MULHOCKAWAY CREEK STORMWATER MANAGEMENT AND WATERSHED RESTORATION PLAN

Prepared

for:

NJDEP Grant ID: RP02-084
319(h) Nonpoint Source Pollution Control Program
HUC14 ID: 02030105-020-030

New Jersey Water Supply Authority
December 2007

TABLE OF CONTENTS

Tables

Figures

Appendices

ACKNOWLEDGEMENTS

This project was a collaborative effort of the New Jersey Water Supply Authority, the New Jersey Department of Environmental Protection, Hunterdon County Soil Conservation District and the project committee. TRC Omni Environmental was contracted perform fecal coliform track down sampling, analyze ground water recharge potential, investigate the legal aspects of best management practice maintenance, and develop retrofit projects.

New Jersey Water Supply Authority
Amy L. Shallcross, PE: Project Manager and Author
Jen (Yongzhen) Zhang: Fieldwork, GIS Support
Robert O'Neil: Municipal Regulation
Todd Kratzer: Water Quality Analysis

New Jersey Department of Environmental Protection
Nick Zripko, Grant Manager

Hunterdon County Soil Conservation District
Chris Testa: Stormwater Inventory

TRC Omni Environmental (now two firms: TRC Solutions and Omni Environmental)
Jeremiah Bergstrom: Project Manager, TRC Solutions
Brian Friedlich: Sampling, Project Descriptions, Omni Environmental
Greg Soska, Michael Wright: Sampling, Omni Environmental
Tom Amidon: Project Manager, Omni Enviromental

Project Committee Members (in addition to above)
Honachefsky, Bill (Sr.), NJDEP; Jimenez, John, Bethlehem Township; MacGonagle, Cinny, Bethlehem Township Environmental Commission; Mathews, Thomas, Hunterdon County Engineering; Van Abs, Dan, formerly NJWSA; Koven, Tom, Bethlehem Township Environmental Commission; Sween, Eric, Bethlehem Township Environmental Commission; Mazza, Frank, Union Township Committee; O'Neil, Robert, NJWSA; Bischoff, W. F., Union Township Resident; Coe, Jim, Hatch Mott MacDonald (Bethlehem Township); Haynes, Rob, Union Township, Mayor; Mulhall, Matt, Union Township Committee; Nargi, Robert, Union Township Environmental Commission; Armstron, Caroline, Hunterdon County Planning; Bogart, Robert, Maser Engineering (Union Township); Bonasera, Anthony, Maser Engineering (Union Township); Brand, Tom, NJDEP; Bunting, George, Landowner; Clother, Bill, Hunterdon County Parks & Recreation; Concannon, Dennis, Trout Unlimited; Deering, Tricia, Landowner; Dziamara, Sue, Hunterdon County Planning; Freiday, Tim, Hunterdon County Soil Conservation District, Goldberg, Frank, Union Township Environmental Commission; Harclerode, William, Union Township Environmental Committee; Hershey, Leilani, Hunterdon County Planning; Honachefsky, Bill (Jr.), Citizen; Johnson, Bruce, Bethlehem Township Planning; Jonas, Skip, Landowner; KlipStein, Ken, NJDEP; Kiovsky, Doug, Hunterdon County Parks and Recreation, Kibler, William, South Branch Watershed Association; Kirkpatrick, Brian, Union Township Planning Board; Martin, Melanie, Hunterdon County Planning; Pohorely, Gary, Hunterdon County Agricultural Development Board; Riehl, Andy, Hunterdon Coalition; Schulman, Richard, Hunterdon Hills Playhouse; Souza, Steve, Princeton Hydro (for both Townships); Steffey, Rick, Hunterdon County Planning; Lee, William, Foster Wheeler; Witherall, Ben, South Branch Watershed Association.

EXECUTIVE SUMMARY

The Mulhockaway Creek Stormwater Management and Watershed Restoration Project was initiated as a regional stormwater management plan to be developed with a 319 Nonpoint Source Pollution Control Grant from the NJDEP. The Mulhockaway Creek watershed was considered a good candidate for a regional stormwater management plan because water quality standards for pathogens and temperature were exceeded, aquatic life was rated as moderately impaired and the Creek is tributary to a major water supply reservoir and recreation area.

One aspect of a stormwater management plan is the development of new municipal ordinances or design standards if additional stormwater management is required to protect water resources. Regulations developed as a result of the Highlands Act to protect water resources significantly limit major development in the Mulhockaway Creek watershed and the new stormwater regulations are expected to be protective of water quality from the impacts of future development. As a result, the project focus was shifted from the development of additional performance standards for new development to identification of management measures to address impacts from existing nonpoint source pollution problems concentrating on stormwater issues. The work included creation of a stormwater infrastructure inventory, evaluation of existing best management practices (BMPs) and determination of retrofit opportunities and remedial actions for existing stormwater problems. In addition, a monitoring program was conducted to track down sources of pathogen contamination and identification of management measures to address likely sources. The monitoring program was conducted to support NJDEP's Fecal Coliform Total Maximum Daily Load (TMDL), which serves as a preliminary surface water quality management plan to address pathogen contamination in the stream.

This report summarizes the work performed to develop the plan and contains:

- a characterization and assessment of the watershed focused on nonpoint source pollution and stormwater;
- a synopsis of the stormwater infrastructure inventory;
- a review of stream conditions based on visual assessments;
- an evaluation of stream water quality;
- recommended watershed restoration programs and projects, including priorities; and,
- a summary of track-down monitoring for the Fecal Coliform TMDL and identification of management measures to address potential sources, prepared as a separate document for implementation of the TMDL.

The executive summary presents the results of the project in terms of the nine minimum elements required of a watershed restoration plan.

Background

The Mulhockaway Creek drains the western portion of the Spruce Run Reservoir watershed and is located in the Raritan River Basin. The Reservoir is used to supplement stream flows to support aquatic life and to allow water to be withdrawn from the Raritan River in Bound Brook for treatment and distribution as drinking water. In addition, the Division of Parks and Forestry, part of New Jersey Department of Environmental Protection (NJDEP), operates a portion of the Reservoir area for recreation, including fishing, swimming, sailing, boating, picnicking and camping. NJDEP's Division of Fish and Wildlife lists Spruce Run Reservoir and the Mulhockaway Creek as places to fish and stocks the Mulhockaway Creek with trout. Thus, the quality and volume of water from the Creek and in the Reservoir need to be maintained, if not improved, so all of these uses can be preserved.

The United States Environmental Protection Agency (USEPA) requires states to assess their water bodies to determine if they are achieving the Clean Water Act goals of fishable and swimmable waters and other possible uses. Achievement of designated uses is evaluated by comparing water quality data to surface water quality standards established for a particular use. The Mulhockaway Creek meets water quality standards for water supply (industrial, agricultural, and drinking water), but does not meet the standards for primary contact recreation and aquatic life (general and trout). Water quality standards for secondary contact recreation have not been established in New Jersey and the Creek has not been assessed for fish consumption. Lake designated uses are recreation (primary contact and aesthetics), aquatic life and fish consumption. Spruce Run Reservoir meets water quality standards for primary contact recreation and aquatic life, but has not been assessed for aesthetics.

Sources and Root Causes

The sources and root causes of impairment to the stream are ubiquitous and diffuse although some concentrated areas have been identified in the watershed. Sources are both anthropogenic and natural, recent and the result of historical land uses.

Pathogen Contamination

Pathogen contamination, usually from fecal matter, is detected through a surrogate measurement of bacteria and impairs the stream for primary contact recreation. Fecal Coliform was used to determine the impairment in the Mulhockaway Creek. NJDEP postulated in the Fecal Coliform TMDL[1] that the sources of fecal coliform bacteria in the Mulhockaway Creek were likely from deer and geese based on large percentage of forest. However, there are agricultural operations with livestock that are not excluded from the stream. The watershed contains some older, more-densely developed areas where some cesspools and septic systems have failed. A pumped sanitary sewer main traverses two

[1] Total Maximum Daily Load. The total maximum load that a stream can assimilate is calculated and assigned to point and nonpoint sources of the substance. The study conducted to support the load determination is a TMDL, which serves as a preliminary surface water quality management plan. The Mulhockaway Creek Fecal Coliform TMDL can be found on the NJDEP website using the following link; http://www.state.nj.us/dep/watershedmgt/DOCS/TMDL/june2006/Raritan%20FC.pdf

branches of the Creek although the sanitary wastewater is only from an office park and the main is not known to leak. The companion document to this report (Fecal Coliform TMDL Implementation Recommendations) presents an evaluation of the potential sources of fecal contamination based on additional more-detailed monitoring, a remote-sensing analysis, windshield surveys, and local knowledge.

Elevated Stream Temperatures

The Mulhockaway Creek is characterized as a trout-production water for which the water quality standard for temperature is 20 degrees Celsius to support the health of the fishery. When the temperature standard is violated, the stream is considered impaired for aquatic life (trout). Monitoring data within the last ten years indicate that the temperature exceeds this standard in the summer, with temperature observations of 21 degrees Celsius as early in the day as 9:00 am. No diurnal temperature data for the stream were available for additional evaluation. Typical anthropogenic sources of elevated stream temperatures include surface water discharges, particularly from cooling towers and wastewater treatment plants, and runoff from paved and impervious surfaces. Other sources include lack of tree canopy and poor riparian buffers as well as discharges from shallow water bodies such as ponds. For the Mulhockaway Creek, the likely cause of high stream temperatures is the lack of riparian vegetation and associated tree canopy, since there is only one small on-site wastewater treatment plant discharge and no known thermal (cooling tower or other) dischargers in the watershed. Stream visual assessments of the Mulhockaway Creek in twenty locations indicate that the riparian buffer was sparse or in poor condition at six locations. However, runoff from impervious surfaces may also be a factor although no summertime wet weather measurements have been made. During summer rain events, stormwater runoff can readily absorb heat from pavement and be of sufficient volume to increase the temperature of the stream, particularly in the vicinity of the stormwater outfall. In addition, the Creek flows directly through many shallow ponds (know as in-line ponds) and the water may be heated therein.

Aquatic Life

Biological monitoring of bottom-dwelling insects (macroinvertebrates) indicate that aquatic life (general) is stressed because of the dominance of pollutant-tolerant species. The Mulhockaway Creek has been assessed three times since 1994 and the classification has changed from non-impaired in 1994 to moderately impaired in 1999 and 2004. The likely causes of the degraded assessment are erosion and sedimentation or changes in streamflow (reductions in baseflow, increased peak flows) rather than toxic compounds. Water quality data indicate that toxic substances, including pesticides and herbicides, are below established water quality standards for aquatic life and human health. High velocity flows causing erosion may make the stream bottom uninhabitable or flush the insects downstream. When material eroded from the stream banks and bed settle during periods of low flow, the voids between the bottom material are filled, leaving little protective areas for the insects to establish themselves. Although NJDEP assumes impairment throughout the watershed based on an assessment at one location, stressed aquatic life may be localized because inspection of macroinvertebrates during stream visual assessments indicated healthy populations at a majority of the sites.

Erosion and Sediment

Erosion and sedimentation are also indicators of problems in the watershed and are the transport mechanism for other nonpoint source pollutants, since nutrients and other compounds are adsorbed to suspended solids and sediments. Erosion is a natural geologic process that can be exacerbated when the flow to the stream is altered or the stream experiences a flood. When land surfaces are made impervious, stormwater cannot infiltrate into the ground nor can it be impeded by vegetation or irregular land surfaces, yielding higher volumes of runoff that become concentrated and travel at much higher velocities. Higher velocity flows incorporate loose particles over which they flow and shear material from surfaces with which they come in contact, such as exposed soil, stream banks and the streambed. As stream flow diminishes after a rainfall event, material entrained in the flow settles onto the streambed until it becomes re-suspended during higher flow conditions. Sediments and solids are ultimately delivered to and deposited in Spruce Run Reservoir at the mouth of the Mulhockaway Creek.

Required Load Reductions

Per the Clean Water Act, when a pollutant adversely impacts a water body[2], the Total Maximum Daily Load (TMDL) of the pollutant that can be assimilated by the water body is calculated. Then, required reductions of point and nonpoint sources are determined that would reduce the pollutant concentrations so that the water body is no longer adversely impacted[3] and some assimilative capacity is reserved for potential future loads and as a margin of safety. The allowable load from a source or source type is then determined and assigned as either a Waste Load Allocation (WLA)[4] for point sources and a Load Allocation (LA) for nonpoint sources. The TMDL serves as a preliminary plan to improve surface water quality and recommends actions that may reduce sources and improve water quality to meet standards and achieve designated uses.

In 2003, NJDEP calculated a Total Maximum Daily Load (TMDL) for fecal coliform, an indicator bacteria for pathogen contamination, for 48 streams in the Raritan Basin, of which the Mulhockaway Creek was one. The required reduction in the fecal coliform load is estimated as 91 percent based on the Mulhockaway Creek summer geometric mean of 464 col/100 ml from data collected between 1994 and 2001 by the NJDEP. Bacteria are non-conservative contaminants because phenomena, such as growth and expiration, and physical processes such as settling and re-suspension affect the concentration. Another consideration is that different sources of bacterial contamination, such as feces, have different amounts of bacteria per gram and likely different abilities to survive and flourish in the stream rather than in the intestinal tracts of humans or animals. Considering natural sources and all of the processes bacteria may undergo in the stream, a 91 percent reduction in bacterial contamination is difficult to translate to the required load reductions and associated management options. Regardless of the reported percentage reduction required, the ultimate goal of the TMDL and its implementation is for the stream to meet the Clean Water Act goal of fishable and swimmable waters.

[2] Determined by violation of a water quality standard (either numeric or narrative).
[3] Reductions of contaminants to below regulatory limits.
[4] Although bacterial contamination is likely non-point source in origin, the NJDEP reported waste load allocations for bacteria and did not assign them to sources.

TMDLs have not been developed for erosion and sedimentation, elevated stream temperatures or stressed aquatic life in the Mulhockaway Creek so there are no specific load reductions and none were developed through this project. Loads and required load reductions would be difficult to quantify for these impairments. Erosion and sedimentation can be considered both an impairment (from excessive flows) and a cause of impairment through habitat destruction and transport of pollutants attached to the sediment. Since there are no major thermal discharges to the Creek, the temperature impairment may also be classified as a natural impairment. Methodologies to calculate the required length and width of riparian buffer to reduce thermal load from sun exposure or address elevated temperatures from road runoff have not yet been developed. Stressed aquatic life is often an indicator of other pollutants or forms of pollution. In many cases and likely for the Mulhockaway Creek, stressed aquatic life can be caused by erosion, increased velocity, sediment deposition, and scour, all of which may deteriorate macroinvertibrate habitat.

Nonpoint Source Management Measures

Through the stormwater inventory and fecal coliform track down monitoring program watershed wide and specific projects have been identified as potential management measures that will serve to improve the assessed status of the Creek and the watershed. These measures address fecal coliform sources and the performance of existing stormwater facilities. Some of the measures are appropriate for the minimization of erosion and sedimentation and the reduction of stream temperature, and thus may address the aquatic life impairment. Recommended management measures include:

- A comprehensive agricultural management program:
    - nutrient and manure management
    - exclusion of animals from the stream
    - establishment, re-establishment or refurbishment of riparian buffers;
- Sanitary survey(s), a precursor to an onsite wastewater management program;
- Repair and/or replacement of septic systems and/or cesspools;
- Removal of illicit connections:
    - Roof drains
    - Sump pumps
    - Pools
    - Misplaced/misdirected septic system laterals
- Stormwater outlet stabilizations;
- Catch basin inserts;
- Swale and ditch retrofits;
- Detention basinretrofits;
- Detention basin maintenance program and retrofits;
- Ordinances for improvement of detention basin maintenance;
- Ordinances for protection of riparian areas; and
- Stream and riparian area restoration.

The recommended management measures are discussed below and in more detail in the report section about *Recommended Mitigation and Restoration Measures*.

Recommended Projects

Five watershed wide projects and fourteen site-specific projects were identified for watershed restoration. The projects were selected to address the impairments to the Creek and maximize the benefits from existing best management practices (primarily detention basins) and stormwater infrastructure (ditches and swales). Table ES-1 presents these watershed restoration projects, which are explained in detail in Appendix A.

Quantification of the benefits of each project, such as removal of fecal matter or total suspended solids reduction, was difficult because the watershed wide projects require further project identification and assessments. In addition, other factors besides a quantifiable result may make a project more attractive, including, but not limited to, availability of implementation funding, willing partners, reported success in the literature, and visibility. Considering this, five projects (with sub-projects) were prioritized for more immediate implementation, although all projects should be implemented as funding becomes available.

The Comprehensive Agricultural Management program is high priority because implementation of projects identified through the program may alleviate many of the problems facing the watershed: fecal contamination, erosion and sedimentation, elevated stream temperature and aquatic life. Sanitary surveys will identify and track down specific sources of human pathogens and fecal contamination that must be addressed and can be the precursor to an onsite wastewater management plan. The potential adoption of ordinances to assure maintenance of best management practices and the protection of riparian areas provides mechanisms for the townships to enforce maintenance requirements and prohibit detrimental activities in the stream corridor. Stream and riparian area restoration may be appropriate in some locations to remediate damaged areas. Interstate 78 swale and ditch retrofit offers opportunities to manage stormwater from a large impervious area. The wetland swale proposed will filter pollutants, slow and potentially cool higher temperature runoff from a large impervious surface, before it reaches the trout stream. The rehabilitation of the Country Acres Detention Basin, which releases high velocity flow and sediment upstream of the Hoffman Park restoration project, has many benefits. The basin will be converted to a functioning bioretention basin so that more stormwater will be intercepted and infiltrated. The outlet will be reconstructed so the energy from the discharges will be dissipated and erosion in the drainage ditch will be less likely to erode. The Union Township Middle School swale retrofit and rain garden provides an opportunity to add an educational component to a mitigation project that slows stream velocity traps sediment and uses plants for pollutant removal.

Table ES-1. Recommended Nonpoint Source Management Measures

WATERSHED RESTORATION PROJECTS	Priority	Water Quantity	Water Quality	Infiltration	Stabilize Erosion
Watershed-Wide					
Comprehensive Agricultural Management*+			X		X
Nutrient Management Plans (40 Farms)*			X		X*
Integrated Crop Management (1,800 acres)	**1**		X		X
Outreach and Education Program (4 weeks/yr – 5yrs)			X		X
Match EQIP and CREP Funds			X		X
Good Initial Targets					
Old Farm Road Fencing, Riparian Buffer and Manure Management Plan #	**1a**		X		X
Van Syckel's Riparian Buffer and Manure Management (equine)#	**1b**		X		X
Van Syckel's Manure Management (Poultry)#	**1c**		X		X
Sanitary Surveys and Illicit Connection Detection and Removal *	**2**	X	X	X	X
Roadside Ditch Retrofits	**4**	X	X	X	X
Good Initial Targets					
I-78 Swale and Wetland Retrofit	**4a**	X	X	X	X
Others (poor and failing ditches)				X	X
Ordinances for Maintenance of Stormwater Facilities and Riparian Area Protection	**3**	X	X	X	X
Stream and Riparian Area Restoration		X	X	X	X
Site Specific					
Outlet Stabilizations (Reduction of Pollutant Generation)					
OPG-109 Pipe Repair and Stabilization		X	X		X
OPG-213 Pipe Repair and Stabilization		X	X		X
OPG-369 Outlet Stabilization (Country Acres)			X		X
Best Management Practice Retrofits (Collection, Interception and Treatment)					
Catch Basin Inserts for Hickory Ridge			X		
Catch Basin Inserts Kensington Court			X		
Union Township Middle School (Perryville Road) Rain Garden and Swale	**6**		X	X	X
Country Acres Detention Basin Retrofit	**5**	X	X		
Mill Brook Basin Retrofit		X	X	X	
Perrryville Office Park Detention Basin Landscaping			X		
Hawk Ridge Bioretention Wetland Basin		X	X		

*** Recommended measure is a first step. Full implementation, such as manure management facilities, septic system replacement, etc. will require site specific evaluations.**

+ Nutrient Management Plans usually recommend livestock exclusion fencing. This limits the amount of feces deposited in the stream channel. As well, the trampling of the stream bed and banks and overgrazing of riparian vegetation are eliminated or minimized.

 # Project descriptions not included in Appendix A. These projects will be implemented through the Comprehensive Agricultural Management Project.

Measurable Milestones

The goal of the stormwater management and restoration plan is for the Mulhockaway Creek to meet its designated uses and maintain or improve the water quality of Spruce Run Reservoir. The uses that the Mulhockaway Creek does not meet include primary contact recreation and aquatic life (general and trout). Measurable milestones for achieving the primary contact recreation designated use are discussed in the Fecal Coliform TMDL Implementation Recommendations, a companion report to this document, and involve 1) management measures to achieve an intermediate assumed secondary contact recreation threshold or standard, 2) reassessment of the impairment and determination of pollutant sources with microbial source tracking, and 3) either classification as natural sources or implementation of additional management measures to achieve primary contact recreation standards. The designated use of secondary contact recreation, and potentially primary, is likely achievable through implementation of agricultural best management practices and addressing contamination sources identified through a sanitary survey.

Attaining a classification of non-impaired for aquatic life (general, trout) will depend upon meeting water quality standards for temperature and continuing to the meet water quality standards for pH, dissolved oxygen, total dissolved solids and total suspended solids. In addition, biological monitoring results will need to improve and fish assessments will need to remain optimal. An intermediate goal would be to improve or maintain the biological monitoring score.

No measurable milestone is recommended for erosion and sedimentation at this time because there are no baseline measurements or qualitative metrics identified for the Creek. However, a first step in management of erosion and sedimentation is the dissipation of energy at stormwater outfalls and ditches, which would reduce velocities and the associated energy that create erosion and the sedimentation issues downstream.

Implementation

Implementation of these programs and projects will likely be undertaken by:

- NJWSA;
- Bethlehem Township;
- Union Township;
- NJDEP;
- North Jersey Resource Conservation and Development Council (NJRC&DC);
- Natural Resource Conservation Service, (NRCS);
- South Branch Watershed Association (SBWA);
- Raritan Basin Watershed Alliance (RBWA);
- Hunterdon County Department of Parks and Recreation;
- Hunterdon County Department of Health; and
- Others.

These organizations have partnered on many projects for source water protection and watershed restoration and are committed to continue. NJWSA has a unit devoted to watershed protection and has begun implementing some of the plans they have developed. Bethlehem and Union Townships, Hunterdon County Department of Parks and Recreation, Hunterdon County Board of Health, RBWA, SBWA, NJRC&DC, NRCS, and NJDEP have participated in many of NJWSA's projects and programs and are willing to continue doing so in addition to projects of their own. NJDEP will need to take the lead on the sanitary survey, likely with the help of the Department of Health (State and/or County). Any and all of these organizations may be interested in the implementation of actions which will lead to the Mulhockaway Creek meeting designated uses or improve water quality.

Technical Assistance and Funding

The NJWSA is dedicated to source water protection and has been recognized for its work in watershed protection. In particular, the Authority has worked with the organizations listed previously to align environmental protection goals and projects to be protective of water resources. In 2001, NJWSA released the Raritan Basin Watershed Management Plan and facilitated the development of the Raritan Basin Watershed Alliance (RBWA), a partnership of organizations dedicated to the protection of the Raritan Basin. The Alliance's first major project was the Riparian Preservation and Restoration Initiative for which stream assessment methods are being evaluated and developed and potential funding sources are being evaluated for projects to improve riparian areas. Through the USEPA Targeted Watershed Grant, NJWSA has worked with Bethlehem and Union Townships to align their master plans and ordinances to be protective of water resources. River Friendly Programs, based on those developed by the Stony Brook Millstone Watershed Association, were implemented in the Raritan Basin and as a result NJWSA has contracted with NRCS/NJRC&DC to accelerate the participation in the River Friendly Farm Program in the Raritan Basin.

As projects are identified, the NJWSA and others may apply for 319 grants for implementation. The sanitary survey can be the first step towards an onsite wastewater management plan, which is eligible for a 604(b) Water Quality Planning Grant. When resurfacing work is proposed on Interstate 78, the Federal Highway Administration can be approached for Transportation Enhancement Grants under (23 U.S.C. 101(a)(35)) to address water pollution from highway runoff including installation of soil erosion controls, detention and sediment basins, and river clean-ups.

Schedule

Many of the projects identified can be implemented immediately or with some additional design work and permitting. As mentioned previously, NJWSA has begun a program similar to the Comprehensive Agricultural Management Program by accelerating their outreach efforts for participation in the River Friendly Farm Program with assistance from NJRC&DC. No specific schedule has been set because funding sources for the projects need to be identified and obtained. Lead organizations also need to be identified for each project.

Criteria and Monitoring Program

NJDEP performs biological monitoring for the Mulhockaway Creek approximately every 5 years. Through a cooperative monitoring program with NJDEP, the United States Geological Survey (USGS) collects quarterly water quality samples at their streamflow gauge. When water quality monitoring of the Mulhockaway Creek is not included in the cooperative monitoring program rotation, NJWSA funds the water quality monitoring for the Mulhockaway Creek. NJWSA also funds the USGS streamflow gauge. Thus, there is a high likelihood that data will be available to evaluate the long-term improvements to the watershed into the future at this location. Additional monitoring may be desirable for baseline measurements upstream and downstream and before and after implementation of specific projects or to isolate tributary subwatershed areas (as in the fecal coliform track down monitoring). However, at this time, the major collection of baseline data is at the USGS gauge and data will most likely be collected there in the future to assess the watershed.

Education

Outreach and education for the Stormwater Management and Watershed Restoration Plan may occur through many different existing programs. Both Townships' municipal stormwater management plans require them to conduct a yearly educational event and distribute brochures provided by the NJDEP. Additional information about this project can be distributed in conjunction with the required mailing. Both Townships, NJWSA and RBWA have websites, which can be vehicles for the dissemination of the plan and information about the management measures. The plan and resulting projects can be highlighted in the RBWA "Basin Bulletin", a newsletter issued four times per year. The Spruce Run Initiative members have worked together in the past to develop a septic system maintenance education program for residents and may possibly be enlisted to develop other educational programs or materials about nonpoint source pollution. As with the Hoffman Park Restoration project on the eastern most tributary from the south, signs can be displayed during project implementation and thereafter to educate the public about the intent of the project and how it serves to improve the stream.

INTRODUCTION

In 2002, the New Jersey Water Supply Authority (NJWSA) pursued, and the New Jersey Department of Environmental Protection (NJDEP) provided, a 319(h) Nonpoint Source Pollution Control Grant to develop a stormwater management and watershed restoration plan for the Mulhockaway Creek, which conveys runoff from the western portion of the Spruce Run Reservoir watershed. The Reservoir is New Jersey's third-largest water supply reservoir (11 billion gallons) and a recreational resource for fishing, boating and swimming.

The Mulhockaway Creek is described as a trout production fishery and is considered to be a stream of exceptional value for water supply purposes. Monitoring data indicate that the stream does not meet surface water quality standards for temperature and fecal coliform. The Mulhockaway Creek is also rated as moderately impaired for aquatic life. The stream experiences excessive flows evidenced by erosion and voluminous sediment deposits. The elevated stream temperatures jeopardize the trout fishery and higher levels of fecal coliform are indictors for the potential presence of human pathogens, which impair the stream for primary contact recreation. [5] Aquatic life evaluations may be less than desirable due to elevated stream temperatures, erosion and sediment deposition or toxic contaminants. Erosion and sedimentation may be natural or due to anthropogenic sources, such as removal of vegetation for agriculture and development and/or the routing of stormwater flows. Water quality monitoring of the Mulhockaway Creek indicated that toxic contaminants were below established ambient surface water quality standards or other levels of concern (human health, acute aquatic life, chronic aquatic life); therefore, sedimentation, erosion and elevated stream temperatures are the likely causes of the aquatic life impairment.

The Spruce Run Reservoir, the ultimate recipient of water from the Mulhockaway Creek, is classified as trout maintenance reservoir and supports a healthy sport fishery for striped bass hybrids and largemouth bass among other fish species. According to a report by the New Jersey Division of Fish and Wildlife about the Spruce Run Reservoir fishery, the Reservoir is eutrophic with anoxic conditions in the summer approximately 15 feet below the water surface (at the thermocline). Anoxic conditions are indicative of moderately productive algae and aquatic plant growth, which are often the result of excessive nutrient contributions to the water body, usually phosphorus from nonpoint source pollution. According to sparse, but recent data, the reservoir meets water quality standards for primary contact recreation and aquatic life, but is not assessed for recreation aesthetics. Other tributaries to the Reservoir besides the Mulhockaway Creek do not meet water quality standards for fecal coliform, temperature, pH, phosphorus and cadmium. However, the Reservoir itself met the water quality standard for phosphorus.[6]

[5] Impairements are reported in NJDEP's 2006 Integrated List. This list is a combination of the Clean Water Act 303(d) and 305(b) lists, which indicates a stream's designated uses and water quality based on whether or not surface water quality standards are met.
http://www.state.nj.us/dep/wmm/sgwqt/wat/integratedlist/integratedlist.html

[6] The water quality standard for phosphorus is 0.05 mg/l in lakes and tributaries to lakes. Value from Fisheries Study 0.04 mg/l on 11/3/2006.

The Mulhockaway Creek has one permitted continuous surface water point source discharger[7], which contributes relatively little flow to the stream. The discharge is a recently refurbished on-site wastewater treatment system for a school. There are other types of permitted surface water dischargers, such as stormwater and construction dewatering, but these are intermittent or temporary. The water quality problems in the watershed emanate almost exclusively from nonpoint source pollution and excessive stormwater flows.

WATERSHED DESCRIPTION

Geography and Topology

The Mulhockaway Creek is located in the central western part of New Jersey within the communities of Bethlehem and Union Townships in the northwest corner of Hunterdon County. Interstate 78, a major east-west thoroughfare and parallel State Route 173 bisect the watershed. Several county roads (C.R.) serve as major through routes. These include C.R. 614 (Little York – Pattenburg Rd.), C.R. 625 (Jutland - Charlestown Road), and C.R. 635 (Perryville Rd/Mechlin Corner Rd). C.R. 579 (Bloomsbury Rd) follows the southern ridge of the watershed. The watershed is west of the Spruce Run Reservoir and contains portions of the Clinton Wildlife Management Area. Historical locales in the watershed include Pattenburg, Perryville and Norton.

The Mulhockaway Creek watershed ranges in elevation from 980 feet above sea level in the southwestern-most portion near Bloomsbury Road (C.R. 579) and Sawmill Lane to 273 feet above sea level at the Spruce Run Reservoir. The watershed is steeply sloped in its headwater areas along the ridges and much less so in the center valley region, which is roughly located between Van Syckel's Road and the Interstate 78 corridor. The geography and topological relief of the Mulhockaway Creek watershed are shown on Figure 1.

Hydrology

The Mulhockaway Creek watershed comprises 14.8 square miles (9,500 acres) of the western portion of the Spruce Run Reservoir watershed and is within NJDEP's Watershed Management Area 8 (WMA 8): North and South Branch Raritan Rivers. The Hydrologic Unit Code (HUC 14)[8] for the watershed is 02030105-020-030. The Mulhockaway Creek is comprised of several unnamed tributaries which join just upstream of the Spruce Run Reservoir. The watershed is bordered by the Jugtown Mountain and the Musconetcong Mountains in the west, the watersheds of the Musconectong River (Jaynes Brook and unnamed tributaries) on the north western side, the Hakihokake, Harihokake and Nichisakawick Creeks on the southern side, Cakepoulin Creek and Sydney Brook/Grandin Creek on the south eastern side, and the Black Brook on the eastern side. Black Brook also drains into Spruce Run Reservoir, but the

[7] Permitted through the NJPDES Program.
[8] The Hydrologic Unit Code (HUC) is a watershed classification system developed by the United States Geological Survey. The number following HUC indicated the level to which the watershed is delineated. The Raritan Basin is a HUC8, the Spruce Run Reservoir watershed is a HUC11, etc.

Musconectong River and Hakihokake, Harihokake and Nichisakawick Creeks flow into the Delaware River. Cakepoulin Creek and Sydney Brook/Grandin Creek drain to the South Branch Raritan River. The Mulhockaway Creek watershed contains 31.3 miles of stream. Of these, 18.1 miles are first order[9], 11.2 are second order and 2 miles are third order or larger[10].

Subwatersheds were delineated for several of the tributaries and named after roads within them to provide a spatial reference for discussion purposes. These subwatersheds are presented in Figure 2. The Charlestown Branch of the Creek flows south and merges with the Mulhockaway east of Charlestown Road and just upstream of the Reservoir. The subwatershed contains the northern portion of Charlestown and Hackett Roads. The Norton Church Branch flows in a southerly direction and is just west of the Charlestown Branch. The subwatershed is traversed by Norton Church Road near the bottom and Mine Road in the headwaters. The Fox Farm Branch, bisected by Fox Farm Road, is the third stream north and west of the Reservoir and flows in a southeasterly direction. The Main Stem of the Mulhockaway Creek flows west to slightly northeast. Little York-Pattenburg Road (C.R. 614) runs through the subwatershed in the western portion and Van Syckel's Corner Road in the eastern portion, north of Interstate 78. The Baptist Church Branch, which includes three small tributaries, enters the main stem, mid watershed and is the third stream south and west of the Reservoir. Baptist Church Road is along the eastern side of this subwatershed. The second stream south and west of the Reservoir is the Driftway Branch. Driftway is a private drive that crosses the headwaters and the Perryville Office Park is located near the middle of the subwatershed. The eastern-most stream south of the Reservoir is the Mechlin Corner Branch, which contains two stream restoration projects implemented under the EPA Targeted Watershed Grant for the Raritan Basin. Perryville and Mechlin Corner Roads follow the eastern edge of the watershed.

Geology

Mulhockaway watershed is located in the Highlands and Piedmont Plain physiographic provinces of New Jersey. The transition zone roughly parallels the border of Bethlehem and Union Townships approximately 1,700 feet to the south and includes some additional area in Union Township in the east. The Highlands province is part of a larger geologic formation called the Reading Prong province that extends into Pennsylvania and primarily consists of highly metamorphosed pre-Cambrian rock. The Piedmont province is composed of sedimentary and metamorphic rock of the Triassic and Jurassic age. The Highlands are described as broad, rounded or flat-topped ridges between narrow valleys, while the Piedmont Plain has rolling hills with wide, shallow valleys. Figure 3 presents the geology of the watershed along with the Highlands Area designations. Also of significance is the presence of Karst bedrock or Carbonate Geology in the watershed, primarily in Union Township. These geologic formations develop voids and channels as

---

[9] Strahler Stream Order classifies stream size base on a hierarchy of tributaries. A"1" indicates a headwater stream.
[10] Based on NJDEP's 1995/1997 stream coverage. The 2002 draft hydrography coverage does not yet contain information about stream order and thus could not be used for this calculation.

ground water gradually dissolves bedrock resulting in extremely rapid and unpredictable ground water flows.

Soils

The Mulhockaway Creek watershed contains more than 20 soil types in three associations: Parker-Edneyville-Califon, Pattenburg, and Washington-Berks-Athol. The Parker-Edneyville-Califon association soils are deep, gently to steeply sloping, somewhat excessively drained, gravely, cobbly with some loam, formed from weathered granite and gneiss and underlain by gneiss. The soils are also described as cobbly loam with 3 to 25 percent slopes. The cobblestones, gravel, moderate to low fertility and steep slopes make the soil only moderately suitable for farming. These soils are primarily located in the northern portions of the Norton Church, Fox Farm and Charlestown subwatersheds, away from the stream.

The Pattenburg association consists of deep, gently to steeply sloping soil, well drained, gravelly soils and occurs immediately south of the Highlands. The association is also described as gravelly loam with slopes ranging from 2 to 40 percent. Permeability ranges from poor to moderate and bedrock depths are approximately 3 to 6 feet. According to the Hunterdon County Soil Survey, most of the soils are farmed although steeper areas tend to be wooded. In the Mulhockaway watershed, these soils are located south of Interstate 78 and southeast of Little York – Pattenburg Road (C.R. 614) in the southern Main Stem, Baptist Church, upper Driftway and upper Mechlin Corner watersheds.

The Washington-Berks-Athol association is composed of moderately deep, gently sloping to steep, well-drained soils that are south of the Highlands and interspersed and around the Pattenberg association. The soils contain glacial drift and include large amounts of limestone, gneiss and chert gravel in loam and are well-suited for farming corn, alfalfa and general crops. These soils are primarily located in the lower portions of all subwatersheds. The southern portion of the watershed in Union Township is also underlain by carbonate rock in areas. The carbonate formation is located under Little York – Pattenburg Road (C.R. 614) south of Interstate 78 and is 1,800 feet at its widest. North of Interstate 78 the formation underlies the area between the border between Bethlehem and Union Townships and Van Syckel's Road with some additional area south and east of Charlestown Road.

Most of the soils in the watershed are non-hydric except those along the banks of the streams. The majority of the soils have moderate to high hydraulic conductivity indicating moderate to high infiltration rates. The soils are described as having low water retaining capacity so that water flows through them quickly. Approximately three-quarters of the soils in the watershed are described as well-drained with depths to the water table greater than six feet. Approximately ten percent of the watershed soils have depths to water table of three to six feet and another ten percent have depths to the water table of one to three feet. Approximately five percent of watershed soils are underlain by a high water table less than one foot from the ground surface. Bedrock also tends to be less than five feet from the surface. The soil drainage conditions and calculated percentages are described in Table 1.

Table 1: Soil Drainage Condition Group

Drainage Condition	Definition	Acres	Percentage of Soils in Watershed
E – Excessively	Soils have very high and high hydraulic conductivity and low water holding capacity. Depth to water table is more than 6 feet.	0	0%
W – Well	Soils have moderate hydraulic conductivity and water holding capacity. Depth to water table is more than 6 feet.	5,563	58.7%
MW – Moderately well	Soils have a layer of low hydraulic conductivity, wet state high in the profile. Depth to water table is 3 to 6 feet.	788	8.3%
P – Poorly	Soils may have a saturated zone, a layer of low hydraulic conductivity, or seepage. Depth to water table is less than 1 foot.	456	4.8%
SE – Somewhat excessively	Soils have high hydraulic conductivity and low water holding capacity. Depth to water table is more than 6 feet.	1,663	17.5%
SP- Somewhat poorly	Soils commonly have a layer with low hydraulic conductivity, wet state high in the profile. Depth to water table is 1 to 3 feet.	987	10.4%
VP – Very poorly	Soils are wet to the surface most of the time. Depth to water table is less than 1 foot, or is ponded.	23	0.24%
Source: NRCS Soil Survey Geographic (SSURGO) Database.			

The hydrologic soil group classifies the runoff generation potential from a soil and is used in the calculation of stormwater volumes that need to be managed. There are four major groups (A, B, C, D) and a few subgroups (B/D, C/D – in this watershed). The properties of the soil that determine the soil group include the infiltration rate and the transmission rate. The former is the rate that water enters the soil; the later is the rate that the water moves through the soil. “A” soils have the lowest runoff potential, while “D” soils have the highest. Of note, ground cover is used independently of the soil group. Figure 4 presents the distribution of hydrologic soil groups within the watershed.

The NRCS database provides an interpretation of limitations of each soil for sewage disposal (suitability for septic systems). Soils within the watershed are mostly rated to have “very limited” suitability for septic tank absorption fields. Although the hydraulic conductivity is moderate to high, the depth to bedrock in the Mulhockaway ranges from zero to six feet below the surface. The overlying soil is readily saturated limiting the ability of the water to percolate and be filtered. Steep slopes are another constraint on the suitability for septic systems due to the potential for seeps. The underlying carbonate area in the watershed should also be considered a limitation on suitability because of the potential for swift water movement through solution cavities into ground water supplies without adequate filtration.

The erosion hazard classification of a soil is the potential to erode naturally if not adequately protected and unrelated to historical or prevailing land use practices. A soil’s erosion potential is largely determined by soil texture, organic matter content, structure, hydraulic conductivity, and to a lesser extent, slope. When referencing the watershed soils' suitability for farming, the Hunterdon County Soil Survey[11] indicates that erosion must be controlled for many of the soils in the watershed. In the Mulhockaway Creek watershed, 31 percent of the soils are "highly erodible" and 61 percent are "potentially highly erodible" soils. The remaining 8 percent of soils are classified as "not highly erodible." "Highly erodible" soils tend to be located in the headwaters and Charlestown subwatershed, while "not highly erodible" soils are located around and close to the Creek. The less erodible soils near the Creek indicate that the stream has eroded to more resistant substrate and lateral erosion may be more likely than downward erosion. Within the Creek itself, the substrate (bottom material) is approximately 40 percent gravel and 60 percent sand with little clay or silt.

Water Budget

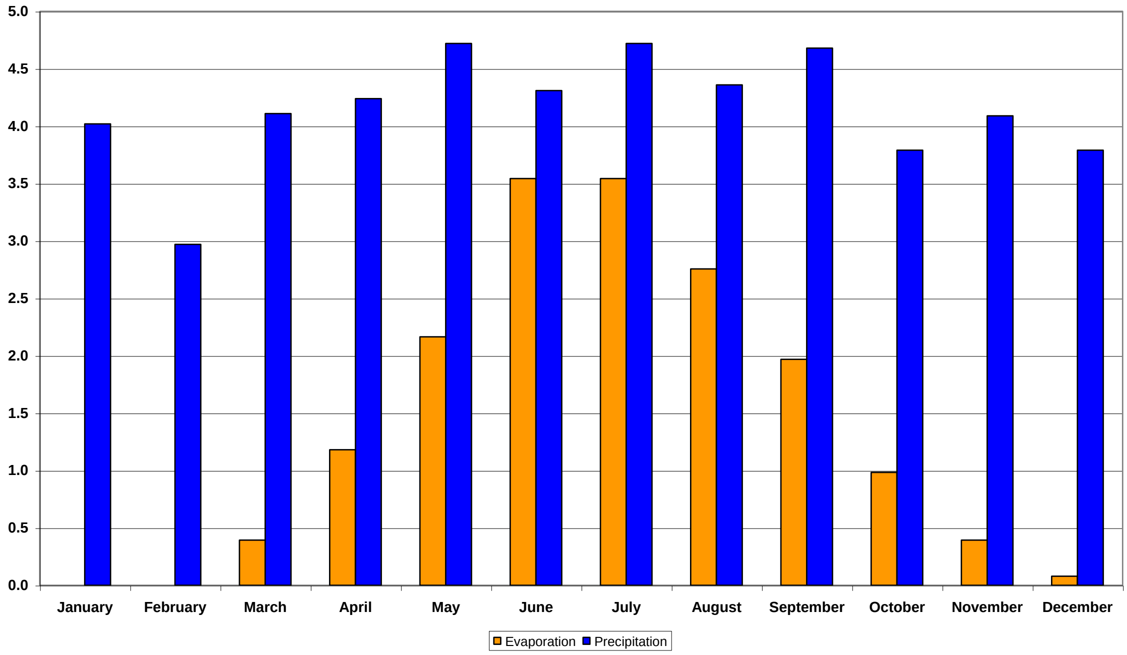
Once on the ground, precipitation infiltrates into the soil, is intercepted and absorbed by plants, and evaporates or flows overland into streams (runoff). Water is also evaporated from within the leaves, stems, flowers and fruits of plants. This process is called transpiration. Evaporation and transpiration are often calculated together and called evapotranspiration. Flow that runs off the land is called runoff or stormwater. The volume of precipitation that becomes stormwater is related to the amount of impervious surface and vegetation of the land. Within the Spruce Run Reservoir watershed, approximately 19 percent of precipitation infiltrates into the ground, 29 percent becomes runoff and 52 percent is evapotranspired.[12] Water that infiltrates into the ground either recharges the shallow aquifer or flows through the soil until intercepted by a stream, where it becomes baseflow.

The average annual precipitation[13], based on data from 1971-2000, is approximately 49.3 inches per year at the Flemington Gauge[14] and 47.5 inches at the Wertsville Gauge (near Ringos, NJ)[15], both operated by the National Weather Service. Previous long-term average rainfall based on the historic record (1918-2000) was approximately 45 inches. Typical monthly rainfall amounts are between 3 and 5 inches. Evaporation without transpiration averages approximately 17 inches per year, with no evaporation occurring between December and February and more than 3 inches per month occurring in June and July. Figure 5 presents average annual precipitation and evaporation for the area.

---

[11] U.S. Department of Agriculture, Soil Conservation Service. 1974. Soil Survey: Hunterdon County, New Jersey.
[12] Raritan Basin Tech Reports. 2000. www.raritanbasin.org/reports/water budget report.pdf
[13] Although the USGS maintains a rain gauge at the Spruce Run Reservoir, the record is of insufficient length for long term statistics.
[14] NOAA 283029 Flemington NNW.
[15] NOAA 289363 Wertsville

Figure 5. Average Annual Precipitation and Evaporation



Precipitation based on data from 1971-2000, compiled by NJ State Climatologist. Evaporation data obtained from NOAA.

Ground Water

Ground water is stored in the voids between soil particles or fractured rock. The soil and rock formations with water-filled voids are known as aquifers. The level of water in an aquifer is called the water table and represents the top of the aquifer or saturated zone of the soil. Ground water recharge is precipitation that infiltrates from the land surface and travels below plant roots and unsaturated soils, filling the voids of soil and fractured rock at the water table. Once in the saturated zone, ground water naturally flows towards low areas, such as streams, where it becomes surface water as either a spring or stream baseflow. Many factors affect the amount of recharge that occurs in a given area, including climate (e.g. the amount, intensity, and form of precipitation, and the effect of wind, humidity and air temperature on evapotranspiration), soil, surface geology, and vegetation. Ground water also varies seasonally. During the growing season, vegetation intercepts precipitation and returns water to the atmosphere through transpiration and evaporation, which are higher during the warmer months. Most recharge occurs during late fall, winter, and early spring, when plants are dormant and evaporation rates are minimal.

Ground water recharge is an important consideration for stormwater management. NJDEP'stormwater management rules require that all new development maintain 100 percent of the site's average annual pre-developed ground water recharge volume. For this requirement, ground water recharge is calculated using a method developed by the

New Jersey Geological Survey (NJGS), called (GSR-32).[16] GSR-32 uses land use/cover, soil type, average annual precipitation and a climate factor to calculate ground water recharge.

Average annual ground water recharge was calculated for the Mulhockaway Creek using 1995/97 and 2002 land use/cover data from NJDEP and revised climate factors for GSR-32. In 1995, the recharge rate ranged from 0 to 18.31 inches per year while in 2002 the rate ranged from 0 to 18.95 inches per year. The total recharge volume for Mulhockaway Creek watershed increased from 3,032 millon gallons in 1995 to 3,049 millions gallons in 2002, a 0.5 percent increase, which is attributable to the error associated with delineating land uses. There are other potential reasons for the increase in recharge volume from 1995 to 2002. Wetlands and water are assumed to contribute no ground water recharge and are not considered by GSR-32. When wetlands are converted to either urban, agriculture, or forest, the ground water recharge will increase. In 2002, the new land use delineation had 13 fewer acres of water and wetlands than the 1995 classifications. Forest areas usually receive more ground water recharge than agricultural areas, so when area previously delineated as agricultural is converted to forest the recharge increases. Forest area increased by 37 acres between the 2002 and 1995 land use delineations. Even though more urban area has been developed, the decrease in ground water recharge from development is offset by the wetland losses and their conversion to forest. The ground water recharge rates based on 2002 land use data are presented in Figure 6.

The Stormwater Rules require that 100 percent of the average annual pre-development ground water recharge be infiltrated on site although not all locations are appropriate for infiltration best management practices (BMPs). To determine suitable sites for recharge BMPs or mitigation banks, the TRC Omni Environmental conducted a GIS analysis, which combined tax parcel data, geology, soils, land use, topography, and hydrologic information. Digital Tax Parcel data from Hunterdon County GIS was used as the base data for the analysis to find suitable sites or parcels for the infiltration of surface water and recharging ground water. Parcels were rated for suitability based on ownership, size, carbonate rock area and GSR-32 ground water recharge. Figure 7 presents the suitability of areas within the watershed for infiltration BMPs. Details of the analysis are presented in Appendix B.

Land Use and Land Cover

Land use and land cover data developed by NJDEP in 2002 indicates that the land uses in the Mulhockaway Creek watershed are predominantly forested (47 percent), urban (23 percent), agriculture (17 percent), and wetlands (11 percent). The remainder of the area (2 percent) is classified as barren or water surfaces. Forested areas are primarily described as deciduous in nature with the majority classified as having crown closure greater than 50 percent. More than 84 percent of the wetlands are deciduous wooded wetlands. Of the total urban area (2,220 acres), more than 72 percent (1,602 acres) is classified as rural residential[17], 4 percent (84 acres) is low to medium density

---

[16] New Jersey Geological Survey Gelogical Survey Report GSR-31: A Method for Evaluating Ground-Water-Recharge Areas in New Jersey, undated.

[17] Land use code 1140

residential[18]. Commercial, industrial, major roadways, recreational fields, rights-of-way and built-up land[19] comprise the remaining 24 percent (534 acres) of the urban lands. More than 91 percent of the agricultural lands are characterized as pasture and cropland.

The wetland areas draining to the Spruce Run Reservoir, including those within the Mulhockaway Creek watershed, have been designated as USEPA Priority Wetlands. Wetlands included on the United States Environmental Protection Agency (USEPA) Priority Wetlands List have been identified as the most important and vulnerable wetlands of the State. These wetlands contain unique habitat, rare wetland plants, important surface water systems, and critical water supplies. Potential threats to these wetlands include additional development and nonpoint source pollution. Table 2 summarizes the land use types within the Mulhockaway Creek watershed by subwatershed. Land use is shown in Figure 8.

Open Space Preservation

Prior to 2002, 1,238 acres of land were preserved in the watershed as farmland or open space. To avoid fragmented open space preservation and focus preservation efforts on watershed protection, one of the first projects conducted for the Spruce Run Initiative was the development of a Critical Area Preservation Plan. The Initiative partners developed a set of criteria to identify parcels for preservation that would be most beneficial to water quality. The criteria included riparian areas, high ground water recharge, dense forest, habitat for threatened and endangered species, prime agricultural soils, flood plain buffer, and parcel size (greater than 30 acres)[20]. Based on the analysis of critical areas, approximately 4,500 acres in four concentrated areas were identified for preservation of which 1,060 acres had already been preserved. As of June 2007, approximately 1,700 acres in the critical areas have been preserved. Throughout the watershed, a total of 2,030 acres have been preserved. Figure 9 presents the preserved open space as of June 2007 and targeted parcels and areas for preservation.

Table 2. Land Use and Land Cover

Type of Land Use	Total Area (Acres) by Type	Total Area (Percent) by Type	Land Use Code	Land Use Description	Total Area (Acres) by Land Use
Agriculture	1621	17%	2100	CROPLAND AND PASTURELAND	1477.5
			2200	ORCHARDS/VINEYARDS/NURSERIES /HORTICULTURAL AREAS	52.5
			2400	OTHER AGRICULTURE	90.9
Barren	57	0.6%	7300	EXTRACTIVE MINING	37.3
			7500	TRANSITIONAL AREAS	19.3
Forest	4498	47%	4110	DECIDUOUS FOREST (10-50% CROWN CLOSURE)	548.2

[18] Land use codes 1130 and 1120, respectively.
[19] Land use codes 1200, 1300, 1410, and 1700, respectively.
[20] See “Presevation of Critical Areas in the Spruce Run Reservoir Watershed : A report of the Spruce Run Initiative.” http://www.njwsa.org/WPU/SRI/SRI_Plan.pdf

Table 2. Land Use and Land Cover

			4120	DECIDUOUS FOREST (>50% CROWN CLOSURE)	3337.0
			4210	CONIFEROUS FOREST (10-50% CROWN CLOSURE)	7.1
			4220	CONIFEROUS FOREST (>50% CROWN CLOSURE)	14.4
			4230	PLANTATION	9.4
			4311	MIXED FOREST (>50% CONIFEROUS WITH 10-50% CROWN CLOSURE)	4.6
			4312	MIXED FOREST (>50% CONIFEROUS WITH >50% CROWN CLOSURE)	13.8
			4321	MIXED FOREST (>50% DECIDUOUS WITH 10-50% CROWN CLOSURE)	12.0
			4322	MIXED FOREST (>50% DECIDUOUS WITH >50% CROWN CLOSURE)	6.5
			4410	OLD FIELD (< 25% BRUSH COVERED)	125.2
			4420	DECIDUOUS BRUSH/SHRUBLAND	78.6
			4430	CONIFEROUS BRUSH/SHRUBLAND	16.7
			4440	MIXED DECIDUOUS/CONIFEROUS BRUSH/SHRUBLAND	323.9
Urban	**2219**	**23%**	1120	RESIDENTIAL, SINGLE UNIT, MEDIUM DENSITY	26.9
			1130	RESIDENTIAL, SINGLE UNIT, LOW DENSITY	57.4
			1140	RESIDENTIAL, RURAL, SINGLE UNIT	1601.3
			1200	COMMERCIAL/SERVICES	107.5
			1300	INDUSTRIAL	20.3
			1400	TRANSPORTATION/COMMUNICATION/UTILITIES	12.0
			1410	MAJOR ROADWAY	92.9
			1462	UPLAND RIGHTS-OF-WAY DEVELOPED	7.4
			1463	UPLAND RIGHTS-OF-WAY UNDEVELOPED	55.6
			1499	STORMWATER BASIN	18.3
			1700	OTHER URBAN OR BUILT-UP LAND	193.6
			1710	CEMETERY	3.1
			1800	RECREATIONAL LAND	13.5
			1804	ATHLETIC FIELDS (SCHOOLS)	8.8
Water	**46**	**0.5%**	5100	STREAMS AND CANALS	3.7
			5300	ARTIFICIAL LAKES	42.4
Wetlands	**1036**	**11%**	1461	WETLAND RIGHTS-OF-WAY	7.0
			1750	MANAGED WETLAND IN MAINTAINED LAWN GREENSPACE	7.0
			2140	AGRICULTURAL WETLANDS (MODIFIED)	66.3
			2150	FORMER AGRICULTURAL WETLAND (BECOMING SHRUBBY, NOT BUILT-UP)	6.4
			6210	DECIDUOUS WOODED WETLANDS	875.7
			6231	DECIDUOUS SCRUB/SHRUB WETLANDS	18.0
			6233	MIXED SCRUB/SHRUB WETLANDS (DECIDUOUS)	36.3
			6234	MIXED SCRUB/SHRUB WETLANDS (CONIFEROUS)	9.0
			6240	HERBACEOUS WETLANDS	4.8
			6241	PHRAGMITES DOMINATE INTERIOR WETLANDS	3.2
			7430	DISTURBED WETLANDS (MODIFIED)	2.6
				Total Area (Acres) by Subwatershed	**9476**

Future Development

The Highlands Act was passed in 2004 and protects the region as a special resource area for water supply, limiting new development and land use to that which is sustainable by the Highlands Region. The majority of the Mulhockaway Creek watershed is designated as Highlands Preservation Area, and subject to the full suite of associated regulations. The remaining area, designated Highlands Planning Area, is along the Interstate 78 corridor between Exits 11 and 12 in Union Township. Municipalities can voluntarily impose the Highlands regulations in the Planning Area, but must impose the regulations in the Preservation Area. Although the contact zone between the Highlands and the Piedmont Plain is within the Mulhockaway Creek watershed, the entire watershed area, except the highway corridor, was designated as Highlands to protect Spruce Run Reservoir.

A build-out analysis was performed for the portions of Bethlehem and Union Townships in the Mulhockaway Creek watershed to determine the remaining development potential within the watershed. The analysis was based on the Highlands Regulations as of April 2007 and current municipal zoning and does not account for future land preservation, Highlands Exemptions or low-income housing requirements. Considering existing development, critical areas (wetlands, stream buffers, flood plains, steep slopes greater than 25 percent) and other highlands restrictions, only 93 existing parcels[21] on approximately 1,430 acres may potentially be developed, 42 parcels (868 acres) in Bethlehem Township and 51 parcels (565 acres) in Union Township. The anticipated future additional development will increase the percent impervious of the entire watershed by approximately 0.8 percent, raising the watershed percent impervious from 5.3 percent to 6.1 percent. Figure 10 presents the estimated build out in the watershed.

In Bethlehem Township, future development will likely be residential because the portion of the Township in watershed is located in the Highlands Preservation area. The estimated increase in impervious surface in the portion of the watershed located in Bethlehem Township is 16 acres from the resulting 45 residential units. In Union Township, 51 parcels on 565 acres remain eligible for development, 43 residential parcels on 514 acres and 8 commercial parcels on 51 acres. The potential build-out results in 67 residential units and 40 acres of commercial development. This predicted development in Union Township will increase the impervious surface by 61 acres: 16 acres in the Highlands Preservation area and 45 acres in Planning Area.

Ecological Resources

The Mulhockaway Creek watershed contains sensitive habitat, state threatened and endangered species, rare plants and a trout fishery. As previously noted, the watershed has sensitive wetlands habitat and almost half is forested.

[21] Some parcels will be subdivided.

Wildlife and Wildlife Habitat

According to the Landscape Project Database, the majority of the Mulhockaway Creek watershed is categorized as "state-endangered" species habitat, primarily forest habitat. In addition, the riparian areas surrounding the two most eastern tributaries (Driftway and Mechlin Corner branches) between Interstate 78 and the reservoir and the western branch of the northeastern most tributary (Charlestown Branch) contain "federally-listed" forested wetlands habitat. Wood turtle habitat is delineated roughly to be within and around the 300-foot stream buffer.

Consultation with the Natural Heritage Program and Landscape Project data indicated the presence of species of concern within the Mulhockaway Creek watershed (HUC 02030105-020-030). These species are listed in Table 3. No additional species or sensitive wildlife habitat were identified within one quarter mile of the watershed boundary.

Table 3. Species from the Natural Heritage Program

Common name	Scientific name	State status
Bat hibernaculum[22]	*Bat hibernaculum*	Imperiled[23]
Bobcat	*Lynx rufus*	Endangered
Bobolink	*Dolichonyx oryzivorus*	Threatened
Bog turtle	*Clemmys muhlenbergii*	Endangered
Cooper's hawk	*Accipiter cooperii*	Threatened
Eastern box turtle	*Terrapene Carolina*	Special concern
Eastern meadowlark	*Stumella magna*	Declining
Grasshopper sparrow	*Ammodramus savannarum*	Threatened
Jefferson salamander	*Ambystoma jefffersonianum*	Special concern
Kentucky warbler	*Oporomis formosus*	Special concern
Northern Copperhead	*Agkistrodon contortrix contortrix*	Special concern
Northern parula	*Parula Americana*	Special concernt
Northern spring salamander	*Gyrinophilus p. porphyriticus*	Special concern
Sharp-shinned hawk	*Accipiter striatus*	Special concern
Veery	*Catharus fuscescens*	Special concern
Vesper sparrow	*Pooecetes gramineus*	Endangered
Wood turtle	*Clemmys insculpta*	Threatened
March 13, 2007 correspondence from Herbert A. Lord of the Natural Heritage Program		

Fisheries

NJDEP uses the Fisheries Index of Biotic Integrity (FIBI) to assess the attainment of the Clean Water Act goal of "fishable" waters. Data collected to determine the index are also used to develop biological criteria, prioritize sites for further studies, provide biological impact assessments, and assess status and trends of the state's freshwater fish assemblages. The FIBI[24] measures the number of fish species, types of fish species, number of benthic insects, types of benthic insects, ratios of trout species to piscivores (top carnivores) and proportion of individuals with disease or abnormalities.

---

[22] LT on the Federal List. LT=Taxa formally listed as threatened.

[23] Imperiled is not a standard State Category, but the Nature Conservancy has assigned the species a State Element Rank of S2, which means "Imperiled in New Jersey because of rarity (6 to 20 occurances). Most likely, the species loss is the result of habitat destruction.

[24] http://www.state.nj.us/dep/wms/bfbm/fishibi.html

In 2002, NJDEP's Bureau of Freshwater and Biological Monitoring determined the FIBI for the Mulhockaway Creek at site FIBI053, which is located upstream of the USGS streamflow gauge (01396660 Mulhockaway Creek at Van Syckel). Notwithstanding elevated stream temperatures, the Mulhockaway Creek was rated as excellent, which means:

- the Creek is comparable to the most desirable habitat with minimal human disturbance;
- all species expected in the region for the habitat and stream size were present;
- the most pollution intolerant species are present (the most sensitive species can survive); and
- the food chain and predator-prey relationships[25] are balanced.

Fish stocking by the Division of Fish and Wildlife has influenced and maintained the current fishery in the Mulhockaway Creek. Table 4 presents the fish species observed during the 2002 sampling to determine the FIBI.

Table 4. Fish Species Observed in the Mulhockaway Creek at Route 635 (FIBI053)

Common Name	Scientific Name	Number Found	Size Range (inches)
Blacknose Dace	*Rhinichthys atratulus*	149	
Brown Trout	*Salmo trutta*	127	2.4-12.8
White Sucker*	*Catostomus commersoni*	99	
Longnose Dace	*Rhinichthys cataractae*	**60**	
Largemouth Bass*	*Micropterus salmoides*	40	1.0 - 6.7
Tesselated Darter	*Etheostoma olmstedi*	30	
Slimy Sculpin	*Cottus cognatus*	23	
Bluegill*	*Lepomis macrochirus*	16	
Smallmouth Bass*	*Micropterus dolomieu*	15	2.2-6.7
Brook Trout*	*Salvelinus fontinalis*	7	6.5- 9.4
Pumpkinseed*	*Lepomis gibbosus*	4	3.1
American Eel	*Anguilla rostrata*	3	
Brown Bullhead*	*Ameiurus nebulosus*	3	3.1-3.9
Rainbow Trout*	*Oncorhynchus mykiss*	1	9.8
Yellow Perch*	*Perca flavescens*	1	
Source: http://www.state.nj.us/dep/wms/bfbm/download/ibi2002Vol2-52-55.pdf Species listed in order of abundance. Samples collected on August 1, 2002. * Regulated as a fishable species under current New Jersey Fish and Wildlife codes			

Fish Consumption Advisories

Fish consumption advisories have not been issued for the Mulhockaway Creek, but have been for Spruce Run Reservoir. According to the 2004 NJDEP Health Advisories Report[26] for Hunterdon County, mercury consumption advisories have been issued for largemouth and smallmouth bass in the Spruce Run Reservoir. Largemouth and

---

[25] Trophic status
[26] http://www.state.nj.us/dep/dsr/advisories/hunterdon.htm

smallmouth bass consumption should be limited to one meal per week for the general population and one meal per month for high-risk individuals (i.e., pregnant women, infants and children and elderly individuals). For the general public, no limits were issued for hybrid striped bass or trout, although high-risk individuals are advised to eat no more than one meal per month. The Creek has not been assessed for fish consumption, but by association with the reservoir, could be considered to have a fish consumption advisory for largemouth and smallmouth bass.

Rare Plant Species and Ecological Communities

The Natural Heritage Program evaluated the Mulhockaway Creek watershed for rare plants and ecological communities in or within one-quarter mile of the boundary and reported the rare species within Hunterdon County. Only one plant species, the small whorled pogonia (isotria medeloides) is on the Federal List and it is within a class[27] of plants "formally listed as threatened." Of the vascular plants[28] listed, 45 are considered State Endangered. The information about rare and endangered plant species in Hunterdon County and the Mulhockaway Creek watershed that was provided by the Natural Heritage Program is presented in Appendix C.

PHYSICAL CONDITION

Streams and rivers function to convey water from high to low points in the terrain in addition to providing habitat for wildlife and aquatic organisms. The force of gravity pulling the water downhill provides the energy to erode soil and cut stream channels to facilitate the movement of water. A stream's conveyance function is often evaluated by its shape and configuration, also known as its geomorphology. Erosion, the resulting sedimentation and the state of the riparian area are major factors in the watershed affecting the physical condition of the stream as well as its water quality and suitability for aquatic life.

Natural Erosion

Water erosion is one of many geologic processes that form the landscape. Downward erosion deepens a channel or valley, while lateral[29] erosion widens them. Downward erosion tends to occur early in stream evolution when the terrain is steep (high gradient) and until a limiting condition is reached, such as hard to erode bedrock or another water body, such as the ocean or a lake. Lateral erosion tends to occur when downward erosion reaches more resistant substrate material. Most erosion occurs during floods or times of high flow, when higher velocity water transports sediment and suspended particles shear material from the streambed and channel banks. The steep slopes and erodible soils in the headwater regions of the watershed may indicate the potential for natural erosion from these areas. Due to less erodible soils near and in the stream, lateral erosion may be more likely.

---

[27] Taxa

[28] Vascular plants are those which can circulate water, nutrients, minerals and photosynthetic products throughout the plant. Examples of vascular plants include ferns, clubmosses, horsetails, flowering plants, conifers and other gymnosperms.

[29] Also known as headward erosion.

Hydromodification

Hydromodification is defined as changes to the hydrologic characteristics of a stream and streamflow and which may cause degradation of water resources. Although hydromodification can result from natural processes, for the purposes of discussion herein it will be considered anthropogenic in character. Activities that result in hydromodification include physical changes to the channel and stream banks (dredging, debris removal, straightening or rerouting, adjacent construction, dams or impoundments, culverts and bridges, or other flow routing or disrupting structures)[30] or volumetric changes to the flow (diversions, discharges, releases from impoundments). Hydromodification includes the introduction of stormwater flows, which are routed into the stream in greater volume and at a faster velocity than what would occur naturally through structures that potentially change the flow dynamics of the stream, if for only during periods of runoff. Although a natural process, much erosion is caused by anthropomorphic land altering activities, including forestry, agriculture, construction, addition of impervious surfaces and stormwater management.

Erosion and Sedimentation in the Mulhockaway Creek Watershed

The Mulhockaway Creek undergoes both natural and anthropogenic erosion, some of which results from historic land use activities, such as timber harvesting, agriculture and creation of impervious surfaces (for example, roads, sidewalks, roofs, lawns). In the 1700s and 1800s, iron was mined in the area and timber for fuel was available in large quantities to make the charcoal necessary for smelting. The Union Furnace, located on Spruce Run, was used to make cannon balls for the Continental Army during the Revolution and operated until the late eighteenth or early nineteenth century. One reported reason for the furnace closure was the lack of wood to burn for charcoal, implying that the local forests, including those surrounding the Mulhockaway Creek were over harvested to support the iron furnace.[31] Deforestation reduces impediments to overland flow and interception of precipitation by vegetation, resulting in more water and sediment delivered more rapidly to the stream, disrupting the state to which the stream has evolved. Continued exposure of the erodible soils in the watershed through agricultural activities yielded significant sediment transport into and by streams. Such sediment is called legacy sediment, defined as “sediment that was eroded from upland slopes during several centuries of intensive land clearing, agriculture, and milling (dams for ponding water and channel alterations to direct flow through the mill). Sediment in the stream channel is also the result of severe bank erosion, likely due to more recent hydromodification and the resulting higher flows.

Riparian Areas

The riparian area or buffer, sometimes considered the floodplain, is the land located immediately adjacent to streams, lakes, or other surface waters. Riparian areas vary in width, shape, and character and do not stop at a uniform distance away from a stream or watercourse. Vegetation in the riparian buffer may be comprised of wetlands, grasses and

[30] USEPA. 1993.
[31] Bernard F. Ramsburg, “First 275 Years of Hunterdon County – 1714 to 1989: Industry.”

trees or any combination thereof. Riparian areas provide aquatic and terrestrial habitat, slow runoff, filter pollutants, and enhance infiltration. Riparian areas differ from upland areas because of high levels of soil moisture, frequent flooding, and the assemblage of plant and animal communities. The transition from riparian to upland areas may be gradual and not always well-defined.

The riparian area in the Mulhockaway Creek watershed was evaluated using NJDEP's 2002 land use/cover data. Riparian areas were defined using four criteria: wildlife passage corridor, wetlands and wetland transition areas, flood prone areas, hydric soils, which may overlap one another. Throughout the watershed, approximately 22 percent of the historic riparian area has been converted to urban or agricultural land uses. Approximately, 40 percent of the historic riparian area is forest and 38 percent is either water or wetlands.

Stream Assessments

Under a separate grant from USEPA,[32] stream visual assessments were conducted to gather baseline information about the streams in the Mulhockway Creek watershed. The condition of the stream is evaluated based on channel configuration and conditions, riparian characteristics and aquatic habitat. NJWSA used the United States Department of Agriculture – Natural Resources Conservation Service (USDA-NRCS) Stream Visual Assessment Protocol, which uses fifteen indicators to evaluate the condition of a stream. Figure 11 presents the locations of the twenty visual assessments conducted within the Mulhockaway Creek watershed. Most of the assessments were performed at road crossings because the Creek and its branches meander through private property, which limited access to the stream for assessments. Of twenty visual assessments conducted, three stream segments were rated "poor", sixteen were rated "fair" and one was rated "good." The major problems are destabilized banks, stream erosion, channel incision and inadequate riparian vegetation. The visual assessments are summarized by tributary below and the results are presented in Table 5.

[32] 2003 EPA Targeted Watershed Grant for the Raritan Basin

Table 5. Stream Visual Assessment Results

Location	SVA ID	Visual Assessment Indicator*: Channel Condition	Hydrologic Alteration	Riparian Zone	Bank Stability	Water Appearance	Nutrient Enrichment	Barriers to Fish Movement	Instream Fish Cover	Pools	Invertebrate Habitat	Canopy Cover	Riffle Embeddedness	Macroinvertebrates Observed	Overall Score
Charlestown Headwaters	31	8	7	2	5	6	6	3	8	7	7	3	5	13	**6.2**
Charlestown Mid-Watershed	15	8	7	7	7	8	8	3	8	7	9	9	7	10	**7.5**
Charlestown Downstream	22	6	7	4	5	8	7	3	6	4	7	4	5	10	**5.8**
Norton Chuurch Mid-Watershed	30	8	7	4	6	7	7	3	8	7	8	5	7	13	**6.9**
Fox Farm Mid Watershed	14	8	7	6	7	8	7	3	8	7	9	8	8	9	**7.3**
Fox Farm Downstream	5	8	8	3	7	8	8	3	5	7	8	6	4	12	**6.7**
Mulhockaway Main Stem Upstream of Pattenburg	17	5	7	2	5	8	6	3	6	7	7	3	5	9	**5.6**
Mulhockaway Main Stem Downstream Pattenburg	23	5	7	6	9	8	8	3	7	5	7	8	8	10	**7.0**
Mulhockaway Main Stem Upstream of Confluence with Baptist Church Branch	16	7	7	8	5	7	7	3	8	8	8	8	7	12	**7.3**
Mulhockaway Main Stem Downstream of Baptist Church Branch	24	8	7	7	4	8	7	3	6	6	7	8	8	14	**7.2**
Mulhockaway Main Stem North of Interstate 78	19	8	7	8	4	8	8	3	8	6	7	7	5	11	**6.9**
Mulhockaway Main Stem at USGS Gauge on Charlestown Road	4	6	7	6	4	9	10	3	5	7	10	7	5	10	**6.8**
Baptist Church above Confluence with Mulhockaway Main Stem	18	8	7	6	5	8	7	3	5	6	7	5	7	14	**6.8**
Driftway Upstream in Western Hoffman Park	26	7	8	8	8	6	4	3	7	na	8	6	8	11	**7.0**
Driftway Upstream of RailRoad Culvert	29	7	8	7	8	6	5	3	3	na	6	7	5	10	**6.3**
Driftway Downstream of Railroad Culvert	27	6	7	8	5	6	7	3	7	6	7	6	7	11	**6.6**
Driftway South of Intersate 78	28	6	6	7	6	8	7	3	7	6	7	7	7	12	**6.8**
Driftway between Interstate 78 and USGS Gauge	20	9	8	8	8	6	7	3	6	5	8	8	7	13	**7.4**
Mechlin Corner at Old Farm Road near Headwaters	25	8	7	1	5	7	6	1	5	5	7	1	8	13	**5.7**
Mechlin Corner Mid-Watershed in Eastern Hoffman Park	21	5	7	9	6	8	7	1	5	5	6	5	9	13	**6.6**

Legend		
	Green	Good >10 for macroinvertebrates; >7 for other indicators; >7.5 for overall score
	Yellow	Fair >5 and < 10 for macroinvertebrates; >4 and <7 for other indicators; >6.1and <7.4 for overal score
	Orange	Poor <5 for macroinvertebrates; <4 for other indicators; <6 for overall score
		SVA ID = Stream Visual Assessment ID

Indicator	Descritpion
Channel condition	Natural vs. altered channel (channelization; installation of riprap, dikes or levies; or downcutting or incision).
Hydrologic alteration	Connectivity to the floodplain (structures or channel incision that limit the stream's access to the floodplain).
Riparian zone	Stream's vegetated buffer area (good: extends at least two channel widths on each bank. Poor: only extends less than half the channel width on each bank).
Bank stability	Bank condition (Good: banks are level with the floodplain and stable; Poor: higher and eroding with exposed tree roots or slope failures).
Water appearance	Water clarity (Good:clear with visible bottom; Poor: cloudy or turbid).
Nutrient enrichment	Presence of algae and/or aquatic macrophytes (Good: diverse plant community and clear water; Poor: greenish water and overabundance of algae and/or macrophytes).
Barriers to fish movement	Withdrawals, culverts, dams or diversions both up and downstream of the reach.
Instream fish cover	Available cover types for fish habitat (e.g., woody debris, riffles, pools, and cobble).
Pools	Abundance and depth of pools within the reach.
Invertebrate habitat	Number of cover types available as habitat.
Canopy cover	Coldwater versus warm water fisheries. (Good: shaded and protected areas; Poor: little to no shade).
Manure presence*	Evidence of livestock in or near the stream (not evaluated for EPA Project)
Salinity*	Non-applicable for the project watershed.
Riffle embeddedness	Embeddedness of cobble or gravel in sediment.
Macroinvertebrates observed	Type and diversity of species present. (Good: diversity of pollution intolerant species; Poor: dominated by more pollution tolerant organisms).

Best professional judgement and relative comparison to other reaches in the region or watershed are used to assign indicator values and may be subjective.

Charlestown Branch

Three visual assessments were conducted in this subwatershed: headwaters, mid-watershed and downstream above the watershed. The ratings were fair, good and poor, respectively. In the headwaters, lawn area is mown to the stream banks and invasive species are plentiful in the riparian area on the other side of the stream. Mid-watershed, the stream is in good condition, but the riparian buffer could be improved. In the downstream area, the channel was straightened and the stream banks are severely eroded, near vertical and approximately 4 to 6 feet high. Figure 12 presents photographs of the Charlestown Branch.

Figure 12. Charlestown Branch Visual Assessment Locations

Headwaters

Mid-Watershed

Downstream

Norton Church Branch

Only one visual assessment was conducted and the stream was in fair condition. The assessment was located mid-watershed, where the banks were undercut. Lawn abuts the edge of the stream on the west and forest comprises the riparian buffer on the east. Figure 13 presents the visual assessment location of the Norton Church Branch.

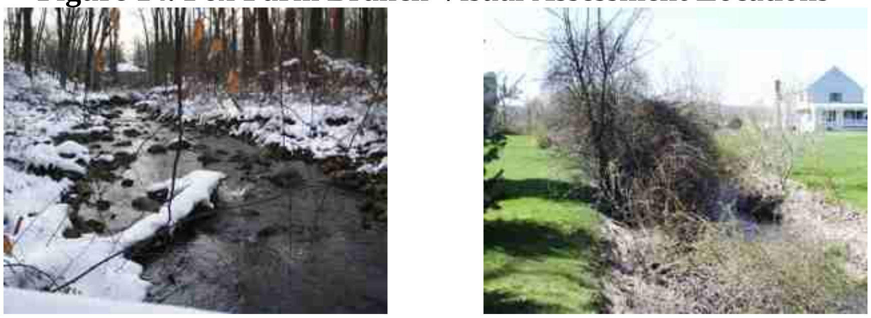
Figure 13. Norton Church Branch Visual Assessment Locations

Mid-Watershed

Fox Farm Branch

The stream was assessed and rated fair in two locations: mid-watershed and downstream. The mid-watershed location shows signs of erosion with near vertical banks, exposed tree roots and fallen trees. The downstream location is a low-lying area with residential properties adjacent to the stream. Lawns are mown to within several feet of the stream, but there is a narrow riparian buffer, mostly containing invasive species. Figure 14 presents the two visual assessment locations for the Fox Farm Branch.

Figure 14. Fox Farm Branch Visual Assessment Locations

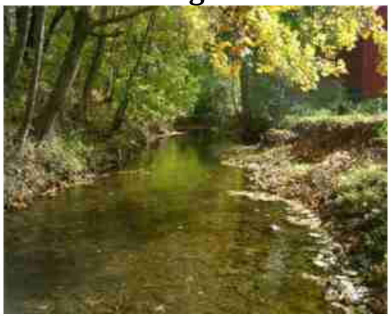


Mid-Watershed **Downstream**

Main Stem Mulhockaway Creek

The headwaters of the Main Stem were inaccessible for assessment, but six were conducted along the stream, four south of Interstate 78 and two north of Interstate 78. The uppermost assessment, downstream of the headwater area was located in Pattenburg where older residential development is located with lawns adjacent to the stream. The stream's condition is poor. The banks are eroded and the channel was straightened to accommodate the railroad. The stream was rated fair at the other four sites, all located approximately mid-watershed. The buffers were typically good, although there were signs of high flows, evidence of erosion and obvious sediment deposition. North Jersey Resource Conservation and Development Council (NJRC&DC) installed willow plantings in the reach downstream of Pattenburg in an attempt to reestablish the riparian buffer. The downstream visual assessment was located at the USGS stream gauge and also rated as fair. The channel and riparian buffer were considered to be in fair condition but bank stability was poor. The six visual assessment locations along the Main Stem and the location of the stream gauge (at the downstream most assessment) are presented in Figure 15.

Figure 15. Main Stem Mulhockaway Visual Assessment Locations


Upstream in Pattenburg


Downstream and Outside of Pattenburg


Just Upstream of Baptist Church Branch


Downstream of Baptist Church Branch


North of Interstate 78


At USGS Gauge 01396660

Baptist Church Branch

The Baptist Church tributary was assessed upstream of the confluence with the Main Stem and downstream of the railroad culvert. This branch was rated as fair because of high banks and undercutting in the upper portion of the reach assessed. In this location the stream has poor banks, little fish cover and lacks adequate tree canopy. Many trees were leaning with their roots exposed due to soil erosion. Figure 16 presents the visual assessment location on the Baptist Church Branch.

Figure 16 Baptist Church Branch Visual Assessment Location


Above Confluence with the Main Stem

Driftway Branch

Five assessments were performed along this branch of the Creek. Two assessments were conducted in Hoffman Park, two between the railroad and Interstate 78 and one approximately halfway between Interstate 78 and the confluence with the Mechlin Corner Branch. The southern most assessment was located upstream of a large pond and near a small agricultural area. The banks were slightly undercut and the stream was rated fair at this location. The next downstream location was below the large pond and upstream from the railroad culvert. Invasive species were observed within the riparian zone and this reach of the stream had been straightened. Another assessment was performed downstream of the railroad and the branch was rated as fair, primarily due to channel straightening. The visual assessment south of Interstate 78 was located at the edge of the Perryville Office Park property and rated the stream as fair. The riparian zone was primarily filled with invasive species, and some lawn was present in the lower end of the assessed reach. North of Interstate 78 and the Hunterdon Hills playhouse, the stream was rated as fair and just shy of a good rating. The stream channel, banks and riparian area are considered to be in good condition. Driftway Branch assessment locations are presented in Figure 17.

Figure 17. Driftway Branch Visual Assessment Locations

Upstream in Hoffman Park

Upstream of Railroad Culvert

Downstream Railroad Culvert

South of I-78

Between I-78 and USGS Gauge

Mechlin Corner Branch

Two assessments were completed on this branch of the Mulhockaway Creek: one near the headwaters and one approximately mid-watershed. The headwater site was rated as poor due to an inadequate riparian zone and canopy and the mid-watershed site was rated fair. The headwater area contains a development of more than 60 homes on 1.5 to 2 acre lots. Some of the drainage is routed to a detention basin and some of the road drainage is discharged directly to the stream. The riparian buffer consists of lawn adjacent to the stream banks and the stream was rated poor. At this location, known as Old Farm Road, a riparian buffer was replanted as part of the EPA Targeted Watershed Grant and the homeowner agreed not to mow within 30 feet of the stream banks. The mid-watershed portion of the stream, located in Hoffman Park, was rated fair. The riparian area was mostly forest and meadow. A culvert under an access road was inhibiting flow as evidenced erosion around the headwall. Below the culvert, the banks were nearly six feet high and the channel had been straightened for agriculture in the past. The culvert was replaced with a bridge and, and the stream channel was lengthened with meanders to decrease the gradient and reduce velocity. In stream structures were added to reinforce the flow pattern of the meanders and reestablishment of the riparian buffer. The channel is still acclimating to its new configuration. Figure 18 presents the visual assessment locations before and after the restoration projects.

Figure 18. Mechlin Corner Branch Visual Assessment Locations

Headwaters: Old Farm Road | **Mid-Watershed: Hoffman Park**

Pre-Restoration

Post-Restoration

Summary of Visual Assessments

The stream system is impacted by high-energy flows caused by the steepness of the watershed in the headwaters, poor stormwater management from developments and roadways, and legacy damage caused by forestry and agriculture through the stripping of vegetation and channel straightening. These factors all work to increase the flow, velocity and erosive forces of stormwater and streamflow. Historic land uses have exposed the watershed's erodible soils to higher velocity flows generated by steep slopes and loss of vegetation. Stormwater management systems, piped and ditched drainage, were designed to quickly route the water to the stream through less resistant pathways. Energy not used by the water to overcome friction in the pipe or ditch is expended as increased velocity within the pipe or ditch or at the outlet/outfall structure. Straightening the stream has reduced the energy lost through meanders and has similar effects to piping or ditching stormwater.

SURFACE WATER QUALITY

The Mulhockaway Creek is classified as FW2-TPC1, which means a fresh waterbody (FW2) not defined as pristine[33] or in the pinelands that contains high quality water suitable for trout production (TP), and is protected from degradation due to its exceptional characteristics (C1)[34]. Trout production waters are used by trout for spawning and nursery purposes and have more stringent water quality standards for temperature and dissolved oxygen[35]. NJDEP Division of Fish and Wildlife also stocks the Creek with trout each spring. All trout production streams are classified as Category 1 (C1) streams. The Mulhockaway Creek is also C1 because it is tributary to Spruce Run Reservoir (water supply), which is also designated as C1. Streams and reservoirs that have been designated as Category 1 are protected by antidegradation policies, which require no measurable change[36] in water quality.

Designated Uses and Impairments

For the US Environmental Protection Agency (EPA), as a requirement of the Clean Water Act[37], New Jersey must prepare an inventory of the state's water bodies[38], their designated uses, whether or not the uses are met, and, if known, the cause of impairment if the water body does not meet its uses. This information is reported to EPA in the Integrated List and Sublists[39] in even numbered years. Designated uses indicate what types of activities are supported by the water body. New Jersey assesses fresh water bodies for support of aquatic life (general and trout), fish consumption, primary and secondary contact recreation[40] and water supply for drinking water, agriculture and industrial uses. A water body achieves a designated use if it meets the surface water quality criteria associated with the designated use; otherwise, it is considered impaired.

To determine whether or not a stream meets its designated uses, NJDEP evaluates fresh water quality based on concentrations of conventional parameters, pathogen indicators, toxic compounds, biological monitoring data and fish tissue analyses. Conventional parameters include dissolved oxygen, pH, temperature, total phosphorus, nitrate, total

[33] FW2 is anything not FW1, which is defined as pristine waters.
[34] "C1" means Category One water, which means those waters designated for protection from measurable changes in water quality characteristics because of their clarity, color, scenic setting, other characteristics ofaesthetic value, exceptional ecological significance, exceptional recreational significance, exceptional water supply significance, or exceptional fisheries resource(s).
[35] For Trout Production waters: Dissolved oxygen cannot be less than 7.0 mg/l at any time and no thermal alterations can cause the water temperature to exceed 20°C or 68°F.
[36] "Measurable changes" means changes measured or determined by a biological, chemical, physical, or analytical method, conducted in accordance with USEPA approved methods as identified in 40 C.F.R. 136 or other analytical methods (for example, mathematical models, ecological indices) approved by the Department, that might adversely impact a water use (including, but not limited to, aesthetics). New Jersey Surface Water Quality Standards 7:9B-1.4 Definitions.
[37] The Clean Water Act (CWA); 33 U.S.C. ss/1251 et seq. (1977) Sections 303d and 305b.
[38] Water bodies are reported as they are assessed through water quality and biological monitoring.
[39] The Integrated List is the combination of the 303(d) and 305(b) lists.
[40] New Jersey only assesses saline waters for secondary contact recreation.

suspended solids, total dissolved solids, chloride, turbidity, fecal coliform, enterococcus, and Escherichia coli (E. Coli).[41] Toxic parameters include un-ionized ammonia, metals, and organics. Organics include current and historical pesticides and volatile organic compounds (VOCs). The metals evaluated are cadmium, arsenic, copper, chromium, lead, mercury, nickel, zinc, silver and cyanide. In addition, a survey of the benthic communities (bottom dwelling insects) is conducted to determine if unknown toxic compounds or pollutants, for which samples were not analyzed, may be adversely affecting the aquatic community.

Based on NJDEP's assessment, the Mulhockaway Creek is suitable for water supply (drinking water - as a source to be treated, agriculture and industry). The Mulhockaway Creek is considered impaired for primary contact recreation and aquatic life (general and trout). Impairments were defined based on high fecal coliform concentrations for primary contact recreation, high stream temperature and moderately impaired biological monitoring results for aquatic life, and fish consumption due to advisories for Spruce Run Reservoir. NJDEP has not established secondary contact recreation water quality standards for FW2 waters and thus attainment of this use was not assessed for the 2006 Integrated List or prior lists.

Monitoring Stations

Through a cooperative program with NJDEP, the United States Geological Survey (USGS) has collected quarterly water quality samples from the Mulhockaway Creek from 1976 to the present. The samples were collected at the streamflow gauging station (denoted "01396660 Mulhockaway Creek at Van Syckel, NJ") located where C.R. 635, Jutland-Charlestown Road, crosses the Creek and 0.3 miles upstream of Spruce Run Reservoir. The streamflow gauge has been operating since July of 1977 and is co-funded by NJWSA and USGS. The gauging station location is shown on Figure 1. NJDEP's Bureau of Freshwater and Biological Monitoring also uses this location (called AN0321 and FIBI053) for biological, habitat and fish assessments.

Summary of Historic Water Quality Data

Data from the cooperative monitoring program were obtained from the USGS database, National Water Information System (NWIS): web interface. Biological monitoring data were available from the NJDEP's Bureau of Freshwater and Biological Monitoring. Fish tissue data were available for Spruce Run Reservoir but not the Mulhockaway Creek. The USGS also analyzed a single sample for volatile organic compounds, pesticides and other toxic chemicals for the National Water Quality Assessment Program (NAWQA). The Mulhockaway Creek sample was collected at baseflow in June 1997 and none of the parameters exceeded water quality standards or were of concern. Results from the biological monitoring performed by the Bureau of Freshwater and Biological Monitoring indicate that the Creek is moderately impaired for aquatic life, evidenced by more pollution tolerant species of macroinvertebrates.

[41] 2006 Integrated List Methods Document

Water Chemistry

Table 6 presents a summary of the data from the cooperative monitoring program. During the period of record (1976 through present[42]), violations of water quality standards for conventional pollutants occurred for fecal coliform, pH, total phosphorus, total suspended solids and water temperature. However, since June 2000, only two parameters violated the water quality standards: fecal coliform and water temperature. Exceedences of the fecal coliform water quality standard are likely the result from both diffuse and concentrated nonpoint sources rather than point sources.[43] Water temperature may be exceeding the 20ºC water quality standard due to poor riparian vegetation leaving the stream exposed to sunlight, warmer water being transferred to the stream from upstream water impoundments (including ponds and wetlands), or from stream reaches receiving runoff from heated impervious surfaces (Interstate 78). Permitted discharges are not likely to contribute to elevated stream temperatures since the only one in the watershed is small in volume compared to stream flow.[44] Additional monitoring was conducted to assess the fecal contamination and is discussed in the Fecal Coliform TMDL Implementation Recommendations.

Trend Analyses

Previously, for the Raritan Basin Watershed Management Project, the USGS evaluated water quality data from the Mulhockaway Creek from 1976 through 1997 to assess trends between concentrations and flow, between concentrations and growing seasons and over time.[45]. With the additional data collected since the USGS evaluation, statistical comparisons were performed to determine changes in concentrations over time, differences between the growing seasons, and correlation with flow condition. Changes over time were evaluated by comparing sets of data. The USGS compared data from 1976-1991 and 1991-1997. In addition, a comparison was made for data prior to 1998 and post-1998. Growing season differences were determined by contrasting data collected between May and October with data collected between November and April. Flow correlations were developed through comparison of samples collected in low flow, less than 4.1 cubic feet per second (cfs) and high flow, 23 cfs. These are flows that are exceeded 90 percent of the time and 25 percent of the time, respectively. Metals data were insufficient in quantity to accurately calculate trends.[46] The trend analysis is summarized in Table 7.

---

[42] Data collected prior to September 2005 were evaluated.

[43] Fecal coliform exceedences are discussed in detail in the companion report "*Fecal Coliform TMDL and Implementation Recommendations*."

[44] See below in section on *Point and Nonpoint Source Loading.*

[45] USGS. *Evaluation of Streamflow, Water Quality, and Permitted and Nonpermitted Loads and Yields in the Raritan River Basin, New Jersey, Water Years 1991-98,* Water-Resources Investigation Report 03-4207

[46] Prior to the late 1990's, water quality samples were not collected using "clean techniques" required by the analytical method and current standard data collection procedures so the data is typically not used to assess water bodies. In addition, analytical techniques used did not always have quantification or detection limits small enough to measure concentrations near the water quality standard.

Table 6. Summary of Historic Water Quality Data

Parameter	Entire Data Set: No. Samples	Minimum	Median	Maximum	Ambient Water Quality Standard for FW2-TP(C1) (not to exceed)	Number of Exceedences	Date of last Exceedence	Notes
Conventional (mg/l)								
Biochemical Oxygen Demand	143	1	1.1	4.5	no standard			
Boron	30	6	10	40	no standard			
Chloride	157	5.6	13	72.9	250 mg/l			
Dissolved Oxygen	159	7.3	10.6	15.6	>= 7 mg/l			
Hardness	45	20	63	92	no standard			No data past 1986
Nitrate and Nitrite	101	0.5	0.98	1.45	no standard			No data past 1994
pH	158	6.4	7.75	9.5	>=6.5 - <= 8.5	5	8/3/1988	
Sodium	157	5.1	8.2	41.3	no standard			
Sulfate	157	8.6	16	25	250 mg/l			
Total Dissolved Solids	156	51	118	200	500mg/l			
Total Kjeldhal Nitrogen	138	0.03	0.265	2.7	no standard			
Total Organic Carbon	91	0.5	2.2	45	no standard			No data past 1991
Total Phosphorus	122	0.007	0.023	0.92	0.05 mg/l	30	5/24/2000	
Total Suspended Solids	61	1	3	67	25 mg/l	2	2/2/1999	
Water Temperature	180	0	12.5	23	0.6^{o}C deviation and 20^{o}C	15 > 20^{o}	8/11/2005	
Bacteria/Pathogen Indicators (mpn/100 ml)								
Fecal (MPN)	155	20	300	24000	*90%<=400/100 ml*	62 (40%)	8/3/2005	
Fecal (Annual Geometric Mean))	8	101	397	1097	*200/100 ml*	4	2005	Annual means since 1998 excluding 1999
E. Coli (MPN)	29	100	400	2800	235/100 ml	20	8/3/2005	
E. Coli (Annual Geometric Mean)	6	178	473	752	126/100 ml	6	2005	Annual Means since 2000
Enterococci	66	10	310	4400	*61/100 ml*	50	8/3/2005	
Enterococci (Annual Geometric Mean)	6	62	340	996	*33/100m*	6	2005	Annual Means since 2000
Metals ug/l								
Cadmium [1]	25	0.04	1	2	3.4 ug/l (human health)	0		
Copper [1]	24	0.6	1.35	9	1300 ug/l (human health)	0		
Lead	24	0.06	1	11	5 ug/l (human health)	0	6/6/1989	No sample greater than 1 ug/l since 1992
Mercury	36	0.01	0.1	0.5	0.05 ug/l (human health)	0	-	See note below
Zinc [1]	36	1	10	100	7400 ug/l (human health)	0		

The minimum, median and maximum values for all data are presented. The median represent the middle value of all samples, such that half of the samples had larger values and half had smaller. The median, rather than the mean, is often used to describe the central tendency of the data and is not skewed by extreme values or non-detect measurements.

Mecury: Violating samples reported as "less than"/ detection limits greater than criterion

[1] Surface water criteria for acute and chronic toxicity require hardness data. Hardness data are only available up to 1986.

Table 7. Summary of Trend Analyses

	Entire Dataset ANOVA Significant Differences			USGS Study Kendall Tests Significant Differences			
	Flow	Growing Season	With Time	Flow	Growing Season	With Time	Highest Concentrations
Alkalinity (as CaCO3)				> at Low	> Grow		Low/Grow
Biochemical Oxygen Demand (BOD)	No	No	No	No	No		Low/Non-Grow
Boron	-						
Chloride	No	> Non-Grow	Increasing	> at High	No	Increasing	
Dissolved Oxygen (DO)	No	> Non-Grow	No	> Non-Grow	No		
Hardness	-	-	-	> at Low	No		
Nitrate and Nitrite (NO2NO3)		-	-	> at Low	No	Decreasing all	
pH	No	No	No	> at Low	No		
Sodium	No	> Non-Grow	Increasing	No	No		High/Non-Grow
Sulfate	No	No	Decreasing	No	> Non-Grow		Low/Non-Grow
Total Dissolved Solids (TDS)	> At LOW	No	Increasing	> at Low	No	Increasing at Low	
Total Kjeldhal Nitrogen (TKN)	No	No	No	No	No	Increasing at Low	
Total Organic Carbon (TOC)						Decreasing Low	
Total Phosphorus	No	No	No	No	No		
Total Suspended Solids (TSS)	No	No	No				High/Non-Grow
Water Temperature	> At LOW	> Grow	No	> Grow	No		
Fecal (MPN)	> At LOW	No	No	No	> Grow		

The results indicated that the trends in water quality determined by the USGS have persisted. Comparison of pre-1998 and post-1998 data indicates that sodium, chloride, total dissolved solids and sulfate exhibit statistically significant trends over time[47]. Sodium and chloride concentrations have increased, with peak concentrations occurring during the winter months (non-growing season). Figure 19 illustrates the positive annual trend (based on quarterly samples) in sodium and chloride concentrations. This upward trend may be directly associated with snow and ice removal since the amount of deicing materials used is proportional to the length and width of the road network to which residential streets have been added. The increases may also be due to a change in deicing compounds (for example, from a mixture of sand and cinders to sand and salt). In addition to a statistically significant increase in chloride and sodium concentrations, total dissolved solids (TDS) are also increasing and are attributable to increased deicing or change in deicing compounds. Annual total dissolved solids concentrations are presented in Figure 20. Sulfate concentrations have decreased over time. Figure 21 illustrates the negative trend in annual average sulfate concentrations. One theory for the decreasing trend in sulfate concentrations is possibly the declining use of copper sulfate to suppress algal growth in ponds. Formerly, the copper sulfate may have washed out from in-line ponds, which may no longer be treated or are treated with other chemicals. Unfortunately, no data are available to confirm or refute this theory. USGS results also indicated a decreasing trend in Nitrite plus Nitrate concentrations and decreasing trends during low flow of total organic carbon (TOC) and total kjeldhal nitrogen (TKN – ammonia plus organic nitrogen).

The data demonstrate significant differences between the growing and non-growing seasons for chloride, dissolved oxygen, fecal coliform and sodium. Chloride, dissolved oxygen and sodium concentrations are all greater during the non-growing season; whereas, fecal coliform is greater during the growing season. The solubility of dissolved oxygen in water is inversely related to temperature and the fecal coliform growth rate is greater at higher temperatures, therefore, these trends are expected. Higher concentrations of chloride and sodium in the non-growing (winter) season would also expected because deicing only occurs in colder months.

Only fecal coliform and total dissolved solids demonstrated significant differences with flow. The average fecal coliform concentrations for higher flows were an order of magnitude higher than the average concentrations for low flows. Higher levels of fecal bacteria during storm flows can be associated with nonpoint pollution sources, including runoff from agricultural practices, domestic animal and wildlife feces, failing septic systems and resuspension of channel sediments. Channel sediments can sustain large bacteria colonies. Larger dissolved solids concentrations during higher flows are also likely since salts used for deicing wash off impervious surfaces during runoff events.

[47] An ANOVA analysis was performed between the pre-1998 data set and the post-1998 dataset.

Figure 19. Positive Trend in Average Annual Sodium and Chloride Concentrations

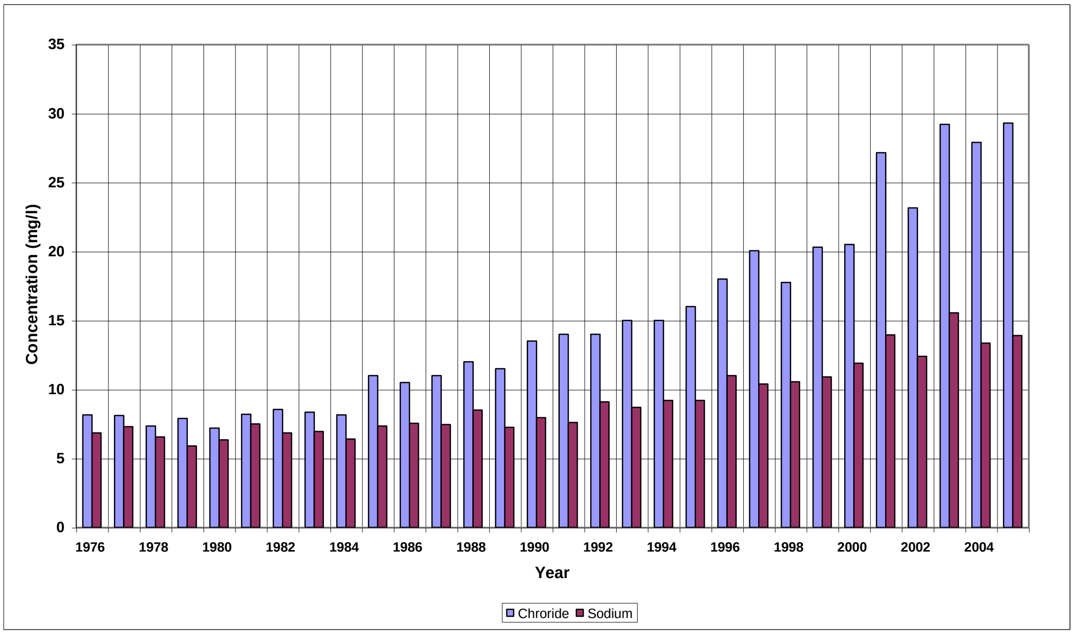


Figure 20. Positive Trend in Total Dissolved Solids Concentrations

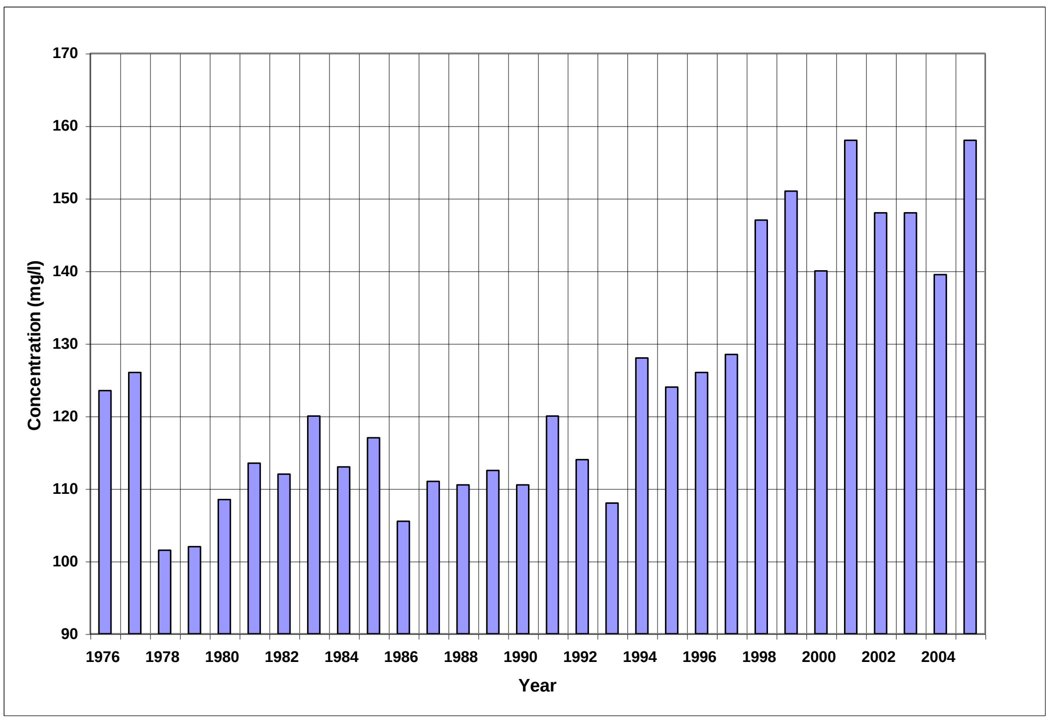
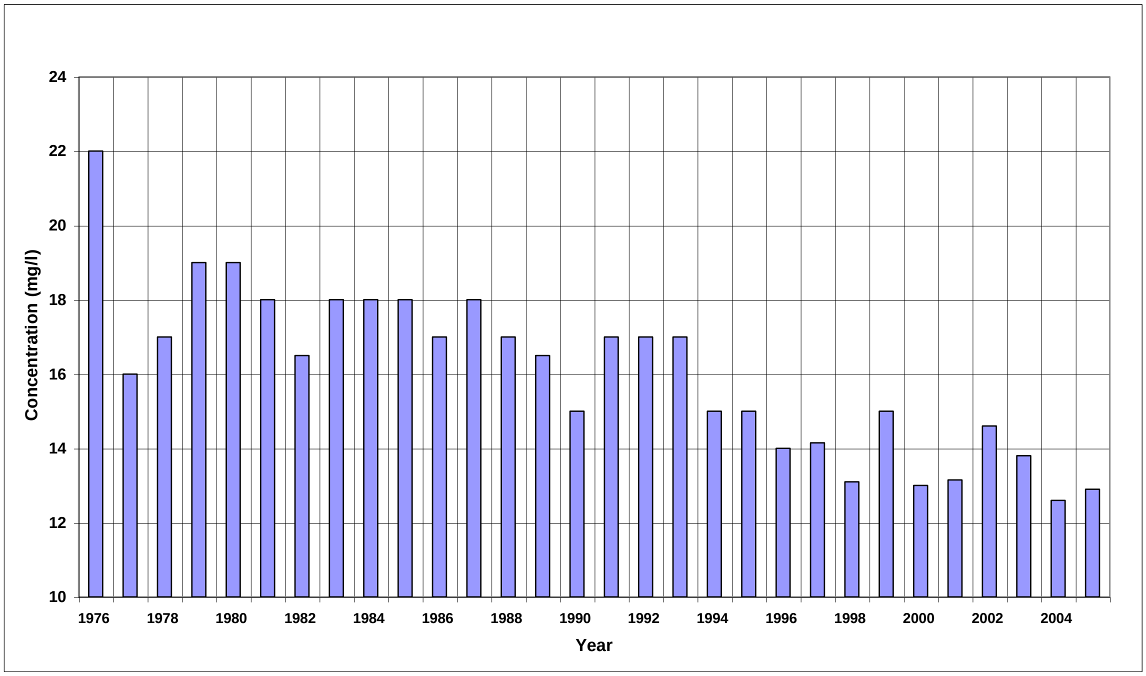


Figure 21. Negative Trend in Average Annual Sulfate Concentrations



Biological Monitoring

Biological assessments ascertain the health of the watershed by the abundance and diversity of bethnic macroinvertibrates (stream bottom-dwelling organisms, visible without magnification). The Bureau of Freshwater & Biological Monitoring created the Ambient Biomonitoring Network (AMNET), which contains station AN321 on the Mulhockaway Creek near the USGS streamflow gauge 01396660. Once every 5 years the instream benthic macroinvertebrate communities are evaluated using a USEPA-developed statistical methodology referred to as Rapid Bioassessment Protocol (RBP). Visual observations, stream habitat assessments and limited physical/chemical parameters are collected at each site. The Mulhockaway Creek was evaluated in 1994, 1999 and 2004. The biological monitoring data indicates that the Creek is moderately impaired for aquatic life even though the habitat scores are optimal and even increased between 1999 and 2004. The decline in the biological assessment (New Jersey Impairment Score[48]) is of concern although the habitat still maintains a rating of optimal. Table 8 presents the summary of the biological monitoring for the Mulhockaway Creek.

[48] http://www.state.nj.us/dep/wms//bfbm/rbpinfo.html

Table 8. Biological Monitoring Results for the Mulhockaway Creek (AN321)

	Date	NJIS	Habitat
Round 1	May 10, 1994	30 (non-impaired)	NA
Round 2	May 5, 1999	24 (non-impaired)	164 (optimal)
Round 3	April 22, 2004	21 (moderately impaired)	177 (optimal)

NJIS: New Jersey Impairment Score
Non-impaired (24-30): Benthic community comparable to other undisturbed streams within the region. A community characterized by a maximum taxa richness, balanced taxa groups and good representation of intolerant individuals.
Moderately Impaired (9-21): Macroinvertebrate richness is reduced, in particular EPT taxa. Taxa composition changes result in reduced community balance and intolerant taxa become absent.
Severely Impaired (0-6): A dramatic change in the benthic community has occurred. Macroinvertebrates are dominated by a few taxa that are very abundant. Tolerant taxa are the only individuals present.

Habitat evaluated based on 10 criteria, which differ by the type of stream: High Gradient (steep) vs. Low Gradient (gently sloped). See: http://www.nj.gov/dep/wms//bfbm/appendix/habitat.html

NA: Not available or not evaluated

Sources:
Round 1: http://www.state.nj.us/dep/wms//bfbm/download/AMNETrnd1Data.pdf
Round 2: http://www.state.nj.us/dep/wms//bfbm/download/AMNETrnd2Data.pdf
Round 3: http://www.state.nj.us/dep/wms//bfbm/download/AMNETrnd3Data.pdf
Note: Habitat Score for the Fish IBI in August of 2002 was 141 – sub optimal.

Point and Nonpoint Source Loadings

The Mulhockaway Creek has both point and nonpoint sources of pollution, with the majority from nonpoint sources. The only continuous[49] permitted surface water discharger to the Mulhockaway Creek is a small on-site wastewater treatment plant at the Union Township School. The average daily treatment plant discharge is 0.002 million gallons per day (mgd), which is less than 0.025 percent (25 one-thousandths of a percent) of the average daily flow of the Creek of 7.7 mgd.[50] The maximum reported daily average was 0.039 mgd, 0.5 percent (one-half of a percent) of the average daily flow.

The USGS study determined total daily loads for the Mulhockaway Creek watershed for parameters that had sufficient data available. The load of chloride increases from low to high flow, indicative of nonpoint source behavior. Peak loads are correlated to the higher flows during the winter months and maximum loads occurred during the non-growing season. All of the parameters evaluated exhibit an order of magnitude increase from low to high flow. Table 9 presents the estimated permitted and non-permitted loads for the watershed.

[49] Non-stormwater
[50] Based upon available Discharge Monitoring Report Data from July 2000 through December 2006.

Table 9. Estimated Permitted and Non-permitted Loads (pounds/day)

	Low Flow (90 percentile)			Median Flow			High Flow (25 percentile)		
Parameter	**Permitted**	**Nonpoint**	**Total**	**Permitted**	**Nonpoint**	**Total**	**Permitted**	**Nonpoint**	**Total**
TKN	0.02	2	2		9	9		17	17
BOD	0.08	26	26	0.09	72	72	0.09	111	111
Chloride	*	290	290	*	1,193	1,193	*	2,206	2,206
TDS	10.20	2,980	2,990	10.2	8,261	8,271	10.2	12,959	12,969
NO2NO3	0.48	22	23	0.5	64	64	0.5	100	101
TOC	0.07	35	35	0.1	141	141	0.1	256	256
TP	0.01	0.20	0.21	0.01	1.10	1.11	0.01	2.10	2.11
TSS	0.07	36	36	0.1	174	174	0.1	345	345

Nonpoint Source Loads based on USGS Study. Data from 1991 through 1997. Data not available for point sources.
TKN: Total Kjeldhal Nitrogen (Ammonia plus Organic Nitrogen); BOD: Biochemical Oxygen Demand; TDS: Total Dissolved Solids; NO2/NO3: Nitrite plus Nitrate; TOC: Total Organic Carbon; TP: Total Phosphorus; TSS: Total Suspended Solids.

In September 2003, a watershed nonpoint source pollutant loading model[51] was developed for the Spruce Run Reservoir Watershed to assess the potential increase in pollutant loads during buildout conditions. The model calculated loads for biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), total phosphorus, total nitrogen, lead, copper and zinc, pollutants typically evaluated for stormwater and nonpoint source studies. Based on assumptions used in the model, only metals and total phosphorus were anticipated to increase under buildout conditions. Phosphorus is anticipated to increase due to the conversion of agricultural areas into residential development, where higher loading coefficients are used to account for lawn fertilizers. Metals are expected to increase due to the potential commercial and light industrial development in the watershed. The study concludes that ordinances are already in place in both Bethlehem and Union Townships that protect water quality and limit the type and extent of future development. Of note, it may seem counter intuitive to have a reduction in the total suspended solids load. Because the majority of lands available for development are agricultural, the future load decreases because residential areas are assumed to have a lower total suspended solids load than attributed to agricultural lands. This underscores the importance of better agricultural practices that control sediment movement from fields into streams and runoff from impervious surfaces from greenhouses.

STORMWATER INVENTORY AND ISSUES

In 2004, the NJDEP promulgated stormwater rules and regulations that required communities to apply for a general permit and develop a municipal stormwater management plan. Both Bethlehem and Union Townships are known as Tier B municipalities, which have less stringent stormwater management requirements than more densely populated Tier A municipalities. Some of the requirements for Tier B communities are development of a municipal stormwater management plan, enactment of stormwater control ordinances, enforcement of Residential Site Improvement Standards (RSIS), educational programs, storm inlet labeling and assurance of detention basin

[51] CDM, September 2003, "*Watershed Model for Watersheds of the Spruce Run Reservoir.*"

maintenance. Although a stormwater inventory is not specifically required for Tier B communities, one was conducted within the Mulhockaway Watershed as part of this project to assist in the assessment of stormwater issues.

Between October 2004 and April 2006, the Hunterdon County Soil Conservation District (HCSCD) inventoried and photographed most of the stormwater infrastructure in the watershed. Table 10 presents a summary of the stormwater inventory. More than 2,600 features were located and more than 1,900 were photographed. Although they were located, catch basins and pipe inlets were not photographed. Pertinent information was collected about each feature, particularly information about size, type, vegetation and erosion. The types of features and the information collected about each are described below. Figures 22 through 33 show the locations of the stormwater infrastructure. The Stormwater Inventory was provided to each Township, NJDEP and Hunterdon County and is also available through the HCSCD and NJWSA. Photographs of the stormwater infrastructure also are located in Appendix D.

Table 10. Stormwater Inventory Summary

Feature Type	Description	Located Features	Photographs of Feature Types
Swales & Ditches	Flow paths greater than 2 inches in depth which convey concentrated stormwater flow	260	339
Outfall Pipes	Structures where stormwater exists or is discharged from a piped conveyance system	460	572
Culverts	Structures through which convey permanent non-ephermal water bodies through road embankments and other obstructions	96	138
Catch Basins	Inlets through which surface stormwater enters a piped conveyance system	1072	n/a
Pipe Inlets	Structures where concentrated stormwater flow enters the piped conveyance system via horizontal or nearly horizontal pipe in the absence of a catch basin	245	n/a
Detention Basins	Bermed or excavated areas designed to hold and detain peak stormwater flows caused by impervious surfaces	24	89
Detention Basins Inlets	Pipes where stormwater enters or discharges into a detention basin from a piped conveyance system	34	44
Detention Basins Discharges	Pipes where stormwater exits or is discharged from a detention basin	23	48
Detention Basin Outlet Structures	Structure which controls the flow of water from the interior of a detention basin to the receiving water body or conveyance to a receiving water body	26	48
Best Management Practices	Structures created to aid in the improvement of water quality	27	30
Dams & Diverters	Structures and/or berms designed to impound water or flow obstructions, including debris, which impound water and impede flow	22	35
Confluences	Locations where two streams converge	36	51
Areas of Concern	Locations of suspected or potential detriments to water quality	52	91
Stream Photographs		248	305
Other Photographs			114
Total Features		2625	
Total Photographs			1904

Swales and Ditches

Stormwater conveyance in the Mulhockaway Watershed includes more than 16 miles of swales and ditches (swales) mostly along County and Township roads. HCSCD developed a rating system to characterize swales, considering sediment loading, erosion, slopes, treatment ability, and maintenance status. Swales are classified as excellent, good, fair, poor or failing dependant upon how well they conform to New Jersey Standards for Soil Erosion and Sediment Control and how well they seem to be functioning.

Excellent swales are those, which were constructed according to design standards, with the correct balance of slope, width and depth to convey stormwater without causing erosion. Excellent swales also have sufficient vegetative cover to potentially remove suspended solids, sediment, and nutrients and likely protect water quality. Approximately 3,800 feet of swales located throughout the watershed were classified as excellent. Figure 22 presents examples of excellent swales.

Figure 22. Examples of Excellent Swales

SDO-4

SDO-9

SDO-75

Good swales do not meet design standards but are not likely to degrade water quality. Problems with the swales include steepness, poor geometry, stabilization with stone, limited wetted perimeter or vegetation. Good swales usually only have one of these issues. More than 18,000 feet of swales were characterized as good. Figure 23 presents examples of good swales.

Figure 23. Examples of Good Swales

SDO-37
Turf Grass Swale

SDO-81
Mixed Vegetation Swale

SDO-131
Stone Swale

Swales described as ***fair*** are those that demonstrate both positive and negative attributes related to conveyance or water quality, but are likely causing a water quality impact. Typically, a fair swale might have salt-stressed vegetation with weeds and bare spots but good geometry or a steep slope with a rocky bottom, but good vegetation. Such swales are not of immediate concern, but could use improvement. More than 40,000 feet of swales are classified as fair. Figure 24 presents examples of swales rated as fair.

Figure 24. Examples of Fair Swales

SDO-36
Vegetated Swale

SDO-54
Turf Grass

SDO-213
Mixed Vegetation Swale

Poor swales lack stability and show evidence of either erosion or significant deposition. They are usually inadequately designed and not maintained. Many are populated with stressed vegetation or invasive species and do not accommodate observed stormwater flow. More than 20,000 feet of swales were classified as poor and are scattered throughout the watershed. Examples of poor swales are presented in Figure 25.

Figure 25. Examples of Poor Swales

SDO-44
Mixed Vegetation Swale

SDO-101
De-vegetated Swale

SDO-164
De-vegetated Swale

Swales in the worst condition were characterized as ***failing***. Failing swales lack stability and are becoming or are severely eroded. Erosion and sediment transport from failing swales have the potential to degrade water quality, in addition to potentially compromising stormwater conveyance and the nearby roadway. Approximately 2000 feet of swales are failing in the Mulhockaway Watershed. Figure 26 presents examples of failing swales.

Figure 26. Examples of Failing Swales

SDO-23

SDO-85

SDO-210

The HCSCD suggests the following to the Townships and County to address ditches and swales:

- Develop a maintenance plan for swales and ditches;
- Protect excellent and good swales from construction activity;
- Address and correct flaws of fair and poor swales during adjacent construction projects;
- Monitor condition of fair and poor swales and prioritize for remedial actions; and
- Correct failing swales as soon as possible, independent of other projects. Many of the failing swales should probably be piped or heavily armored if space is not available for construction of a swale that would meet design standards.

Outfall Pipes

HCSCD identified approximately 450 outfall pipes into the Mulhockaway Creek and its many branches. Outfall pipes are any pipe discharging or potentially discharging water to the stream, but not pipes from detention basin outlets. Outfalls from detention basins are mapped as detention basin discharges. Information collected about each pipe included:

- composition (reinforced concrete, metal, plastic, etc.);
- shape (round, elliptical, square);
- conduit outlet protection (Is outlet stable?);

- headwall (Is one present?);
- potential illicit connection; and
- evidence of erosion;

Of the identified outfall pipes, approximately 85 percent have inadequate conduit outlet protection, which stabilizes the outlet pipe where it discharges to the stream. Approximately half of the outfall pipes show significant evidence of erosion. More than 100 outfall pipes have strong evidence of an illicit connection or conveyed dry weather flow at the time of inspection (an indicator of a potential illicit connection). Illicit connections in this watershed may include pool discharges, roof drains, sump pumps and septic system laterals. Figure 27 presents examples of typical outlet pipes in the Mulhockaway Creek Watershed.

Figure 27. Examples of Outfall Pipes

OPG-342 Outfall Pipe with No Conduit Outlet Protection

OPG-454 Multiple Outlets with Headwall and Wingwalls

OPG-7 Outfall Pipes With Erosion

Culverts

The Mulhockaway Creek and its many tributaries flow through 96 culverts. Of those, 53 involve the piping of the stream under a roadway and 21 are boxed culverts (mostly under Interstate 78). The remainder of the culverts are primarily arched or elliptical in shape. Figure 28 presents examples of the types of culverts in watershed. Approximately one-third of the culverts need some type of maintenance.

Figure 28. Examples of Culverts

CUL-96
Double Barrel Culvert under Private Road

CUL-54
Box Culvert Under Mine Road in Bethlehem Township

CUL-40
Piped Stream Under Driveway

CUL-29
Boxed Culvert and Channel Under Interstate 78

CUL-61
Culvert Under Charlestown Road

CUL-45
Arched Culvert Under Railroad

Catch Basins and Pipe Inlets

Catch basins collect roadway, swale or other concentrated drainage and direct it to the piped stormwater conveyance system. HCSCD located 1,072 catch basins throughout the watershed (437 in Bethlehem and 635 in Union). Of those, more than 360 direct stormwater runoff into detention basins. However, 189 catch basins collect drainage from Routes 78 and 173 and none of the runoff is detained. Pipe inlets function as catch basins in their absence. HCSCD identified 245 pipe inlets in the watershed. Some of these inlets are the upstream ends of pipes under driveways. Catch basins and pipe inlets were not photographed.

Detention Basins and Components

Detention Basins are defined as bermed or excavated structures designed to detain or retain peak stormwater flows caused by the construction of additional impervious surfaces. Structures include storage (freeboard), a piped inflow and a flow regulating outlet structure. Usually, flow regulation does not occur for smaller storm events and runoff is only detained for the 25-year and greater events. For detention basins, HCSCD determined if there was a low flow channel and its condition and configuration; if the structure needed maintenance; if there was significant erosion; if floatables were present; if sediment is present and a problem; and if maintenance of vegetation was required, including removal or reestablishment. HCSCD identified 12 detention basins in

Bethlehem Township and 14 in Union Township that are located within the Mulhockaway Creek Watershed. Table 11. provides a summary of the detention basin inventory. Figure 29 presents examples of detention basins.

Table 11. Summary of Detention Basins Problems

Issue	Bethlehem	Union	Total
Maintenance Needed	6	7	13
Significant Erosion	2	4	6
Floatables Problem	5	4	9
Accumulated Sediment	5	5	10
Vegetation Rehabilitation	7	7	14

Figure 29. Examples of Detention Basins and their Components

MDB-10: Detention Basin Overgrown with Vegetation

MDB-7: Well Maintained Detention/Infiltration Basin

MDB-17: Well Maintained Turf Grass Detention Basin

Stream Confluences

While exploring the watershed to inventory stormwater infrastructure, the HCSCD walked much of the Mulhockaway Creek and photographed many of the confluences. Confluences were located using field reconnaissance, aerial photography and other available maps, such as as-build drawings. The confluences with the major tributaries with the Main Stem are presented in Figure 30.

Figure 30. Main Stem Stream Confluences

CON-35
Confluence of Charlestown Branch and Main Stem

CON-34
Confluence of Norton Church Branch and Main Stem

CON-36
Confluence of Fox Farm Branch and Main Stem

CON-5
Confluence of two Headwater Streams on the Main Stem

CON-24
Confluence of Baptist Church Branch and the Main Stem

CON-14
Confluence of Driftway and Mechlin Corner Branches

Dams

Three types of dams were found in the Mulhockaway Creek watershed: earthen, concrete and debris. Dams are defined as berms designed to impound water or obstructions to flow, specifically debris, which impound water by impeding flow. Examples of dams found in the watershed are presented in Figure 31.

Figure 31. Examples of Dams

DAM-23
Debris Dam on Charlestown Branch

DAM-19
Concrete Dam on Fox Farm Branch

DAM-2
Earthen Dam on Main Stem

Best Management Practices

For the inventory, Best Management Practices (BMPs) were defined as structures created with the intent to aid in the improvement of water quality. The types of structures found include gabion stabilized stream banks, scour holes, road drainage diversions, infiltration basins, stone slope stabilization and grouted rip-rap scour protection. Many of the structures found require some type of maintenance. Examples of the BMPs found in the watershed are presented in Figure 32.

Figure 32. Examples of Best Management Practices

BMP-5
Stone Slope Stabilization

BMP-20
Infiltration Basin

BMP-3
Scour Hole

BMP-9
Roadside Drainage Diversion

BMP-2
Gabion Stabilized Stream

BMP-27
Grouted Rip-Rap Scour Protection

Areas of Concern

While exploring the watershed to inventory stormwater infrastructure, HCSCD identified 52 locations suspected to be detrimental to water quality. Hot spots were classified based on land use or type of problem: Agricultural, Industrial, Residential, Erosion, Sediment, Nutrient and Other. Agricultural impacts are usually caused by improper manure storage, animals in the stream, lack of riparian buffer and non-conservation minded tillage. Figure 33 presents some of the areas of concern in the watershed.

Figure 33. Examples of Areas of Concern

AOC-37: Animals not Fenced from Stream

AOC-46: Severe Erosion Downstream of Stormwater Outfall

AOC-4: Sediment Deposition in the Stream Channel

AOC-29
Unstable Residential Access to Stream Channel

AOC-30
Interstate 78 Drainage with Iron Bacteria

AOC-40
Localized Nutrient Enrichment

Additional Observations and Recommendations

Through the process of inventorying stormwater infrastructure in both communities, the HCSCD made the following observations and suggestions about the watershed:

- <u>Agriculture:</u> Agricultural activities may contribute significantly to nonpoint source pollution and erosion in the watershed. The watershed has livestock, crop and nursery operations, all of which can be managed effectively to minimize nonpoint source pollution. Livestock needs to be excluded from the stream channel and riparian corridor to limit erosion from animal traffic and fecal contamination of the stream. Manure must be managed to limit exposure to stormwater and the contribution of nutrients and fecal matter to the stream. Crops change in the county depending upon the cost of the commodity. HCSCD is witnessing a change in crops from hay to corn, a more intensive land use. Proper tillage and integrated crop management (ICM) will reduce the amount of sediment, nutrients, pesticides and herbicides delivered to the stream. Impervious surfaces from nurseries and other greenhouse operations are contributing to increased runoff volumes and velocities, exacerbating existing erosion and sedimentation problems in stream channels. Runoff from these areas must be better managed to reduce damage to the stream. A comprehensive agricultural management program should be developed for the basin to address agricultural issues in the watershed.[52]

- Future Development and Land Disturbance: Although the watershed is well protected given the Category 1 status of all the streams, its location in the Highlands Preservation Area, and limited potential for development, the Creek must be more stringently protected from soil disturbance associated with construction. Restabilization and revegetation activities should be closely monitored to ensure that impacts from disturbed areas are minimized. Road construction and activities along the gas and power right-of-way and highways are of concern due to the potentially large areas of disturbance and soil compaction from large equipment. Both communities should consider a stream corridor ordinance to restrict activities in the floodplain and 300-foot riparian buffer. Riparian buffers should be rigorously protected because they filter pollutants and attenuate runoff before it enters the stream channel.
- Deer and Invasive Species: Recent surveys have estimated deer density in Hunterdon County at over 180 per square mile.[53] The Hunterdon County Board of Agriculture concluded that severe damage to agricultural crops has resulted from an over abundant deer population.[54] Within the County, the reported deer harvest has declined by 27% between a peak of 14,700 in 1999 to 10,700 in 2006.[55] In addition to agricultural damage, deer are of concern because of the fecal coliform impairment in the watershed and their impact on forested areas. HCSCD observed forest areas in the watershed stressed by deer browse and invasive species (multiflora rose – *Rosa multiflora*, barberry – *Berberis thunbergii*, autumn olive - *Elaeagnus umbellate*), which are less palatable to deer. Regeneration of native vegetation is suppressed because non-native invasive species can grow with little to no competition. Autumn olive and multiflora rose shade the herb layer limiting the growth of lower level vegetation, which holds soil and provide protection from erosion. HCSCD observed notable exposure of soil in forests within the watershed.

[52] The comprehensive agricultural management program is discussed in the Mitigation and Restoration Projects section and in more detail in Appendix X.
[53] New Jersey Audubon Society, Forest Health and Ecological Integrity Stressors and Solution Concepts, White Paper.
[54] Governor's Report on Deer Management in New Jersey, 1999, Department of Environmental Management, Division of Fish Game and Wildlife in consultation with the Department of Agricuture.
[55] http://www.state.nj.us/dep/fgw/pdf/deer_harv_county95-06.pdf

- Infrastructure: Since the inventory was completed, some corrective projects have occurred in the watershed. Several dirt roads have been paved, some drainage in steep sloped areas has been piped and several eroded ditches have been stabilized. However, limited right-of-ways hinder most corrective actions. The Townships and County have begun paving dirt roads, piping drainage from steep-sloped areas and stabilizing some eroded ditches. Road grit and chip (from chip and oil road surfaces) are commonly found near stormwater outlets and in the stream channels.
- Detention Basins: There are few detention basins compared to the amount of impervious surface in the Mulhockaway Watershed and the maintenance of them ranges from manicured to abandonment. The responsible parties should be required to develop maintenance plans and perform the maintenance. The Townships should develop an inspection program to ensure that detention basins are maintained.
- Swales and Ditches: The majority of stormwater conveyance in the watershed is by open swale. Although open swale drainage can have many benefits for stormwater control, many of the ditches and swales are too steep to effectively convey the water without erosion. Salt and traffic seem to cause the most harm to good grassed or vegetated swales.
- Stream channels: Most stream segments indicate excessive flow by cut banks, sediment deposits, and exposed tree roots. Little to none of the stormwater from the road network, particularly Interstate 78 and State Route 173, is detained causing higher velocity discharges into the streams. Many of the stormwater discharges have no energy dissipation mechanisms. The Townships, County and State should look for opportunities to add energy dissipation appurtenances or measures to existing drainage systems and stormwater outfalls most likely during road reconstruction and/or repaving.

MUNICIPAL REGULATIONS

Both Bethlehem and Union Townships have met the requirements imposed by NJDEP's stormwater management rules of adopting stormwater management ordinances and developing stormwater management plans. Through the EPA Targeted Watershed Grant, both Townships participated in a Municipal Assessment Program. Municipal representatives (those on the Township council, planning board, environmental commission, etc.) were surveyed about their vision and their citizens' vision of the municipality. Several key issues were identified through the survey process and were analyzed in more detail through a review the municipal master plans and implementing ordinances. Areas of particular interest included:

Bethlehem Township	Union Township
1. Preservation of Rural Character Open space preservation Farmland preservation Development pressure Woodlands protection Smart growth 2. Protection of Water Resources Surface waters, floodplains, and riparian areas Ground waters, wellhead protection, and recharge areas 3. Public Outreach and Education Communication, cooperation, coordination Engaging the public	1. Preservation of Rural Character Open space preservation Farmland preservation Development pressure and traffic mitigation Woodlands and tree protection Scale of commercial growth Scenic vistas 2. Protection of Water Resources Surface waters, floodplains, and riparian areas Ground waters, wellhead protection, and recharge areas Steep slope protection Soil erosion and sedimentation control 3. Public Outreach and Education Utilization of public parks Engaging the public

The visions and goals of both Townships are aligned with protecting the watershed and the Mulhockaway Creek. However, additional ordinances, which are more protective, should be considered.

Bethlehem Township has developed an inventory of all headwater streams and has updated its Environmental Resource Inventory (ERI, August 2005) in a parcel based-GIS format. Streams and wetlands are recorded, but not riparian areas per se. The Environmental Commission and Planning Board use the ERI when considering subdivisions and land developments. The Township Master Plan (June, 1984) does not list riparian areas as critical. Critical areas associated with riparian areas, including wetlands and floodplains (FEMA identified 100 year floodplain), are only regulated for developments that are subject to subdivision or site plan approval. Section 102-38A5 of the Township Code (p. 10291) states: “In addition to all other applicable township requirements, development on sites containing critical areas shall provide for the following: (a) No principal or accessory building shall be located in whole or in part, within a critical area...”

In Union Township, the policies of the Township Master Plan, Conservation Plan Element (April 2000) seek to preserve ecological resources “by encouraging land development which preserves natural amenities and does not aggravate problems affecting the Township and water quality of the Spruce Run Reservoir.” (p. B7-1). The plan does not specifically identify riparian areas as an ecological resource. The

Township's Natural Resource Inventory (October 2003) lists floodplains and wetlands but does not inventory riparian areas in particular. The Township Code provides, "All applications for subdivision and site plan approval, or building permits (Underscore added) shall include maps delineating the natural and historic resources..." (Section 30-6.2 p. 3197) "Resources" include floodplains, floodplain soils, wetlands, shorelines, and floodplain woodlands (Palustrine Association). Section 30-6.3b (p.3199) prohibits disturbance in floodplains, floodplain soils, and wetlands and limits disturbance to 30% on shorelines and 5% in floodplain woodlands. Section 30-6.4a.3 (p.3203) requires a soil erosion and sedimentation control plan where 5000 sq. ft. of land will be disturbed. This includes disturbances on existing single-family lots and is therefore more stringent than Soil Conservation District standards. Union Township undertook a comprehensive revision to their Master Plan and Land Use Regulations resulting in zoning changes along the I-78 corridor, which limits future commercial growth. The changes also limit impervious surfaces in most of the township to a maximum of 3 percent. The Environmental Commission is updating the township's open space inventory, including recorded conservation easements and other preserved lands.

Clearly both Bethlehem Township and Union Township have adopted plans and implementing ordinances, which seek to protect the natural resources that make their respective communities unique. Both municipalities recognize the Mulhockaway Creek as an important feature, which warrants protection. However, riparian areas are not specifically recognized as a critical environmental feature in either municipality. The State recognizes the Mulhockaway Creek as a Category One stream and offers, through Stormwater, Wetlands, and Flood Hazard Area Regulations, Highlands Act Master Plan, protection from most new encroachments within 300 feet. In light of the extensive research conducted by the Department of Environmental Protection in proposing amendments to the Water Quality Management Planning Rules,[56] a new emphasis is being placed on the value of riparian areas. Accordingly, it is recommended that each community amend its Master Plan and Environmental Resource Inventory to include a discussion of the value of riparian and using the definitions offered by the DEP, identify all riparian areas in each township. Further, Land Use Regulations in each community should be amended to prohibit encroachment into riparian areas, consistent with the proposed state rules. This additional level of protection would apply to land alterations and construction activity not otherwise regulated by the state.

MITIGATION AND RESTORATION PROJECTS

Restoration Projects

Based on the research and fieldwork performed for this project, the Hunterdon County Soil Conservation District (HCSCD), the project consultant (TRC Omni Environmental[57]), the project committee and the New Jersey Water Supply Authority (NJWSA) have identified four watershed wide projects and fourteen site specific projects

---

[56] (see: http://www.nj.gov/dep/njflood/docs/web_rule_8_31_06.pdf, p.6 and 99)
[57] TRC Omni Environmental has become two firms: TRC Solutions and Omni Environmental. Members of both firms worked on the project.

for watershed restoration. The projects were selected to address the impairments to the Creek and maximize the benefits from existing best management practices (detention basins) and stormwater infrastructure (ditches and swales). Table 12 presents these watershed restoration projects and a summary of each project is located in Appendix A.

Watershed Wide Projects

Watershed wide mitigation and restoration projects include a comprehensive agricultural management program, a sanitary survey and illicit discharge removal program, additional municipal ordinances and roadside ditch retrofits. The comprehensive agricultural management program will be an integrated five-year voluntary effort to encourage and implement agronomic best management practices in the watershed through the development of nutrient management plans and provision of integrated crop management services. A program coordinator will implement an education and outreach program about agronomic best management practices protective of water quality and coordinate funding mechanisms through various farm bill programs (EQIP,[58] CREP[59]). In addition, alternate funds, such as those for source water protection,[60] will be sought to supplement the federal and/or state monies provided through these programs or to fund best management practices for operations not eligible for farm bill programs. Nutrient management plans are usually required for participation in farm bill programs. Typical best management practices include exclusion of animals from the stream, which protects the stream from bacteria and erosion, improvements to the riparian buffer, which stabilizes stream banks and minimizes exposure to sunlight, and manure handling systems, which prevent or minimize bacteria and nutrients from entering the stream. Sanitary surveys are used to track down discharges to stormwater infrastructure that may contain bacteria and other pathogens. Illicit discharge removal may reduce the amount of pollutants and volume and velocity of runoff entering the stream channel. Reducing runoff volumes and velocities minimizes erosion and sediment transport. Approximately 2,000 feet of ditches were considered failing and 20,000 feet were classified as in poor condition. Poor and failing ditches were noted to be severely eroded or contain large sediment deposits. Repairing these ditches or reconstructing them to meet sediment and erosion control standards will likely reduce material transport to the streams and erosion at the discharge location. In addition, the vegetation in many of the ditches could be improved, which will reduce flow velocities and capture sediments and pollutants. The potential adoption of ordinances to assure maintenance of best management practices and the protection of riparian areas provides mechanisms for the Townships to enforce maintenance requirements and prohibit detrimental activities in the stream corridor.

[58] Environmental Quality Incentives Program: http://www.nrcs.usda.gov/PROGRAMS/EQIP/
[59] Conservation Reserve Enhancement Program:
http://www.fsa.usda.gov/FSA/webapp?area=home&subject=copr&topic=cep
[60] The NJWSA rate contains $15.00/million gallons for source water protection for fiscal year 2008.

TABLE 12. Mitigation and Restoration Projects

WATERSHED RESTORATION PROJECTS	Priority	Water Quantity	Water Quality	Infiltration	Stabilize Erosion	Municipality	Potential Soil Loss (lbs/yr)	Additional TSS Removal	Additional TP Removal	Cost	Cost/Lb TSS	Cost/Lb TP	Cost/lb soil	Additional Implementation Costs**
Watershed-Wide														
Comprehensive Agricultural Management*+			X		X	Both	NQ	NQ	NQ	**$ 227,800**	NQ	NQ	NQ	YES
Nutrient Management Plans (40 Farms)*			X			Both	NQ	NQ	NQ	$ 44,800	NQ	NQ	NQ	Implementation
Integrated Crop Management (1,800 acres)	1		X			Both	NQ	NQ	NQ	$ 135,000	NQ	NQ	NQ	Implementation
Outreach and Education Program (4 weeks/yr – 5yrs)			X			Both	NQ	NQ	NQ	$ 48,000	NQ	NQ	NQ	
Match EQIP and CREP Funds			X			Both	NQ	NQ	NQ	Unknown	NQ	NQ	NQ	Match Farm Bill Funding
Good Initial Targets														
Old Farm Road Fencing, Riparian Buffer and Manure Management Plan #	1a		X			Union	NQ	NQ	NQ	$ 8,420	NQ	NQ	NQ	Manure Mgmt. Implementation
Van Syckel's Riparian Buffer and Manure Management (equine)#	1b		X			Union	NQ	NQ	NQ	$ 5,520	NQ	NQ	NQ	Manure Mgmt. Implementation
Van Syckel's Manure Management (Poultry)#	1c		X			Union	NQ	NQ	NQ	$ 1,120	NQ	NQ	NQ	Manure Mgmt. Implementation
Sanitary Surveys and Illicit Connection Detection and Removal *	2	X	X	X	X	Both				**$ 75,000**				YES - disconnections and septic system/cesspool repairs and replacements
Roadside Ditch Retrofits	4	X	X	X	X	Both				**NQ**				Project Specific
Good Initial Targets														
I-78 Swale and Wetland Retrofit	4a	X	X	X		Union	NQ	594	3.5	$ 201,500	$ 339	$ 57,571		
Others (poor and failing ditches)				X		Both	NQ	NQ	NQ	NQ				Project Specific
Ordinances for Maintenance of Stormwater Facilities and Riparian Area Protection	3	X	X	X	X	Both				**$ 12,000 per**				Per Ordinance
Stream and Riparian Area Restoration		X	X	X	X	Both	NQ	NQ	NQ	NQ	NQ	NQ		Project Specific
Site Specific														
Outlet Stabilizations (Reduction of Pollutant Generation)														
OPG-109 Pipe Repair and Stabilization		X	X		X	Union	4,000	450	1.8	$ 154,700	$ 344	$ 85,944	$ 39	
OPG-213 Pipe Repair and Stabilization		X	X		X	Union	15,120	630		$ 33,000	$ 52		$ 2	
OPG-369 Outlet Stabilization (Country Acres)			X		X	Union	2,240	1,650		$ 212,000	$ 128		$ 95	
Best Management Practice Retrofits (Collection, Interception and Treatment)														
Catch Basin Inserts for Hickory Ridge			X			Bethlehem		2,450		$ 28,050	$ 11			
Catch Basin Inserts Kensington Court			X			Bethlehem		600		$ 13,650	$ 23			
Union Township Middle School (Perryville Road) Rain Garden and Swale	6		X	X	X	Union		557	5	$ 131,300	$ 236	$ 26,260		
Country Acres Detention Basin Retrofit	5	X	X			Union		1,520	4.6	$ 207,400	$ 136	$ 45,087		
Mill Brook Basin Retrofit		X	X	X		Union		930	7	$ 79,400	$ 85	$ 11,343		
Perrryville Office Park Detention Basin Landscaping			X			Union		1,470	8	$ 116,500	$ 79	$ 14,563		
Hawk Ridge Bioretention Wetland Basin		X	X			Bethlehem		819	3.3	$ 55,200	$ 67	$ 16,727		

*** Recommended measure is a first step. Full implementation, such as manure management facilities, septic system replacement, etc. will require site specific evaluations.**

+ Nutrient Management Plans usually recommend livestock exclusion fencing. This limits the amount of feces deposited in the stream channel. As well, the trampling of the stream bed and banks and overgrazing of riparian vegetation are eliminated or minimized.

 # Project descriptions not included in Appendix A. These projects will be implemented through the Comprehensive Agricultural Management Project.

Site-specific Restoration Projects

Site-specific projects were developed based on the inventory of stormwater infrastructure and best management practices in the watershed. Through the stormwater inventory, many outlets were classified as causing downstream erosion and three of the more severe locations were chosen as projects for outlet stabilization. Adding energy dissipation to an outlet structure and stabilizing the adjacent surrounding and immediately downstream area will likely reduce the erosion potential at these locations and the amount of sediment delivered to the stream channel. Many of the detention basins in the watershed were not maintained properly if at all. Detention basins conditions included sediment deposition greater than one foot, blocked outlet structures, overgrown vegetation, prolific invasive species, eroded outlets and trash deposits. For two basins with limited access and possibly no easements, an alternative retrofit is the installation of catch basin inserts, which collect the sediment before it arrives in the detention basin. An additional two detention basins have potential for modification into wetland basins or bioretention basins. Wetland and bioretention basins provide sediment and nutrient removal and allow for more infiltration of stormwater before discharge. Two detention basins, although functioning as designed, could be altered to provide additional infiltration, reducing volumes and velocities from the outlet structure or buffered with riparian vegetation, reducing the presence of geese and minimizing bacteria and pathogen contamination. The stormwater conveyance system at the Union Township Middle School on Perryville Road could potentially be modified into a vegetated/bioretention swale, which would slow runoff velocities, trap sediment and allow for nutrient uptake by plants. In addition, the project provides an opportunity for public education and could be used in the Township’s stormwater education program.

Project Prioritization

Quantifying the benefits of each project is difficult at best. Although pollutant removals can be calculated for some of the projects, such as potential total suspended solids removal through detention basins, other benefits cannot or require information for which the funds spent obtaining that information might be better used for implementation. For instance, erosion and sedimentation are dependent upon soil composition, flow volume and velocity, slope, channel configuration, outlet configuration and upstream land uses, among other factors. Benefits for the agricultural projects will not be quantifiable until the program is underway and best management practices have been identified for specific agricultural operations. Reductions of sources of bacteria do not directly correlate to a reduction of bacterial or pathogen load because animal feces contain different amounts of bacteria and bacteria can proliferate or expire based on different environmental factors such as stream temperature and exposure to sunlight.

Considering the difficulties in quantifying the effectiveness of each of these projects, the recommended priority for project implementation is based on qualitative factors such as eligibility for funding, implementation timeline and formerly known successes. The suggested prioritization is summarized below.

1. **Comprehensive Agricultural Management Program:** Agricultural best management practices create the best opportunity to address all of the major impairments (bacteria, temperature, erosion) to the Mulhockaway Creek. Nutrient management plans will require farmers to address the exposure of manure to stormwater runoff and the stream, which will also limit the opportunities for bacteria and pathogen transport. Likely management measures are exclusion of livestock from the stream and improvement of the riparian buffer. Establishing, reestablishing or recreating a riparian buffer will reduce erosion through bank stabilization with vegetation and likely shade the stream, reducing stream exposure to sunlight and temperature increases. Through integrated crop management, the farmer can determine the appropriate amount of manure needed to ensure optimum crop growth without over application of manure, fertilizers and pesticides.

   The program can be implemented immediately and can work in conjunction with NJWSA's River Friendly Farm Implementation in the Raritan Basin Watershed. Agricultural landowners and their tenants can be educated about opportunities available to them through various farm bill aid programs and be helped with the requirements for program application. Development of a funding source to match farm bill program funds or support projects not covered by such programs will increase the likelihood of implementation of agricultural best management practices that will be protective of water quality. Three properties have been identified where livestock needs to be excluded from the stream, the riparian buffer needs to be improved or established and better manure handling needs to be implemented. These sites should be targeted first.

2. **Sanitary Survey and Illicit Discharge Removal:** Not all stormwater runoff should be directed immediately into the stormwater conveyance system or stream channel. Runoff from impervious surfaces should be routed over pervious surfaces such as lawns or vegetated swales to allow cooling of the stormwater (runoff may absorb heat from roofs and pavement), settling of particulate matter and reduction of velocity. Discharges from cooling towers, sump pumps, pool filters (backwash), and other water uses should not be released into the stormwater conveyance system or stream channel without energy dissipation and preferably should be infiltrated. In the Mulhockaway Creek watershed, there are areas of high septic system density and older residential areas, known to have septic system failures and cesspools. In saturated ground water conditions, including a high ground water table, septic system and cesspool leachate may become hydraulically connected to the stream through ditches and poorly grouted pipes or may be directly discharged into the stream. The HCSCD found more than 100 outfall pipes suspected of being an illicit connection, but no direct sanitary sewage discharges were observed. Since potential illicit connections (roof drainage, sump pumps and pool filter backwash) have already been identified and areas are known to have septic system failures and cesspools, a sanitary survey and illicit connection detection program should be implemented. Such a survey will also be useful to both communities in preparing a septic management plan

and mandatory maintenance plan, both required by the proposed Water Quality Management Planning Rules. Detailed information about sanitary surveys and illicit connection detection and removal is available through the USEPA. The survey program will allow the communities and the Department to determine if sanitary wastes are being discharged[61] to the stream without adequate soil contact time for bacteria and pathogen expiration and provide opportunities to reroute and potentially dissipate the energy from flows that should not be directly discharged to the stream channel. Both Union and Bethlehem Townships are considered Tier B communities and are not required to detect and remove illicit discharges as part of their Statewide Basic Requirements. However, the impairments to the Mulhockaway Creek must be addressed and a survey and removal program is an appropriate strategy to manage nonpoint sources. Sanitary surveys are often conducted for source water protection and as a multi-barrier approach to disinfection and protection of ground water wells.[62] This project can be commenced immediately with staff time (NJDEP or County Health Department) and disconnection projects and septic system repairs and replacement can begin as soon as specific locations are identified and funding is available.

3. **Ordinances:** While the Townships have recognized the importance of riparian areas, the regulatory framework for the protection of them could be stronger. A stream corridor or riparian ordinance to limit activities, not just new development, in riparian areas are appropriate and include provisions for preservation of forests, designated habitat, steeps slopes and riparian areas. Approximately half of the detention basins in the watershed were not properly maintained and may constitute a public health hazard. Basins were found to be overgrown with vegetation, partially filled with sediment, and scoured areas downstream. The municipal stormwater permits of each Township require the assurance of the management of stormwater best management practices. Several ordinances were developed which may be useful for the Townships to do so. They include prescribing the same maintenance requirements on existing facilities than those currently required of new development, requiring funding to assure future maintenance, assessments for the Townships to be reimbursed for performing maintenance on non-municipally-owned facilities, permitting of stormwater facilities, and declaration of the facility as a nuisance. These ordinances are potential tools for the Townships to manage stormwater facilities that are not maintained.

4. **Interstate 78 Swale and Wetland Retrofit:** None of the runoff from Interstate 78 is detained nor is the velocity from the runoff dissipated. The runoff is routed directly into the channelized streams in the culverts under the highway with no energy dissipation or treatment for water quality. A portion of the runoff from State Route 173 and Interstate 78 is collected in a ditch and routed through a pipe under Van Syckel's Road to the Creek. All of the drainage area contributing to

[61] Directly, via the stormwater conveyance system, or through hydraulic connection.
[62] Multiple barrier approach information found at
http://www.epa.gov/safewater/smallsys/pdfs/guide_smallsystems_sdwa.pdf

this ditch is from the impervious highway surfaces or largely impervious right-of-ways. The ditch is rated as fair but shows signs of both erosion and sediment deposition. Conversion of the ditch to a vegetated swale and wetland treatment system reduces runoff velocity because the stormwater is routed through vegetation. The runoff volume is reduced because the vegetated swale and wetland allow for more infiltration than the existing swale. This project is also expensive and located on private property; however, the project provides the opportunity to collect and treat runoff from highway and right-of-way surfaces and evaluate the effectiveness of wetland treatment systems on highway runoff. The project is not in the Interstate 78 or State Route 173 right-of-ways and will not likely require NJDOT or Federal Highway Administration Approvals. The project may be eligible for Environmental Stewardship funds from the Transportation Equity Act (TEA) grant program.

5. **Country Acres Detention Basin Retrofit:** One of the Country Acres detention basins has not been maintained since its construction in the early 1980s. The property owners believed that allowing the basin to fill with vegetation other than turf grass was more beneficial than leaving the basin in its original condition. The basin is somewhat infested with invasive species (stiltweed) and the berms are overgrown with woody vegetation. Death and decay of established woody vegetation can cause failures of the berm, especially if the root wad is dislodged. In addition, an unknown individual, in an attempt to dissipate the volume and velocity of the basin discharge added an orifice plate to the outlet pipe, which reduces the effective flow area creating more concentrated flow (similar to squeezing a hose to create additional water pressure). Although this allows the detention basin to retain water for a longer period of time and infiltrate water during smaller storms, the reduction in the outlet size increases the discharge velocity during intense, high runoff volume events and has caused erosion downstream of the outlet. The sediment is greater than two feet deep in locations and none has been removed from the basin post construction. Since the 1980s, vegetated detention basins have become more popular and acceptable to regulators. This detention basin can be rehabilitated and converted into a wetland or bioretention basin capable of treating the water quality design storm, a current requirement of NJDEP for new detention basins. Although on private property, the homeowners are highly motivated to revitalize this detention basin.

6. **Union Township Middle School Vegetated Swale and Rain Garden:** This site-specific project involves the remediation of a turf grass swale, pipe and stormwater outlet. Currently, the stormwater is discharged to the wooded buffer and then flows to the stream. The flow path through the wooded buffer is eroded and there is substantial sediment deposition in the stream channel. The stormwater management system collects runoff from 12 acres of highly impervious area (roofs, sidewalks, parking lots, playing fields and the county road) and is somewhat expensive compared to other projects where pollutant removals can be quantified. However, there are many coincidental benefits to this project. The project is located on public property, so more funding mechanisms

exist for project implementation. The location on the school property presents an excellent opportunity for education about stormwater, wetlands and wildlife. The site can be referenced in the Township's stormwater education materials and used to demonstrate the benefits of vegetation in stormwater management. The bioretention swales are similar to rain gardens and the River Friendly Resident program can be promoted with the project as an example.

Implementation of these projects, not including the matching funds for agricultural best management practices, removal of illicit connections, septic system repairs and replacements, and legal costs for ordinance adoption will cost approximately $800,000. The comprehensive agricultural management program and the sanitary survey and illicit connection detection and removal program target the whole watershed and will focus efforts on remedying multiple impairments. Further prioritization was not completed because the remaining recommended projects will likely have longer lead times because approvals from landowners, including homeowners associations, will be required. The non-prioritized projects should still be implemented and will lead to positive changes in the watershed; however, efforts and funding dollars should be focused on the prioritized projects because of their likelihood to produce results and coincidental benefits.

NEXT STEPS

The Mulhockaway Creek and its watershed are a critical water resource for the state of New Jersey. The Creek feeds Spruce Run Reservoir, a water supply and recreational facility, provides valuable habitat, and is a well-known trout-stocked stream. Impairments to the watershed include pathogen contamination (violations of fecal coliform criteria, an indicator bacteria), elevated stream temperature, impaired aquatic life, and erosion and sedimentation. The root causes of these impairments are both natural and anthropogenic and are not necessarily conducive to setting numeric targets or goals. However, the overall goal for the plan is to instigate the implementation of actions and management measures to remedy the known impairments and restore and protect the Creek's designated uses. As the Mulhockaway Creek and Spruce Run Reservoir are Category 1 waterbodies, another goal is to maintain and/or improve the water quality of both. Implementation of the mitigation and restoration projects, identified herein, will likely remedy or begin the process of remedying the impairments in the watershed. The next steps for enacting the Mulhockaway Creek Stormwater Management and Restoration Plan are define objectives and milestones to assess progress and secure funding, technical assistance and project partners to conduct and/or construct the identified projects.

Milestones and Implementation Strategies

Given the character of the impairments to the Creek and the omnipresent root causes, selection and establishment of milestones may be difficult. An adaptive management approach is most appropriate for addressing nonpoint sources of pollution and should be considered. Concentrated nonpoint sources (outfalls without energy dissipation, failing septic systems, unmanaged manure – in pastures and on crop fields) with typical solutions should be addressed and then whether or not the designated uses are met should be assessed. Reductions in sources are more likely to be achieved by readily identifiable sources. If designated uses are still not met, more diffuse sources or those without obvious remedies or management measures can be pursued. Below are suggested objectives and milestones to assess the success of the management actions and implemented/constructed projects.

Primary Contact Recreation/Fecal Coliform and Pathogen Impairment

The Fecal Coliform TMDL Implementation Recommendations Report outlines a strategy with three milestones for achieving the primary contact designated use:

- Meet an assumed secondary contact recreation threshold of 700 col/100 ml (an intermediate milestone);
- Reassess sources to target additional efforts; and
- Meet primary contact recreation standard or reclassify designated use.

While the NJDEP does not have a secondary contact recreation standard for FW2 waters, the Creek would likely meet the secondary contact recreation standard prescribed for the Delaware River and saline waters. Since the stream is shallow and immersion is highly unlikely, achieving the assumed secondary contact recreation standard would likely protect the majority of persons using the stream. Rather than expending implementation funds on microbial source tracking, it may be more appropriate to use those resources to address the problems. Several more concentrated potential sources have been identified that should be managed.

Elevated Stream Temperatures

The Mulhockaway Creek has violated trout production stream water temperature standards; however, the assessment is based on quarterly single sample measurements and violations only occurred for summer observations. Temperature is a surrogate standard for the protection of trout and aquatic life; so three potential milestones are a non-impaired aquatic life rating, optimal habitat designation (currently is), and meeting the temperature standard of not above 20 degrees Celsius. The sources of thermal load include sunlight exposure, discharges from shallow impoundments, and heated runoff from impervious surfaces since there is only one minor point source discharger in the watershed. Thus, the most appropriate management measures are related to improving the riparian buffer (for shading) and detaining stormwater from impervious surfaces to dissipate the heat before discharge to the stream. There are no milestones except achieving the temperature standard at this time. NJDEP might consider reclassifying the temperature impairment as natural because stream exposure to sunlight, shallow impoundment discharges and runoff from impervious surfaces are not likely to be controlled and the temperature violations, have occurred on hot summer days. With reclassification however, NJDEP should encourage and support vegetated riparian buffer improvement and reestablishment projects.

Erosion and Sedimentation

In this watershed, erosion and sedimentation are a root cause for temperature and aquatic life impairments (loss of riparian buffer and filled or eroded habitat) and a vehicle for the transport of nonpoint sources of pollutants to the reservoir (where they accumulate). The

Creek was primarily rated as fair for its physical condition and could be considered impaired by legacy sediment and poorly detained runoff from impervious surfaces. There are no baseline measurements[63] for erosion and sedimentation in the watershed, so it would be difficult to set a meaningful goal for its reduction. Until an assessment and baseline measurement program can be established, projects, which reduce the velocity and force of stormwater entering the stream channel, should be implemented. Specific projects include the stabilization and addition of energy dissipation to stormwater outfalls and ditches. In doing so, the erosive forces do not have time to develop and additional sediment is not eroded from the ditch or area receiving the stormwater discharge. A baseline monitoring program at several cross-sections along a few tributaries and the Main Stem should be established to develop the body of data necessary to understand and evaluate the problem.

Aquatic Life

Since toxics[64] are not likely to be causing the moderately impaired aquatic life rating, elevated stream temperatures, erosion, and sedimentation are the likely reason. The strategy for addressing aquatic life impairments will be the same as that for elevated stream temperature and erosion and sedimentation. The major milestone is achieving and maintaining a non-impaired aquatic life rating.

Funding and Technical Assistance

The New Jersey Water Supply Authority (NJWSA) is the steward of the Spruce Run Reservoir and its watershed and has funding available for projects that are protective of source water. The Watershed Protection Unit of the NJWSA has developed expertise in watershed protection and management and is committed to maintaining and improving, the quality of Spruce Run Reservoir and its tributaries. In this watershed, NJWSA has conducted a riparian buffer restoration and a stream channel restoration project in the Mulhockaway Creek Watershed, preserved open space and is actively seeking participation in the River Friendly Farm program with NJRC&DC. The NJWSA has applied for and received grants for source water protection.

The Raritan Basin Watershed Alliance (RBWA) is a coalition of partners interested in protecting the Raritan River Watershed, which includes the Mulhockaway Creek watershed. One project being conducted by RBWA is a riparian initiative, which seeks to develop a comprehensive system, from evaluation to implementation, for riparian area protection and restoration, which includes a funding component. An evaluation of assessment techniques is being developed in association with the New Jersey chapter of the American Water Resources Association. Funding mechanisms are still being investigated.

[63] Although measurements were made for the Hoffman Park stream restoration project on the Mechlin Corner Branch, the stream was significantly altered and is still changing in response to the new channel design and instream structures. At this time, the site is unlikely to be representative of conditions throughout the watershed.
[64] Based on analysis of the Mulhockaway Creek by the USGS NAWQA Program in 1997.

The NJDEP has issued 319(h) nonpoint source pollution control grants for source water protection activities and preference is given to watersheds and impaired stream segments. Once this plan is approved by NJDEP, the recommended projects will be eligible for grant funding.

For management measures related to agriculture, the USDA has farm bill programs that match or provide funding for the implementation of practices protective of water quality, including establishment of riparian buffers, fencing to exclude animals from water bodies, and manure management systems. The programs include the Environmental Quality Incentives Program (EQIP), the Conservation Reserve Enhancement Program (CREP) and similar New Jersey Farm Bill programs. Since some of the projects involve agricultural operations, these grant programs may be tapped for funding.

Rutgers Cooperative Extension Water Resources Program is actively involved in watershed restoration projects and serves as a valuable resource to those interested in restoration activities. While not a source of funding, they are developing a body of technical expertise, which may be tapped for implementation. For example, the staff developed a community-based learning program, which teaches students about stormwater management by allowing them to design and build a rain garden. Such a program might be appropriate in this watershed.

Additional Watershed Protection Efforts and Previous Projects

The Mulhockaway Creek watershed benefits from many watershed and environmental programs, which seek to improve water quality and directly or indirectly strive to manage nonpoint source pollution. In 1999, the NJDEP contracted with the NJWSA to develop a watershed management plan for the Raritan Basin. The plan was completed in December 2002 and interested stakeholders formed the Raritan Basin Watershed Alliance (RBWA), partnerships for the protection and restoration of water and environmental resources in the watershed. In addition, the municipalities in the Spruce Run Reservoir watershed and the NJWSA formed the Spruce Run Initiative, specifically to prevent water quality degradation and loss of water supply. Organizations have partnered to implement watershed protection activities locally and include Bethlehem Township, Union Township, NJDEP, North Jersey Resource Conservation and Development Council (NRC NJRC&DC), Natural Resource Conservation Service (NRCS), South Branch Watershed Association (SBWA), Hunterdon County Soil Conservation Service, Hunterdon County (Deparments of Health, Parks and Recreation, and Roads and Bridges), among others. There are many interested stakeholders likely willing to aid in the implementation the mitigation and restoration projects or others similar to those proposed. Table 13 summarizes some of the projects beneficial to the watershed and the coalitions that strive to protect the watershed. Brief descriptions of the projects and programs follow.

TABLE 13. Additional Watershed Protection Efforts and Projects

Program	Description	Status
Spruce Run Initiative (SRI)	Townships, including Bethlehem and Union, have formed a partnership to develop and implement projects beneficial to water quality, particularly the purchase of properties for preservation.	On-going, primarily consists of coordinated land acquisition and education program development for residents
SRI Critical Areas Preservation Plan	Identified parcels for preservation based on Critical Area Analysis	On-going. 640 additional acres have been preserved in critical areas of the Mulhockaway Creek watershed
SRI Smart Growth Highway Corridor Plan	Identified locations along zoned commercial areas where development should be controlled	Completed. Recommendations being implemented. Union Township changed zoning based on recommendations
SRI Spruce Run Reservoir Nonpoint Source Loading Model	Calculated potential Nonpoint Source Pollution resulting from build out. Identified subwatershed areas that may need additional protections through zoning or other ordinances	Completed. Demonstrated need for maintaining or improving municipal ordinances. Model will be used to assess benefits of land preservation and new ordinances.
NJWSA Watershed Lands Acquisition	NJWSA secured non-profit partners and funding to preserve watershed lands.	On-going. NJWSA continues to target parcels identified in critical areas.
EPA Targeted Watershed Grant-Restoration	Two segments of the Mulhockaway Creek were restored.	On-going. Monitoring to assess progress. Some adaptive management needed.
EPA Targeted Watershed Grant-Pollution Prevention	Developed education and outreach programs to manage pollution at the source or avoid its generation. Residents, businesses and farms were targeted for River Friendly Certifications. A salt workshop presenting alternative deicing measures was developed for municipalities.	On-going. Bethlehem and Hunterdon County representatives attended a road salt alternatives workshop. Farms targeted for River Friendly participation.
EPA Targeted Watershed Grant-Municipal Assessments	The Townships' Environmental Goals and Master Plan were evaluated for consistency.	Completed. Some recommendations being implemented. Sound relationships developed.
Highlands Act and Regional Master Plan	State is developing a master plan for the protection of water resources in the New Jersey Highland. Preservation areas were delineated where more stringent requirements will be imposed before land-altering activities can occur.	On-going. The Mulhockaway Creek, watershed, except for Interstate 78 corridor is designated as Preservation Area, which has stringent development criteria developed to protect water quality.
Raritan Basin Watershed Management Plan	Baseline information was developed for the watershed along with regional strategies for protection of the watershed, riparian areas, water supply, and stormwater control, among others.	Raritan Basin Watershed Alliance is implementing the plan, beginning with Riparian Area initiatives.

The Spruce Run Initiative

The Spruce Run Initiative is a partnership among the municipalities in the Spruce Run Reservoir Watershed (Bethlehem, Lebanon and Union Townships and Glen Gardner and High Bridge Boroughs), Hunterdon County and NJWSA to prevent water quality degradation and loss of water supply. The intention of Initiative is to achieve this goal through the coordination of watershed protection projects, land acquisition and preservation efforts so that all partners benefit while not usurping home rule. One advantage of this partnership is that the municipalities have worked with the County and NJWSA to develop and implement detailed plans for linking dedicated open space to protect contiguous forests, riparian corridors and critical habitats that cross property boundaries. Through coordination, the municipalities will avoid the creation of isolated open space, which has limited environmental benefit compared to larger expanses of preserved area. The municipalities have been improving their local land use ordinances and development controls to minimize the impacts of new development. The outcomes of projects are aimed at the protection of natural resources – improved protection of the Spruce Run Reservoir, one of the State's largest reservoirs, and the many trout production streams of the reservoir watersheds.

Critical Areas Preservation Plan

One of the first projects conducted for the Spruce Run Initiative was the development of a Critical Area Preservation Plan. The Initiative partners developed a set of criteria to identify parcels for preservation that would be most beneficial to water quality. The criteria included riparian areas, high ground water recharge, dense forest, habitat for threatened and endangered species, prime agricultural soils, flood plain buffer and parcel size. Based on the concentration of critical areas to preserve, six project areas were defined, two of which are located in the Mulhockaway Creek Watershed: Mulhockaway Headwaters and Hoffman Farms. The analysis identified 4,500 acres in the watershed that should be targeted for preservation.

Spruce Run Reservoir Watershed Nonpoint Source Pollutant Loading Model

NJWSA funded development of a watershed pollutant loading model for the Spruce Run Reservoir Watershed, which includes the Mulhockaway Creek Watershed. The intent of the model was to provide information to help target water quality protection efforts, remedial projects and land acquisition throughout the watershed. Camp, Dresser and McKee developed the model using USEPA's stormwater management model (SWMM) and evaluated the hydrology and pollutant loadings for existing land use (1995/97 land use data updated with information from the Townships and County) and future build-out land use (based on 2001 zoning information). The model will be used in the future to assess the benefits of watershed protection efforts.

Spruce Run Initiative Smart Growth Highway Corridor Study

In 2003, the Association of New Jersey Environmental Commissioners (ANJEC) provided a grant to the NJWSA and Bethlehem, Lebanon, and Union Townships and High Bridge Borough[65] to develop a plan to direct commercial development away from environmentally sensitive areas within the Spruce Run Watershed. The intent is for the

[65] Glen Gardner was not eligible to participate since they do not have an environmental commission.

project to focus attention towards the highway corridors to improve integration of commercial development and redevelopment within the communities using smart growth principles and improve protection of water resources through zoning changes. The Route 173 Study Area bisects the Mulhockaway Creek Watershed and runs parallel to Interstate 78. The recommendations from the study include defining commercial nodes along Exits 13-15 (not in the Mulhockaway Watershed) and Exit 11 of Interstate 78. Exit 12 is close to a tributary to the Mulhockaway Creek and near the headwaters of a small direct tributary to the Reservoir, so the study recommended that Union Township steer development away from that area. At the nodes, zoning should be changed to encourage small-scale retail sales and service establishments, Restaurants, Cafes and Taverns. Along the corridors, zoning should be adjusted to encourage the same uses as at the nodes, but at a lower density, and discourage large-scale retail sales and services (shopping centers, big box warehouses), auto dealerships, drive-in restaurants, warehouse/self storage, and office.

NJWSA Watershed Acquisition Plan

The NJWSA has been working in partnership with government and not-for-profit entities since 2001 to preserve watershed lands in the Spruce Run Watershed through the Spruce Run Initiative. The partners to the open space coalition include Lebanon Township, Union Township, Bethlehem Township, Clinton Township, Hunterdon County, Green Acres, the State Agriculture Development Committee, and the Hunterdon Land Trust Alliance. Through this program, the SRI and neighboring municipalities hope to bring greater efficiencies to the preservation of watershed lands through (1) voluntary partnership respecting each partners' particular expertise; (2) collaboration in formulating creative acquisition strategies; and (3) education among partners as to effective acquisition methodologies.

During 2001 and 2002, the SRI identified critical watershed parcels in the Spruce Run watershed through development of the Critical Areas Preservation Plan report, worked with municipal representatives in property owner outreach, developed partnerships, commenced negotiations and acquired critical area parcels throughout the watershed. In July of 2002, the NJWSA committed approximately two and one-half percent of its Raritan Basin water revenues ($5 per million gallons sold) to the acquisition process. While insufficient to serve as direct acquisition funding, the Authority focused those funds on expenditures beneficial to reducing the delay in preservation such as securing early appraisals, environmental assessments, title searches and other administrative expenses.

In July 2003, NJWSA committed an additional 2.5percent of its Raritan Basin water revenues to fund direct acquisitions and a full-time Property Administrator position within the NJWSA. In addition to continuing activities that began in 2001 and 2002, the NJWSA and its SRI partners preserved four properties totaling 650 acres in Lebanon Township. In January 2004, the NJWSA started to focus on other areas of efficiency with preservation. In particular, the NJWSA launched the pooled municipal finance program, to assist municipalities in financing their watershed purchases at significantly below market interest rates. The program will result in a total increase in the amount of open space preserved. In the future, the SRI will continue to augment preservation efficiencies through expanded partnership for preservation within critical watershed areas, continued capitalization of low interest financing, identification of additional funding sources, and education of other preservationist to the collaborative preservation model.

EPA Targeted Watershed Grant

In 2003, the Stony Brook-Millstone Watershed Association and NJWSA received a Targeted Watershed Grant from EPA to implement watershed restoration, preservation and protection, and pollution prevention projects in three project areas within the Raritan Basin. One of the project areas is the northern portion of the South Branch Raritan River watershed, which contains the Mulhockaway Creek Watershed.

Watershed Restoration

Through this grant, Stream Visual Assessments were conducted to evaluate the physical condition of streams in the Spruce Run Reservoir Watershed. Two reaches along the Mechlin Corner branch of the Mulhockaway Creek were targeted for restoration activities. At the Old Farm Road site, the stream with lawn mowed to the edge in the riparian buffer, was re-vegetated with native species. At the Hoffman Park site, a comprehensive stream restoration project was implemented. The Mulhockaway was incised at this location and may have been straightened for agricultural purposes. An undersized culvert, which caused backwater and severe erosion during higher flow events and prevented fish passage, was replace with a bridge over the natural stream bottom. Approximately 700 feet of the channel was reconfigured to include meanders, log veins, and riffles. The stream restoration at Hoffman Park received an award from the New Jersey Association of Floodplain Managers.

Prevention and Protection

The NJWSA performed municipal assessments for both Bethlehem and Union Townships. Guided by the goals of a particular community, NJWSA provided a detailed evaluation of the communities' Master Plan and ordinances using a Municipal Assessment Process developed by the Stony Brook-Millstone Watershed Association. The services are provided at no cost to the participating municipalities and the process itself has no regulatory effect. Each municipality is assessed against their own vision, not a "scorecard" to determine how well aligned the collective vision (master plan) is with the land use ordinances. The NJWSA then recommends how each Township could improve their protection of water resources through their land use ordinances. The goal is the ensure that the municipality's regulations are protective of and prevent detrimental effects to water resources and

Pollution Prevention

Another aspect of the grant is to implement pollution prevention education programs and actions and test what methods produce the best participation. The education programs include Road Salt Education Programs for Municipal and County representatives and the River Friendly suite of programs: Business, Resident, Golf Course and Farm. Of note, Representatives from Union Township, Bethlehem Township and Hunterdon County have attended the Road Salt Education Seminars.

Highlands Act and Regional Master Plan

The Highlands Act requires that more stringent land use regulations be developed and implemented to protect the water, ecological and cultural resources. The region is known for its high quality water, but has been recognized as in need of protection due to increasing urban runoff potential, potential population increases and hydrologic alteration. Through land use controls, the region's ability to provide water for 4.5 million persons in New York and New Jersey can be maintained. One proposed restriction is to limit imperviousness to three percent on a site. This limits the amount of runoff that can be generated and preserves ground water recharge in the remaining area. The Mulhockaway Creek will benefit from the Highlands Act through the requirements for protection of forests, designated habitats, riparian areas, and steep slopes (erosion protection).

Raritan Basin Watershed Management Plan

The Raritan Basin Watershed Management Plan was completed in 2002 and the Raritan Basin Watershed Alliance was formed to coordinate the implementation of the plan among the many stakeholders in the basin. Eight basin-wide watershed management strategies were developed and include:

- RB-S1 Lands for Water Initiative Strategy
- RB-S2 Critical Areas Preservation in Development Strategy
- RB-S3 Water Supply Budgets and Allocations Strategy
- RB-S4 New Raritan Basin Surface Water Supply Strategy
- RB-S5 Watershed Planning and Policy Toolbox Strategy
- RB-S6 Institutional Capacity for Stormwater Management
- RB-S7 Watershed Based Stormwater Management Plan Strategy
- RB-S8 Ground Water Recharge Restoration Pilot Projects Strategy

In addition, three sets of strategies were developed for Watershed Management Area 8: North and South Branch Raritan River and include: Headwaters and Stream Management, Land Use and Open Space, Stormwater and Hydrology.

SUMMARY

Under a 319(h) Nonpoint Source Pollution Control Grant, a stormwater management and associated watershed restoration plan was developed for the Mulhockaway Creek. Through the project and other concurrent projects, much information was synthesized to develop an understanding of the watershed. Impairments to the watershed can be addressed through the implementation of the recommended projects, using an adaptive management approach. Since nonpoint source pollution is diffuse and water quality measurements can vary significantly, improvements may not be evident until some time in the future. Conveniently, the NJDEP, USGS and NJWSA are committed to funding water quality sampling in this watershed. Thus, data will be collected to assess the success of implementing the management measures. The recommended management measures are the beginning of a program to alleviate and eventually eliminate the impairment. Additional projects may be necessary to restore the watershed to a non-impaired status.

REFERENCES

Ayers, M.A., Kennen, J.G., and Stackelberg, P.E., 2000, Water Quality in the Long Island–New Jersey Coastal Drainages New Jersey and New York, 1996–98: U.S. Geological Survey Circular 1201, 40 p., on-line at http://pubs.water.usgs.gov/circ1201/

Brown, E., D. Caraco and R. Pitt. 2004. Illicit Discharge Detection and Elimination: A Guidance Manual for Program Development and Technical Assessments. Water Permits Division, Office of Water and Wastewater, U.S. Environmental Protection Agency, Washington, D.C.

Camp Dresser and McKee. 2003. Watershed Model for Watersheds of the Spruce Run Reservoir. New Jersey Water Supply Authority, Somerville, NJ.

ENSR Corporation. 2006. Stormwater TMDL Implementation Support Manual. United States Environmental Protection Agency Region I.

Hatch Mott MacDonald. Township of Bethlehem, Hunterdon County, NJ, Municipal Stormwater Management Plan, March 2006.

Hunterdon County: County History, http://www.co.hunterdon.nj.us/history.htm

Hunterdon County: The First 275 Years of Hunterdon County 1714- 1989, http://www.co.hunterdon.nj.us/depts/c&h/275years.htm

Maser Consulting P.A. Stormwater Management Plan for Township of Union, Hunterdon County, New Jersey, April 2006.

Mockus, Victor, 1972. National Engineering Handbook, Section 4, Hydrology. United States Department of Agriculture.

NJDEP. Biological Monitoring Data for the Mulhockaway Creek. http://www.state.nj.us/dep/wms/bfbm/download/rar99.pdf

NJDEP. Fish IBI http://www.state.nj.us/dep/wms/bfbm/download/ibi2002Vol2-52-55.pdf

NJGS. 1993. A Method for Evaluation Ground Water Recharge Areas in New Jersey. New Jersey Geological Survey, Geological Survey Report GSR-32.

NJWSA. 2002. Raritan Basin Watershed Management Plan

NJWSA. 2002. Ground Water in the Raritan Basin

NJWSA. 2002. Surface Water Quality and Pollutant Loadings

NJWSA. 2000. Water Budget in the Raritan Basin.

Papson, Robert, 2007. Fisheries Management Plan for Spruce Run Reservoir, Hunterdon County, New Jersey. New Jersey Division of Fish and Wildlife Bureau of Freshwater Fisheries.

Princeton Hydro, LLC, 2003. Natural Resources Inventory: Township of Union, Hunterdon County, New Jersey. Township of Union Environmental Commission.

Princeton Hydro, LLC, 2005. An Interactive Environmental Resources Inventory for the Township of Bethlehem, Hunterdon County, New Jersey. Township of Bethlehem.

Reiser, R.G., 2004, Evaluation of Streamflow, Water Quality, and Permitted and Nonpermitted Loads and Yields in the Raritan River Basin, New Jersey, Water Years 1991-1998: U.S. Geological Survey Water-Resources Investigations Report 03-4207, 210 pp.

U.S. Department of Agriculture, Soil Conservation Service. 1974. Soil Survey: Hunterdon County New Jersey.

U.S. Environmental Protection Agency. 2005. Draft Handbook for Developing Watershed Plans to Restore and Protect Our Waters. EPA 841-B-05-005. Office of Water (4503F), United States Environmental Protection Agency, Washington D.C. 414 pp.

U.S. Environmental Protection Agency. 2006. Draft National Management Measures to Control Nonpoint Source Pollution from Hydromodification. EPA 841-D-06-001. Office of Water (4503F), United States Environmental Protection Agency, Washington D.C. 324 pp.

U.S. Environmental Protection Agency. 1999. Guidance Manual for Conducting Sanitary Surveys of Public Water Systems; Surface Water and Ground Water Under the Direct Influence (GWUDI). EPA 815-R-99-016. Office of Water (4607), United States Environmental Protection Agency, Washington D.C.

USEPA. 1993. Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters. EPA 840-B-92-002, U.S. Environmental Protection Agency, Office of Water.

U.S. Environmental Protection Agency. 2001. Protocol for Developing Pathogen TMDLs. EPA 841-R-00-002. Office of Water (4503F), United States Environmental Protection Agency, Washington D.C. 132 pp.

U.S. Environmental Protection Agency. 1999. Protocol for Developing Sediment TMDLs. EPA 841-B-99-004. Office of Water (4503F), United States Environmental Protection Agency, Washington D.C. 132 pp.

Van Abs, Daniel J. 2002. Preservation of Critical Areas in the Spruce Run Reservoir Watersheds: A Report of the Spruce Run Initiative.