as a general surface water, specifically a freshwater stream that supports trout, but not trout reproduction due to habitat or other deficiencies. As such, the Alexauken is subject to that specific subset of SWQS for FW2-TM waterbodies. In particular, designation as TM water indicates that the stream is capable of supporting trout by maintaining required low water temperatures throughout the summer months. The designation of the creek as a C1 waterbody was formalized in July 2004 through the petition of four regional environmental organizations. The listing of a C1 stream is based on certain characteristics of exceptional ecological significance or other values that are to be protected from measurable changes in water quality characteristics and shall be improved to protect or maintain designated uses. More specifically, the Alexauken Creek is therefore protected by a 300 foot buffer adjacent to either bank on the main stem and all tributaries, and as such is afforded some of the greatest degrees of regulatory protection in the State through its C1 designation.

In order to address these documented impairments in water quality and stream ecologic function West Amwell Township, as the applicant in a partnership with various parties, sought and was awarded a 319(h) grant in response to a State Request for Proposal to develop, implement, and prepare the Alexauken Creek Watershed Protection Plan. Project partners for the task include:

- Delaware Township Environmental Commission
- East Amwell Township Environmental Commission
- City of Lambertville
- Hunterdon County Planning Board
- Hunterdon Land Trust Alliance
- Delaware Riverkeeper Network
- The Regional Planning Partnership
- Sourland Planning Council
- and Project Supporter Stony Brook-Millstone Watershed Association

The overarching goals of the Alexauken Creek Watershed Protection Plan are simple:

- To accurately and extensively characterize surface water quality, biological condition, and potential sources of pollutant loading in the Alexauken Creek watershed
- To ensure protection from negative measurable changes in water quality and, where feasible, enhance surface water quality in the Alexauken Creek watershed

The comprehensive characterization of the Alexauken Creek and its watershed was a crucial component in the formation of this document for a variety of reasons, chief of them being that up to this point the stream had not been systematically studied or monitored. As such, the creek was alternately listed in the 2004 *Integrated Water Quality Monitoring and Assessment Report* on Sublist 1 as attaining aquatic life uses while being designated on Sublists 2, 3, and 5 in the 2006 report. These alternate listings correspond, respectively, to general use attainment with at least one impairment in use designation or uncertainty in status, insufficient data to characterize use attainment, and non-attainment of a designated use. Since the Alexauken Creek watershed spans two HUC-14 subwatersheds (14-digit hydrologic unit code) there are two assessment units for this waterbody, and the noted deficiencies, as described above, were related to non-attainment of aquatic life uses and both were related to temperature impairments. Additional impairments have been documented by several sources over time. Several AMNET (Ambient Biomonitoring Network) reports indicated that some of the monitored sites on Alexauken Creek were characterized as moderately impaired, as based on the composition of the benthic infauna (macroinvertebrates). Likewise, the Delaware River Basin Commission (DRBC) noted elevated *Enterococcus* concentrations in Alexauken Creek in their 2001 dataset.

The formal comprehensive monitoring was accomplished through the course of 2007 and the methodology, results, and assessment were published in the 2008 *Alexauken Creek Characterization and Assessment Report*. The problems noted in 303(d) lists and other sources were largely confirmed by lengthy field investigations. In particular, summer mean temperatures were shown to be excessive and to exceed FW2-TM SWQS at several of the monitored stations. Similarly *E.coli* mean 30-day concentrations exceeded the standards, and several stations had macroinvertebrates communities that were characterized as moderately impaired utilizing the New Jersey Impairment Scoring (NJIS) schema. In addition to the confirmation of the impairments the characterization surveys also discovered that there were additional impairments to stream water quality reflected both in the *in-situ* (measured in the field) and discrete water quality parameters. These impairments are reflected in a variety of metrics, but stormwater quality or stormflows seemed to be most affected and of lowest quality. Physical impairments were also observed in the volunteer Visual Assessments which revealed that in-stream processes, such as erosion or sedimentation, and riparian corridor encroachments are endemic throughout the watershed and are both the cause of and symptomatic of water quality and ecological impairments in Alexauken Creek.

While impairments are noted in the function of Alexauken Creek water quality and other processes including biological colonization water quality is in fact generally good in the watershed and the creek. Despite moderately high water quality coupled with policy and regulatory protections Alexauken Creek stands at a critical stage. While stream quality has only been loosely assessed up to the start of this project it does seem that the available indices indicate a decline in water quality over time that is commensurate with increasing development in the watershed. Furthermore, small increases in nutrient loading, thermal regime, and modifications to channel morphology and sediment transport in the stream could spell major changes in water quality and physical changes to the habitat which would alter biological communities. Looking ahead there is mounting development pressure in Hunterdon County which could threaten stream health and make mitigation of the stream more difficult.

This Watershed Protection Plan therefore functions as a guide to satisfy the second stated goal: resource protection from degradation and enhancement. This document will be formatted to address in order the nine elements of a Watershed Protection Plan as laid out by the EPA. These nine elements are meant to address all phases of a protection plan from characterization to conceptual mitigation and practical design, costing, and implementation and evaluation. The following list represents a summarized and abbreviated description of the nine elements as outlined in the *Handbook for Developing Watershed Plans to Restore and Protect Our Waters* (EPA, 2008).

1. Identification of causes of impairments and pollutant sources
2. An estimate of load reductions expected from management measures
3. A description of NPS management measures and implementation sites
4. Estimate the amount of technical and financial assistance to implement
5. Information and education of the public and inclusion in plan development

6. Schedule for implementing the NPS management measures
7. A description of interim measurable milestones for implementation
8. Developing criteria to determine loading reduction and achievement of standards
9. Monitoring to evaluate implementation effectiveness utilizing developed criteria

By addressing these elements a thorough and comprehensive plan can be created that in the end will affect improvements in water quality and ultimately improve stream function. This document is therefore based on several key concepts that are implicit in the stated nine elements: characterization and assessment is based on the best available science and data, public participation of residents and stakeholders is tantamount to success, design and implementation must be thoroughly addressed and planned, and the proper performance and implementation of management measures is met through monitoring and adaptive management.

2.0 Identification and Characterization of Impairments

This section deals with the identification and characterization of impairments in the Alexauken Creek related both to nonpoint sources and other stressors. This section corresponds to the first of the nine elements listed by the EPA. The first element is described as follows:

> *Identification of causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions, and any other goals identified in the watershed plan. Sources that need to be controlled should be identified at the significant subcategory level along with estimates of the extent to which they are present in the watershed (e.g., X number of dairy cattle feedlots needing upgrading, including a rough estimate of the number of cattle per facility; Y acres of row crops needing improved nutrient management or sediment control; or Z linear miles of eroded streambank needing remediation).*

This section has largely been addressed in the *Alexauken Creek Characterization and Assessment Report* (2008), and the results of that document will be summarized here. This section will also frame the results of the characterization report in relation to various policies, standards, rules, and regulations regarding stream quality and designated use attainment.

2.1 General Characterization

2.1.1 Study Area

The Alexauken Creek is a FW2-TM Category One stream located in Hunterdon County, New Jersey that discharges directly to the Delaware River within the City of Lambertville. The watershed encompasses portions of four municipalities in the southern and western margins of the county (West Amwell Township, Delaware Township, East Amwell Township, and the City of Lambertville) for a total watershed area of nearly 9,700 acres or 15.1 square miles. Similarly, the watershed of the creek drains portions of two United States Geological Survey (USGS) HUC14 Subwatersheds: 020401052100-10 and 020401052100-20, which nearly evenly split the watershed in half.

2.1.2 Municipal Environmental Ordinances

The municipalities in the Alexauken Creek watershed have been proactive in protecting and preserving the environment as policy and codifying this in ordinance and regulation. NJDEP adopted Phase II Stormwater Rules in 2004 which issued a series of Statewide Basic Requirements (SBR) that seek to minimize NPS pollution and impacts. All four municipalities in the watershed are characterized as Tier B for smaller municipalities. The four municipalities have adopted a variety of measures that meet or exceed Tier B SBRs. Most of the constituent municipalities have adopted ordinances, which will be discussed in greater detail elsewhere, including:

- Stream Corridor Protection
- Stream Buffers
- Woodlands Protection
- Steep Slopes
- Threatened and Endangered Species/Critical Habitats
- Groundwater Protection

2.1.3 Demographics

Hunterdon County is a fast growing county subject to mounting development pressure which is driven in part by the rural character of portions of the county, including this watershed. Development pressure is high due to the desirability and rural character of the area and the presence of large, undeveloped tracts of land. According to the US Census Bureau the population of the county grew by 20% by between 1990 and 2000 to a total population of 129,746 and is predicted to grow an additional 16% by 2020. The area has a median age of 42.6 years, above the State average, and a median income 40% more than the State median.

2.1.4 Geology and Soils

The Alexauken Creek watershed lies within the Piedmont physiographic province. While 80% of the area consists of sedimentary rock formations, notably the Passaic Formation, the most unique geological feature is the Sourland Mountains. This area consists of Jurassic diabase, also known as trap rock, which is weather resistant and is a poor yielding aquifer. This igneous intrusion, located along the eastern edge of the watershed, is characterized by steep slopes and low development levels. The sedimentary rock formations, particularly the Passaic Formation, exhibit less relief and are widely used for agriculture.

According to the National Resource Conservation Service (NRCS, formerly Soil Conservation Service or SCS) *Soil Survey of Hunterdon County* 26 soil series are identified in the watershed. Penn channery silt loam and the Lehigh soil series are the predominant soils in the watershed. Many of the soils in the watershed are characterized by high seasonal water tables and shallow depths to bedrock, both of which indicate low hydraulic conductivity.

Three (3) soil series are characterized as Prime Agricultural Soils which exhibit a list of characteristics conducive to agricultural uses, particularly crops. In addition, there are a variety of Soils of Statewide Importance, which are soils in land capability Class II and III that are likewise important for the production of crops but do not meet the stricter criterion to classify as Prime Agricultural Soils.

A vast majority of the soils in the watershed are classified as potentially highly erodible. Erodibility is defined by soil characteristics as well as other factors such as slope, vegetative cover, and runoff velocities. In addition, highly erodible soils were also identified in the watershed. These soils are strongly associated with the major stream channel corridors particularly in the lower portions of the main stem and along the east and south branches in the headwaters near the Sourlands. The identification of highly erodible soils in these areas indicate that the stream is naturally subject to high erosion within the channel itself and a sink for eroded materials in the riparian corridor.

2.1.5 FEMA Floodplains

The Federal Emergency Management Agency (FEMA) issues floodplain maps that describe flood events in the 100-year and 500-year flood zones. These areas are based upon exceedance probabilities and not periodicity of flood events. The 100-year floodplain is also known as the Special Flood Hazard Area, and these areas are also split into two designations. Zone AE represents the 100-year floodplain for which Base Flood Elevations (BFE) has been established; the BFE is based on detailed area-specific hydraulic analyses and is tied to vertical datum. Zone A, which has no BFE, is based on area topographic models of flooding. In the Alexauken Zone A encompasses all mapped areas upstream of the Rt. 202 corridor including the east and south branches up into the headwaters, but is described only along the USGS Blue Line streams and not the mapped SCS streams. A small part of Zone A is also established on the north branch just south of Garboski Road. The remainder of the main stem downstream of Rt. 202 is ascribed to Zone AE which does include BFE values. Zone X500 or 500-year floodplains have also been established for portions of the main stem and small areas along some of the smaller tributaries.

2.1.6 Groundwater Recharge

The groundwater recharge capability within the watershed varies widely as based on the New Jersey Geological Survey (NJGS) GSR-32 methodology. Wetlands and areas with hydric soils have very low or negligible recharge potential, and in the Alexauken Creek watershed these areas are largely confined to the Sourlands region along the eastern edge of the watershed boundary, although small, isolated pockets are found elsewhere. This indicates that Sourlands have poor groundwater recharge potential and that water supply in this area is critical. The remainder of the watershed shows modest potential recharge ranging from 1 to 11 inches per year. Higher recharge rates, ranging from 12 to 14 inches per year, were identified primarily in the northern portions and headwater areas of the watershed.

2.1.7 Landscape Project and Natural Heritage Program

The Landscape Project is operated by the New Jersey Division of Fish and Wildlife Endangered and Nongame Species Program to protect biological diversity and wildlife in functioning ecosystems. The Landscape Project categorizes these ecosystems according to the Project Priority Ranking system, with increasing numerical rank representing more functional systems particularly with identification of increasingly rare species such that habitats with known occurrence of threatened or endangered species are ranked the highest (Rank 5).

In the Alexauken Creek watershed nearly 90% of the land mass is designated a critical habitat area. The four major habitat types listed in descending order by area are forest, grassland, forested wetland, and emergent wetland. The majority of the area is designated Rank 1 and 2 which identifies suitable habitats that are not known to be used by more imperiled species. The highest ranked habitat is a grassland along the northern boundary that is Rank 4 which signifies the known occurrence of at least one State-listed endangered species. Grasslands in particular are a declining habitat and grassland birds are unfortunately well represented on the various lists including endangered, threatened, and species of special concern. Overall, the Alexauken Creek watershed has a high habitat value and is known to be used by various listed species.

Mapping indicates that there is no occurrence of Bald Eagle (*Haliaeetus leucocephalus*) or Wood Turtle (*Glyptemys insculpta*) within the watershed. Rutgers University has identified and certified four vernal pools in the watershed, but additional pools that have not been certified were identified by volunteers conducting the Visual Assessment of the watershed.

The New Jersey Natural Heritage Program is similar to the Landscape Project and documents through the Natural Heritage Database the occurrence of rare communities. Natural Heritage Priority sites are based strictly on rare plant communities. There is only one priority site in the watershed, which is the Holcombe Island Natural Heritage Priority Site, located near the mouth of the Alexauken Creek; the area within the watershed boundary is only 5.5 acres. Formerly the East Amwell Grassland Macrosite was identified as a Priority Site but was delisted due to the lack of a rare plant community. However, this area is still characterized as a Critical Habitat Area.

2.1.8 Land Use/Land Cover and Impervious Surfaces

Land use and land cover (LU/LC) is a critical component to the understanding of the Alexauken Creek watershed, because it describes and quantifies the development patterns and uses of the watershed. LU/LC data is a reliable indicator of potential impairments in water quality in streams and often serves as the base data for various pollutant load budgets and hydrology models. All LU/LC data utilized in the C&A report and this document references the 2002 NJDEP LU/LC dataset which utilizes a modified Anderson classification system.

As mentioned above, the Alexauken Creek watershed has rural characteristics. The greatest single LU/LC category is agriculture, which accounts for 36% of the watershed, and includes cropland and pastureland among other uses (Table 1). The second largest LU/LC category was forest at 32% of the watershed; the dominant forest type is deciduous forest. Low density and rural residential development accounted for 10% of the watershed area. These LU/LC codes are characterized by large lot sizes. Other important LU/LC categories include field/scrub/shrubland, wetlands, and other mixed urban uses respectively accounting for 9%, 7%, and 3% of the watershed. Five other broad land use types were found within the watershed but these all account for less than 1% of the total. Interestingly, the general rank of LU/LC remained consistent throughout the four municipalities although the percent distribution varied somewhat.

Table 1: Watershed LU/LC

LU/LC Category	Area	% of total watershed area
Agricultural	3,474	36%
Forest	3,135	32%
Low Density/Rural Residential	957	10%
Field/Scrub/Shrubland	846	9%
Wetlands	714	7%
Urban/Mixed Urban/Other Uses	314	3%
Lakes/Streams	76	<1%
Recreational Land	71	<1%
Barren/ Transitional Areas	51	<1%
Commercial/Industrial	25	<1%
High/Medium Density Residential	13	<1%
Watershed Area	**9,676**	**100%**

Impervious surfaces were also identified and mapped. The impervious areas were calculated by multiplying the percent impervious cover of various LU/LC codes by the associated area. In total only 2.5% of the watershed is impervious.

The rural nature of the watershed is confirmed by its low level of urban land uses (including low density and rural residential uses) and overall low level of impervious surfaces coupled with large tracts of forest and agricultural land. While urban, commercial, and industrial land uses are often implicated as the main contributors to NPS loading these less urbanized uses can also degrade stream quality and contribute to pollutant loading. It is generally true that these less intensely developed watersheds do have smaller loads of toxics such as metals and petroleum hydrocarbons, but rural watersheds are more likely to contribute nutrient pollutants and solids. Where agriculture is an important component of the makeup of the land it is typically the primary loader of phosphorus and nitrogen and may contribute large solids loads as well. Similarly, low density residential development may act in a similar fashion although the unit areal load may be smaller than agricultural uses. In the end, the loading related to residential and agricultural uses can contribute to eutrophication in streams as well as deposition of solids. Likewise, while the amount of impervious cover is low even low amounts can affect the delivery of pollutants via stormwater and increase hydraulic loading which can lead to streambank erosion. The role of LU/LC will be examined in further detail in the pollutant load analysis and hydrologic modeling later in the document.

2.2 Visual Assessment

An important component of the characterization of the stream and the watershed was the volunteer Visual Assessment. This work was coordinated by the Delaware Riverkeeper Network, a project partner, which was responsible for the recruitment and training of the volunteers. These volunteers represent a concerned segment of the watershed population, and their efforts are an important part of the community outreach associated with this project. In total 60 volunteers were identified for the project and received an intensive 7 hour training session, which was followed by an in-field practical to assess proficiency followed by further instruction as needed.

The training was conducted to familiarize the volunteers with the developed assessment methodology, which was approved by NJDEP through the submission of a Quality Assurance Project Plan (QAPP). The finalized methodology was an amalgamation and derivation of a variety of stream assessment protocols including:

- United States Department of Agriculture (USDA) Stream Visual Assessment[1]
- Center for Watershed Protection's Unified Stream Assessment: A User's Manual[2]
- NJDEP's Visual Assessment Protocol used by Watershed Ambassadors[3]
- NJDEP AMNET Physical/Habitat protocol[4]
- DRN's Integrated Assessment[5]
- The Pfankuch Channel Stability Evaluation[6]

The modification of assessment protocols was predicated on providing the following various types of data including: reach accessibility and potential monitoring conditions, invasive plant species and extent of colonization, land uses within 50' and ¼ mile of the stream channel, drainage ditch and outfall locations and qualification of conditions, and location and characterization of exceptional resources such as vernal pools, wetlands, and unmapped headwater tributaries. A semi-quantitative visual habitat assessment was also

[1] USDA NWCC Technical Note 99-1. Stream Visual Assessment Protocol, December 1998.
[2] Kitchell, Anne, and Tom Schueler, Center for Watershed Protection. Unified Stream Assessment: A User's Manual Version 1.0, March, 2004.
[3] NJ DEP, Division of Watershed Management. Visual Assessment.
[4] NJ DEP, Bureau of Freshwater and Biological Monitoring, Stream Habitat Assessment for AMNET Sites.
[5] Albert, Richard, Dan Salas, & Dave Williams, Delaware Riverkeeper Network. Integrated Stream Assessment, 2002.
[6] Pfankuch, Dale J. 1975. Stream Reach Inventory and Channel Stability Evaluation. USDA Forest Service,. R1-75-002. Govt. Printing Office, # 696-260/200.

developed that was similar to the EPA Rapid Bioassessment Protocols[7] for high-gradient wadable rivers. This protocol assigned numerical values from 1 to 10 (10 = highest quality) to a variety of metrics. While the chief purpose of this assessment was documentation of resources, the semi-quantitative format allowed the data to be manipulated and more easily compared than qualitative or categorical data. The metrics scored in this survey were:

- Vegetated buffer width
- Vegetated buffer conditions
- Pool variability
- Floodplain encroachment
- Bank stability
- Channel conditions
- Manure presence
- Available cover for aquatic life including benthic macroinvertebrates and fish
- Barriers to fish movement
- Velocity/depth variability

The base unit of assessment was termed the segment, each segment approximating a linear stream mile; in total 30 segments were created for 28.6 USGS Blue Line stream miles. Each segment was evaluated by reaches with the number of assessed reaches varying between one and eight reaches per segment divided according to field conditions, confluence of tributaries, and accessibility. Throughout the process, 23 of the 30 identified stream segments were assessed, and stream segments that were not assessed were generally the result of private property restrictions. Segments were also grouped into larger units or quadrants including Southwest, Northwest, Northeast, and Southeast which allowed assessment on a larger landscape scale.

2.2.1 Visual Assessment Results

Overall, the stream segments showed considerable variability when reviewed on the basis of the semi-quantitative surveys. In fact, even reaches within individual stream segments showed considerable variation due to changing conditions within the stream and in the adjacent watershed. The maximum possible score utilizing this scheme was 120, and individual stream scores ranged from a minimum of 54 to a maximum of 107; the mean score for all segments was 82.2.

The quadrants also exhibited variability, but are useful in relating LU/LC and landscape/watershed placement to overall stream quality. The Southeast quadrant, which contains and is adjacent to the Sourlands, had the best mean score of 91.3 followed by the Northwest quadrant, a forested headwater area, at 87.1. The Northeast quadrant is bisected by the Rt. 202 corridor and scored 79.4. The Southwest quadrant, which

[7] Barbour, Michael T., et al. 1999. Rapid Bioassessment Protocols for Use in Wadable Rivers and Streams: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition, USEPA. Washington D.C.

contains the mouth of the stream and occupies the furthest downstream reaches of the creek, scored the lowest at 75.6. A more complete accounting of the individual quadrants, stream segments, and reaches is given in the following sections. The most notable impacts to the stream segments overall were bank instability. While much of the watershed may be characterized as forest, the consistent development within 50' of the streambanks throughout much of the watershed has led to impaired buffer widths and buffer conditions and is a major driver in causing stream impairment.

2.2.2 Southeast Quadrant Visual Assessment Results

As noted above, this quadrant drains the Sourland Mountain portions of the watershed and adjacent areas and includes the largest tracts of contiguous forest in the watershed. Stream segments assigned to this segment include Z, AA, BB, CC, and DD. While both the east and south branches of the stream flow through this quadrant, this area can be considered amongst the headwaters of the stream and among the farthest from the mouth. These stream segments are also associated with extensive wetlands and critical resource areas. Overall, riparian buffer coverage and condition and bank stability was rated as excellent throughout the stream reaches.

Access was characterized as fair in this area as the areas adjacent to the stream are largely privately held, and, as such, stream segment Z was not assessed. Erosion was characterized as minimal in this stretch and was identified in only two of the stream segments, AA and CC. Erosion was noted in one of three reaches in AA and three of seven reaches in CC. The severity was low and erosional features tended to be less than 30' in length. The potential for erosion seemed to be minimized primarily by the adjacent land uses. Streamside land use is mixed and includes and forest, agriculture, residential, and roadways, but this area is primarily forest.

While the presence of discharges and drainage ditches was noted in segments AA and BB the severity of these outfalls was minimal and seemingly did not contribute to undue erosion or other impairment. One of the major outfalls to the stream was the discharge from the online impoundment on segment BB. While segment Z was not surveyed the worst water quality impairments were documented near the outfall of the farm pond near Rocktown-Lambertville Road.

Invasive species were identified in segments AA, BB, and DD and represented primarily by Multiflora Rose (*Rosa multiflora*) and Japanese Honeysuckle (*Lonicera* spp.) Segment DD was the most widely colonized.

Five vernal pools were identified in this quadrant's survey of exceptional resources (Figure 1). Two of these were previously certified in the Rutgers University database. The three unmapped pools were located near segment BB, and the presence of obligate vernal pool species was noted, including Wood Frog (*Rana sylvatica*) and a Jefferson Salamander (*Ambystoma jeffersonianum*). Numerous wetlands were identified in this quadrant but these seemed to largely overlap with GIS data layers.

Figure 1: Vernal Pool and *Ambysotma* sp. eggs

All of the surveyed stream segments in this quadrant scored above the watershed average, and ranged from 85.5 at segment AA to 102 at segment DD, which also corresponded to increasing distance upstream. Individual reaches in segment AA ranged from 57 to 111. Impairments in lower scoring sections corresponded to decreased buffer widths, conditions, and barriers to fish passage. Segment BB generally scored well but buffer conditions varied between reaches and the presence of manure piles near the banks, barriers to fish passage (particularly the impoundment) and pool variability scored somewhat low. Segment CC had ample buffer widths, but the condition of the buffers was somewhat diminished due to a lack of distinct plant growth phases and the presence of invasive species. Within the stream numerous barriers to fish passage were identified and there was poor velocity and depth variation. Segment DD scored the best of the segments in this quadrant but scores were slightly hampered by low stream velocities and channel variability.

2.2.3 Southwest Quadrant Visual Assessment Results

This quadrant encompasses those lower segments of the stream including the mouth of the creek at its confluence with the Delaware River. A number of significant tributaries discharge to the Alexauken throughout this quadrant and stream order (size) varies significantly throughout the quadrant including small headwater, larger tributaries, and the main stem. This area is characterized by mixed land uses including agriculture, forest, residential, transportation, and commercial uses. The main stem of Alexauken Creek runs roughly parallel to the Rt. 202 corridor in this quadrant. Ten stream segments are assigned to this quadrant: A, B, C, D, E, F, G, H, I, and J. Portions of segments A, B, D, and H form the main stem of the creek. Accessibility to the stream was variable in this quadrant, but was generally good. Only segments E and J were not surveyed. The defining characteristics of this quadrant were the variability in segment and reach condition. However, the biggest problems observed in this quadrant were poor buffer width and poor buffer condition, which led to numerous examples of bank instability and erosion. In those places where floodplain encroachment was minimized the segments scored well and exceptional resources were identified.

Erosion was widespread throughout this quadrant, and was noted in all seven of the surveyed segments (erosion was not assessed in segment F)(Figure 2). Stated differently, erosion was documented in 19 of the 35 reaches, and was more pervasive in this quadrant than the other three. Segment A was marked by erosional features, but these areas were mostly confined to areas adjacent to the confluence with the Delaware River; however, erosional features varied in length from 25’ to 125’. Segment B was documented to have an erosional feature up to 250’ in length, while erosional features in segment C were measured between 75 and 85’ which is significant due to the small size of this tributary. An expansive area of erosion, 300’, was identified in reach 2 of segment D. Erosion was noted in segment G as well as a lack of riparian buffer, and in segment H six instances of erosion were identified with feature lengths up to 200’. Segment I had the worst erosional problems, which were characterized as severe in reaches 2 and 3. Reach 3 in particular was very poor and the banks were so unstable in these areas that the channel condition was totally degraded according to a variety of metrics; floodplain encroachment was also noted in this area.

Land use was mixed throughout this quadrant as was stream order, and varied from ample forest buffers to agricultural and residential encroachments within 50’ of the streambanks. For this reason a generalized description is not appropriate, but it has been noted that varying land use types are strongly correlated with the associated semi-quantitative scoring of each surveyed reach. Segment A, the furthest downstream reach, was characterized by a variety of land uses including agriculture, residential, to more dense residential and commercial uses. Large roads passed through this area as well and roadside drainage disturbances were well documented as was erosion. Stream segment B had lower intensity use and included contiguous forest, agriculture, and residential uses. It must noted that animal holding areas, ATV disturbances, utility impacts, and timber management were all noted within ¼ mile of the stream. Segment C and D were similar in overall land uses to segment B with ATV use and utilities disturbances noted. In segment D the land use determined to be of most importance was the presence of numerous large manure piles within close proximity to the streambank at reaches 3 and 4. In segment F only a single reach was investigated but residential development and ATV disturbance was noted within 50’ of the banks, and narrow buffers were surrounded by agricultural areas. Segment G originated in forested areas and a mix of uses was seen downstream. Heavy ATV use has led to severe cuts and ruts which have increased runoff velocities and contributed to in-stream erosion. Segment H had numerous land uses within 50' of the banks including grazing areas, utility impacts, and road drainage discharges. Segment I was scored as the worst surveyed segment in the entire watershed. Dominant land use was agriculture and specific impairments include the dumping of trash into drainage ditches and pervasive ATV use including stream crossing. As such in-stream habitat was severely impaired and the banks were extremely unstable.

Figure 2: Erosional Feature

Related to the streamside land uses, particularly roadways, but also residential and agricultural uses, there was a large number of drainage ditches and other outfalls in this quadrant. These discharges are characterized in the report because they can be vectors for pollutant loading (either point or nonpoint) and erosion. Most of the drainage ditches in the area were related to roadside ditches, but agricultural ditches and outfalls from basins were also identified. The ditches varied in form but many were stoned and vegetation lined. Severity of their impact was generally limited although there were significant erosion or other habitat impairments related to these ditches in segment A and H. A lesser number of piped outfalls were identified, but some of these were quite large, up to 60" in diameter. The severity of impact was generally moderate with the worst impacts associated with Rt. 202 storm drains and outfalls in segments G and I.

Invasive plants seem to be pervasive throughout this quadrant. While surveys were conducted on just four of the segments these plants were widespread. The dominant invasive was Multiflora Rose, although Lesser Celandine (*Ranunculus ficaria*) and Japanese Honeysuckle were also widespread.

During the surveys six vernal pools were identified, none of which had been previously identified in the Rutgers database. Additionally three wetland areas and unmapped headwater tributaries were identified within 50' of the stream bank in several segments but the exact coordinates were not recorded.

For the semi-quantitative assessment the Southwest quadrant scored the lowest, with segment scores ranging from 54 to 100. As noted in the C&A report this variation seemed to be directly tied to streamside land use factors and that segments in forested areas or in protected open space areas had amongst the best rankings in the watershed while other segments were amongst the worse, including the worst, segment I. Segments I, G, A, and F, all of which scored poorly were noted to have poor riparian buffer widths and condition, low bank stability, poor aquatic cover, and poor velocity and depth regimes. The remaining scored segments, H, C, D, and B all scored higher than the watershed average and thus exhibit a good level of functional stream integrity, and it was these areas which were in lightly developed areas and had good buffer widths and buffer conditions which served to maintain bank stability and avoid erosional issues that plague other parts of the stream. Even these segments had issues; segment H had a single reach with poor buffer conditions and bank stability, segment C had poor velocity, and segment D had manure piles near the banks. Segment B, which scored the best in the quadrant, was generally suitable but buffer width and condition were somewhat degraded.

2.2.4 Northwest Quadrant Visual Assessment Results

The Northwest quadrant included seven stream segments: K, L, M, N, O, P, and Q. This quadrant is focused primarily on the evaluation of the north branch of Alexauken Creek and its tributaries. Land use is fairly evenly split between large forested tracts, agriculture, and rural residential development often in conjunction with agricultural uses. The position of the quadrant would characterize the smaller tributaries as headwaters of the creek. Relative to other quadrants little land is preserved open space although Farmland Preservation and other categories are included. The Northwest quadrant was rated as the second best on the basis of the semi-quantitative scoring, and segment M was tied for the highest scoring segment in the watershed. Accessibility was generally fairly high in this area although segment L was not assessed due to private property restrictions. Erosion was localized and severe in some areas of this quadrant and tended to be closely tied to specific impairments such as drainage outfalls or floodplain encroachments. Many exceptional resources were identified or confirmed mapped features. Generally individual stream segments scored closely to the watershed average and displayed much variability in individual reaches.

The qualitative assessment of erosion in this quadrant showed that erosion was fairly widespread and was observed in at least one reach of all assessed segments. Most of the effects of erosion seemed to be fairly localized in this quadrant and again tied with buffer conditions. While buffer conditions and width was fairly good in general, the reaches with decreased buffer width or quality did exhibit erosion. Segment K, which had the worst erosion, had deep cuts and long erosional features concurrent with encroachments that exacerbated erosion by outfalls and other discharges. Additionally, due to the fairly high gradients in this area some of the erosion was probably the result of steep slopes. Segment Q also had severe erosional problems with reported vertical cuts up to 5', although the lengths of the features were relatively short. The remaining segments seemed to have erosional feature lengths that were generally short, somewhat localized, and not particularly severe. Again, these areas were tied to impaired buffers.

Land uses adjacent to the streambanks were similar to those of other quadrants and included residential areas such as lawns, roads, road drainage, utility impacts, and agricultural uses. In particular, agricultural land uses were reported within 50' of the top of bank of each of the evaluated stream segments in this quadrant, with the exception of segment M (Figure 3). Segment K had the most intensive land use with four distinct agricultural categories as well as others that contributed to severe erosion in this segment. Conversely, segment M, which had few adjacent land uses, was the best scored segment in the quadrant and tied for the best overall. Segment N also had few land uses but agricultural practices extended to the top of bank. The remaining segments displayed mixed land uses characterized by lawns, agriculture, and unpaved roads.

The drainage ditch survey of the area showed that almost all of the outfalls or ditches in the area discharged to segment K. The source of the discharges included agricultural fields, lawns, and roads. While the severity was not ranked particularly high at any of the ditches, about half of them were noted to be eroding. However, erosion in this segment was indicated to be quite high.

Each segment in this quadrant was noted to be impacted by invasive plants. As in other areas Multiflora Rose was dominant invasive, but Japanese Honeysuckle was also widespread. Species impacting wetlands and riparian margins include Common Reed (*Phragmites australis*), Lesser Celandine, and Bamboo (tribe Bambuseae).

Exceptional resources were identified at a high rate in this quadrant, and for the most part confirmed mapped resources. Identified wetlands matched very closely to the NJDEP data while intermittent/ephemeral stream channels, both wetted and dry, matched SCS streams. In most cases the documentation of unmapped channels served to extend the length of SCS mapped tributaries. A single vernal pool was identified in this survey as were a meadow and a farm pond. The apparent number of intermittent streams is largely a function of the undulating topography of this quadrant.

Figure 3: Agricultural Stream Crossing

The Northwest quadrant was scored as the second best in the volunteer visual assessment. For the most part individual segments were scored closely to the watershed average of 82, but individual segments scored from a minimum of 77 at Q to a watershed best 107 at M. As with the Southwest quadrant intra-segment variability was very high as reaches exhibited different conditions. The source and symptom of many of the impairments was again related to buffer condition and drainage features. Segment K, which exhibited severe erosion at points, scored above the watershed average and individual reach scores ranged from 45 to 103. This was highlighted by bank stability in successive reaches alternately scoring highest and lowest for bank stability. Manure issues were noted in some of the stream segments and velocity and depth variability tended to be somewhat poor in this quadrant as was in-stream cover, but portions of this stream include shale or sedimentary outcroppings that naturally offer little cover. The variability may also be related to the small size of some of the tributaries in this in area.

2.2.5 Northeast Quadrant Visual Assessment Results

The Northeast quadrant consists of segments R, S, T, U, V, W, X, and Y, but due to accessibility issues segments S, T, and V were not assessed. Access tends to be somewhat poor in this quadrant as three of eight segments were off limits, but accessibility tends to be fair otherwise due in part to public land holdings. The primary land uses in this quadrant include the typical mixture of forest, agriculture, and residential areas and other more intense uses as well. Also important to this quadrant is infrastructure uses including paved roadways. Green Acres and Farmland Preservation are prominent among the open space preservation programs that preserve large portions of this quadrant. This quadrant includes the confluence of several major tributaries and also includes several fairly large impoundments and drains a part of the diabase sill to the east. Causes of impairments in this quadrant are related to narrow riparian buffers, poor buffer quality, and stream discharges which led to poor channel conditions and bank instability.

In this quadrant, as the others, erosion continues to be widespread, but the frequency is somewhat decreased (Figure 4). Erosion was noted in four of the segments; only segment Y had no indication of erosion. Reduced buffer widths, most less than 100' and several less than 25' increased the rate of erosion as did several drainage features. Most of the erosional features were of moderate length, but features in excess of 100' were documented in segments R and W.

Land uses were variable in this watershed and contributed to variable stream conditions as well. Interestingly, the graded scoring seen in the semi-quantitative assessment matched the landscape position and land uses of the area. Segment R had a mix of residential and agricultural land uses within 50' of the stream and forested areas. A series of impoundments are located on this section. Segment U is amongst the most developed areas in the watershed and agricultural, residential, industrial, transportation, and commercial uses are found adjacent to the stream in this area. This segment also flows through the Rt. 202 corridor. Segment W had much the same composition as segment U, but of lesser intensity. Segment X was a transitional area of the watershed and while agriculture and residential development were amongst the noted riparian land uses this reach is mostly forested. Segment Y is almost entirely forested but recreational uses such as ATV use and hiking trails are located near the banks. Some agriculture and residential uses were found within ¼ mile of the banks.

Drainage features were found at a relatively high density in the central segments, but were not documented in the less developed portions. Segments U and W in particular had several drainage ditches and outfalls draining roadways and fields, although the condition of the features were good, they were implicated as contributing to erosion in the stream channel itself.

Invasive species colonization was somewhat decreased in this quadrant, although Multiflora Rose was widespread in segments R and W. The lower colonization results from a combination of active management in maintained areas and limited disturbance in more natural areas which limit initial colonization. Few exceptional resources were identified in this quadrant. Two potential vernal pools were identified although no vernal pool species were observed. Additionally, two intermittent unmapped headwaters were identified. Other features identified included meadows that are probably agricultural areas.

Figure 4: Bank Sloughing

As noted above, the results of the semi-quantitative visual assessment were graded with the worst scoring segments located farthest downstream and with greater levels of development. Segment R, the worst scoring, had poor buffers, in-stream cover, and bank stability. Segment U was thoroughly assessed, with eight individual reaches surveyed, and individual reaches were scored from 48 to 107. Floodplain encroachment, channel condition, and bank stability were amongst the chief impairments, as they were in segment W. Segment X scored better overall but in-stream cover and velocity suffered. However, left bank stability was rated a 1 (the lowest score) at one of the reaches. Segment Y scored well all around and was tied as the best of the segments in the watershed.

2.3 Water Quality Monitoring

Water quality monitoring was a major component of the characterization of the Alexauken Creek and its watershed and represents a direct measurement of impairments. This data can and will be utilized in several capacities: to document and assess the water quality of the Alexauken Creek, to determine if the creek satisfies SWQS and other rules regarding quality, and to calibrate and confirm models. The water quality monitoring program used in this study was a systematic and comprehensive assessment of water quality and focused on characterizing eight stations in the stream and two additional reference streams under both baseflow and stormflow conditions. Water quality metrics focused on *in-situ* (in the field) monitoring, discrete parameters, and bacteriological sampling. As with the volunteer visual assessment, the sampling program was conducted under a QAPP approved by NJDEP. Additional work conducted at each of the identified stations (Table 2) included stream macroinvertebrate sampling, discharge monitoring (discussed in the hydrology section), and EPA RBP Visual Habitat Assessment completion at each station.

Table 2: Water Quality Monitoring Stations

Station Number	Station Name/Location	HUC-14
1	Lambertville	020401052100- 20
2	Green Acres	020401052100- 20
3	Hamp Road	020401052100- 20
4	North Branch – Queen Road	020401052100- 20
5	North Branch – Bowne Station Road	020401052100- 20
6	Rt. 202	020401052100- 10
7	East Branch – Wildlife Management Area	020401052100- 10
8	South Branch - Lake	020401052100- 10
9*	Hakihokake	020401051700- 20
10*	Lockatong	020401052000- 30

* Reference Stations, Continuous Temperature Only

2.3.1 Summer Continuous Temperature Monitoring

Continuous summer temperature monitoring was an important component of the characterization of the creek since the designation of Alexauken Creek as a Trout Maintenance water carries a temperature standard such that average summer temperature is not to exceed 68°F in order to support a cold water fishery. This was accomplished by deploying temperature data loggers set to record at 10 minute intervals throughout the course of the study; the summer period was considered to last from May 15 through September 30. Temperature was monitored at ten stations including two reference stations on streams outside the project area. These reference stations were chosen because of their designation and for comparative reasons; the Hakihokake Creek in Milford, New Jersey is a TP waterway while the Lockatong Creek, in Delaware Township is a TM stream between the Delaware River and the Idell Bridge, the reach which was sampled.

Of the eight sampled stations in the Alexauken Creek watershed average summer temperatures exceeded the 68°F standard at four of the stations. Interestingly, of the reference streams the Lockatong also exceeded this threshold value. Three of the stations were clustered in the lower portion of the watershed, stations 1, 2, and 3, and the fourth was located at station 8 immediately downstream of the impoundment on the south branch. The thermal pollution in the lower reaches is indicative of the decreased canopy cover or reduced riparian buffer width in the areas upstream of these stations, while the exceedance at station 8 is a function of the thermal stability and hydraulic retention of the impoundment. While the remaining stations met the standards two other stations, stations 4 and 6, had average temperatures in excess of 67°F. Some additional analysis was conducted concerning temperature. Mean daily maximum was also calculated and this exceeded the standards at all stations except at the Hakihokake Creek. Maximum values were also identified at each of the stations; all of the Alexauken Creek stations exceeded 76°F and station 3 at Hamp Road reached 87°F at one point.

As noted above, Alexauken Creek is listed on Sublist 5 of the 303(d) list for temperature. This study largely confirms that temperature is a problem in Alexauken Creek and that land use including impaired buffers and impoundment of the stream contributes to thermal pollution. Additionally, Alexauken Creek appears to compare favorably with the other monitored trout waters. Anecdotally, anglers were observed catching Rainbow Trout (*Oncorhynchus mykiss*) along the most thermally impaired sections of the creek indicating that there is at least some degree of trout holdover.

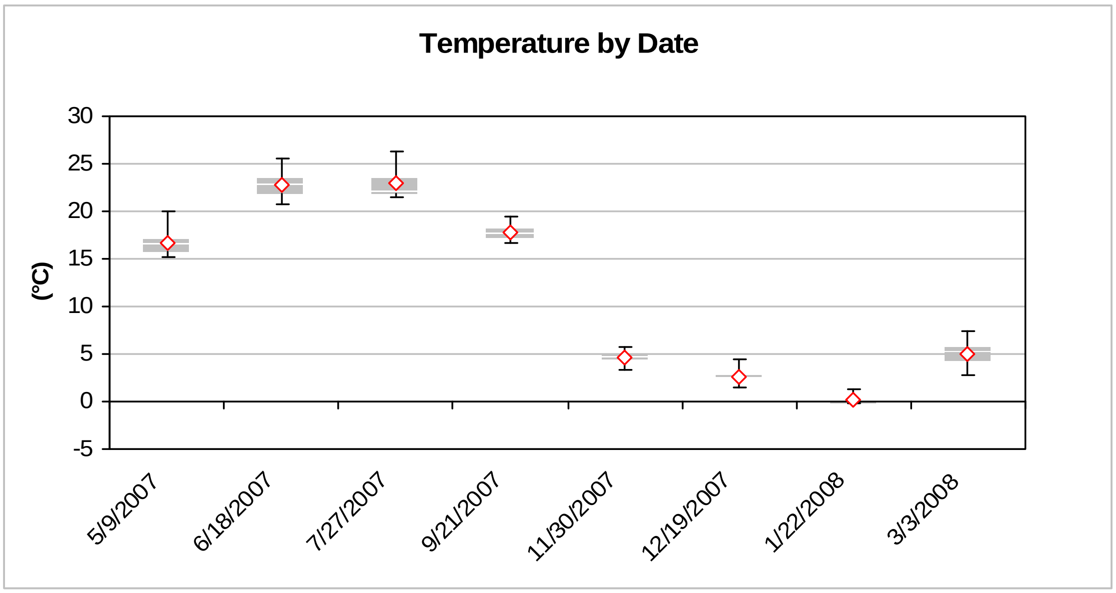
2.3.2 *In-situ* Temperature

In-situ monitoring was conducted at all stations during each of the baseflow events with the use of a calibrated multi-probe water quality meter. This parameter was investigated in addition to the continuous temperature monitoring to corroborate the data. Overall, the stations exhibited some clear differences when viewed on an annualized basis. Station 7 on the east branch exhibited the lowest temperature throughout most of the study, particularly during the warm summer months, and the lowest temperature overall. During the winter months the furthest downstream stations, 1 and 2, had the lowest temperatures. The warmest temperatures varied between stations. Station 8 had the highest temperatures in the late spring, late summer, and late winter which represents the retention of heat during cooling periods related to the thermal and hydraulic mass of the lake immediately upstream of this station. Station 5, which is primarily groundwater fed, had the highest observed temperatures in late fall, early winter, and early spring consistent with groundwater discharges exhibiting higher temperatures than surface waters during this period. Station 3 at Hamp Road had the highest temperatures in early summer and early fall which was driven by poor canopy cover at the site and poor buffers upstream. It seems apparent that temperatures at station 3 are also somewhat influenced by the substrate composition of shale bedrock outcrops that tend to warm rapidly and retain this heat. Station 8 had the highest mean temperature followed by station 3; these two stations also exhibited the highest maximum temperatures. All stations exhibited peak temperatures in excess of 68°F or 20°C.

On a seasonal basis Alexauken Creek tends to warm quickly (Figure 5). Mean May temperature was 16.7°C and by June was up to 22.8ºC, the same value measured in July. Following the July sampling event there was a significant cooling trend although the

September sampling data yielded a mean temperature of 17.9°C. Mean temperatures cooled rapidly thereafter and the mean of the stations did not exceed 5°C over the course of the next three sampling events. During the January sampling event three of the stations had temperatures below 0°C and the highest measured temperature, at station 8, was 1.34°C. By March, temperatures started to climb back up with a mean value of 5.1°C. While the continuous temperature monitoring is a better indicator of the temperature regime in the creek the *in-situ* temperature values largely confirmed that during the summer months water temperatures routinely exceed the TM temperature standards.

Figure 5: *In-situ* Water Temperature

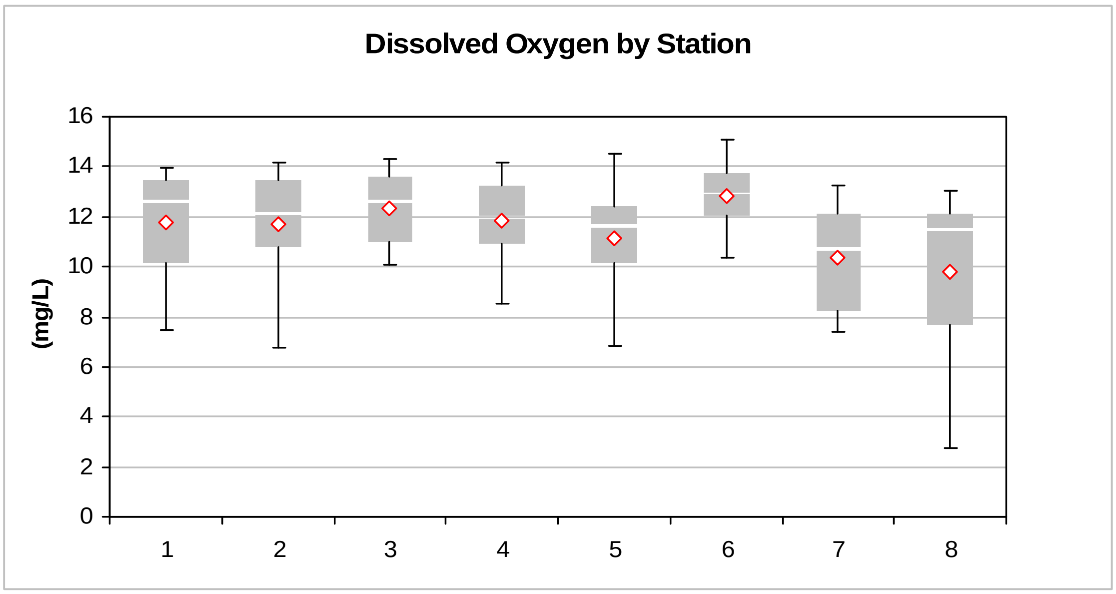


2.3.3 Dissolved Oxygen

In aquatic ecosystems dissolved oxygen (DO) is one of the most important parameters and acute or chronic hypoxic or anoxic conditions in streams can radically alter the fauna and cause mass die-off of riverine organisms. DO is controlled by a variety of processes including temperature, flow turbulence and velocity, photosynthetic production, and biological respiration or consumption. DO can be a reliable indicator of pollution and eutrophication. State SWQS for FW2-TM stream state that these waterbodies are have an average 24 hour dissolved oxygen concentration not less than 6.0 mg/L with no single measurement falling below 5.0 mg/L.

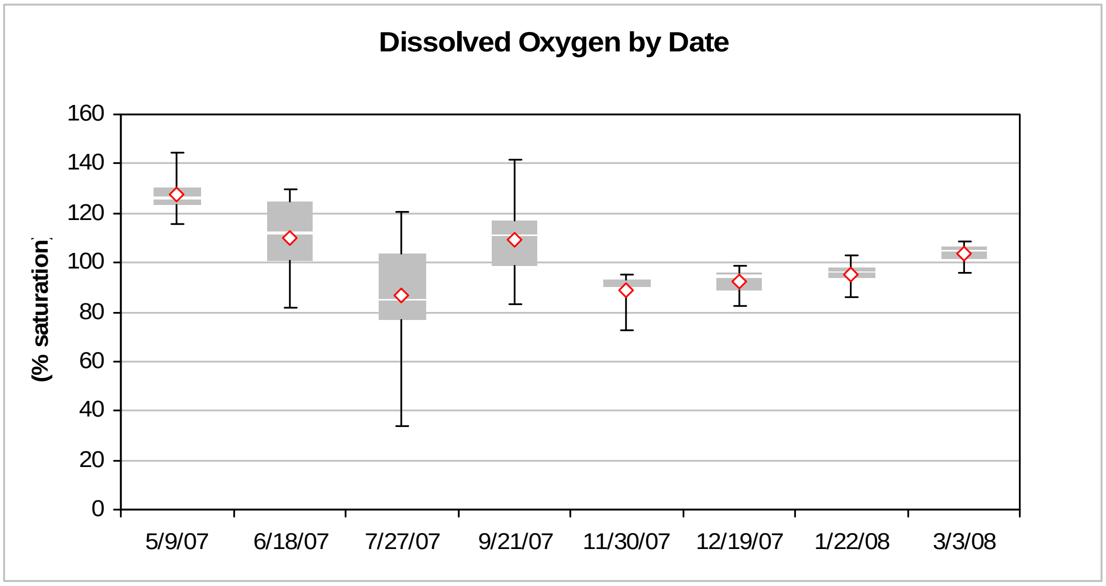
DO was measured at each of the stations during each baseflow monitoring event with the use of a calibrated water quality meter. In this study DO was measured in two ways: the primary method was a direct measurement of concentration while the second method was a derivation of concentration accounting for temperature, percent saturation. Percent saturation is useful in determining DO trends over time since it normalizes the effects of temperature and therefore allows comparisons on a seasonal basis. It also allows for a more thorough understanding of biological processes which can contribute to supersaturated conditions (DO > 100% saturation) in eutrophic waterbodies.

Figure 6: Dissolved Oxygen Concentration by Station



For the most part DO levels met the standards. The single exception to this was a low value of 2.74 mg/L recorded below the spillway of the impoundment at station 8 in July (Figure 6). Otherwise, no other station exhibited a concentration less than 6.79 mg/L. While a comprehensive diel sampling program was not conducted in order to more accurately calculate 24 hour averages, it appears that the 6.0 mg/L 24-hour average standard was likely to have been met at all stations during all events, with the exception of the July event at station 8. This assumption is predicated on the percent saturation data that indicated that for the most part DO tends to be moderated in the system (Figure 7). Other than the first sampling event conducted in May mean percent saturation ranged from 110% to 87% across all stations. In May percent saturation was much higher which was a function of the active growth of periphyton in this period. While percent saturation was high during the day and it can be assumed that concentrations and percent saturation decreased during the night, the early spring event lacks the accumulation of decaying periphyton and allochthonous (terrestrial) organic material that is most likely to drive down DO concentrations in streams. Furthermore, base DO concentrations are still high enough and temperatures low enough at this point to stay above the 6.0 mg/L standard. Overall, DO concentrations were lowest during the summer months when water temperatures and biological oxygen demand (BOD) was highest and highest during the winter months.

Figure 7: Dissolved Oxygen Percent Saturation by Date



Stations 6 and 3 had the highest mean DO concentrations over the course of the study, while station 8 was the lowest on average. As mentioned previously station 8 also had the lowest measured DO concentration in the study, while station 6 had the highest measured concentration at 15.1 mg/L. The high levels observed at 6 and 3 are also observed in the percent saturation data. Interestingly, these stations share a similar bottom configuration, which is sedimentary bedrock outcrops and somewhat higher local channel slopes. During the growing season the heaviest periphyton growth was observed on the stable channel bottom at these two stations and increased gradients helped increase turbulence and the introduction of atmospheric oxygen into the water. Low DO concentrations at station 8 are driven by the influence of the impoundment and lake processes, including increased temperatures, serve to alter the DO regime at this station. Overall, DO concentrations generally met SWQS and are adequate for supporting aquatic organisms including coldwater fishes.

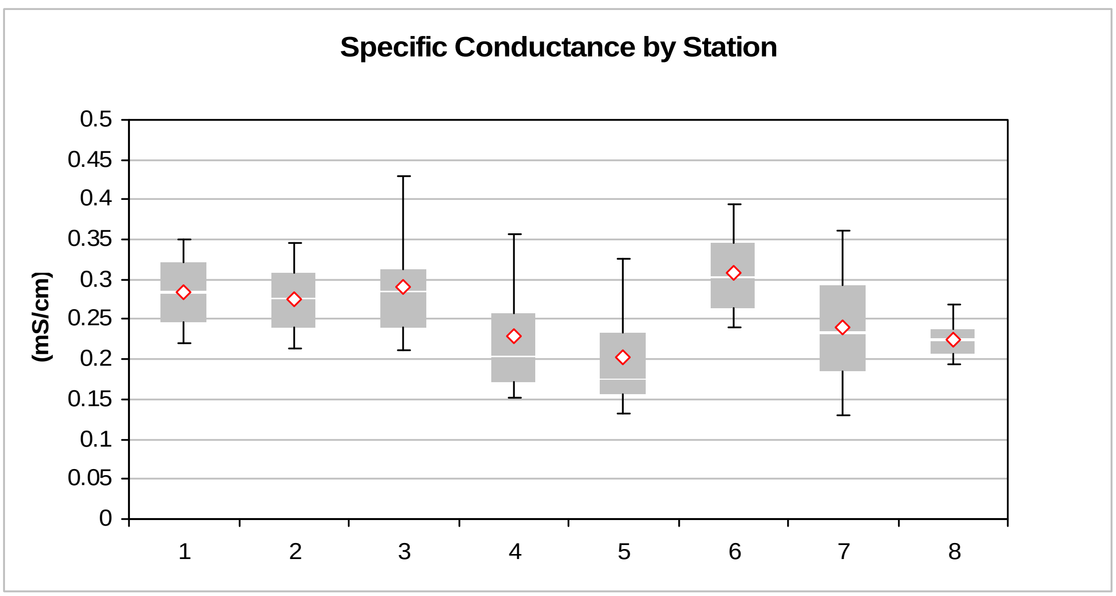
2.3.4 Specific Conductance

Specific conductance, or conductivity, was measured *in-situ* during seasonal baseflow sampling. Conductivity is the ability of water to conduct an electrical current and, as such, is a proxy measure of dissolved constituents in the water. Specific conductance is the normalization of conductivity for temperature. Dissolved components in the water are derived from the soil and geologic features of a watershed and stormwater runoff.

High values can be an indication of pollution from sources such as road salts or fertilizers. Generally, dissolved constituents are critical for aquatic organisms and are used in metabolic processes and used to build tissue including bone and shell.

In the Alexauken Creek specific conductance was generally moderate, although seasonal and inter-station variability was apparent in the data. Headwaters and tributaries tended to have lower values than lower areas in the watershed, which is likely a function of decreased development levels in these areas and also the crystalline rock geology of the Sourlands portion of the watershed. Station 6 had the highest average conductance of 0.309 mS/cm, which is related to the higher levels of development upstream of this station, although the highest single measured conductance value was recorded at station 3 (Figure 8).

Figure 8: Specific Conductance by Station



Seasonally, conductance increased throughout the spring and summer to peak values in September, followed by a less orderly decline throughout the fall and winter to low mean values recorded in early March in 2008. This pattern is somewhat typical in regional streams; increasing values measured in the summer are related both to increased percentage of groundwater contributions to stream flow, which carry higher loads of dissolved constituents than surface waters, during dry periods and decreased conductance in wetter parts of the year. During wet periods increased hydrologic loads can dilute dissolved constituents and surface runoff may contribute decreased concentrations of dissolved ions; while stormwater runoff linked to moderate storm events may have reduced ionic composition, particularly after the first flush event, the total load of dissolved components is higher since loading is a function of concentration multiplied by runoff quantity.

Specific conductance values were acceptable throughout the course of the study at all stations and are consistent with regional values. While no cause for concern or signal of excessive pollution the variation in stations that was linked with landscape position and LU/LC does indicate that there is enrichment of ionic constituents in Alexauken Creek related to development patterns.

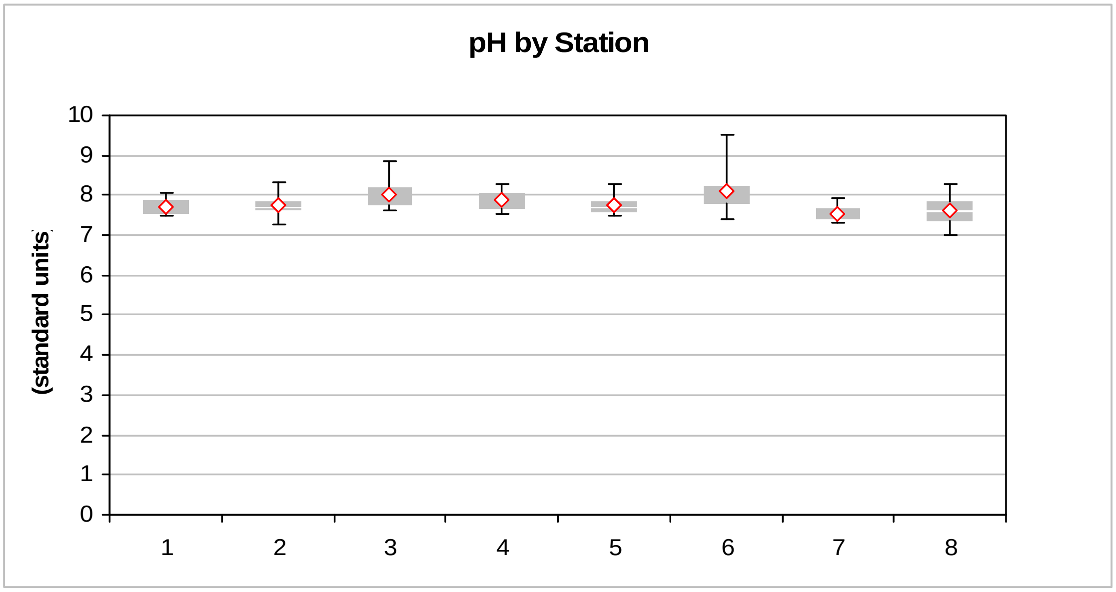
2.3.5 pH

pH is a unitless measure that describes the concentration of hydrogen ions in water, or more basically is a measurement of the acidity (<7.0) or basicity (>7.0) of water. As with conductance, pH can be largely influenced by the soils and geology of the watershed, but in addition can be affected by biological processes and pollution. From a biological perspective, primary production (photosynthesis) or respiratory processes will respectively cause pH to increase (become more basic) or decrease (become more acidic). Most aquatic organisms have a fairly narrow tolerance range of pH and most organisms in the Alexauken Creek are adapted to neutral to basic pH values. SWQS for FW2 waterbodies state that pH is not to deviate from a range between 6.5 and 8.5.

pH values in the Alexauken Creek exhibited both spatial and seasonal variation. pH only exceeded the SWQS on a single date, May 9, and values above 8.5 were recorded at both station 3 and 6. This date also represented the highest mean pH value across stations and was associated with vigorous periphyton growth, particularly at stations 3 and 6 at which values of 8.85 and 9.51 were recorded; the same biological signal was also detected in the DO data. pH then continued to decline throughout the year and the mean values ranged between 8.1 and 7.6.

Station 6 had the highest mean pH value averaged across the entirety of the study at 8.12 followed by station 3 at 8.00 (Figure 9). Stations 7 and 8 had the lowest mean pH values. pH values in Alexauken Creek were generally acceptable and capable of supporting the typical fauna of the region. However, pH in this stream is clearly affected by photosynthetic activity. This indicates that there is some degree of nutrient pollution in the stream which allows such vigorous growth. It also indicates that inadequate canopy cover or buffering transmits too much light to the stream bed which encourages the growth of periphyton and also leads to in-stream warming.

Figure 9: pH by Station



2.3.6 Discrete Parameters

A series of discrete parameters were evaluated in the Alexauken Creek. Discrete water quality parameters are those metrics which are analyzed in a laboratory from collected water samples. These parameters vary from *in-situ* parameters (described above) which are measured in the field with a water quality meter. The discrete metrics analyzed in this study included:

- Total Phosphorus (TP)
- Nitrate-N (NO_3-N)
- Total Kjeldahl Nitrogen (TKN)
- Total Dissolved Solids (TDS)
- Total Suspended Solids (TSS)

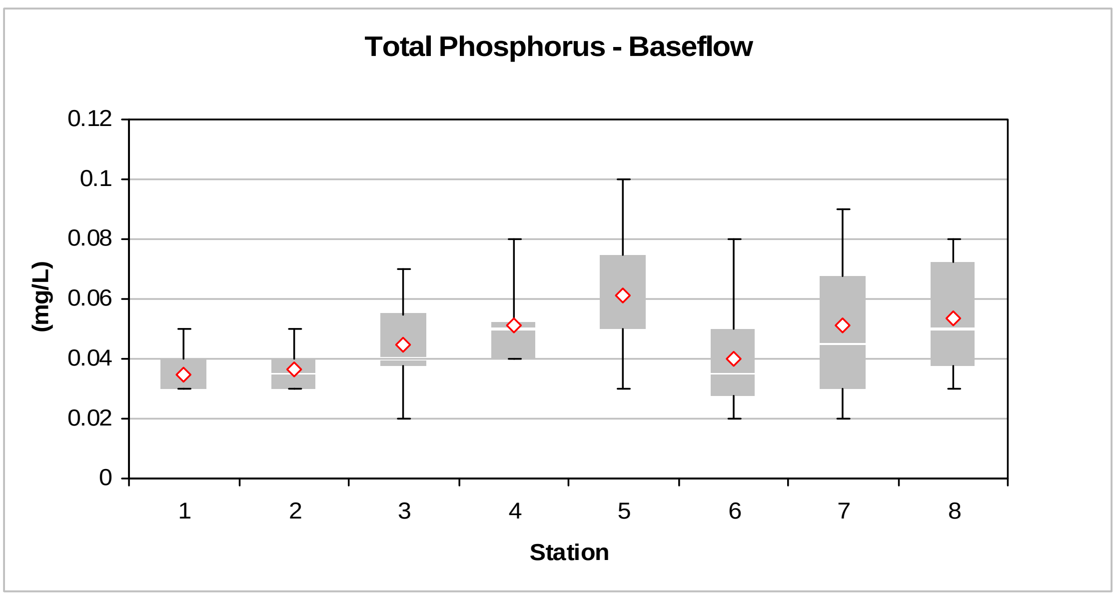
Discrete grab samples were collected at each of the stations during each baseflow monitoring event and composite samples were collected during each stormflow monitoring event.

2.3.7 Total Phosphorus

Total phosphorus is probably the nutrient that has garnered the most attention in relation to the eutrophication of waterbodies. This is because TP is generally the limiting nutrient in most freshwater ecosystems and thus is a control on the growth rates of plants and algae. While not as critical in streams as in lakes TP nonetheless can contribute to excessive primary production in aquatic systems. The major source of TP in streams is particulates like inorganic sediments and organic detritus. Soluble forms of phosphorus are generally found in much lower concentrations because it is rapidly assimilated, but excessive concentrations can indicate pollution. Excessive loading is related to stormwater inputs, sediment, channel erosion, fertilizers, septic sources, and animal loading. SWQS for TP in streams sets an upper bound of 0.10 mg/L unless TP is proven not to be the limiting nutrient.

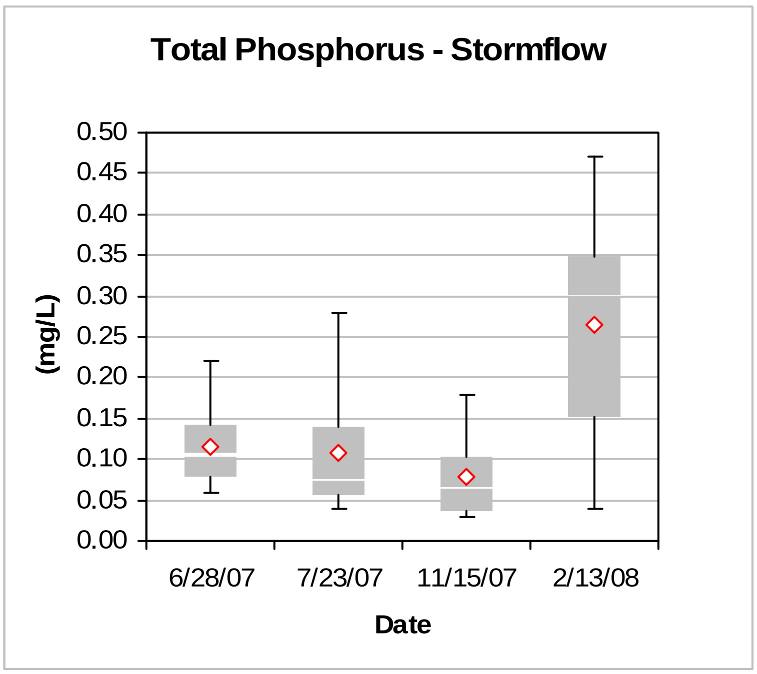
Under baseflow conditions TP tended to be relatively stable throughout the course of the monitoring with mean values by date ranging between 0.041 and 0.058 mg/L except for the March event which was even lower. Variation between stations was fairly high with values averaging between 0.035 and 0.061 mg/L (Figure 10). No TP concentrations exceeded 0.10 mg/L under baseflow conditions, although 0.10 mg/L was measured at station 5 during the June event. Baseflow TP concentrations were generally higher in the headwaters which could indicate increased terrestrial sources or enriched soluble fractions from groundwater.

Figure 10: TP by Station



Stormflow TP data exhibited very different patterns related to landscape position, development level, and storm event intensity. Three of the seasonal storm monitoring events were conducted under modest storm intensity due to the dry conditions that year. TP concentrations showed some increases during storm events and the increases were most notable in the headwaters which routinely exceeded the 0.10 mg/L standard. However, the final monitoring event was conducted during an intense storm in which there was snow pack on the ground. During this event all stations exceeded the SWQS, except station 8 which is moderated by the impoundment upstream, and values up to 0.47 mg/L were recorded, which are extremely high (Figure 11). The highest concentration tended to be measured at the downstream stations with the exception of station 5, although station 5 had documented streambank disturbance which led to excessive erosion. It seems very likely most of the TP load during this storm was linked to solids loading, which was very high. The very high TP concentrations lower in the watershed point to erosional processes in this area as severe and a leading cause of impairment in the watershed.

Figure 11: TP Stormflow



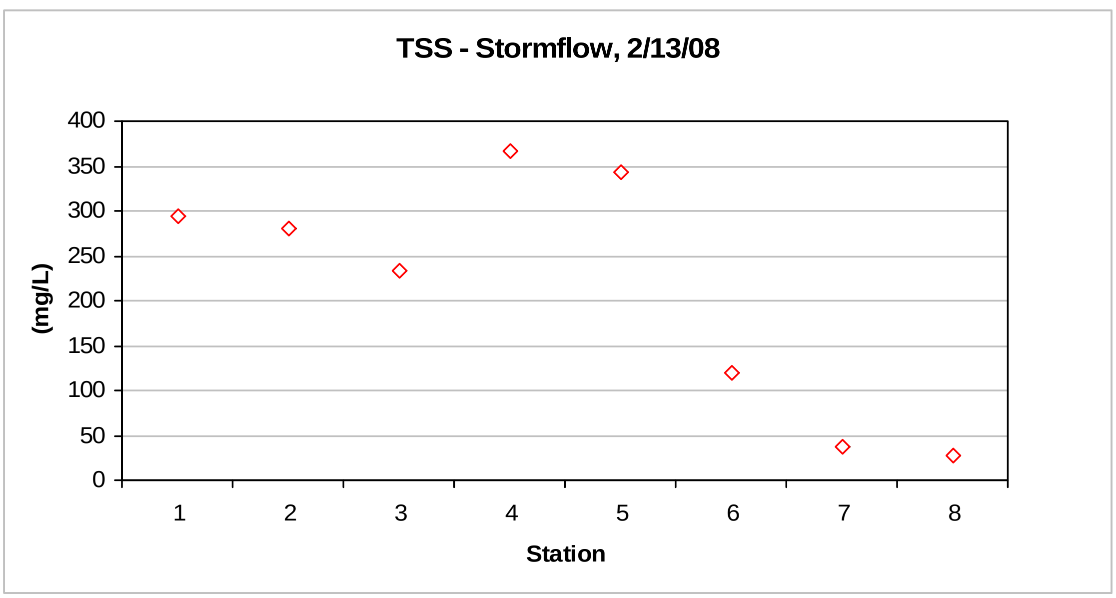
2.3.8 Total Suspended Solids

Total suspended solids measures the concentration of both organic and inorganic particulates in the water and may be characterized alternatively as non-filterable residue. In streams TSS is usually associated with particulate matter eroded from the watershed or under increased hydraulic loading from within the stream channel. Poor management practices and increased imperviousness of the watershed leads to increased solids loading. Increased solids loading in streams is detrimental to many aquatic organisms that lead to a loss of habitat and smothering of organisms and changes in the hydrogeomorphology of the system. In FW2-TM SWQS suspended solids concentration is not to exceed 25 mg/L.

Under baseflow conditions TSS concentrations tended to be quite low in the Alexauken Creek. For stations 1 through 7 TSS never exceeded 9 mg/L. Station 8, as with many parameters, was a bit of an outlier, with higher mean concentrations throughout the baseflow events. The cause of this not known exactly but it seems likely that much of the solids loading is phytoplankton (algae) particulates from the impoundment. Overall, TSS is quite low normally under baseflow, and frequently was below the minimum detection limit (MDL).

Suspended solids during stormflow events tended to be variable, with a general correlation with rainfall intensity or storm size. During the first three sampled storm events the 25 mg/L threshold was exceeded only at station 6 and 7, with station 7 exhibiting a significantly higher concentration than the other stations. However, as with TP, the final storm event sampled on February 13, 2008, which was sampled during a 2.38" inch precipitation event, yielded very high TSS numbers (Figure 12). During this event all stations exceeded the TSS SWQS of 25 mg/L, however stations 7 and 8 exhibited modest concentrations relative to the other stations. The remaining stations all exceeded 119 mg/L, with station 5 measured at 366 mg/L, an area adjacent to bank disturbance. These are extremely high values and represent very high erosion within the watershed and the creek proper. This distinct split in concentration seems to be strongly linked to surrounding land use in the lower portion of the watershed in which residential, infrastructure, and agricultural land uses figure prominently in the composition of the lower watershed.

Figure 12: TSS Stormflow, 2/13/2008



The extremely high TSS concentrations observed during high intensity storm events not only exceeds SWQS but is a serious impairment in the stream. This heavy loading means that sedimentation is a serious issue in the Alexauken Creek and certainly degrades in-stream habitat, an observation confirmed in the volunteer visual assessment data. Furthermore, this data indicates that stormwater is poorly managed in the watershed and that measures must be taken to control stormwater quality by reducing the concentration of solids but also for quantity to reduce the potential for bank and bed erosion.

2.3.9 Total Dissolved Solids

Total dissolved solids (TDS) is another measure of solids that accounts for dissolved organic and inorganic substances of micro-granular materials; this parameter may also be called filterable residue. TDS is in essence a direct measure of the ionic constituents that affect the conductance of water. Again, the source is related to soils and geology in the watershed, groundwater inputs, and surface runoff. High values may be an indication of pollution in the watershed. SWQS for FW2 waterbodies for TDS have a limit of 500 mg/L or no increase above background levels that would interfere with designated uses, whichever is more stringent.

As mentioned in the description above, TDS is a measurement of the ionic components of water detected through conductivity monitoring. As such, TDS patterns closely mimic those discussed in the specific conductance section above. Average TDS concentrations under baseflow conditions ranged from 136 mg/L to 193 mg/L. There was generally a modest difference between stations, although stations 4 and 5 tended to be lower than the remaining stations. Some seasonal variation was observed with highest mean TDS concentrations observed during September. The highest observed value during baseflow was 324 mg/L at station 3, while the minimum value was 79 recorded at station 5.

Stormflow TDS concentrations were generally lower than those measured during baseflow, although comparable, with mean concentration by station ranging from 132 mg/L at station 8 to 173 mg/L at station 3. While TDS loading is certainly higher during storm events the somewhat reduced concentrations are a result of dilution related to increased hydraulic loading during storm events. TDS concentrations never exceeded SWQS.

It is important to point out the disparity between TSS and TDS. While TDS accounts for a larger fraction of solids loading than TSS, as is typical in freshwater systems in this region, TDS did not exhibit the wide shifts between baseflow and stormflow events, even when accounting for the intensity of the precipitation event. This indicates that hydraulic loading and subsequent erosion of the watershed and the stream resulting in the transport of particulates are perhaps most important in driving in-stream impairments in the Alexauken Creek watershed and that special attention must be paid to mitigating these issues to affect positive water quality and biota benefits.

2.3.10 Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen or TKN is the sum of organic nitrogen and ammonia fractions including particulates. Ammonia and ammonium are generally derived from the decomposition of plant tissues, but septic loading and agriculture also figure as prominent sources. Organic nitrogen and particulate nitrogen derives from similar sources but also includes nitrogen fixed in phytoplankton cells and from terrestrial sources. While TKN is not a regulated parameter under SWQS it is frequently measured in combination with nitrate and nitrite, inorganic species of nitrogen, which when summed approximate Total Nitrogen. Increases in TKN values can indicate anthropogenic pollution from sources such as wastewater or fertilizer runoff. Excessive TKN concentrations can also be toxic to aquatic life due to the presence of ammonia in this parameter, although ammonia toxicity is strongly influenced by temperature and pH.

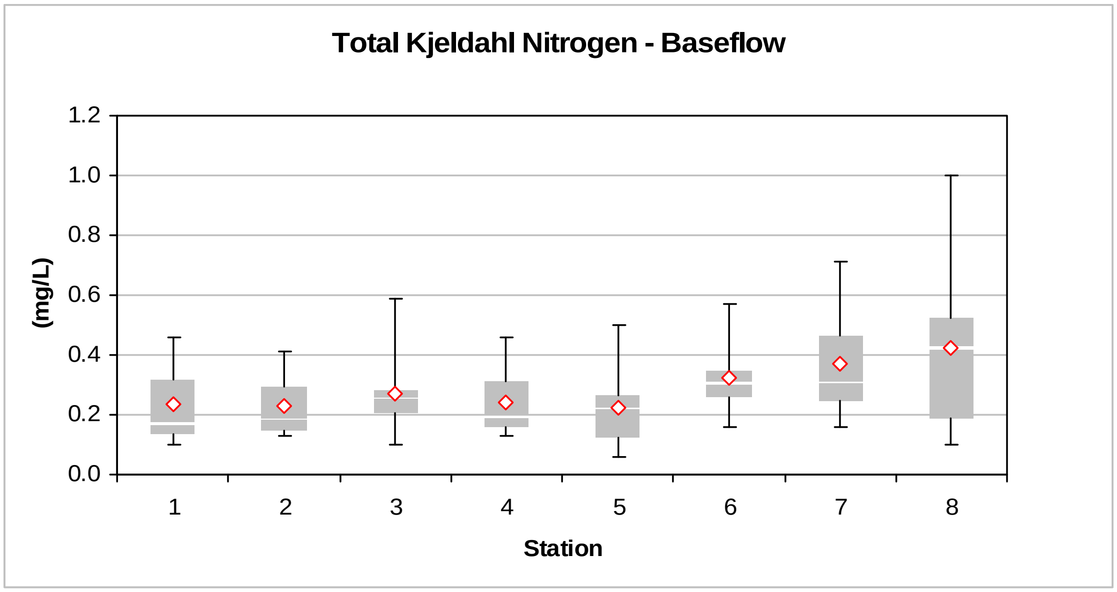
The lower stations on the Alexauken from station 1 through station 5 exhibited a fairly narrow range of concentration at baseflow, although stations 6, 7, and 8 all exhibited increased concentrations relative to the other monitored sites. These elevated concentrations were relatively easy to explain and directly tied to surrounding land use. At station 8, which had the highest mean concentration of 0.42 mg/L, concentration was increased due to the decomposition of plants and phytoplankton in the lake, while station 7 was enriched due to the spreading of manure in the adjacent fields. Station 8 had the highest measured TKN value of 1.00 mg/L, and amongst the downstream stations station 3 had a peak concentration of 0.59 mg/L; station 3 is located immediately downstream of pasture land.

Over time TKN showed higher values in the late winter and early spring which declined through the summer and rebounded in the late fall and winter (Figure 13). This pattern is likely driven by biological uptake during the growing season and reduced delivery during the drier summer months.

Stormflow events showed some elevation in mean concentration, although storm intensity was a factor as well as the interim between storms. The biggest increases were observed in the lower portion of the watershed and were particularly evident in peak values. Peak values increased during stormflow relative to baseflow and exhibited the biggest increases at stations 2, 4, 5, and 7. This indicates that stormwater runoff can be an important factor in driving TKN concentrations.

Overall, TKN concentrations were fairly modest in Alexauken Creek, particularly under baseflow conditions with the exception of station 8 which is greatly influenced by the upstream impoundment. Even during stormflows concentrations were not exceedingly high but do indicate that stormwater runoff can drive up concentrations particularly during higher intensity storms or after a long dry period which can accumulate pollutants. Agricultural land uses seem to be strongly linked to TKN loading in the Alexauken Creek watershed.

Figure 13: Total Kjeldahl Nitrogen - Baseflow

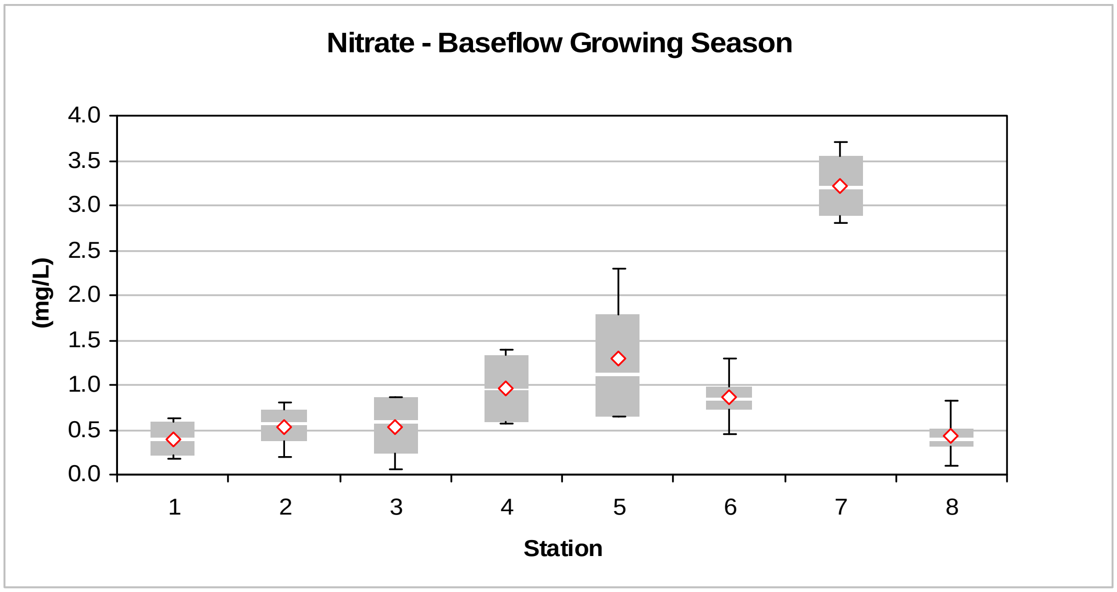


2.3.11 Nitrate

Nitrate is usually the most important nitrogen species simply because it is the most widely available and typically most other available species undergo nitrification by various nitrogen bacteria and are converted to nitrate. Nitrate is a primary growth nutrient utilized by macrophytes and algae. This parameter tends to be extremely variable seasonally, spatially, and hydraulically. This is due to its variety of sources including groundwater, stormwater runoff, wastewater, biological fixing, excretion, and decomposition of organics, and its sinks include biological assimilation. Additionally, nitrate is extremely soluble and thus highly mobile in water. Nitrate is primarily regulated under drinking water standards and is not to exceed 10 mg/L.

Because of the complexity of nitrate concentrations it is easier to determine trends by stratifying nitrate baseflow data into growing season (events from May through September) and non-growing season (events from November through March) groups to represent low seasonal means and high seasonal means. During the growing season there was considerable variation between stations; seven stations had mean seasonal values of less than 1.3 mg/L with a general increase with increasing distance from the mouth (Figure 14). Station 7 was a definite outlier and the seasonal average was calculated as 3.23 mg/L, much higher than the other stations; station 8 was also an outlier but exhibited low values driven by the assimilation of nitrate in the impoundment upstream of this reach. Intra-station variation was relatively low as all stations, except 5, exhibited a concentration range of less than 1.0 mg/L. This pattern was driven by biological assimilation of nitrogen with the cumulative effect resulting in reduced concentrations lower in the watershed and reduced groundwater loading at this time, although concentrations at station 5 remained higher due to more consistent groundwater discharge in the upstream wetland complex. The high concentration measured at station 7 is cause for concern and is squarely correlated with adjacent agricultural practices.

Figure 14: Nitrate - Baseflow, Growing Season



Baseflow concentrations during the non-growing season were remarkably different and the average across all stations was twice that observed in the growing season (Figure 15). The largest jumps in concentration occurred at station 1, 2, 3, 4, and 6. The average stations tended to be more consistent although station 8 was still much lower than any of the other stream stations. Increased concentration is due to the increased input via higher groundwater contributions and no active biological assimilation.

Stormflow nitrate concentrations tended to be somewhat higher than growing season baseflow, but otherwise exhibited similar patterns, with decreasing concentrations downstream and higher values in the upper reaches (Figure 16). Concentrations remained very high at station 7 relative to the other stations. Overall, there was modest seasonal variation between stormflows on average, but in the lesser storm events there was decreased dilution of concentrations around station 7. Station 7 exhibited the greatest seasonal stormflow variation with increased concentrations in the growing season storms.

Nitrate is extremely variable in the Alexauken Creek watershed. Overall, concentrations were moderate during both baseflow and stormflow events. Streams and watersheds which typically experience the worst nitrogen problems tend to be more highly developed and treated wastewater effluent tends to be the largest problem, which is not an issue on the Alexauken. However, excessive nitrate loading is occurring at station 7 and this is clearly linked to manure spreading and other practices in the adjacent fields.

Figure 15: Nitrate - Baseflow, Non-Growing Season

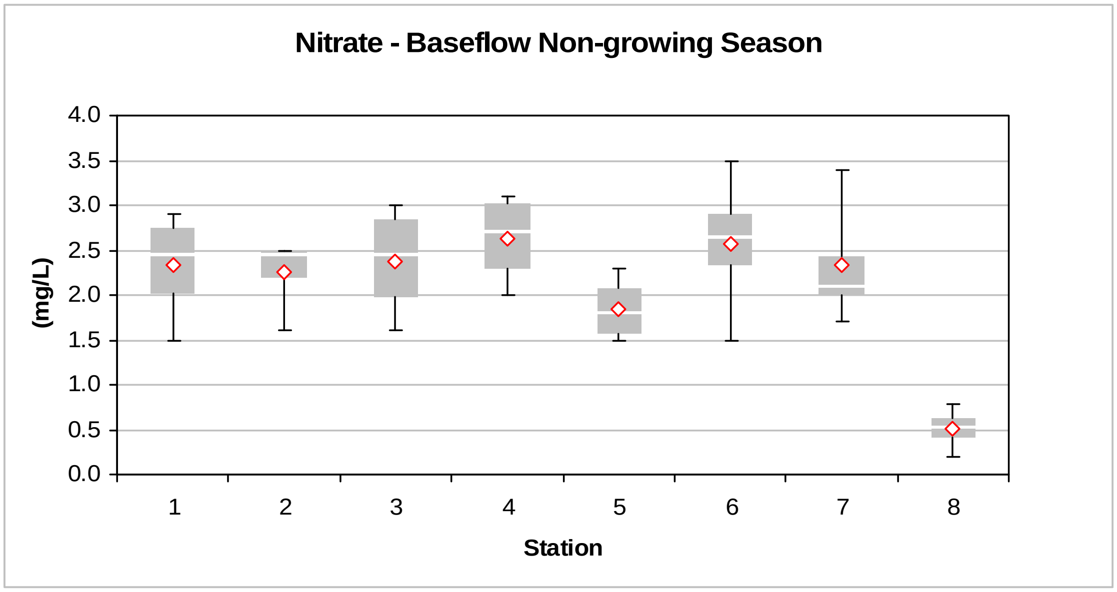
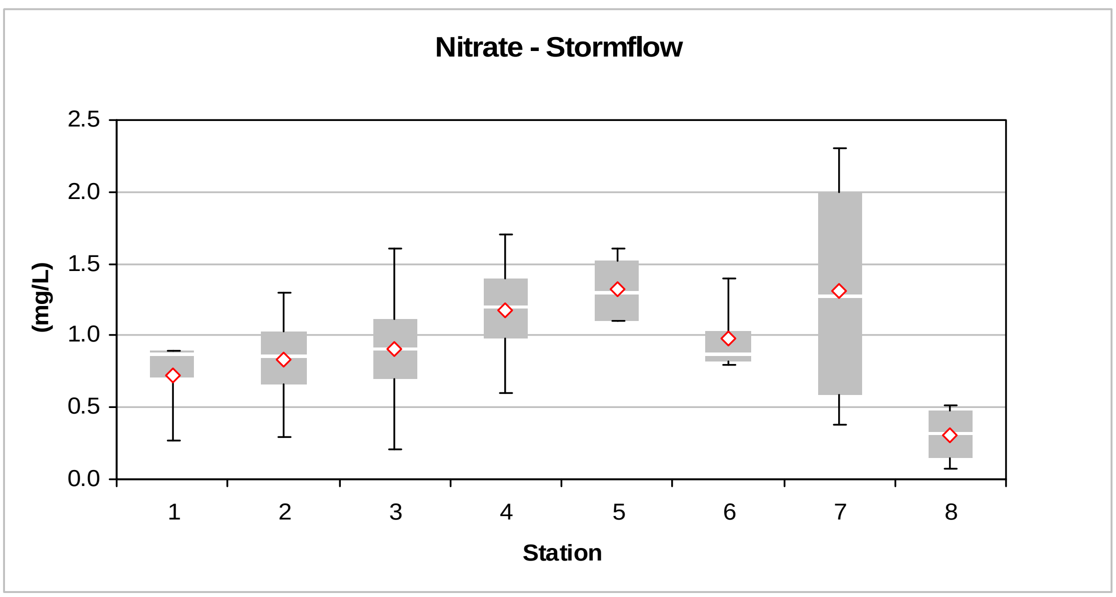


Figure 16: Nitrate - Stormflow

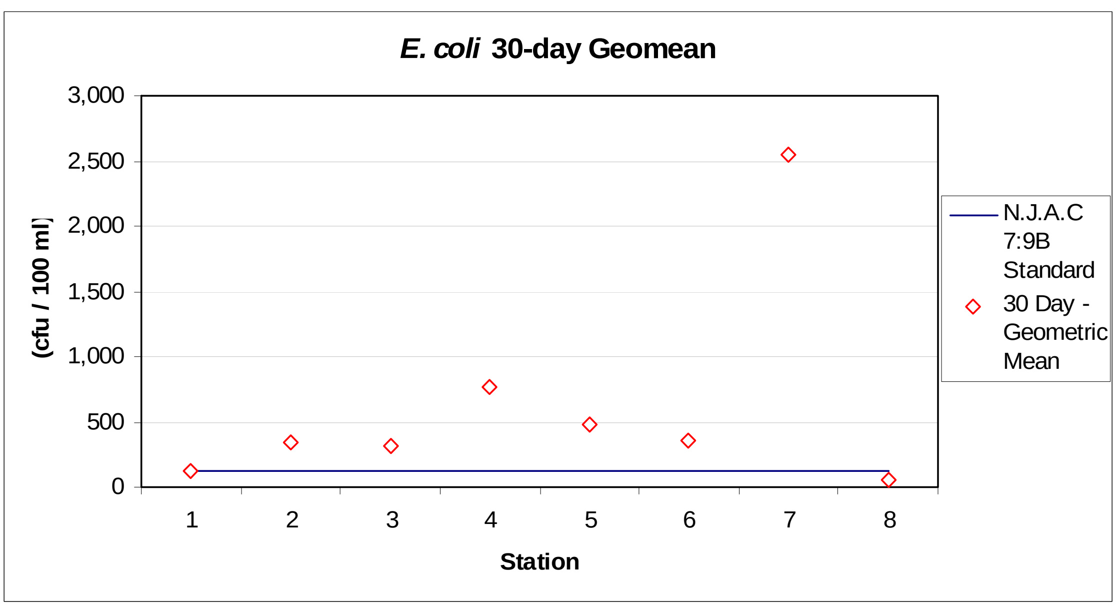


2.3.12 *E. coli*

E. coli, one of the fecal coliform bacteria, was sampled throughout the study to assess base fecal levels, to complement monitored nutrient parameters, identify source impairments, and to evaluate use designation of primary and secondary contact recreation uses of FW2 streams. The SWQS for this parameter focus on both average values over a time period, not to exceed a geometric mean of 126 cfu/100 mL (cfu = colony forming units), and single samples, maximum not to exceed 235 cfu/100 mL. A single seasonal sample was taken at each station in the spring, fall, and winter, while five samples were taken in a period of 30 days mid-summer.

E. coli sampling showed that Alexauken Creek is impaired by coliform loading and routinely exceeds SWQS. Seasonal variability was quite noticeable and spring samples were quite low, with all stations below 70 cfu/100 mL. However, in the summer months concentrations skyrocketed with the exception of station 8, which is mitigated by the upstream impoundment. During this period, July 20 to August 20, the geometric mean exceeded 126 cfu/100 mL at stations 1 through 7, and single sample maximums at those stations all exceeded 650 cfu/100 mL with a maximum of 46,000 cfu/100 mL at station 7 (Figure 17). Again, the practice of spreading manure adjacent to the stream is implicated in these extreme values measured at station 7. Station 4 exhibited high mean concentrations of *E. coli* and while the source is not clear septic discharge may be a contributor. In the fall and winter *E. coli* levels fell precipitously nearing the spring levels of 2007 although single sample maximum values were exceeded at stations 5 and 6 during this period.

Figure 17: *E. coli* 30-day Geomean



E. coli concentrations routinely exceed standards throughout the watershed and therefore represent a health concern in violation of primary contact uses. Even when considered on an annual basis all stations exceeded the geometric mean with the exception of stations 1 and 8, and all stations except 8 exceeded the single sample standard.

2.3.13 Macroinvertebrates

The benthic infauna or macroinvertebrates were also sampled during the course of the water quality characterization since macroinvertebrates are gaining prominence as a reliable indicator of water quality and as a biological metric of the same. More specifically, Alexauken Creek has been identified on Sublist 5 for Aquatic Life, general. The sampling of the macroinvertebrate community was based on AMNET methodology and New Jersey Macroinvertebrate Index Score (NJIS). Macroinvertebrate sampling was conducted twice, once in the spring and again in the fall, to more accurately characterize longer term trends in the benthic infauna community.

For the most part the stations received Non-Impaired assessment ratings; the ranking given to NJIS metric scores between 24 and 30 (Table 3). Looked at seasonally there was some difference in scores, with the fall sampling yielding decreased average scores, although during each event only a single station was identified as moderately impaired: station 8 in May and station 7 in November. The seasonal difference may be related to drought conditions experienced during the summer months for the most part and difference in scoring tended to be moderate. The exception was station 7, which exhibited a 9 point drop from spring to fall. Most impairments in the system were related to reduced scores in Modified Family Biotic Index, which is a description of community tolerance values, and therefore the community at large showed a disposition for somewhat tolerant organism indicating stream pollution. Related to this was a somewhat decreased Percent EPT (Ephemeroptera = Mayflies, Plecoptera = Stoneflies, Trichoptera = Caddisflies) score at several stations, a metric describing the presence of pollution sensitive taxa. While Percent EPT was reduced, the EPT Index, the sum of EPT taxa or EPT diversity, remained fairly high.

Table 3: Macroinvertebrate Survey Results

	May 2007		November 2007	
Site	**NJIS Score**	**Assessment**	**NJIS Score**	**Assessment**
Station 1	27	Non-Impaired	27	Non-Impaired
Station 2	30	Non-Impaired	27	Non-Impaired
Station 3	30	Non-Impaired	27	Non-Impaired
Station 4	30	Non-Impaired	30	Non-Impaired
Station 5	30	Non-Impaired	30	Non-Impaired
Station 6	30	Non-Impaired	27	Non-Impaired
Station 7	24	Non-Impaired	15	Moderately Impaired
Station 8	21	Moderately Impaired	24	Non-Impaired

2.3.14 Visual Habitat Assessment

Visual Habitat Assessments, utilizing the EPA RBP methods for high gradient wadable rivers, were conducted at each of the sampling stations. This methodology involves scoring ten individual metrics and summing the results to calculate the final score. This data was taken to evaluate the stations on a more localized and site specific basis to better correlate some of the results from the other portions of the water quality study. Additionally, this data is meant to complement and expand the results of volunteer visual assessments in a more quantitative format.

All stations were scored as sub-optimal (101 to 150) to optimal (151 to 200), and individual station scores ranged from 114 to 167 (Table 4). The metric that on average was scored the worst was sediment deposition, followed by the related metrics of bank stability, embeddedness, and epifaunal substrate/available cover. These parameters are primarily indicative of erosion and subsequent deposition of eroded materials and therefore indicate that Alexauken Creek is sensitive to erosion and increases in hydraulic loading. The best parameters tended be vegetative protection, channel alteration, and channel flow status. These metrics are somewhat misleading as the volunteer assessments showed encroachment in the floodplain and development/land uses in the adjacent watershed were issues in many parts of the streams, but in the areas that were sampled there was generally ample buffer. However, what this pattern makes clear is that while local protection of stream reaches may be high the effects of land use patterns upstream are equally as important and somewhat more uniform. In other words, in-stream impairment is cumulative and not completely correlated with local conditions beyond the bank that might indicate higher quality than what is manifest in the channel. Generally, quality of sampling sites is fairly high and scored well, however impairments are also evident which lead to scoring below optimal values. Most of the noted impairments are related to erosional processes in the creek.

Table 4: Visual Habitat Assessment Survey Results

Habitat Parameter	Stn 1	Stn 2	Stn 3	Stn 4	Stn 5	Stn 6	Stn 7	Stn 8
1. Epifaunal Substrate/Available Cover	13	11	17	11	12	15	8	18
2. Embeddedness	17	12	17	12	10	16	5	16
3. Velocity/Depth Regime	14	11	11	15	20	17	10	14
4. Sediment Deposition	15	10	14	11	6	14	5	17
5. Channel Flow Status	14	18	17	18	14	11	18	16
6. Channel Alteration	12	17	20	18	20	15	14	17
7. Frequency of Riffles	15	7	18	18	14	17	13	18
8. Bank Stability	11	14	18	16	9	9	10	17
9. Vegetative Protection	16	18	17	18	20	18	16	20
10. Riparian Vegetative Zone Width	16	17	14	15	16	7	15	14
Total Score	**143**	**135**	**163**	**152**	**141**	**139**	**114**	**167**

2.4 Pollutant Loading Analysis

A pollutant loading analysis was conducted for this study utilizing the Unit Areal Loading (UAL) model[8] which integrated GIS data. Loading coefficients came from a variety of sources including Uttormark et al., Reckhow (1980), USEPA (1980), and Schueler (1986) which were further refined based on watershed soils, vegetation, and land cover conditions. The pollutant modeling focused on several of the pollutants most commonly implicated in stream eutrophication and sedimentation including Total Phosphorus, Total Nitrogen, and Total Suspended Solids. Several iterations of the model were run to identify and assess various trends in pollutant loading over time that accounted for pollutant loading under current LU/LC conditions, recent historical conditions (1986) to account for short-term changes in the watershed, and future loading under build-out conditions. Other analyses focused on examining the differences between historical or baseline conditions, prior to European colonization, and current development as well as pollutant loads from developed portions of the watershed relative to undeveloped areas. Most analyses furthermore broke the loading into discrete units of either municipalities or HUC-14 subwatershed. The following represents a summary of the pollutant loading presented in the C&A report.

2.4.1 Current Pollutant Loading

For the most part pollutant loading in the watershed is correlated to contributing land area of each of the assessed units (municipality or HUC-14 subwatershed). The two largest municipalities, West Amwell and Delaware Townships, account for 61% and 30% of total watershed area. Similarly, West Amwell contributes 57%, 57%, and 58% respectively of TN, TP, and TSS loads, while Delaware Township respectively contributes 32%, 32%, and 31% (Table 5). The remaining two municipalities, East Amwell Township and the City of Lambertville contribute slightly more than their land mass area (8% and 1%) to each of the modeled pollutants. Percent contribution of individual pollutants deviates from contributing area related to differences in LU/LC composition which in turn results in differential loading. For instance, while West Amwell is the largest overall contributor to pollutant loading in the watershed as a function of its land predominance, it contributes less pollutants on a per unit area basis. The decreased specific loading is related to the LU/LC which has a lower percentage of higher loading land uses such as residential and agriculture lands than the other municipalities.

The HUC-14 subwatersheds showed a similar split in loading rates. While roughly even in total land area HUC-14 0204015100-20, which encompasses the western portions of the watershed, generates higher pollutant loads of TN, TP, and TSS, respectively calculated as 58%, 56%, and 55% of the total. This HUC-14 has a greater percentage of land uses that develop higher pollutants loads particularly low-density/rural residential

[8] Uttormark, P.D., J.D. Chapin, and K.M. Green. 1974. Estimating Nutrient Loadings of Lakes from Nonpoint Sources. U.S. EPA. EPA 660/3-74-020. 112pp.

development and agricultural lands. The other HUC-14 subwatershed, 0204015100-10 has a higher density of forests and wetlands that contribute smaller specific loads.

The Alexauken Creek watershed is approximately 9,676 acres, or 15.1 square miles. In total this watershed generates approximately 53,000 pounds of nitrogen, 3,200 pounds of phosphorus, and 5.8 million pounds of sediment annually, which means that controlling pollutant loading is a key factor in improving and mitigating measured water quality and stream function impairments. A significant pattern evident in the review of the pollutant loading data is that more intensely developed subwatersheds and municipalities generate higher per-unit area pollutants loads than less developed areas. While an obvious conclusion, it is based on specific conditions in the watershed that contribute to increased loading. Highly developed areas have more impervious cover, increased soil compaction, soil disturbances, and increased stormwater volume all of which decrease infiltration. Similarly agricultural areas are subject to soil compaction and soil disturbances. The increased impervious cover increases runoff velocities which more effectively mobilizes and transports many pollutants and contributes to stream channel scouring. Similarly disturbed or barren sites contribute increased pollutant loading.

Mitigation therefore must focus on targeted measures to control and reduce pollutant loads from developed (including agricultural) areas. This requires a two-pronged approach of source control, limiting initial generation of pollution, and mitigation of developed loads.

Table 5: Current Pollutant Load

Municipality/ HUC-14	Area		TN		TP		TSS	
	Acres	%	lbs/yr	%	lbs/yr	%	lbs/yr	%
West Amwell	5,926.98	61.3%	30,585	57.4%	1,820	57.5%	3,365,152	58.0%
Delaware	2,882.23	29.8%	17,078	32.1%	1,005	31.7%	1,804,735	31.1%
East Amwell	775.11	8.0%	5,135	9.6%	305	9.6%	567,527	9.8%
Lambertville	91.75	0.9%	449	0.8%	37	1.2%	62,825	1.1%
020401052100-10	4,892.14	50.6%	22,191	41.7%	1,397	44.1%	2,630,205	45.3%
020401052100-20	4,783.92	49.4%	31,056	58.3%	1,770	55.9%	3,170,034	54.7%
Total	**9,676.07**	**100.0%**	**53,246**	**100.0%**	**3,167**	**100.0%**	**5,800,239**	**100.0%**

2.4.2 Historic Pollutant Loading

This iteration of the pollutant model is based on comparing recent historic pollutant loading from 1986 to the current loading. While representing a relatively short period of time this interval was marked by some remarkable shifts in LU/LC (Table 6). Significant increases were noted in forest, wetlands, low density/rural residential, recreation lands, and commercial/industrial land uses. Losses were documented for agricultural, field/brush/shrubland, and barren/transitional areas. For the most part grassland-associated lands, such as agriculture, and field/brush/shrub, exhibited the largest declines with a combined loss of 812 acres or 16%. As listed above, this was counterbalanced by an increase in disparate LU/LC like forest, wetland, residential, and recreational uses. The pattern that emerges is twofold: development pressure led to the conversion of some of these grasslands to residential uses, while the abandonment of some of these areas saw the reversion to forests and wetlands.

Table 6: LU/LC Changes from 1986 to 2002

Land Use Category	Area		Net Change	
	1986 Acres	2002 Acres	Area Acres	% %
Agricultural	4075	3474	-601	-14.7%
Forest	2759	3135	376	13.6%
Field/Brush/Shrubland	1057	846	-211	-20.0%
Wetlands	586	714	128	21.8%
Low Density/Rural Residential	692	957	265	38.3%
Urban/Mixed Urban/Other Uses	332	314	-18	-5.4%
Lakes/Streams	51	76	25	49.0%
Barren/Transitional Areas	63	51	-12	-19.0%
Recreational Land	28	71	43	153.6%
Commercial/Industrial	21	25	4	19.0%
High/Medium Density Residential	12	13	1	8.3%

Pollutant loads have changed over the investigated time period (Table 7). TP and TSS showed relatively little change, with a 1% reduction in TSS and a 1% gain in TP in 2002 relative to 1986. These are moderate values in a watershed that saw some level of development over time, but increases attributable to residential and urban loading were offset by the reduction of agricultural uses. While overall levels were moderate changes in the individual municipalities or subwatersheds was larger. In fact decreased TP and TSS loading was noted in Delaware, East Amwell, Lambertville, and HUC-14 020401052100-20, and only West Amwell and 020401052100-10 drove increases, which is consistent with a greater loss of grassland land types in these areas. TN loading however did show a significant increase of 8% across the watershed and was reflected in all municipalities except Lambertville, which contributed little to begin. HUC-14 020401052100-20 also showed a 15.5% increase in TN loading. The increase of this nutrient seems to be directly linked to increases in residential development which is a well known source of nitrogen derived from fertilizers and onsite septic system effluent.

Table 7: Pollutant Load Changes from 1986 to 2002

Municipality / HUC-14	TN		TP		TSS	
	Net Load lbs/yr	Change %	Net Load lbs/yr	Change %	Net Load lbs/yr	Change %
West Amwell	2,713	9.7%	68	3.9%	147,598	4.6%
Delaware	905	5.6%	-18	-1.7%	-177,406	-9.0%
East Amwell	352	7.4%	-10	-3.3%	-23,157	-3.9%
Lambertville	-51	-10.1%	-12	-23.9%	-1,555	-2.4%
020401052100-10	-251	-1.1%	30	2.2%	21,691	0.8%
020401052100-20	4,171	15.5%	-1	-0.1%	-76,212	-2.3%
Total	**3,920**	**7.9%**	**29**	**0.9%**	**-54,521**	**-0.9%**

2.4.3 Current Developed and Undeveloped Pollutant Loading

This analysis is a refinement of the current pollutant budget that examines the impacts of developed lands versus undeveloped lands. Developed land is defined in this analysis as any developed land use, such as residential or commercial, as well as land uses such as agriculture; in effect, this classification represents any deviation in LU/LC from natural uses. The undeveloped lands therefore are the natural uses such as forests and wetlands. Besides identifying the effects of landscape alteration this analysis can also be used to estimate that portion of the load that may be termed manageable which is equivalent to the developed load. This is the load that can be presumed to be mitigated or managed in some fashion, especially through the use of BMPs, to reduce pollutant levels. It is also assumed that the undeveloped load cannot be reduced significantly below the existing loading. Efforts in the undeveloped areas should therefore focus on preservation, conservation, and restoration as opposed to the interception and treatment of runoff.

The results of this analysis, which are presented as percentages in the table below (Table 8), show clearly the effect of development on loading in the Alexauken Creek watershed. While developed lands account for little over half of the watershed area (52.3%) the pollutant load originating from these areas accounts for 77% of TN, 79% of TP, and 80% of TSS loading. In contrast, the undeveloped portions of the watershed contribute only 23% of TN, 21% of TP, and 20% of TSS loading. This is a great disparity and is a good example of the relative effects of development on pollutant loading even in moderately developed watersheds. It also shows that much of the load is derived in areas that can be actively managed to reduce overall loading.

Table 8: Current Developed and Undeveloped Pollutant Load

Municipality/HUC-14	Area		TN		TP		TSS	
	% Undev.	% Dev.	% Undev.	% Dev.	% Undev.	% Dev.	% Undev.	% Dev.
West Amwell	33.7%	27.5%	15.4%	42.0%	12.9%	44.6%	12.9%	45.1%
Delaware	11.4%	18.3%	5.9%	26.2%	6.2%	25.5%	5.5%	25.6%
East Amwell	2.1%	5.9%	1.3%	8.3%	1.2%	8.5%	1.2%	8.5%
Lambertville	0.5%	0.5%	0.3%	0.5%	0.3%	0.9%	0.3%	0.8%
020401052100-10	27.4%	23.1%	11.2%	30.4%	9.1%	35.0%	9.0%	36.4%
020401052100-20	20.3%	29.1%	11.7%	46.6%	11.5%	44.4%	11.0%	43.7%
Total	**47.7%**	**52.3%**	**23.0%**	**77.0%**	**20.6%**	**79.4%**	**19.9%**	**80.1%**

2.4.4 Impacted and Baseline Pollutant Loading

This analysis is similar to the historic pollutant loading analysis but compares pre-European settlement of the area to current pollutant loads. The baseline load is calculated by assuming that only two land uses were present at that time, forest and wetland. All areas identified as wetland in the 2002 LU/LC dataset were assumed to be historically wetland while all other classes were considered forest.

As with other analyses this iteration shows that current development patterns in the watershed have greatly increased pollutant loads relative to natural or baseline conditions prior to settlement (Table 9). TSS in particular has shown a very large increase over time, and the current load is 332% of the base load, while TN and TP are respectively 265% and 216% of baseline loading. The increase in the loading of TSS is reflected in the field observations that point to sedimentation of the stream and erosion within the channel and the watershed at large as major issues in the watershed.

Table 9: Baseline and Current Pollutant Load

Municipality/HUC-14	TN			TP			TSS		
	Baseline	Current	%	Baseline	Current	%	Baseline	Current	%
	lbs	lbs	%	lbs	Lbs	%	lbs	lbs	%
West Amwell	11,949	30,585	256.0%	829	1,820	219.6%	1,019,951	3,365,152	329.9%
Delaware	6,286	17,078	271.7%	489	1,005	205.6%	564,643	1,804,735	319.6%
East Amwell	1,683	5,135	305.1%	130	305	234.6%	147,365	567,527	385.1%
Lambertville	192	449	233.7%	14	37	260.4%	17,990	62,825	349.2%
020401052100-10	9,681	22,191	229.2%	651	1,397	214.4%	801,035	2,630,205	328.4%
020401052100-20	10,430	31,056	297.8%	810	1,770	218.4%	948,914	3,170,034	334.1%
Total	**20,110**	**53,246**	**264.8%**	**1,462**	**3,167**	**216.6%**	**1,749,948**	**5,800,239**	**331.5%**

2.4.5 Projected Future Land Use and Pollutant Loading

An annual pollutant budget was also calculated for projected land use under build-out conditions. The base LU/LC data for this analysis was provided by the Hunterdon County Planning Board and was published in the Cross-Acceptance Plan. Future development conditions were derived using a review of current municipal zoning regulations and various restrictions such as minimum lot size and maximum percent impervious coverage to identify potentially developable lands. Land that is not developable either because of characteristics such as steep slopes or wetlands or preserved status as open lands or other similar designations was also identified. Land without identified development constraints is then assumed to become fully developed under regulatory constraint and LU/LC reclassified accordingly. This condition of maximum development is considered full build-out.

It was determined using the described methods that in excess of 2,800 acres or 29% of the Alexauken Creek watershed may be available for development or more intensely developed in the future (Table 10). The remaining areas in the watershed are deemed undevelopable because they currently fully developed, exhibit characteristics not suitable for development, or they are preserved.

The results of the UAL were somewhat surprising at face value. All three modeled pollutants showed a reduced potential for loading under build-out conditions. This is counterintuitive given the effects on current loading related to development levels versus historical and baseline levels, but is based primarily on the transition of agricultural lands to residential development; 56% of the identified developable lands are in fact used for agricultural production. The difference in loading is then explained by the reduced application of fertilizers and manure as well as decreased soil erosion linked with pasture lands and cropland associated with agricultural uses relative to rural residential land despite increased "intensity" of development.

Nitrogen is projected to have a 12% decrease in nitrogen loading, 11% decrease of TSS, and 7% decline of phosphorus. For the most part these declines tend to be watershed-wide across municipalities and relatively uniform. The exception was Lambertville, which showed slight increases in TN, TP, and TSS but overall these increases are less than 2% of the future projected loads and as such are negligible in the total budget. The HUC-14 subwatersheds were less uniform than the municipalities and the percent decrease of loading much more modest in 0204015100-10 which even showed a modest increase in TP loading. It must be noted that this subwatershed is currently less developed and is therefore more susceptible to changes in pollutant loading with any land use changes.

It should be stressed that while watershed loading of TSS may decrease, in-stream concentrations are likely to increase under development pressure. The mechanism for this is that under more developed conditions, particularly with increases in impervious cover related to residential development, stream hydraulic loading is going to be higher during peak flows and stormflow events. This would increase scour and bed and bank erosion in the Alexauken and overall lead to increased solids loading in the stream. Overall the modeled reductions in pollutant loading are a testament to careful planning decisions, statutory adoption of environmental regulations, and preservation and conservation actions by the municipalities that minimize the impacts of development even at build-out conditions. However, efforts must be made to ensure that BMPs are utilized to all extents practical to minimize any alterations in pollutant budgets and to mitigate any other issues in watershed and stream function not specifically related to pollutant loading such as wildlife populations, contiguity of forests and tributaries, and thermal loading to streams.

Table 10: Build-Out Pollutant Load

Municipality/HUC-14	Area Developable		TN Net Load		TP Net Load		TSS Net Load	
	Acres	%	lbs	%	lbs	%	lbs	%
West Amwell	1,605	27.1%	-3,760	-12.3%	-13	-0.7%	-298,294	-8.9%
Delaware	1,020	35.4%	-2,275	-13.3%	-163	-16.2%	-248,135	-13.7%
East Amwell	176	22.7%	-524	-10.2%	-36	-11.8%	-67,169	-11.8%
Lambertville	22	23.8%	0.2	0.1%	5	14.5%	2,256	3.6%
020401052100-10	1,264	25.8%	-603	-2.7%	42	3.0%	-118,495	-4.5%
020401052100-20	1,559	32.6%	-5,956	-19.2%	-249	-14.1%	-492,847	-15.5%
Total	**2,823**	**29.2%**	**-6,558**	**-12.3%**	**-207**	**-6.5%**	**-611,342**	**-10.5%**

2.5 Hydrology

The hydrologic component of a stream study is yet another crucial area of the characterization of any watershed because the hydrology of a stream system impacts all stream functions at a fundamental level and because it integrates a wide variety of watershed and climate factors. The investigation of hydrology in the Alexauken Creek watershed focused on evaluating precipitation, evapotranspiration (the combined effects of temperature driven evaporation and transpiration of surface and groundwater by vegetation), overland runoff, groundwater interflow, and tributary flow. The characterization of the Alexauken Creek watershed hydrology was based on combining empirical field data collection and modeling various components of the hydrology.

2.5.1 Climate Review

Climate is the main driver of hydrology and a review of both temperature and precipitation is necessary to understand these systems and required inputs of the various models. The data presented in Table 11 is from the NOAA 30-year climate record. On average the Alexauken Creek watershed receives about 48.8″ of rain per year. July through September is typically the wettest period while October through December is the driest period, although the variation between months is slight. Mean annual temperature is 53°F; July is the warmest month while January is the coldest.

Table 11: Climate Review

30-Year Precipitation and Temperature Normals, Lambertville, NJ

	Precipitation (m)	Precipitation (in)	Temperature (°C)	Temperature (°F)
January	0.103	4.04	-0.89	30.40
February	0.073	2.89	0.11	32.20
March	0.107	4.22	5.06	41.10
April	0.101	3.98	10.61	51.10
May	0.117	4.59	16.33	61.40
June	0.103	4.07	21.44	70.60
July	0.129	5.06	24.00	75.20
August	0.112	4.40	23.22	73.80
September	0.116	4.56	18.94	66.10
October	0.089	3.49	12.50	54.50
November	0.096	3.79	6.83	44.30
December	0.095	3.74	1.61	34.90
Annual Total/Mean	1.240	48.83	11.65	52.97

2.5.2 Volumetric Stream Discharge

Volumetric discharge was measured directly in the field to quantify discharge during each monitoring event and to gauge how the flows compared to average values. Alexauken Creek is not a gaged (USGS terminology) stream and therefore there are no reliable long-term evaluations of stream discharge for this watershed or instantaneous records. For this reason a staff gage was erected at station 1G in Lambertville and a stage discharge ratings curve was developed for the staff gage. In total, discharge was monitored 12 times during the course of the study.

During the course of monitoring stream stage or staff gage height varied from 0.88′ to 1.58′ and corresponding discharge ranged from 0.78 cfs to 36.5 cfs. This shows that modest increases in stream stage can have pronounced effects on total discharge. Overall the ratings curve was shown to be very accurate although extrapolation outside the range of calibration is problematic. This was discovered during a storm event when stream stage was measured at 4.56′ and discharge was calculated as 19,000 although the nearby Lockatong Creek, which is gaged and has a similar size and hydrology was estimated at 1,290 by USGS during the same period.

Seasonal effects were very apparent in the Alexauken Creek characterized by low summer discharge values. Specifically, the summer of 2007 was very dry and somewhat warmer than average and significant monthly rainfall deficits (>2.5″) were recorded in

May and September. This was observed in stream discharge statistics when the stream was discharging just 0.78 cfs in September a very small number for a watershed of this size. Even summer stormflows were very modest, with spring and summer mean calculated discharge at 7.8 cfs. While these were very low flow storms they were still much higher than equivalent baseflow in the same period. The highest stormflow observed during the study occurred during February 2008 and was estimated to be 1,500 cfs based on a comparison with the Lockatong Creek.

An additional analysis was conducted during a baseflow event to correlate discharge at the ungaged stations (stations 2 through 8) to the gaged station and to compare this discharge to percent contribution of the watershed. Besides a better understanding of the relative rates of discharge at each station a significant deviation from percent contributing area could indicate an additional hydrologic function that would require further investigation. For the most part percent discharge followed percent contributing area, although the stations located near the Sourlands had somewhat decreased discharge probably as a result of decreased groundwater interflow. Conversely, stations 4 and 5 showed somewhat increased discharge which is a function of the wetlands in this area.

2.5.3 Regional Hydraulic Loading Model

This model was developed by Princeton Hydro to analyze the hydrology of regional streams, to calibrate other models, and to compare the results to measured stream discharge. The base calculation for the Regional Hydraulic Loading Model (RHL) is specific hydraulic discharge, or discharge per unit area. The strength of this metric is that empirical streamflow data neatly integrates all stream hydrology components including baseflow, stormflow, overland runoff, and net groundwater contributions as well as other processes such evapotranspiration and loading functions related to LU/LC and other watershed characteristics. This model relies on the use of the excellent USGS discharge data from regional streams which can be chosen specifically for fitness based on LU/LC patterns, geology, and watershed size. For the analysis of Alexauken Creek the following streams were examined: Neshanic River, Lockatong Creek, Wickecheoke Creek, Tohickon Creek, Pike Run, and Stony Brook.

Mean annual specific discharge was calculated as 1.6 cfs/mi^2 (Table 12). Of the six creeks mentioned above Lockatong Creek and Wickecheoke Creek were not utilized for calibration purposes since their period of record is too short and thus not reliable for calculating robust long-term averages. The most important trends taken from this analysis is that stream discharge in regional creeks is highly seasonal and that specific discharge between regional streams is very similar. In August, the month with the lowest mean specific discharge, discharge is only 38% of the annual average. Looked at differently, August discharge is only 21% of that in March, the month with the highest mean discharge.

Table 12: Regional Hydraulic Loading Analysis Specific Discharge (cfs/mi^2)

Month	Lockatong Creek	Wickecheoke Creek	Tohickon Creek	Neshanic River	Pike Run	Stony Brook	Mean, all	Mean, without LC and WC	% of Annual Mean
January	3.41	3.08	2.46	2.22	2.43	2.20	2.28	2.33	144.99%
February	1.00	0.38	2.16	2.26	2.43	2.34	2.34	2.29	142.90%
March	2.18	4.81	3.10	2.92	2.61	2.97	2.83	2.90	180.62%
April	5.33	6.50	2.46	2.14	2.24	2.45	2.28	2.32	144.72%
May	0.57	0.60	1.86	1.28	1.55	1.39	1.41	1.52	94.76%
June	3.36	5.04	1.04	0.93	1.10	0.88	0.97	0.99	61.49%
July	0.57	0.86	0.82	0.74	1.14	0.72	0.87	0.85	53.23%
August	0.11	0.14	0.50	0.70	0.58	0.63	0.64	0.60	37.55%
September	0.57	0.60	1.05	0.74	0.91	0.67	0.78	0.84	52.56%
October	2.62	2.48	1.07	0.66	1.27	0.76	0.90	0.94	58.59%
November	3.14	4.85	1.78	1.32	1.55	1.28	1.38	1.48	92.33%
December	2.01	1.69	2.47	1.95	2.24	2.09	2.09	2.19	136.25%
Mean	**2.07**	**2.59**	**1.73**	**1.49**	**1.67**	**1.53**	**1.56**	**1.61**	**100.00%**

2.5.4 Corrected Modified Rational Method

The Modified Rational Method is used on a small scale to evaluate hydrologic loading to streams based on precipitation, LU/LC, and soil properties. Runoff coefficients used in the model are derived from NRCS Technical Release 55 (TR-55) Curve Numbers. The use of this model for calculating gross discharge is widely accepted by the USEPA and NJDEP. However, this model grossly overestimates annual loads because it is designed for use in microbasins. Princeton Hydro therefore uses a correction to more accurately predict stream hydrology. The chief correction is an evapotranspiration term, which accounts for the strongly seasonal variability in stream hydrology. In addition there is a correction for abstraction and groundwater storage such that in months when PET is greater than precipitation there is an assumption that at least a portion of any received precipitation will be available as either surface runoff or groundwater which contributes to stream discharge. The final assumption of this model is that in watershed scale studies the model predicts not only surface runoff but also accounts for groundwater discharges to streams. This is based on the level of correlation with streamflow from the RHL model, and the RHL model is therefore used to calibrate the correction factor for the Modified Rational Method.

Several iterations of this model were run to calibrate using the RHL model. The best fit for the correction factor is 25%; this means that the model assumes at least 25% of precipitation will be converted to stream discharge even when potential evapotranspiration exceeds precipitation for a month. As with the RHL model the Corrected Modified Rational Method shows a stark contrast in seasonal hydrology with very high reductions of discharge during the summer months and increased flows during the winter and early spring (Table 13). Calculated mean annual discharge on Alexauken Creek is 22.5 cfs. In total over 20 million cubic meters are discharged annually from the Alexauken Creek.

The hydrology patterns certainly play an important role in the ecology of Alexauken Creek. Nutrient loading patterns and concentrations are susceptible to great variation in conjunction with variable flows, uptake, and source loading. Erosional processes and solids loading will also vary and bed load mobility is decreased during low flow periods. *In-situ* water quality parameters will vary greatly as well. Additionally, the simple lack of water in summer characterized at times by a loss in wetted channel width has significant effects on the invertebrate population while spring peak flows and water velocity may be important cues to trigger migration in diadromous fishes.

Table 13: Corrected Modified Rational Method, 25% Correction

Month	Volume	Discharge	Specific Discharge	% of Annual Mean
	m3	cfs	cfs/square mile	%
January	3,041,849	40.11	2.65	178.51%
February	2,174,282	31.74	2.10	141.26%
March	2,740,471	36.13	2.39	160.82%
April	1,712,252	23.33	1.54	103.83%
May	1,050,797	13.85	0.92	61.66%
June	766,109	10.44	0.69	46.46%
July	952,460	12.56	0.83	55.89%
August	828,226	10.92	0.72	48.60%
September	858,343	11.69	0.77	52.05%
October	997,728	13.16	0.87	58.55%
November	2,176,408	29.65	1.96	131.98%
December	2,733,165	36.04	2.38	160.39%
Annual Total/Average	**20,032,090**	**22.47**	**1.49**	**100.00%**

2.5.5 Posten Method

The Posten Method was utilized to estimate interflow or an estimate of shallow groundwater inputs to Alexauken Creek. The Posten Method was developed to estimate northern New Jersey groundwater inputs based on a regression of empirical data. For the hydrology of this system the results of the Posten Method are not used as additive component but rather to merely describe the potential groundwater component of the other hydrology models, particularly the Corrected Modified Rational. In essence the Posten Method is simply a loading coefficient for groundwater with no correction for seasonality.

The Posten Method estimated annual interflow of approximately 11.3 million cubic meters annually, which is approximately 57% of total stream discharge. On a monthly basis interflow is calculated to be approximately 0.94 million cubic meters. While not adjusted for seasonal variability it seems clear that shallow groundwater sources account for most of the summer flows in Alexauken Creek and that the estimate of groundwater contributions seems to be fairly well correlated with summer discharge totals. The importance of maintaining groundwater recharge even within the rooted zone are therefore critical to maintaining summer flows in the Alexauken.

2.5.6 Comparing 2007 Discharge to Long-Term Averages

Since 20007 was shown to be an outlier in terms of precipitation and therefore streamflow it may be useful to evaluate the trend on hydrology. Since Alexauken Creek does not have a long-term hydrologic database the nearby Neshanic River was used as a proxy to demonstrate the effect of drought on stream flows in this region. The Neshanic River discharge data was compared to the mean monthly discharge for each month (Table 14). In September, when the Alexauken was discharging at only 0.78 cfs, the Neshanic River discharged at 0.73 cfs which is only 3.8% of the September monthly mean. Besides the very low summer totals, this look at current versus historic flow regimes shows that annual hydrology is inherently variable and that significant deviation from long-term mean values is the norm.

Table 14: Neshanic River, Review of Current and Historic Discharge

Month	Mean Monthly Discharge, 2007	Mean Monthly Specific Discharge, 2007	Mean Monthly Specific Discharge, 1930-2006	2007 Discharge as % of Mean Monthly, 1930-2006
	cfs	cfs/square mile	cfs/square mile	%
January	78.81	3.07	2.22	138.3%
February	14.59	0.57	2.26	25.2%
March	90.77	3.53	2.92	121.0%
April	218.60	8.51	2.14	397.5%
May	20.79	0.81	1.28	63.0%
June	6.71	0.26	0.93	27.9%
July	6.99	0.27	0.74	36.8%
August	5.70	0.22	0.70	31.7%
September	0.73	0.03	0.74	3.8%
October	19.28	0.75	0.66	113.4%
November	15.99	0.62	1.32	47.0%
December	75.81	2.95	1.95	151.6%

2.6 Identified Impairments

This section reviews the results of the characterization of the Alexauken Creek watershed provided above with intent to identify specific causes of impairment and pollutants that will be targeted by this Watershed Protection Plan (WPP). More specifically it references standards and regulations applicable to FW2-TM (C1) waterbodies and compares these to measured conditions and observations regarding stream water quality and watershed function to enforce compliance with protective measures in place. The end goal therefore is to prepare a list of known impairments and their causes and to mitigate, enhance, and improve these identified targets to ensure not only compliance with designated uses and water quality but to improve watershed ecosystem function in general.

For the most part this section references the New Jersey Surface Water Quality Standards (N.J.A.C. 7:9B) to identify impairments against standards. In total there are eight specific impairments documented that need to be addressed in the WPP:

- Water Temperature
- Benthic Macroinvertebrate Community Composition
- *E. coli*
- Dissolved Oxygen
- Total Phosphorus
- Total Suspended Solids
- pH
- Stream Channel Erosion and Invasive Species Colonization

Each of these areas will be discussed in turn with reference to the standard or regulatory measure they violate, the effect on the stream or watershed ecosystem, the cause of the impairment, and a summary of its documented state in the Alexauken Creek watershed.

2.6.1 Water Temperature

As noted above water temperature in Alexauken Creek has been a known problem and was one of the reasons that Alexauken Creek was included on the 303(d) Sublist 5 with non-attainment of aquatic life uses with a deficiency in temperature. SWQS state that Trout Maintenance waters shall not exceed a summer mean of 68°F (20°C). This standard exists to protect the coldwater fishery for trout, but also protects macroinvertebrate communities that require cool water. Trout are particularly sensitive to prolonged periods of high temperature because they are adapted to survive in coldwater streams and lakes which form their natural habitat. Secondarily, higher temperatures also decrease oxygen solubility and trout and other coldwater fishes have a high oxygen demand.

Alexauken Creek was shown to exceed mean summer temperature standards at stations 1, 2, 3, and 8. The level of exceedance was moderately low with the station maximum summer mean of 21.4°C recorded at station 1. Conversely the stations that did meet the standards barely did so and the lowest mean summer temperature of 18.8°C was recorded at station 7. Mean daily maximum exceeded the standard at all stations. While instantaneous peak temperatures are not regulated all stations exceeded 24.7°C (76.4°F). There is evidence that peak values may be just as important as seasonal means in the viability of supporting cold water fish.

There are several causes contributing to the thermal pollution of Alexauken Creek but it seems clear that degradation of riparian buffers is chief among them. Degraded buffers and reduced canopy cover allow direct irradiation of the stream channel to increase temperatures. Another one of the major drivers affecting temperature is the impoundment of several of the large tributaries; some of these are linked in series. Again this allows increased irradiation due to a lack of canopy as well as increased hydraulic residence time. Substrate composition, including outcrops of dark shale bedrock, may contribute to stream warming, particularly near station 3. The last factor to be considered is that summer discharge was very low during the 2007 summer and decreased flow velocities coupled with increased residence time likely contributed to increased temperatures.

2.6.2 Benthic Macroinvertebrate Community Composition

Benthic macroinvertebrates have also been determined to be impaired in Alexauken Creek. The 2008 Integrated List identifies Aquatic Life, General use on Sublist 2 indicating at least one impairment in designated use. Aquatic life use is determined in a variety of manners including biological assessment of the benthic macroinvertebrate community, but more typically relies on water quality parameters related to physical measurements of dissolved oxygen, temperature, and pH, as well as various chemical constituents including total phosphorus and ammonia among others. While there are no specific numerical standards under the SWQS associated with benthic macroinvertebrates there are protections granted by the designation of the stream. One of the primary designated uses of FW2 waterbodies is the “maintenance, migration, and propagation of the natural and established biota”, which certainly extends to the macroinvertebrate community. Similarly the Category One anti-degradation standards provide “protection from measurable changes in water quality...and ecological integrity (habitat, water quality, and biological functions).

The best metrics of the macroinvertebrate community rely on the use NJIS Impairment Scoring from AMNET published in the Integrated Water Quality Monitoring and Assessment Report. Three stations, AN0098, AN0097, and AN0096, have been surveyed several times since 1992 which are analogous to stations 1, 4, and 8 in the current study. All three of these stations have shown some decline relative to previously recorded data (Table 15). While scores improved slightly at stations 1 and 4 in 2007 relative to 2003, station 8 showed a decline to a score of 21. Looked at somewhat differently in the initial two surveys conducted by AMNET in 1992 and 1997 all three stations were designated by their scores as non-impaired, while in 2003 both stations 1 and 4 were scored as moderately impaired. For this study stations 1 and 4 regained non-impaired designation, although station 8 was characterized as moderately impaired during the May event. Looking at the remaining sampled stations with no AMNET analog, station 7 scored a 15 in the November sampling which characterizes the station as moderately impaired.

Table 15: NJIS Benthic Macroinvertebrate Scoring

Date	AN0098/Stn 1	AN0097/Stn 4	AN0096/Stn 8
Jul-92	30	24	27
Jul-97	30	24	27
May-03	21	21	24
May-07	27	30	21
Nov-07	27	30	27

Benthic macroinvertebrates are perhaps the most important component of stream biota. Unlike other ecosystems, smaller stream systems are more reliant on detritus and allochthonous carbon (contributed from outside the stream) than autochthonous sources (from algae and plants). As such the typical role of primary producers such as periphyton is reduced and stream invertebrates serve as the base of the food chain. It is typically the benthic infauna that drives diversity and biomass in stream systems and serves as the forage source for fish and amphibian predators. Therefore, benthic macroinvertebrates are directly involved in carbon cycling and sustaining higher trophic levels and impairment of their communities represents not just a loss in water quality but a loss of ecologic function in general. Benthic macroinvertebrates also serve as a useful indicator of stream function because they integrate biological as well as chemical and physical factors.

Impairment in stream invertebrate communities is somewhat more complicated than the causes of other non-biological systems and is thus two-tiered. Direct causes of declines in communities or a shift to more pollution tolerant communities is caused by a variety of factors with the largest being increased pollutant loading. Pollutants can be direct acting toxics or other indirect effects associated with nutrient loading and eutrophication. Other causes of impairments include increasing temperature, decreased dissolved oxygen concentrations, and loss of habitat through sedimentation. The second tier of impairments therefore is related to the reasons these factors have changed in the first place which is related to increased watershed pollutant loading. It is these factors touched upon in the temperature section above and in the following sections that contribute to a loss of benthic macroinvertebrate quality.

2.6.3 *E. coli*

Bacterial counts, specifically *E. coli*, are regulated under the SWQS. For FW2 waterbodies there are two standards based on an instantaneous value and an average value. *E. coli* is not to exceed a geometric mean of 126 cfu/100 mL, and no single sample is to exceed 235 cfu/100 mL. This standard is set to meet primary and secondary contact recreation uses in waterbodies and therefore is related to human health uses. Even then *E. coli*, the predominant gut bacterium of warm-blooded vertebrates, is treated as a potential vector of pathogens such as viruses and bacteria. In an environmental context it can be viewed in a similar manner, and is more useful as a proxy measure of nutrient loading, although direct effects of fecal loading can also impact aquatic and related terrestrial communities.

In the Alexauken Creek stations 1 through 7 widely exceeded single event maximum and 30-day geometric mean bacterial counts and thus do not meet contact use designations; only station 8 was in full compliance with the standards. Similarly on seven of the eight sampled dates the single sample count standard was exceeded by at least one of the sampling stations; May 8, 2007 was the only date on which no concentration was detected above 235 cfu/100 mL. By far station 7 had the highest counts recorded with a single sample maximum of 46,000 cfu/100 mL and a summer geometric mean of 2,548 cfu/100 mL. Station 8 did not exceed the summer geometric mean or the single sample standard although a high value of 230 cfu/100 mL was recorded on one date.

As with many of the noted impairments in this system the causes of elevated bacterial counts is multi-faceted. However, the most obvious cause is related to livestock production. This is especially evident at station 7 where the spreading of manure in the adjacent fields leads to incredibly high values particularly during storm events. The stockpiling of manure near the stream or tributaries was also documented at various locations throughout the watershed. In a more general sense the diffuse effects of pasturage and livestock were observed. It is also important to note that wildlife is also likely a large source of loading to the creek, especially that related to Canada Goose (*Branta canadensis*), which were observed at various locations throughout the watershed and were often in close proximity to impoundments. To a lesser degree failing septic systems or systems sited within the floodplain likely contribute to microbial loading in the stream, although because housing density is light this probably is not a major source.

2.6.4 Dissolved Oxygen

Dissolved oxygen is identified in the SWQS and FW2-TM waters are assigned a special standard meant to sustain coldwater fishes and aquatic fauna. The 24-hour average for DO is set to be not less than 6.0 mg/L and not less than 5.0 mg/L at any time. The standard for TM waterbodies was established to ensure that adequate DO levels are preserved for coldwater biota which generally has a higher oxygen demand, which in part is related to the colder temperatures of these systems. DO in streams is influenced by water temperature, with increasing DO solubility with decreasing water temperature, channel slope, canopy cover, biological production via photosynthesis, and respiration.

In the Alexauken Creek DO concentrations were generally acceptable. The single exception occurred on July 27, 2007 at station 8 when DO was measured at 2.74 mg/L, which fell below the instantaneous standard of 5.0 mg/L. No other single measurement fell below 6.79 mg/L. Looked at differently DO% saturation never fell below 72.4% at any station except station 8. As such, DO is generally acceptable for the maintenance of aquatic life and coldwater biota specifically in Alexauken Creek.

The cause of impairment in dissolved oxygen is related to the impoundment upstream. The impoundment upstream of station 8, and impoundments in general, can have a variety of effects on stream hydrology and are known to alter thermal regimes, solids transport, and the hydraulics of stream systems. It is therefore likely that the low DO concentrations observed in the stream at station 8 are due to localized effects within the impoundment. Low DO concentrations in impoundments frequently occur due to algae blooms and the subsequent senescence and bacterial decomposition of excess organic waste. Overall, concerns regarding DO concentrations in the Alexauken Creek are minimal but pulsed slugs of anoxic or hypoxic water could lead to localized biotic impairments and violation of the SWQS.

2.6.5 Total Phosphorus

The total phosphorus standard for FW2 streams is 0.10 mg/L, unless it is determined to not be the limiting nutrient. TP is generally the limiting nutrient in most freshwaters in this region and is generally the nutrient most identified with eutrophication. In streams excessive TP concentrations promote excessive growth of periphyton and is a proxy measure of pollutant loading in general. It may also be used to evaluate designated uses such as aquatic life.

In the course of this study discrete parameters were measured under both baseflow and stormflow conditions. Under baseflow conditions TP never exceeded the SWQS standard of 0.10 mg/L, although this concentration was reached at station 5 during the June event. During stormflows TP concentrations routinely exceeded the limits. Mean stormflow TP concentration was calculated at 0.14 mg/L. All monitored stations exceeded the standard at least once and at least two of the stations exceeded the standards during each of the monitored stormflow events. The direct effects of TP loading on the biota of the stream are witnessed by excessive periphyton growth in some portions of the stream.

TP loading in the Alexauken Creek is related to several different factors. In most stream systems TP loading is most strongly associated with solids loading in the absence of point source contributions such as wastewater treatment plants that generally contribute dissolved phosphorus species. Exceedance of standards is also closely associated with stormflows in the Alexauken Creek which further indicates that elevated solids loading is related to TP in the stream. Solids loading is derived both from watershed erosion and transport and to in-stream solids loading including normal bed load mobility and bank and channel erosion. In both cases degraded riparian buffers related to streamside land uses are certainly implicated in promoting increased solids loading and erosion in the stream. Poor quality buffer lacks the ability to effectively capture particulates in stormwater runoff, detain water, and stabilize creek banks, while increased coverage of impervious surfaces increases hydraulic loading and in-stream erosion.

2.6.6 Total Suspended Solids

In FW2-TM waterbodies total suspended solids are not to exceed 25 mg/L, a more stringent standard than is applied for NT (non-trout) waters. As with other parameters coldwater fishes and other aquatic organisms display an increased sensitivity for solids loading which can interfere with respiration, diminish feeding, and decrease habitat quality.

TSS patterns were similar to those observed for TP. Under baseflow conditions all stations fully attained SWQS and never exceeded 14 mg/L; measured values were typically below detection limits. Under stormflow conditions a different pattern emerged and under moderate stormflows values were slightly elevated but typically met the standards. However, during intense storms or design storm events stormflow concentrations increased by nearly two orders of magnitude (100 fold) and all stations exceeded the standard. While stations 7 and 8 also exceeded the standards at stormflow the magnitude of the increase was much smaller. It is important to note that for the most part TSS concentrations are quite low in the creek and that there is little to no impairment related to TSS concentrations at baseflow discharge or during the predominant flow regime.

Impairments associated with solids loading in the creek are independently observed in the volunteer visual assessments, the visual habitat assessments, and the macroinvertebrate data. The dual effects of both erosion and sedimentation were frequently noted in the visual assessments as were the secondary effects including increased substrate embeddedness and lack of suitable habitat. The macroinvertebrate data also reflected solids loading in the stream through increased MFBI or Hilsenhoff Family Tolerance Value scores which indicate increased organic pollution including particulate forms. Impairments related to solids loading affect more than substrate composition and can cause significant changes to stream fluvial morphology and likewise affect the hydraulics of the system. This can include a filling of deeper pools or a loss of velocity.

There are several causes contributing to increased loading in the Alexauken Creek. One of the primary reasons that excessive sediment loading is occurring in the creek is related to the geology and soils of the watershed. Over 94% of the watershed is comprised of highly erodible or potentially highly erodible soils based on a variety of soil, slope, climate, and land use factors which immediately indicates that this watershed is sensitive to soil disturbances even under undeveloped conditions. This point is well illustrated during stormflow events, particularly of higher intensity, when TSS concentrations can reach very high levels. It also shows that potential for erosion is high not only in the watershed but in the stream channel as well. Contributing to increased erosion and transport of sediment above baseline levels in the watershed is impaired riparian buffers and encroachment into the floodplain. This has, as mentioned above, a two part effect: it increases the amount of impervious area in the critical areas which increases the generation of runoff and erosion near the banks and in the stream, and it also reduces the mitigating effect of riparian vegetation to reduce the transport of particulates.

2.6.7 pH

pH, similar to some of the other water quality metrics, is influenced not only by abiotic processes related to watershed characteristics, but can be potentially strongly influenced by biological productivity, especially production (photosynthesis) and respiration metabolic functions that alternatively increase and decrease pH values. For FW2 waterbodies pH shall be maintained between 6.5 and 8.5 (standard units) according to the SWQS. This standard reflects the normal range of non-coastal plain waterbodies in this region and deviations outside of this standard may indicate pollution that directly alters normal pH regimes or indirectly affects pH through nutrient enrichment that spurs excessive growth and respiration. In fact, nutrient policies have been formulated in part to manage pH variability. pH can have a strong effect on many biologic and metabolic processes and deviation outside the range can impact the biota of a stream system.

Generally, pH levels are acceptable in the Alexauken, and only dipped below neutral once. On the first date sampled two stations were shown to deviate from the standard: station 3 was measured at 8.85 and station 6 was measured at 9.51. No other exceedance was recorded. It seems unlikely that there was any direct harm related to these values.

The cause of this small exceedance is related to seasonal growth patterns and station specific characteristics. The exceedance at that date was certainly the product of dense periphyton growth on the stable shale substrate of these two stations, although it is interesting to note that TP concentrations were slightly elevated at that date at both of those stations although the measured concentration was in accordance with SWQS. This indicates that nutrient enrichment from diverse sources as described above can be slightly problematic at times in the stream. pH values may also be slightly elevated in the stream due to a decreased pH buffering capacity common in regional streams related to the geologic composition of the respective watersheds. pH values are generally good in the stream and adequate to support aquatic biota, but may signal increasing eutrophication.

2.6.8 Stream Channel Erosion and Invasive Species Colonization

This category captures several important impairments noted in the study and directly deals with the condition of the stream and streambanks as a function of watershed processes and because of its potential in negatively influencing water quality. This grouping of impairments therefore is not specifically recognized by name in the SWQS or other related rules, however certain language related to general surface water classification (FW2) and the Category One antidegradation policies do encompass these impairments. The primary designated use of FW2 is: Maintenance, migration and propagation of the natural and establish biota. These items therefore require not only adherence to water quality standards for specific measurable parameters but the maintenance of the aquatic ecosystem which must include substrate quality and composition, channel stability, riparian vegetation, channel morphology, and hydraulics all of which contribute to biotic composition and utilization. Similarly, the antidegradation policy for Category One streams is set for:

> *Purposes of implementing the antidegradation policies set forth at N.J.A.C. 7:9B-1.5(d), for protection from measurable changes in water quality based on exceptional ecological significance, exceptional recreational significance, exceptional water supply significance, or exceptional fisheries resource(s) to protect their aesthetic value (color, clarity, scenic setting) and ecological integrity (habitat, water quality, and biological functions).*

This language specifically identifies the protection of ecological integrity including habitat and biological functions. From a mechanistic perspective the measurable change in water quality could relate to all of the parameters discussed above but would also refer to habitat integrity represented by channel and riparian buffer condition as critical components of the stream ecosystem.

The physical state of the stream and banks vary considerably throughout the watershed, but in many places stream erosion and the presence of invasive vegetation on the banks represents a major loss of habitat integrity. In the individual quadrants utilized in the volunteer visual assessment erosion was documented in 24% of surveyed reaches in the Southeast and up to 54% of the reaches in the Southwest. Invasive species colonization of surveyed reaches for individual quadrants varied between 10% and 69% of the reaches. Floodplain encroachment, soil disturbance, and development within 50′ of the top of bank, and other perturbations were also frequently reported throughout the watershed. This type of impairment is most likely the root cause of much of the impairment in the watershed and the stream. Certainly these uses have led to increased erosion, nutrient and pollutant loading, invasive species colonization, a loss of stream canopy, and stream warming, all of which contribute to a decreased ability to support a robust coldwater biota.

3.0 Estimate of Load Reduction

This section will detail the scale and general type of reductions in impairments identified above. This section corresponds to the second of the nine elements listed by the EPA.

An estimate of the load reductions expected from management measures.

The impairments identified in the Alexauken Creek, the characterization of the watershed, and the standards against which impairments are measured do not afford the ability to approach attainment of designated uses and water quality in this watershed in a simple load based approach. This is in part because impairments identified in the Alexauken Creek and its attendant watershed transcend the simple water quality metrics used to evaluate nonpoint source pollution impairments. For several of the examined water quality metrics seasonality and relative discharge rates showed a dichotomy in water quality in which baseflow conditions were acceptable while stormflows exceeded standards many times over. Additionally, certain impairments, such as water temperature, cannot be neatly quantified by loads. The following sections will therefore focus on describing the measures that will preserve and enhance water quality and ecosystem integrity in the system. As such, a practical and realistic approach to managing and correcting impairment will be maintained throughout the protection plan.

A central theme of this protection plan will be to address current water quality issues throughout the Alexauken Creek watershed. For the most part many of the key protections that will maintain and protect water quality in the future are already in place. State protections include the Stormwater Management Rules (N.J.A.C. 7:8), Flood Hazard Area Control Act Rules Act (N.J.A.C. 7:13), and of course the Surface Water Quality Standards (N.J.A.C. 7:9B) amongst others that work in concert to minimize impacts related to future development. The constituent watershed municipalities have also adopted as ordinance various protections for stream buffers, woodlands, floodplain, and other sensitive environmental features.

3.1 Temperature

Temperature is one of the parameters for which a simple load reduction does not adequately describe the measures that need to be taken to ensure use attainment. Based on a strict interpretation of the water quality rules summer mean temperatures will need to be decreased by up to 1.9°C (3.4ºF) at the worst performing station, 3. In particular the three stations nearest the mouth exceeded the mean summer temperatures as did station 8 in the headwaters, while the remaining stations were below maximum summer mean values. It must be pointed out that the temperature survey in the creek occurred during a period of extremely low flows and increased ambient temperatures that drove up temperatures and thus exaggerated non-attainment of temperature standards. To affect these temperature changes an evaluation of source impairment and management alternatives is necessary.

Impairments in stream temperature were driven primarily by a lack of riparian buffer and canopy cover in the stream with secondary impacts related to in-stream impoundments. Most mitigation related to temperature impairments therefore focuses on maintaining vegetative cover, which provides shading, and maintaining flows and flow velocity which minimizes the timed exposure to solar irradiation. The actual mitigation activities typically focus on preserving natural buffers, streambank planting with shrubs and trees, the removal of impoundments, altering the flow regime of impoundments, and utilizing infiltration designs for stormwater management BMPs. Since the impoundments on the Alexauken are privately held it is likely that riparian restoration activities will be the most effective in reducing temperatures.

One way to assess the potential effects of stream shading provided by riparian buffers is to more closely examine the effects of localized buffer and buffer conditions upstream of the sampling stations. Of the four stations that did satisfy temperature standards the riparian buffer was relatively high quality with a canopy over the station and more importantly the riparian buffer upstream of the station was intact. The stations that exceeded temperature standards were impacted mostly by buffer impairments upstream although both station 1 and 3 did not have high quality buffer. For example, station 2 had good riparian buffering and canopy but exceeded temperature standards because of impairments upstream at station 3 and above. It is also important to note that station 2 also exhibited a mean temperature reduction of 1.4°C (2.5°F) relative to station 3 largely as a result of increased shading and it is not unreasonable to expect that in a more typical year with increased summer flows station 2 would have satisfied the standard. Further examination of the temperature data better illustrates the effects of adequate riparian buffering locally and upstream. At station 2 mean daily maximum was 3.0°C lower than station 3 and maximum temperature was 4.9°C lower although mean daily minimum showed almost no difference. The difference in maximum temperatures versus minimum temperatures suggests that temperature exceedance at station 2 is most strongly influenced by warming upstream and that increased shading between stations 2 and 3 limits additional warming and temperature peaks.

The total mapped network of the Alexauken Creek and all tributaries derived from USGS Blue Line streams and SCS streams GIS data is calculated to contain approximately 57.7 stream miles. A review of the false color infrared aerial photographs shows that approximately 31.8% or 18.4 linear stream miles have impaired or non-existent riparian buffers. While these impairments are observed throughout the watershed there are clusters where the frequency is higher particularly along the Rt. 202 corridor and the northwestern quadrant. The designation of degraded buffer in regards to providing shade is based on both buffer width, buffer continuity, and vegetation height and coverage as determined from the photographs with preferential designation on those stream reaches with southern exposures; this review is not meant to imply an exhaustive survey but a screening level of characterization. In any case, this analysis does imply that a significant percentage of the stream is inadequately shaded which leads to increased mean daily, mean daily maximum, and maximum temperatures.

For the reason discussed above not only water temperature, but poorly shaded stream miles, should factor in the calculus for improving stream temperatures. At a minimum the goal should be to achieve mean summer temperatures at the failing stations which means temperatures should be reduced by approximately 2.0°C at these stations. More typical summer conditions should help achieve this goal by increasing flow velocity and cool groundwater contributions. To mitigate some of the thermal pollution riparian buffer conditions and stream canopy cover must be improved. Currently, 18.4 miles of the stream network are shown to have inadequate buffers although much of this tends to be in short stream reaches which pass through better shaded areas downstream. A realistic and achievable goal then should be the enhancement of approximately 10 stream miles with adequate buffers with a strong focus on the main stem and major tributaries with permanently wetted channels. These efforts will be discussed in greater detail below but much of the work could rely on natural vegetation succession and colonization in these areas fostered by a cessation of mowing or other frequent disturbances.

3.2 Total Suspended Solids

Total suspended solids (TSS) concentrations in Alexauken Creek have been shown to be out of compliance with State water quality standards. Although baseflow concentrations are generally acceptable, and typically below laboratory detection limits, stormflow concentrations tend to be very high. In general, TSS concentrations display some direct, positive relationship with storm intensity and stormflow concentrations may be an order of magnitude or more above the standard. For this reason, and others, a simple load determination is not appropriate and more reliance must be placed on recognizing the limitations of the system, identifying the characteristics of the creek and the watershed that contribute to this pattern of solids loading, and the ability to manage these loads.

A primary issue in limiting TSS loading is the fact that nearly the entire watershed consists of highly erodible or potentially highly erodible soils. The erosion prone nature of the majority of the region's soils limits to some extent the level at which erosion and sediment loading can be controlled in the watershed. The erodibility also indicates that the stream itself may be more prone to erosion than similar streams. Furthermore nearly 48% of the watershed is undeveloped and unfarmed and there is no practical method or reason for managing loads developed in these undisturbed areas. For these reasons efforts must focus on limiting solids loading from developed or otherwise utilized portions of the watershed and in-stream erosion. More specifically, this will involve reducing source generation in the watershed, capture of solids in stormwater, and reducing stream erosion through minimizing stormwater volumetric discharge.

As discussed above a simple load calculation is not sufficient to set a targeted reduction. Baseflow and low intensity precipitation events pose little risk of either erosion or sediment delivery to the system as confirmed by in-stream sampling and as such solids standards are satisfied the vast majority of the time. However, high intensity storm events contribute very large loads. Analysis of these data would suggest a required load reduction of up to 93%. In a rural watershed characterized by erosion prone soils such a sizable load reduction is not a realistic, achievable target. In fact, in order to achieve such a reduction it would be necessary to reduce the creek's solids load to a level actually 22.6% of the modeled pre-development (natural) solids load. A reduction of this magnitude is therefore not only unachievable, but impractical. Additionally, such an approach could actually lead to sediment starvation in the stream without the ability to naturally replenish bed load or contribute nutrient sources which are critical components of native stream systems.

Another typical approach to identify targets is to calculate an average annual concentration by dividing total load by total stream hydrologic load. This approach yields a value of 131 mg/L of TSS which would require an 81% reduction to meet the standard, however when the same exercise is performed utilizing the baseline or pre-development load average TSS concentration is still 40 mg/L which would require a 37% reduction under completely forested conditions to achieve the 25 mg/L standard which illustrates that the standard is not realistic for this watershed. That is why many other regulatory authorities utilize a multi-tiered standard that is based on exceedance distribution to account for variable storm intensity and acute versus chronic effects. Measured stormflow concentration averaged across all stations for the four seasonal monitoring events was 63 mg/L.

A better approach to quantifying load reductions would describe stormwater management measures and associated efficiency in reducing overall stormwater volumes and peak stormwater flows and increasing solids removal capacity. This approach therefore describes realistic and implementable strategies rather than setting an arbitrary target, but meets overriding environmental conservation and enhancement goals by reducing nonpoint source loading and stormwater quantity. Some of the general strategies to reduce solids and stormwater loading in this watershed include: preservation, enhancement, and creation of streamside riparian buffers; streambed and bank stabilization; implementation of cultural BMPs to reduce loading from developed and agricultural lands; retrofitting existing stormwater infrastructure to improve removal performance; and construction of structural BMPs such as infiltration basins at critical areas.

Since TSS loading in the watershed is so diffuse most effort should focus on the repair of riparian buffers; nearly 32% of the buffers in the watershed appear to be highly degraded. Besides the benefits in reducing solids loading and in-stream erosion the maintenance and enhancement of buffers also treats other NPS loading problems and creates valuable habitat. Indigenous forested buffer offers perhaps the best solids removal efficiency of any non-intensive restoration technique, reported at 70%, and implementation may be as simple as planting appropriate vegetation. If there is an assumption that overall solids loading is distributed equally along the tributary network restoration of buffers in the targeted 10 mile reach discussed in temperature reduction section above at 70% removal efficiency could decrease solids loading to the streams in a best case scenario by approximately 12% or 703,700 pounds annually. Similarly, a conversion to forested riparian buffer yields decreased stormwater runoff and the modeled change from lawn to forest could decrease peak discharges up to 17% in the converted area which decreases the potential for bank and bed erosion. Vegetated filter strips are somewhat more intensive to implement as they depend on creating a uniform grade, but in the end consist of introducing plant communities to filter and settle solids and minimize erosion. Removal rates vary from 60% to 80% dependent on the plant communities.

Agricultural BMP are important in the source control of solids loading in the watershed. This would focus on utilizing conservation tillage practices. Given the efforts by USDA and NRCS as well as local Soil Conservation Districts and other advocates for agriculture it can be assumed that many farmers already actively practice many BMP including conservation tillage practices, crop rotation, and cover crop planting in an effort to conserve valuable top soil, improve yields, and protect waterways.

Another means by which solids loading and stream erosion can be reduced would be to retrofit and upgrade any existing stormwater basins or related BMPs. To date there are only a few sizable basins within the watershed, with one of them being associated with a recently completed residential sub-division located in the Mt. Airy portion of the Alexauken Creek watershed. The initial inspection of these basins suggests that their performance, in terms of stormwater recharge, pollutant attenuation, and overall volume control, could be improved by implementing some basic, simple retrofits. This would include the removal of the concrete low flow channels and the revegetation of the basins with a native, wet meadow/meadow plant mix.

The New Jersey Stormwater Best Management Practices Manual (NJDEP, 2004) lists a variety of other strategies to reduce solids loading that offer high removal efficiency but are intensive due to permitting, engineering, construction, and materials which substantially increases cost. These types of projects may also have a substantial footprint which could be prohibitive in siting the design. The following lists some of the applicable management alternatives and removal efficiency that may be appropriate for use in the Alexauken watershed: bioretention system, 90%; stormwater wetland, 90%; infiltration basin, 80%; and pervious pavement, flow reduction. Manufactured treatment devices or MTDs should also be considered particularly as retrofits of existing systems or in areas with limited space. A number of these systems have been approved in New Jersey and removal rates vary between 50% to 80%.

3.3 Total Phosphorus

Total phosphorus exhibited a pattern similar to that observed for TSS in relation to the SWQS. Under baseflow conditions TP concentrations never exceeded the standard, but all stations exceeded the standard at least once during storm events and concentrations tended to be higher during higher intensity storm events. As with TSS, this pattern defies a simple load based reduction as an appropriate means of improving ecological function of the stream and use attainment, and a description of removal efficiencies for management alternatives will be more useful.

TP is generally highly correlated with solids loading in streams without large point sources or dissolved phosphorus loads and the most effective control methods generally focus on controlling solids loading. Since TP is highly correlated with solids many of the same limitations that exist for solids loading in this watershed are applicable to TP. Solids and phosphorus loading is prone to be excessive in the watershed due to the erodible soils of the watershed, but under baseflow conditions SWQS are attained. As such, the enhancement and creation of vegetated riparian buffers will be among the most useful for controlling TP loading in the Alexauken. Management should therefore focus primarily on reducing peak concentrations during higher intensity storm events, limiting additional loading to the system, and maintaining low baseflow concentrations. Since many of the management measures discussed for solids control are effective in managing TP the same solutions will be evaluated for TP control.

Using some of the same analyses that were employed for TSS shows some of the same issues in trying to calculate a realistic load reduction. Utilizing the concentration standard strictly based on stormflow exceedance could require a reduction of 78.7% to reduce the measured high of 0.47 mg/L to attainment of 0.10 mg/L. Conversely, calculating an annual average by dividing total calculated TP load by annual hydrologic load yields a mean TP concentration of 0.07 mg/L, below the SWQS for TP. These conflicting accounts highlight the difficulty in determining an appropriate load reduction. The following section discusses the phosphorus removal rates associated with the various strategies employed for solids.

The enhancement or creation of indigenous forest buffer and other vegetative filters offer phosphorus removal rates of approximately 30%. Utilizing the same reasoning as with solids loading that TP loading to the tributary network from nonpoint sources is generally equitable on a landscape scale the restoration of 10 stream miles to an indigenous forest buffer would reduce TP loading to the Alexauken Creek by 550 pounds or 5.2% of the total phosphorus load. While the magnitude is less than that described for the removal of solids this can still be an important reduction in phosphorus rates. Additionally, the benefit of reduced stormwater loading will further decrease TP loading related to the erosion of the stream channel.

Other management alternatives tend to offer higher removal rates and when used in targeted areas can offer larger load reductions although at increased costs. Bioretention basins offer removal rates of approximately 60% and constructed stormwater wetlands can remove up to 50% of TP loads. These systems benefit through dual removal mechanisms including the physical filtering and settling of solids as well as bioassimilation or uptake by plants. Infiltration basins and pervious pavement can also remove approximately 60% of influent TP loads. Manufactured treatment devices also offer TP removal capabilities, but removal rates are poorly described in the literature simply because they tend not to be evaluated for TP removal. However, some common types, such as baffle boxes and vortex units, seem to offer removal rates of approximately 20% to 40%.

Cultural and agricultural BMPs can be very important in controlling phosphorus loading in rural watersheds because of the diffuse nature of the loading. Cultural BMPs generally focus on actions related to property maintenance. In regards to phosphorus this would include maintenance and repair of onsite septic systems and reducing loading related to lawn fertilizer applications and erosion. Use of phosphorus-free lawn fertilizers was shown in a pilot study to reduce TP loading by between 12% and 16% in residential areas. In the Alexauken Creek watershed maintained lawn space from various LU/LC classifications accounts for approximately 12.7% of the land area and a 16% reduction from these areas could reduce TP loading by 82 pounds or 2.6% of the total. Regular septic system maintenance may also be important in reducing TP loading to the Alexauken. Septic systems generally remove about 48% of incoming phosphorus (CEEP, 2006), mostly in the form of solids. Given the estimated number of single-unit dwellings regular tank pumping can maintain this high removal efficiency leading to the annual capture of 262 pounds of TP or approximately 8.3% of the annual load.

Manure management will be an important consideration in this watershed. At a minimum the NJDA Animal Waste Management Rules should be enforced that require that manure piles be located at least 100’ from any State water. One dairy cow produces approximately 4 pounds of phosphorus per year and managing manure away from the tributary network is critical in reducing phosphorus loading particularly during storm events where leachate and particulate forms are easily transported to streams. Utilizing conservation tillage practices can decrease TP loading by up to 30% on agricultural lands.

3.4 *E. coli*

High *E. coli* concentrations are endemic throughout the Alexauken Creek watershed and are observed throughout the year, although summer counts were higher due to microbial growth directly within the stream and decreased flow or dilution factor during this period. Control of *E. coli* is going to be difficult because no point source, such as a wastewater treatment facility, is readily identifiable, wildlife are likely to be major loaders, and septic effluent from residential lands are likely to be minor contributors. As such much of the coliform loading in this watershed may be characterized as unmanageable. An additional complicating factor related to coliform loading is that only minor portions of the load are related to particulates bigger than individual cells so the mobilization of bacteria mimics dissolved substances or colloids. Management of *E. coli* will have to focus strongly on manure management techniques.

Traditional BMPs used for stormwater management tend to offer relatively low removal efficiency for reducing fecal loads. A recent study in the journal *Stormwater*[9] based on paired influent and effluent concentrations show that vegetated swales and detention basins are not effective in reducing bacteria and have been shown in many cases to actually increase concentrations. Retention ponds and media filters including bioretention cells show the most benefit, but all evaluated BMPs showed a high degree of variability and even the better performing types may at times show increased concentrations post-treatment and that none of the measures are able to reduce

[9] Clary, J. et al. 2008. *Can Stormwater BMPs Remove Bacteria?* Stormwater. http://www.stormh20.com/may-2008/bacterial-research-bmps.aspx

concentrations below contact standards. The ability of retention basins to reduce concentrations is confirmed in field collected data from station 8 which had the lowest measured concentrations as a result of the removal efficiency provided by the impoundment upstream of the sampling location. Overall, these systems may provide reductions in concentration up to 70%, but overall reductions are likely to be small as these reported reductions would apply only to the catchment area of an installed BMP.

Manure management techniques will likely be more important in reducing manageable coliform loads including *E. coli*. Studies indicate that storage prior to field applications is probably the most effective way of reducing bacterial concentrations and storage up to a month has the capacity to reduce concentrations by up to 99%, although storage solutions including stockpiling still require management. The use of vegetated buffers in agricultural applications may have somewhat higher percent removal but this may be a factor of higher initial concentrations in agricultural settings as opposed to more typical BMP catchments. The reported efficiency of agricultural BMPs for the control of microbes is very variable but seems to range between 50-70% for filter strips, vegetated swales, and riparian buffers. While this is probably not adequate to meet primary contact standards locally in stream segments adjacent to fields that receive manure applications it could represent a sizable decrease in total loading and at stations downstream.

3.5 Stormwater Runoff

Considerations for stormwater management typically focus on reducing runoff related to new development or redevelopment with the main consideration for management being reducing peak discharge rates. More recently stormwater management has focused on a paradigm of managing stormwater quality to reduce contaminant concentrations. This focus has been fostered in part by the nature of the technical regulations. However, since stormwater volume has led to increased erosion in this watershed as well as other impacts it will also be useful to think of runoff as a pollutant load. Reducing runoff volume will be challenging as is management for other loads because this type of loading is diffuse across the watershed. Reducing volume instead of just rates will depend on displacing runoff primarily through increasing infiltration processes or potentially by increasing potential evapotranspiration. The benefits of these actions besides an overall reduction in runoff volume is increased groundwater to sustain higher baseflow, reduced erosion, reduced contaminant loading, and potentially reduced stream temperatures.

As with many of the management measures discussed above a simple load reduction calculation is impractical. Most BMPs that offer infiltration or groundwater recharge capabilities such as infiltration basins are highly correlated with site specific conditions, particularly the infiltration rates of native soils as well as soil compaction, however an achievable target for most infiltration systems is 100% recharge of the catchment area for the water quality design storm, typically the 1-year storm (1-year average return frequency). Another design standard for these systems is that they infiltrate at a minimum 0.5 inches/hour. Stormwater wetlands and bioretention systems also offer some volume reduction with reported values between 20% to 60% due to ET losses.

Retrofitting existing stormwater systems can also reduce runoff volumes but the lack of stormwater infrastructure in the watershed minimizes any practical benefit for this approach. The use of pervious pavement systems function similarly to dry wells with a minimum design standard of 0.5 inches/hour of infiltration.

The use of less intensive BMPs is likely to be of greater benefit to the Alexauken Creek watershed overall and should concentrate on land uses such as rural residential development and agriculture because these areas offer the best opportunities to successfully manage runoff volume. Managing roof runoff from houses and outbuildings including barns and sheds is probably one of the easiest ways to reduce runoff volumes and peak discharge rates. While the total area of roofs in this relatively rural watershed is small they contribute disproportionately to stormwater volume. Both rain barrels and dry wells can completely recharge all stormwater generated from roof runoff and rain barrels add a beneficial reuse component as this water can be used to irrigate lawns and gardens. Dry wells are usually designed to handle storm intensities up to the 1-year storm event which in an average year will account for a majority of all precipitation falling on roofs.

In addition to reducing runoff volume traditional rate reduction solutions should be considered as well. In the Alexauken Creek watershed the enhancement of buffer habitats will offer some benefit both in reducing runoff rates by detaining sheet flow through increased roughness attributable to vegetation and through simple infiltration of the detained water. The use of runoff curve numbers may be the most reliable method of describing anticipated reductions in the generation of stormwater. The curve number for forested lands in good condition in soils classified as hydrologic group B is 55, indicating that roughly 55% of precipitation on the site will result in runoff with the remainder being infiltrated by the soils or lost to the atmosphere via evapotranspiration. Pastures in fair condition in hydrologic soil group B have a curve number of 69, farmsteads with lanes and buildings and associated land uses have a curve number of 74, and 1-acre lots corresponding to rural residential development in the watershed have a curve number of 68. Conversion of pasture, farmstead, and rural residential to a forested riparian buffer could conceivably reduce the generation of stormwater respectively by 20%, 26%, and 19% in these areas. Besides affecting a reduction in total volume runoff loading rates would be reduced with a longer time of concentration, the time at which peak stream discharge is reached upon the commencement of a storm event. Reducing stormwater in the areas adjacent to the tributary network of the Alexauken Creek will have a greater affect in reducing erosive forces than more generalized measures throughout the watershed.

3.6 Invasive Species

Invasive species management is generally not regulated in a quantifiable fashion such that a certain percent colonization of an invasive triggers a removal action. Despite this, invasive vegetation is widespread and needs to be controlled in the watershed. There are several negative effects associated with invasive vegetation the most prominent being the competitive exclusion of native plants with a resultant impairment of ecological function and habitat value in the riparian corridor. Invasive vegetation may also be an indicator of disturbance as many invasive plants are pioneer species and within riparian systems can be indicative of frequent or excessive erosional or depositional process that are favorable for colonization. The more problematic and prevalent invasives observed during the volunteer visual assessment surveys include Multiflora Rose, Bamboo, and Common Reed.

Treatment methods for invasive vegetation will vary but would likely consist of both herbicide application and mechanical removal in concert. Addressing the root causes of invasive plant colonization, primarily the disturbance of riparian buffers and secondarily the intentional introduction of invasives (i.e. Multiflora Rose and Bamboo), require both an educational aspect and of course a restoration of riparian buffers throughout the watershed. The goal to achieve a reduction of invasive species in the watershed will therefore focus on implementing the general plan of riparian buffer restoration in the watershed with a stated goal of ten miles of restoration. It is therefore important to establish thresholds at which increased action is devoted to the removal of invasives during restoration. In areas where virtual monocultures of invasive plants have been identified in otherwise undisturbed riparian corridors treatment or removal should be triggered when 100' linear feet of monoculture (defined for this report as plant community percent composition of 75% of invasive species) or a stand in excess of 1000 square feet. This ensures that at a minimum large stands are adequately treated in more naturalized areas where continued rapid expansion is unlikely due to a lack of disturbed soils. In disturbed portions of restoration areas especially where bare soils are present treatment intensity should be increased such that stands exceeding 25' or 250' square feet are treated. In areas where intensive replanting of native shrubs and other vegetation is attempted, particularly where there is a conversion of lawns, agricultural areas, or other developed land covers, all invasives should be removed prior to planting. This should be followed by additional removal post-planting as necessary during a critical phase before full coverage of natives is achieved when invasives often exhibit the most vigorous growth.

4.0 Description of Nonpoint Source Management Measures

This section is the heart of the watershed protection plan and discusses in detail the management measures to be implemented in the watershed to assure protection of Alexauken Creek. This section corresponds to the third of the EPA nine elements.

> *A description of the nonpoint source management measures that will need to be implemented to achieve load reductions in the second* [*element*]*, and a description of the critical areas in which those measures will be needed to implement this plan.*

Up to this point in the Watershed Protection Plan the impairments observed and documented in the creek and the watershed have been fully characterized and identified and a general estimation and quantification of the changes necessary to protect the ecological state established. Additionally, some discussion has been made in a general sense of the measures to be implemented to protect the ecological integrity of the stream upon which this section will expand.

The characterization and assessment of this watershed contained within this document show that while the water quality of the Alexauken is moderately high a number of impairments have affected the ecologic integrity of the watershed and the general water quality of the stream. Therefore the overarching goal of this protection plan is to identify and implement those measures deemed appropriate to address those specific impairments and protect the water quality and integrity of the watershed to improve these functions. An important caveat of protecting and increasing water quality is that all efforts must be conducted in manner that is realistic and achievable with commensurate attention and resources. Since this watershed is rural the impairments in the stream and watershed and the base causes are diffuse. This therefore will require full public buy-in to affect positive changes in water quality especially in light of the limited holdings of public lands where improvement projects could be implemented by the constituent municipalities.

In review, there are six NPS pollutants including traditional and non-traditional loads that have been identified as the source of most major use impairments throughout the Alexauken Creek watershed. These include:

- Temperature or Thermal Load
- Total Suspended Solids
- Total Phosphorus
- *E. coli* or Pathogens
- Stormwater Runoff
- Invasive Species

Increased loading of these pollutants as well as the root causes of their generation have been discussed in detail in the sections above, but a brief summary is found below in

Table 16, along with a description of the generalized major management measurements that need to be enacted to ensure the protection and improvement of the water quality and ecological function of Alexauken Creek. Many of the proffered management measures for the protection of the Alexauken Creek watershed are low intensity solutions that require a minimum of engineering, materials, construction, and funding, all of which is reflective of the diffuse yet extensive NPS loading identified in the watershed and appropriate for meeting protection goals. Because these measures are low intensity this increases the potential for widespread implementation to affect meaningful protection and improvements, but which will, as mentioned above, be strongly reliant on public education and community participation to enact.

Table 16: NPS Management Measures

NPS Management Measures				
NPS Load	**Source**	**Management Measures**		
		Primary	**Secondary**	**Tertiary**
Temperature	Reduced Canopy, Impoundment	Buffer Enhancement	Impoundment Removal	Structural BMPs
Total Suspended Solids	Soil Erosion, Channel Erosion	Buffer Enhancement	Bank Stabilization	Agriculutral BMPs
Total Phosphorus	Soil Erosion, Fertilizer Use	Buffer Enhancement	Cultural BMPs	Manure Management
E. coli	Agriculture, Wildlife	Manure Management	Buffer Enhancement	Cultural BMPs
Stormwater Runoff	Impervious Surfaces, Lack of Infrastructure	Structural BMPs	Cultural BMPs	Buffer Enhancement
Invasive Species	Floodplain Encroachment, Erosion	Invasive Species Management	Buffer Enhancement	Open Space Preservation

A scoring matrix was then used to rank and prioritize these various generalized load reduction methods listed above, including auxiliary measures not shown. The scoring system awarded 4 points to each of the primary measures, 3 points to secondary measures, 2 points to tertiary methods, and 1 point to other methods, and then tallied. This matrix is included in Table 17 below. Not surprisingly, riparian buffer enhancement was chosen as the most important NPS load reduction strategy for the watershed because of the inherent benefits associated with buffer enhancement including bank stability, nutrient uptake, decreased runoff, and improved wildlife habitat, and because degraded riparian buffers have been characterized as probably the greatest detriment to water quality and ecology in the watershed. Riparian buffer enhancement and all of the management measures shown above as well as the auxiliary management measures will be discussed in turn in this section of the document. These discussions will focus on a variety of components as necessary including structural BMPs, cultural BMPs, and agricultural BMPs. General conceptual solutions to be utilized as templates and specific implementation sites will also be provided. A review of regulatory protections is discussed first to better explain the regulatory framework including protection goals and standards.

Table 17: NPS Management Measures Matrix

NPS Management Measures Scoring Matrix	Primary	Secondary	Tertiary	Other	Total Score
Buffer Enhancement	3	2	1	0	20
Cultural BMPs	0	2	1	2	10
Structural BMPs	1	0	1	4	10
Manure Mangement	1	0	1	0	6
Invasive Species Management	1	0	0	0	4
Bed and Bank Stabilization	0	1	0	1	4
Open Space Preservation	0	0	1	2	4
Agricultural BMPs	0	0	1	1	3
Impoundment Removal	0	1	0	0	3

4.1 Existing Regulations

A variety of ordinances, rules, and regulations currently exist to protect water quality in waterbodies throughout New Jersey originating from local municipalities to the federal government. In fact, it is these rules on the books that will ensure the water quality of the Alexauken Creek remains high looking ahead and that simple enforcement and implementation of these rules is going to be among the strongest tools in protecting the watershed in the future. Most of the existing regulatory framework regarding stream protection is focused on mitigating impacts related to planned future development and changes in land use. The smart planning is attested to by the results of the build-out pollutant loading analysis which shows a decrease in pollutant loading under full build-out conditions based on a variety of development constraints including zoning. While potential future impairments are well addressed the pollutant loading and impairments related to current development and land use patterns, especially within defined stream buffers up to 300’ from the channel, is not defined as fully pointing to the need for a watershed protection plan. This document therefore must address mitigating current impairments to improve water quality as it currently stands in addition to implementing those regulations that protect water quality in the future. The following section is a review of some of the more important regulatory measures related to water quality and watershed protection for the Alexauken Creek.

4.1.1 New Jersey Surface Water Quality Standards

The New Jersey Surface Water Quality Standards (N.J.A.C. 7:9B) have been discussed at great length in the sections above and really form the basis for much of this document. The SWQS define the designated use and general classification of the Alexauken, provide a series of scientifically based water quality standards, and establish the antidegradation policies relative to water quality. From this perspective the SWQS regulate the current water quality of the stream and through antidegradation components regulate future uses expressed as water quality metrics.

The specific parameter-based water quality standards were discussed above. While water quality in the creek is fairly high there were documented deficiencies to a varying degree at certain stations or sampling date for water temperature, *E. coli*, dissolved oxygen, total phosphorus, total suspended solids, and pH. In fact, the non-attainment of designated uses established in the SWQS and documented in the New Jersey *Integrated Water Quality Monitoring and Assessment Report* including 305(b) and 303(d) lists had the Alexauken Creek listed on Sublist 5 for non-attainment of aquatic life (trout and general) uses based on temperature impairment which served as a driver in the genesis of the Watershed Protection Plan. The SWQS ultimately stand as one of the strongest protections of water quality in the Alexauken Creek watershed in the future.

In addition to the defined parameters list specified in the SWQS the antidegradation policies can also be interpreted in a more qualitative fashion particularly in regard to protecting aesthetic value and ecological integrity of Category One streams as outlined in the SWQS. In particular, maintaining habitat quality and biological functions is an important part of the antidegradation policy and thus includes assessing stream functions that are not as easily measured as contaminant concentrations or other parameters. These stream functions would include descriptions of biological communities including benthic macroinvertebrates, fish, periphyton, and riparian vegetation as well as stream habitat related to substrate, aggradation/degradation, and erosion and bank stability.

4.1.2 Stormwater Management Rules

The Stormwater Management Rules (N.J.A.C. 7:8) dictate a broad set of goals related to managing stormwater at a variety of governmental levels including municipalities, counties, regional and interstate commission, and various state agencies. The basic goals of these rules are to: reduce flood damage, minimize increases in stormwater runoff, reduce soil erosion, maintain groundwater recharge, maintain stream channel integrity, reduce pollutant loading, and ensure proper design, performance, and maintenance of stormwater BMPs. It also encourages and provides guidance for the formulation of regional and municipal stormwater management plans and stormwater control ordinances. This set of rules and the production of stormwater management plans is primarily focused on stormwater management associated with major development, but may include stormwater management focused on upgrades and retrofits for existing land uses.

The Stormwater Management Rules provide special protection for C1 waters and mapped tributaries in the same HUC14 watersheds, such as Alexauken Creek, through the establishment of Special Water Resource Protection Areas (SWRPA). The SWRPA is a 300’ buffer on both banks measured perpendicular to the top of bank or from the centerline of a stream with poorly defined banks applied to C1 waters. From a regulatory perspective and functionally SWRPAs act as regional BMPs. The purpose of the

SWRPA is to limit encroachment in this buffer to preserve important ecological functions and any encroachment in the any shall be limited to areas of previous development or disturbance. Even when encroachment is allowed within the SWRPA the buffer shall not be reduced below 150'. This extends to the discharge of stormwater and no outfalls can be located within 150' of the stream. In some senses, the strict prohibition of disturbance in the buffers can be limiting for restoration activities or managing stormwater for existing land uses, but the protection of riparian buffers is a powerful tool for maintaining water quality and effectively addresses the primary causes of impaired water quality in the Alexauken.

Any encroachment in the SWRPA on C1 streams and tributaries is based on satisfying two criteria: that the site is developed or disturbed and the proposed activities do not degrade the functional value of the SWRPA. The second criterion is satisfied through conducting a Functional Value Assessment, which consists of four components. Habitat function is evaluated based on its potential suitability for threatened and endangered species and general vegetative character. Nonpoint source pollutant loading is also considered for the SWRPA, but the pollutant removal effects related to structural BMP constructions are discounted since any removal is only related to the post-construction footprint which could generate additional pollutants. Temperature moderation is considered as one of the key functional values of SWRPA and must be protected. Besides referring to canopy and vegetative coverage BMPs that impound water could affect the temperature regime if inadequately shaded and discharging overland to the stream. Channel integrity is also evaluated and is assessed through the volume and rate of stormwater runoff as well as recharge potential within the SWRPA.

4.1.3 Flood Hazard Area Rules

The Flood Hazard Area Rules (N.J.A.C. 7:13) are an expansive set of rules related to land uses, development, and other activities related to or located within flood hazard areas and riparian zones of regulated waters. The general intent of the rules is to minimize damage to life and property associated with flooding caused by development in flood hazard areas, preserve water quality, and protect wildlife and vegetation. The rules include a number of methodologies for determining flood hazard area and riparian zone and defines regulated waters and regulated activities. Six methods are described for determining flood hazard area and in non-tidal waters this is usually based on some derivation of the 100-year flood elevation with appropriate constraints. Riparian zones are also determined in various ways, but a 300' wide riparian zone from each bank is designated for all C1 waterbodies including the Alexauken Creek. The 300' riparian zone distance coincides with the SWRPA, but each references separate rules and from a regulatory perspective are separate entities although functionally they both exist to protect and preserve existing buffers. Besides defining the limits of the flood hazard zones and regulated waters it also defines regulated activities which range from in-stream activities to encroachment in the floodplain. A thorough understanding of regulated activities is important in assessing permitting requirements and the level of effort and detail needed to implement management alternatives for the protection plan; it must be stressed however that additional permits may be required to undertake regulated activities such as freshwater wetlands permits. Regulated activities are classified in four groups: permit-by-rule, general permit, individual permit, and emergency permit.

Permit-by-rule is the least intensive class and requires no prior approval from the State, only a notification prior to initiating work. These activities are generally anticipated to have little to no impact to the riparian zone or increased chance of flooding following the technical regulations with specific instructions for each activity. Many of the proposed management activities that will be discussed elsewhere in the document are likely to be considered as permit-by-rule including activities such as constructing an aquatic habitat enhancement device, conducting normal property maintenance, implementing soil conservation practices outside a floodway, and planting native vegetation.

General permits are required for the next class of activities. These types of activities are generally more intensive and may involve the use of heavy machinery or operating within the stream channel, and carry a higher burden of detail as well as prior approval from the State upon review. At a minimum these permits require submitting engineering or surveying plans sealed by the responsible party. These permits may also require obtaining additional permits and abiding by various other rules including the Standards for Soil Erosion and Sediment Control (N.J.A.C. 2:90). These activities include, but are not limited to, channel cleaning, constructing agricultural roadways and fords, wetlands restoration, outfall installation and maintenance, and repairing or relocating flood damaged structures. Each of the general permits is accompanied by a specific set of limitations to protect both the floodplain and the regulated activity.

Individual permits are issued for larger and more complex projects set within a regulated area or those that fall outside the purview of general permits. These activities include non-agricultural crossings, bank stabilization, stormwater discharges, construction activities, and utilities crossings. Permit submissions are also more complex and must include full engineering drawing sets, hydrology and hydraulic assessments, flood hazard area identification methodology, existing and final grading plans, construction methodology, and identifying and addressing potential impacts as well as many other requirements. Individual permits must satisfy not only all requirements related directly to the Flood Hazard Rules, but also satisfy Water Quality Management Planning Rules (N.J.A.C. 7:15). Individual permits will be required for in-stream restoration activities including bed and bank stabilization activities requiring grading or importing new materials or any activity related to disturbance of the channel or the riparian zone. Individual permits are enforced to protect flood storage capacity and other natural and constructed resources and functions, water supply, ecological functions, drainage, and navigation associated with waterbodies and flood hazard areas.

Emergency permits are issued to undertake regulated activities when immediate action is required to protect the environment and public safety, health, or welfare. Two basic conditions are linked to approval and the permit shall only be approved if severe environmental damage will occur or there is an immediate and high risk to public health and safety and there is a high probability that the impacts to the environment or public welfare will occur before a general or individual permit could be reasonably obtained. Again, these permits are related only to emergency activities and barring a catastrophic flood event in the Alexauken Creek watershed will likely not be utilized for any restoration activities.

4.1.4 Freshwater Wetlands Protection Act Rules

The Freshwater Wetlands Protection Act Rules (N.J.A.C. 7:7A) are based in part on satisfying the Federal Water Pollution Control Act (Clean Water Act) regulations. In scope and function they are similar to the Flood Hazard Area rules and define identification methodology, regulated activities, and permits. The end goal of these rules is to protect the integrity of freshwater wetland systems including habitat and hydrologic functions which are critical components of stream systems and watersheds. Some of the benefits associated with wetland systems include their habitat value to plant and wildlife communities, flood storage, mitigation of contaminated stormwater, stormwater storage, and providing a buffer for streams in both the headwaters and lower in the basin.

Identification of freshwater wetlands is performed under the three-parameter approach that focuses on hydrology, soils, and plant communities. Wetland determination is subject to review by NJDEP and the findings published as a Letter of Interpretation (LOI) which defines presence or absence and the delineation of the wetland boundary. Wetlands are further defined as one of several classes, including Ordinary Resource Value, Intermediate Resource Value, and Exceptional Resource Value, which carry different regulatory weight with increasing protection for higher value resources. One of the variable protections associated with the different classes is the Transition Area width which increases with higher resource value wetlands to provide refuge and buffer the wetland.

Regulated activities associated with wetlands are similar to those defined for flood hazard areas and include disturbance from excavation, fill, dredge operations, drainage or disturbance of water stage or groundwater table, dumping, construction, or destruction of vegetation. These activities may be performed under several permit classes including general permits encompassing freshwater wetlands permits, open water fill, or transition area waivers, individual permits, and emergency permits. There are a large number of general permits, nearly 30, that cover a variety of activities including maintenance of existing structures, utilities, channel cleaning, additions to existing structures, habitat creation and enhancement, trails, and bank stabilization amongst others. Individual permits may be granted for projects in which a combination of general permits is insufficient or have additional permit conditions that would not be sufficient to ensure compliance with the act. Emergency permits are granted on an emergency basis where there is an unacceptable threat to the environment, public safety, or property, and that there is not a reasonable expectation of receiving a general or individual permit before the anticipated threat.

The enforcement of the wetlands rule is certainly important in protecting the resources of the watershed. In terms of implementing restoration strategies these rules are likely to play a part. Bank stabilization, in-channel habitat restoration, channel cleaning, and the removal of all invasive vegetation are all activities regulated under general permits within certain restrictions including disturbance area or linear distance of the activities. However, other activities, such as planting native vegetation by hand, are unregulated and may be performed freely with the conditions outlined in the rules.

4.1.5 New Jersey Pollution Discharge Elimination System Rules

The New Jersey Pollution Discharge Elimination System Rules (NJPDES, N.J.A.C. 7:14A) is similar to the federal National Pollution Discharge Elimination System, and is charged to protect potable water sources, the chemical, physical, and biological integrity of waterbodies, health and human safety, and ecological integrity from the discharge of pollutants. Regulated activities under the NJPDES rules include discharge to ground or surface waters, indirect discharge, land application of wastewater, animal feed operations, stormwater and storm sewers, site remediation, and wastewater treatment plants as well as other activities. Much of the enactment of the NJPDES rules is related to water quality based effluent limitations listed within the rules and related to other statutory vehicles such as the Surface Water Quality Standards. The effluent standards target a variety of pollutants and physicochemical parameters including nutrients, solids, floatables, petroleum hydrocarbons, microbes, temperature, and a large suite of additional parameters.

In addition to the broad categorization above all municipalities and other agencies in the state are required to file for Municipal Separate Storm Sewer (MS4) permits related to storm sewers draining roadways and public complexes. MS4 permits are granted on condition of satisfying the Statewide Basic Requirements (SBR) including public involvement and participation, reduction of pollutants, long-term operation and maintenance of BMPs, controlling solids and floatables, and implementing Municipal Stormwater Management Plans which are enacted through local ordinance, policy, or inclusion in the Master Plan. The constituent municipalities in the Alexauken Creek watershed have completed and are in compliance with MS4 permits and all are designated as Tier B communities.

The NJPDES rules are important for protecting both surface and groundwater resources from point and nonpoint source pollution. In the Alexauken Creek watershed nonpoint source pollution is a larger contributor to pollutant loading than point sources and the SBRs for the MS4 permits ensure that nonpoint sources related to roadways and other infrastructure are addressed. However, as with many of these statutes, the NJPDES rules are directed mostly towards new development or redevelopment activities and therefore have a reduced efficacy in treating and managing stormwater discharge from existing development.

4.1.6 Constituent Municipality Ordinance

Table 18: Regulatory Review of Watershed Municipalities

Regulatory Measure	Municipal Measure
Stream Corridor Protection	***West Amwell**:* included in Twp. Ordinance as Stream Corridor Protection; stream corridor is measured from the top of bank or centerline if bank is not defined and is to be an overlay of existing zoning.
	***Delaware**:* included in Twp Ordinance; stream corridor is established at a horizontal distance no less than 100ft on either side of the stream.
	***East Amwell**:* included in Twp Ordinance; none of the land within fifty (50) feet of the top of the bank of any stream shall be permitted to be developed or regraded.
	***Lambertville**:* none stated in Municipal Land Use Ordinance
Stream Buffers	***West Amwell**:* variety of buffer widths apply, ranging from 75ft to 150ft or the entire delineated 100-year floodplain
	***Delaware**:* None of the land within 50ft of the top of the bank of any stream shall be permitted to be developed or regraded.
	***East Amwell**:* buffer area to be noted on development design.
	***Lambertville**:*
Woodlands Protection	***West Amwell**:* development of any woodlands within the required stream corridor buffers, wetlands, wetland transition areas or floodplains are to be avoided or minimized.
	***Delaware**:* applies when area is greater than 0.25 acres and varies upon type of woodland
	***East Amwell**:* applies to Sourland Mtn. District only-clearing should not exceed 30,000ft^2 and limited to within 500ft of the street.
	***Lambertville**:* none stated in Municipal Land Use Ordinance
Steep Slopes	***West Amwell**:* 25% or greater classified as critical, development to occur outside of steep slope area without intrusion to vegetation on slope.
	Delaware: restricts disturbances on slopes greater than 15% (but allows driveways). No disturbance > 25%.
	***East Amwell**:* 12% or greater are classified as steep, preservation to be noted on development design, slopes over 30% are considered critical areas.
	Lambertville: slopes greater than 15% are recognized as steep slopes.
Threatened & Endangered Species/ Critical Habitats	***West Amwell:*** critical environmental areas include slopes greater than 25%, flood hazard areas, wetlands and transition areas and open waters; T&E to be identified in NRI
	Delaware: none stated
	East Amwell: EIS to identify T&E species and habitat; these areas to be avoided
	Lambertville: none stated
Groundwater Protection	***West Amwell:*** groundwater formations are afforded 150ft protection under stream corridor protection
	Delaware: not included as an environmental and natural resource, no afforded protections
	East Amwell: incorporated in Water Supply chapter of Twp code
	Lambertville: none stated

As discussed above, the constituent municipalities of the Alexauken Creek watershed have been proactive in establishing local ordinances to protect sensitive ecosystems and natural resources, as included in Table 18 shown above. Most of these ordinances are based on the identification and preservation of critical habitats or natural resource features protected by limiting disturbance or development or offsetting such activities through the use of buffers. In practical application many of these ordinances are similar to the state regulations discussed above, but often offer a stronger degree of protection based on more stringently applied restrictions or increased buffer widths. These types of environmental regulations fall in several categories including stream corridor protection, stream buffers, woodlands protection, steep slope ordinances, threatened and endangered species and critical habitat areas protection, and groundwater protection.

4.2 Riparian Buffer Enhancements

The enhancement, preservation, and protection of riparian buffers is the most important measure for protecting water quality in the Alexauken Creek watershed. As mentioned above, riparian buffers serve a great variety of ecological functions and their observed degradation throughout the watershed is the primary cause of most of the water quality impairments and other observed ecological damage. Enhancing and protecting riparian buffers therefore is the most important management measure to be implemented. One of the reasons that riparian buffer enhancement is so important is that the benefits are multi-lateral. For instance, the enhancement of a degraded buffer, one that is characterized by lack of native vegetation including shrubs and trees, soil disturbances, and impervious surfaces among other problems, offers improved canopy coverage and stream shading which reduces stream temperature thereby improving benthic macroinvertebrate habitat with resultant improvements in community structure, as well as decreased biological productivity related to periphyton growth thus leading to improvements both in excessive DO and pH. The following list exhibits some of the benefits of riparian buffer enhancement:

- Increased shading and maintenance of lower temperatures
- Decreased algal productivity
- Nutrient removal through vegetative uptake
- Vegetative trapping of solids and other pollutants
- Reduced runoff velocity and increased infiltration and evapotranspiration
- Increased bank stability and decreased erosion and sedimentation
- Functional wildlife habitat and protection of rare species
- Barrier to Canada Goose access and decreased coliform loading
- Reduced flood damage
- Improved carbon cycling and allochthonous material deposition
- Reduced invasive vegetation colonization

As such, it is evident that buffer enhancement will provide a variety of benefits in reducing a number of specific NPS pollutant loads.

4.2.1 No-Mow Zones

The establishment of no-mow zones is probably the most easily implemented BMP that can significantly improve stream function in the Alexauken watershed. The mowing of riparian buffers or the establishment of maintained lawn space was reported in the vast majority of surveyed stream segments in the volunteer visual assessment and mowing was often continued to the very top of the stream bank within feet of the wetted channel

(Figure 18). Foremost this has led to severe bank instability often characterized by mass wasting and severe undercutting. Besides the erosion and subsequent sediment deposition of the unstable banks much of the function associated with vegetated buffers, including shading, nutrient uptake, and wildlife habitat, among others, is lost.

Figure 18: Lawn Encroachment to Bank

The ideal solution is to simply establish no-mow zones in at least a 50' buffer extending from the top of both banks where vegetation is allowed to simply grow unimpeded. In some senses this type of buffer is already stipulated in various technical regulations and municipal stream buffer and stream corridor ordinances, but existing lawns and "routine" maintenance is often granted exemption. While the establishment of no-mow zones seems simple there will certainly be some resistance to comply, especially with a 50' buffer that may comprise a large portion of maintained lawns or smaller residential lots. A compromise would be to establish as an absolute minimum a 10' riparian no-mow zone to at least establish the vegetation necessary to maintain bank integrity, decrease erosion, and provide at least some shading and other associated functions. While this should probably be adopted as ordinance and applied to existing maintained lawns, with obvious enhanced protections already in place for new development, education will probably be the strongest tool in promoting this practice and effectively conveying the benefits listed above will be crucial in this conversion.

The establishment of no-mow zones is also hastened by the lack of adjunct requirements. Establishing no-mow zones is free, and in fact is less costly and requires less labor than continual seasonal mowing, requires no permits, is consistent with zoning regulations, and can be implemented immediately without consulting or engineering. Another benefit is limited maintenance of no-mow zones. This consists primarily of the removal of invasives species which can be accomplished through chemical treatment or mechanical removal which is recommended for most residential settings. Overall, this approach should be strongly promoted to protect and enhance water quality.

4.2.2 Riparian Buffer Planting

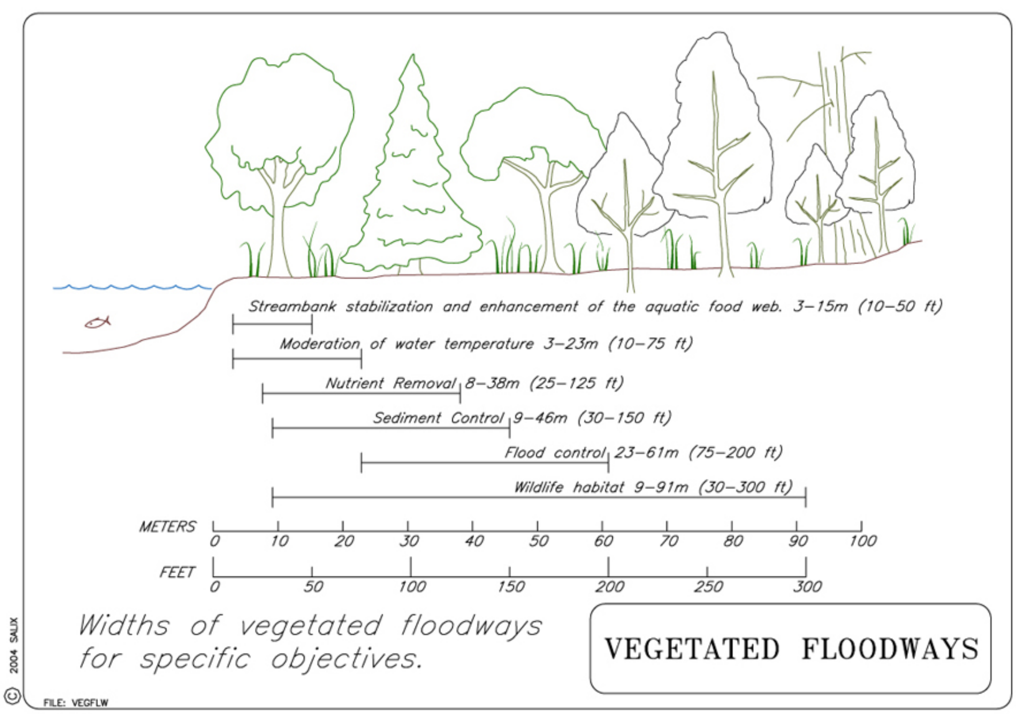
The next step in riparian buffer enhancement is a more thorough approach focused on the restoration of native vegetation. Crucial to this scheme is the replication of natural riparian vegetation communities which integrate multiple vegetation types including herbaceous plants, shrubs, and trees, and may be structured to match different communities including riparian forests and scrub/shrub wetlands. In addition, these planting plans can be tailored as necessary to provide enhancement of existing but degraded buffers or the complete mitigation of severely degraded or non-existent buffers such as in maintained lawns. The design philosophy of riparian buffer planting is to restore the natural pollutant removal capabilities and stabilizing properties of fully functioning riparian buffers by adapting to site specific conditions such as soil moisture and incorporating those considerations into a three-dimensional plan that prominently features vertical design elements, such as trees, to produce a self-sustaining plant community.

The intensity of this buffer restoration is somewhat higher than simple no-mow zones, but most of the effort and cost is upfront with relatively low maintenance requirements. Degraded riparian buffers can be recognized by maintained lawn space, a lack of herbaceous, shrub, or tree components, exposed soils and erosion, the predominance of invasive plants, and structures and other encroachment, as seen below (Figure 19).

Figure 19: Lack of Riparian Buffer

The planting and enhancement of riparian buffers should target establishing buffers with a width of at least 50'. Even at limited width forested buffers show amazing capacity to remove pollutants; Figure 20 below shows that many of the stated benefits of riparian buffer enhancement can be achieved in as little as 50'. While 50' is a reasonable goal it will not always be achievable due to various site restraints including landowner placed restraints. As with the no-mowing zone as little as 10' of enhanced buffer can be valuable. In such a circumstance many of the benefits associated with planting will be reduced, but will not be eliminated. In particular, focusing on near-bank planting of woody vegetation can serve the roles of bank stabilization and shading almost without diminishment. Even in an area where a full 50' has been selected as a candidate site for enhancement through planting the focus needs to remain on the near-bank areas to affect the greatest change. Additionally, the scope of the planting does not have to be all encompassing. As mentioned above the loss of any component of the riparian buffer, either herbaceous, shrub, or tree, signals a degradation of the buffer, but the missing component can also serve as the focal point of restoration activities. For example, many buffers, particularly in lawns, obviously lack the shrub layer yet the large trees adapted to floodplains are still in place and the herbaceous layer still exists although in a maintained state. In such a case discontinuing mowing and augmenting the existing community with planted shrubs is probably sufficient to set the conditions to allow the regeneration of the buffer.

Figure 20: Forested Buffer Functions Relative to Width



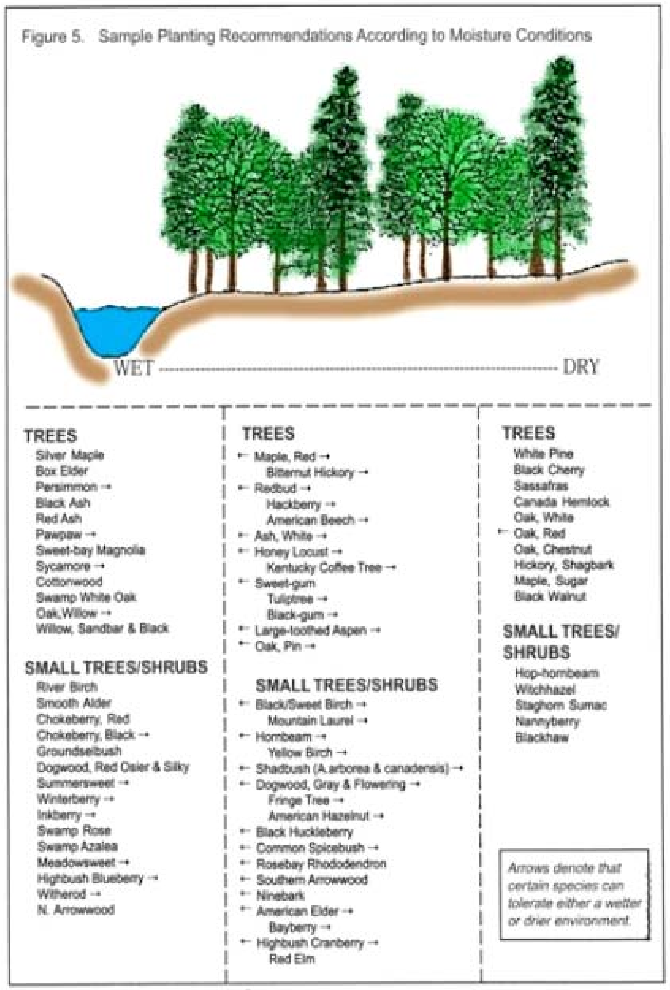
Prior to initiating planting site preparation may be necessary to remove debris and invasive plants. The planting or re-planting of riparian buffer proposed here is designed to restore functionality and work within the confines of a selected site without much earthmoving. More intensive streambank stabilization projects requiring extensive engineering, excavation, and grading that incorporate planting will be discussed elsewhere in this document. For the most part buffer planting should be relatively low intensity and require primarily hand tools to dig holes to insert plants. Coir fiber mats may be installed in areas where there is extensive soil disturbance to help herbaceous vegetation become established, but other materials, like coir fiber logs that are typically installed along the toe of the bank, are not consistently effective in riparian settings and may not persist after several bank full discharge events. The relatively low key planting and removal of vegetation can, for the most part, be conducted without securing permits although consultants and sponsors collaborating on the design and installation need to be cognizant of potential restrictions.

As mentioned above several different plant types are to be utilized in the planting plan. While all plant types should be incorporated together the composition will change when moving away from top of bank such that wetland indicator species or those adapted for periodic inundation will be placed closer to the channel with a gradient shift towards upland species with increasing distance from stream. As such, the idealized planting plan would consist of three zones corresponding roughly to the bank, the floodplain, and the terrace (although sources adopt widely varying naming schemes) with each zone incorporating the three plant types as seen below (Figure 21).

The herbaceous layer is planted to prevent surface erosion and provide much of the stormwater filtering capacity as well as reducing runoff velocity. There are a wide variety of herbaceous plants, particularly grasses that are used in enhancing riparian buffers. The table shown below (Table 19), taken from the NJ Stormwater BMP Manual, lists a variety of these plants as well as some pertinent information regarding natural history and life cycle as well as a variety of seed mixtures suited for different conditions. Paradoxically, some of the species listed are introduced and should probably be avoided in order to create a more natural species composition. Seeding rates vary considerably between mixes from 3 to 35 pounds per acre, but most mixtures require about 15 pounds per acre; in a 50’ buffer this is equal to almost 900 linear feet. It may also be desirable, especially where aesthetics are an important component of the restoration goal, to add wildflower mixes and other herbaceous plants as well as the grasses and groundcovers. Many of these herbaceous plants may be purchased and planted as plugs.

The shrub and small tree component begins to provide much of the bank stability with increased root zone depth, as well as providing shading and wildlife habitat. Finally, the large trees are responsible for creating canopy cover, transpiring water, and adding soil stability. Spacing guidelines vary, but the PA Stormwater BMP Manual recommends a mature tree density of approximately 320 trees per acre. Because the goal is the enhancement of natural systems it is important to plant in a fluid fashion with clustering and other natural features maintained to the exclusion of straight lines and other ordered designs.

Figure 21: Riparian Planting Zones



As with no-mow zones public outreach and education are paramount in encouraging buffer planting projects. While planting plans may require professional guidance, particularly in choosing the correct species or matching the existing vegetation in adjacent undisturbed buffers, replanting buffers is a relatively simple operation. Material needs are largely limited to the actual plants which are available from a number of nurseries in New Jersey and Pennsylvania specializing in native plants and supplying materials for streambank restoration projects. Funding will likely be a limiting factor for much of this work, despite relatively low costs, especially compared to most other BMPs. This is where the municipalities need to develop a cost-sharing program with landowners to provide materials or alternatively offer some other financial incentive. Funding should be available from a variety of sources as long as there is a coherent plan to implement its distribution and completion. It should also be noted that this work may be conducted in a modular fashion so that plants are added to the site or multiple sites over time focusing on the particular site needs and working from the bank outward. Maintenance should be relatively modest for most plantings after the initial planting and watering period and consist mostly of replacement of failed plants that are detected during spring or summer survey events. There may be several causes for failure including herbivory by deer and mice, compromised nursery stock, or selecting the wrong plant for a site, which is usually a function of soil moisture. Herbivory can be easily controlled by utilizing vinyl tree guards or wraps and repellant sprays while plant selection errors can be corrected with the consultation of an environmental professional.

Table 19: Herbaceous Plants

Species	Common Name	Remarks
Agrostis gigantea	Redtop	SP,I,CG
Agrostis palustris	Creeping bentgrass	P,I,CG
Calamagrostis candensis	Canada bluejoint	P,N,CG
Cinna arundinacea	Wood reedgrass	P,N,CG
Dicanthelium clandestinum	Deertongue	P,N,WG
Elymus virginicus VA./riparius	Riparian wildrye	P,N,CG
Lolium multiflorum	Annual ryegrass	A,I,CG
Panicum virgatum	Switchgrass	P,N,WG
Poa trivialis	Rough bluegrass	P,I,CG
Poa palustris	Fowl bluegrass	P,N,CG
Puccinellia distans	Alkali saltgrass	P,N,CG
Tripsacum dactyloides	Eastern gamagrass	P,N,WG

Legend:
P = perennial CG = cool-season grass
A = annual WG = warm-season grass
I = introduced CL = cool-season legume
N = native SP = short-lived perennial

4.3 Cultural BMPs

Cultural BMPs include those actions taken to reduce point and nonpoint source pollutant loading that do not rely primarily on the installation of complex structural or engineered solutions. In the context of this WPP cultural BMPs include those practices primarily adopted by homeowners, but also commercial, municipal, and other similar parties to limit pollutant loading. In general, these types of activities are often simple, easy to implement, and low cost. With widespread adoption within the community these techniques can be very effective and yield large improvements in water quality at low cost. Cultural BMPs were also ranked as the second priority for NPS management measures and incorporate other management measures called out in greater detail such as BMP maintenance and Septic Management which will be discussed in further detail in their respective sections.

Cultural BMPs were identified as important management measures for TP loading and *E. coli* loading and were also auxiliary measures for TSS control, stormwater runoff, and invasive species. The institution of cultural BMPs in this watershed is important because they reflect small changes in behavior that are relatively easy to implement and for the most part require awareness of the benefit of adopting these practices. The following section describes a variety of cultural BMPs that should be adopted in the Alexauken Creek watershed.

4.3.1 Fertilizer Use

Fertilizer use within residential areas is common given the propensity to develop manicured lawns and flowerbeds; the same is true of other landscape uses including parks, athletic fields, cemeteries, and other spaces with maintained lawn space. In addition to being unnecessary in many cases due to sufficient soil nutrient concentrations, the application of fertilizer is often conducted during those periods when rainfall is the heaviest (April through June and September through October). The phosphate and nitrogen salts present in commercial fertilizers are easily transported in runoff during storm events and are easily assimilated by aquatic macrophytes and algae contributing to stream eutrophication and potential nuisance growth.

This reinforces the need for the implementation of integrated pest management (IPM) techniques in upland areas within 300’ of the tributary network. IPM is a common sense approach to the use of fertilizers and pesticides that incorporates technical considerations, and can be easily used at the individual home level to limit the transport of fertilizers and pesticides within the watershed. Unfortunately, a considerable amount of over application of pesticides and fertilizers occurs during the routine care of residential lawns and other lawn areas. Homeowners often operate under the assumption that if “a little is good, more is better”. This leads to the over-application of products and an increased potential for the off-site transport of pesticides and fertilizers. A key element of community IPM entails the limited use of fertilizers and the use of specific types of fertilizers. Specifically, it is highly recommended, given the potential for increasing eutrophication, that the community only use non-phosphorus and slow-release nitrogen lawn fertilizers.

Residents should also be educated about conducting soil pH and nutrient testing before applying fertilizers to their lawn. Fertilizer uptake and retention is promoted by proper soil pH. A detailed survey of homeowners in Virginia commissioned as part of the Chesapeake Bay initiatives, found that less than 20% actually tested their soils to determine whether fertilization was actually necessary (Watershed Protection, 1994). Although soil pH can have a significant bearing on the ability of soils to retain nutrients, such testing is not commonly conducted by homeowners. Thus, the simple application of lime can improve phosphorus uptake and retention. Fertilizer applications must also be properly timed in anticipation of rainfall events. Rain induced fertilizer losses are greatest immediately following an application because the material has neither become adsorbed by the soil nor taken up by the plants. Fertilizer applications must also account for seasonal lawn needs. For example, nutrients are most needed by lawns in the spring and fall, not throughout the summer. Therefore much, if not all of the fertilizers applied to a lawn in the summer go unassimilated.

Residents should also be informed about the benefits of aeration and thatch control, both of which promote a healthy lawn without the need for fertilizers. However, de-thatching and aeration are rarely conducted as part of routine lawn maintenance (Watershed Protection, 1994). Soil aeration is especially important as lawns can become compacted over time and function almost no differently in respect to the generation of runoff than impervious surfaces (Schueler, 1995). Aerating lawns helps promote better infiltration and reduces the generation of runoff and the off-site transport of nutrients and pesticides.

As noted above, an additional means by which to decrease fertilizer and pesticide use and the subsequent transport of these pollutants is through the use of alternative lawn cover. Where appropriate, the use of native plants or plants that have lower irrigation needs than typical suburban lawns needs to be promoted. As part of the ongoing strategy to reduce the influx of lawn related pollutants into Chesapeake Bay, the National Park Service has started to use native ground covers to reduce the need for fertilization and irrigation (NPS News-Notes, 1996).

4.3.2 Yard and Pet Waste

Another localized source of nutrients that is relatively easily controlled is that of pet wastes. In addition to providing an ample source of phosphorus these wastes are unsightly and may cause health concerns due to high fecal coliform bacteria concentrations in runoff coming into contact with waste sources. Reduction of nutrient and pathogen loading may be obtained through the implementation of municipal ordinances and education requiring the retrieval of pet wastes and proper disposal with the residential garbage service. Yard wastes, including grass clippings and leaves, should also be properly managed. Indiscriminate dumping into waterways leads to excessive solids and nutrients loading. Yard waste can be composted onsite to provide eco-friendly mulches, disposed at municipal organic recycling centers, or disposed in trash collection systems subject to provider policy. The beneficial reuse of yard wastes can also reduce the need for chemical fertilizers.

4.3.3 Waterfowl Control

Wastes associated with nuisance waterfowl, primarily Canada Goose, can be a significant nutrient source. Studies have shown a single goose may contribute approximately 0.5 lbs of phosphorus per year to waterbodies. In addition to being a source of nutrient pollution geese are also a potentially significant source of bacterial loading in the Alexauken which is amplified by direct defecation into waterways or the adjacent reaches. While a comprehensive assessment of goose populations throughout the watershed was not conducted reports from the visual assessment indicate that geese and ducks may congregate in nuisance densities at the impoundments. Many of these waterfowl may be so-called residents that have a weak migratory instinct and will stay in place as long as there is ice-free water and available food.

In order to prevent excessive goose populations several approaches may be implemented. One of the most effective approaches, especially in stream settings where aerial access to stream corridors is negated by canopy, is to establish shoreline buffers that inhibit access. These buffers may be as simple as establishing a no-mow zone at the top of bank which also has the added benefits of nutrient removal and bank stabilization. There are also several commercially available deterrent products including Flight Control™ that are non-toxic and effective in applications such as golf courses. Intentional or directed feeding should be strictly inhibited. Finally, there are other techniques including harassment by dogs, which can be effective in a short term capacity or for longer periods if a high frequency is employed. Other control methods such as the use of predator silhouettes including dogs and coyotes seem to have very limited utility.

4.3.4 Road Salt Application

The most commonly used and effective means of keeping road conditions safe under icy and snowy conditions involves the application of sodium chloride (NaCl or salt). This deicing agent is readily available and inexpensive. However, road salt is released into the environment as it runs off impervious surfaces into adjacent soils and nearby waterbodies or percolates into the groundwater. There is no natural removal mechanism for NaCl in fresh surface waters. Additionally, numerous studies have documented that over time residual road salt accumulates in the soils of drainage ditches or in the discharge swales of stormwater catch basins. These salts in turn may leach out into the groundwater over time or during periods of heavy rains. Salt is also released into the environment from other sources the most notable being salt storage piles, salt loading areas, car and truck washing areas, and sites where large amounts of snow is stock piled over the winter. Studies completed by various groups including New York State Department of Transportation, USEPA, Environment Canada, and Minnesota have shown that chloride containing compounds negatively impact soils, vegetation, aquatic biota, water quality (both surface and groundwater), and drinking water supplies in addition to causing corrosion to vehicles, bridges, and other infrastructure.

Though NaCl is inexpensive and efficient in melting and preventing ice and snow accumulation on roads, its impacts to the environment and infrastructure (through corrosion) can be significant. There are alternatives to traditional road salt; however, the alternatives tend to be much more expensive and would cause municipalities to cover additional costs to address modified storage, handling, equipment and spreading operations. Some alternatives appear to be viable options; however, a greater understanding of the extent of the environmental and infrastructure impacts of NaCl alternatives still needs to be investigated.

The primary determinant of environmental impact related to road deicing in streams is elevated conductance values. While measured conductance was within acceptable limits there was some limited elevation in the stream. As population levels continue to rise coupled with increased traffic it is likely that there will be increased demand to apply deicing agents in the future and this issue needs to be addressed to minimize potential impacts to natural resource. Watershed municipalities should adhere to the SBRs or de-icing material storage and develop a plan that incorporates the following elements:

1. Right Material- will depend on the conditions being treated: when pavement temperature is very cold, materials with low working temperature or mixtures of materials may be more appropriate.
2. Right Amount- of materials also depends on conditions, such as the amount of residual chemical on the pavement surface, the expected pavement temperature, and the amount of precipitation expected.
3. Right Place- placement of materials is important in doing the job and not wasting product. This requires the right equipment and trained operators.
4. Right Time- timing is important to minimize waste and maximize effectiveness. If temperature pavement is above freezing, salt may be ineffective and should not be applied.

The incorporation of salt brines within the deicing protocols is recommended in various sources, and has been recommended in workshops sponsored by the NJWSA and implemented by local communities, such as Princeton Township. Studies indicate that less salt is used in the brine format than if municipalities rely on solid forms of salt. Several other items should be noted in deicing application, some examples include: (1) the use of proper equipment like a pavement temperature sensor; (2) an instrument that controls the rate of salt application; (3) storm and weather tracking to provide guidance and assist in making snow and ice control decisions by officials and operators; and (4) taking special precautions near systems such as wetlands and streams, which are sensitive to salt.

4.3.5 Water Conservation

Water conservation practices offer several benefits including the protection of groundwater resources, decreased operational stress on septic systems and other wastewater treatment systems, and decreased potential to generate runoff. Many strategies exist to conserve water. In residential settings the following practices are generally advocated:

- High efficiency plumbing fixtures

- Low flush toilets
- Plumbing maintenance
- Maximizing load size for washing machines, dish washers, and similar appliances
- Utilizing native or drought resistant landscaping
- Altering irrigation practices
- Irrigating with captured water from rain barrels

Changing irrigation practices can yield substantial benefits to reducing water consumption, especially in a rural watershed. Several common sense practices can lead to considerably less consumption:

- Avoid irrigating impervious surfaces
- Limit irrigation to early or late in the day to minimize evaporation
- Assess soil moisture before irrigating, factoring in recent and forthcoming precipitation events
- Utilize drip irrigation systems where applicable
- Utilize low pressure sprinkler systems

These recommendations can be extended beyond residential settings and are useful for institutional holdings such as schools, parks, and municipal buildings, and in agricultural settings as well.

4.3.6 Septic Management

The wastewater management needs within the Alexauken watershed are exclusively met by means of on-lot wastewater treatment systems (septic systems). Data shows that even recently constructed, code-consistent septic systems located within 300’ of a lake or stream generate both nitrogen and phosphorus that can potentially enter the waterbody via shallow groundwater flow paths. This includes all septic systems regardless of age or design that are functioning satisfactorily and show no evidence of failure. As such, all septic systems represent a source of nutrient loading to the stream. Although the existing septic loads are likely small this does not preclude the need for septic management. The following provides recommendations concerning how existing and future septic related nutrient loads to Alexauken Creek can be best minimized and managed by implementing cultural BMPs.

The proper management and maintenance of septic systems is the most feasible and achievable means of minimizing septic-related nutrient loading of existing septic systems and protecting the watershed against future septic failures. Successful septic management involves the integration of public education, product modification, septic system inspection and maintenance, and water conservation practices. Managing the performance of septic systems to decrease nitrogen and phosphorus loading is consistent with the overall source control objectives needed for long-term resource protection.

Regardless of their distance from the tributary network, residents should be educated about the use of various products and practices that they can implemented on an individual scale to reduce nutrient loading and improve septic system performance.

Product modification entails the use of non-phosphorus or low phosphorus wash products that minimize septic-related phosphorus loading to the environment. Today, most wash products contain little if any phosphorus, so it should not be too difficult to select the correct dishwashing liquid, dishwasher soap, laundry detergent, and hand and body soaps to accomplish this. Product modification also applies to the education of homeowners regarding the disposal of paint, solvents, fats and oils, or leftover household chemicals and cleaning products in septic systems. Improperly disposed household chemicals and degreasing agents can cause serious upsets to the biological treatment processes that occur in the septic tank itself and in the soils of the disposal field. Equally important, these products can result in serious groundwater pollution and the contamination of drinking water wells. There are no specific regulations in place pertaining to the discharge of such materials. As such, this needs to be accomplished through public education. Fortunately there are numerous fliers and brochures readily available through the USEPA and other sources including a number of fact sheets available through the National Environmental Services Center (NESC) Small Flows Clearinghouse[10], which specializes in the dissemination of information on the correct maintenance and operation of septic systems. Therefore it is recommended that all residents of the watershed be provided with educational materials dealing with the problems caused by improper discharge of household wastes into their septic systems.

Similarly the community needs to be educated concerning the lack of any benefit associated with enzymes, bacterial inoculants, or other products advertised as septic tank supplements. As demonstrated by the USEPA these products do very little to enhance septic system operation. They also give a false sense of maintenance to the property owner and may actually dissuade them from regularly pumping or inspecting their system. Again, the NESC Small Flows Clearinghouse is a very good source of information on this matter.

Also, residents should be cautioned about the use of garbage disposal units. Excessive or improper use of these devices can increase organic loading and further stress the operation of a septic system by adding to both the sludge and grease layers. Furthermore, once ground up, the disposed solids may exist as fine particulate material that resist settling. This can decrease the operational efficiency of a septic system and accelerate the clogging of the leach field.

Inspections and routine maintenance are usually the two controversial elements of most septic management programs. There is an innate resistance by homeowners to allow periodic inspections or to comply with mandatory pump out schedules. The prevailing thought among most homeowners is, “if it flushes, it’s OK”. However, as demonstrated in studies conducted as part of nationwide septic management studies, routine inspections

[10] http://www.nesc.wvu.edu/wastewater.cfm

help decrease the occurrence of large scale failures by identifying and correcting septic tank and leach field problems before they become serious or magnified. Similarly, routine pump outs decrease the build-up of sludge and grease in the septic tank itself, both of which can be transported into the leach field and create clogging problems. In general, routine inspection and pump out should be viewed as an insurance policy for the long-term proper operation of a septic system and not an imposition on the property rights of a homeowner.

Water conservation is another tool that can be used along with routine pump out and inspection to help protect and increase the operational longevity of septic systems. These measures are intended to reduce hydrologic loading to the leach field. Included in this category are the use of low flush toilets, flow reduction fixtures, and other similar devices designed to reduce water usage. It can also encompass lifestyle habits such as spreading out laundry wash loads over a number of days, shorter showers, and other similar cooperative techniques.

4.3.7 BMP Maintenance

Maintenance of existing stormwater infrastructure is another extremely important cultural BMP and one that is frequently overlooked. Almost all structural BMPs including the various basin types and storm sewer systems require periodic maintenance that is crucial to ensure the continued proper functioning of these systems. Routine maintenance activities are generally not costly, but may be somewhat labor intensive which leads to a lapse in the upkeep of these systems despite regulatory and ordinance requirements as identified in the MS4s and Municipal Stormwater Management Plans.

Maintenance of structural BMPs usually consists of the following basic activities.

Visual Inspection – can be the most efficient method of determining whether a structure or system is functioning as designed and can be used to direct further maintenance or repair as required. Inspectors should be qualified professionals trained in recognizing structural or functional inadequacies of a wide variety of systems. Most BMPs should be inspected annually. BMPs that utilize vegetation as an integral component of their function should be inspected during the growing season.

Vegetation Management – These practices vary according to BMP type and the specification of design and vegetation composition. Many BMP types, such as dry retention basins, recommend periodic mowing, although efforts should be made to maintain grasses at lengths of at least 6” to increase the efficacy of the system. If bare spots develop in groundcover they should be quickly reseeded or have new sod installed to prevent erosion and maintain high transpiration. BMPs that have native landscaping features should try to maintain viable vegetation which may require periodic replanting of diseased or dead vegetation, especially in the first several growing seasons. Invasive species should always be removed upon identification to limit colonization of the site through mechanical or chemical means. While woody vegetation may feature in some

BMP designs it is generally discouraged on engineered berms particularly near the spillway or weir and should be removed to prevent instability caused by roots.

Debris and Litter Removal **–** The accumulation of foreign objects in many BMPs may cause impairments by impeding design flows, clogging outlets, damaging vegetation, and impacting aesthetics. In particular the blockage of outlet structures may lead to serious failures including overtopping and bank instability. Removal of this debris may typically be performed manually, but may require construction machinery.

Mechanical Components **–** Some of the more complex BMPs may consist of pumps, gates, valves, pipes, access ports, and supporting infrastructure such as fences and locks that need to be periodically inspected and maintained to ensure proper function. Performance is generally maintained through periodic operation, removal of debris, and lubrication. More modern stormwater BMPs may include the use of filters, filter fabrics, or other media that require periodic replacement as stated in manufacturer specifications.

Biological Control **–** A variety of organisms can impair the function of BMPs. As mentioned above waterfowl can prove problematic causing nutrient removal BMPs such as basins to act as sources rather than sinks when densities become high, and animals such as Muskrats (*Ondatra zibethicus*) may damage berms. These animals are frequently dealt with by disturbance or trapping. Other biological factors affecting BMP performance are related to unwanted vegetation. Invasives species, as discussed above, are removed mechanically or through the use of herbicides and proactively managed by limiting erosion or depositional features that are easily colonized. Algae blooms are common in many retention basins due to a variety of conditions including enriched nutrient concentrations, shallow depths, and high water temperatures which may foster filamentous algae mats and blue-green algae blooms, which produce cyanotoxins that may be dangerous to wildlife or livestock utilizing the source water. Algae are frequently controlled by the application copper-based algaecides or a variety of Integrated Pest Management (IPM) solutions, which are encouraged in New Jersey, including aeration and destratification systems. Mosquitoes may also be problematic in less naturalized BMP systems and may be controlled through the use of insectivorous fishes, circulation, or chemical and organic larvacides.

Sediment Removal **–** This type of maintenance tends to be expensive, necessary to maintaining design function, logistically complicated, and overlooked. Besides the cost of removing sediment, permitting can be a barrier to the disposal of captured sediment. On large basins the frequency of sediment removal varies but is generally 5 to 15 years, and this time frame may contribute to foregoing necessary sediment removal activities. Nonetheless, removal is important and needs to be done to ensure design efficiency and provide necessary storage capacity for both solids and stormwater. Removal of sediment in retention and detention basins, as well as treatment forebays and swales, requires the use of heavy equipment, on-site dewatering facilities, and a final disposal site.

The problem is even more severe in storm sewer systems. Catch basins in roadways and adjacent to impervious areas generally offer minimal storage capacity that fills quickly with road grit and other materials. At a minimum most catch basins and even larger manufactured treatment devices (MTD) should be inspected on a six to twelve month schedule and cleaned as necessary. The cost, labor, and disposal requirements are typically much lower and most of this sediment removal activity can be accomplished with a vacuum truck. Removal of sediment in this type of system is perhaps more crucial to maintaining function and will improve the capture of solids and increase hydraulic efficiency thereby lowering the instance of roadway flooding.

Street Sweeping – Street sweeping can be an important practice in preventing the in-filling of roadside ditches, catchment basins, and other such infrastructure leading to a loss of hydraulic and treatment efficiency. In particular this practice is valuable at construction or redevelopment sites and may also be used to good effect near agricultural access points or near the intersection of paved and unpaved roads.

Many of the issues discussed above are addressed in technical regulations, ordinance, easements, and memoranda of understanding that outline fiduciary responsibilities including budgeting and labor. The MS4 requirements neatly handle the identification of responsible parties for maintaining storm sewers on public roadways and public spaces. However, these types of requirements are not universal, especially when related to new private development or older complexes. In fact instituting the practice of identifying responsible parties for the required maintenance of structural BMPs is itself a BMP and one that must be followed diligently to maintain functionality of BMPs and to limit nonpoint source pollutant loading to the Alexauken.

4.3.8 Rain Barrels

Impervious coverage in the Alexauken watershed is relatively limited but still contributes to increased hydraulic loading of the tributary network. During storm events the runoff produced is generally of a higher velocity and shorter duration that what would be observed in a forested setting. This allows greater erosion of surrounding soils and therefore higher nutrient and sediment loading. One management option that would help mitigate the negative effects of increased impervious areas is the use of rain barrels.

The installation of rain barrels that intercept rainfall from roof surfaces via the downspouts reduces the overall higher flows that result from increased runoff velocities from these impervious surfaces. Essentially, these barrels capture rainfall that would otherwise serve as a transport vector for nutrients and sediments (Figure 22). In addition, the water contained within rain barrels serves as a water source for uses such as residential irrigation of gardens and lawns helping to conserve water resources. Costs for rain barrels are entirely based on initial material expenditure with little in the way of upkeep. Rain barrels may be converted from recycled food barrels or purchased from many environmental retailers, in many different styles which match a home’s exterior, and pre-fitted with spouts.

Figure 22: Rain Barrels

4.4 Structural BMPs

Structural BMPs have also been determined to be a potentially important component of NPS load reduction strategies in the Alexauken Creek watershed. The utility of widespread implementation of structural BMPs throughout the watershed is unlikely because of the general lack of the development density or development types that are usually associated with most traditional structural BMPs. Additionally, the lack of public holdings, especially developed lands, will also limit implementation in the watershed. However, the construction or installation of structural BMPs will be useful in targeting specific problem areas in the watershed where lower intensity solutions such as cultural BMPs or riparian buffer enhancement do not offer the level of treatment or mitigation necessary to achieve water quality protection goals. The construction of structural BMPs is of course integral to new development designs and required by a variety of regulatory vehicles from municipal ordinance to State law and technical regulations. The following section represents a review of a variety these structures and their potential use in the watershed. Table 20 shown below reviews a wide variety of structural BMPs in relation to hydrologic and pollutant treatment capabilities. Discussions of their applicability and efficacy will be reviewed below. It should be noted that site conditions will often be the primary determinant in the success or failure of a given BMP. Additionally, it is possible to link a number of BMP together to function in concert, thus creating a pollutant removal "train" that achieves a greater cumulative improvement in water quality, management of peak flow, and reduction in total runoff than could be achieved with a single BMP.

Table 20: NPS Management Measures

Best Management Practice Screening Matrix (EPA 2005).	Hydrologic Factor				Pollutant Factor				
Structural Management Practice	**Interception**	**Infiltration**	**Evaporation**	**Reduced Peak Flow**	**Total Suspended Solids**	**Nutrients**	**Fecal Coliform Bacteria**	**Metals**	**Temperature**
Bioretention	●	ɵ	ɵ	ɵ	●	●	●	●	●
Conventional dry detention	○	○	ɵ	●	○	○	●	ɵ	ɵ
Extended dry detention	○	○	ɵ	●	ɵ	ɵ	●	ɵ	○
Grass swale	ɵ	ɵ	○	○	ɵ	○	○	●	ɵ
Green roof	●	○	●	ɵ	○	○	○	○	●
Infiltration trench	○	●	○	ɵ	●	●	●	●	●
Parking lot underground storage	ɵ	ɵ	○	●	●	●	ɵ	●	●
Permeable pavement	ɵ	ɵ	ɵ	ɵ	ɵ	○	ɵ	○	ɵ
Sand filter	○	○	○	○	●	●	ɵ	●	●
Stormwater wetland	●	○	ɵ	●	●	●	●	●	ɵ
Water quality swale	ɵ	ɵ	ɵ	ɵ	●	●	○	●	●
Wet pond	○	○	●	●	●	●	●	●	○
Table key: ○ Poor, Low or No Influence, ɵ Moderate Influence, ● Good, High Influence [11]									

4.4.1 Detention Basins and Wet Ponds

Conventional dry detention, extended detention, and wet ponds are relatively similar systems, differentiated mainly by hydraulic retention period and thereby offering

[11] The recommendations in Table 20 were based primarily on the following references: USEPA National Management Measures to Control Nonpoint Source Pollution from Urban Areas, NJDEP Stormwater BMP Manual, NYDEC Stormwater Manual on Structural BMPs, and the Connecticut Stormwater Manual.

different NPS load treatment efficiency. All of these systems are designed to capture runoff from developed areas and attenuate peak discharge volumes up to the design storm limit. Conventional dry detention systems typically discharge all intercepted runoff in less than 24 hours and provide insufficient solids removal below minimum State requirements. Extended detention basins have a similar function but detain water for a minimum of 24 hours and may offer solids removal rates of 40 to 60% dependent on design; treatment efficacy increases with hydraulic retention period. Wet ponds offer both stormwater detention and a limited amount of permanent storage and may offer 50 to 90% solids removal capabilities.

These systems, while attenuating peak flows, offer very little volume reduction with no infiltration capacity and limited evaporation. Other components of the design also limit other aspects of NPS control. Conventional and extended detention basins continue to be constructed with concrete low flow channels, as illustrated in this detention basin located in the watershed in Figure 23, which do a poor job of treating first-flush stormwater runoff, which typically contains the highest levels of solids, nutrients, metals, and other pollutants. Extended detention and wet ponds could also raise water temperatures contributing to summer stream warming.

Figure 23: Detention Basin

This type of structural BMP still has utility, especially in larger catchments, but is reflective of an older design philosophy less concerned with treatment and volume reduction and primarily focused on peak flow attenuation. For new development it is recommended that these systems be replaced with other structural BMPs such as bioretention systems, stormwater wetlands, and infiltration designs that utilize wetland vegetation and other components to increase evapotranspiration, improve filtering and solids removal capacity, and reduce volumes. These newer systems also offer increased aesthetic and habitat value as well as less maintenance demand related to mowing after initial planting. For existing detention basins and wet ponds several retrofits options should be considered. The first option is to retrofit outlets and control structures to add detention time, particularly during the first-flush, thus effectively converting conventional detention basins to extended detention basins or further to wet ponds; this type of retrofit will be discussed further in this section. The second option is to convert existing systems to infiltration systems where soils allow or stormwater wetlands and bioretention features otherwise; the benefits and design standards of these systems including conversions will be discussed in the following section.

Figure 24: Outlet Modification

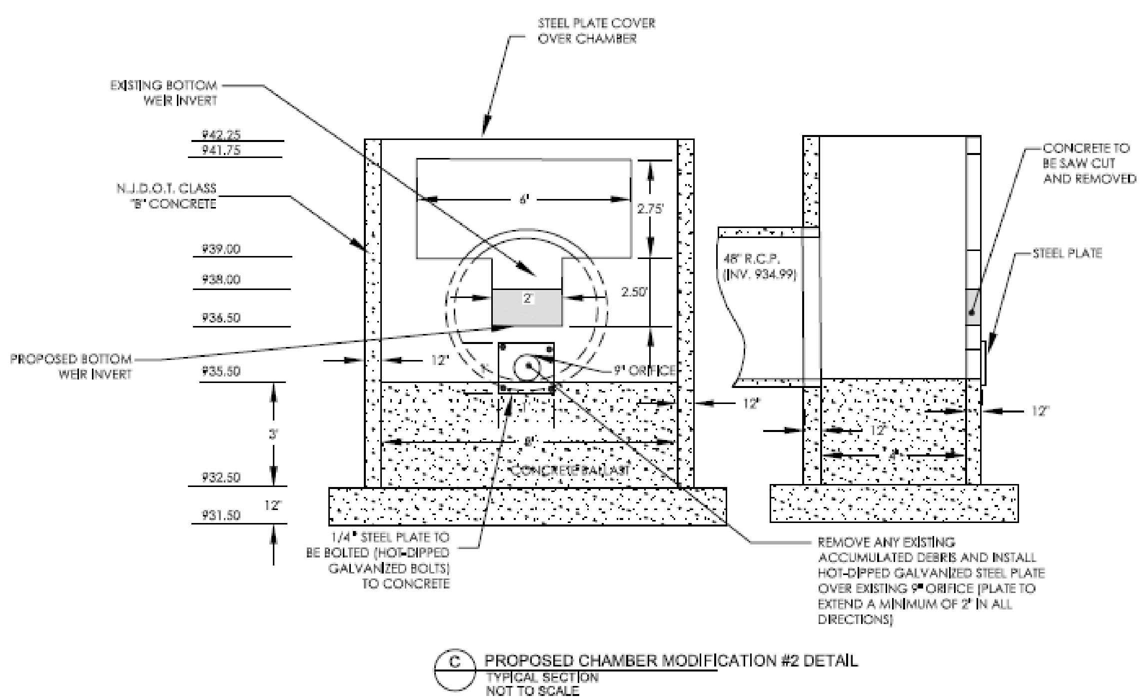


Figure 24 shown above is a conceptual detail for retrofitting a detention basin outlet structure. This type of retrofit proposes two simple modifications entailing the blockage of the low flow orifice and raising the weir invert. This accomplishes two important functions: first, by blocking the low flow outlet the first-flush and runoff from low intensity storm events is allowed to be treated by increasing detention period and retaining directed runoff instead of simply discharging through the structure; second, the raising of the weir invert increases detention during moderate and large storm events allowing increased capture of stormwater pollutants. This is all accomplished without serious engineering or installation effort and furthermore does not impact the ability of the basin to handle design storm volumes or increase the risk of overtopping.

4.4.2 Bioretention Systems

There are a variety of bioretention systems designs that go by numerous names including bioretention basin, constructed wetland, stormwater wetland, shallow marsh, and newer systems such as rain gardens and green roofs. In all cases these systems rely heavily on plant material, specifically wetlands plants and plants adapted to alternating inundation and dry cycles. Specific benefits of utilizing plants, especially native species, in stormwater management designs include:

- Runoff volume reduction related to increased plant evapotranspiration
- Potential increases in infiltration due to increased permeability related to root growth
- Bioassimilation of nutrients and other pollutants in plant tissue
- Decreased erosion within the BMP due to adequate groundcover
- Increased trapping of solids and bacteria related to mechanical filtering of the vegetation
- Decreased warming due to additional shading

Secondary benefits include:

- Decreased maintenance related to mowing
- Improved aesthetic value, especially with the use of wildflowers
- Enhanced wildlife habitat
- High vegetation should limit site utilization by geese

While the effort to construct new bioretention BMPs is similar to that for traditional designs with some increased cost due to the purchase of plant materials overall permitting, engineering, and construction are virtually the same, however the NPS management benefits are significantly increased as many bioretention systems are capable of removing 80 to 90% of solids. The increased pollutant capture capability may reduce the overall complexity and cost of these systems as pre-treatment or linking BMPs may not be necessary to meet stormwater management rules. The retrofitting of existing systems to be upgraded to bioretention systems may be considerably easier and consist of little more than selecting appropriate vegetation and planting. This is ably demonstrated when comparing the following figures (25 and 26).

Figure 25: Extended Detention Basin

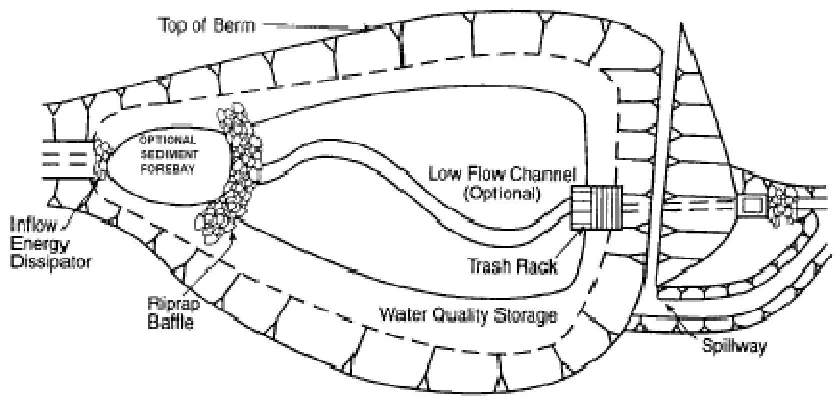
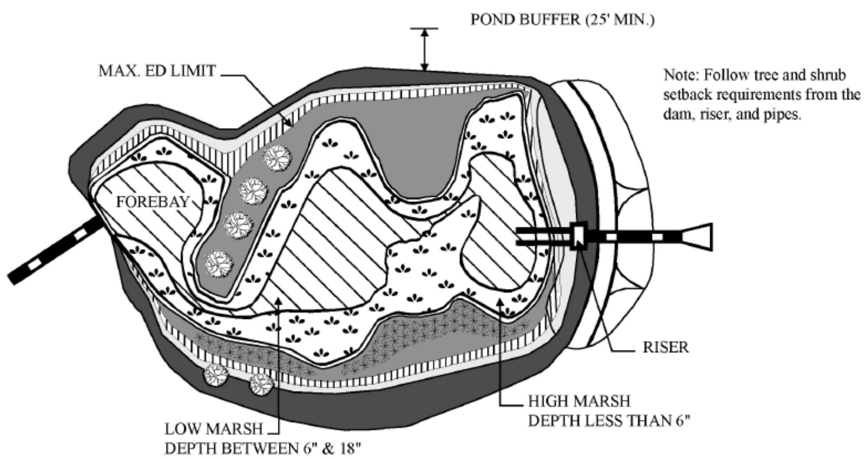


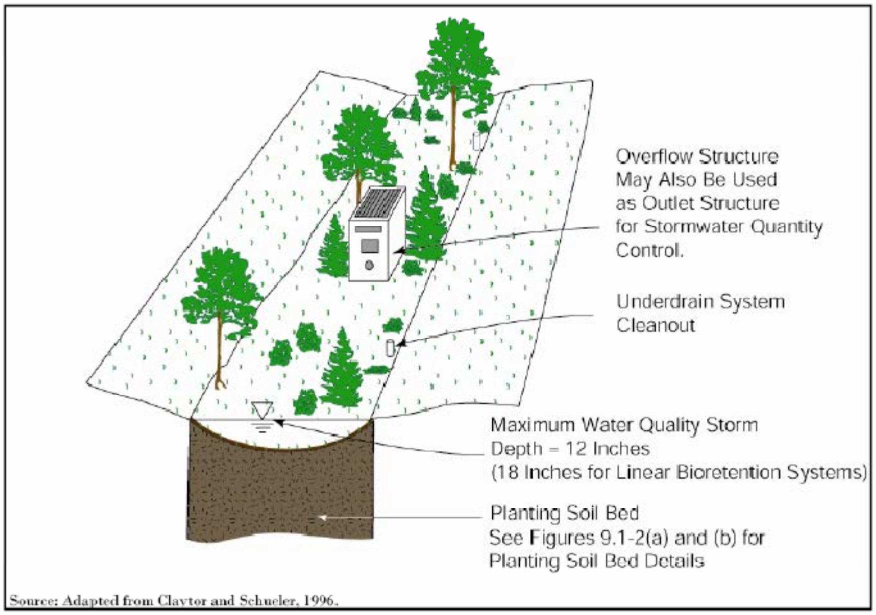
Figure 26: Constructed Stormwater Wetland



For the most part these systems share many of the same components including engineered berms, control structures, sediment forebays, general basin morphometry, and storage capacity. The primary difference lies in the utilization of plant materials, and secondarily in extending the linear flow path or increasing sinuosity. The extended detention basin has no specific vegetative component other than a non-native groundcover requiring mowing, while the stormwater wetland has high and low marsh communities composed of wetland plants as well as trees. The small difference, as mentioned above, provides a great array of benefits to a standard design. The image provided below is an example of a retrofitted detention basin, which is nearly indistinguishable from a natural wetland (Figure 27).

Figure 27: Constructed Stormwater Wetland

Figure 28: Constructed Stormwater Wetland Schematic



Typical bioretention systems may be relatively complex systems requiring extensive engineering design and construction as shown above (Figure 28). The efficacy of many systems depends strongly on the design of the planting bed. The planting bed material is a specific composition of soils components, largely sands, and amended as necessary with organic material. This overlays additional permeable layers consisting of sand, gravel underdrains, and in some designs may include geotextiles and other drainage features. These types of designs and retrofits should be strongly considered for any new development and encouraged from the initial design.

On smaller scale settings additional bioretention systems should be considered. In most residential settings or commercial properties with a "campus" layout rain gardens should be considered. Their function is almost identical to larger systems and differs chiefly in scale. Water directed towards rain gardens may be derived from roof runoff or small parking lots. A schematic design is shown in the figure below (Figure 29) taken from the Portland BMP manual, as well as an image from a rain garden installed at the DRBC campus in Trenton, New Jersey (Figure 30).

Figure 29: Rain Garden Schematic

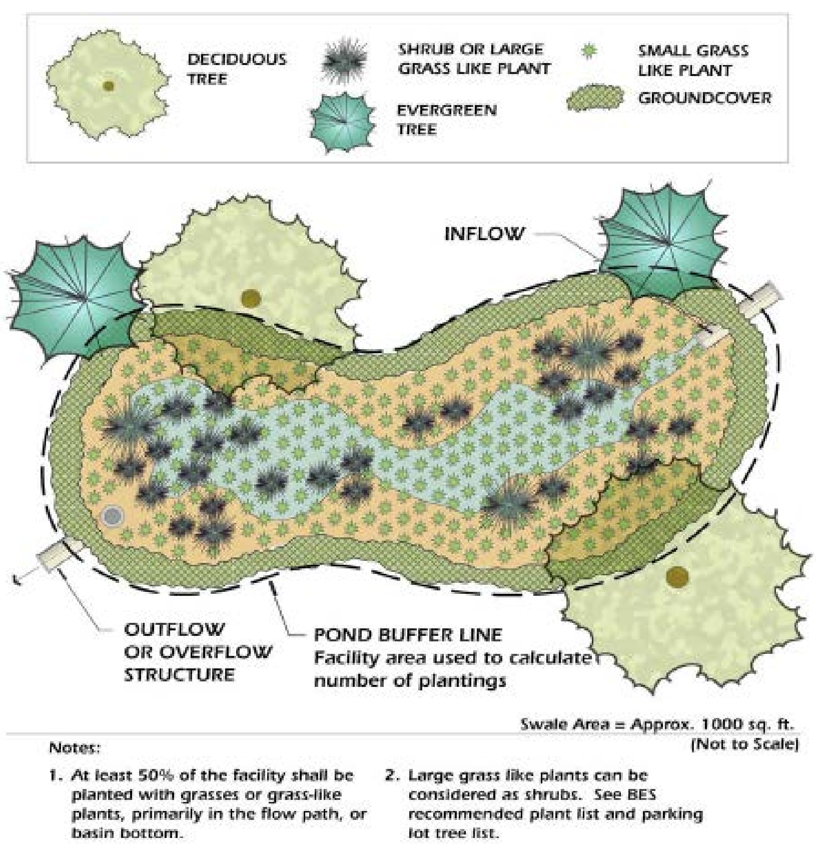


Figure 30: DRBC Rain Garden

4.4.3 Infiltration Systems

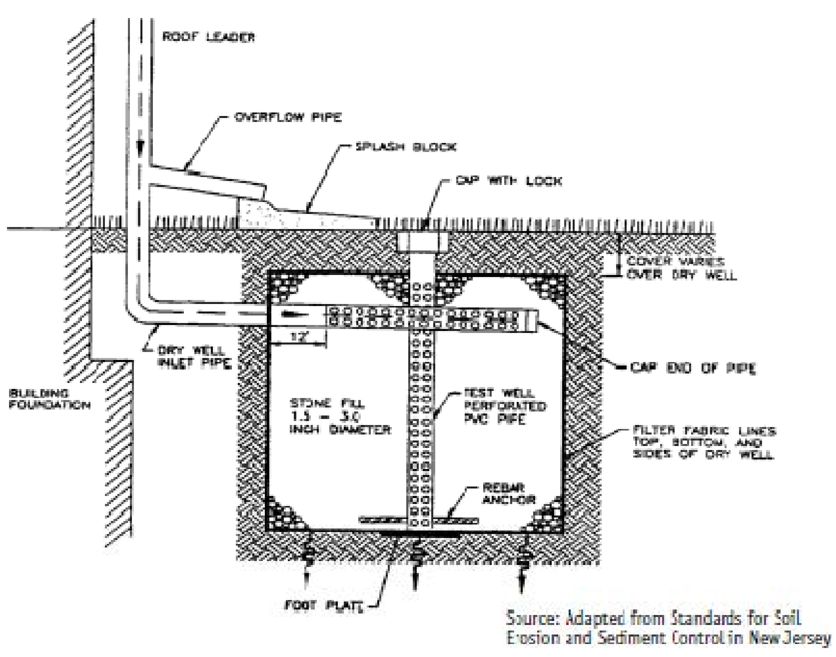
Infiltration BMPs should also be strongly considered for use in the Alexauken watershed. Infiltration BMPs, including infiltration basins, infiltration trenches, permeable pavement, dry wells, and sand filter, offer a variety of benefits:

- High treatment efficacy for the removal of solids and other NPS pollutants
- Reduction of stormwater volume quantity and discharge rate
- Groundwater recharge
- Reduced stream warming

The reduction of stormwater quantity is especially attractive in the Alexauken because stormwater loading is a major problem contributing to excessive erosion, sedimentation, and bank instability throughout the watershed. Additionally, the C1 status of the stream limits the discharge of stormwater to the stream and the ability to infiltrate through the soil limits the need for direct surficial discharge. However, the utility and practicality of implementing larger infiltration BMPs may be limited in the watershed. Siting limitations are a major concern as infiltration basins cannot receive water with potentially hazardous components such petroleum hydrocarbons, metals, pesticides, or where the potential for the release or spill of any toxic materials may occur, which largely rules them out for use in industrial or commercial settings. Similarly, care must be taken near potable water supplies or where a potential exists for the flooding of basements or other structures. Design standards state that infiltration systems must be constructed at least two feet above seasonal high water tables or above bedrock to ensure proper drainage. Identifying these types of sites may be difficult in the watershed. Much of sedimentary geology in the watershed is overlain by relatively shallow soils and much of the diabase intrusion has very shallow high water tables and poor percolation. For this reason adoption of infiltration technologies will be strictly limited by site conditions which need to be fully evaluated during early planning stages. However, lower intensity infiltration technologies, such as dry wells and permeable pavement that treat discrete areas, may find wider applicability and should be encouraged in residential settings and for new development.

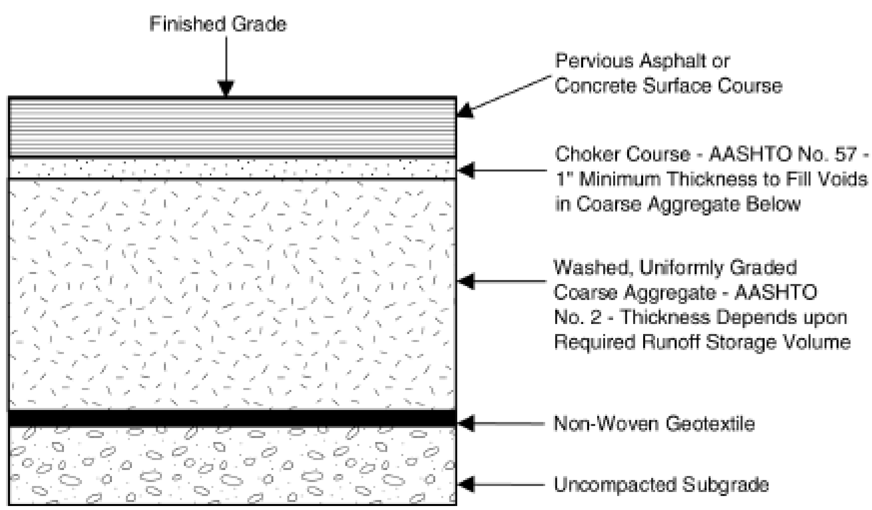
Dry wells are bound by the same site restrictions as other infiltration BMPs but generally treat clean water from roofs where the major concern is controlling volume. The NJ Stormwater BMP manual recommends complete infiltration of the design storm in a 72 hour period and a maximum catchment of 1 acre. Dry wells are an environmentally friendly BMP that should be encouraged for residential uses in the watershed (Figure 31).

Figure 31: Dry Well Detail



Permeable pavement or pervious paving systems are BMPs primarily designed to reduce the quantity of runoff generated from traditionally paved areas such as roadways and parking lots, but may also be applied on a smaller scale to areas such as patios or walkways. The primary mechanism of these systems relies on infiltrating captured water, but systems with storage beds also have the capability to capture solids with an adopted TSS removal rate of 80%. There are generally three types of systems: porous pavement, permeable pavers with storage beds, and permeable pavers without storage beds. Porous pavement describes porous asphalt and pervious concrete over a storage bed. Permeable pavers describes different individual, usually pervious pavers that can be concrete, brick, cobble, crushed aggregate, natural stone, or unit pavers that infiltrate through the void spaces or at the joints of the pavers. These systems may or may not have subsurface storage, but those without have a reduced capability to infiltrate larger storm events and may still generate runoff though at a reduced rate. Pavers can also be turf block designs that incorporate load bearing surfaces and permeable soil plant with grasses to provide additional infiltration, solids removal, and evapotranspiration. The images below show details for permeable pavement and installed turf blocks (Figures 32 and 33).

Figure 32: Permeable Pavement Detail



Maintenance requirements vary between the systems, but can be relatively intense. Permeable pavement in particular requires routine maintenance with seasonal sweeping and high pressure washing to remove captured solids and maintain open pore spaces. In paver systems the burden is reduced but those with integrated vegetation require care of the plant materials. Snowplowing, which is a concern in the Alexauken, must be conducted with care in paver systems to avoid displacement of the pavers. As with other infiltration devices site soil conditions can be a primary determinant of their applicability and they cannot be located where there is a chance of hazardous materials release that could contaminate the groundwater.

Figure 33: Turf Blocks

Traditional infiltration basins may also be considered for the Alexauken. Besides the capacity to treat stormwater runoff and pollutant loads infiltration basins are valuable for their ability to limit stream warming by directly discharging to shallow groundwater through soil media and preventing the discharge of warm, impounded stormwater to streams. For the most part the design of large infiltration basins are similar to dry detention basins with the exception that the bottom of the basin is a permeable sand layer that allows the infiltration of stormwater directed to the basin.

The sand filter incorporates some of the design elements of the other infiltration systems and relies primarily on the percolation of directed stormwater through a large sand bed to filter out a variety of pollutants including solids, nutrients, coliform bacteria, but ultimately differ by the subsequent discharge of at least a portion of the filtered runoff inflow through an underdrain. These systems are designed to receive runoff from highly impervious areas with a high degree pollutant loading. Because the sand bed must maintain high percolation rates to properly function these systems are typically built with forebays to effectively capture much of the large debris and solids prior to discharging to the sand bed. As a consequence maintenance demands can be relatively high based on the frequent clearing of the forebay. This system probably has limited utility in the watershed.

4.4.4 Water Quality Swales

Water quality swales come in a variety of designs and configurations and may be called by a variety of names including grass swale, vegetated swale, vegetated filter, dry swale, wet swale, and water quality swale. These designs, like the bioretention BMPs, utilize vegetation adapted for frequent inundation to provide a variety of pollutant removal services as well as to reduce runoff velocities. One of the primary differences is that these systems are designed for the conveyance of water and detention period or stored volume is generally limited.

The simplest design is the grassed swale, which is simply a grass lined swale constructed in maintained lawn space. Because the grass is typically mowed in this design, the amount of treatment in this system is quite limited and is generally valuable only for pre-treatment to other BMPs and in limiting erosion. A vegetated swale, sometimes referred to as a dry swale, has a similar channel morphometry, generally trapezoidal with modest slopes, but is planted with a variety of native plants including trees to provide mechanical filtration and maintain channel stability. These systems may also incorporate very small check dams within the channel to reduce velocities and provide short term detention. Figure 34 illustrates a conceptual design of a vegetated swale and a location within the Alexauken watershed where such a design may be implemented (Figure 35). Wet swales are similar to dry swales but also incorporate small permanent pools and function more closely to a series of linked wetland cells.

Figure 34: Vegetated Swale Detail

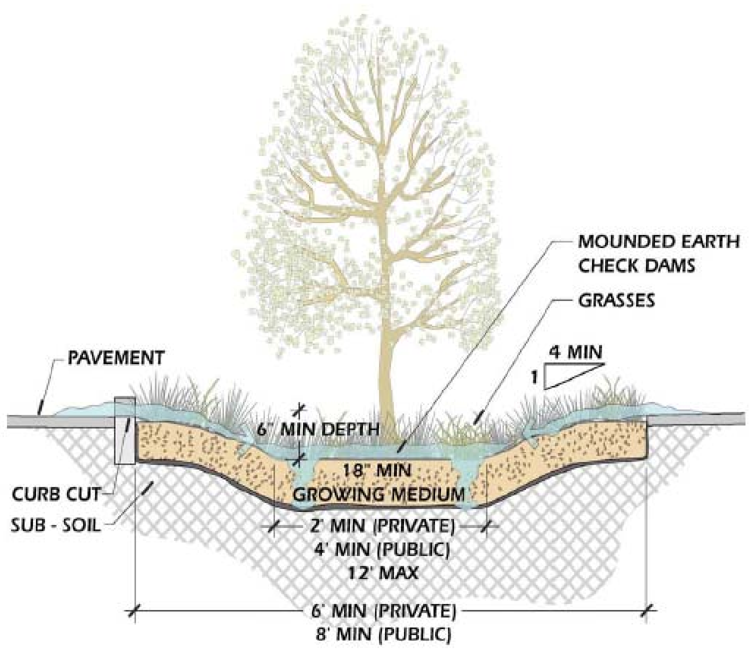


Figure 35: Vegetated Swale Candidate Site

Vegetative filters are related to swale features but are designed to treat sheet flow and not concentrated flow in a channel. As such they are oriented perpendicular to the flow path and parallel to elevation contours on a slope, generally less than 5% grade. In some senses vegetative filters mimic the function of riparian buffers and native forests. The figure below (Figure 36) illustrates the schematic of a vegetative filter while Figure 37 shows a candidate site.

Figure 36: Vegetative Filter Schematic

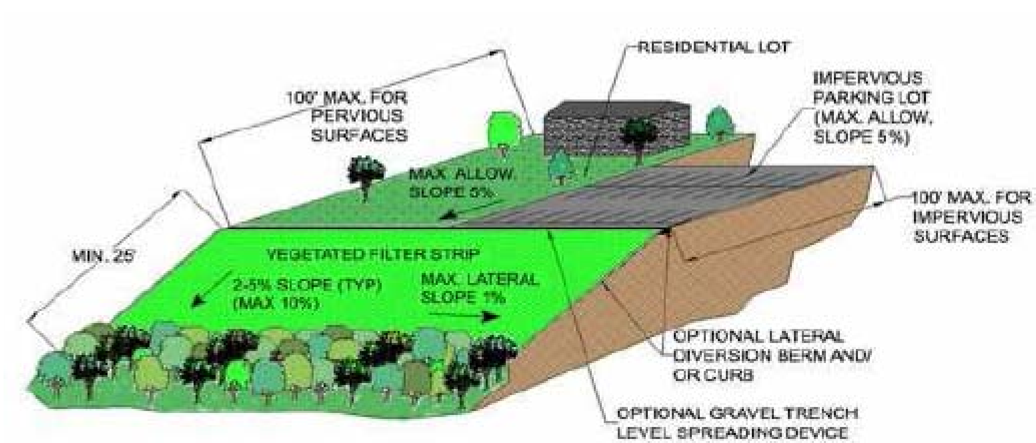


Figure 37: Vegetative Filter Candidate Site

Incorporating these design elements is important for minimizing erosional processes in new developments. Additionally, they can be used to treat drainage issues on developed lands.

4.4.5 Manufactured Treatment Devices

Manufactured treatment devices (MTDs) are pre-fabricated structural BMPs designed to mitigate stormwater pollutant loading with most offering solids and nutrient capture and some are also effective for the removal of metals, bacteria, debris, and hydrocarbons. These devices are generally used to treat small catchments that are usually highly impervious and may contribute disproportionately to pollutant loading or are installed where there is limited space to site traditional BMPs and where other site limitations such as soil permeability may exist. MTDs utilize a variety of methods to achieve pollutant removal including:

- Filtration Chambers
- Filtration or Adsorptive Media
- Vortex Flows
- Vegetative Components
- Settling Chambers

In New Jersey these types of systems are certified by the New Jersey Corporation for Advanced Technology (NJCAT) for solids removal rates, although other pollutants may also be certified concurrently. Currently, only two devices have final certification, while all others have an interim certification subject to continued performance reviews (Table 21). Adopted removal rates are certified at either 50% or 80%, although many offer higher performance than indicated. These certifications may be important in meeting stormwater management quality rules.

Table 21: NJCAT MTDs

Stormwater MTD	Manufacturer	NJDEP Adopted TSS Removal Rate (%)
AquaFilter Filtration Chamber	AquaShield, Inc.	80
Aqua-Swirl Concentrator	Aqua-Shield. Inc.	50
Bayfilter	BaySaver Technologies, Inc.	80
BaySeparator	BaySaver Technologies, Inc.	50
Downstream Defender	Hydro International, Inc.	50
FloGard Dual-Vortex Hydrodynamic Separator	CONTECH Stormwater Solutions, Inc.	50
High Efficiency Continuous Deflective Separator (CDS) Unit	CONTECH Stormwater Solutions, Inc.	50
Jellyfish Filter	Imbrium Systems Corporation	80
Media Filtration Systems	CONTECH Stormwater Solutions, Inc.	80
Stormceptor OSR	Imbrium Systems Corporation	50
Stormceptor STC	Imbrium Systems Corporation	50
StormVault*	CONTECH Stormwater Solutions, Inc.	80
Stormwater Management StormFilter*	CONTECH Stormwater Solutions, Inc.	80
TerreKleen Stormwater Device	Terre Hill Concrete Products	50
V2B1	Environment 21, LLC	50
High Efficiency Continuous Deflective Separator (CDS) Unit	CONTECH Stormwater Solutions, Inc	50
VortFilter System	CONTECH Stormwater Solutions, Inc.	80
VortSentry System	CONTECH Stormwater Solutions, Inc.	50

* - Final Certification

MTDs may have limited use in the Alexauken Creek watershed due mostly to the lack of road and other stormwater management infrastructure. However, MTDs may be useful along some of the roadways where catch basins and other stormsewer components discharge to the tributary network, and thus would be used mostly in a retrofit capacity to add improved treatment capability to existing systems. Maintenance is key to these systems, particularly those that utilize filter media or where excessive road grit and other solids may be captured. The maintenance of these types of systems would certainly be classified as cultural BMP, as discussed above, and could consist of, dependent on design, replacing cartridges or vacuuming.

It should also be noted that there are a number of additional, highly effective MTDs that do not have NJCAT certification. These MTDs should not be discounted for use in the Alexauken Creek watershed. Some of these structures, for example the Suntree Technologies Baffle Box and Modular Wetlands are very effective and can be used in both a retrofit and stand alone capacity. The importance of using NJCAT certified technologies has more to do with NJDEP permit compliance or qualification for NJDEP funding as opposed to treatment efficiency. As such, this criterion alone should not be used to evaluate the applicability of an MTD.

4.5 Manure Management

Manure management may be rightly considered an agricultural BMP but the elevation of fecal coliform in the Alexauken and subsequent impact on contact recreational use of the stream and potential human health effects demands that this management measure be discussed more prominently. Manure management was identified as the primary management solution to control coliform bacteria loading in the watershed based on the results of the volunteer visual assessment, specifically the storage and application of manure adjacent to the tributary network, as well as the results of water quality monitoring. The need to address proper manure management is an important initiative in terms of avoiding negative impacts on water quality due to the agricultural character of the community. Because the use of manure helps the farmer re-use animal waste and fertilize the soil, it is important that its management be outlined in an agreeable manner that does not jeopardize farm production or stream health.

Manure solids are composted with materials such as leaves and grass clippings, to produce soil nutrient supplements high in organic content. Because manure contains both animal waste products and decaying vegetation, improper management can threaten water quality in terms of fecal and nutrient contamination. Proper manure management is important because it prevents these pollutants from migrating to surface and ground waters. Application of manure to the land at the proper time, using proper management techniques, and in proper amounts recycles the nutrients through the soil, reducing the expense of commercial inorganic fertilizers as well as the need to add organic matter. Proper application of manure can improve soil quality, fertility, and water-holding capacity.

Since large, commercial farms are regulated by Right to Farm, the manure management initiative proposed as part of this WPP would only affect small farms in the watershed. Because small farms are vital to preserving the agricultural character of the watershed and essential in providing services to the community, manure management is recommended as a voluntary measure so as not to financially burden these small scale operations. It is strongly recommended that small farms, that have the financial resources, comply with the NJ Dept of Agriculture (NJDA) Animal Waste Rules (draft). It is encouraged that farmers conform to additional measures that are not required but are highly recommended by NJDA, such as fencing along waterbodies.

(http://www.state.nj.us/agriculture/divisions/anr/agriassist/animalwaste.html).

The five general requirements of the NJDA Animal Waste Rules are:

1. No agricultural animal operation shall allow animals in confined areas to have uncontrolled access to waters of the State
2. Manure storage areas shall be located at least 100 linear feet from waters of the State
3. The land application of animal waste shall be performed in accordance with the principles of the NJDA BMP Manual
4. No dead animals and related animal waste resulting from a reportable contagious disease or an act of bio-terrorism shall be disposed of without first contacting the State Veterinarian
5. Any person entering a farm to conduct official business related to these rules shall follow bio-security protocol (NJDA 2009)

Various farming BMP practices to minimize discharges of pathogens, nutrients, and pesticides are highlighted in publications funded by the USDA-NRCS in fact sheets provided at the website: http://www.sera17.ext.vt.edu/SERA_17_Publications.htm. This supplementary information could be distributed to farmers as education and outreach materials and used as a resource for drafting farm conservation management plans.

Filter strips are one of the methods described in the NJ Agricultural BMP Manual as an effective, low cost manner to manage and reduce manure related water quality impacts. Vegetated filter strips were previously discussed in Section 4.4.4. These BMPs are recognized as one of the most effective methods of reducing excessive bacteria loading. Manure storage through field stacking can be an important method for reducing loading when weather and antecedent soil conditions precludes routine handling. Indeed, some studies have shown that storage is probably the most effective method in controlling bacterial loading although this method may do little to control nutrient loading related to manure.

The strategies discussed above are relatively inexpensive to implement. Other manure management solutions, such as the construction of combined waste facilities, while offering high treatment efficacy may be cost prohibitive for most smaller farmers in the area. As with many other management measures, community outreach will be important in implementing these changes to affect positive water quality in the watershed. It should also be mentioned that while manure management guidance from the State and other sources tend to concentrate on cattle operations, horse farms, including non-commercial operations, also need to be strongly considered in the overall manure management goals in this plan, which is chiefly to reduce the bacterial loading and nutrient loading in the watershed.

4.6 Invasive Species Management

Invasive species have been shown to be a major problem in the Alexauken, as they are throughout the Mid-Atlantic region and much of the country. Some of this is the result misguided efforts to combat soil erosion promoted by the then Soil Conservation Service to plant invasive species such as Multiflora Rose. Others species are escapees from landscaping projects and others uses and many continue to be sold at commercial nurseries. *Phragmites*, one of the most common invaders of riparian and wetland habitats, is believed to be hybridized cultivar of a native plant. In any case, the riparian corridors throughout the watershed are infested with invasive plants. The main problems associated with invasive species is that they crowd out native plants and provide far fewer ecological services and as such provide poor habitat, poor forage, alter natural carbon cycling, and nutrient uptake (Figure 38).

Figure 38: *Phragmites*

There are many methods for managing invasive plant species, but few are as effective as chemical treatments, especially in large monocultures. This is in part related to the growth form and life cycle of many of these plants as well as the lack of natural herbivores or plant pests and the high effort required for mechanical removal. There are several major concerns with the use of pesticides in natural settings namely toxicity to non-target organisms and contamination of ground and surface waters and soils. While these are valid concerns public perception exceeds the actual risks. The most common chemicals used to treat most problematic species in wetland settings, such as *Phragmites*, Purple Loosestrife, Bamboo, Lesser Celandine, and even Multiflora Rose, are glyphosate and secondarily imazapyr. Both of these chemicals specifically target metabolic processes unique to plants and thus have very low toxicity to non-target organisms such as fish and mammals, tend to bond to soil particles thus reducing groundwater contamination, and generally breakdown in the environment quickly when exposed to sunlight and other conditions. Additionally, regulatory controls from the Federal and State level on the purchase and application of these chemicals is quite high.

The use of glyphosate, sold under the brand names Rodeo™ and AquaPro™, is probably the most appropriate product for use in this watershed to control most of the common invasives colonizing the riparian corridor. Dependent on proximity to open water and whether an area is deemed a wetland an Aquatic Pesticide Permit will need to be issued by the NJDEP Pesticide Control Program prior to treatment and the application made by a licensed pesticide applicator with the appropriate certifications. Landowners can also make limited applications with commercially available products as long as the restrictions printed on the container label are followed. Treatments can be highly targeted and range from broadcast sprays to backpack spraying and even hand wiping to limit non-target mortality. The highly targeted treatment methods can be especially effective in limiting recolonization of planted sites as part of routine maintenance.

Once large scale monocultures have been chemically treated mechanical removal becomes much more tenable. Mechanical control techniques include physical removal, girdling, tilling and excavation, and repeated mowing. These methods, once again, may be important in maintaining sites after buffer enhancement planting or other site transformation. The important component of maintaining sites is maintaining control to prevent vegetative colonization through the spread of rhizomes or seeding.

4.7 Bed and Bank Stabilization

Bed and bank stabilization is the keystone of most current stream restoration projects. These projects usually revolve around the maintenance of bed and bank stability, prevention of erosion, limiting excessive or accelerated sedimentation, restoring floodplain connectivity, improving fish passage, maintaining natural hydraulic and hydrologic conditions, and protecting at-risk infrastructure. The opportunity to affect all these changes is available in the Alexauken Creek. Two caveats must be kept in mind when considering the implementation of bed and bank stabilization projects: first, the Alexauken watershed is composed primarily of highly erodible soils and along steeper slopes the formation of gullies and other erosional features is natural; second, much of the erosion identified in volunteer visual assessment occurred in forested areas where access to the stream channel is severely limited and efforts to improve the access for heavy equipment could offset the environmental benefit of accessing these areas. The focus of bed and bank stabilization implementation should therefore focus on areas where accessibility is relatively high and where erosion is a clear result of anthropogenic causes, such as the removal of all riparian vegetation or other buffer encroachments. The following section will discuss some of the varied streambank stabilization projects that are applicable in the watershed.

Table 22 below shows most of the major stabilization methods currently employed (utilizing commonly accepted terminology), as well as their primary function, best uses, and implementation complexity. These various methods will be discussed below as separate functional groups.

Table 22: Bed and Bank Stabilization Measures

Method	Primary Functions	Best Use	Implementation Complexity
Bank Grading	Floodplain Connection, Bank Stabilization	Long Runs, Bends	Moderate
Bendway Weir	Flow Deflection	Outer Bend	High
Boulder Placement	Flow Deflection	Habitat Creation	Low
Boulder Toe	Toe Protection	Outer Bend	Moderate
Brush Mattress	Bank Stabilization	Inner and Outer Bend, Habitat Creation	Low
Cross Vane	Grade Control, Flow Alignment	Prevent Head Cuts, Habitat Creation	High
Engineered Rock Riffle	Grade Control, Flow Alignment	Prevent Head Cuts, Habitat Creation	High
Gabion Baskets	Toe and Bank Protection	Limited Space	High
J-Hook Vane	Flow Deflection	Outer Bend, Habitat Creation	High
Live Fascines	Bank Stabilization	Inner and Outer Bend, Habitat Creation	Low
Longitudinal Peaked Stone Toe Protection	Toe Protection	Long Runs, Outer Bend	Moderate
Riprap	Toe and Bank Protection	Outer Bend, Long Runs	Moderate
Rock Vane	Flow Deflection	Outside Bend	High
Rootwad Revetment	Toe Protection	Outer Bend, Habitat Creation	Moderate
Step Pool	Grade Control, Flow Alignment	Prevent Head Cuts, Limited Space	High
Vegetation Planting	Bank Stabilization	Inner and Outer Bend, Habitat Creation	Low

4.7.1 Bank Stabilization

A variety of methods are used to stabilize streambanks ranging from fairly simple projects such as planting to more complex methods such as grading and eventually the placement of gabions and riprap (discussed under toe protection strategies). The choice of method depends on a variety of factors including site hydraulics, stream order, erosion severity, channel incision, floodplain connectivity, and proximity to structures.

Most modern stream stabilization and restoration projects rely heavily on a vegetative component. As with riparian buffer enhancement vegetation serves a variety functions the most important of which is the stabilization of the bank through the rooting of both herbaceous and woody vegetation. While some projects may begin and end with bank plantings where hydraulics permit and erosion is relatively mild almost all other projects, especially those involving grading and excavation, utilize bank plantings as the final component of the project. A more complete accounting of bank planting is specified in Section 4.2.2, but trees that feature prominently in local bank plantings include Black

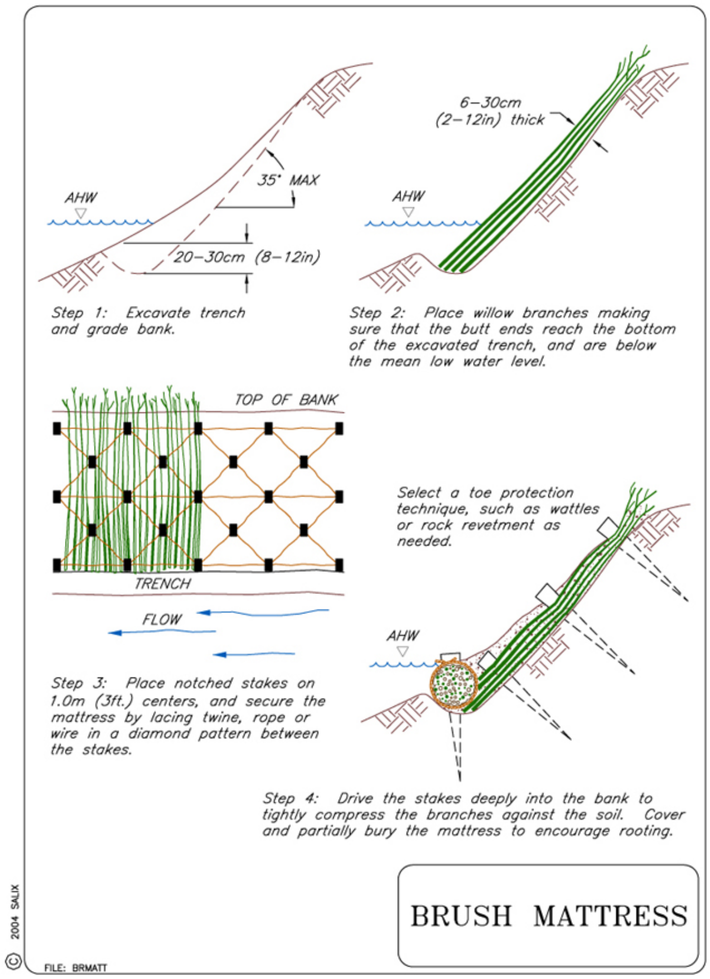
Willow (*Salix nigra*), Box Elder (*Acer negundo*), Green Ash (*Fraxinus pennsylvanica*), and River Birch (*Betula nigra*). Candidate sites for simple planting would include those with mild erosion and a lack of riparian vegetation (Figure 39).

Figure 39: Planting Candidate Site

There are also more highly engineered approaches to vegetative planting, including the use of brush mattresses and live fascines as well as vegetated riprap designs. Brush mattresses, live fascines, and vegetated riprap solutions usually follow more extensive work, particularly bank grading, but take advantage of willows and potentially Red-Osier Dogwood (*Cornus sericea*) to stabilize banks and to reduce velocity and bank shear stress. Brush mattresses are simply willow or dogwood cuttings placed perpendicular to the channel lining the bank and anchored in place with stakes and ropes. The roots are placed in a trench below the normal water line and the toe protected with wattles or riprap (Figure 40).

Live fascines serve a similar purpose but are bundles of willow cuttings 6 to 12 inches in diameter stacked parallel up the face of the bank. They also promote the growth of willows along the banks but may serve an additional purpose as bank armoring materials until normal growth and colonization occurs. Riprap may also be placed over fascines with a reorientation of the bundles or live stakes may be inserted in the voids in the riprap. Gabions can be treated similarly but generally use a larger tree as opposed to the cuttings described above.

Figure 40: Brush Mattress Detail



Bank grading is also useful for stabilizing banks especially when paired with plantings and toe protections, and is often seen on outside bends or along long eroded runs. More complex bank grading including major excavation in channels that are extremely incised may be performed to create a new floodplain. More generally though, bank grading is used to reduce the hydraulic angle of incidence thus decreasing erosive forces along the outside bend, allowing excessive flows to reach the floodplain, and providing stable substrate for planting using brush mattresses and fascines, or armoring with riprap which significantly increases the roughness coefficient. The slope of the grade varies with the desired outcome, but a 3:1 slope is often desired for most planting exercises or other bioengineering. A grading or slope flattening detail is provided below (Figure 41) and would be the preferred stabilization method for the site depicted in Figure 42.

Figure 41: Bank Grading Detail

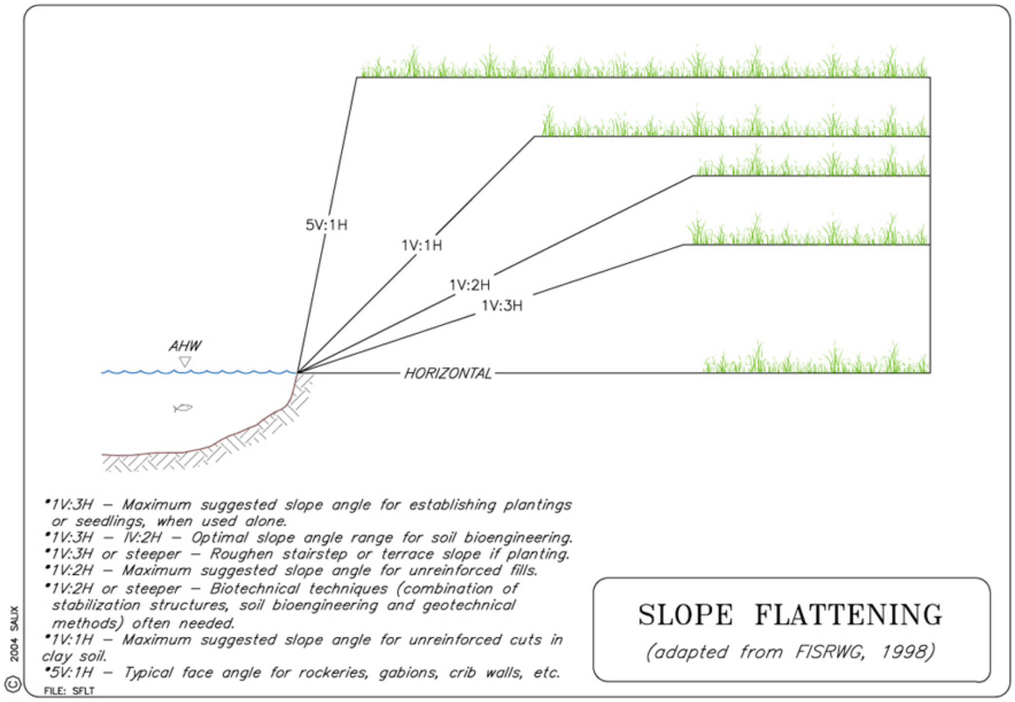


Figure 42: Bank Grading Candidate Site

The practical implementation of these types of bank stabilization measures is generally low to moderate. Flood Hazard Area Rules may require at least general permits for some of these activities, and engineering consultation will probably be required for at least grading activities.

4.7.2 Toe Protection

Toe protection measures serve a slightly different purpose than the bank stabilization measures discussed above and are designed primarily to absorb hydraulic forces and sheer stresses that cause excessive erosion, mass wasting, and endanger nearby infrastructure. More specifically, these measures involve the placement of heavy materials, usually stone, along the toe of the bank, sometimes extending up the bank, to limit erosive effects. These types of strategies may be considered bank armoring, a practice that is gradually losing favor in stabilization projects because these types of systems can be unattractive, may be subject to failure or "overkill" (excessively engineered), and are largely artificial. However, the limitations of many project sites, including the required protection of structures and roadways or a simple lack of space to implement preferred design elements means that these protective measures are still important for bank and bed stabilization projects. Indeed, the judicious use of toe protections is absolutely critical to the success of many projects.

One of the best toe protection measures involves the use rootwads or rootwad revetments (Figure 43). The rootwad describes the lower portion of a tree; a trunk with limbs removed but the major portion of the root ball retained. These are usually placed in the toe of the bank on an outside bend with the trunk angled slightly back and keyed in deeply to the bank so that the anterior section of the root ball is flush with the bank, seated on a footer log, and oriented perpendicular to the main flow vector. The rootwad is then able to absorb most of the hydraulic impact to decrease erosion, but unlike some of the other toe protection measures serves other functions in the stream. The roots themselves can significantly increase local roughness in the stream thus slowing flow velocities. These rootwads are also fantastic fishery habitat and offer refugia from predation and flow, provide ambush points for predators, and foster abundant forage as the organic roots become well colonized by benthic macroinvertebrates.

Rootwads have several additional benefits to consider. Availability of the raw material tends to be high as they can be collected from construction sites where large trees have been removed or even onsite at restoration projects as some trees may have fallen into the river due to excessive or erosion or are removed during grading processes. Additionally, larger materials are generally more efficacious and implementation is limited only by the size of rootwad available as there are anecdotes of redwoods being utilized in Pacific coast projects.

Figure 43: Rootwad Placement

Boulder toe protection designs function similarly to rootwad to provide bank stability and prevent erosion along outside bends utilizing large boulders instead of trees. In addition to protecting the toe of the bank the boulders may be stacked as necessary to provide additional armoring higher up the bank. Design specifications are generally mutable but the resistive boulders should be placed to achieve approximately 50% embedment. Bank grading and the placement of fill material behind the boulders is usually encouraged. The material behind the boulders is usually planted with woody vegetation. A boulder toe design is shown below (Figure 44).

The placement of riprap and gabion baskets are among the most familiar bank stabilization and bank protection measures. Riprap is coarse rock, relatively well graded (non-uniform or well distributed) and angular placed along outside bends or longer runs where erosion has been noted. Most designs feature a trench or other retaining feature at the toe of the bank to help maintain the rock in place. Grading is usually extensive in these projects as a uniform surface and grade is required to maintain the rock in place with a final slope of 1:1 or 2:1. Geotextiles or other bedding materials may be necessary to ensure proper drainage and seating of the riprap, which must be carefully sized to handle hydraulic conditions during stormflow events to maintain bank stability. Newer designs may incorporate vegetation planted either in the void spaces between the riprap or planted in amended fill materials on the face of the riprap, the rock serving as an underlying layer. This type of approach is now considered somewhat excessive and unnecessary unless there is a need to absolutely lock the channel and bank in place.

Figure 44: Boulder Toe Protection

Gabions are large wire cages filled with coarse rock, similar to the material used in riprap applications. Gabions have several advantages over riprap related to the cages which provide increased structural integrity and thus allow smaller rock to function as a single unit or be placed where larger rock would be required in a riprap placement. For this reason gabion baskets can be used in much steeper applications, and may be placed almost vertically without concern for the angle of repose (the angular limit at which loose materials can be stacked), which is an important consideration where space is a defining limitation. There are several other gabion designs including gabion mattresses, which are much shallower than baskets with a larger footprint and gabion sacks which is mesh sack filled with rock. Both of these designs must be placed on flatter slopes than baskets. Gabions are almost always filled in place which aids greatly in their installation. As mentioned above gabions may be vegetated as discussed above and shown in Figure 45 below. The successive image (Figure 46) identifies a location in the Alexauken where gabion baskets may be required to withstand high shear forces eroding the bank in order to protect the road situated at the top of bank.

Figure 45: Vegetated Gabion Detail

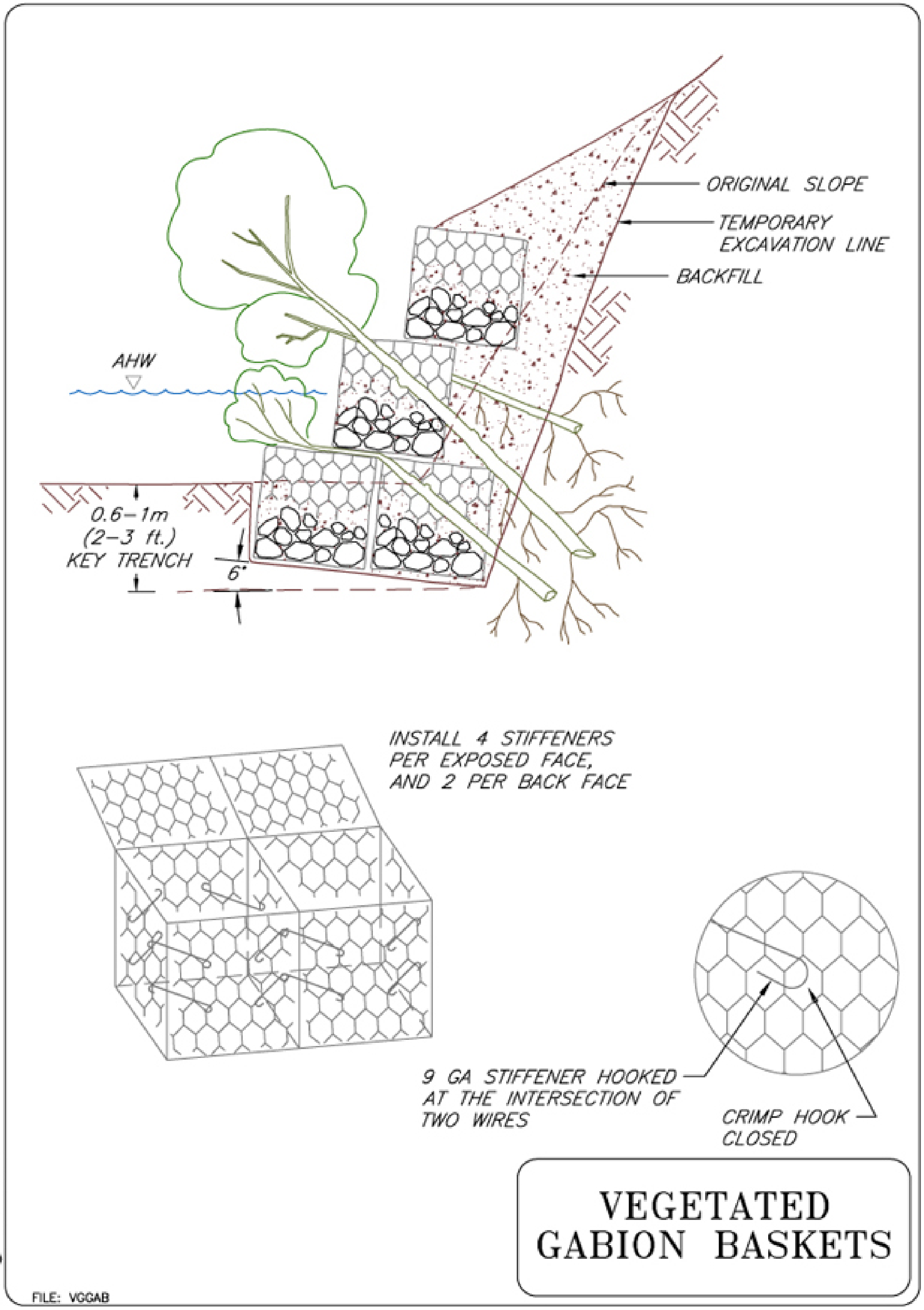


Figure 46: Potential Gabion Placement

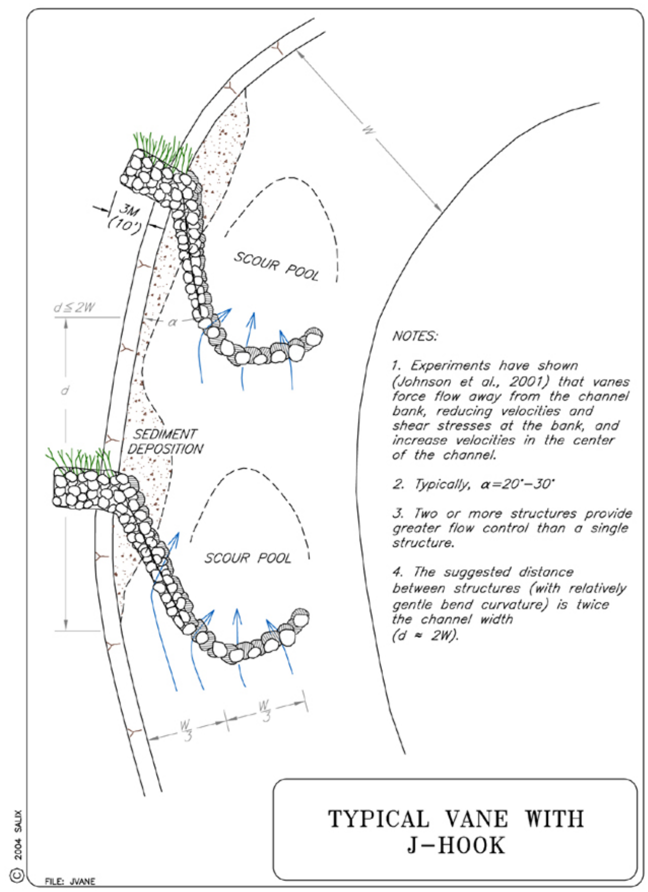
4.7.3 Flow Deflection

Another series of structural bank stabilization methods includes the use of flow deflection devices. Unlike toe and bank protection measures which are designed to absorb the impact of accelerated flows to prevent erosion flow deflection devices alter the hydraulics of the system and divert the majority of the discharge away from the bank and towards the center of the channel. Another major difference of this type of device is that they extend into the channel from the bank. A variety of flow deflection devices are currently utilized including bendway weirs, J-hook vanes, rock vanes, and rock spurs, but most are simple variations on a similar design.

Rock spurs are the simplest flow deflection devices, but utilize the same design strategies to limit erosion. At their simplest rock spurs are merely rock piles abutting the bank and extending into the channel. The primary function is to reduce near bank velocity, shift the thalweg towards the center of the channel, and minimize the potential for erosion.

J-hooks and rock vanes or vane arms are more highly engineered designs that are longer linear features that extend from the bank upstream at approximately 20 to 30° off the stream bank with a gentle slope down the face of the vane. The main difference between the designs is that the J-hook has a curve at the end contributing to a scour pool and habitat creation (Figure 47), a feature missing in normal vane arms. Placement is critical to these devices and a common design flaw is not locating the vane far enough upstream. This is exhibited in the detail below which should probably have shifted the placement slightly upstream to initiate flow realignment sooner. The second common mistake is that too few features are installed to adequately maintain the desired flow path including at the egress of the curve. Finally, the third error is a tendency to expand the angle such that the main arm is installed at a 45° angle or larger. This type of installation minimizes the velocity gradient across the face of the vane thus decreasing the potential to redirect flow. However, good designs are proven to be effective at limiting erosion and show even higher efficacy when paired with other bank stabilization methods. As with other complex designs, good engineering is the key to the success of these solutions.

Figure 47: J-Hook Detail



The image below (Figure 48) would likely be a good site in the Alexauken watershed to implement a flow deflection solution. Such a design would deflect the heaviest flows away from the bank, and a J-hook design would provide scour to minimize sediment deposition and provide some larger and hydraulically more complex features in the stream bed.

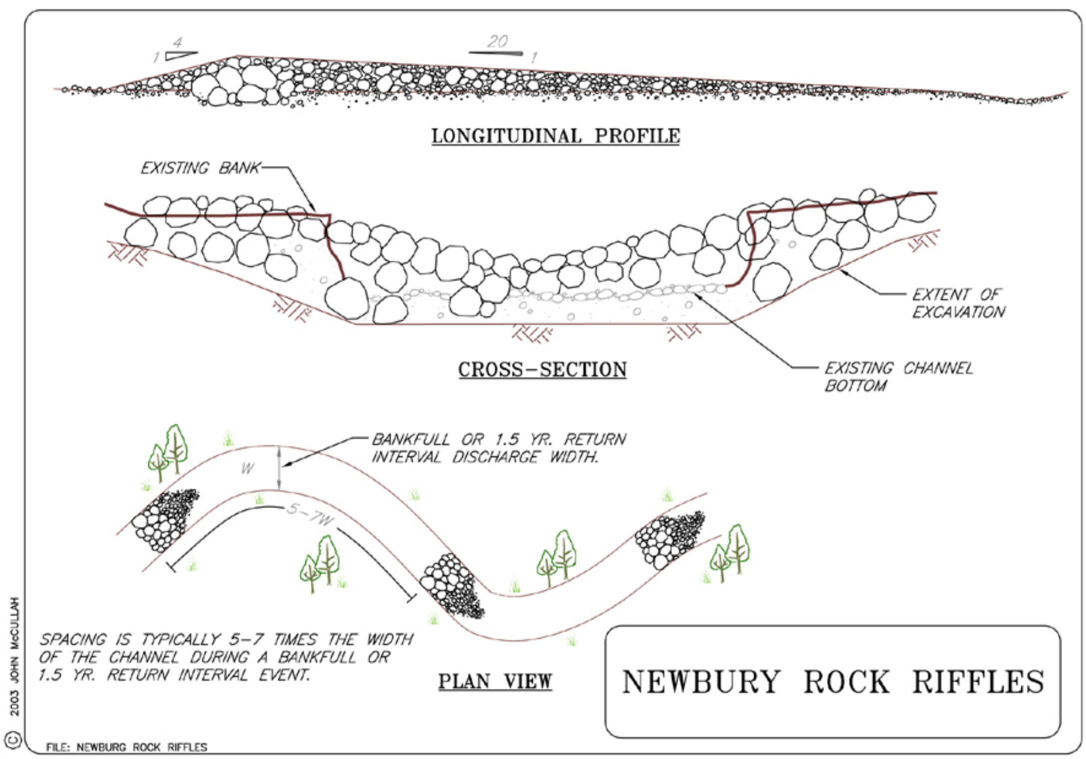
Figure 48: Flow Deflection Candidate Site

4.7.4 Grade Control

In-stream grade control is also another important component of bed and bank stabilization. While erosion is mostly thought of as a problem with the banks channel incision includes both horizontal (bank) and vertical (bed) erosion. The erosion of bed materials results in entrenchment or a hydraulic disconnect of the channel with the floodplain. Since the stream no longer is able to flood the adjacent plain all the flow is forced through the incised channel resulting in even greater erosion. Under these conditions a typical type of erosional process that develops is the head cut, an erosional feature in the bed that migrates upstream. Grade controls therefore mitigate these processes and include several structures such as engineered rock riffles, step pools, and cross vanes or V-weirs. Other grade controls used historically such as dams will not be discussed here as they exacerbate erosion/sedimentation processes and represent other risks such as stream warming, altered hydraulics, and fish passage barriers. Grade control measures are also frequently used when stream channels have been extensively reshaped or when impoundments have been removed to prevent the formation of head cuts and to align flows in the center of the channel. Another use of grade control structures is to elevate the entire channel of severely incised streams to restore floodplain connectivity.

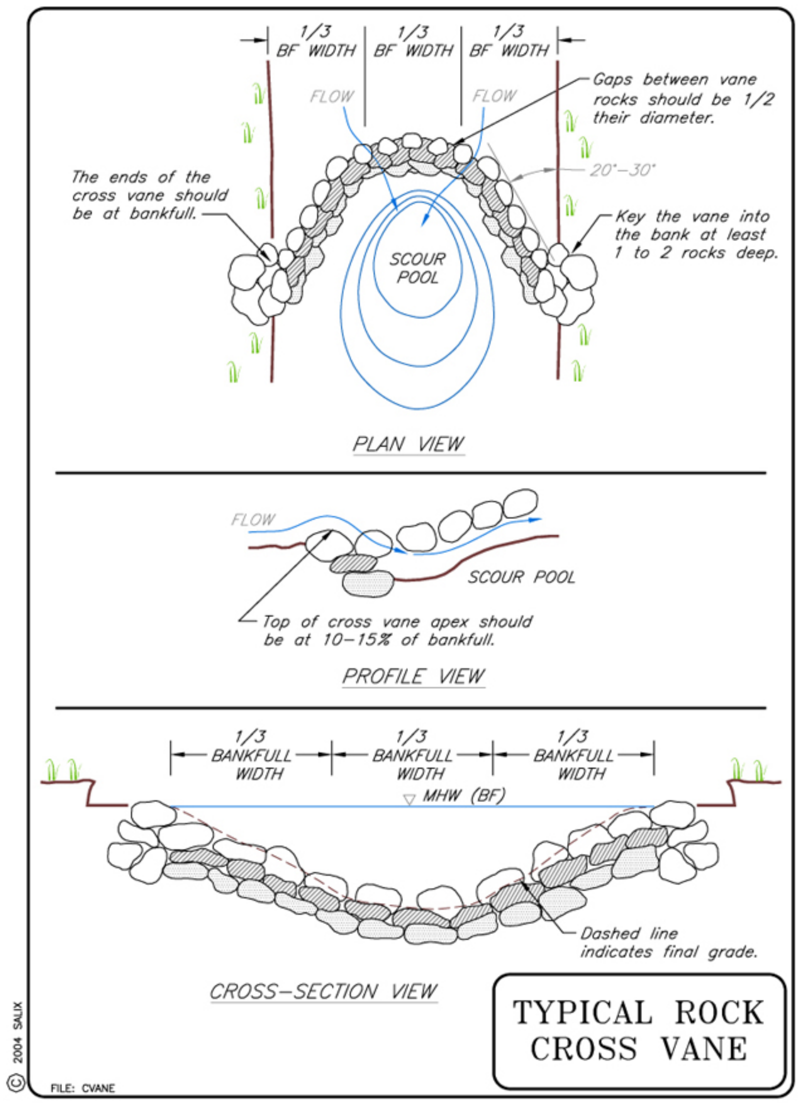
Engineered rock riffles replicate naturally occurring riffles in streams (Figure 49). Besides providing grade control and preventing erosion rock riffles are also important habitat features. Riffles are generally characterized by high grades relative to other stream segments and coarse sediments or substrate. This combination of factors introduces turbulent streamflow through these areas which creates highly oxygenated water. High DO levels and coarse substrates are critical to maintaining healthy macroinvertebrate populations in streams, particularly the EPT taxa discussed above in Section 2.3.13, which are among the primary macroinvertebrate indicator groups of stream health.

Figure 49: Engineered Rock Riffle Detail



The cross vane or V-weir is similar to rock vane designs described in the previous section but extend completely across the stream and when seen in plan view look like a normal rock vane connected to a J-hook vane (Figure 50). Their function is of course grade control but also the alignment of flow in a channel. Like other vane designs they work by lowering flow velocity along the bank, but also structurally shape channel morphology. Cross vanes have the added benefit of limiting downstream sediment deposition and creating a scour feature at the toe of the vane. Combined these features can help improve DO concentrations, limit bed and bank erosion, and provide habitat complexity.

Figure 50: Cross Vane Detail



The removal of the stream obstruction located in the watershed (Figure 51) would certainly require a grade control structure post-removal, likely a cross vane. In this setting a cross vane would stabilize any head cut, connect the hydraulic jump above and below the obstruction, and align flow through the center of the channel.

Figure 51: Grade Control Candidate Site

A final grade control measure is the step pool. Step pools are similar to cross vanes, but linked in series and utilized in higher gradient streams. While the angularity of the vane would be reduced other details remain essentially unchanged. An important design feature that must be accounted for in this type of design is the relative difference between pool elevations. These must be maintained at an acceptable height to allow fish passage; this height would vary based on targeted species. Step pools may also be used to realign water in tight, steep bends where the use of flow deflection techniques such as J-hooks would be impractical because of space limitations.

4.8 Open Space Preservation

Open space preservation is an important component of this WPP and the continued thrust of watershed municipalities to preserve open spaces must be maintained to preserve natural resources, mitigate development related impacts to stream water quality, and improve the ecologic function of the watershed. Open space preservation works through several means to protect the integrity of the watershed. Primarily, it preserves natural features that have important ecologic and hydrologic functions, including species diversity, habitat, pollution mitigation, groundwater recharge, and stream baseflow. Second, it limits further development which is intrinsically tied to water quality and other ecological impairments. Third, it benefits the public by providing recreational opportunities and preserving the rural character of the watershed.

Much of the open space preservation in the watershed is related to the Farmland Preservation program, conservation easements and other deed restrictions, and Green Acres holdings. Other preservation classes include municipal, county, and state holdings and utility easements. These types of holdings, particularly Farmland Preservation, Green Acres, and deed restrictions on private lands should continue to be pursued as is outlined in the West Amwell Township Open Space Plan and other planning documents. While a sizable portion of the watershed is currently preserved or has regulatory protections related to classification as wetlands or flood hazard zones, the build out analysis based on the cross acceptance plan indicate that over 29% of the watershed is considered developable under existing zoning ordinances. Much of the potential development would consist of the conversion of agricultural lands to residential development. As mentioned above, many of the existing ordinances, township policies, and technical regulations provide a measure of protection, but a more explicit set of goals is useful to direct preservation activities. Continued open space preservation in the watershed should focus on:

- Open space acquisition through existing programs and models
- Low impact development
- Protection of natural resources
- Preservation of rare or at-risk plant communities, ecosystems, and wildlife
- Adoption and upgrade of BMPs during development and redevelopment
- Preservation of agricultural land elements
- Promotion of agriculture and landowner friendly initiatives
- Habitat connectivity through the implementation of greenways initiatives

Implementation of these types of programs is of course dependent on funding sources and public outreach to foster participation. Many programs, agencies, and policies have been created to aid in the preservation of open spaces including the following:

- NJ Department of Agriculture Farmland Preservation Program
- NJDEP Green Acres Program
- Hunterdon County Soil Conservation District
- Natural Resources Conservation Service (NRCS)
- Conservation Reserve Enhancement Program (CREP)
- Conservation Reserve Program (CRP)
- Environmental Quality Incentives Program (EQIP)
- Farm and Ranch Land Protection Program (FRPP)
- Grassland Reserve Program (GRP)

- Wetlands Reserve Program (WRP)
- Wildlife Habitat Incentives Program (WHIP)
- D&R Greenway Land Trust
- River Friendly Farms Certification Program (North Jersey RC&D)

All of these programs and additional opportunities should be investigated to ensure additional protection of open spaces in the watershed.

4.9 Agricultural BMPs

Agricultural BMPs have a long history in this country and were originally implemented to promote soil conservation, increase yields, conserve water, and decrease fertilizer use, while newer strategies have focused more strongly on preserving natural resources, promoting wildlife, and mitigating NPS pollution impacts while maintaining the original design goals of increased farm yields. In the Alexauken watershed agriculture is an important economic driver and one of the dominant land uses, yet most of the farms are relatively small and focus on the production of row crops (corn, soy beans, grains) and hay, small dairy and beef operations, and horses. As such, none of the problems associated with large industrial farms or confined feed lot operations are evident in the watershed and thus lower intensity solutions are recommended. For the most part, many of the recommendations for agricultural BMPs are already utilized in the watershed, but more uniform adoption is recommended. Many of the incentive programs listed above are tailor made for agricultural adoption and ample technical assistance from government agencies is available to implement these programs. The following recommendations are taken primarily from the *On-Farm Strategies to Protect Water Quality* document published by New Jersey Association of Conservation Districts, which is in essence a thorough agricultural BMP manual. While this document discusses many different agricultural BMPs this section will focus on those deemed of greatest utility in the Alexauken watershed. Many of the recommended BMPs described in the manual have been discussed in the preceding sections of this document and may be found above including riparian buffer enhancement, filter strips, and manure management.

The table displayed below shows the pertinent agricultural BMPs for the Alexauken watershed that have not been discussed elsewhere in this document (Table 23). For the most part these BMPs focus on the control of erosion and sedimentation although many also offer nutrient loading reduction benefits as well. Many of these strategies take advantage of a vegetative component to maintain ground cover and prevent soil erosion, but it should be noted that these strategies in controlling erosion also reduce runoff volume and rates by decreasing runoff velocity, enhancing infiltration, and promoting evapotranspiration, and these reductions in runoff are a crucial component of maintaining channel integrity in the tributary network. It is also worth noting that many of these BMPs are procedural relying specifically on altering practices rather than installing structural solutions to minimize NPS loading. This table was developed utilizing data from the agricultural BMP manual.

Table 23: Agricultural BMPs

BMP	Erosion and Sedimentation	Nutrient	Pest and Pesticide	Barnyard, Manure, and Waste	Grazing
Conservation Cover	●	ɵ			
Conservation Crop Rotation	●	●	ɵ		
Contour Farming	●				
Contour Strip-cropping	●	ɵ			
Cover Cropping	●	●	ɵ		
Field Borders	●				
Grassed Waterways	●	ɵ			
Residue Management	●	ɵ	ɵ		
Nutrient Management Plans		●			
Green Manure Cropping	ɵ	●			
Livestock Fencing	ɵ				●
Pasture Management	ɵ	ɵ		ɵ	●
Stream Crossing	●				ɵ

● - primary
ɵ - secondary

Conservation cover, conservation crop rotation, cover cropping, and pasture management all rely on maintaining vegetative cover in agricultural areas. Conservation cover specifically refers to the establishment of permanent vegetation in areas retired from active production. Cover cropping on the other hand is the seasonal establishment of cover crops, such as winter wheat or winter rye, after the harvest of primary crops in the summer or fall to provide cover until the next planting. Crop rotation is the practice of rotating different crops through several fields to limit nutrient deprivation and may be used in conjunction with techniques such as green manure cropping to bolster soil nitrogen levels through the periodic planting of legumes.

Residue management is another important technique that sees use in the watershed and is based on maintaining plant residues at 30% or greater coverage to prevent erosion, and depending on site conditions can decrease erosion and sedimentation by as much as 90%. Residue management is based on the implementation of conservation tillage practices including no-till, mulch till, and ridge till.

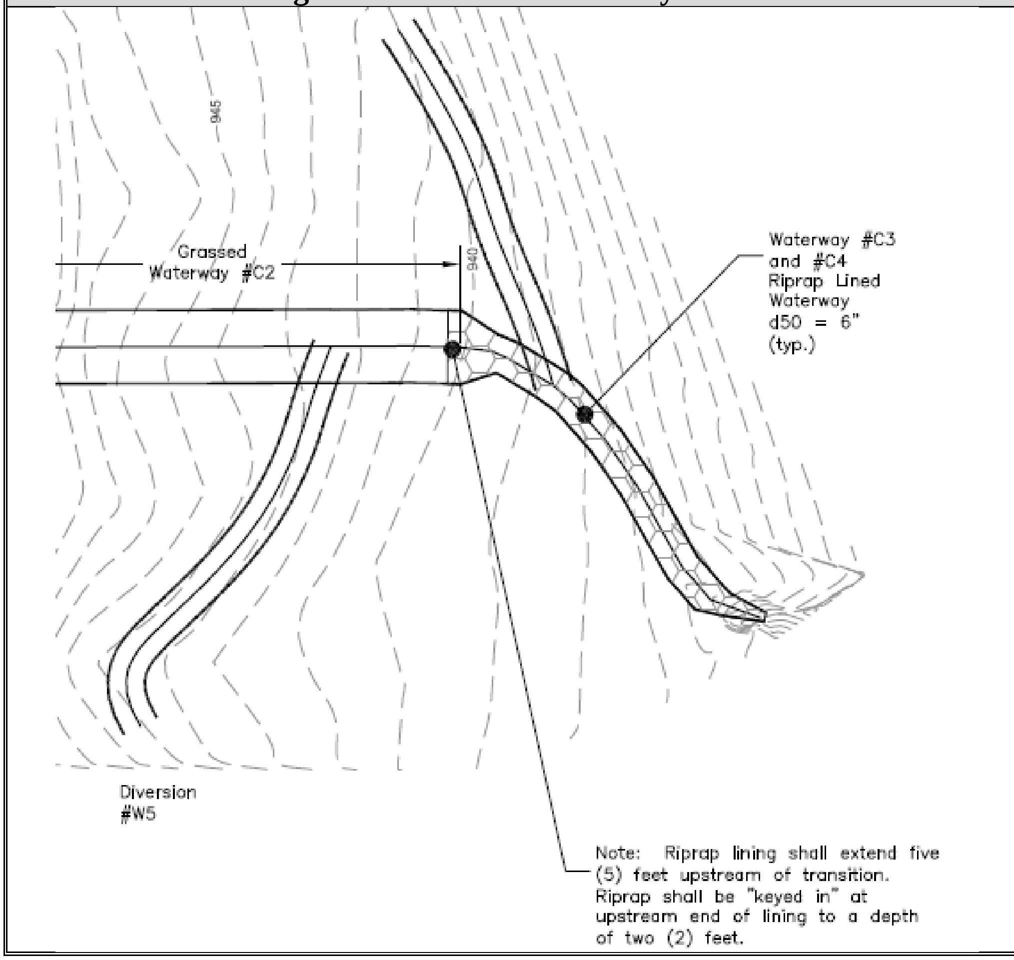
Contour farming and derivations such as contour strip-cropping and contour buffer strips is the simple practice of tilling, planting, cultivating, and harvesting across the slope of a field or parallel to the contours. This is done mainly to slow flow velocity and prevent the transport of sediment into adjacent waterways. This is a basic practice that has been promoted for a long time, but has not been uniformly adopted in the watershed. The widespread implementation of contour farming could provide substantial benefits in the watershed and prevent the loss of valuable topsoil in farmed fields. In fact the high erodibility of many soils in the watershed increases the importance of implementing BMPs that minimize erosion including contour farming, residue management, and cover solutions.

Grassed waterways and diversion methods should be strongly considered for implementation throughout the watershed. As a result of topography many of the fields in the watershed are sloping and are situated close to the tributary network. As such, management of runoff and water in general is a concern in these fields, and many drainage features discharge directly to adjacent tributaries. Because of the direct discharge field drainage features have an even greater potential to deliver eroded sediments directly to the stream. In the image provided below (Figure 52) a small drainage ditch located in the watershed is showing signs of erosion and the in-filled outfall at the bottom is clearly blocked, minimizing the capacity to effectively manage runoff in the field and contributing to erosion and sedimentation issues.

Figure 52: Eroded Ditch

The implementation of grassed waterways would be ideal for this situation. Like vegetated swales discussed in the structural BMP section above, the grassed waterway is merely an agricultural application of the same principles used in agricultural fields. Namely, grassed waterways utilize a permanent groundcover to provide surface stability to prevent erosion and the vegetative filtering and removal of suspended sediments in directed runoff. The following detail, taken from a Princeton Hydro engineering plan shows a schematic view of a grassed waterway with tributary diversion situated on the contour (Figure 53). While additional diversions are not required, especially if there is adequate riparian vegetation at the toe of the field or a vegetated field border, grassed waterways should be considered in the Alexauken.

Figure 53: Grassed Waterway Detail



Nutrient management is a connected series of BMPs designed primarily to reduce costs associated with fertilizing and improving yields, while limiting the NPS loading of nutrients to waterways. As such nutrient management plans must consider the handling of manure, crop rotation, cover cropping, and fertilizer use. The use of fertilizers is probably the most important component of many nutrient management plans and simple practices such as soil testing, knowledge of crop requirements, and good application practices can significantly reduce fertilizer demand and nutrient loading.

Finally, stream fencing and crossing improvements should be considered to limit in-stream erosion, solids loading, and bank instability. While livestock access to tributaries in the watershed seems to be limited, agricultural crossings are fairly common and few are improved structures, as illustrated in Figure 54, a typical agricultural stream crossing in the watershed.

Figure 54: Unimproved Agricultural Stream Crossing

There are a variety of simple fixes, one of the most popular being the hog panel stream crossing with gravel driveways, and where livestock cross, fencing (Figure 55). These solutions can significantly reduced localized bed instabilities, which can result in the formation of migrating head cuts and erosion upstream, and solids loading to the stream.

Figure 55: Improved Agricultural Stream Crossing

4.10 Impoundment Removal

The removal of impoundments is usually a contentious issue for a variety of reasons, but both online, and offline impoundments contribute significantly to stream warming and are barriers to fish passage. They may also contribute to downstream erosion if improperly engineered, change sediment transport dynamics, and present a danger to downstream users upon failure. Safety issues are important consideration because many dams are inadequately maintained once their active use is discontinued. However, many impoundments continue to serve useful purposes and may provide irrigation water, function as regional detention basins that capture solids, and provide recreational opportunities. The number of impoundments in the Alexauken watershed is generally limited and most if not all are located on private property. While homeowners may be encouraged to remove functioning impoundments, the major thrust of impoundment removal in the Alexauken should focus on the removal of dam, culverts, or other obstructions that serve no purpose, are failing, or have been breached and abandoned. It is important to note that trees and other natural “obstructions” should be left in place and are a natural component of stream channels and channel shaping processes. It should also be noted that normal roadway crossings are beyond the scope of impoundment removal as small bridges are a vital part of the load road infrastructure. Unless there are specific problems such as road flooding or structural failure these bridges and pipes should be left alone.

Besides the problems discussed above failed dams and other structures may cause significant erosional problems. As these obstructions fail they are breached or otherwise bypassed typically resulting in severe bank erosion. Additionally, debris is left which may pose a danger. When these structures fail captured sediment is then resuspended and deposited elsewhere downstream leading to increased sediment embeddedness and reduced macroinvertebrate habitat. If the deposition is severe enough it can also cause localized flooding.

The image shown below (Figure 56) is an example of a failed impoundment located in one of the Alexauken tributaries. The image depicts a disused dam that is crumbling in place. This structure is certainly a barrier to aquatic life and likely causes localized flooding during storm events as water becomes impounded. It is this type of structure which can be removed fairly easily that should be targeted. Removal of this class of impoundment would increase in-stream movement of aquatic organism and return natural hydrologic and hydraulic function to the stream.

Impoundment removal can be a complicated process requiring engineering consultation and a rigorous permitting process. However, the state recognizes the need to remove these small impoundments and looks favorably on restoration processes. From an implementation standpoint the removal is generally simple, and may be accomplished with a trackhoe or other excavation equipment; removal may also require the excavation of captured sediments impounded behind the obstruction.

Figure 56: Failed Impoundment

The challenging part of dam removal may be the restoration process. Typically, after the removal of the obstruction bank and bed stabilization measures are implemented, as discussed above in the bed and bank stabilization section. This may include flow deflection devices, toe protection and bank armoring, and grade control. Grade control, provided by a cross vane or an engineered rock riffle is usually a crucial component and is installed to prevent the formation of headcuts and limit erosion. Bank plantings and riparian buffering are also encouraged to convert the riparian corridor to more natural function.

4.11 Specific Candidate Restoration Sites

Appendix I contains 38 specific candidate restoration sites within the Alexauken Creek watershed to implement a variety of NPS reduction measures discussed above. These sites are plotted on a USGS topography map and State orthoimagery. These sites were selected based on the results of the volunteer visual assessment including photographic documentation and text descriptions of observed impairments in the stream corridor as well as stakeholder input. Each of the sites was numbered with numbers increasing with distance from the confluence with the Delaware. For each of the selected sites a description of the problem was provided followed by a series of specific recommendations as well as site photographs showcasing the issue. Other details specified in the photographic account and Restoration Site Project Detail table found in Appendix I include:

- Segment and Reach Identification
- Position (Latitude/Longitude)
- Block and Lot
- Ownership Class
- Reach Classification (all sites are designated FW2-TM(C1))
- Cost
- Projected Permits
- Anticipated Benefit
- Time to Completion
- Priority and Rank

Implementation priority and rank are an important concept in this plan. Each site was assessed a priority determined by rank. While all these sites have merit and deserve attention the priority rankings draw attention to those projects that should be considered sooner. The semi-quantitative ranking matrix was based on the severity of the problem, physical extent of the problem, risk to infrastructure and assets, temporal considerations, clear identification of the source of the impairment, accessibility and land use setting, and benefit of mitigation versus cost. Table 24 below describes the components used to evaluate priority. Each of these categories was qualitatively evaluated relative to all identified sites and scored from 1 to 3, with 1 representing the lowest concern or importance with successive increases to high concern at score 3. These scores were then summed across all categories with benefit/cost assessed with extra weight. The highest sum scores received the lowest numerical rank and highest priority. Project 26, an expansive riparian enhancement and bank stabilization project, received the highest summed score of 24, and was ranked 1. Conversely, Project 1, consisting of simple debris removal from the channel, had the lowest score of 10 and was ranked 12. Many of the scores overlapped resulting in ties for rank. Ranks 1 through 5 are considered high priority, ranks 6 through 8 are medium priority, and ranks 9 through 12 are considered low priority.

The qualitative scoring of the categories is based largely on the project experience of Princeton Hydro in implementing these types of solutions in the field. This is especially true of cost estimates, which are explained in further detail in Section 5.0, and a general sense of the complexity of these works. This project experience, including engineering, the acquisition of permits, scientific field studies, funding, and designing within regulatory requirements, is also bolstered by various training classes in Rosgen restoration techniques as well as others promoted by the USACE and NJDEP, a variety of sources in the literature, and implementation throughout the Mid-Atlantic and New England states.

Table 24: Priority Evaluation

Priority Considerations	Explanation and Example
Severity	More severe problems are ranked higher. A site with 5 feet of bank erosion would receive higher priority than a site with 2 feet of erosion.
Extent	The greater the area affected or the greater the water quality impairment would receive higher ranking. An erosional feature 100 feet long would score higher than 20 foot reach
Risk to Assets	A risk to a defined asset scores higher than otherwise. A site where roadway stability is potentially impacted by erosion scores higher than an erosional feature in an undeveloped reach. Assets would also include buildings, farm land, and other similar categories.
Temporal	Impairments or impacts that are likely to further degrade at an accelerated rate or cause problems in the immediate future are ranked higher.
Source Identification	Impairments in which a causal action is linked to an observed impairment would receive higher priority. An erosional feature directly related to outfall discharge would score higher than a generalized erosion feature
Accessibility and Land Use Setting	Priority is given to those sites that are accessible or where impairments are noted in developed lands (residential, agricultural, commercial, industrial) rather than non-developed lands. For example, channel instability in a reach running through maintained lawn space would receive higher ranking than a similar feature in a riparian forest. Accesibility refers to the abilty to access the site with equipment. Again, forested areas will score lower than maintained spaces both because of physical access and potential collateral loss to functioning habitats.
Benefit versus Cost	The benefit of a given mitigation strategy is weighed against financial cost, complexity, and overall effort and is related in part to both severity and extent. Projects that provide greater benefit to water quality and ecology are given higher priority.

An important consideration of this WPP is public acceptance of the plan and proposed restoration measures. While public buy-in is addressed further in Section 6.0 and will be aggressively pursued moving forward in order to realize the implementation of management measures the public support to this point has been very positive and a key in the development of the plan. The cornerstone of public support in the development process has been West Amwell Township, the grantee and sponsor of this plan. West Amwell has shown full commitment to this project and is active in the promotion of the document. Much of the support has come through activities designed to encourage participation in the creation of the WPP and through garnering support of various stakeholders and citizen groups. In particular the Environmental Commission and the

Agricultural Advisory Commission have expressed their concern in mitigating development related impacts to the watershed and in suggesting and sponsoring candidate restoration sites in several meetings conducted jointly with Princeton Hydro. Other project partners, including the remaining constituent municipalities, have also supported this document. One of the most important project partners was the Delaware Riverkeeper Network who coordinated and trained the volunteers who conducted the visual assessment of the watershed. In total, some 60 volunteers donated their time in assessing the watershed which highlights the grassroots support of the citizenry in restoring and conserving the Alexauken watershed. Perhaps of greater note was the response of the landowners themselves. Prior to the initiation of the visual assessment activities property access forms were distributed to landowners in the tributary network. Of 30 identified stream segments, the coarse assessment unit, permission was granted to survey 23 of the segments a 77% success rate. Overall, 107 individual stream reaches were surveyed within the larger segments which indicates the willingness of landowners to scientifically assess issues within the watershed and to address these issues. Since little publically held land is adjacent to defined tributaries the demonstrated support of landowners in conjunction with project partners and municipalities is key in implementing this plan.

While the appendix describes specific sites and specific NPS mitigation measures many of the impairments encountered in the tributary network are repeated throughout the watershed and the recommendations included therein can serve as a template for implementation at other sites. Indeed, while the list of restoration sites is thorough and contains a variety of impairments and mitigation strategies at a large number of locations it is not totally exhaustive, due to access restrictions, and many of the recommendations can therefore be extrapolated to other locations as identified.

5.0 Technical and Financial Assistance

This section discusses technical and financial assistance necessary to achieve the goals and objectives of the WPP. More specifically it discusses the implementation costs and needs associated with the listed NPS management measures and identifies responsible parties. This section corresponds to the fourth EPA element.

> *Estimate of the amount of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement this plan.*

This WPP has been designed to focus on low intensity designs; that is NPS management measures that are relatively low cost which require minimal technical assistance to implement thus enabling landowners and other interested parties to participate with minimal expenditure. These types of projects are ideal for this watershed in order to treat the diffuse nature of NPS loading utilizing management strategies that are environmentally friendly and mimicking natural processes, such as vegetative bank stabilization. However, many of the management measures discussed above are costly and require permitting and engineering studies that will likely require governmental sponsorship. While the use of these more intensive designs is limited they are still important and proper planning considerations including funding must be secured in order to meet the protection goals.

At the basic level there are number of factors that affect implementation. One of the most basic is cost. Cost estimates should include materials, labor, monitoring (pre- and post- installation), engineering, permit acquisition, and maintenance. Funding project implementation, or securing the monies identified by cost estimates, is probably the most critical step in advancing work. Funding may be derived from a wide variety of sources including governmental and non-governmental organizations (NGO), private donations or other fundraisers, taxes, or low-interest loans. Not to be overlooked are in-kind matches including landowner cost sharing and other similar initiatives. Securing funding also entails the identification of responsible parties to sponsor projects, which in the watershed will likely stem primarily from the municipalities but will also rely heavily on landowners. Technical assistance, particularly for agricultural BMPs, will be provided by a number of government organizations. Many of the lower intensity solutions and agricultural BMPs will likely be provided to landowners by municipal and county authorities, but many of the structural projects will require assistance from scientists and engineers to thoroughly characterize the site, file necessary permits, design the solutions, oversee construction, and monitor the results. Another important component is the informational and educational component to provide the community outreach to educate and mobilize the citizens of the watershed.

The following section provides generalized estimates of technical and financial assistance needed to implement the NPS management measures discussed above and to meet the NPS reduction objectives throughout the watershed.

5.1 Riparian Buffer Enhancements

The implementation of riparian buffer enhancements has been identified as the primary NPS reduction measure recommended for implementation in the WPP. This is in large part due to the relative simplicity of these mitigation measures, their efficacy in treating and mitigating numerous NPS pollutant loads, and relatively low costs. Table 25 lists the specifics of riparian buffer enhancement implementation.

Table 25: Riparian Buffer Enhancements

Riparian Buffer Enhancement	
No-Mow Zones	
Description	No-mow zones along stream banks to promote vegetation, bank stability, shading, and other functions.
Responsibility	Landowner, Municipality.
Technical Assistance	Limited, consultant for development of educational information.
Information and Education	Development of mailings and demonstration or workshops. May consider a $50 one-time voucher for program participation.
Funding Sources	Municipality.
Maintenance and Monitoring	Very limited. Removal of invasive vegetation.
Costs	$0 to landowner. $25,000 to municipalities with participation of 500 landowners, plus workshop and mailing costs, anticipated at less than $5,000.
Riparian Buffer Planting	
Description	Replanting of native riparian vegetation to provide a variety of NPS reduction functions.
Responsibility	Landowner, Municipality.
Technical Assistance	Again limited. A standard planting list should be provided for interested landowners. Some permitting may be required on more intensive projects, especially with the removal of invasive vegetation. Professional help may be desirable on larger projects or the use of volunteers. Implementation for a site can be protracted to ease labor and materials costs. County Conservation District, consultants, municipal Environmental Committees, and similar sources may provide technical
Information and Education	Development of mailings and demonstration or workshops. May consider a cost sharing program for the purchase of plant materials, tree shields, and repellants.
Funding Sources	319(h) grants for public holdings implementation, NRCS grants, NJ Environmental Infrastructure Financing Program, municipal funding, and private funding.
Maintenance and Monitoring	Periodic monitoring of site. Replacement of dead or browsed vegetation as necessary. Bank stabilization surveys to determine impacts. Larger stream monitoring efforts to assess cumulative effects on temperature and NPS loading.
Costs	Materials include plants, repellants, tree shields, and invasive species removal. On projects requiring permitting, design work, and planting plans consultant fees may range from $3,000 to $10,000. Projects requiring only supplemental planting of certain vegetation types such as herbaceous plants and shrubs costs should be less than $1,000 per acre (an area equal to a 50' wide buffer of approximately 900' in length). More intensive designs including complete restoration of vegetated materials may range from $5,000 to $10,000 an acre including labor, materials, and consultant fees. Expected total cost to implement up to 10 stream miles of riparian buffer enhancement along both banks at the upper bound cost of $10,000 per acre would total approximately $1.2 million.

For the most part implementation will hinge on community outreach to provide information concerning the benefits of riparian buffer enhancement and to develop the public will to implement these plans. Generally technical assistance need is fairly limited and a plant list as well as some general planting guidelines may be sufficient to initiate such projects. Some consulting may be required if buffer enhancements are specifically utilized to provide bank stability rather than general NPS reductions and habitat enhancement. Bank stability plantings may also require a land use permit. In any case ample funds should be available to implement these projects. Total cost for the restoration of up to 10 linear stream miles in the watershed is anticipated to cost around $1,200,000, a relatively low cost relative to other BMPs considering the scale of implementation or even when weighed against the cost of open space preservation.

5.2 Cultural BMPs

Cultural BMPs are another measure that need to be implemented throughout the watershed, which, like riparian buffer enhancement measures, will depend strongly on public outreach. Unlike other measures a simple change in procedure or practice is the impetus of most of these measures which means little expenditure or procurement of materials. Technical assistance on the implementation may be necessary, but should be limited; information is provided in Tables 26, 27, and 28.

Table 26: Cultural BMPs

Cultural BMPs	
Fertilizer Use	
Description	To promote the use of non-phosphorus and slow release nitrogen lawn fertilizers and to alter application practices to minimize runoff.
Responsibility	Landowner.
Technical Assistance	Limited. Confined to development of educational program.
Information and Education	Landowner education program development and mailing. Also, interface with local vendors to ensure availability of product.
Funding Sources	Municipal.
Maintenance and Monitoring	None.
Costs	Educational costs of $3000.
Yard and Pet Waste	
Description	To promote the responsible disposal of ward and pet waste to minimize bacterial and nutrient loading to the stream.
Responsibility	Landowner.
Technical Assistance	Limited. Confined to development of educational program.
Information and Education	Landowner education program development and mailing.
Funding Sources	Municipal.
Maintenance and	None.
Costs	Educational costs of $3000.
Waterfowl Control	
Description	To limit NPS loading, especially bacteria, related to Canada geese.
Responsibility	Landowner.
Technical Assistance	Limited, confined to development of educational program. May require professional to disturb resident birds, addle eggs, or apply repellants.
Information and Education	Landowner education program development and mailing.
Funding Sources	Municipal.
Maintenance and Monitoring	None.
Costs	Educational costs of $3,000. Site costs may range from $500 to $3,000.

Table 27: Cultural BMPs

	Road Salt Application
Description	To limit water quality impacts related to road salt application by changing application practices and maintaining acceptable yard and storage conditions.
Responsibility	NJDOT, County Road department, Municipal road department.
Technical Assistance	Limited to road crews.
Information and Education	Road deicing seminars are held periodically throughout the state.
Funding Sources	State, County, and municipal. NJDOT and USDOT grants may be available.
Maintenance and Monitoring	Monitoring would be part of a larger water quality monitoring effort with special attention paid to seasonal variation in conductance or TDS measures.
Costs	Cost should be limited to employee training programs. Storage facility upgrades are assessed on an individual basis. Product cost differentials are low.
	Water Conservation Practices
Description	The reduction of water consumption to protect groundwater sources and limit wastewater generation.
Responsibility	Landowner.
Technical Assistance	Limited, confined to development of educational materials.
Information and Education	Landowner education program development and mailing.
Funding Sources	Municipal.
Maintenance and Monitoring	None.
Costs	Educational costs of $3,000. High efficiency plumbing fixtures and appliances should be upgraded on a normal schedule.
	Septic Management Practices
Description	The maintenance of onsite septic systems to promote proper function and reduce bacterial and nutrient loading to surface and groundwater.
Responsibility	Landowner.
Technical Assistance	Limited, confined to development of educational program.
Information and Education	Landowner education program development and mailing. Many educational materials are available from the USEPA, ANJEC, and the Groundwater Foundation.
Funding Sources	Municipal.
Maintenance and Monitoring	None.
Costs	Educational costs of $3,000. The offer of $25 vouchers to promote regular septic tank has been used with success elsewhere in the state. Watershed wide cost up to $25,000. Homeowner costs to pump septic tanks is usually around $300.

Table 28: Cultural BMPs

	BMP Maintenance
Description	The maintenance of BMPs to ensure continued efficacy per design standards.
Responsibility	Variable, including landowner, developer, municipality, county, MUAs, or responsible road crews. Identifying and assigning responsibility, as well as funding, is a goal in establishing normal BMP maintenance routines.
Technical Assistance	Design engineer and developed SOPs, NJ Stormwater BMP manual, NJDEP, and other similar
Information and	Relatively limited. Should be predicated on information obtained from design engineer and SOPs.
Funding Sources	Variable, see Responsibility.
Maintenance and Monitoring	Monitoring BMPs for efficacy is an important component of maintenance. Maintenance activities may include: visual inspections, vegetation management, debris and litter removal, mechanical components, biological controls, sediment removal, and street sweeping.
Costs	Cost vary widely depending on need. Projects requiring heavy equipment, such as sediment removal, may be substantial. Annual maintenance costs should be budgeted at 5-10% of installation cost.
	Rain Barrels
Description	Using rain barrels to minimize roof runoff, beneficial reuse of captured water, and limiting further withdrawals from groundwater.
Responsibility	Landowner.
Technical Assistance	None.
Information and Education	An awareness campaign should be implemented that could be dovetailed with water conservation practices and other environmental news.
Funding Sources	Landowner.
Maintenance and Monitoring	Limited, periodic use of captured water.
Costs	$150 per install, less for clean, recycled barrels.

5.3 Structural BMPs

Structural BMPs are much more technically difficult to implement and thus are considerably more costly than most of the other NPS pollution reduction measures discussed in the WPP. The simple lack of developed infrastructure in the watershed also limits their use, but new development will absolutely require these measures, as will identified “hot spots” or problem areas that require engineered treatment solutions to meet water quality standards, performance goals, and general environmental stewardship. While the education of the public at large is not necessary familiarity of regulators and policy makers is crucial especially as new designs are developed and gain favor through additional environmental benefits and different design philosophy. Technical assistance needs are certainly high for these systems and will require consultant engineering help for the most part, but on public properties the design work may be sponsored by government engineering staffs or subcontracted. On privately held lands much of the cost is likely to be absorbed by the landowner, but when tied to infrastructure or public properties ample opportunity exist to access public funds and grants. Tables 29 and 30 provide some of the technical considerations for structural BMP implementation.

Table 29: Structural BMPs

Structural BMPs	
Detention Basins and Wet Ponds	
Description	A standard structural stormwater BMP to limit flooding by reducing rates and providing TSS and nutrient removal capacity.
Responsibility	Landowner, municipality in public settings, and sometimes the developer.
Technical Assistance	High, requires extensive engineering including surveying and geotechnical analysis.
Information and Education	Limited, but the promotion of systems offering greater NPS reduction efficiencies should be considered.
Funding Sources	Landowner, sometimes municipality. Modification and retrofits may be eligible for 319(h) grants and other stormwater infrastructure funding.
Maintenance and Monitoring	Routine inspections and mowing. Periodic dredging to remove captured sediments in the basin and the forebay. Influent and effluent monitoring to assess removal efficiency.
Costs	Costs estimated using EPA formula at around $40,000 for 1 acre-ft of storage with declining cost for storage with increased basin size, 10 acre-ft basin estimated at $250,000. Installation projected primarily for newly developed sites
Bioretention BMPs	
Description	An advanced structural stormwater BMP to limit flooding by reducing rates and providing increased TSS and nutrient removal capacity utilizing vegetation as a key design element.
Responsibility	Landowner, municipality in public settings, and sometimes the developer.
Technical Assistance	High, requires extensive engineering including surveying and geotechnical analysis. Retrofits of detention basins to bioretention designs should be considered.
Information and Education	Limited, but the promotion of these systems relative to standard detention systems in relation to NPS reduction efficiencies should be considered.
Funding Sources	Landowner, sometimes municipality. Modification and retrofits may be eligible for 319(h) grants and other stormwater infrastructure funding.
Maintenance and Monitoring	Maintenance of vegetation to maintain healthy plant communities is recommended. Mowing and other routine maintenance is not necessary for these designs.
Costs	Costs estimated using EPA formula at around $60,000 for 1 acre-ft of storage with declining cost for storage with increased basin size, 10 acre-ft basin estimated at $290,000. Installation projected primarily for new sites. Retrofits of existing basin cost much less and would consist of appropriate scientific/engineering evaluation of the basin, modification of the existing outlet and low flow channels, design, plant materials and planting.
Infiltration BMPs	
Description	Structural BMP designed to infiltrate captured stormwater up to design storm or decrease the generated runoff volume.
Responsibility	Landowner, municipality in public settings, and sometimes the developer.
Technical Assistance	High, requires extensive engineering including surveying and geotechnical analysis. Retrofits of detention basins to infiltration designs may be considered. Utility in the watershed likely limited by soil percolation.
Information and Education	Limited, but the promotion of these systems relative to standard detention systems in reducing runoff volume should be considered.
Funding Sources	Landowner, sometimes municipality. Modification and retrofits may be eligible for 319(h) grants and other stormwater infrastructure funding.
Maintenance and Monitoring	Maintenance requirements are fairly high in this type of system due to the propensity of the sand layer pores to become blocked over time thus reducing infiltration capacity. Pervious pavement systems require frequent sweeping or power washing.
Costs	Costs estimated using EPA formula at around $20,000 for 1/4 acre-ft of treatment in infiltration basins. Infiltration trenches may cost $5 per ft^3 treated. Pervious pavement may run $90,000 to $130,000 an acre.

Table 30: Structural BMPs

	Water Quality Swales and Vegetative Filters
Description	Structural BMP designed to capture and convey water while managing NPS loads.
Responsibility	Landowner, municipality in public settings, and sometimes the developer.
Technical Assistance	High, requires extensive engineering including surveying and geotechnical analysis. Retrofits of existing swales should be considered.
Information and Education	Limited, but the promotion of these systems relative to standard ditches and conveyances should be considered.
Funding Sources	Landowner, sometimes municipality. Modification and retrofits may be eligible for 319(h) grants and other stormwater infrastructure funding. Agricultural uses may be funded through a variety of NRCS sources.
Maintenance and Monitoring	Maintenance requirements should be fairly low, although plantings must be maintained. Periodic removal of solids may be required, especially with systems that use small check dams.
Costs	Costs estimated using EPA guidance at around $15,000 to $30,000 per acre utilizing sod placement, other designs likely cheaper. Vegetated swales, particularly simpler designs, are estimated to be less costly than curb and gutter designs.
	Manufactured Treatment Devices
Description	Structural BMP manufactured offsite and inserted in-place. May be used to retrofit existing systems for NPS control.
Responsibility	Municipality, county, or state in public settings, and usually a developer or other party for private holdings.
Technical Assistance	Medium. Large systems may require extensive engineering and other studies. Smaller or simpler systems may be simple bolt-on designs. NJ Stormwater BMP Manual, NJCAT, and manufacturers recommendations and consultants to advise.
Information and Education	None.
Funding Sources	319(h) grants when related to public infrastructure.
Maintenance and Monitoring	Maintenance requirements are high in most of these systems. In particular sediment removal using excavators or vac-trucks can be costly, or the replacement of media filters and should likely be scheduled several times per year based on projected solids capture.
Costs	Vary widely according to size and treatment capacity and are set by the respective manufacturers. Larger designs may range from $5,000 to well over $150,000. Engineering and monitoring costs can be quite high ranging from $5,000 to $30,000 and potentially more. Installation costs may also be high. Costs are most closely linked with site specific conditions.

5.4 Manure Management

The management of manure in the watershed, while technically an agricultural BMP, has been called out separately due to potential loading issues in the watershed. While not a ubiquitous problem in the watershed the concentrated loading associated with manure handling and disposal in the watershed has called special attention to this issue. For the Alexauken watershed low intensity solutions for manure handling have been specified based primarily on the proper handling and spreading as specified by the NJDA. This therefore relies on the formation of manure handling plans which outline BMPs. Other more technical solutions such as the installation of vegetated buffer strips may be considered where the capacity for storage, topography, or proximity to tributary networks requires it. In such cases technical assistance may be required, but as with most efforts, information and education will be one of the priorities for instituting better manure management practices.

Table 31: Manure Management

	Manure Management
Description	Implementation of practices and structural controls to limit NPS bacterial and nutrient loading to the tributary network.
Responsibility	Landowner.
Technical Assistance	Much technical assistance is available including the NRCS, NJ Dept. of Agriculture, NJ Agricultural BMP Manual, Rutgers Cooperative Extension, and the county Conservation District.
Information and Education	I/E efforts are crucial to this effort and should be based on the wide variety of available materials.
Funding Sources	NRCS Grants, River Friendly Farm Program with NJ RC&D, County Soil Conservation District, Landowner
Maintenance and Monitoring	Maintenance varies considerably with selected method. Vegetated filter strips may require periodic maintenance planting. Monitoring implemented on watershed scale to monitor coliform concentrations and at identified hot-spots.
Costs	Filter strips may run as high as $30,000 per acre but are likely to be less, and simple establishment of vegetated buffers is expected to average $5,000 per acre. The development of manure management plans is expected to be as low as $1,000 per plan.

5.5 Invasive Species Management

The management of invasive species in the Alexauken watershed is crucial to restoring suitable wildlife habitat and maintaining high riparian buffer efficiency in the capture of NPS pollutants and other valuable ecological services. The control of invasive vegetation may be a relatively simple, though labor intensive project and one that will likely require the use of a certified pesticide applicator when spraying adjacent to the tributary network and on large scale removal efforts. Education should be provided on the benefits of restoring native vegetation and the removal of invasive species which should be packaged with other educational efforts. It will also be important to fully educate the public about potential issues in the use of chemical herbicides and the safe handling of such material. Invasive species control is also one of the BMP maintenance items and will need to be considered in the maintenance plans of most other BMPs and be integrated in most riparian buffer enhancement and bank stabilization projects. The control of invasive species using professional services is estimated to run between $1,000 to $2,000 per acre for both chemical and mechanical removal activities. Table 32 provides more information.

Table 32: Invasive Species Management

Invasive Species Management	
Description	Chemical treatment and mechanical removal to limit the spread of invasive species. May be used in advance of riparian buffer enhancement and as a maintenance measure.
Responsibility	Landowner.
Technical Assistance	NRCS and NJDEP Pesticide Control Program. Certified applicators likely needed for larger projects.
Information and Education	I/E should be packaged with other programs.
Funding Sources	Landowner, NRCS grants, component of 319(h) grants.
Maintenance and Monitoring	An important maintenance technique for stream restoration projects. Simple invasives control may require follow up treatments to ensure complete removal and to limit new colonization.
Costs	Certified applicator costs will range from $1,000 to $1,500 per acre for chemical treatment and up to $2,000 per acre for mechanical removal. Landscapers and others may charge less for mechanical removal.

5.6 Bed and Bank Stabilization

Bed and bank stabilization, along with structural BMPs measures, are among the most complex measures recommended for the watershed and will require significant technical assistance for most projects. Bed and bank stabilization measures involve a number of strategies including planting, the use of various toe protection measures including riprap and boulder toes among others, the use of flow deflection devices to redirect flow away from vulnerable banks, and grade control structures. Technical assistance can be found among a number of government agencies especially during the planning phases, but the implementation will require private consultation for surveys, hydraulics and hydrology (H&H) studies, engineering, and installation. Funding for these projects will also vary, but 319(h) grants may be a major funding source for these activities, especially due to the identification and inclusion of these designs in this document. Maintenance and monitoring requirements will again depend on assessing function in the field, particularly after the first several storm events and during floods. It is also necessary to consider that bed and bank stabilizations are targeted measures and that multiple management measures may be utilized in conjunction. For example, bank grading would almost certainly be followed by bank plantings and ideally the establishment of a riparian buffer. Costs, therefore for these activities vary widely. Material costs can be modest for most of these designs with the bulk of funding going towards the design and installation phases. Permitting for these designs is also a special consideration and the anti-degradation protections afforded by the C1 status of the stream will increase the complexity of permitting in this watershed. Many of these jobs, on the scale likely to be seen in the Alexauken Creek, will start around $10,000 to $20,000 dollars, but more extensive measures, particularly where severe or long erosional features are being repaired, may easily run a range of $50,000 to $100,000, as indicated in Tables 33 and 34.

Table 33: Bed and Bank Stabilization

Bed and Bank Stabilization	
Bank Stabilization	
Description	A variety of bank stabilization measures to limit erosion or lateral migration including planting, brush mattresses, live fascines, and bank grading.
Responsibility	Landowner, municipality or other government agency on public lands.
Technical Assistance	Will vary according to selected measure. Planting, brush mattresses, and fascines are easily installed but bank grading will require engineering assessment and H&H studies as well as excavators.
Information and Education	Limited. The use of the low-tech solutions should be discussed with riparian buffer enhancements.
Funding Sources	Private funding from watershed groups and other interested parties, 319(h) grants, NRCS grants.
Maintenance and Monitoring	Properly installed designs should require minimal maintenance, but site should be frequently checked during first several flood events. Channel stability monitoring may be required and more holistic watershed monitoring to measure cumulative effects.
Costs	Variable. Low tech installations estimated at $15 to $30 per linear foot, while bank grading may run $20 to $30 per linear foot.
Toe Protection	
Description	Bank armoring using hard materials such as rootwads, riprap, boulder toe, and gabions designed to absorb hydraulic impacts and prevent bank failure and erosion.
Responsibility	Landowner, especially in the protection of privately held infrastructure, municipality, or other government agency on public lands. NJDOT, other agencies responsible for roads, and utilities may share responsibility.
Technical Assistance	High degree of technical assistance required for H&H studies, engineering, and installation. County and municipal engineering departments, county Conservation District, watershed management groups, or others may assume design for public entities otherwise private consultants, which may also be used as contractors.
Information and Education	None.
Funding Sources	319(h) grants for public holdings implementation, NRCS grants, NJ Environmental Infrastructure Financing Program, municipal funding, and private funding.
Maintenance and Monitoring	Maintenance should be limited, but visual inspections are necessary. Monitoring may look at bank stability, erosion, and water quality impacts and pre- and post-installation monitoring may be required.
Costs	Costs vary considerably. Installation for rootwads is $500 each, 1 cubic yard of riprap placed is $100, and 1 cubic yard of gabions is $200. Engineering, hydraulic studies, and permitting will vary by site, but $10,000 may represent a starting cost.
Flow Deflection	
Description	Installation of flow deflection devices to redirect erosive flow along streambanks.
Responsibility	Landowner, especially in the protection of privately held infrastructure, municipality, or other government agency on public lands. NJDOT, other agencies responsible for roads, and utilities may share responsibility.
Technical Assistance	High degree of technical assistance required for H&H studies, engineering, and installation. County and municipal engineering departments, county Conservation District, watershed management groups, or others may assume design for public entities otherwise private consultants, which may also be used as contractors.
Information and Education	None.
Funding Sources	319(h) grants for public holdings implementation, NRCS grants, NJ Environmental Infrastructure Financing Program, municipal funding, and private funding.
Maintenance and Monitoring	Maintenance should be limited, but visual inspections are necessary. Monitoring may look at bank stability, erosion, and water quality impacts and pre- and post-installation monitoring may be required.
Costs	Material costs are relatively low relative to installation and design. Channel excavation is estimated at $25 per cubic yard. Rock vanes and similar designs are estimated at $150 per linear foot. Again, engineering, hydraulic studies, and permitting are likely to start around $10,000.

Table 34: Bed and Bank Stabilization

	Grade Control
Description	Structures such as cross vanes, step pools, and engineered rock riffles to minimize bed incision.
Responsibility	Landowner, especially in the protection of privately held infrastructure, municipality, or other government agency on public lands. NJDOT, other agencies responsible for roads, and utilities may share responsibility.
Technical Assistance	High degree of technical assistance required for H&H studies, engineering, and installation. County and municipal engineering departments, county Conservation District, watershed management groups, or others may assume design for public entities otherwise private consultants, which may also be used as contractors.
Information and Education	None.
Funding Sources	319(h) grants for public holdings implementation, NRCS grants, NJ Environmental Infrastructure Financing Program, municipal funding, and private funding.
Maintenance and Monitoring	Maintenance should be limited, but visual inspections are necessary. Monitoring may look at bank stability, erosion, and water quality impacts and pre- and post-installation monitoring may be required.
Costs	Channel excavation is estimated at $25 per cubic yard. Cross vanes and similar designs are estimated at $150 per linear foot. Again, engineering, hydraulic studies, and permitting are likely to start around $10,000. Costs may be substantially reduced, especially for the installation of rock riffles, if native bed materials are utilized.

5.7 Open Space Preservation

The protection of high quality natural resources, environmental functions, and rural livelihoods through open space preservation programs has been a cornerstone of environmental policy in the municipalities of the Alexauken Creek, and must be maintained moving forward. Technical assistance is relatively limited, but conferring the benefits of preservation is paramount to the success of continuing efforts. The identification of properties suitable for preservation will depend largely on the use of natural resource inventories in addition to other programs. A wide variety of funding sources is available for the preservation of open space including dedicated open space funds and taxes, Green Acres, and Farmland Preservation Program among others. Costs will be extremely variable and outright purchases will depend on market value of specified property, while deed restrictions and easements may depend on other criteria. Table 35 summarizes some of the components of open space preservation programs.

Table 35: Open Space Preservation

	Open Space Protection
Description	Preservation and protection of natural resources and areas as well as agricultural lands.
Responsibility	Landowner and municipality primarily, but other parties such as the county and state.
Technical Assistance	Primarily municipal with a reliance on existing Open Space Plans, also county, NJDA and various stakeholder groups.
Information and Education	Continued education on the value of preserving open spaces.
Funding Sources	Multiple. Municipal open space tax, Green Acres, NJDA Farmland Preservation Program, NRCS, stakeholders, D&R Greenway Land Trust, and others.
Maintenance and Monitoring	Maintenance should include conversion to environmentally friendly land uses where appropriate using a variety of strategies discussed in the WPP. Periodic monitoring to establish resource inventory.
Costs	Variable. Outright purchase will be market value. Conservation easements, deed restrictions, and other similar devices to be determined by appropriate authority and existing policy.

5.8 Agricultural BMPs

The agricultural BMPs recommended for this watershed are of relatively limited scope to increase the adoption rate. One of the critical components of these BMPs therefore is the outreach component to inform the agricultural community of their benefits. Implementation and technical assistance may be provided by a variety of agricultural authorities including the NRCS, NJDA, and County Conservation District among many other. These authorities may also serve as the primary funding sources for the implementation of these projects. For the most part many of the recommendations are based on changing practices and not the physical installation of structural BMPs, and therefore many of the recommendations are based on the implementation of management plans that are outlined in the NJ Agricultural BMP manual. Some of the more technical methods, such as the installation of grassed waterways to repair eroded drainage features, the development of vegetated filter strips, or improved agricultural stream crossings may require a certain amount of engineering assistance. It should be noted that many of the measurement strategies, such as residue management and cover cropping, are already in use in the watershed, but must be continued to be utilized to maintain water quality. Costs will vary widely according to method but the development of manure management plans, contour cropping, and other methods are generally low cost. No-till methods and other similar measures would represent the cost in the purchase of equipment or resources needed to implement these farming strategies, while grassed waterways or vegetated filter strips may cost up to $15,000 per acre dependent on design, but may be more simply implemented for as low as $1,000 per acre. Minimal costs are associated with the installation of improved stream crossings. Table 36 provides an overview of the technical assistance needs for agricultural BMPs.

Table 36: Agricultural BMPs

Agricultural BMPS	
Conservation Cover	
Description	The implementation of conservation cover, conservation cover, pasture management, conservation crop rotation, and other measure to limit soil erosion and NPS pollutant loading.
Responsibility	Landowner and Conservation District.
Technical Assistance	NRCS, Conservation District, NJDA, and other agricultural authorities.
Information and Education	High value on the promotion of such techniques and continued promotion. Many of these techniques are standard procedures on agricultural lands in the watershed.
Funding Sources	Variety of NRCS and NJDA grants.
Maintenance and Monitoring	Low. Monitoring should be included in large scale watershed studies.
Costs	Generally low. For the most part this represents a change of procedure. Educational costs estimated to $5,000. Cost with some methods, such as no-till, may require the initial purchase of expensive equipment.
Conservation Tillage	
Description	The implementation of conservation tillage practices to minimize runoff generation and erosion.
Responsibility	Landowner and Conservation District.
Technical Assistance	NRCS, Conservation District, NJDA, and other agricultural authorities.
Information and Education	High value on the promotion of such techniques and continued promotion. Many of these techniques are standard procedures on agricultural lands in the watershed.
Funding Sources	Variety of NRCS and NJDA grants.
Maintenance and Monitoring	Low. Monitoring should be included in large scale watershed studies.
Costs	Low. For the most part this represents a change of procedure. Educational costs estimated to $5,000. Costs will be incurred in a reduction of production area if conservation buffer strips and other measures are implemented.
Grassed Waterways	
Description	The use of grassed waterways and improved conveyance systems to limit potential for erosion and solids loading.
Responsibility	Landowner and Conservation District.
Technical Assistance	NRCS, Conservation District, NJDA, and other agricultural authorities. Engineers and other private consultants may be utilized for the design phase.
Information and Education	High value on the promotion of such techniques and continued promotion.
Funding Sources	Variety of NRCS and NJDA grants.
Maintenance and Monitoring	Periodic maintenance including inspection and replacement of plants or seeding as needed. Monitoring should be included in large scale watershed studies.
Costs	Dependent on design costs can range significantly $1,000 to $15,000 per acre. The simple implementation of no-mow zones, to selective planting, to sod placement and hydroseeding explains the large range.
Improved Stream Crossing	
Description	Improved stream crossing to limit erosion within the channel and the transport of sediments.
Responsibility	Landowner and Conservation District.
Technical Assistance	Limited to NRCS, Conservation District, NJDA, and other agricultural authorities.
Information and Education	High value on the promotion of such techniques and continued promotion.
Funding Sources	Variety of NRCS and NJDA grants.
Maintenance and Monitoring	Periodic replacement of stone as necessary.
Costs	Material costs are low starting at around $500. Permitting and engineering burden is also minimal for small crossings.

5.9 Impoundment Removal

Impoundment removal in the Alexauken will help to restore normal stream hydraulics, reduce stream warming, and restore fish passage. Impoundment removals are highly technical projects and will require substantial H&H studies and engineering to both remove the impoundment and then restore bed and bank conditions. Impoundment removal will certainly require technical assistance, but much funding is being made available from a variety of sources including non-profit groups to affect widespread removals throughout the northeast. For the most part many of the impoundments in the Alexauken watershed are relatively small and removed easily, with most of the associated costs belonging to *in-situ* studies, permitting and regulatory compliance, and bank restoration activities. Smaller impoundment removals will probably cost approximately $10,000 to $20,000 (Table 37).

Table 37: Impoundment Removal

Impoundment Removal	
Description	The removal of impoundments, debris, and other obstructions that are barriers to fish passage, impound sediments, and cause changes in stream hydraulics.
Responsibility	Landowner.
Technical Assistance	Probably the most technically driven strategy discussed here, requires H&H studies, surveys, engineering, and construction expertise. Other technical assistance may be obtained from American Rivers, Dam Safety, Army Corps of Engineers, NRCS, US Fish and Wildlife Service, and others.
Information and Education	High value on the promotion of such techniques and continued promotion. Many of these techniques are standard procedures on agricultural lands in the watershed.
Funding Sources	Variety of sources including 319(h), Fish and Wildlife, NJDEP, American Rivers, stakeholders, private, and other.
Maintenance and Monitoring	Maintenance may include adaptive management solutions to ensure proper design function and should primarily focus on adjunct restoration features such as plantings.
Costs	Costs are variable. Actual removal, especially of small impoundments such as those identified in the Alexauken, are removed at minimal expense. Adjunct activities such as engineering, permitting, and restoration activities such as the installation of grade controls and plantings account for the bulk of the expense. Very small impoundments, such as those found on first-order tributaries, may be removed for as little as $10,000 - $15,000, with increasing costs thereafter.

5.10 Monitoring

While monitoring will be discussed in greater detail in Section 10.0 of this report it is important to outline some of the basic efforts and costs associated with the monitoring program. As this document is predicated on the identification of water quality impairments monitoring will be an important step in tracking the progress and success of the WPP. The monitoring referred to in this section is geared towards watershed scale studies rather than site specific efforts that will be designed as part of specific implementation projects. The watershed scale studies will be fairly technical and will require approval from NJDEP prior to implementation, although the work will be conducted by environmental consultants and may utilize volunteer monitoring to lower costs and increase public participation. Funding will largely follow that of other projects, and money may be utilized from other projects. Costs for monitoring will vary significantly based on the intensity of the design, but at a minimum should continue to monitor problematic nutrients, solids, *in-situ* parameters such as temperature, pH, and dissolved oxygen, and should probably also include hydrology modeling. Periodic review of the material and updates and pollutant loading and hydrology models is also recommended. The following table (Table 38) summarizes the amount of technical and financial assistance associated with monitoring efforts.

Table 38: Monitoring

	Monitoring Program
Description	The implementation of a watershed monitoring program as required by this document to track changes in water quality and environmental function over the course of the project.
Responsibility	Muncipality primarily, but site specific monitoring will be associated with each project.
Technical Assistance	NJDEP will provide technical approval of monitoring plan methodology, but monitoring will likely be conducted by professional consultants and should consider the use of volunteer monitors.
Information and Education	Monitoring results will be communicated regularly to stakeholders and be used to track progress, measure milestones, and drive further efforts.
Funding Sources	Variety of sources including 319(h), Fish and Wildlife, NJDEP, stakeholders, private, and other.
Maintenance and Monitoring	Monitoring should be conducted annually, preferably on a seasonal basis.
Costs	Costs are variable dependent on laboratory fees, level of detail, number of stations, and sampling frequency. Cost is likely to run around $10,000 per year for a thorough watershed monitoring approach. Periodic review of collected material and updates to models recommended at 5 year

6.0 Information and Education

This section reviews the information and education aspect of the Watershed Protection Plan. More specifically, it deals with identifying and building stakeholder involvement, developing educational and outreach programs and materials, and encouraging the adoption of measures and practices to protect the watershed and water quality. This section corresponds to the fifth EPA element.

> *An information and education component used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.*

The protection and preservation of water quality in the Alexauken Creek watershed is contingent upon the education of the target audience including elected officials, residents, landowners, farmers, and businesses in the watershed. The goals therefore of information and education programs should include:

- Improve communication, training, and coordination among local, county, and state governments, local committees, and environmental and stakeholder organizations for watershed related activities.
- Improve public education and raise awareness to promote stewardship of watershed resources, improve water quality, and reduce nonpoint source pollutants.
- Improve environmental and land conservation efforts by preserving open space and sensitive environmental areas and habitats
- Celebrate successes to recognize noteworthy efforts, encourage participation, and continue the implementation of the Alexauken Creek Watershed Protection Plan

This WPP has already successfully identified a variety of project partners and stakeholder groups that have the ability and capacity to successfully promote conservation efforts and disseminate educational materials. In addition to the primary grantee and project sponsor West Amwell Township, the following parties have been identified as project partners:

- Delaware Township Environmental Commission
- East Amwell Township Environmental Commission
- City of Lambertville
- Hunterdon County Planning Board
- Hunterdon Land Trust Alliance
- Delaware Riverkeeper Network
- The Regional Planning Partnership
- Sourland Planning Council

A number of outreach activities should be considered for the implementation of this WPP. A survey conducted by Hunterdon County polled residents to determine the efficacy of various outreach programs; the results are listed in Table 39 below. Mailing newsletters was determined to be the most effective outreach tool of those queried, followed by newspaper advertisements and internet content. Information posted at public facilities, flyers sent from schools, and broadcast media were deemed ineffective in communicating information. While these efforts were not as favorably rated much of the loss in effective communication seems to be likely tied to reduced audience delivery rather than an ineffective format. However, in general these types of information and education outreach efforts can be quite effective and show the willingness of the public in general to peruse written materials.

Table 39: Outreach Efficacy Survey

Outreach Effort	Effective	Not Effective	Not Sure
Mailing Newsletters	81%	7%	12%
Newspaper Advertisements	69%	15%	16%
Website publishing and e-mails	56%	21%	23%
Brochures, flyers, and posters at public facilities	41%	31%	28%
Flyers sent home from school	40%	49%	11%
TV and radio media	32%	39%	29%

In addition to these outreach methods other programs should be considered. Other effective outreach programs include:

- Demonstration projects
- Watershed tours and hikes
- Workshops and staff training seminars
- Volunteer opportunities for cleanups, planting, and monitoring
- Planning efforts and local ordinances

The development of information programs and educational materials should rely heavily on the abundance of available information published by EPA, NJDEP, and other sources that is specifically focused on the implementation of I/E programs for watershed protection plans and general NPS pollutant reductions. One of the best and most exhaustive sources for the development of outreach programs is the EPA's *Getting in Step: A Guide for Conducting Watershed Outreach Programs*; this document can be downloaded at: http://www.epa.gov/OWOW/watershed/outreach/documents/getnstep.pdf.

While the *Getting in Step* document discusses the outreach program development and implementation, the informational and educational materials are also available from a wide variety of sources. One of the more useful sites is the EPA *Nonpoint Source Outreach Digital Toolbox,* which can be accessed online at: http://www.epa.gov/nps/toolbox. The NJDEP Division of Watershed Management also provides a variety of tools at the outreach and education webpage (http://www.nj.gov/dep/watershedmgt/outreach_education.htm) which discusses a variety of programs such as the New Jersey Watershed Ambassadors Program, Project WET (Water Education for Teachers), and Clean Water Raingers and other educational publications, as well as volunteer monitoring. The various project partners also provide a wealth of outreach materials including the Land Trust Alliance, Delaware Riverkeeper Network, and the Hunterdon County Planning Board.

A sampling of the other groups and websites that should be consulted include:

- The Groundwater Foundation - www.groundwater.org
- NJDEP Stormwater and Nonpoint Source Pollution – www.njstormwater.org
- The River Network – www.rivernetwork.org
- EPA Handbook on Septic Management - www.epa.gov/owm/septic/pubs/onsite_handbook.pdf
- Association of New Jersey Environmental Commissions - www.anjec.org/
- Green Values Stormwater Toolbox – http://greenvalues.cnt.org/
- North Jersey Resource Conservation and Development Council *River Friendly Farms* - www.raritanbasin.org/RaritanAg/RF_Farm/index.htm
- Center for Invasive Species and Ecosystem Health - www.invasive.org/
- New Jersey NRCS Programs - www.nj.nrcs.usda.gov/programs/
- New Jersey Department of Agriculture - www.state.nj.us/agriculture/

With the variety of available resources it will be necessary to carefully screen these materials to select those consistent with the goals of this WPP. It will also be important to make the document itself available to the public as it represents a thorough documentation of existing natural resources in the watershed with a concentration on characterization of water quality and potential impairments.

7.0 Implementation Schedule

This section outlines the implementation schedule for the recommended NPS management measures. This section corresponds to the sixth EPA element.

> *Schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.*

Implementation of the recommended measures is dependent on a number of factors, many of which have been discussed in section 5.0 including cost, funding, and the amount of technical assistance required. The schedule should therefore focus on meeting the goals outlined in the document above. This will require a coordinated effort to initiate implementation in a proper and efficient sequence. It should once again be noted that the plan has been designed to be implemented over a number of years in order to distribute costs over time not only for the respective municipality but also for homeowners. A phased implementation schedule also allows project sponsors to more effectively manage a smaller number of projects at any particular juncture and to take advantage of continued education efforts to win support for project adoption. The following sections will outline the short term, medium term, and long term project implementation schedule.

7.1 Short Term Schedule

Short term is defined as a period of implementation lasting approximately 1 to 2 years. This implementation period will focus primarily on initiation tasks including planning activities, additional studies and surveys, identifying and acquiring technical assistance and securing funding. The success of the WPP will be largely dependent on this first phase to identify and mobilize the components necessary to implement NPS pollution reduction measures. It is also important to consider the entire development cycle of many of the discussed measures which may require lengthy hydrology and hydraulics studies as well as permitting and that final implementation may take several years from project initiation.

Most of the various management recommendations should be initiated during this phase. In particular municipal planning will be required to develop an internal timetable for implementation and spending which must include public input. High priority projects, identified in the candidate restoration site appendix (I), need to be addressed in the short term schedule to fix some of the more egregious problems that have a disproportionate affect on water quality or represent some other severe risk. Education and information communication must be initiated immediately in order to educate and build the public support upon which this plan is contingent. Technical assistance should be retained during this period in order to initiate the requisite studies or design work. Similarly, the non-technical or low cost solutions, such as cultural BMPs, should start to be implemented in order to affect water quality changes almost immediately. A summary table for the short term implementation schedule is provided below.

Table 40: Short Term Implementation Schedule

Short Term Implementation (1 to 2 years)	
Activity	**Description**
Planning	Further prioritize project implementation and timelines.
Technical Assistance	Identify and contact parties to provide the technical assistance to initiate project design and implementation.
Secure Funding	Investigate funding including grant oppurtunities and the use of public funds, low interest loans, or other financial vehicles.
Information and Education	Ramp up I/E efforts to effectively communicate message, interface with stakeholders, and build project support .
High Priority Projects	Initiate activities for the implementation of high priority measures identified in the restoration site appendix including bank stabilization, obstruction removal, and infrastructure protection projects.
Other Projects	Initiate projects that require a minimum of technical assistance including no-mow zones, low tech riparian buffer enhancement, cultural BMPs, invasive species control, and manure management plans. Many of these efforts will be predicated on the I/E activities. Open space preservation activities should be maintained during this period.
Monitoring	The monitoring program should be developed and implemented in this period. Early monitoring should focus on the collection of additional baseline data, particularly stream temperature, solids, and *E. coli* .

7.2 Medium Term Schedule

The medium term is defined as the period lasting from 2 to 5 years from the adoption of the WPP. This period is the work horse of the WPP and is the period when the bulk of implementation work should be conducted. More importantly, this period should build on the work conducted during the first phase of the schedule, namely implementing projects based on prioritization rankings, utilizing secured funds, constructing completed designs, and maintaining public participation in implementation garnered through I/E efforts. More specifically, this is the timeframe in which many of the more technically difficult measures are designed and installed including riparian buffer enhancement, structural BMPs, and bed and bank stabilization projects among others. Completion of projects located on public lands should be prioritized, but private projects should also be technically supported during this period. Maintenance of installed BMPs should be fully integrated during this point, and monitoring activities started in earnest to begin to document water quality changes. The table below provides a summary of the implementation activities.

Table 41: Medium Term Implementation Schedule

Medium Term Implementation Schedule (2 to 5 years)	
Activity	**Description**
Planning	Utilize the developed planning tools to begin widespread project implementation.
Project Designs	Designs for all selected mitigation measures should be completed during this period. More specifically, this will include designs for riparian buffer enhancement, structural BMPs, bed and bank stabilization, agricultural BMPs, and impoundment removal.
Implementation	Implementation for most measures should be started during this period. High priority projects should at least be initiated if not completed and low and medium priority projects started. Projects on public lands should be completed during this period if possible.
Landowner Projects	Projects initiated by landowners should begin during this period with appropriate assistance for funding and technical concerns provided by the municipality or other responsible agency.
Information and Education	I/E activities are continued as an integral component of the WPP. While education and participation is still the primary message relaying implementation success should become more prominent.
Maintenance	Maintenance activities should be fully incorporated into any implementation projects and otherwise adopted for existing BMPs.
Monitoring	Routine monitoring should now be fully integrated into the WPP activities to document the environmental effects of project implementation. This data should be freely available and effectively communicated to stakeholders.

7.3 Long Term Schedule

The long term implementation schedule extends from year 5 to 10. This period is marked by the final implementation of the recommended measures. Most projects should be designed by this time and the focus will be implementing the remaining medium and low priority designated activities. This period will also involve the implementation of projects for which funding posed a problem. Monitoring will play an increasingly important role during this phase as the monitoring results will be used to assess the efficacy and functionality of the implemented measures versus the listed milestones and SWQS. Consequently, the monitoring results may be used to direct further activity in this period to address any potential shortcomings. Information and education programs continue to be important in this period and should stress not only landowner involvement but successes associated with BMP adoption and the results of the monitoring. The following table provides a summary of the long term implementation schedule.

Table 42: Long Term Implementation Schedule

Long Term Implementation Schedule (5 to 10 years)	
Activity	**Description**
Implementation	Project designs should for the most part be completed by this time and finally implemented *in-situ*. Medium priority projects should be implemented first followed by low priority projects. This period will also be utilized to implement projects where funding had been lacking previously. Meeting milestones as indicated by project completion and water quality metrics will be important in this period and may require additional planning to comply with the WPP.
Information and Education	I/E activities are continued as an integral component of the WPP. Education is still important in this period as is the encouragement of landowner participation, but the implementation of specific projects as well as documented changes to water quality and environmental quality should be fully integrated.
Maintenance	Maintenance activities continue to be routine, although the intensity of maintenance may decline as projects are deemed functional.
Monitoring	Monitoring during this period should be strongly focused on meeting water quality and other environmental goals during this period. Comparisons to SWQS are important during this point, and failure to meet goals will be used to assess project implementation and identify additional opportunities to improve water quality.

8.0 Milestones

This section outlines the development of interim milestones used to track project implementation as outlined in the preceding section. Milestone development is an important planning tool to chart progress and sets clear objectives for the implementation process. This section corresponds to the seventh EPA element.

> *A description of interim measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.*

The development of milestones is somewhat difficult due to the uncertainty of funding looking ahead and thus some of the longer term milestones are less well defined. However, the ability to follow the implementation schedule and complete the opening phases of the WPP, namely careful planning, the continued identification of priority sites, information and education, and public buy-in, will jumpstart the implementation process to make sure that defined goals of improving water quality and protecting natural resources in the watershed are met.

8.1 Reporting

To measure the success of this Watershed Protection Plan a variety of milestones and measurable criteria are suggested related to four basic strategies: Planning and Agency Coordination, Mitigation Projects, Monitoring, and Education. It is recommended that the watershed communities track their progress on implementing the various aspects of this WPP by summarizing their activities in Annual Reports disseminated to stakeholders and submitted to the NJDEP Division of Watershed Management.

It should be noted that the milestones are configured to assess the implementation progress and other goals in the period preceding the stated objective. Each of the listed milestones, with the exception of Year 1 milestones conforms to the end of an implementation cycle as outlined previously. For example, the Year 5 milestones conform to the medium term implementation schedule and the stated objectives for this milestone will assess project implementation and success from years 2 through 5. Similarly, the Year 10 milestone tracks and assesses the implementation of the long term schedule from years 5 through 10. The short term implementation schedule is tracked by both Year 1 and Year 2 milestones. Increased scrutiny of this period has been proposed to ensure the initiation of the plan. Stated somewhat differently the milestones can also be thought of as the specific goals and objectives for the preceding period. In other words the milestones for Year 5 should be pursued in the implementation period from years 2 through 5 and the milestones will then be used to track whether significant progress was made.

8.2 Milestones Year 1

The first year milestones are based on the initiation of the project to lay the groundwork from which to build and subsequently implement creek and watershed restoration and management projects. An important goal during this period of implementation is the adoption of the plan by both West Amwell Township and NJDEP. Upon plan acceptance planning steps need to be initiated to invite public comment and further identification and prioritization of candidate restoration sites. At the same time public outreach efforts should be initiated as well as education efforts to generate the technical acumen and will to implement many of these measures. While the first year may be primarily a planning period it will also be important to begin identifying technical assistance and seeking funding opportunities to correct the high priority issues noted in Appendix I and any others proposed by the public. The following table shows a list of Year 1 milestones.

Table 43: Milestones Year 1

Milestones Year 1	
Adoption	Have WPP adopted by NJDEP and West Amwell Township.
Information	Publish WPP and make freely available to stakeholders, including residents, landowners, and farmers. At a minimum the adopted plan should be available online and a hardcopy available at the municipal building. A presentation regarding the WPP will be conducted by Princeton Hydro at the municipal building.
Planning	Develop and publish the project priority list based on the WPP and stakeholder recommendations.
Funding and Technical Assistance	Secure technical assistance and apply for grants to implement 50% of high priority projects.
Education	Begin publishing educational materials about the WPP in at least two formats including newsletters and newspaper advertisements.
Monitoring	Initiate monitoring program and publish draft results.
Other Projects	Begin implementation of several demonstration projects including riparian buffer enhancement and cultural BMP adoption.

8.3 Milestones Year 2

The second year milestones become somewhat more diverse and concentrate on developing designs and implementing projects. In effect the milestones in this period are enacting the planning and design elements developed in the first year and assess the overall implementation of the short term schedule. The year 2 milestones also include numeric goals for implementation and public participation, including initiation of all high priority goals and securing participation of 10 landowners. Year 2 will also mark the first point at which monitoring data is utilized to evaluate water quality trends. Education continues to be an important component of WPP implementation and workshops should be held to instruct municipal employees on adopted measures and to further educate the public. The completion of at least one demonstration project is recommended, which would be an ideal location for the public workshop. Milestones set for this period, especially the implementation of design work, will ensure that project implementation is progressing as planned. Any deviation can be addressed and corrected in this period. Table 44 lists the Year 2 Milestones.

Table 44: Milestones Year 2

Milestones Year 2	
Information and Education	Expand these efforts. Develop a website as a clearinghouse for all information pertaining to the WPP including educational materials, priority lists, monitoring results, and the WPP. Update Master Plan to incorporate elements of the WPP.
Workshops	Hold at least two workshops. One should be focused on municipal and county employees to communicate the goals of the WPP and to implement cultural BMPs. The second workshop should focus on community outreach to implement BMPs. Materials such as a standard riparian buffer planting list should be provided as well as plans for cost sharing or funding.
Funding and Technical Assistance	Continue to seek funding and assistance for projects. Initiate implementation plans for the remaining high priority items. Develop initiation plans for 20% of medium priority projects.
Assess Participation	Secure participation of at least 10 landholders for riparian buffer enhancements. Update Master Plan
Demonstration Project	Complete at least one demonstration project, preferably on publically owned property to showcase project potential. This should probably focus on riparian buffer enhancements, but may also include adopted cultural BMPs.
Monitoring	Utilize collected data to assess water quality trends.

8.4 Milestones Year 5

The milestones for the fifth year are strongly related to actual *in-situ* installation of NPS management measures and assess project implementation and water quality objectives from years 2 through 5, the medium term implementation schedule. The main components of this milestone include increased functionality of riparian buffers, with a goal of implementing up to 4 stream miles of enhancements, 80% implementation of high priority projects, and 50% implementation of medium priority sites. This period also marks the first point at which monitoring data is routinely used to evaluate implementation projects. In particular goals are set for meeting temperature standards at 80% of the monitoring stations as well as decreased nutrients and solids in stormwater. An evaluation of the open space preservation program should be developed at this point. A comprehensive review of monitoring data is also in order and may include updated pollutant and hydrology modeling using collected data and up-to-date GIS data. The review of the program in general should be used to direct further project implementation in the watershed and may re-order the priority list. The year 5 milestones are found below in Table 45.

Table 45: Milestones Year 5

	Milestones Year 5
Water Quality Standards	Demonstrate compliance with SWQS for temperature at 80% of monitoring stations. Demonstrate decreased stormwater concentrations of TP, TSS, and *E. coli*. Demonstrate decreased invasive species colonization and decreased rates of erosion. Demonstrate increased NJIS or similar New Index macroinvertebrate scores.
Project Goals	80% implementation of high priority sites and 50% implementation of medium priority sites dependent on the availability of funding. Continue developing plans for the implementation of medium and low priority sites.
Riparian Buffer Enhancement	Demonstrate inititation of riparian buffer enhancement projects on 4 stream miles. Secure participation of 40 landowners.
Monitoring	Prepare a five year plan summarizing collected data and update pollution loading and hydrology models using current NJDEP published GIS databases. Use results to direct further work.
Information and Education	Continue expansion of education program and dispense educational materials on riparian buffer enhancements, septic management, manure management programs, cultural BMPs, and WPP implementation successes.
Open Space	Evaluate open space acquisitions and other preservation measures and identifiy further opportunities for preservation.

8.5 Milestones Year 10

The milestones set for the tenth year are predicated on meeting the final goals of the WPP. In particular this includes the restoration of 10 miles of riparian buffer throughout the watershed as well as demonstrating 10% reduction of TP, TSS, and *E. coli* stormwater concentrations and decreased erosion and invasive species colonization in the watershed. All prioritized items should be addressed at this point given the availability of funding. A final report should be prepared summarizing all project activity and relying heavily on collected water quality monitoring data to analyze affects to water quality. This final report should build on the work conducted over the preceding 10 years to define goals for the future and to continue to implement projects. The year 10 milestones are found in Table 46 below.

Table 46: Milestones Year 10

Milestones Year 10	
Implementation	Complete installation of prioritized items. Complete 10 stream miles of buffer enhancement. Tally new open space preservation.
Water Quality Standards	Meet temperature standards at all monitoring stations. Exhibit 10% reductions in TP, TSS, and *E.coli* stormwater concentrations. Show decreased erosion and insave species colonization.
Monitoring	Compile final report showing monitoring results. Use the final data to direct future efforts in the watershed.
Planning	Prepare an assessment of the implementation of the WPP and update it to meet new objectives and continue preservation and NPS pollution mitigation in the watershed.

9.0 Monitoring Criteria

This section defines the criteria used to determine NPS loading reductions and other goals. As explained in the EPA guidance document these criteria are not the same as the state SWQS, but in the case of this project many of the parameters will likely be adopted as criteria. Due to the exhaustive watershed characterization summarized in this WPP and explained in further detail in the *Characterization and Assessment Report*, many if not most of the water quality monitoring tools and other environmental survey methods should be utilized again for this monitoring effort both as a set of standard metrics and for comparative purposes. This section is the eighth EPA element.

> *A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward obtaining water quality standards.*

As mentioned above, most of the groundwork for the establishment of monitoring criteria was completed in the characterization phase of the WPP. Utilizing those metrics already in place will increase statistical significance of any water quality comparison, a crucial step in determining the performance of implemented projects, especially when assessing cumulative loading reductions. It is important to note that many of the metrics identified were triggers to the listing of the Alexauken Creek on the 303(d) list and therefore the origin of this WPP.

9.1 *In-situ* Metrics

The collection of *in-situ* data will be of utmost importance in the monitoring efforts, as water temperature was one of the primary symptoms of degraded water quality in the watershed. In addition to temperature, other *in-situ* parameters should include specific conductance, pH, and dissolved oxygen (concentration and percent saturation). These metrics have been fully characterized in the watershed and represent a comparative baseline for future efforts. These measurements may also be reliable indicators of restoration efforts and are valuable for the ability integrate physical, chemical, and biological signals.

9.2 Discrete Metrics

Discrete metrics, water samples analyzed by an aqueous chemistry laboratory, are complements to *in-situ* measurements and have been a critical component in characterizing the water quality of the Alexauken. Discrete analytes already compiled for the Alexauken include: Total Phosphorus (TP), Total Suspended Solids (TSS), Total Kjeldahl Nitrogen (TKN), and Nitrate (NO_3). At a minimum, TP and TSS should be included in any monitoring program as these two parameters are the primary NPS pollution targets of many of the recommended management measures. TKN and NO_3

may be dropped in future efforts because these nitrogen species were generally within acceptable limits when compared to applicable SWQS, are projected to decrease in the future, and to provide cost savings. However, NJDEP may require continued monitoring of these parameters to continue to track eutrophication trends in the watershed or identify additional loading sources in a more general survey.

In addition to the discrete monitoring of chemical constituents, fecal coliform or *E. coli* monitoring may be considered a discrete analyte. *E. coli* loading was shown to be very high in the watershed, routinely exceeding both acute and chronic standards at the majority of the sampled stations. This exceedance violates recreational use standards, and while swimming may not be a primary recreational activity in the tributary network, elevated *E. coli* concentrations need to be monitored. In addition to normal tracking, some of the recommended management measures specifically target *E. coli* loading and tracking these pathogens will be essential in monitoring the performance of these measures.

Another important consideration in monitoring is the characterization of both baseflow and stormflow events. For the most part *in-situ* monitoring will be confined to the collection of baseflow data, but discrete samples should be collected under both flow regimes due to wide variability under different flow conditions. Indeed, some of the water quality impairments were detected only under stormflow conditions, especially TSS. As many of the recommended management measures are geared towards the treatment of stormwater the collection of discrete samples during elevated flow periods is essential to understanding and assessing the function of implemented management measures.

9.3 Hydrology Metrics

A limited amount of field-collected hydrology data was assembled during the characterization of the watershed, but enhanced efforts should be made to improve hydrology modeling. In particular efforts should be made to monitor stream discharge over time using the established station near the Rt. 29 bridge building on the completed stage-discharge ratings curve. In-stream hydrology monitoring would be useful in assessing both baseflow, with a projected increase due to improved infiltration, and decreased stormflows, characterized by decreased hydraulic loading relative to storm intensity with improved stormwater management. These changes in hydrology are related to a variety of recommended measures and should be tracked to monitor progress and NPS pollution reductions.

9.4 Biological Metrics

Several biological metrics should be considered as monitoring criteria as well including macroinvertebrate and fish surveys; Alexauken Creek was listed for the non-attainment of designated aquatic life uses for general aquatic life and trout. Fish communities are described in the state using the NJDEP Fish Index of Biotic Integrity while macroinvertebrates are scored using the New Index, an update to the older NJIS (New Jersey Impairment Score). Many of the recommended management measures should improve both fish and macroinvertebrate communities through lowering water temperatures and improving habitat by reducing erosion, sedimentation, and nutrient enrichment. The response in these communities should therefore be monitored. It is important to note that both of these survey techniques are periodically repeated by NJDEP, but in absence of this response these efforts should be part of the monitoring program. It should be noted that the change in macroinvertebrate scoring will not be directly comparable and that the original NJIS scores should be recalculated using the New Index method.

9.5 Qualitative Assessments

Qualitative and semi-quantitative assessments may factor in the monitoring of the stream to track water quality and environmental changes. This would include employing methodology similar to that used in the Volunteer Visual Assessments to monitor streamside land uses, erosion, outfalls, invasive species, high value resources, and other properties. Another survey to consider is the Visual Habitat Assessment (VHA). All of these techniques have been used to document existing conditions in the watershed and should play a role in documenting progress in the future. These types of assessments may be employed at a low frequency.

9.6 Other Criteria

A variety of other metrics should be tracked to follow implementation progress in the watershed. While not technically monitoring criteria an accounting of implementation is important to assess milestones. Records should be maintained about the number and type of projects implemented, the number of linear stream feet restored, the area in acres of restoration programs, and the acres of open space preserved.

9.7 Site Specific Criteria

Site specific monitoring is a distinct exercise from the watershed scale monitoring discussed above. However, some of the same criteria may be utilized as required by NJDEP. Performance monitoring of structural BMPs is usually specified prior to permitting and is likely to measure pre-installation versus post-installation NPS pollutant concentration to demonstrate treatment or conversely measure influent and effluent pollutant concentration to calculate removal capacity. Other monitoring may be related to erosion in bank stabilization projects and general function. Another form of site specific monitoring, and likely the one to be utilized most often, is characterizing vegetation growth in restored sites to ensure maximum benefit and to replace vegetation as necessary.

9.8 Use of Criteria

Besides documenting the progress of implementation and improving water quality conditions monitoring also serves to document problems areas or identify deficiencies in the implementation program. In such a case these monitoring evaluations can be used to reorder project implementation or priority to address specific shortcomings. At such a juncture this may require the redesign of certain management measures, the implementation of more projects, or an evaluation of the program at large. It is also important to note that monitoring criteria may uncover new perturbations at which point enforcement actions or other responses may be necessary to correct the problem.

10.0 Monitoring Plan

As discussed throughout this document monitoring is a crucial component of identifying, documenting, and assessing water quality impairments. Armed with such data recommendations can then be made and designed around existing conditions. Perhaps even more importantly, monitoring is then used to assess the effectiveness of implemented management measures and to document the general water quality of the system over the long term. This section corresponds to the ninth and final EPA element.

> *A monitoring component to evaluate the effectiveness of implementation efforts over time, measured against the criteria established to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.*

This monitoring program will mirror many parts of the original characterization effort using similar methodologies to evaluate the criteria listed above. The most significant differences will be in the scope of sampling and it is recommended that sampling frequency and the number of stations be reduced to provide cost savings. In the end the goal of monitoring is to provide data to track and analyze long-term data trends, document water quality changes, evaluate management measure performance, and provide the requisite data to project sponsors, stakeholders, and regulators. All sampling plans will likely require the development of a Quality Assurance Project Plan (QAPP) and approval by NJDEP.

10.1 Quarterly Sampling

Quarterly sampling is recommended for future sampling programs to provide a balance between data collection, data quantity, and cost. Specifically, quarterly sampling, when conducted over a long period, will generate a sizable quantity of data and more specifically allows a seasonal sampling program to generate data throughout the year. This quarterly sampling will focus on the collection of *in-situ* parameters such as temperature, pH, specific conductance, and dissolved oxygen concentration, as well as discrete parameters including TP, TSS, and *E. coli*. Nitrogen species have been omitted as is Total Dissolved Solids (TDS) to control cost and because these parameters have generally been found at acceptable concentrations. *In-situ* measurements shall be made with a calibrated multi-probe water quality meter and discrete samples should be analyzed by a state certified laboratory. This quarterly sampling plan is focused on collecting baseflow data.

The number of stations in this plan is reduced to four. This includes Station 1 at Rt. 29, Station 3 at Hamp Road, Station 6 at Queen Road near Mount Airy, and Station 7 on the East Branch near Rocktown-Lambertville Road (station numbering adheres to the C&A report format). These stations are selected for a variety of reasons. Station 1 represents the lowest station in the watershed and integrates the influences of the entire watershed.

Station 3 was chosen as a central point and a point of known temperature impairment. Station 6 is the uppermost station on the main stem and is largely influenced by the Rt. 202 corridor. Station 7 represents a headwater and is representative of the Sourland soils and geology. This station also exhibited a variety of water quality impairments including excessive *E. coli* concentrations and nutrient loading.

10.2 Storm Sampling

While the quarterly sampling focuses on the collection of baseflow data storm sampling is also important because many of the water quality impairments detected previously were most evident under stormflow conditions. Stormflow sampling should be conducted twice a year, once during the growing season (approximately April to October) and again in the non-growing season (November through March) to explicitly show the affect of seasonality. Sampling should be conducted at the stations identified in the quarterly sampling and consist solely of discrete sampling utilizing the same battery of discrete parameters (TP, TSS, and *E. coli*); *in-situ* sampling may be included but is not necessary. Storm sampling should focus on the collection of samples during elevated flows preferably of a storm with a cumulative precipitation total of an inch or more. Samples may be collected using either an automated sampler or manually composited at a set interval over at least four hours. Ideally the sampling should incorporate the first flush at the beginning of the storm, but elevated flow status is a more important criterion for sampling initiation.

10.3 Continuous Temperature Sampling

Temperature data should be collected continuously throughout the monitoring period to assess water temperature throughout the year. Unlike quarterly sampling events that utilize a water quality meter continuous temperature data will be collected utilizing dedicated temperature data loggers. These data loggers again should be installed at the same four locations described above and should be set to collect discrete data points approximately once per hour.

10.3 Hydrology Sampling

Hydrology sampling needs to be expanded in the Alexauken to validate hydrology models and to determine if implemented management measures are in fact altering the hydrology of the system. More specifically this discharge data will be used to determine a number of hydrologic and hydraulic properties of Alexauken Creek, including average flow, baseflow, response to storm events, and seasonality.

As discussed above a stage-discharge ratings curve was developed during the characterization phase of this project at Station 1. This ratings curve needs to be refined to better reflect higher flow conditions by conducting additional discrete discharge measurements and adding it to the existing dataset. This improved ratings curve will be utilized to calculate stream discharge by inputting stage (stream level) data.

Stage data will be collected with a pressure transducer data logger which will collect continuous stage data at a set interval; sub-hour sampling frequency is recommended for this exercise. The data logger should be installed in close proximity to the existing staff gage.

10.4 Biological Sampling

Biological sampling, including fishery surveys and macroinvertebrate sampling, is periodically conducted by NJDEP personnel, but supplemental sampling may be necessary. Sampling should probably be conducted approximately once every five years, although replicate samples may be considered during each sampling event. Fishery surveys will follow protocol outlined in the FIBI for wadable high-gradient rivers and will focus on electrofishing techniques. Macroinvertebrate surveys will follow the methodology outlined in the High Gradient Macroinvertebrate Index (HGMI) in the AMNET SOP. This method focuses on the collection of macroinvertebrates with D-nets and limited counts (>100) to roughly a family level taxonomy.

10.5 Other Sampling

Additional sampling should focus on the use of the qualitative or semi-quantitative assessments discussed above. Visual Habitat Assessments, as outlined in the EPA Rapid Bioassessment Protocols, should be conducted concurrently with macroinvertebrate sampling. Other large scale efforts, like those employed during the Volunteer Visual Assessment component of this study should probably be conducted at the conclusion of the implementation period to evaluate the widespread results.

10.5 Analysis and Reporting

Analyzing the collected data and presenting it in a useful fashion is important to objectively assess implementation and effectively communicate with stakeholders. This will be accomplished in part by compiling yearly reports summarizing results and monitoring activities. Analysis in these reports should focus on comparative trend analyses using baseline characterization data and framing the report towards meeting milestones and management goals. In addition to this reporting periodic review of the entire dataset needs to be conducted. At this period, including the five and ten year milestones, updates should be made to both hydrology and pollutant models using newly available GIS data as well as all collected data to explore the results of the WPP.

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Appendix I

Restoration Sites

#1: Alexauken Creek Confluence Cleanup

Segment A, Reach 2

Position
N 40.377308°, W 74.951040°

Priority/Rank – Low, 12th

Concerns

- Accumulated Debris
- Bank Erosion

Recommendations

- Debris Removal
- “No Dumping” Signage

#2: Alexauken Creek Bank Stabilization

Segment A, Reach 4

Position
N 40.381779°, W 74.947736°

Priority/Rank – High, tied-4th

Concerns

- Extreme bank erosion
- Mass wasting
- Imperiled structure

Recommendations

- Conduct a detailed Hydrology and Hydraulics Study (H&H)
- Install high intensity bank stabilization structures such as vegetated gabions
- Install flow deflection device such as J-hooks
- Reduce stormwater discharge rates and volumes through stormwater management practices
- Consider removal of structure to avoid future collapse into channel
- Utilize this as a public education example of encroachment development issues

#3: Alexauken Creek Infrastructure Investigation

Segment A, Reach 5

Position
N 40.382532°, W 74.947443°

Priority/Rank – Low, tied-9th

Concerns

- Reported erosion around bridge pylon on Rt. 202 bridge

Recommendations

- Notify NJDOT
- Inspect
- Armor section with riprap or install a flow deflection structure

#4: Alexauken Creek Obstruction Removal

Segment B, Reach 1

Position
N 40.392056°, W 74.939167°

Priority/Rank – Low, tied-9th

Concerns

- Potential Obstruction
- Debris in Channel
- ATV use in floodplain

Recommendations

- Investigate potential obstruction
- Remove as necessary and install grade control such as an engineered rock riffle
- Public education campaign regarding impacts to vegetation and erosion caused by ATV use

#5: Alexauken Creek Tributary Outfall Repair

Segment B, Reach 2

Position
N 40.386028°, W 74.943972°

Priority/Rank – Medium, tied-8th

Concerns

- Gully formation and erosion
- Excessive discharge velocity

Recommendations

- At outfall regrade and convert to a vegetated swale
- At concrete channel reduce flow velocity through conversion to a vegetated swale if possible, a riprap lined channel to dissipate energy, or a step pool channel
- Evaluate at point of discharge to tributary

#6: Alexauken Creek Detention Basin Retrofit

Segment B, Reach 3

Position
N 40.384289°, W 74.936263°

Priority/Rank – High, tied-5th

Concerns

- Limited recharge capacity and volume reduction
- Potential increases in detained water
- Excessive discharge velocity
- Erosion

Recommendations

- Outlet can be modified to provide longer retention
- Conversion to bioretention basin or infiltration basin
- Identify source of erosion and revegetate banks
- Reduce runoff volume through the use of dry wells, rain barrels, or rain gardens

#7: Alexauken Creek Tributary Impoundment

Segment C, Reach 5

Position
N 40.393806°, W 74.943472°

Priority/Rank – Medium, tied-8th

Concerns

- Increased stream temperature due to impoundment
- Gully formation at pond outfall
- Excessive discharge velocity
- Possible failure of pond berm with migrating headcut

Recommendations

- Explore impoundment removal or shoreline aquascaping
- Mitigate headcut with grade control such as cross vane
- Reconfigure outfall pipe to reduce erosive discharge
- Stabilize gully banks with vegetation and coarse substrate

#8: Alexauken Creek Tributary Bank Stabilization

Segment C, Reach 6

Position
N 40.391470°, W 74.943186°

Priority/Rank – Medium, tied-8th

Concerns

- Bank erosion >10 feet
- Downstream sedimentation

Recommendations

- Bank stabilization with vegetated riprap
- Vegetate upper portion of bank
- Utilize large rootwads at toe of bank
- Redirect flow with rock vane
- Promote stormwater management upstream
- Accessibility within an established riparian forest is an issue
- Highly erodible soils significantly contribute to erosion in this area

#9: Alexauken Creek Tributary Bank Stabilization

Segment I, Reach 2

Position
N 40.397590°, W 74.923304°

Priority/Rank – Medium, tied-8th

Concerns

- Bank erosion
- Deposition of fine materials
- Potential loss of canopy vegetation
- ATV crossing and bank erosion

Recommendations

- Establish a no-mow zone or vegetative filter strip at toe of field
- Stabilize bank with boulder toe protection
- Limit ATV crossings or establish hardened crossing

#10: Alexauken Creek Tributary Bank Stabilization

Segment I, Reach 3

Position
N 40.395361°, W 74.916361°

Priority/Rank – Medium, tied-6th

Concerns

- Unknown discharge
- Sedimentation and erosion
- Invasive species

Recommendations

- Establish a no-mow zone or riparian buffer enhancement at margin of field
- Investigate source and water quality of PVC pipe discharge
- Remove invasive vegetation and establish native plants

#11: Alexauken Creek Tributary Stormwater Management

Segment K, Reach 1

Position
N 40.400433°, W 74.924964°

Priority/Rank – Low, tied-10th

Concerns

- Gully formation
- Soil erosion

Recommendations

- The formation of these gullies is linked to field runoff
- Implement vegetated drainage swales and other stormwater management features to reduce runoff velocity
- Forested uplands limit utility of stabilization measures in gully

#12: Alexauken Creek Tributary Riparian Enhancement

Segment K, Reach 1

Position
N 40.405228°, W 74.931088°

Priority/Rank – Low, tied-11th

Concerns

- Dump site and debris
- Maintained lawn with bank erosion

Recommendations

- Debris piles should be removed
- Maintained lawn should have a no-mow zone
- Since trees are established shrub and herbaceous vegetation should be encouraged or planted

#13: Alexauken Creek Tributary Channel Improvements

Segment K, Reach 2

Position
N 40.405039°, W 74.930787°

Priority/Rank – High, tied-5th

Concerns

- Agricultural crossing
- Erosion and solids loading
- Reported manure runoff
- Debris in channel and barrier to passage

Recommendations

- Install a hardened agricultural crossing such as a hog panel crossing and stoned driveway
- Maintain manure management areas away from riparian corridor
- Remove obstruction, stabilization likely not needed

#14: Alexauken Creek Tributary Buffer Enhancement

Segment K, Reach 3

Position
N 40.411474° W 74.937157°

Priority/Rank – Medium, tied-6th

Concerns

- Invasive species monoculture
- Exclusion of native shrub and herbaceous layer

Recommendations

- Mechanical or chemical removal of invasive species
- Riparian buffer enhancement using native vegetation to enhance wildlife habitat value and other services

#15: Alexauken Tributary Outfall Maintenance

Segment K, Reach 6

Position
N 40.408237°, W 74.935699°

Priority/Rank – Low, tied-10th

Concerns

- Outfall sedimentation
- Bed incision

Recommendations

- Implement normal maintenance of upstream devices such as catch basins to limit stream sediment deposition
- Reconnect pipe to stream bed by building up bed with riprap to reduce incision

#16: Alexauken Creek Tributary Bank Stabilization

Segment K, Reach 7

Position
N 40.410400°, W 74.936774°

Priority/Rank – Medium, tied-8th

Concerns

- Channel sedimentation
- Bank erosion

Recommendations

- Establish a no-mow zone and plant shrubs along the swale to stabilize bank and prevent further deposition of bank materials in channel

#17: Alexauken Creek Tributary Wetland Enhancement

Segment K, Reach 8

Position
N 40.411333°, W 74.936861°

Priority/Rank – Medium, tied-6th

Concerns

- Invasive species colonization
- Wetland disturbance
- Agricultural runoff

Recommendations

- Remove invasive species chemically
- Plant wetland vegetation, especially herbaceous species
- Maintain no-mow zone around wetland area
- Limit disturbance in wetland

#18: N. Branch Alexauken Creek Tributary Obstruction Removal

Segment M, Reach 3

Position
N 40.412682°, W 74.919220°

Priority/Rank – High, 3rd

Concerns

- Bank erosion
- Migrating head cut
- Debris and potential passage barrier
- Degraded riparian zone

Recommendations

- Remove obstruction
- Grade banks and vegetate
- Establish grade control such as cross vane
- Enhance buffer above through no-mow zone or planting

#19: N. Branch Alexauken Creek Tributary Buffer Enhancement

Segment M, Reach 3

Position
N 40.412796°, W 74.919837°

Priority/Rank – Medium, tied-7th

Concerns

- Degraded buffer
- Lack of adequate shading
- Invasive species
- Sedimentation

Recommendations

- Riparian buffer enhancement with removal of invasives and subsequent planting of three vegetation types: herbaceous, shrub, and tree
- Establish canopy

#20: N. Branch Alexauken Creek Tributary Obstruction Removal

Segment N, Reach 2

Position
N 40.418160°, W 74.933814°

Priority/Rank – Medium, tied-8th

Concerns

- Major barrier to fish passage
- Altered stream hydrology
- Stream warming
- Captured legacy sediment

Recommendations

- Remove obstruction
- Excavate or grade legacy sediment to reform channel
- Install grade control, such as a step pool

#21: N. Branch Alexauken Creek Tributary Buffer Enhancement

Segment N, Reach 2

Position
N 40.417187°, W 74.931571°

Priority/Rank – Medium, tied-8th

Concerns

- Maintained lawn space in floodplain
- Erosion and sedimentation
- Impaired buffer services
- Reported manure runoff

Recommendations

- Establish no-mow zone or enhanced riparian buffer with three-tier planting
- Vegetated filter strips adjacent to pastures
- Install boulder toe protection on outside bends
- Implement manure management practices

Princeton Hydro pH

#22: N. Branch Alexauken Creek Tributary Buffer Enhancement

Segment N, Reach 3

Position
N 40.416430°, W 74.930247°

Priority/Rank – Medium, tied-7th

Concerns

- Pooled runoff from adjacent pasture
- Outfall causing contributing to bank erosion
- Potential coliform and nutrient loading

Recommendations

- Establish vegetative filter strip at base of field
- Replace corrugated pipe with vegetated swale for conveyance
- Identify source of pipe

#23: N. Branch Alexauken Creek Tributary Impoundment Enhancement

Segment N, Reach 4

Position
N 40.414874°, W 74.930272°

Priority/Rank – Low, tied-10th

Concerns

- Impoundment
- Dam in disrepair
- Invasive species

Recommendations

- Investigate safety of dam
- Removal if deemed unsafe and bank stabilization
- Otherwise consider aquascaping with native wetland vegetation

#24: N. Branch Alexauken Creek Bank Stabilization

Segment O, Reach 2

Position
N 40.421280°, W 74.913215°

Priority/Rank – High, tied-5th

Concerns

- Bank excavation
- Erosion
- Sedimentation
- Vegetation removed

Recommendations

- Stabilize lose soil with brush mattress
- Limit riparian disturbance

#25: N. Branch Alexauken Creek Tributary Wetland Enhancement

Segment Q, Reach 8

Position
N 40.430829°, W 74.925800°

Priority/Rank – Low, tied-11th

Concerns

- Degraded wetland
- Minor erosion
- Invasive species

Recommendations

- Establish a no-mow zone or riparian buffer enhancement around margin of wetland
- Utilize existing native vegetation as a component of protection
- Remove invasive vegetation

#26: Alexauken Creek Riparian Enhancement

Segment R, Reach 1

Position
N 40.403422°, W 74.915305°

Priority/Rank – High, 1st

Concerns

- Severe erosion
- Severe sedimentation
- Lack of riparian buffer
- Stream warming
- Nutrient loading

Recommendations

- Establish riparian buffer enhancement or at a minimum establish vegetative filter strips
- Take advantage of various incentive and protection programs
- Bank grading and toe protection measures
- Minimize runoff generation

#27: Alexauken Creek Conveyance Improvements

Segment R, Reach 1

Position
N 40.403557°, W 74.921922°

Priority/Rank – Medium, tied-8th

Concerns

- Gully formation
- Downstream sediment depostion

Recommendations

- Assess conveyance source
- Where appropriate utilize vegetated swales to convey water
- Otherwise armor channel and bank

#28: Alexauken Creek Outfall and Obstruction Investigation

Segment R, Reach 1

Position
N 40.398719°, W 74.925527°

Priority/Rank – Low, tied-11th

Concerns

- Potential barrier to passage
- Erosion
- Altered hydrology

Recommendations

- Current function and original design of these systems is unknown
- Conduct field investigation to determine function
- Alter outfall flow path
- Possibly remove collapsed bridge

#29: Alexauken Creek Riparian Buffer Enhancement

Segment R, Reach 1

Position
N 40.401236°, W 74.924014°

Priority/Rank – High, tied-4th

Concerns

- Maintained lawn to top of bank
- Severe erosion
- Channel widening

Recommendations

- Bank grading
- Low intensity solutions such as brush mattresses and live fascines should be utilized
- No-mow zone creation

#30: Alexauken Creek Bank Stabilization

Segment U, Reach 6

Position
N 40.402778°, W 74.910657°

Priority/Rank – High, tied-2nd

Concerns

- Severe bank erosion
- Roadway imperiled

Recommendations

- Bank armoring using vegetated gabion baskets along roadway
- Boulder toe protection on other bank

#31: Alexauken Creek Stormwater Infrastructure

Segment U, Reach 7

Position
N 40.402714°, W 74.911480°

Priority/Rank – High, tied-5th

Concerns

- Erosion related to high discharge velocity
- Potential loading of road grit solids and petroleum hydrocarbons and metals

Recommendations

- Routine maintenance of catch basin at upper end of pipe
- Retrofit catch basins for increased pollutant removal using filter media, vortex capture, or other NJCAT certified designs

#32: Alexauken Creek Riparian Buffer Enhancement

Segment U, Reach 8

Position
N 40.403179°, W 74.915872°

Priority/Rank – High, tied-2nd

Concerns

- Severe erosion
- Lack of riparian buffer
- Stream warming
- Agricultural operations to top of bank

Recommendations

- Creation of riparian buffer utilizing native vegetation
- Bank grading to stabilize banks
- Use of flow deflectors to minimize continued lateral migration of stream channel
- Toe protection to prevent further loss of agricultural lands

#33: Alexauken Creek Tributary Agricultural BMPs

Segment W, Reach 2

Position
N 40.405900°, W 74.897341°

Priority/Rank – Medium, tied-7th

Concerns

- Soil erosion
- Gully formation
- Nutrient and solids loading

Recommendations

- Implementation of contour farming
- Creation of grassed waterway to convey runoff and minimize flow velocity and solids loading
- Continued maintenance of plant residue to limit soil erosion

#34: Alexauken Creek Tributary Buffer Enhancement

Segment W, Reach 5

Position
N 40.403851°, W 74.901918°

Priority/Rank – Medium, tied-6th

Concerns

- Maintained lawn to top of bank
- Lack of riparian vegetation
- Erosion and sedimentation
- Stream warming

Recommendations

- Establish no-mow zone
- Transition to riparian buffer planting over time
- Utilize existing trees and other vegetation where appropriate
- Boulder toe protection where necessary

#35: E. Branch Alexauken Creek Vernal Pool

Segment X, Reach 2

Position
N 40.396897°, W 74.898425°

Priority/Rank – Medium, tied-7th

Concerns

- Potential disturbance of outstanding natural resource
- Potential sedimentation and pollutant loading from adjacent pasture

Recommendations

- Public education of outstanding ecological value of vernal pools
- No disturbance of site
- Establishment of increased field border width at top of hill

#36: S. Branch Alexauken Creek Obstruction

Segment AA, Reach 1

Position
N 40.394755°, W 74.901091°

Priority/Rank – Medium, tied-6th

Concerns

- Barrier to fish passage

Recommendations

- Decrease hydraulic jump distance through the installation of small cross vanes in series

#37: S. Branch Alexauken Creek Obstruction

Segment AA, Reach 2

Position
N 40.395675°, W 74.900903°

Priority/Rank – Medium, tied-7th

Concerns

- Barrier to fish passage
- Failed dam may contribute to erosion when breached
- Lack of shrub layer
- Temperature impairment

Recommendations

- Remove obstruction in stream
- If necessary install grade control
- Plant shrubs along bank

#38: S. Branch Alexauken Creek Tributary Buffer Enhancement

Segment CC, Reach 4

Position
N 40.379872°, W 74.893402°

Priority/Rank – Medium, tied-7th

Concerns

- Maintained lawn space to top of bank
- Pollutant loading
- Sedimentation
- Erosion

Recommendations

- Implement no-mow zone
- Transition to riparian buffer enhancement
- Utilize existing trees in design and augment with shrubs and herbaceous plants

Restoration Site Project Details									
Project Number	**Block and Lot**	**Ownership**	**Reach Classification**	**Activity**	**Cost**	**Benefits**	**Projected Permits**	**Time**	**Rank**
1	Lambertville Block 1022 Lot 4	Public - NJDEP	FW2-TM (C1)	Channel cleaning, debris removal	$5,000	Improved habitat quality, scour reduction	7:13 GP1, 7:7A GP26	6 months	12
2	Lambertville Block 1001 Lot 1.02	Private	FW2-TM (C1)	Bank armoring with vegetated gabions, installation of J-hook	$70,000 (does not include house demolition costs)	Increased bank stability, 100 feet of armored channel, increased value of in-stream habitat, decreased bank sloughing	7:13 Individual Permit, 7:13 GP5	18 months	4-tied
3	Lambertville Block 1001 Lot 1.02	Public-Roadway Easement	FW2-TM (C1)	Bank armoring or flow deflection device installation	$25,000	Infrastructure protection	7:13 GP3, 7:7A GP20	9 months	9-tied
4	Delaware Block 62 Lot 5	Private	FW2-TM (C1)	Obstruction removal and installation of grade control	$25,000	Improved fish passage, improved flow dynamics, stream cooling, improved bed stability	7:13 Individual Permit	12 months	9-tied
5	West Amwell Block 3.01 Lot 4	Private	FW2-TM (C1)	Regrade outfall, conversion to vegetated channel	$20,000	Convert 150 feet of concrete lined channel to vegetated swale, reduce erosion from outlet	7:7A GP1, 7:7A GP7, 7:13 Individual Permit	15 months	8-tied
6	West Amwell Block 3 Lot 11	Private	FW2-TM (C1)	Convert basin to bioretention/infiltration basin, repair outlet channel	$60,000	Decrease basin discharge by 50% through infiltration and/or ET, increase TSS removal efficiencies to 80-90% relative to current estimated 40-60%, TP reductions up to 50%, temperature reductions	7:7A GP1	12 months	5-tied

Restoration Site Project Details									
Project Number	**Block and Lot**	**Ownership**	**Reach Classification**	**Activity**	**Cost**	**Benefits**	**Projected Permits**	**Time**	**Rank**
7	Delaware Block 62 Lot 6	Private	FW2-TM (C1)	Explore impoundment removal, install grade control, stabilize and re-vegetate banks, reconfigure outlet	$30,000	Headcut mitigation, temperature reduction, reduced solids loading	7:13 Individual Permit, 7:7A GP20	12 months	8-tied
8	Delaware Block 62 Lot 6.04	Private	FW2-TM (C1)	Stabilize bank with vegetated riprap, vegetate upper bank, install J-hook and rootwads	$40,000	Stabilize 50 feet of severely eroded bank, reduce annual sediment load by 500 cubic feet	7:13 Individual Permit, 7:7A GP20	18 months	8-tied
9	West Amwell Block 5.01 Lot 3	Private	FW2-TM (C1)	Establish a no-mow zone, install boulder toe protection, limit ATV stream crossing	$25,000	No mow zone will increase solids removal capacity of riparian buffer to 70%, boulder toes will limit further bank wasting, enhanced vegetation will limit stream irradiation	7:13 Individual Permit, 7:7A GP20	15 months	8-tied
10	West Amwell Block 5 Lot 15	Private	FW2-TM (C1)	Control of invasive species, re-vegetate banks, investigate discharge source	$15,000	Establishment of 1 acre of native riparian buffer, improved habitat value< TSS and TP load reduction	Aquatic Pesticide Permit, potentially 7:7A GP16	18 months	6-tied
11	West Amwell Block 4 Lot 1	Private	FW2-TM (C1)	Implement stormwater management and vegetated swales upstream	$30,000	Reduction in stormwater discharge rates and reduction of gully formation	7:13 GP2A, 7:13GP4	15 months	10-tied
12	Delaware Block 61 Lot 10	Private	FW2-TM (C1)	Remove debris piles, establish no-mow zone, augment riparian vegetation with shrubs and herbs	$3,000	Establish 1 acre of native vegetation, reduce debris, improve habitat value	7:13 Permit-by-Rule	3 months	11-tied

Restoration Site Project Details									
Project Number	**Block and Lot**	**Ownership**	**Reach Classification**	**Activity**	**Cost**	**Benefits**	**Projected Permits**	**Time**	**Rank**
13	Delaware Block 61 Lot 10	Private	FW2-TM (C1)	Install an improved agricultural crossing, remove debris and obstruction, improved manure management	$7,000	Decrease channel disturbance, limit solids loading, improve fish passage, decresed E. coli loading due to better manure management practices	7:13 GP2C, 7:7A GP26	6 months	5-tied
14	Delaware Block 60 Lot 1.01	Private	FW2-TM (C1)	Invasive species removal combination mechanical and chemical, establish native vegetation	$20,000	Establish 2 acres of native riparian buffer of at least 50 foot width on either bank, decreased stream irradiance, increased nutrient uptake, enhanced habitat	Aquatic Pesticide Permit, 7:7A GP16	18 months	6-tied
15	Delaware Block 61 Lot 15	Private	FW2-TM (C1)	Culvert maintainence with excavation of materials upstream and replacing downstream riprip apron	$4,000	Reduce scour downstream of culvert, limit downstream erosion, improve hydraulic connectivity	7:13 GP1	3 months	10-tied
16	Delaware Block 61 Lot 15	Private	FW2-TM (C1)	Establish a no-mow zone along stream, augment with shrubs	$3,000	Establish 300 linear feet of enhanced riparian buffer, reduce stream warming and limit bank sloughing	7:13 Permit-by-Rule	3 months	8-tied
17	Delaware Block 60 Lot 1.01	Private	FW2-TM (C1)	Chemical removal of invasive species and revegetation with native wetland species	$5,000	Enhance 1 acre of degraded wetland, improved habitat value and nutrient removal	Aquatic Pesticide Permit, 7:7A GP16	15 months	6-tied

Restoration Site Project Details									
Project Number	**Block and Lot**	**Ownership**	**Reach Classification**	**Activity**	**Cost**	**Benefits**	**Projected Permits**	**Time**	**Rank**
18	Delaware Block 58 Lot 4.01	Private	FW2-TM (C1)	Removal of obstruction, install grade control, grade banks and vegetate, establish no-mow zone	$45,000	Improved hydraulics, improved aquatic organism passage, improved stream shading, increased channel stability	7:13 Individual Permit, 7:7A GP20	18 months	3
19	Delaware Block 58 Lot 8.02	Private	FW2-TM (C1)	Riparian buffer enhancement with limited removal of invasives and planting with native vegetation	$24,000	Establish 3 acres of enhanced riparian buffer, improve stream shading, reductions in nutrient and solids loading	7:7A GP16	18 months	7-tied
20	Delaware Block 57 Lot 3	Private	FW2-TM (C1)	Obstruction removal and installation of grade control, excavate impounded sediment to form new channel	$30,000	Removal of impounded sediment, improved flow and fish passage, decreased stream temperature	7:13 Individual Permit, 7:7A Individual Permit	18 months	8-tied
21	Delaware Block 57 Lot 2	Private	FW2-TM (C1)	Establish no-mow zone along tributary, install vegetated filter strips at margin of pasture, and install boulder toe protection.	$40,000	Establishment of over 500 linear feet of riparian buffer, 50 to 70% reduction in localized E. coli loading, increased bank stability and stream shading.	7:7A GP 16, 7:7A GP 20, 7:13 GP 2A	18 months	8-tied
22	Delaware Block 58 Lot 12.01	Private	FW2-TM (C1)	Install a vegetated filter strip at base of field, replace corrugated pipe with vegetated swale	$35,000	Solids and nutrient removal, reduced erosive force, increased infiltration of stormwater	7:13 GP2A, 7:13 GP1, 7:7A GP20	18 months	7-tied
23	Delaware Block 58 Lot 12.01	Private	FW2-TM (C1)	Dam inspection, potential removal and bank stabilization, otherwise aquascaping	$40,000	Restoration of wetland hydraulics and habitat value, decrease potential risk of failure	7:13 Individual Permit, 7:7A GP20	18 months	10-tied

Restoration Site Project Details									
Project Number	**Block and Lot**	**Ownership**	**Reach Classification**	**Activity**	**Cost**	**Benefits**	**Projected Permits**	**Time**	**Rank**
24	East Amwell Block 6 Lot 1	Private	FW2-TM (C1)	Stabilize lose soil with a brush mattress	$15,000	Increase bank stability and mitigate loss of > 50 cubic of soil, protection of bridge downstream	7:13 Individual Permit, 7:7A GP20	12 months	5-tied
25	Delaware Block 43 Lot 17	Private	FW2-TM (C1)	Implement an expanded no-mow zone around wetland, remove invasive vegetation	$5,000	Enhance 1 acre of degraded wetland, improved habitat value and nutrient removal	Aquatic Pesticide Permit, 7:7A GP16	15 months	11-tied
26	West Amwell Block 5.01 Lot 5	Private	FW2-TM (C1)	Establish riparian buffer with 3-tiered planting scheme, bank grading and toe protection devices where needed	$120,000	Establish 3 acres of enhanced riparian buffer, increase bank stability to limit solids loading, decrease localized stormwater generation by 20%	7:13 Individual Permit, 7:7A Individual Permit	36 months	1
27	West Amwell Block 4 Lot 2	Private	FW2-TM (C1)	Convert swale to vegetated swale and install energy reducer at outfall	$20,000	Limit further channel erosion in 150 foot conversion, decreased channel velocity, and increased solids capture	7:7A GP1, 7:13 GP10	15 months	8-tied
28	West Amwell Block 5.01 Lot 3	Private	FW2-TM (C1)	Study to determine current function of outfall system and environmental affects, potential removal of obstruction	$15,000	Assess source and function of outfall, develop engineering design to improve stability and NPS removal	None	12 months	11-tied
29	West Amwell Block 4 Lot 2	Private	FW2-TM (C1)	Bank grading, installation of live fascines, and creation of no-mow buffer	$30,000	Improve bank stability, increase stream shading, addition of 300 linear of vegetated bank	7:7A Individual Permit, 7:13 Individual Permit	18 months	4-tied

Restoration Site Project Details									
Project Number	**Block and Lot**	**Ownership**	**Reach Classification**	**Activity**	**Cost**	**Benefits**	**Projected Permits**	**Time**	**Rank**
30	NA	Public-Roadway Easement	FW2-TM (C1)	Installation of vegetated gabions and boulder toe protection	$150,000	Protection of at-risk roadway, increased bank stability, reduced loading of channel materials	7:13 Individual Permit, 7:7A Individual Permit	24 months	2-tied
31	NA	Public-Roadway Easement	FW2-TM (C1)	Installation of MTD	$50,000	Removal of road grit, petroleum hydrocarbons, and other pollutants, anticipated removal of 10 cyds per year	7:13 GP4, 7:7A Individual Permit	24 months	5-tied
32	West Amwell Block 5.01 Lot 5	Private	FW2-TM (C1)	Stabilization of banks with grading and native planting, installation of 50 foot riparian buffer, installation of flow deflection devices such as cross vanes	$150,000	Stabilization of 500 linear feet of bank, prevention of loss of at least 100 cyds of soil per year, improved habitat quality and stream shading	7:13 Individual Permit, 7:7A Individual Permit	36 months	2-tied
33	West Amwell Block 13 Lot 6	Private	FW2-TM (C1)	Implementation of agricultural BMPs including contour farming and residue management, install grassed waterway	$15,000	Installation of 1/2 acre of grassed waterway, reduced runoff velocity, potential reduction of surface erosion and solids discharge of 80%	7:13 GP2A, 7:7A GP7	15 months	7-tied
34	West Amwell Block 13 Lot 5	Private	FW2-TM (C1)	Establish no-mow zone and augment with shrub plantings	$3,000	Enhanced habitat value and bank stability, improved stream shading and nutrient/solids capture	7:13 Permit-by-Rule	6 months	6-tied

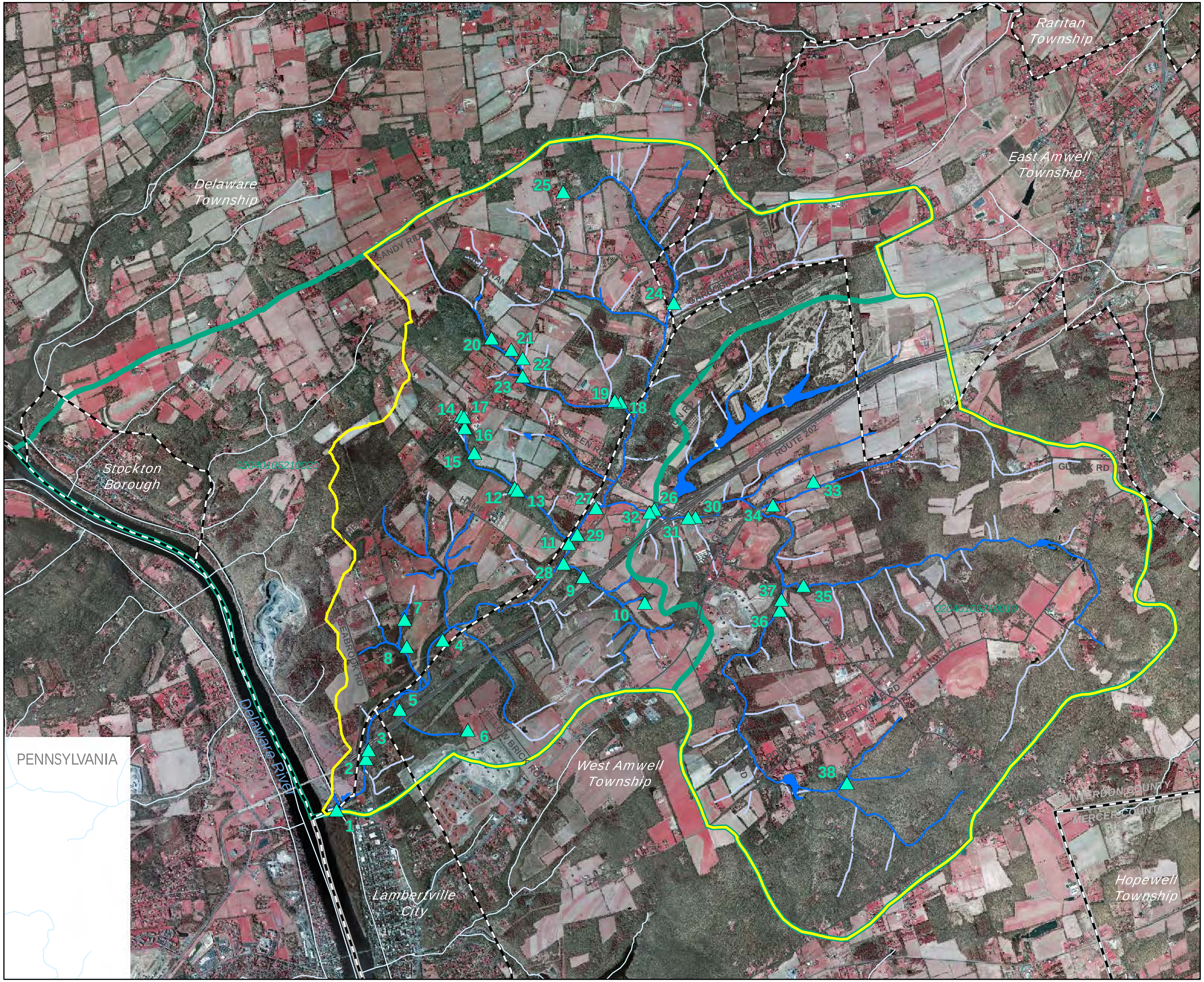
Restoration Site Project Details									
Project Number	**Block and Lot**	**Ownership**	**Reach Classification**	**Activity**	**Cost**	**Benefits**	**Projected Permits**	**Time**	**Rank**
35	West Amwell Block 13 Lot 70.01	Private	FW2-TM (C1)	Protection of vernal habitat with establishment of conservation easement	$30,000	Maintenance of vernal pool habitat and habitat protection obligate species potentially including State-listed species	None	6 months	7-tied
36	West Amwell Block 11 Lot 11	Private	FW2-TM (C1)	Install small cross vanes below hydraulic jump	$20,000	Reconnect stream bed at culvert, decrease scour, restore fish passage	7:13 Individual Permit	12 months	6-tied
37	West Amwell Block 11 Lot 11	Private	FW2-TM (C1)	Removal of small dam and possible grade control installation	$25,000	Improved flow dynamics, increased aquatic organism movement	7:13 Individual Permit	12 months	7-tied
38	West Amwell Block 12 Lot 5	Private	FW2-TM (C1)	Implement no-mow zone, augment existing vegetation with shrubs	$5,000	Restoration of 300 feet of degraded riparian buffer	7:13 Permit-by-Rule	3 months	7-tied

Restoration Site Ranking Matrix, Sorted by Project Number									
Project	**Severity**	**Extent**	**Risk**	**Temporal**	**Source Identification**	**Accessibility/Land Use Setting**	**Benefit/Cost**	**Sum**	**Rank**
1	1	1	1	1	1	1	2	10	12
2	3	2	3	3	3	2	1	18	4-tied
3	1	1	2	2	1	2	2	13	9-tied
4	1	2	1	1	2	2	2	13	9-tied
5	1	2	1	1	3	2	2	14	8-tied
6	2	2	1	2	3	3	2	17	5-tied
7	2	2	2	1	3	2	1	14	8-tied
8	3	3	1	2	2	1	1	14	8-tied
9	2	2	1	1	2	2	2	14	8-tied
10	1	2	1	1	2	3	3	16	6-tied
11	2	2	1	2	2	1	1	12	10-tied
12	1	1	1	1	2	3	1	11	11-tied
13	2	2	2	1	3	3	2	17	5-tied
14	1	2	1	1	3	2	3	16	6-tied
15	1	1	2	1	2	1	2	12	10-tied
16	1	2	1	1	2	3	2	14	8-tied
17	2	2	1	1	2	2	3	16	6-tied
18	3	2	2	2	3	3	2	19	3
19	1	2	1	1	1	3	3	15	7-tied

Restoration Site Ranking Matrix, Sorted by Project Number									
Project	**Severity**	**Extent**	**Risk**	**Temporal**	**Source Identification**	**Accessibility/Land Use Setting**	**Benefit/Cost**	**Sum**	**Rank**
20	2	2	1	1	3	1	2	14	8-tied
21	1	2	1	1	2	3	2	14	8-tied
22	1	2	1	1	3	3	2	15	7-tied
23	2	1	2	1	2	2	1	12	10-tied
24	2	1	2	2	3	3	2	17	5-tied
25	1	1	1	1	1	2	2	11	11-tied
26	3	3	3	3	3	3	3	24	1
27	2	2	1	1	2	2	2	14	8-tied
28	1	2	1	1	1	3	1	11	11-tied
29	2	2	1	2	2	3	3	18	4-tied
30	3	2	3	3	3	3	2	21	2-tied
31	2	2	2	1	3	3	2	17	5-tied
32	3	3	3	2	3	3	2	21	2-tied
33	2	2	1	1	3	2	2	15	7-tied
34	1	2	1	1	2	3	3	16	6-tied
35	2	1	3	2	1	2	2	15	7-tied
36	2	2	2	1	3	2	2	16	6-tied
37	2	2	1	1	3	2	2	15	7-tied
38	1	2	1	1	1	3	3	15	7-tied

Restoration Site Ranking Matrix, Sorted by Project Rank									
Project	**Severity**	**Extent**	**Risk**	**Temporal**	**Source Identification**	**Accessibility/Land Use Setting**	**Benefit/Cost**	**Sum**	**Rank**
26	3	3	3	3	3	3	3	24	1
30	3	2	3	3	3	3	2	21	2-tied
32	3	3	3	2	3	3	2	21	2-tied
18	3	2	2	2	3	3	2	19	3
2	3	2	3	3	3	2	1	18	4-tied
29	2	2	1	2	2	3	3	18	4-tied
6	2	2	1	2	3	3	2	17	5-tied
13	2	2	2	1	3	3	2	17	5-tied
24	2	1	2	2	3	3	2	17	5-tied
31	2	2	2	1	3	3	2	17	5-tied
10	1	2	1	1	2	3	3	16	6-tied
14	1	2	1	1	3	2	3	16	6-tied
17	2	2	1	1	2	2	3	16	6-tied
34	1	2	1	1	2	3	3	16	6-tied
36	2	2	2	1	3	2	2	16	6-tied
19	1	2	1	1	1	3	3	15	7-tied
22	1	2	1	1	3	3	2	15	7-tied
33	2	2	1	1	3	2	2	15	7-tied
35	2	1	3	2	1	2	2	15	7-tied

Restoration Site Ranking Matrix, Sorted by Project Rank									
Project	**Severity**	**Extent**	**Risk**	**Temporal**	**Source Identification**	**Accessibility/Land Use Setting**	**Benefit/Cost**	**Sum**	**Rank**
37	2	2	1	1	3	2	2	15	7-tied
38	1	2	1	1	1	3	3	15	7-tied
5	1	2	1	1	3	2	2	14	8-tied
7	2	2	2	1	3	2	1	14	8-tied
8	3	3	1	2	2	1	1	14	8-tied
9	2	2	1	1	2	2	2	14	8-tied
16	1	2	1	1	2	3	2	14	8-tied
20	2	2	1	1	3	1	2	14	8-tied
21	1	2	1	1	2	3	2	14	8-tied
27	2	2	1	1	2	2	2	14	8-tied
3	1	1	2	2	1	2	2	13	9-tied
4	1	2	1	1	2	2	2	13	9-tied
11	2	2	1	2	2	1	1	12	10-tied
15	1	1	2	1	2	1	2	12	10-tied
23	2	1	2	1	2	2	1	12	10-tied
12	1	1	1	1	2	3	1	11	11-tied
25	1	1	1	1	1	2	2	11	11-tied
28	1	2	1	1	1	3	1	11	11-tied
1	1	1	1	1	1	1	2	10	12



NEW JERSEY COUNTY MAP

Princeton Hydro

PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551

1 inch = 3,000 feet

0 1,500 3,000 Feet

SOURCES:

1. New Jersey 2002 High Resolution Orthophotography obtained from the New Jersey Image Warehouse.
2. Blue line streams and lakes obtained from the NJDEP GIS website.
3. SCS streams were digitized from the Hunterdon County Soil Conservation District's Soil Survey Book.

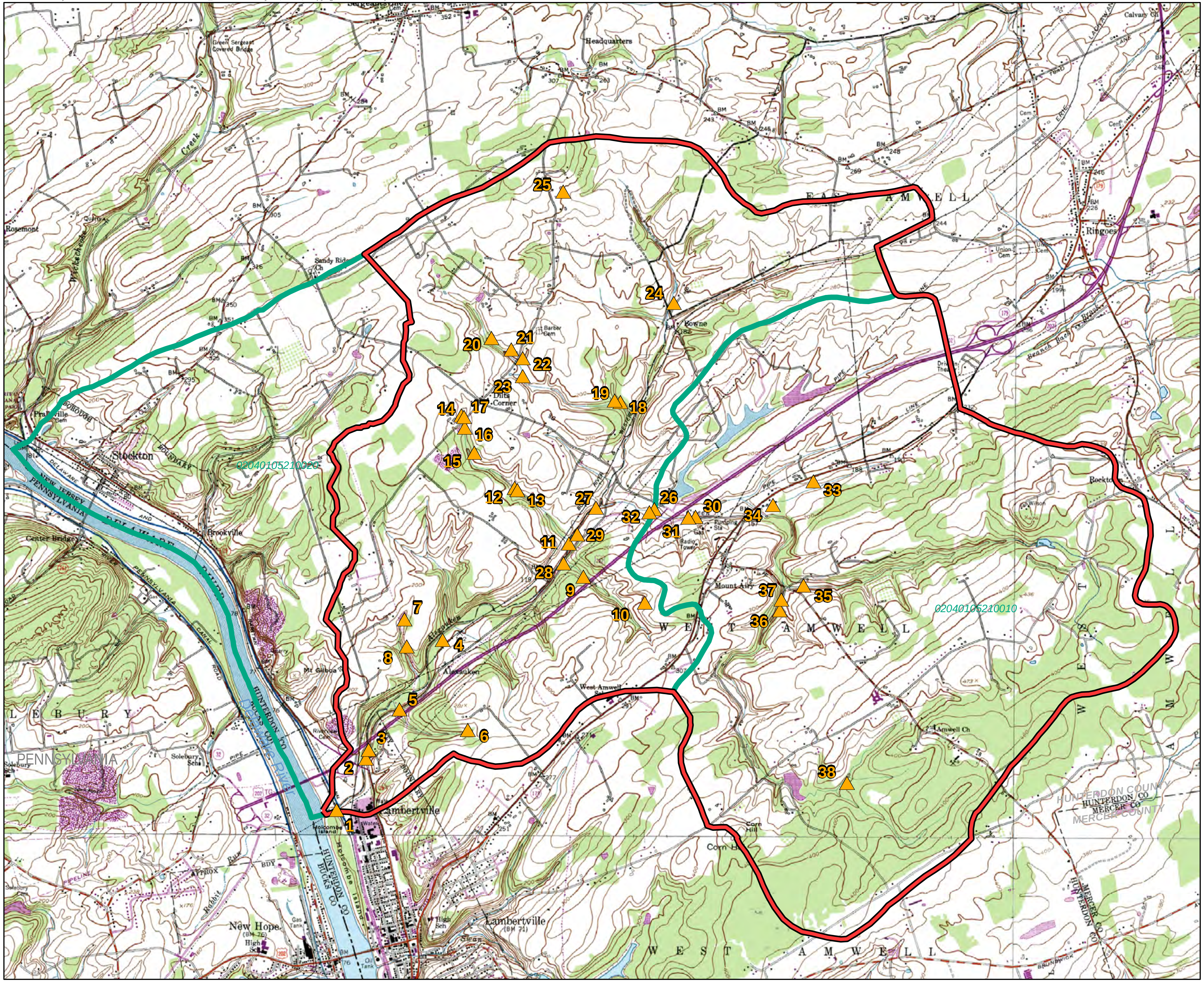
RESTORATION SITES
FIGURE 19

ALEXAUKEN CREEK WATERSHED
DELAWARE TOWNSHIP, EAST AMWELL TOWNSHIP, WEST AMWELL TOWNSHIP, AND LAMBERTVILLE CITY
HUNTERDON COUNTY, NEW JERSEY

LEGEND

- Restoration Site
- Project Area
- Lakes
- NJDEP Blue Line Streams
- SCS Streams
- Roads
- HUC14 Boundaries
- Municipal Boundaries
- County Boundaries

File: P:\0584\Projects\0584002\GIS\MXD\RestorationSites_USGS.mxd July 28, 2010, Copyright Princeton Hydro, LLC.



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NEW JERSEY COUNTY MAP

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1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551

1 inch = 3,000 feet

0 1,500 3,000 Feet

SOURCES:

1. Digital 7.5 minute USGS quads for Stockton, Hopewell, Lambertville, nd Pennington, NJ as exported from Terrain Navigator Professional.

RESTORATION SITES
USGS TOPOGRAPHIC MAP
FIGURE 20

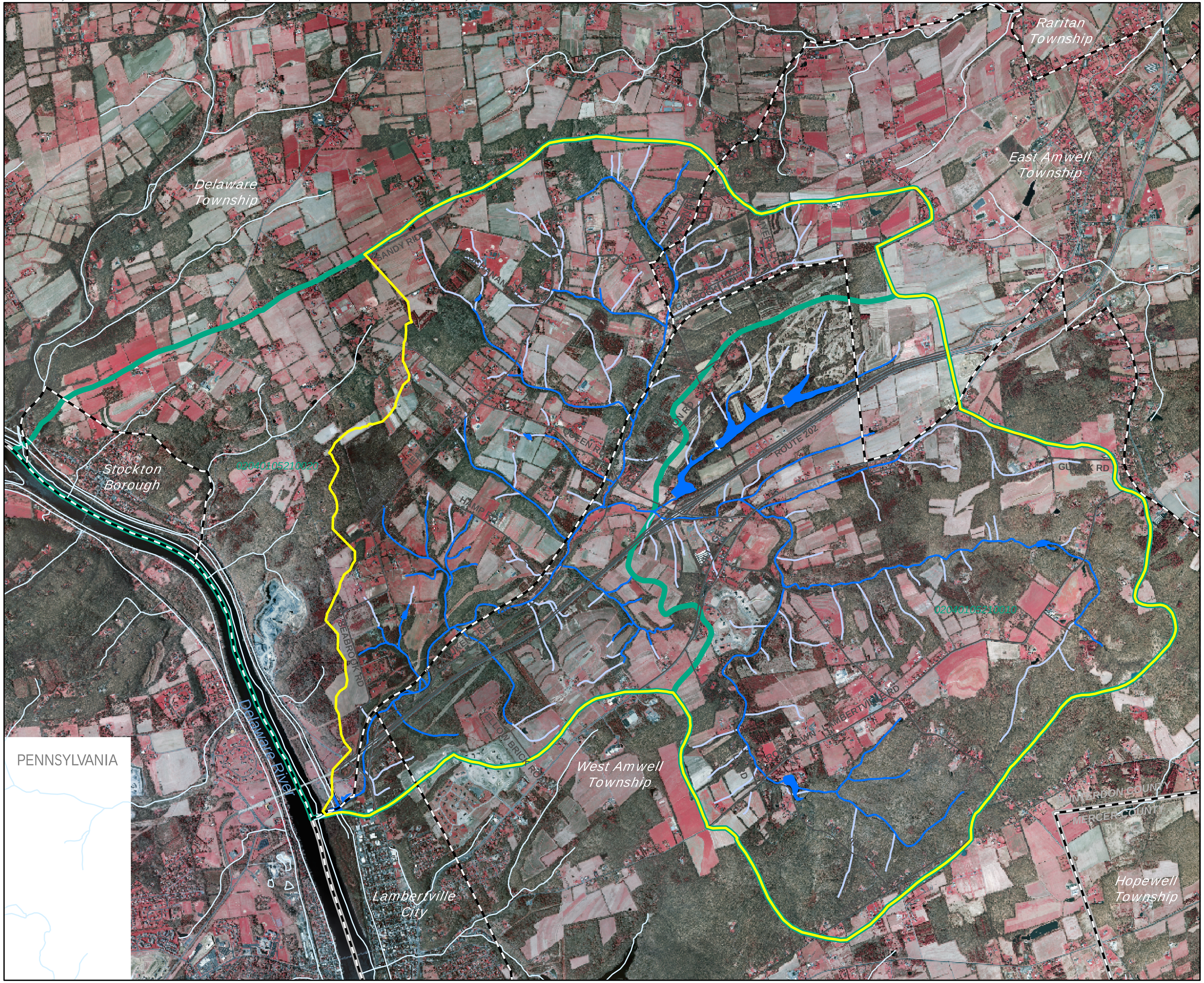
ALEXAUKEN CREEK WATERSHED
DELAWARE TOWNSHIP, EAST AMWELL TOWNSHIP, WEST AMWELL TOWNSHIP, AND LAMBERTVILLE CITY
HUNTERDON COUNTY, NEW JERSEY

LEGEND

- Restoration Site
- Project Area
- HUC14 Boundaries

Appendix II

Selected Maps



NEW JERSEY COUNTY MAP

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RINGOES, NJ 08551

1 inch equals 3,000 feet
0 1,500 3,000
Feet

SOURCES:

1. New Jersey 2002 High Resolution Orthophotography obtained from the New Jersey Image Warehouse.
2. Blue line streams and lakesobtained from the NJDEP GIS website.
3. SCS streams were digitized from the Hunterdon County Soil Conservation District's Soil Survey Book.

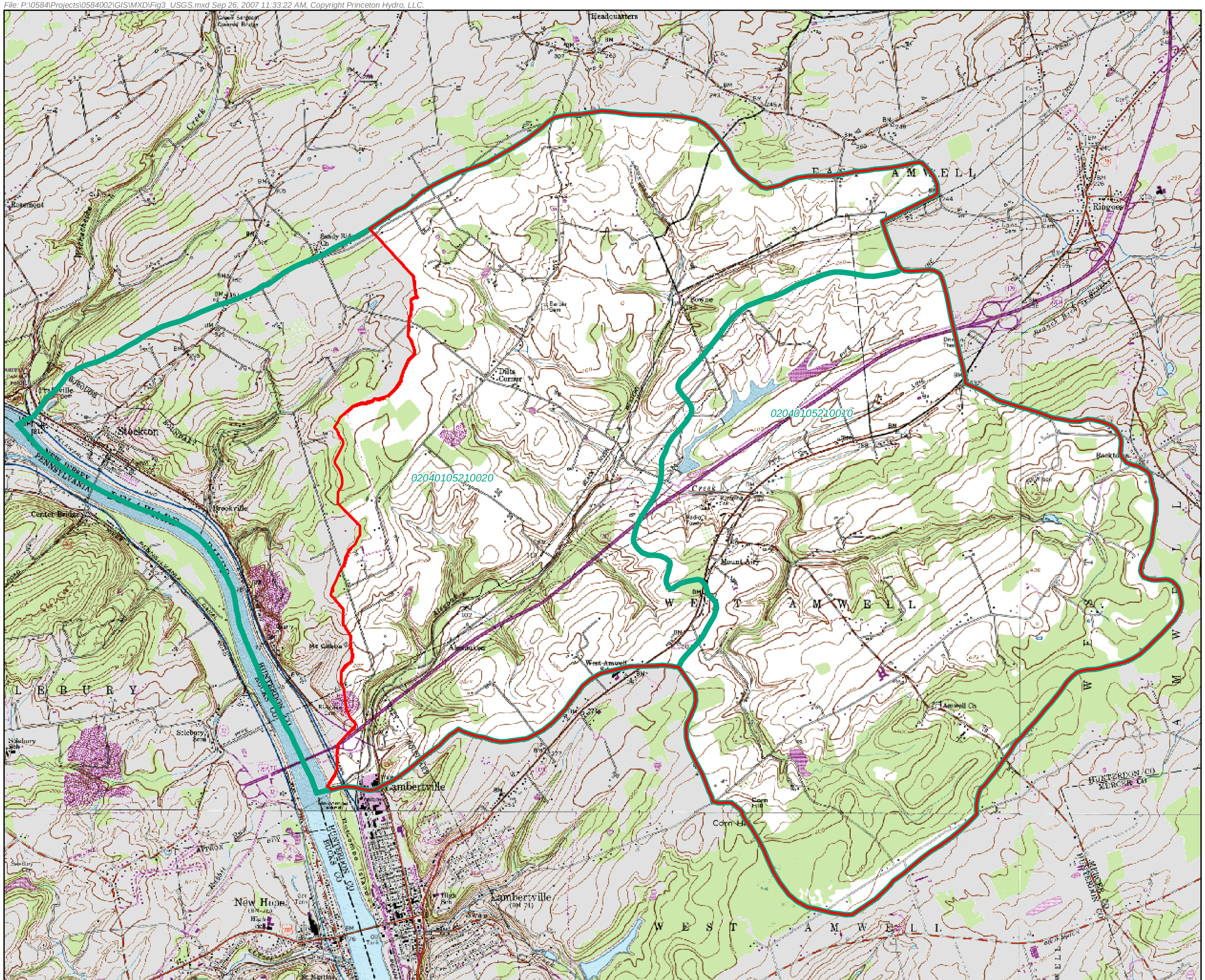
WATERSHED STUDY AREA
FIGURE 2

ALEXAUKEN CREEK WATERSHED
DELAWARE TOWNSHIP, EAST AMWELL TOWNSHIP, WEST AMWELL TOWNSHIP, AND LAMBERTVILLE CITY
HUNTERDON COUNTY, NEW JERSEY

LEGEND

- Project Area
- Lakes
- NJDEP Blue Line Streams
- SCS Streams
- Roads
- HUC14 Boundaries
- Municipal Boundaries
- County Boundaries

File: P:\0584\Projects\0584002\GIS\MXD\Fig3_USGS.mxd Sep 26, 2007 11:33:22 AM, Copyright Princeton Hydro, LLC.



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P.O. BOX 720
RINGOES, NJ 08551

1 inch equals 3,000 feet

0 1,500 3,000 Feet

SOURCES:

1. USGS 7.5 Minute Series Topographic Map for Hopewell and Stockton, NJ, as exported from Terrain Navigator Pro.
2. HUC 14 boundaries as obtained from the NJDEP GIS website.

USGS TOPOGRAPHY MAP
FIGURE 3

ALEXAUKEN CREEK WATERSHED
DELAWARE TOWNSHIP, EAST AMWELL TOWNSHIP, WEST AMWELL TOWNSHIP, AND LAMBERTVILLE CITY
HUNTERDON COUNTY, NEW JERSEY

LEGEND

- Project Area
- HUC14 Boundaries

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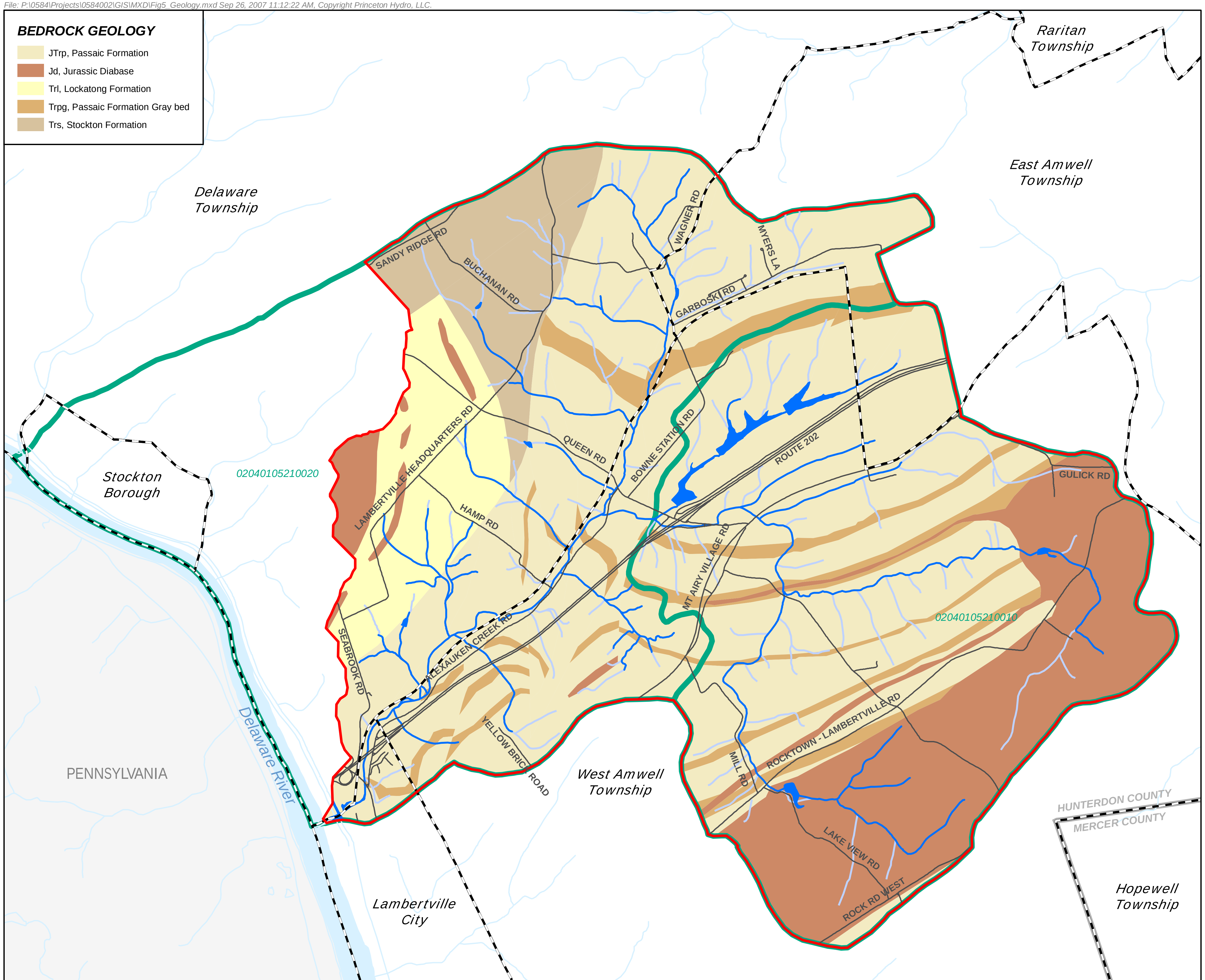

PH Princeton Hydro

NEW JERSEY COUNTY MAP

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RINGOES, NJ 08551

1 inch equals 3,000 feet
0 1,500 3,000 Feet

SOURCES:

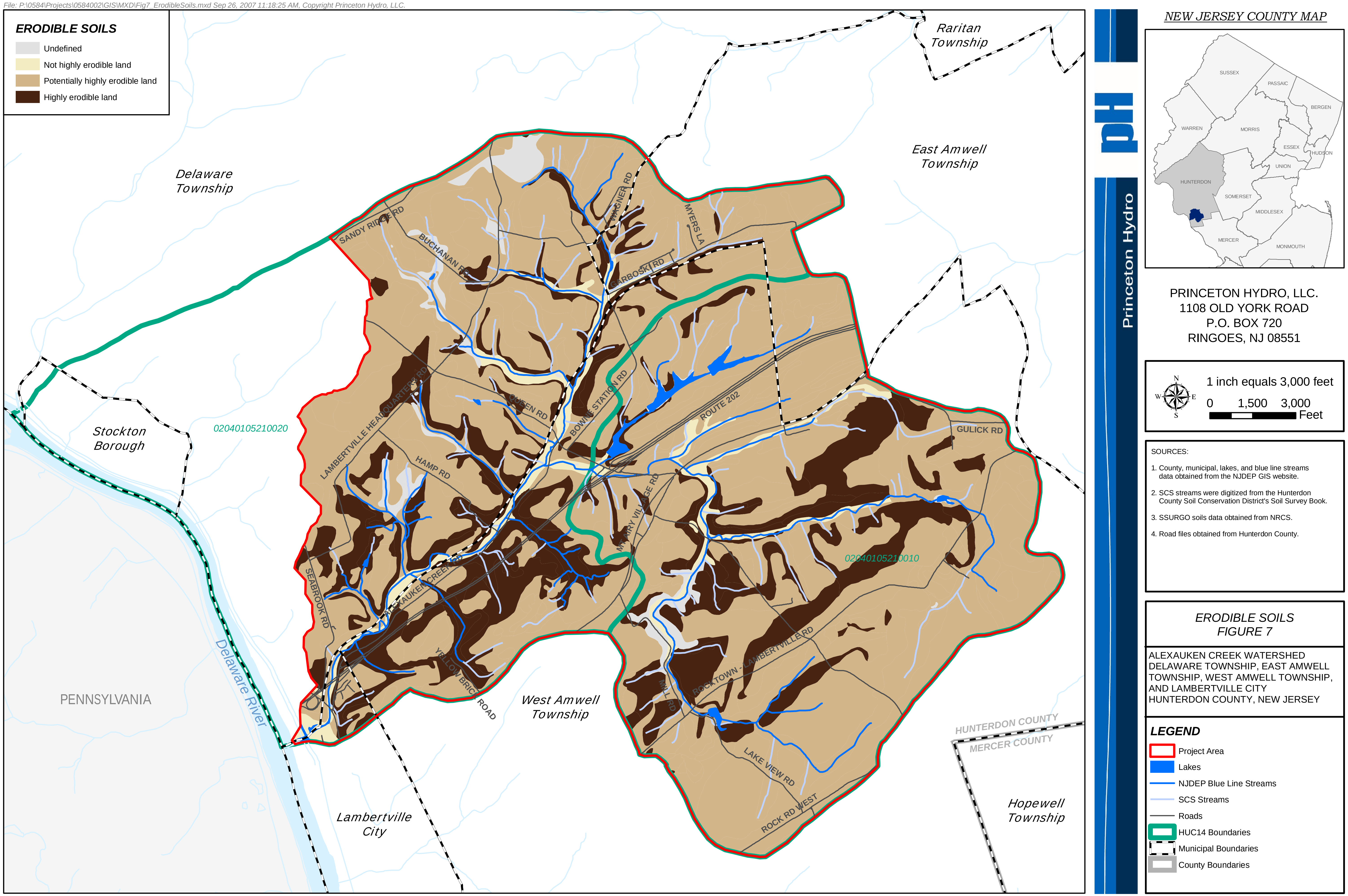
1. County, municipal, blue line streams, lakes, land use and bedrock geology data obtained from the NJDEP GIS website.
2. SCS streams were digitized from the Hunterdon County Soil Conservation District's Soil Survey Book.
3. Road files obtained from Hunterdon County.

BEDROCK GEOLOGY
FIGURE 5

ALEXAUKEN CREEK WATERSHED
DELAWARE TOWNSHIP, EAST AMWELL TOWNSHIP, WEST AMWELL TOWNSHIP, AND LAMBERTVILLE CITY
HUNTERDON COUNTY, NEW JERSEY

LEGEND

- Project Area
- Lakes
- NJDEP Blue Line Streams
- SCS Streams
- HUC14 Boundaries
- Roads
- Municipal Boundaries
- County Boundaries


File: P:\0584\Projects\0584002\GIS\MXD\Fig7_ErodibleSoils.mxd Sep 26, 2007 11:18:25 AM, Copyright Princeton Hydro, LLC.
ERODIBLE SOILS
Undefined
Not highly erodible land
Potentially highly erodible land
Highly erodible land
Delaware Township
Raritan Township
East Amwell Township
Stockton Borough
02040105210020
02040105210010
PENNSYLVANIA
Delaware River
West Amwell Township
Lambertville City
Hopewell Township
HUNTERDON COUNTY
MERCER COUNTY
SANDY RIDGE RD
BUCHANAN RD
WAGNER RD
MYERS LA
BARBOSKI RD
BOWNE STATION RD
ROUTE 202
QUEEN RD
LAMBERTVILLE HEADQUARTERS RD
HAMP RD
GULICK RD
MT AIRY VILLAGE RD
SEABROOK RD
ALEXAUKEN CREEK RD
YELLOW BRICK ROAD
ROCKTOWN - LAMBERTVILLE RD
MILL RD
LAKE VIEW RD
ROCK RD WEST
Princeton Hydro
NEW JERSEY COUNTY MAP
SUSSEX
PASSAIC
BERGEN
WARREN
MORRIS
ESSEX
HUDSON
UNION
HUNTERDON
SOMERSET
MIDDLESEX
MERCER
MONMOUTH
PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551
N
S
E
W
1 inch equals 3,000 feet
0 1,500 3,000
Feet
SOURCES:
1. County, municipal, lakes, and blue line streams data obtained from the NJDEP GIS website.
2. SCS streams were digitized from the Hunterdon County Soil Conservation District's Soil Survey Book.
3. SSURGO soils data obtained from NRCS.
4. Road files obtained from Hunterdon County.
ERODIBLE SOILS
FIGURE 7
ALEXAUKEN CREEK WATERSHED
DELAWARE TOWNSHIP, EAST AMWELL TOWNSHIP, WEST AMWELL TOWNSHIP, AND LAMBERTVILLE CITY
HUNTERDON COUNTY, NEW JERSEY
LEGEND
Project Area
Lakes
NJDEP Blue Line Streams
SCS Streams
Roads
HUC14 Boundaries
Municipal Boundaries
County Boundaries

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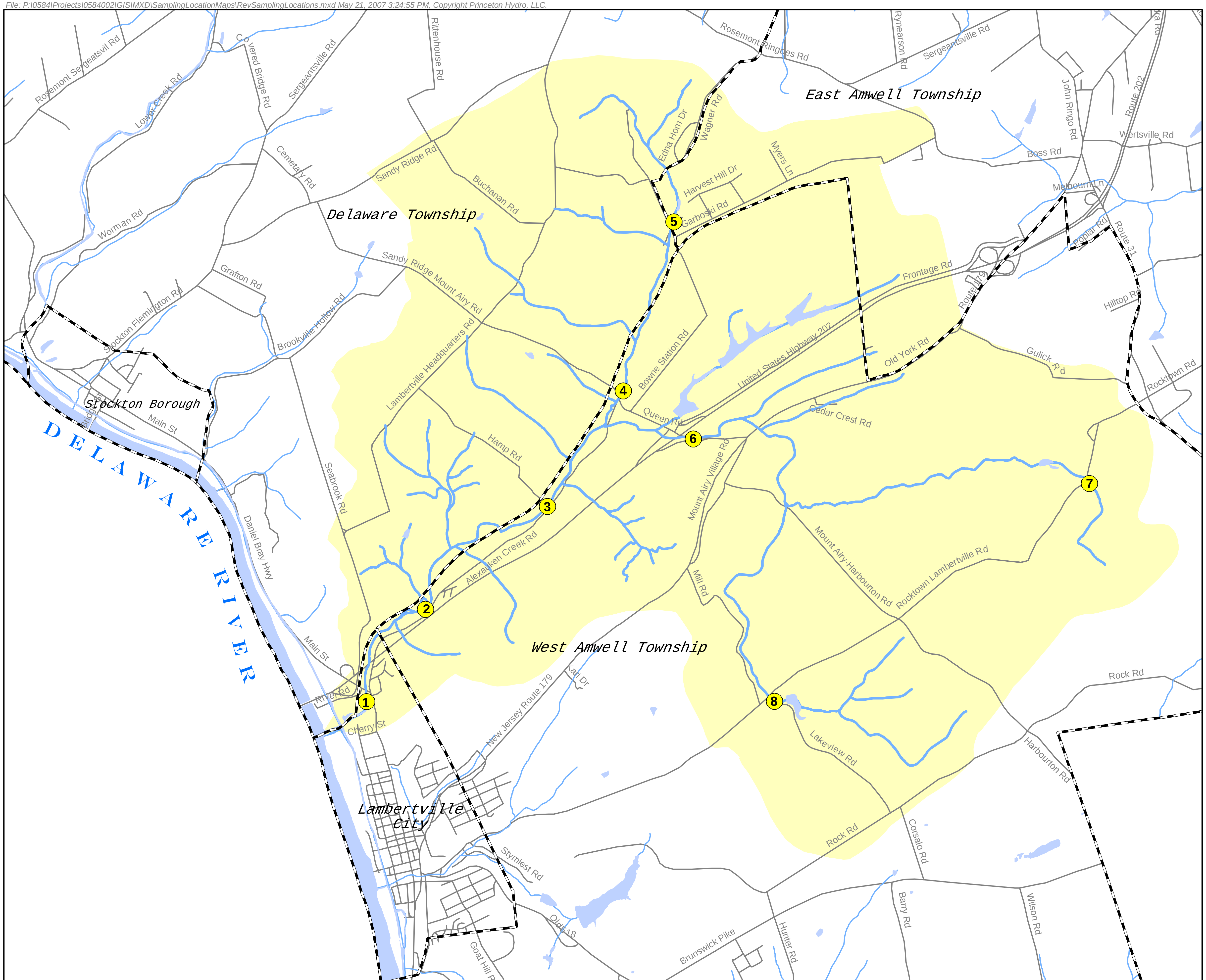
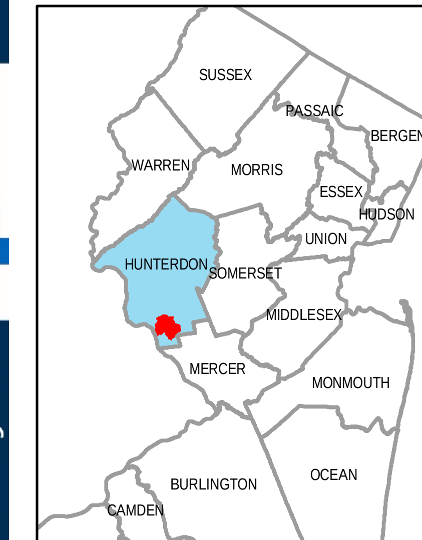


NEW JERSEY COUNTY MAP



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N

0 1,500 3,000 Feet

1 inch equals 3,000 feet

FIGURE 2:
REVISED SAMPLING STATIONS IN THE ALEXAUKEN CREEK WATERSHED

Watershed Protection Plan for the Alexauken Creek Watershed
Hunterdon County, New Jersey

Legend

- Sampling Stations
- Municipal Boundaries
- Lakes
- Alexauken Creek
- Streams
- Roads
- Project Area

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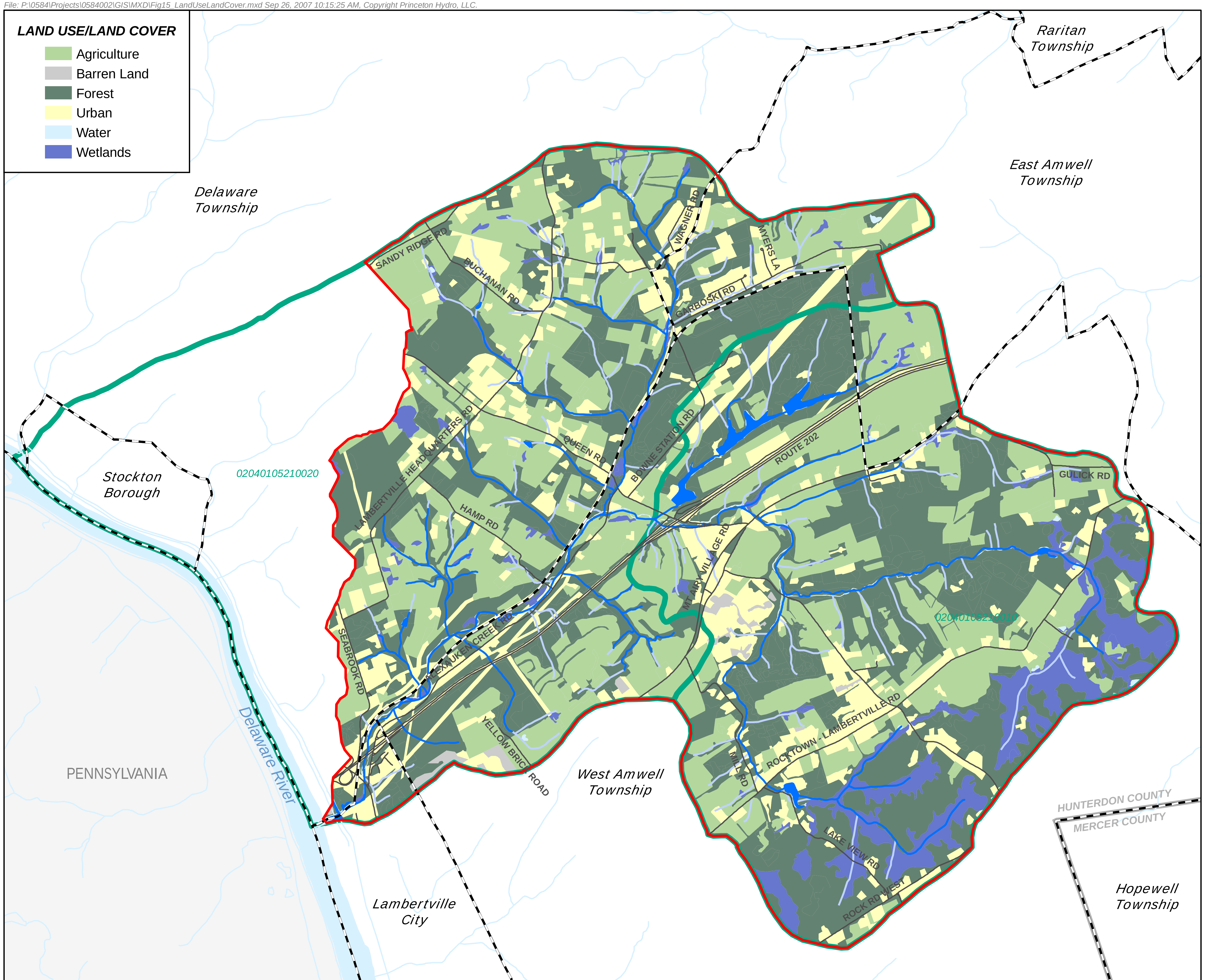

NEW JERSEY COUNTY MAP

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RINGOES, NJ 08551

1 inch equals 3,000 feet
0 1,500 3,000 Feet

SOURCES:

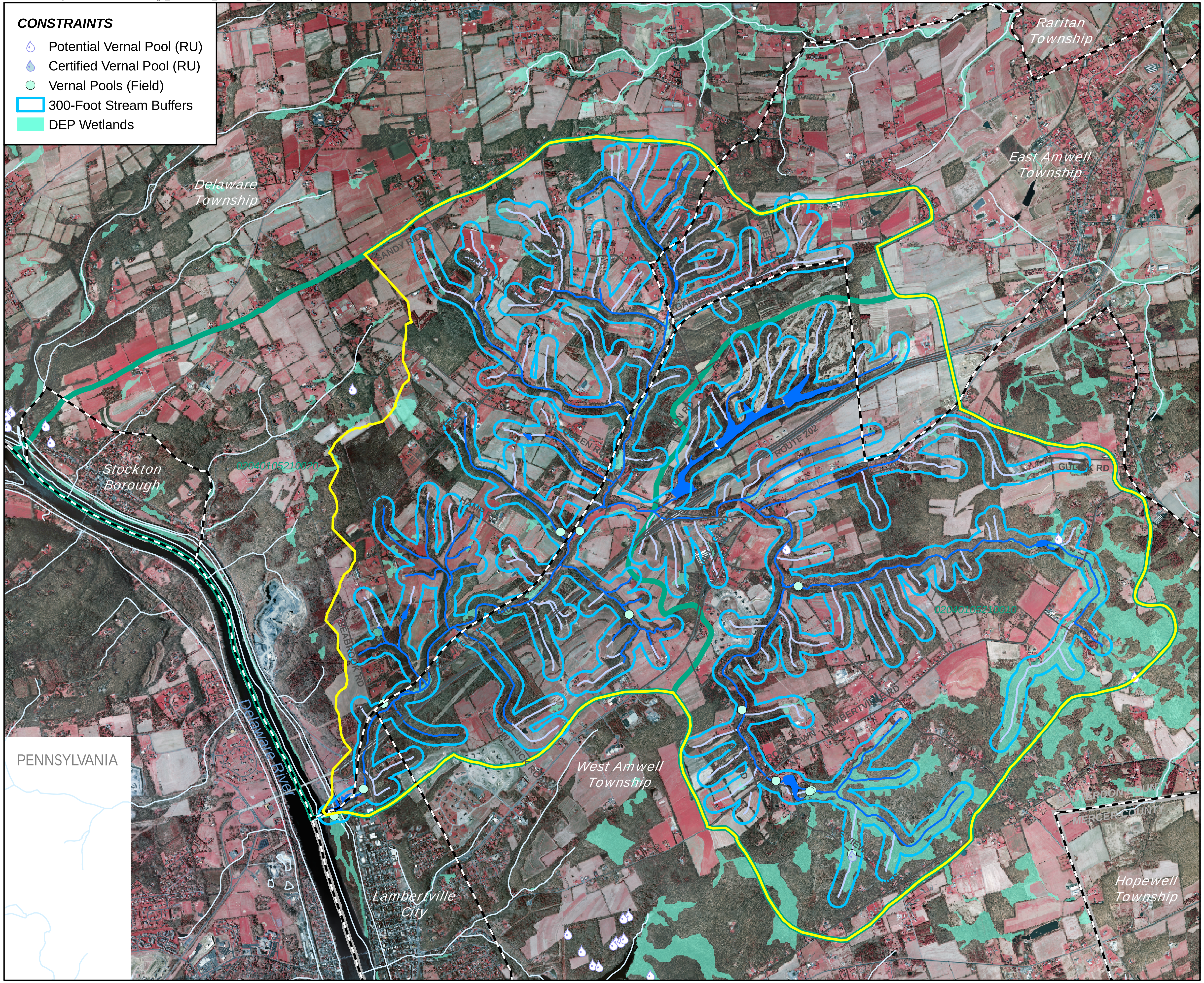
1. County, municipal, blue line streams, lakes, and land use data obtained from the NJDEP GIS website.
2. SCS streams were digitized from the Hunterdon County Soil Conservation District's Soil Survey Book.
3. Road files obtained from Hunterdon County.

LAND USE/LAND COVER
FIGURE 15

ALEXAUKEN CREEK WATERSHED
DELAWARE TOWNSHIP, EAST AMWELL TOWNSHIP, WEST AMWELL TOWNSHIP, AND LAMBERTVILLE CITY
HUNTERDON COUNTY, NEW JERSEY

LEGEND

- Project Area
- Lakes
- NJDEP Blue Line Streams
- SCS Streams
- Roads
- HUC14 Boundaries
- Municipal Boundaries
- County Boundaries



NEW JERSEY COUNTY MAP

Princeton Hydro

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P.O. BOX 720
RINGOES, NJ 08551

1 inch equals 3,000 feet
0 1,500 3,000 Feet

SOURCES:

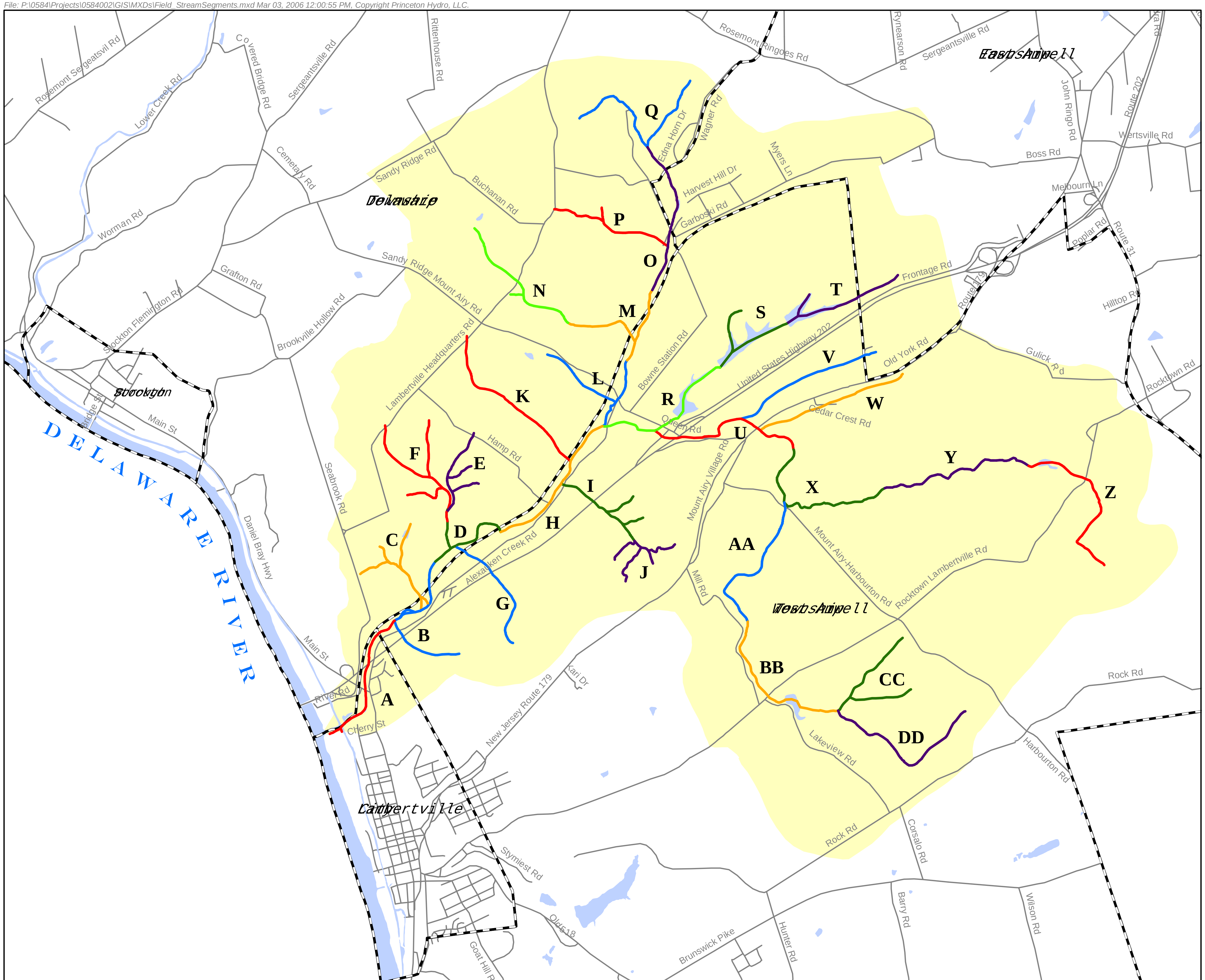
1. New Jersey 2002 High Resolution Orthophotography obtained from the New Jersey Image Warehouse.
2. Blue line streams, lakes and wetlands obtained from the NJDEP GIS website.
3. SCS streams were digitized from the Hunterdon County Soil Conservation District's Soil Survey Book.
4. Potential and certified vernal pools were obtained from Rutgers University. Field vernal pools were located by volunteers.

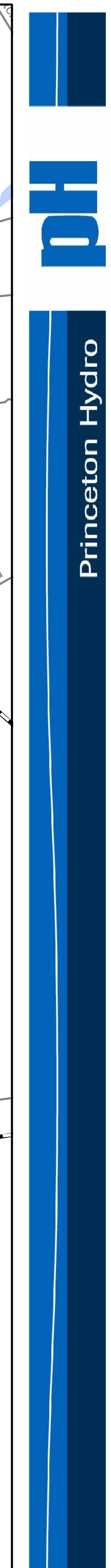
300' BUFFERS & ENVIRONMENTAL CONSTRAINTS
FIGURE 8

ALEXAUKEN CREEK WATERSHED
DELAWARE TOWNSHIP, EAST AMWELL TOWNSHIP, WEST AMWELL TOWNSHIP, AND LAMBERTVILLE CITY
HUNTERDON COUNTY, NEW JERSEY

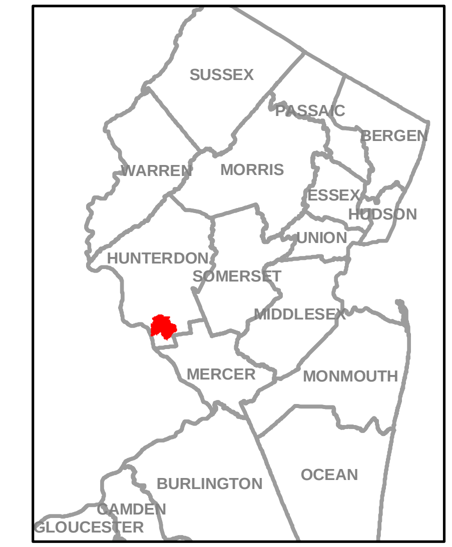
LEGEND

- Project Area
- Lakes
- NJDEP Blue Line Streams
- SCS Streams
- Roads
- HUC14 Boundaries
- Municipal Boundaries
- County Boundaries





NEW JERSEY COUNTY MAP



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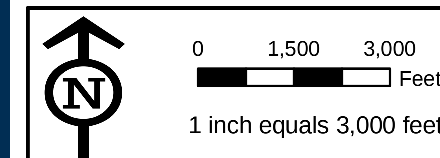

SOURCES:

1. Municipal boundaries, NJDEP blue line streams, and lakes were obtained from NJDEP GIS website.

STREAM VISUAL ASSESSMENT OVERVIEW MAP

Watershed Protection Plan for the Protection and Preservation of the Alexauken Creek Watershed
Hunterdon County, New Jersey

Legend

- Project Area
- Lakes
- Roads
- Municipal Boundaries