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New Jersey Agricultural Experiment Station

Water Resources Program

Upper Salem River Watershed Restoration & Protection Plan: DATA REPORT

Developed by the Rutgers Cooperative Extension Water Resources Program

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RP 07-024

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Watershed Overview

The Salem River Watershed above U.S. Geological Survey (USGS) streamflow gauge #01482500 at Woodstown, NJ (henceforth, the Upper Salem River Watershed) is 14.6 square miles and is dominated by agricultural land uses (Figure 1). Based on a review of aerial photographs, input from Rutgers Cooperative Extension (RCE) of Cumberland County and the Cumberland-Salem Conservation District, and data collection during site visits, the agricultural land uses were further identified as row crops and pastureland. The New Jersey Department of Environmental Protection (NJDEP, 2010) 2007 land use data identifies agricultural land uses within the Upper Salem River Watershed as cropland and pastureland, orchards and vineyards, confined animal feeding operations, and other agriculture (Figure 2).

The Upper Salem River Watershed is comprised of sections of Woodstown Borough, Pilesgrove Township, and Upper Pittsgrove Township in Salem County (Figure 3). Approximately 17.9 miles of river and streams occur within the watershed. The largest surface waterbody in the drainage area is Memorial Lake, which is located near the outlet of this watershed (Figure 3).

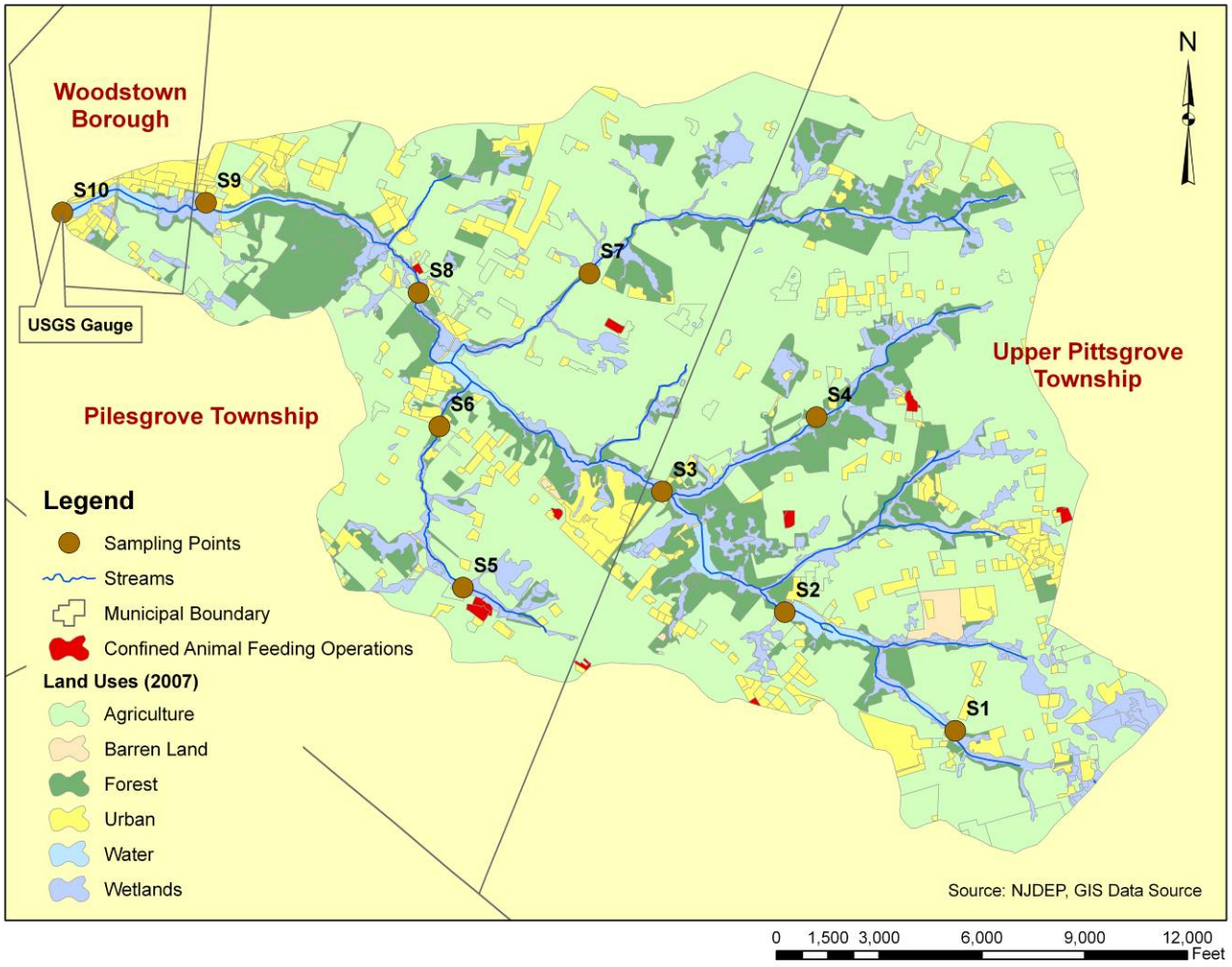

Figure 1: NJDEP 2007 land use/land cover map.

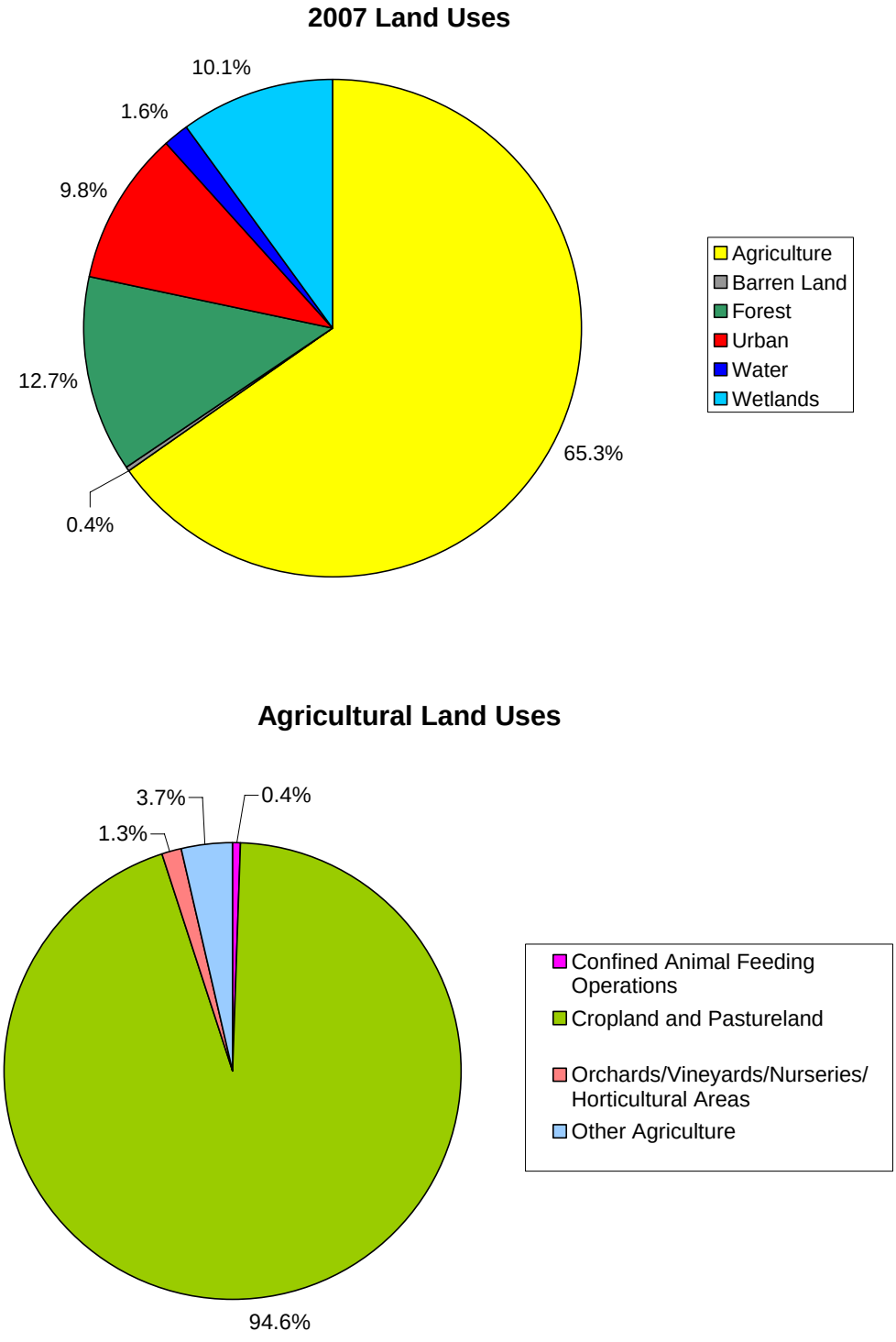

Figure 2: NJDEP 2007 land cover types and agriculture land uses in the Upper Salem River Watershed.

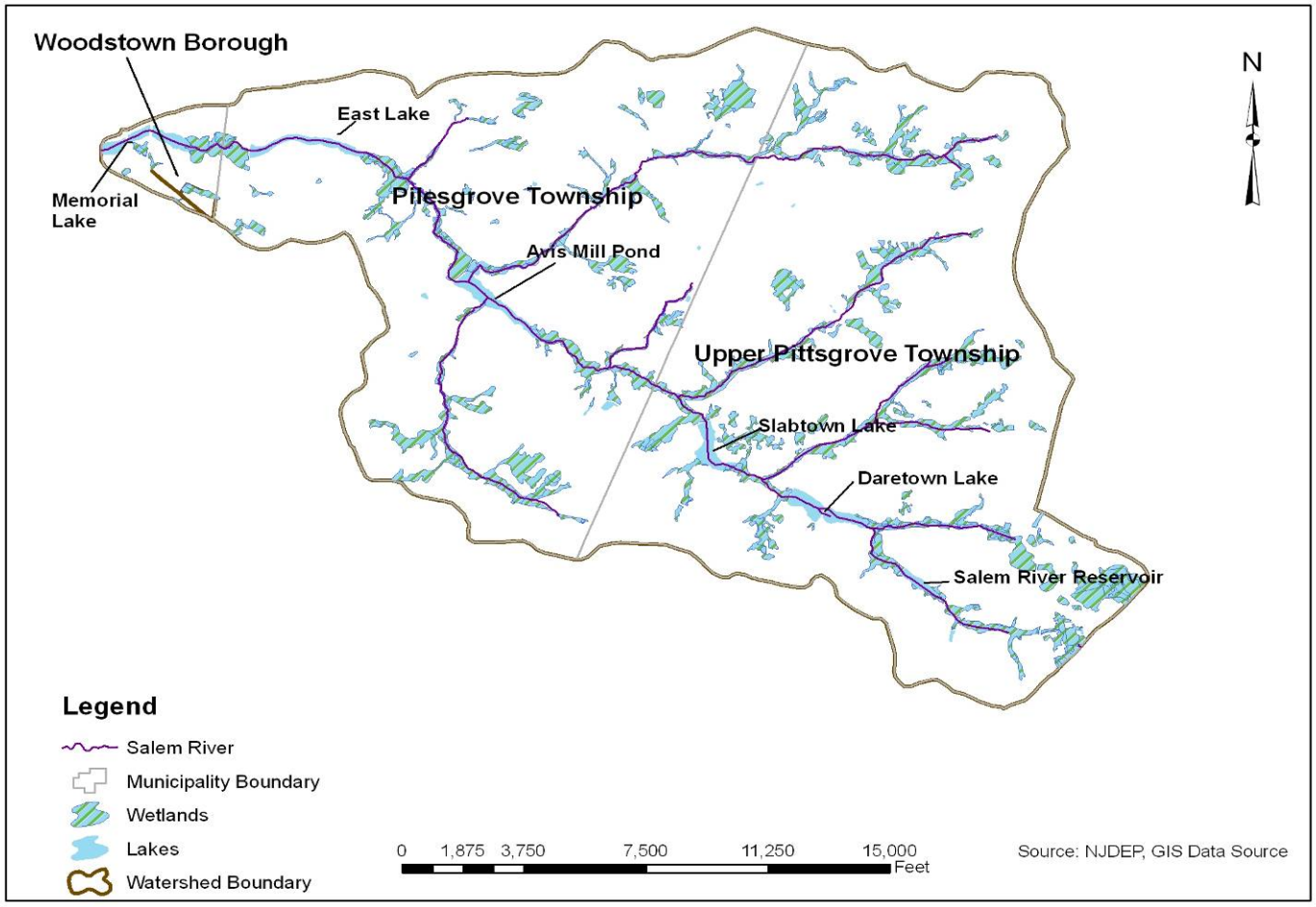

Figure 3: Municipalities and waterbodies located within the Upper Salem River Watershed.

Project Background and the TMDL Development Process

The development of the Upper Salem River Watershed Restoration and Protection Plan was funded in 2005 by the NJDEP (RP 07-024). The overall goal of this project is to develop a plan that when implemented will restore the water quality to the headwaters of the Salem River and Memorial Lake in Woodstown, NJ by reducing phosphorus and fecal coliform loads throughout the watershed. This work has been completed as Phase II of a project originally begun in 2004. The Phase I Report is attached as Appendix A. Phase I of this effort included a characterization of the watershed area through the use of Geographic Information Systems (GIS), development of a Quality Assurance Project Plan (QAPP), and an assessment of the watershed characterization. Additional funding was received in 2006 as part of a United State Department of Agriculture (USDA) National Research Initiative (NRI) grant which greatly expanded the scope of the field sampling activities of this effort.

Total maximum daily loads (TMDLs) are developed by the NJDEP, and approval is given by the U.S. Environmental Protection Agency (USEPA). In accordance with Section 305(b) of the Clean Water Act, New Jersey addresses the overall water quality of the State's waters and identifies impaired waterbodies every two (2) years through the development of a document referred to as the *New Jersey Integrated Water Quality Monitoring and Assessment Report*, a.k.a. the "Integrated List" (NJDEP, 2006). Within this document are sublists that indicate the presence and level of impairment for each waterbody monitored. The lists are defined as follows:

- **Sublist 1** suggests that the waterbody is meeting water quality standards.

- **Sublist 2** states that a waterbody is attaining some of the designated uses, and no use is threatened. Furthermore, Sublist 2 suggests that data are insufficient to declare if other uses are being met.
- **Sublist 3** maintains a list of waterbodies where no data or information are available to support an attainment determination.
- **Sublist 4** lists waterbodies where use attainment is threatened and/or a waterbody is impaired; however, a TMDL will not be required to restore the waterbody to meet its use designation.
    - ➢**Sublist 4a** includes waterbodies that have a TMDL developed and approved by the USEPA, that when implemented, will result in the waterbody reaching its designated uses.
    - ➢**Sublist 4b** establishes that the impaired reach will require pollutant control measurements taken by local, state, or federal authorities that will result in full attainment of designated uses.
    - ➢**Sublist 4c** states that the impairment is not caused by a pollutant, but is due to factors such as instream channel condition, flow alteration, or habitat degradation. It is recommended by the USEPA that this list be a guideline for water quality management actions that will address the cause of impairment.
- **Sublist 5** clearly states that the water quality standard is not being attained and requires a TMDL.

The USGS gauging station #01482500, Salem River at Woodstown, was identified on sublist 4b in 2002 for fecal coliform and phosphorus (NJDEP, 2002), in 2004 for

phosphorus (NJDEP, 2004a), in 2006 for phosphorus and pH (NJDEP, 2006), and in 2008 for pH, phosphorus and mercury (NJDEP, 2009a). A TMDL was proposed in 2003 and approved for fecal coliform (NJDEP, 2004b). The TMDL requires an 84% reduction of fecal coliform loads in the watershed on 17.9 miles of stream. In 2002, Memorial Lake was also identified on sublist 4b for phosphorus (NJDEP, 2002). A TMDL was approved in 2004 that called for a 91% reduction of phosphorus to the water body (NJDEP, 2004c). Memorial Lake was also listed in 2004 and 2006 as impaired for mercury (NJDEP, 2004a, NJDEP, 2006). In 2008 Memorial Lake was not listed (NJDEP, 2008). Mercury impairments are outside the scope of this project and are therefore not addressed for this study.

The purpose of this report is to provide a summary of available water quality data for the Upper Salem River Watershed, as well as describe the protocols and results of data collected by the RCE Water Resources Program and its partners. The water quality investigation that was carried out during this phase of the project addressed task 4 in the proposal, "Implement the QAPP, analyze the newly collected data, prepare a data report, and submit the data report to NJDEP." A complete analysis of this data to target pollution sources and remediation measures will be presented in the Upper Salem River Watershed Restoration and Protection Plan.

Biological Monitoring Data

Biological monitoring data is available for the watershed as part of the Ambient Biological Monitoring Network (AMNET), which is administered by the NJDEP. The NJDEP has been monitoring the biological communities of the State's waterways since

the early 1970's, specifically the benthic macroinvertebrate communities. Benthic macroinvertebrates are primarily bottom-dwelling (benthic) organisms that are generally ubiquitous in freshwater and are macroscopic. Due to their important role in the food web, macroinvertebrate communities reflect current perturbations in the environment. There are several advantages to using macroinvertebrates to gauge the health of a stream. First, macroinvertebrates have limited mobility, and thus, are good indicators of site-specific water conditions. Also, macroinvertebrates are sensitive to pollution, both point and nonpoint sources; they can be impacted by short-term environmental impacts such as intermittent discharges and contaminated spills. In addition to indicating chemical impacts to stream quality, macroinvertebrates can gauge non-chemical issues of a stream such as turbidity and siltation, eutrophication, and thermal stresses. Finally, macroinvertebrate communities are a holistic overall indicator of water quality health, which is consistent with the goals of the Clean Water Act (NJDEP, 2004d). These organisms are normally abundant in New Jersey freshwaters and are relatively inexpensive to sample.

The AMNET program began in 1992 and is currently comprised of more than 800 stream sites with approximately 200 monitoring locations in each of the five major drainage basins of New Jersey (i.e., Upper and Lower Delaware, Northeast, Raritan, and Atlantic). These sites are sampled once every five years using a modified version of the USEPA Rapid Bioassessment Protocol (RBP) II. To evaluate the biological condition of the sampling locations, several community measures are calculated by the NJDEP from the data collected and include the following:

1. Taxa Richness: Taxa richness is a measure of the total number of benthic macroinvertebrate families identified. A reduction in taxa richness typically

indicates the presence of organic enrichment, toxics, sedimentation, or other factors.

2. EPT (Ephemeroptera, Plecoptera, Trichoptera) Index: The EPT Index is a measure of the total number of Ephemeroptera, Plecoptera, and Trichoptera families (i.e., mayflies, stoneflies, and caddisflies) in a sample. These organisms typically require clear moving water habitats.

3. %EPT: Percent EPT measures the numeric abundance of the mayflies, stoneflies, and caddisflies within a sample. A high percentage of EPT taxa is associated with good water quality.

4. %CDF (percent contribution of the dominant family): Percent CDF measures the relative balance within the benthic macroinvertebrate community. A healthy community is characterized by a diverse number of taxa that have abundances somewhat proportional to each other.

5. Family Biotic Index: The Family Biotic Index measures the relative tolerances of benthic macroinvertebrates to organic enrichment based on tolerance scores assigned to families ranging from 0 (intolerant) to 10 (tolerant).

This analysis integrates several community parameters into one easily comprehended evaluation of biological integrity referred to as the New Jersey Impairment Score (NJIS). The NJIS has been established for three categories of water quality bioassessment for New Jersey streams: non-impaired, moderately impaired, and severely impaired. A non-impaired site has a benthic community comparable to other high quality "reference" streams within the region. The community is characterized by maximum taxa richness, balanced taxa groups, and a good representation of intolerant individuals. A moderately impaired site is characterized by reduced macroinvertebrate taxa richness, in particular the EPT taxa. Changes in taxa composition result in reduced community balance and intolerant taxa become absent. A severely impaired site is one in which the benthic community is significantly different from that of the reference streams.

The macroinvertebrates are dominated by a few taxa which are often very abundant. Tolerant taxa are typically the only taxa present.

The scoring criteria currently used by the NJDEP are as follows:

- Non-impaired sites have total scores ranging from 24 to 30,
- Moderately impaired sites have total scores ranging from 9 to 21, and
- Severely impaired sites have total scores ranging from 0 to 6.

It is important to note that the entire scoring system is based on comparisons with reference streams and a historical database consisting of 200 benthic macroinvertebrate samples collected from New Jersey streams. While a low score indicates "impairment," the score may actually be a consequence of habitat or other natural differences between the subject stream and the reference stream.

Starting with the second round of sampling under the AMNET program held between 2000 and 2001 for the Lower Delaware River region, habitat assessments were conducted in conjunction with the biological assessments. The first round of sampling under the AMNET program did not include habitat assessments. The habitat assessment, which was designed to provide a measure of habitat quality, involves a visually based technique for assessing stream habitat structure. The habitat assessment is designed to provide an estimate of habitat quality based upon qualitative estimates of selected habitat attributes. The assessment involves the numerical scoring of ten habitat parameters to evaluate instream substrate, channel morphology, bank structural features, and riparian vegetation. Each parameter is scored and summed to produce a total score which is assigned a habitat quality category of optimal, sub-optimal, marginal, or poor. Sites with optimal/excellent habitat conditions have total scores ranging from 160 to 200; sites with

sub-optimal/good habitat conditions have total scores ranging from 110 to 159; sites with marginal/fair habitat conditions have total scores ranging from 60 to 109, and sites with poor habitat conditions have total scores less than 60. The findings from the habitat assessment are used to interpret survey results and identify obvious constraints on the attainable biological potential within the study area.

The NJDEP Bureau of Biological & Freshwater Monitoring maintains two AMNET stations within the Upper Salem River Watershed (Stations AN0690 and AN0691) (Figure 4). Both stations were sampled in AMNET rounds in 1995, 2000, and 2006. In August 1995, August 2000, and October 2006, AN0690 was assessed under the AMNET program as being moderately impaired. In August 1995 and October 2006, AN0691 was assessed as being severely impaired, and in August 2000 the site was assessed as being moderately impaired (Table 1).

Habitat assessments were also included starting with the October 2000 AMNET sampling. Optimal habitat conditions were found at locations AN0690 in August 2000 and conditions were downgraded to sub-optimal in October 2006. At AN0691, sub-optimal habitat conditions were noted in both August 2000 and October 2006 (Table 1).

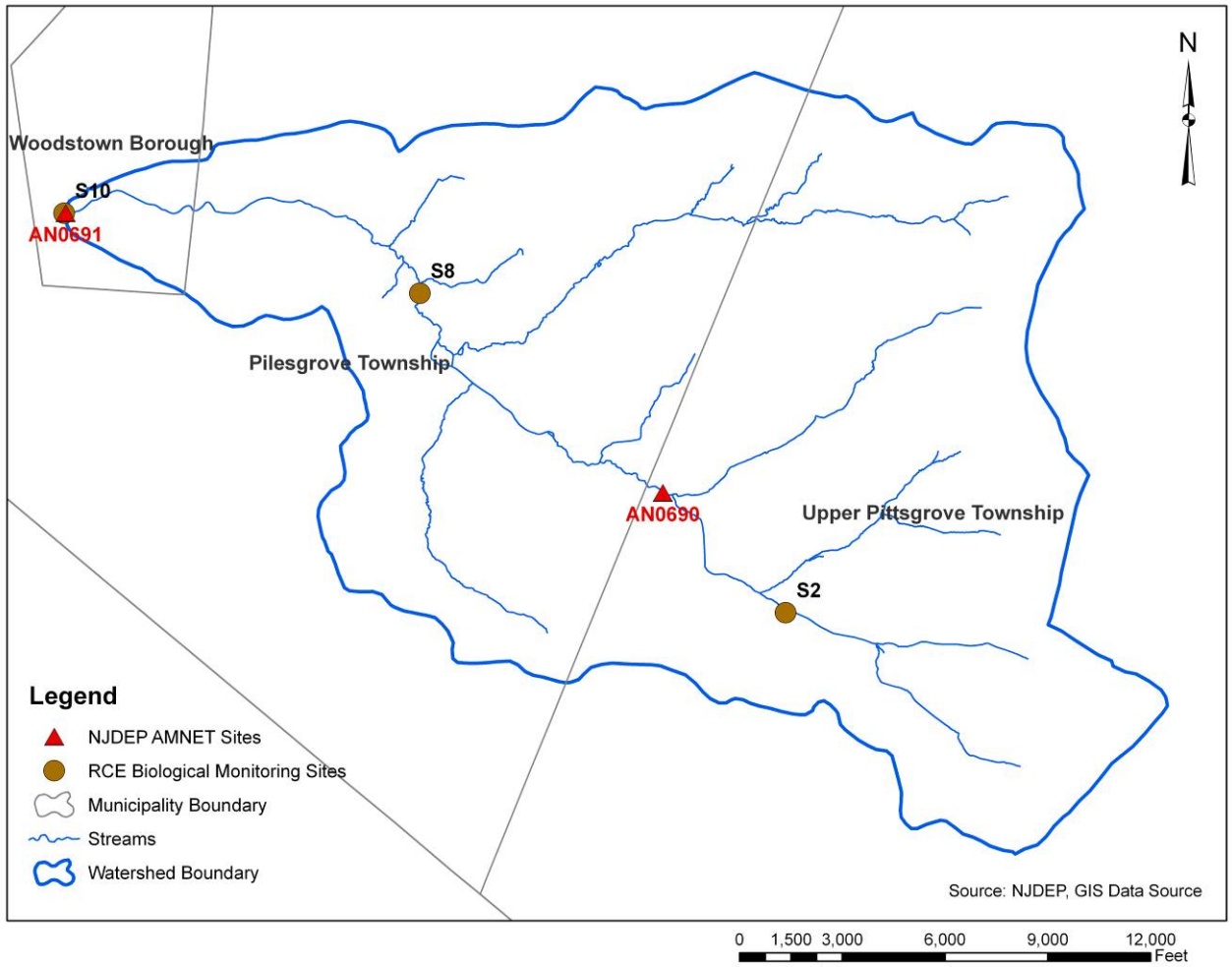

Figure 4: Biological sampling sites in the Upper Salem River Watershed.

Table 1: Summary of NJDEP Ambient Biological Monitoring Network results (NJDEP, 1996; NJDEP, 2003; NJDEP, 2009b).

		1996 Results		2000 Results			2006 Results		
Station	**Location**	**Date Sampled**	**Impairment Status (Score)**	**Date Sampled**	**Impairment Status (Score)**	**Habitat Analysis Result (Score)**	**Date Sampled**	**Impairment Status (Score)**	**Habitat Analysis Result**
AN0690	Commissioners Road Pittsgrove Township	8/24/95	Moderately Impaired	8/2/00	Moderately Impaired	Optimal	10/19/2006	Moderately Impaired	Suboptimal
AN0691	Mill Street Woodstown Borough	8/22/95	Severely Impaired	8/2/00	Moderately Impaired	Suboptimal	10/19/2006	Severely Impaired	Suboptimal

Given these aquatic life impairments, an additional biological assessment of the Upper Salem River Watershed was proposed as part of the development of the Watershed Restoration and Protection Plan for the Upper Salem River. The biological assessment conducted by the RCE Water Resources Program in August 2007 is fully described in Appendix B. The data collected by the RCE Water Resources Program indicate that the Upper Salem River Watershed, within the study area, continues to support a moderately impaired benthic macroinvertebrate community. The benthic macroinvertebrate community occurring within the Upper Salem River Watershed is apparently under some type of stress as evidenced by low taxa richness, the lack of representation of EPT taxa, and relatively high family biotic index scores. The types of organisms found, or the lack thereof, indicate that possible chemical perturbations are occurring within the system, and/or the benthic community may be subject to physical or habitat constraints. The habitat assessment revealed sub-optimal habitat conditions, which may also explain the observed impaired benthic macroinvertebrate community.

Biological assessments have become an important tool for managing water quality to meet the goal of the Clean Water Act (i.e., to maintain the chemical, physical, and biological integrity of the nation's water). Although biological assessments are a critical tool for detecting impairment, they do not identify the cause or causes of the impairment. The USEPA developed a process, known as the Stressor Identification (SI) process, to accurately identify any type of stressor or combination of stressors that might cause biological impairment (USEPA, 2000). The SI process involves the critical review of available information, the formation of possible stressor scenarios that may explain the observed impairment, the analysis of these possible scenarios, and the formation of

conclusions about which stressor or combination of stressors are causing the impairment. The SI process is iterative, and in some cases additional data may be needed to identify the stressor(s). In addition, the SI process provides a structure or a method for assembling the scientific evidence needed to support any conclusions made about the stressor(s). When the cause of a biological impairment is identified, stakeholders are then in a better position to locate the source(s) of the stressor(s) and are better prepared to implement the appropriate management actions to improve the biological condition of the impaired waterway. The SI process is recommended as the next step toward improving the biological condition of the Upper Salem Watershed.

Stream Visual Assessment Protocol (SVAP) Data Collected in the Upper Salem River Watershed

Introduction to SVAP

To characterize watershed health, the USDA Natural Resources Conservation Service (NRCS) developed the Stream Visual Assessment Protocol (SVAP). The SVAP was originally developed for use by landowners (USDA, 1998), but it has also proved to be useful for those familiar with local river systems and flooding occurrences. The protocol provides an outline on how to quantitatively score in-stream and riparian qualities including water appearance, channel condition, and riparian health. There are ten (10) primary SVAP elements:

- channel condition,
- hydrologic alternation,
- riparian zone,
- bank stability,
- water appearance,
- nutrient enrichment,

- barriers to fish movement,
- instream fish cover,
- presence of pools, and
- invertebrate habitat.

There are five (5) additional elements that should only be scored if applicable. These are canopy cover, manure presence, salinity, riffle embeddedness, and observed macroinvertebrates. Elements are scored from 1 to 10 (poor to excellent) with the exception of observed macroinvertebrates, which uses a scale ranging from 1 to 15 (poor to excellent). Once all the individual elements are scored, their average is calculated and the range of mean scores is used to qualitatively describe overall watershed health as follows:

- < 6.0 is Poor;
- 6.1-7.4 is Fair;
- 7.5-8.9 is Good;
- > 9.0 is Excellent.

The SVAP data sheet was modified by the RCE Water Resources Program to include other reach features to aid in pollution source track down in the Upper Salem River Watershed. These reach features include the identification of pipes and ditches, details on erosion or impairment caused by identified pipes or ditches, and access to stream reach for possible restoration. Additionally, all assessed reaches were photo-documented, and a site sketch was made denoting important reach characteristics.

SVAP in the Upper Salem River Watershed

SVAP assessments were conducted in the Upper Salem River Watershed beginning in June 2005. In May 2005, staff members from all project partners were trained in SVAP procedures. The training workshop consisted of a full day of SVAP

introduction and use, and included presentations in a classroom setting and group and paired exercises in the field. This training also included instructions on how to use the RCE online database entry system for SVAP data. The project watershed was divided into a gridded map, and individual maps of each grid were assigned to participating project partners to facilitate completion of the Upper Salem River Watershed SVAP assessments.

Access to the river system was the major obstacle in completing visual assessments in the Upper Salem River Watershed. Due to the agricultural land use dominating the watershed, it was necessary to alert all landowners of this upcoming effort. Therefore, announcements were made in local newspapers, and letters were hand-delivered to the largest landowners. This was advantageous to the project, as feedback from these landowners improved the assessments and additional information about the stream conditions were gained that might otherwise have been unavailable.

SVAP Data

Overall, seventy three river reaches were scored in the Upper Salem River. Across the watershed, the majority of the elements described previously were scored (Figure 5; Table 2). Overall, the Upper Salem River Watershed received a "fair" rating of a 7.24 (Table 2). This average score is not weighted by stream length. While the average score of 7.24 represents a "fair" rating, it is apparent that certain areas in the watershed are impacted (Figure 5). Four locations receiving overall scores of "poor" were seen and investigated further during the water quality investigation in Phase II of this project. A

summary of the SVAP effort for this project is presented as Appendix B of the Phase I Report which has been included as Appendix A in this report.

Table 2: SVAP assessment elements and data.

Element	Count	Minimum	Maximum	Mean	Standard Deviation
Riparian Zone-left	73	1.00	10.00	7.42	1.78
Riparian Zone-right	73	1.00	9.00	7.49	1.96
Channel Modification	73	2.00	10.00	6.55	2.29
Bank Stability-left	73	1.00	9.00	4.78	2.28
Bank Stability-right	73	1.00	9.00	4.48	2.32
Water Appearance	73	5.00	9.00	6.59	1.00
Nutrient Enrichment	73	5.00	9.00	6.51	0.87
Fish Barrier	73	5.00	10.00	9.03	1.07
Instream Fish Cover	73	5.00	10.00	7.99	1.26
Pools	73	6.00	10.00	8.16	1.03
Invertebrate Cover	73	5.00	10.00	8.47	1.20
Canopy Cover	73	1.00	10.00	8.85	2.56
Left Average	73	5.36	8.55	7.26	0.73
Right Average	73	5.42	8.64	7.23	0.73
Site Average	73	5.45	8.59	7.24	0.72

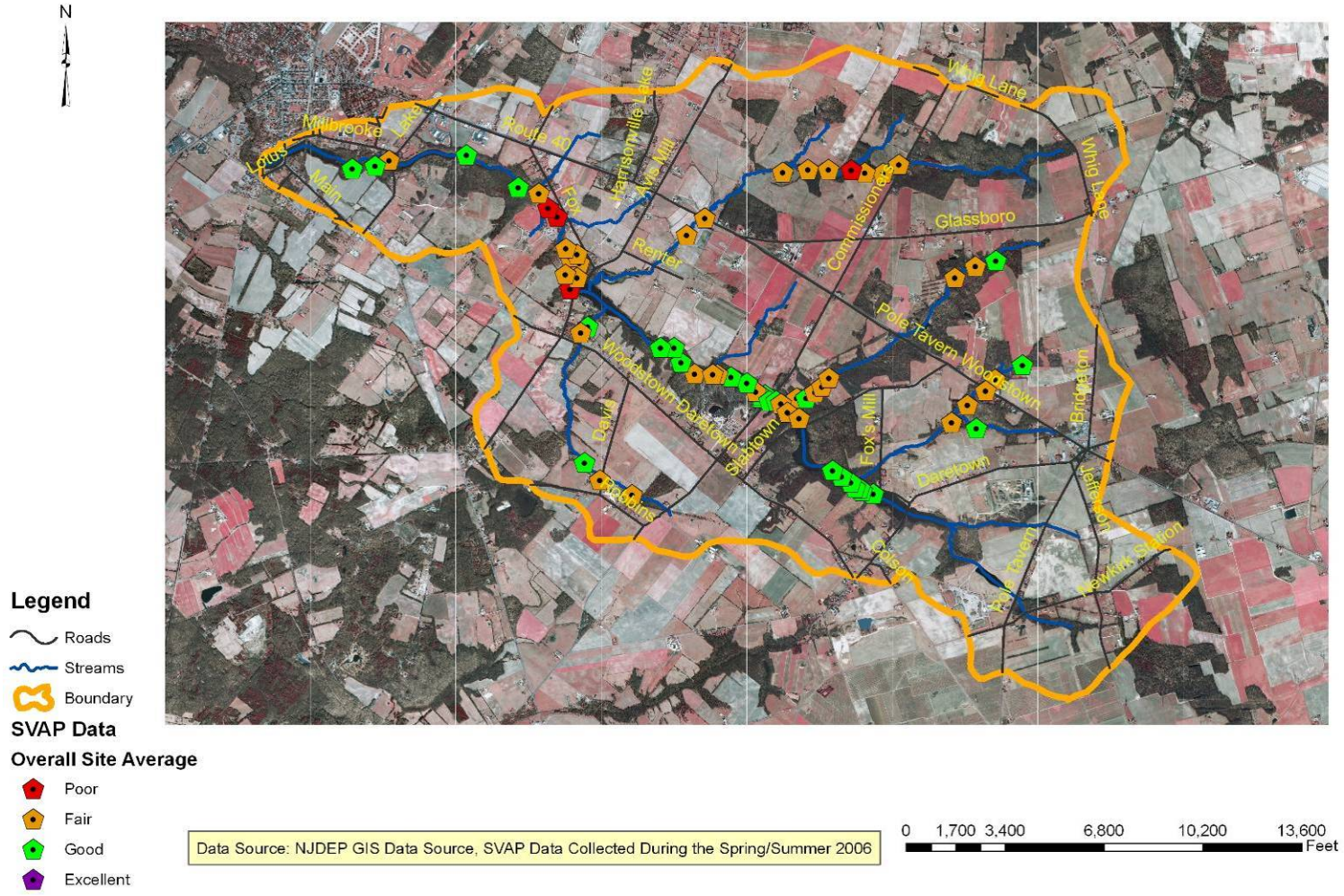

Figure 5: Stream visual assessment reaches with scores in the Upper Salem River Watershed.

Particular categories that were found to be deficient by this effort in the Upper Salem River were bank stability, channel modification, water appearance and nutrient enrichment. Each of these appears to be directly related to the presence of elevated suspended sediment in the water column. The analysis indicated that there is a significant amount of erosion occurring which destabilizes the stream bank and contributes to the sediment load. Bank stability is a serious concern in many areas of the Upper Salem River Watershed with a score well below the rating of "poor." Another indication of the significance of erosion to stream health is the high correlation coefficient that was found between bank stability and nutrient enrichment ($r = 0.96$) indicating that particle-adsorbed nutrients are delivered to the stream via erosion. High concentrations of nutrients in the stream lead to enhanced primary production and nutrient-rich, green waters which are evident from the low scores seen for water appearance. Channel modification is often the source of bank destabilization. Proper erosion reduction measures should be followed when stream crossings or access are installed; in addition, allowing livestock direct access to a stream has the potential to adversely impact each of these categories, as well as representing a direct source of fecal or nutrient contamination to the stream.

Using the SVAP Data

SVAP scores will be evaluated as individual assessment elements and combined with other data collected as part of this restoration planning effort. The SVAP results will be compared to land use, soil characteristics, slope and stream gradient, and water

quality monitoring results to determine the quality of waters within the Upper Salem River Watershed. The SVAP scores, information on pipes, ditches, photos, and remediation notes will be used to identify sources of pollution and potential opportunities for improved management.

Water Quality Sampling Overview

To identify the cause(s) of impairment observed through both the SVAP results and biological sampling, project partners, including NJDEP, the RCE of Salem and Cumberland Counties, the RCE Water Resources Program, and the Cumberland-Salem Conservation District, began water quality monitoring on June 8, 2007. As per the NJDEP-approved Quality Assurance Project Plan (QAPP), *in situ* measurements of pH, dissolved oxygen (DO), and temperature were collected (Appendix C). Stream velocity and depth were measured across stream transects at each sampling station. Using this information, flow was calculated for each event where access to the stream was deemed safe. Water samples were collected and analyzed by QC Laboratories in Vineland, New Jersey (NJDEP Certified Laboratory #PA166) for total phosphorus (TP), dissolved orthophosphate phosphorus, ammonia-nitrogen, total Kjeldahl nitrogen (TKN), nitrate-nitrogen, nitrite-nitrogen, total suspended solids (TSS), fecal coliform, and *E. coli*.

Three separate sampling protocols were followed for the field sampling events including water quality monitoring sampling conducted during three stream flow conditions, ambient monitoring, bacterial only, and storm events (Table 3). Ambient monitoring, which included analysis for all parameters, occurred from June 8, 2007 through June 17, 2009 (Table 3). These events were monitored for all *in situ* parameters,

flow rate, and TP, dissolved orthophosphate phosphorus, ammonia-nitrogen, TKN, nitrate-nitrogen, nitrite-nitrogen, TSS, fecal coliform and *E. coli*. Bacteria only monitoring was conducted in the summer months of July through September 2007 (Table 3). This entailed collecting three additional samples in each of those months for fecal coliform and *E. coli* analysis, as well as the *in situ* parameters and velocity and depth.

In addition, water samples from two storm events were collected in October 2007 (Table 3). Three samples were collected over the course of each storm event for all parameters at all ten (10) monitoring locations.

Surface water samples were regularly collected from ten (10) water quality monitoring stations over the two year field study (Figure 6). Six stations were located on the mainstem Salem River, and four stations were located on tributaries (Figure 6). Station locations are identified in Table 4. All water quality data are presented in Appendices D and E.

Table 3: Dates and associated types of various water quality monitoring events for the Upper Salem River Watershed field study.

Date	Ambient Monitoring for all Parameters	Bacteria Only Monitoring	Storm Event Monitoring
6/8/2007	X		
6/15/2007	X		
6/20/2007		X	
6/27/2007		X	
6/28/2007		X	
7/2/2007	X		
7/6/2007		X	
7/11/2007		X	
7/18/2007	X		
7/25/2007		X	
7/26/2007		X	
8/1/2007	X		
8/10/2007		X	

8/16/2007	X		
8/22/2007		X	
8/29/2007		X	
9/13/2007	X		
9/26/2007	X		
10/10/2007			X
10/11/2007			X
10/24/2007			X
11/7/2007	X		
12/12/2007	X		
12/20/2007	X		
1/9/2008	X		
1/25/2008	X		
2/8/2008	X		
2/27/2008	X		
3/6/2008	X		
3/13/2008	X		
4/11/2008	X		
4/24/2008	X		
5/7/2008	X		
5/28/2008	X		
6/12/2008	X		
6/27/2008	X		
7/11/2008	X		
7/30/2008	X		
8/13/2008	X		
8/28/2008	X		
9/11/2008	X		
9/26/2008	X		
10/9/2008	X		
10/31/2008	X		
11/19/2008	X		
11/25/2008	X		
12/5/2008	X		
12/17/2008	X		
1/22/2009	X		
1/30/2009	X		
2/19/2009	X		
2/26/2009	X		
3/13/2009	X		
3/24/2009	X		
4/8/2009	X		
4/23/2009	X		
5/7/2009	X		
5/20/2009	X		
6/3/2009	X		
6/16/2009	X		
6/17/2009	X		

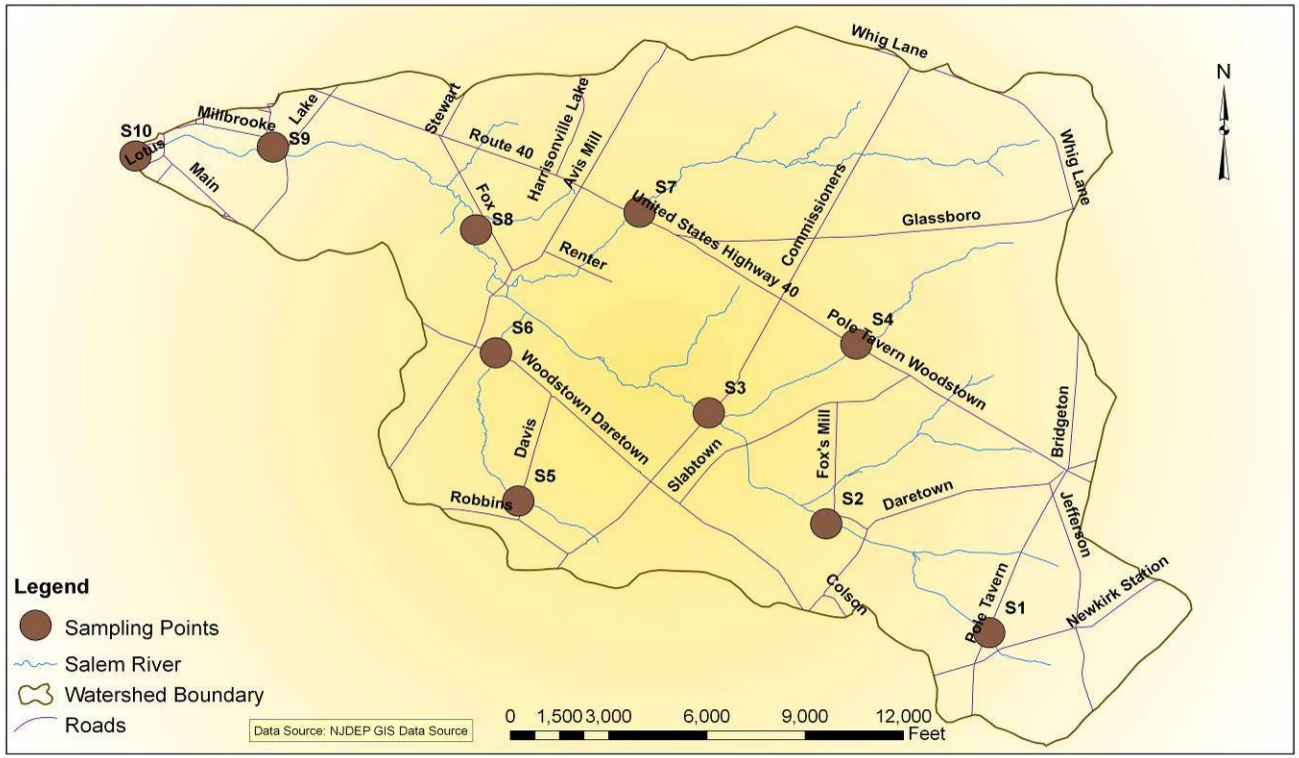

Figure 6: RCE water quality monitoring station locations in the Upper Salem River Watershed.

Table 4: Water quality monitoring location IDs and descriptions.

Site ID	Site Description
S1	Salem River below the Salem River Reservoir
S2	Salem River below Daretown Lake
S3	Salem River and Tributary 1 confluence at Commissioner's Pike
S4	Salem River Tributary 1 at Route 40
S5	Salem River Tributary 2 at Davis Road
S6	Salem River Tributary 2 at County 615
S7	Salem River Tributary 3 at Route 40
S8	Salem River below Avis Mill Pond
S9	Salem River below East Lake
S10	Salem River at Woodstown Station, 01482500

Data Results and Comparison to Water Quality Standards

To evaluate the health of the Upper Salem River at all ten (10) stations, the monitoring results were compared to the designated water quality standards. Water quality standards are developed according to the waterbody's designated uses (NJDEP, 2009c). The Salem River is classified as FW2-NT, or freshwater (FW) non-trout (NT). "FW2" refers to waterbodies that are used for primary and secondary contact recreation; industrial and agricultural water supply; maintenance, migration, and propagation of natural and established biota; public potable water supply after conventional filtration treatment and disinfection; and any other reasonable uses. "NT" means those freshwaters that have not been designated as trout production or trout maintenance. NT waters are not suitable for trout due to physical, chemical, or biological characteristics, but can support other fish species (NJDEP, 2009c). The applicable water quality standards for the parameters of concern for this project are detailed in Table 5. Due to drainage from Memorial Lake (Figure 3), the FW2 lakes standard was applied to TP results from this study.

Table 5: Water quality standards according to N.J.A.C. 7:9B.

Substance	Surface Water Classification	Criteria
TP (mg/L)	FW2 Streams	Except as necessary to satisfy the more stringent criteria in accordance with "Lakes" (below) or where watershed or site-specific criteria are developed pursuant to N.J.A.C. 7:9B-1.5(g)3, phosphorus as total P shall not exceed 0.1 in any stream, unless it can be demonstrated that total P is not a limiting nutrient and will not otherwise render the waters unsuitable for the designated uses.
	FW2 Lakes	Phosphorus as total P shall not exceed 0.05 in any lake, pond, or reservoir, or in a tributary at the point where it enters such bodies of water, except where watershed or site-specific criteria are developed pursuant to N.J.A.C. 7:9B-1.5(g)3.
Bacterial counts (Col/100 mL): Fecal Coliform	FW2	Shall not exceed geometric average of 200/100 mL, nor should more than 10% of the total samples taken during any 30-day period exceed 400/100 mL.
Bacterial counts (Col/100 mL): *E. coli*	FW2	Shall not exceed geometric average of 126/100 mL, nor should more than 10% of the total samples taken during any 30-day period exceed 235/100 mL.
pH	FW2	4.5 -7.5

The NJDEP's Integrated Water Quality Monitoring and Assessment Methods Document advises that if the frequency of water quality results exceed the water quality criteria twice within a five-year period, then the waterway's quality may be compromised (NJDEP, 2004e). NJDEP has further stated that a minimum of eight samples collected quarterly over a two-year period are required to confirm the quality of waters (NJDEP, 2004e). Therefore, if a waterbody has a minimum of eight samples collected quarterly over a two-year period and samples exceed the water quality criteria for a certain parameter twice, the waterbody is considered "impaired" for that parameter. By applying

this rule to the Upper Salem River Watershed water quality data, it is possible to identify which stations are impaired for each parameter that has been identified as a concern for this project (i.e., pH, TP, *E. coli* and fecal coliform). The number of samples exceeding these standards is given in Table 6.

Table 6: Number of samples that exceed water quality standards.

Station	Selected Monitoring Parameters			
	TP	**Fecal coliform***	***E. coli*****	**pH**
S1	2	17	12	0
S2	13	15	12	22
S3	16	31	29	8
S4	5	29	22	2
S5	24	44	39	0
S6	8	42	34	1
S7	6	49	38	3
S8	38	45	33	4
S9	52	48	43	6
S10	51	27	23	19

**Number of samples higher than 400 col/100ml*
*** Number of samples higher than 235 col/100ml*

At the time of this project's initiation and during the time of data collection, fecal coliform was the accepted measure indicating pathogen pollution for New Jersey freshwaters. Since then, the fecal coliform standard has been replaced by the measure of *E. coli*. For New Jersey freshwaters, *E. coli* shall not exceed a geometric mean of 126 colonies/100mL or a maximum count of 235 col/100mL in a single sample (NJDEP, 2009c). For this study, both fecal coliform and *E. coli* were measured to satisfy both the TMDL and other current regulations.

Tabulated water quality monitoring results are provided in Appendix D. Water quality monitoring data have also been graphed with water quality criteria, and these are available in Appendix E.

Microbial Source Tracking

Microbial source tracking (MST) was employed to determine bacterial sources within the Upper Salem River Watershed. MST is the concept of applying microbiological, genotypic (molecular), phenotypic (biochemical), and chemical methods to identify the origin of fecal pollution. MST techniques typically report fecal contamination sources as a percentage of targeted bacteria. One of the most promising targets for MST is *Bacteroides,* a genus of obligately anaerobic, gram-negative bacteria that are found in all mammals and birds. *Bacteroides* comprise up to 40% of the amount of bacteria in feces and 10% of the fecal mass. Due to large quantities of *Bacteroides* in feces, they are an ideal target organism for identifying fecal contamination (Layton *et al.*, 2006). In addition, *Bacteroides* have been recognized as having broad geographic stability and distribution in target host animals and are a promising microbial species for differentiating fecal sources (USEPA, 2005; Dick *et al.*, 2005; Layton *et al.*, 2006).

Three sets of PCR primers (targets) were used to quantify *Bacteroides* from 1) all sources of *Bacteroides* ("AllBac"), 2) human sources ("HuBac"), and 3) bovine sources of *Bacteroides* ("BoBac"). This assay is based on published results from a study sponsored by the Tennessee Department of Environmental Conservation (Layton *et al*., 2006).

Methods

Samples were collected in sterile bottles at all ten (10) monitoring sites as described in the previous section and held at 4˚C until processing. A 100 mL aliquot of each sample was filtered aseptically onto a membrane filter and DNA was extracted from total filtered biomass using a DNeasy® tissue kit. The protocol used in the Upper Cohansey River Watershed is a modification of the procedure found in the DNeasy Tissue Handbook (Qiagen, Inc., 2004).

After extraction, all DNA samples were quantified by spectroscopy (Beckman DU 640) at 260 and 280 ηm and then diluted in sterile water to a concentration of 1 µg/mL. This diluted DNA was used as the template for quantitative, real-time PCR reactions to measure the number of *Bacteroides* present. All other procedures that were followed are outlined by Layton *et al.* (2006).

Results

Bacteroides from all sources ("AllBac") were readily detected at all stations in 100 ml surface water samples by using the qPCR assay (Figure 7). In addition, bovine *Bacteroides* ("BoBac") were detected in only eight (8) of the ten (10) sampling stations (Figure 7).

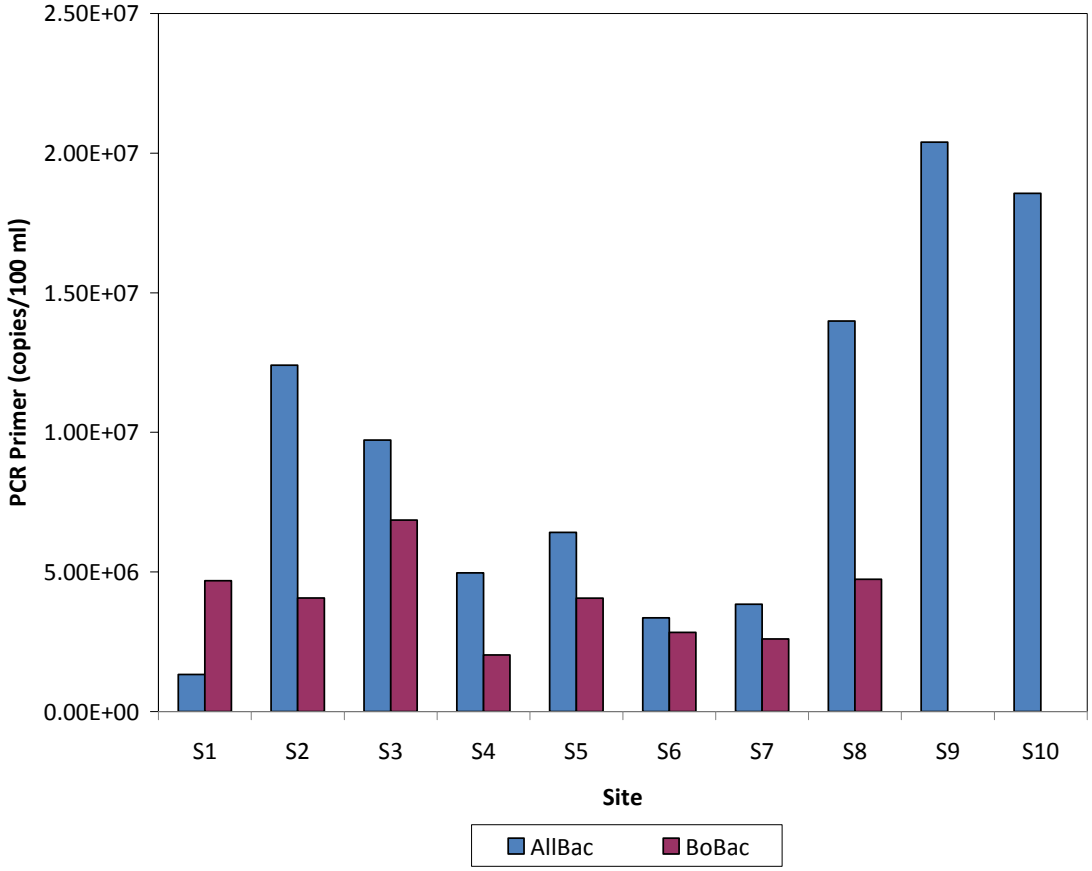

Figure 7: Data Showing the Numbers of *Bacteroides* Detected by the Two Primer Sets at the 10 Sampling Stations in the Upper Salem Watershed.

Data Summary

The data show a variety of water quality concerns in the Upper Salem River Watershed. The AMNET macroinvertebrate results show moderate to severe impairments to the biological communities within the watershed (Table 1). This is also seen in the RCE-collected macroinvertebrate data (Appendix B). The biological community may be impacted by environmental stressors or degraded habitat. Habitat conditions assessed by both NJDEP through AMNET and the RCE assessments show suboptimal conditions in areas within the watershed (Table 2; Appendix B). Habitat

quality may be low due to physical alterations as observed during SVAP assessments conducted throughout the watershed. The overall quality of the streams was assessed as "good" but individual element scores ranged from "poor" to "good" (Figure 5; Table 2). Further analysis of this data may help to explain what physical factors (i.e., erosion, habitat structure, and water availability) may be responsible for the composition of the macroinvertebrate communities seen in the watershed.

While the biological monitoring and SVAP assessments shed light on watershed quality, water monitoring provides possible reasons for this quality. Results indicate that TP, *E. coli* and fecal coliform concentrations are in violation of water quality criteria established by the NJDEP (Appendix D). All ten (10) monitoring locations were in violation of TP, fecal coliform and *E. coli* water quality standards during the sampling campaign (Table 6). The frequency of violation is greatest at the most downstream sampling points (S8, S9, and S10) and the tributary that contains points S5 and S6. The exception to these trends is fecal coliform and *E. coli* violations in Memorial Lake (S10) and TP violations at S6. Presumably fecal coliform and *E. coli* settle out of the water column in Memorial Lake and result in lower concentrations. The reason for fewer violations in S6 than S5 is currently under investigation. A full analysis of the data will be conducted and presented in the Upper Salem River Watershed Restoration and Protection Plan.

References

Dick, L.K., A.E. Bernhard, T.J. Brodeur, J.W. Santo-Domingo, J.M. Simpson, S.P. Walters and K.G. Field, 2005, Host Distributions of Uncultivated Fecal *Bacteroidales* Bacteria Reveal Genetic Markers for Fecal Source Identification. Appl. Environ. Microbiol. 71(6):3184-3191.

Layton, A., L. McKay, D. Williams, V. Garrett, R. Gentry and G. Sayler, 2006, Development of *Bacteroides* 16S rRNA Gene TaqMan-Based Real-Time PCR Assays for Estimation of Total, Human, and Bovine Fecal Pollution in Water. Appl. Environ. Microbiol. 72(6):4214-4224.

New Jersey Department of Environmental Protection (NJDEP), 1996, Ambient Biomonitoring Network Lower Delaware Region Water Monitoring Report. Trenton, NJ.

New Jersey Department of Environmental Protection (NJDEP), 2002, New Jersey 2002 Integrated Water Quality Monitoring and Assessment Report [305(b) and 303(d)]. Trenton, NJ.

New Jersey Department of Environmental Protection (NJDEP), 2003, Ambient Biomonitoring Network Lower Delaware Region Water Monitoring Report. Trenton, NJ.

New Jersey Department of Environmental Protection (NJDEP), 2004a, New Jersey 2004 Integrated Water Quality Monitoring and Assessment Report [305(b) and 303(d)]. Trenton, NJ.

New Jersey Department of Environmental Protection (NJDEP), 2004b, Total Maximum Daily Loads for Fecal Coliform to Address 27 Streams in the Lower Delaware Water Region, Trenton, NJ. http://www.epa.gov/waters/tmdldocs/NJ-2003-Fecal%20Coliform-27%20Streams%20Lower%20Delaware%20Region.pdf.

New Jersey Department of Environmental Protection (NJDEP), 2004c, Total Maximum Daily Loads for Phosphorus To Address 13 Eutrophic Lakes in the Lower Delaware Water Region Water Region, Trenton, NJ. http://www.epa.gov/waters/tmdldocs/NJ-2003-Phosphorus-13%20Lakes%20Lower%20Delaware%20Region.pdf .

New Jersey Department of Environmental Protection (NJDEP). 2004d. Ambient Biomonitoring Network, Watershed Management Areas, Benthic Macroinvertebrate Data, Generalized Executive Summary. http://www.nj.gov/dep/wmm/bfbm/GenExecSum.html.

New Jersey Department of Environmental Protection (NJDEP), 2004e, Integrated Water Quality Monitoring and Assessment Methods Trenton, NJ. http://www.state.nj.us/dep/wms/bwqsa/docs/04%20Methods%20Doc.pdf.

New Jersey Department of Environmental Protection (NJDEP), 2006, New Jersey 2006 Integrated Water Quality Monitoring and Assessment Report [305(b) and 303(d)]. Trenton, NJ.

New Jersey Department of Environmental Protection (NJDEP), 2009a , New Jersey 2008 Integrated Water Quality Monitoring and Assessment Report [305(b) and 303(d)]. Trenton, NJ.

New Jersey Department of Environmental Protection (NJDEP), 2009b, Bureau of Freshwater and Biological Monitoring AMNET Round 3 Data Tables http://www.state.nj.us/dep/wms/bfbm/download/AMNETrnd3Data.pdf.

New Jersey Department of Environmental Protection (NJDEP), 2009c, Surface Water Quality Standards. Trenton, NJ. http://www.state.nj.us/dep/wms/bwqsa/December%202009%20SWQS.pdf.

New Jersey Department of Environmental Protection (NJDEP), 2010, NJDEP 2007 Land Use/Land Cover Update, WMA-17. Trenton, NJ.

Qiagen, Inc., 2004, DNeasy® Tissue Handbook. Valencia, CA.

United States Department of Agriculture (USDA), Natural Resource Conservation Service (NRCS), 1998, Stream Visual Assessment Protocol. National Weather and Climate Center Technical Note 99-1.

United States Environmental Protection Agency (USEPA), 2000, Stressor Identification Guidance Document. EPA/822/B-00/025. Washington, D.C.

United States Environmental Protection Agency (USEPA), 2005. Microbial Source Tracking Guidance Document. EPA/600/R-05/064. Office of Research and Development National Risk Management Research Library. Washington, DC. 151 pp.