UPPER COHANSEY RIVER WATERSHED RESTORATION AND PROTECTION PLAN

Developed by the Rutgers Cooperative Extension Water Resources Program

Funded by the New Jersey Department of Environmental Protection and the New Jersey Agricultural Experiment Station

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Acknowledgements

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Introduction

Project Background and the TMDL Development Process

The purpose of creating this Watershed Restoration and Protection Plan for the Upper Cohansey River Watershed is to ensure that the valuable uses that this freshwater system has provided the area in the past continue into the future. These uses include recreational activities and irrigation for agriculture, along with the ability of the river to provide a healthy ecosystem for aquatic species and surrounding wildlife. The Rutgers Cooperative Extension (RCE) Water Resources Program has undertaken the task of performing water quality testing, land surveillance, geographic information systems (GIS) analyses, and watershed modeling to provide stakeholders within the Upper Cohansey River Watershed with a Watershed Restoration and Protection Plan to ensure the quality of the watershed for the future.

To properly manage water quality, a total maximum daily load (TMDL) was developed based on data collected in the Cohansey River at U.S. Geological Survey (USGS) monitoring station 01412800 at Seeley Lake (NJDEP, 2003a) to address fecal coliform impairment. TMDLs are developed by the New Jersey Department of Environmental Protection (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 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, 2009a). 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 – "Full Attainment"** waterbodies are meeting water quality standards and attaining their designated uses.
- **Sublist 2 – "Attained"** 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 – "Not Assessed"** waterbodies have insufficient data or information available to support an attainment determination.

- **Sublist 4 – "Not Attained"** listings are 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.
  - **Sublist 4b** establishes that impaired waters 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 impairment is not caused by pollutants, but is due to factors such as in-stream channel condition, flow alteration, or habitat degradation.
- **Sublist 5 – "Not Attained"** clearly states that water quality standards are not being attained and a TMDL is required.

According to the 2002 Integrated List (NJDEP, 2002a), the Upper Cohansey River at Seeley Lake did not attain its designated uses and was therefore listed on Sublist 5 for fecal coliform and total phosphorus, requiring development of TMDLs. The TMDL for fecal coliform determined that a 66% reduction in fecal coliform loading to the Cohansey River is needed to achieve water quality standards (NJDEP, 2003a). The TMDL was developed based on summer monitoring results (May through September) from 1994-2000. The TMDL further states that the load duration curve is consistent with storm-driven values of fecal coliform (NJDEP, 2003a).

The TMDL developed for total phosphorus (TP) at this location calls for a relatively high reduction in phosphorus loading. Using the TP standard for freshwater rivers (0.1 milligrams per liter, or mg/L), phosphorus reduction is mandated at 52%. However, since the Cohansey River drains to Sunset Lake, which also has a TP TMDL (NJDEP, 2003b), the applicable lake criterion of 0.05 mg/L has been used for the TP TMDL, requiring a load reduction of 92% (NJDEP, 2009b). This higher reduction of **92%** must be met for the entire lakeshed, which includes portions of the Upper Cohansey River Watershed that this study is addressing.

The purpose of this plan is to synthesize available data on the Upper Cohansey River Watershed, including previous studies and the work of the RCE Water Resources Program, and determine the potential sources and extent of any water quality problems in the Upper Cohansey

River Watershed. Solutions to these problems will also be discussed with examples of such solutions for specific areas within the watershed.

Watershed Description

The Cohansey River Watershed above USGS gauge 01412800 (henceforth, the Upper Cohansey River Watershed) is 31 square miles, includes 32 miles of river and streams, and is located in Watershed Management Area (WMA) 17 (Figure 1). The Upper Cohansey River Watershed is comprised of sections of Hopewell, Stow Creek, and Upper Deerfield Townships in Cumberland County, and Alloway and Upper Pittsgrove Townships in Salem County (Figure 1). The largest portion of the Upper Cohansey River Watershed is located within Upper Deerfield Township. Tributaries to the Upper Cohansey River include Clarks Run, Harrow Run, Parsonage Run and Foster Run and one major surface waterbody, Seeley Lake, is located on the border of Hopewell and Upper Deerfield Townships (Figure 1). A smaller pond, North Pond, is located on Parsonage Run. Previously Bostwick Lake was another large surface waterbody within the watershed until dam failure occurred in 1999. Bostwick Lake, a large man-made lake used for recreation and irrigation storage, evolved into a wetland after a dam breach (Figure 2). In 2009, the dam was rebuilt and Bostwick Lake is currently once again a shallow lake (personal communication with J. Johnson, 3/24/2010).

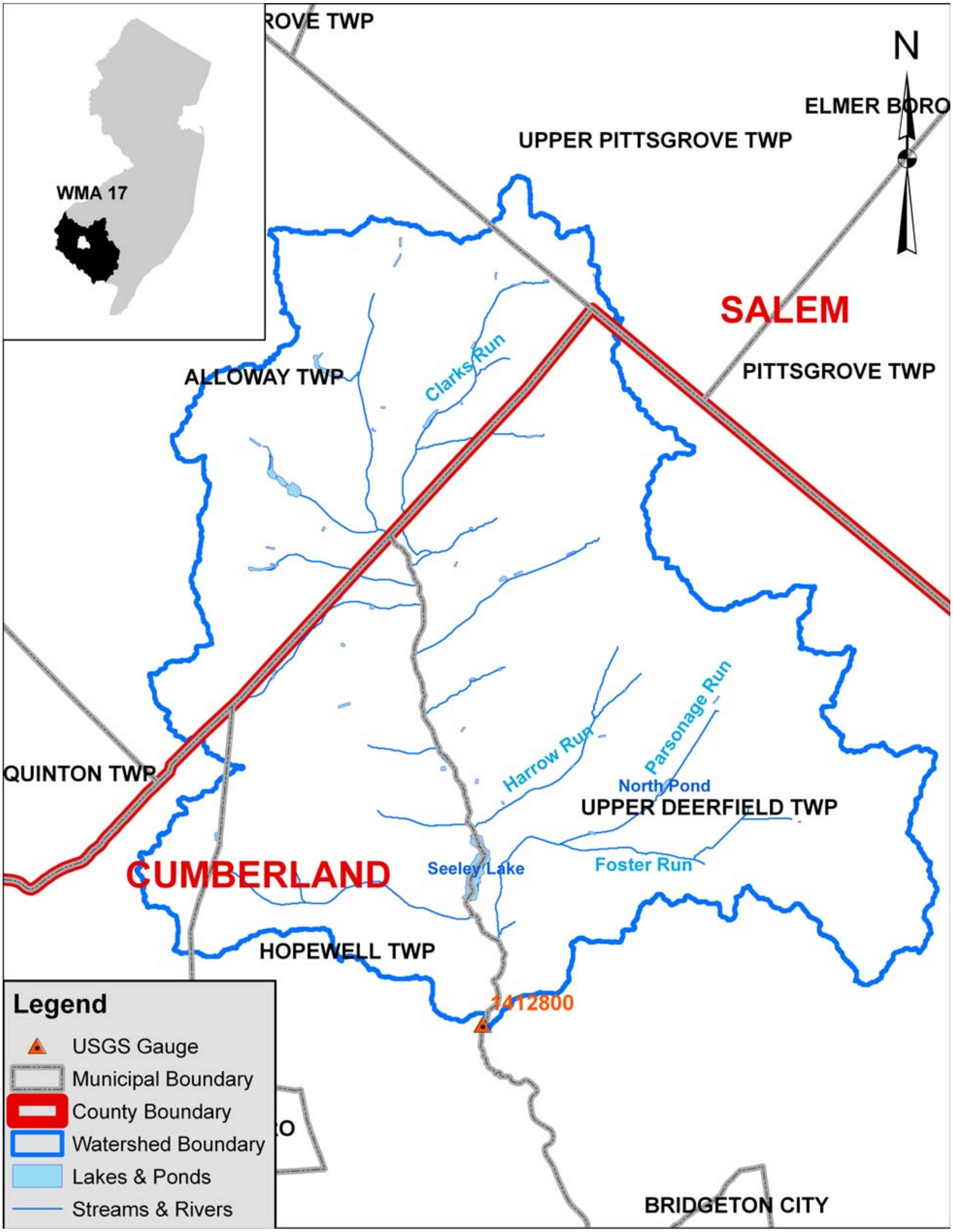


Figure 1: The Upper Cohansey River Watershed.

Figure 2: Aerial photographs of Bostwick Lake from 1995 to 2006 showing its conversion to a wetland (USGS, 1995; NJDEP, 2002b; USDA, 2006).

The watershed is dominated by agricultural land uses (Figure 3; Figure 4; Table 1). Based on aerial mapping and visual watershed surveys completed by the RCE Water Resources Program, agricultural land uses include row crops, field nurseries, sod farms, and container nurseries. NJDEP land use data (NJDEP, 2007) categorizes agricultural land uses as cropland and pastureland, orchards/vineyards/nurseries/horticultural areas, confined animal feed operations, and other agriculture (Figure 4). Forests, urban land uses, and wetlands comprise the majority of remaining land cover within the Upper Cohansey River Watershed (Figure 3; Figure 4).

Subwatersheds were delineated, based on the ten stations identified for monitoring, using ESRI ArcHydro (Version 1.1, August 2004) and the 10-meter digital elevation model available from the NJDEP (Figure 5). The largest of the subwatersheds is FR1 covering 3,708 acres, which is approximately 60% agriculture and has the highest percent of urban area (14.1%) when compared to the other subwatersheds (Table 1). FR1 is also one of only three subwatersheds with industrial land use, stormwater infrastructure, and stormwater detention basins. Also, 17% (317 acres) of the subwatershed area is serviced by Cumberland County Utilities Authority (CCUA). This is the largest subwatershed with centralized wastewater treatment in the Upper Cohansey River Watershed. Watershed-wide, less than 4% of households have centralized wastewater treatment (Figure 6). According to sewer service area plans, 8% of the Upper Cohansey River Watershed could be added to centralized sewer systems in the future.

Table 1: Percent of land use by subwatershed.

Subwatershed	Total Area (acres)	% Agriculture	% Barren Land	% Forest	% Urban	% Water	% Wetland
C1	1,834	54.9%	0.3%	22.1%	7.9%	2.1%	12.8%
C2	1,658	86.7%	0.0%	4.4%	5.9%	0.1%	3.0%
C3	1,376	74.9%	0.2%	13.3%	3.2%	0.2%	8.2%
C4	2,740	80.3%	1.2%	6.3%	5.8%	0.4%	6.0%
C5	2,564	73.5%	0.1%	11.7%	5.1%	0.6%	8.9%
C6	1,344	65.3%	0.0%	15.0%	5.6%	0.7%	13.4%
CL1	793	86.3%	0.0%	4.2%	2.1%	0.7%	6.6%
CL2	593	83.3%	0.0%	0.6%	3.3%	0.4%	12.4%
FR1	3,708	59.6%	2.8%	17.5%	14.1%	0.1%	5.8%
HR1	1,187	76.8%	0.5%	6.0%	12.8%	0.1%	3.8%

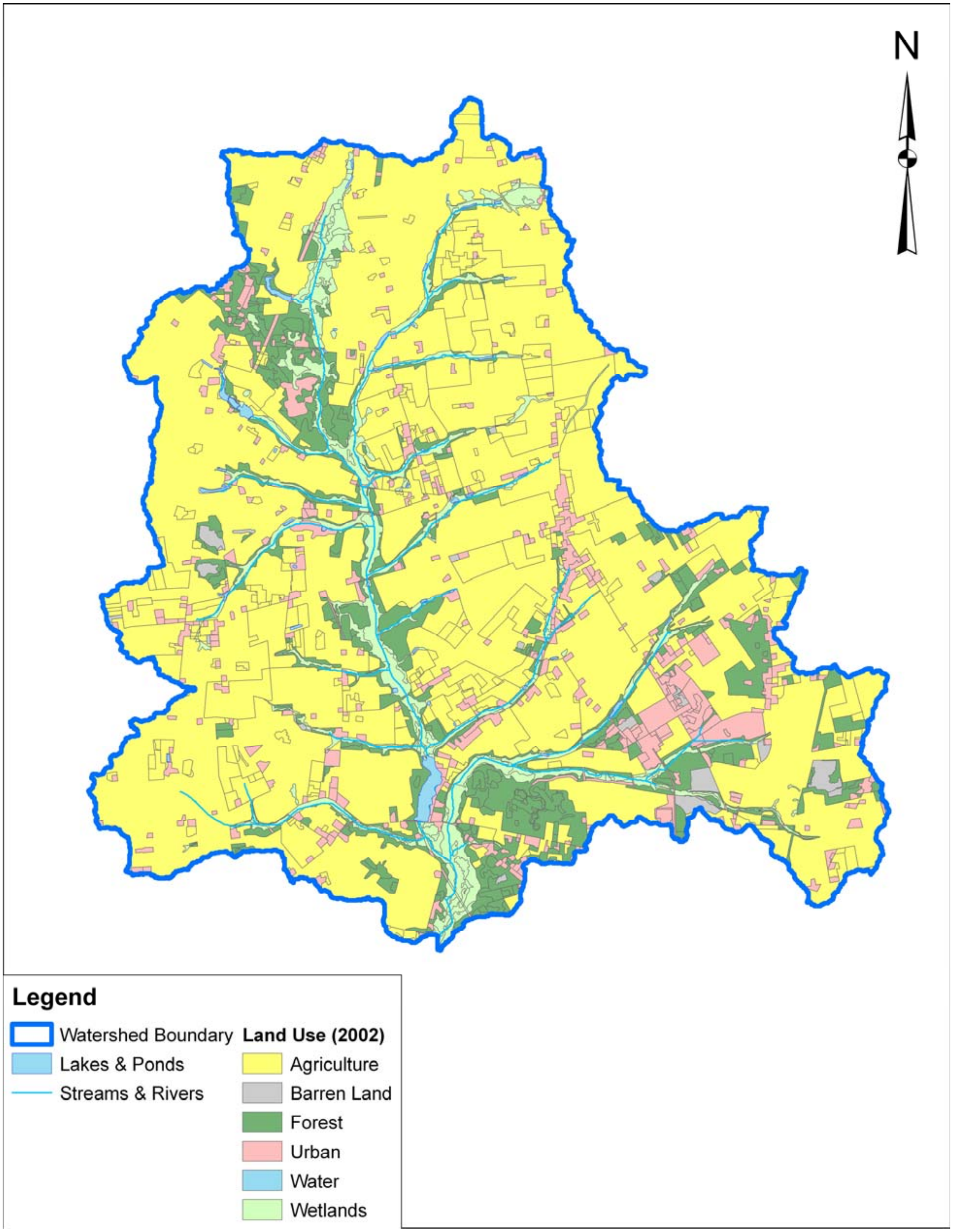
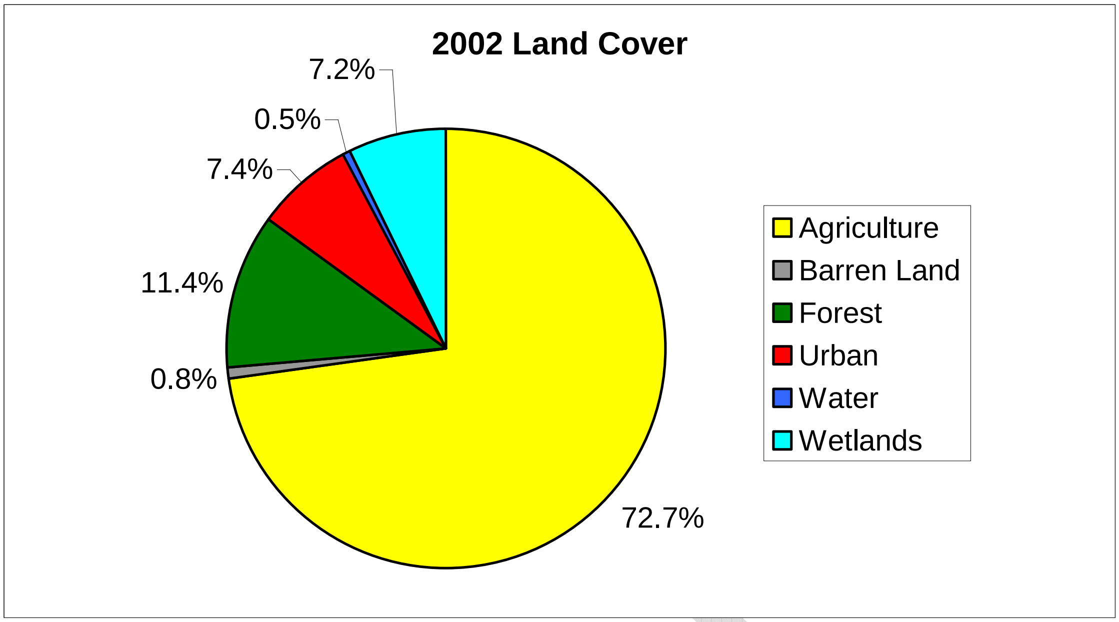


Figure 3: Land uses in the Upper Cohansey River Watershed.



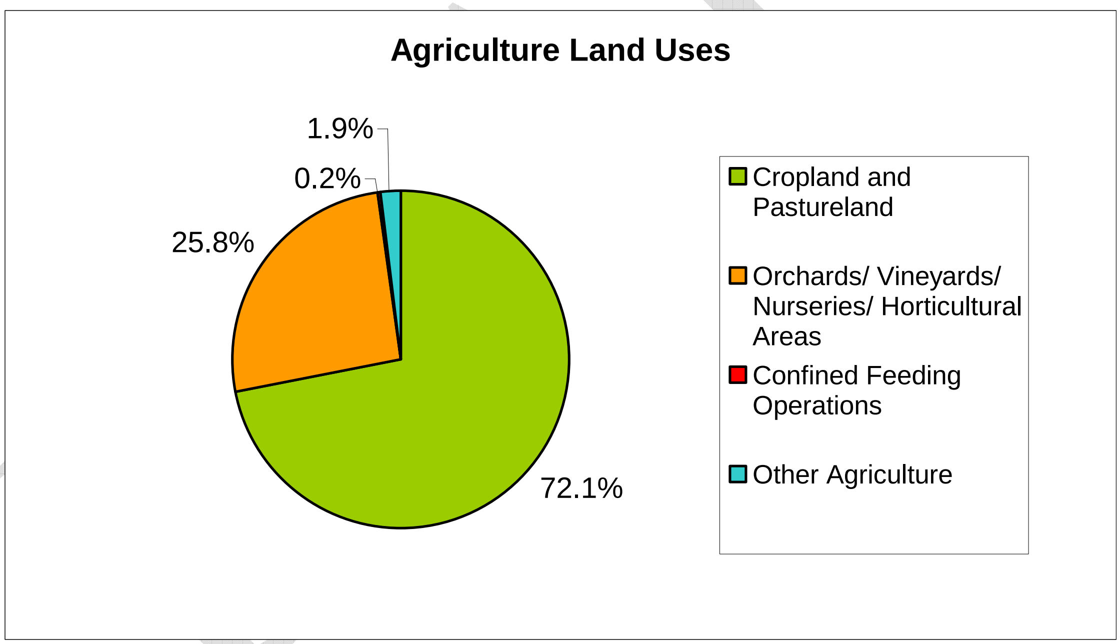


Figure 4: Land cover types and agricultural land uses in the Upper Cohansey River Watershed.

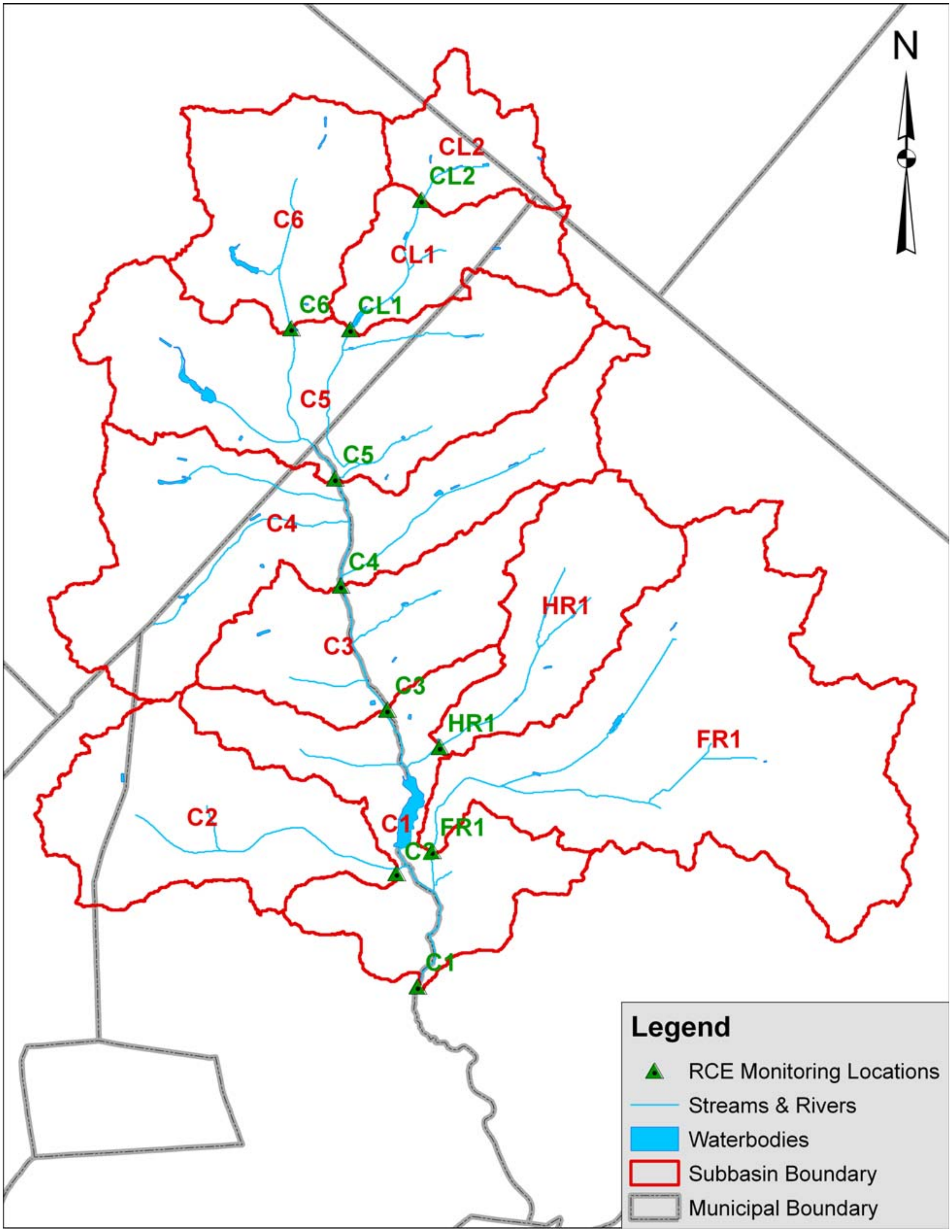


Figure 5: Delineated subwatersheds in the Upper Cohansey River Watershed.

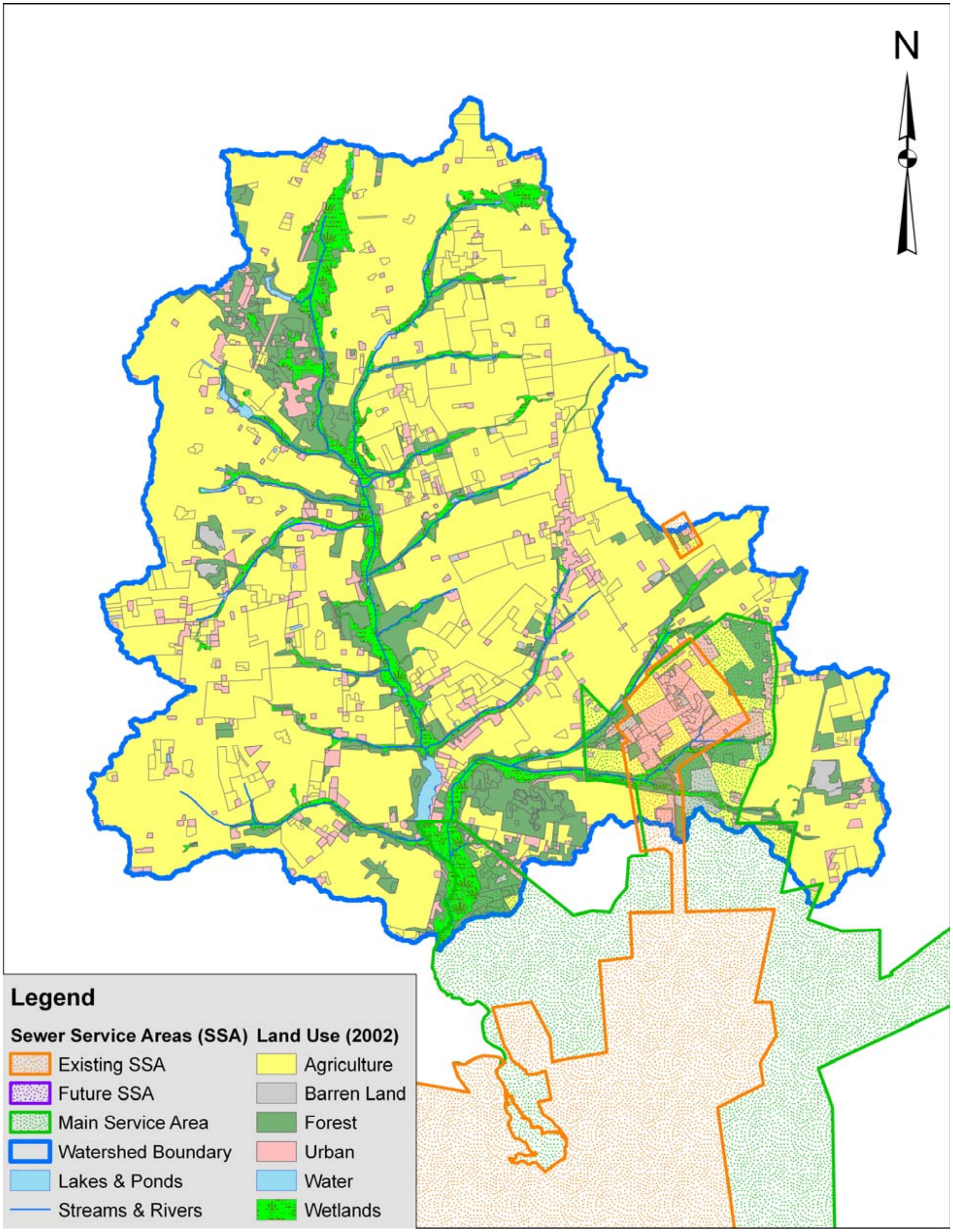


Figure 6: Sewer service areas in the Upper Cohansey River Watershed (Fralinger Engineering, 2007).

Since 1975, USGS has monitored flow at least five times per year on the Cohansey River at USGS gauge 01412800 (Figure 1). The mean discharge since 1975 is 35.0 cubic feet per second (cfs); over the past decade, mean discharge has increased slightly to 37.0 cfs (Figure 7). The Cohansey River tributaries (Clarks Run, Harrow Run, and Parsonage Run) are slow-moving waterways. Clarks Run is the headwaters to the Cohansey River and exceeds 1 cfs only during precipitation events. Parsonage Run, monitored below the confluence with Foster Run, carries the highest volume of all tributaries (averaging 6.9 cfs in dry weather, and 11.1 cfs in wet weather) and is also the largest subwatershed to the Cohansey River. Flow in Parsonage Run is limited and controlled in several locations; one area is the crossing at Route 77, where the size of the culvert is inhibiting flow under the highway. Similarly, Harrow Run has very controlled flow, largely due to agricultural ditching. Within the HR1 subwatershed, flow from ditches through field nurseries is routed to the stream. In many cases, these ditches are actively eroding and transporting sediment to Harrow Run.

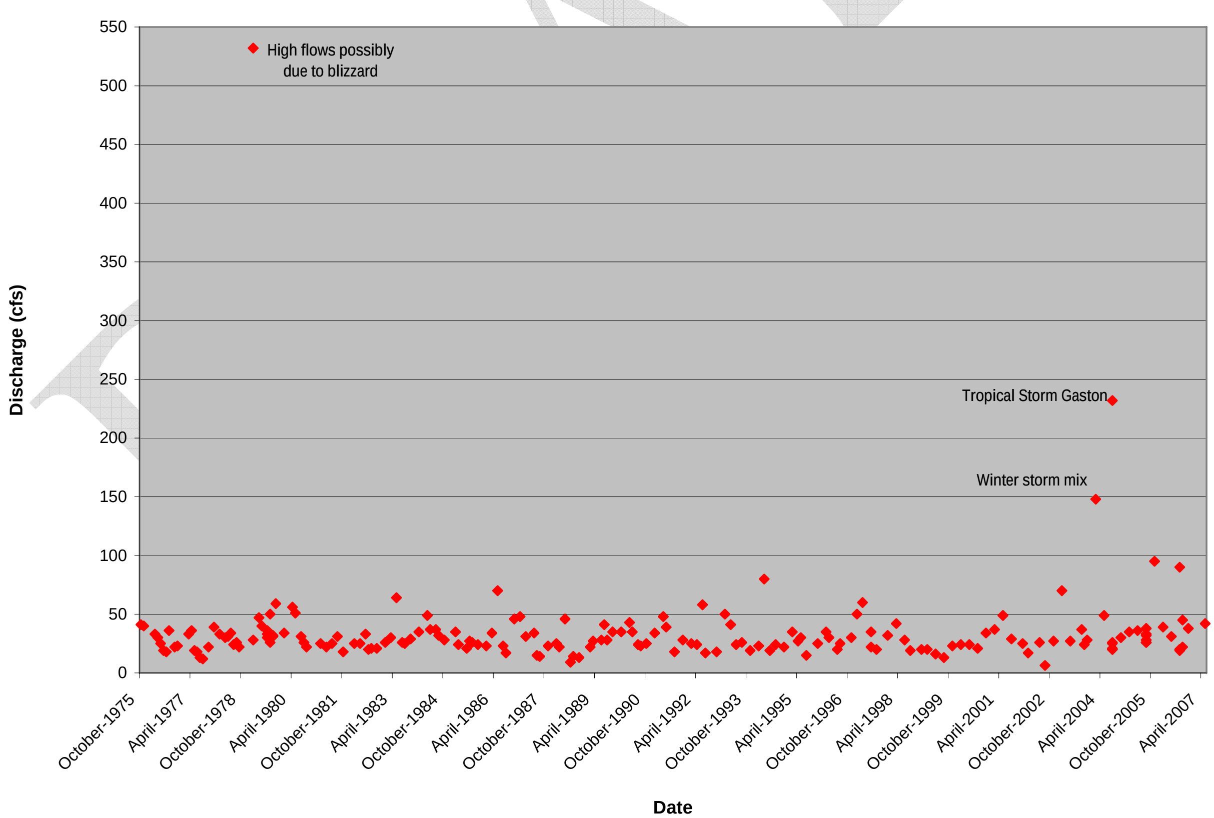


Figure 7: River discharge measurements at USGS gauge 01412800.

The NJDEP classifies waters within the state to properly manage their uses and quality. Almost all waters within the Upper Cohansey River Watershed are classified as FW2-NT/SE1, except a small stretch of Clarks Run, which is classified as FW2-NT (Figure 8). FW2-NT waters are freshwater systems that are subjected to man-made wastewater discharges or increases in runoff from anthropogenic activities and are not used for either the production or maintenance of trout populations (NJDEP, 2009b). FW2-NT/SE1 waters are located at a salt water and freshwater interface and combine the FW2-NT designation and the saline estuarine (SE) designation. The division between these two designations is determined through salinity measurements. Salinity below 3.5 parts per thousand (ppt) are governed by the FW2-NT classification and above 3.5 ppt are classified SE1 (NJDEP, 2009b). The waterways within this portion of the Upper Cohansey River Watershed have salinity concentrations less than 3.5 ppt, so all waters are considered FW2-NT.

There are five New Jersey Pollution Discharge Elimination System (NJPDES) permits allowing discharges in the project watershed (Figure 9). All five are located within the Foster Run subwatershed (FR1) (Figure 9). Four of these belong to Clement Pappas Company, Inc., and one permit belongs to Seabrook Brothers and Sons. All five are minor industrial permits and discharge to Foster Run via a storm sewer system or an unnamed tributary or ditch. The Seabrook Brothers and Sons NJPDES permit (NJ0033006) is categorized as stormwater and thermal surface water discharge. The permit requires monitoring and reporting for temperature, chemical oxygen demand (COD), total suspended solids (TSS), total petroleum hydrocarbons (TPHC), pH, and flow in conduit or through the treatment plant. Between March 2001 and December 2007, there were 27 monitoring dates reported to the NJDEP. On only one occasion was the water quality standard for pH met at the end of pipe. On all other occasions, pH was less than 6.5 standard units (SU) and almost consistently less than 5 SU. Note that for that time period, the water quality standard for pH was 6.5 – 8.5 SU. As of November 2009, the pH water quality standard for this portion of the Cohansey River has been modified to 4.5 – 7.5 SU.

Seabrook Farms also has a discharge to groundwater permit (NJ0087602) and spray irrigation for crops (Figure 9). This permit mandates reporting for nutrients, ammonia-nitrogen (NH_3-N), total dissolved solids (TDS), flow, pH, sodium chloride, and TPHC. As reported according to permit requirements, pH ranged from 3.5 - 7.5 SU. However, upgradient monitoring wells show low pH values comparable to those downgradient of the discharge. It can be assumed that the pH values are either background or are related to the combined subsurface flows from treated effluent and agricultural activities present on adjacent properties (personal communication with J. Gray, 2/20/2008).

The four NJPDES permits from Clement Pappas Company, Inc. (NJ0062731) are also categorized as stormwater and thermal surface water discharges. This discharger is permitted and monitors for TSS, hydrocarbons, pH, chlorine-produced oxidants, COD, temperature, and flow in conduit or through the treatment plant. In February 2005, Pipe 002 from this facility exceeded TSS surface water quality standards for Foster Run (i.e., the effluent result was 43.0 mg/L, and the standard is 40.0 mg/L).

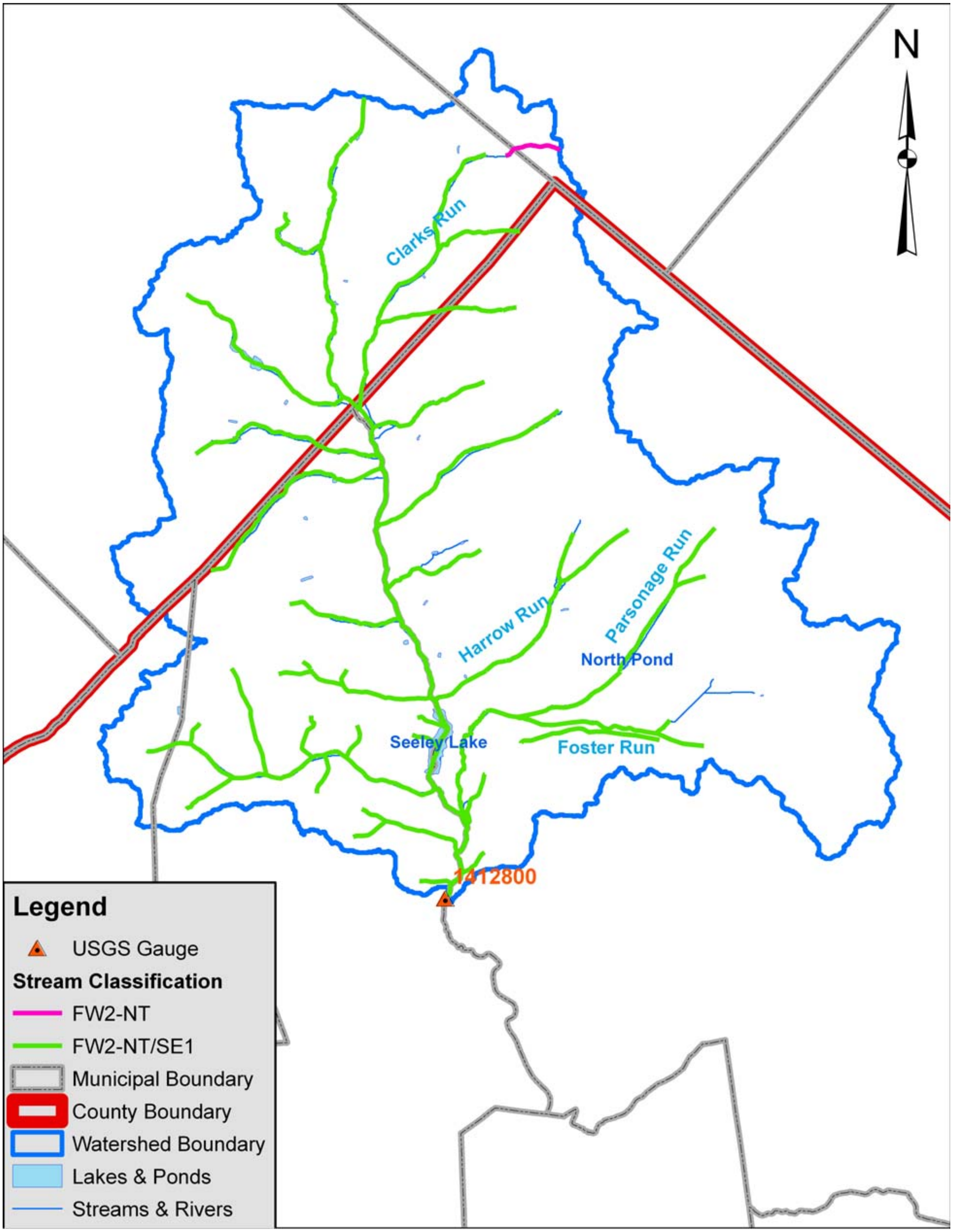


Figure 8: NJDEP stream classifications for Upper Cohansey River Watershed.

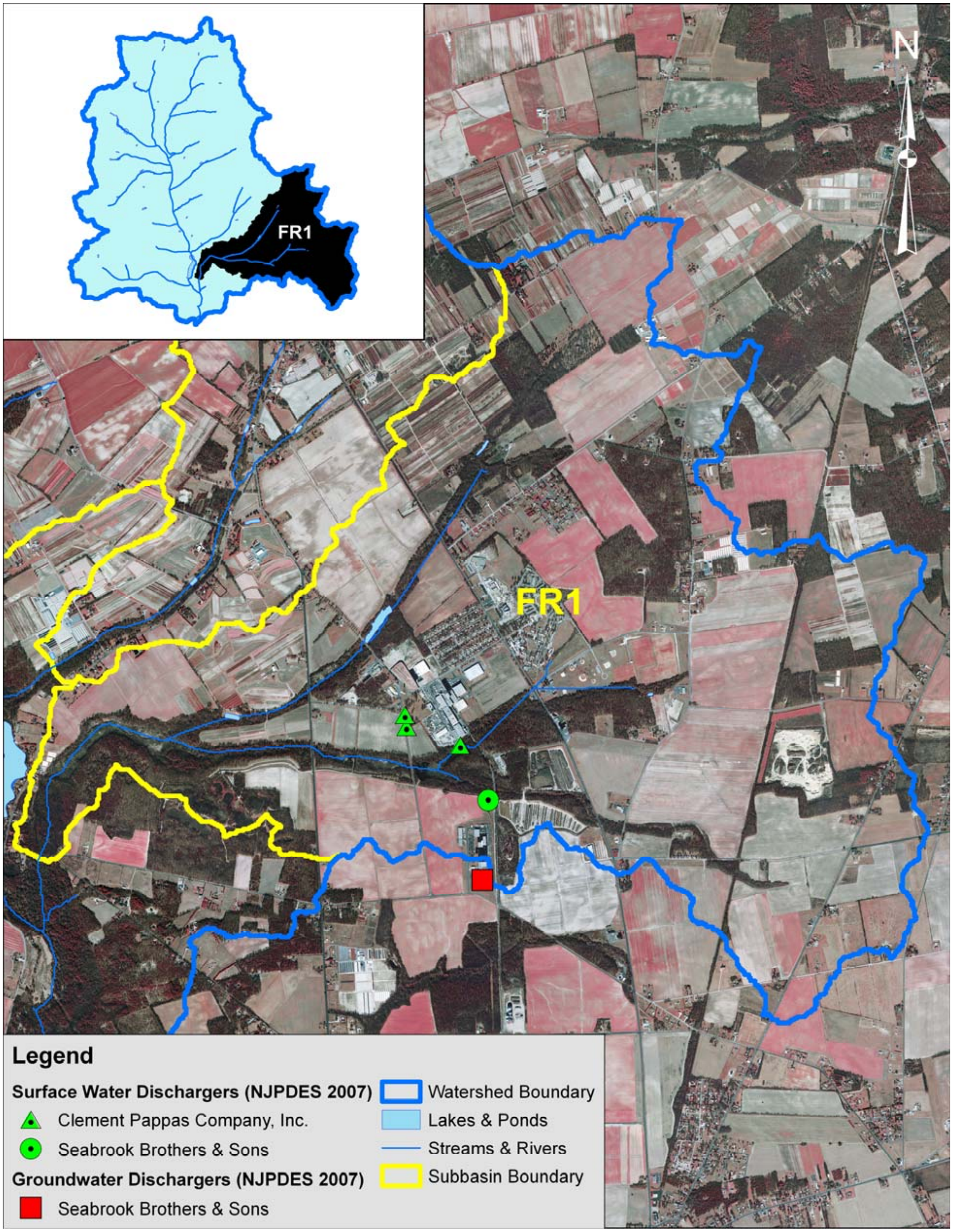


Figure 9: Surface water and groundwater dischargers in the Upper Cohansey River Watershed.

Problem Identification and Analysis

This report contains summaries and analyses of water quality data, stream assessments, and macroinvertebrate sampling conducted in the Upper Cohansey River Watershed. For a complete description of sampling programs and methods, see the *Upper Cohansey River Watershed Restoration and Protection Plan: Data Report* (RCE Water Resources Program, 2009a).

Stream Visual Assessment Protocol (SVAP) Data

The USDA SVAP methodology was followed to gain an understanding of potential physical changes in the Upper Cohansey River Watershed's rivers and streams that may indicate water quality problems. The protocol provides an outline to quantitatively score in-stream and riparian qualities. Such assessed qualities include water appearance, channel condition, canopy cover, and riparian health.

Thirty-five stream reaches were evaluated in the Upper Cohansey River Watershed (Table 2). While only seven of the ten subwatersheds within the Upper Cohansey River Watershed were evaluated, SVAP assessment results provide an overall appraisal of watershed health. The overall mean SVAP assessment score for all thirty-five reaches was 7.41, a resulting watershed quality of "good." Assessment scores ranged from 4.20 ("poor") to 8.80 ("good") (Table 2). There were no signs of manure presence, livestock access to streams, or manure storage facilities within the floodplain (Table 2). Canopy cover was scored at almost every reach and was the highest scored assessment element with an average score of 8.36 (Table 2). Other than riffle embeddedness, which is an optional assessment element (i.e., it is scored only if present), pools were the lowest scoring assessment element. Other assessments with low scores were water appearance and bank stability (Table 2). None of the assessed stream reaches received a score of "excellent" (Table 2).

Upper Cohansey River (Subwatersheds C1 – C6)

Many of the stream reaches with an overall score of "poor" (site average < 6.0) are located in subwatershed C5 (Table 2; Figure 5). Some of the lowest scored assessments were for water appearance (Figures 10a and 10b) and bank stability (Figures 10c and 10d) along the river.

Figure 10a: Turbid water along Beals Road in subwatershed C5.
(Photo: RCE Water Resources Program)

Figure 10b: Cloudy water along Seeley Road in subwatershed C1.
(Photo: RCE Water Resources Program)

Figure 10c: Exposed roots showing unstable banks along the Cohansey River.
(Photo: RCE Water Resources Program)

Figure 10d: Leaning and fallen trees indicative of unstable banks in subwatershed C1.
(Photo: RCE Water Resources Program)

Clarks Run (Subwatersheds CL1 and CL2)

Like portions of the Cohansey River, Clarks Run received low assessment scores for bank stability and water appearance (Figures 11a and 11b).

Figure 11a: Outfall pipes with turbid water along the Clarks Run.
(Photo: RCE Water Resources Program)

Figure 11b: Exposed stream banks indicative of instability along Clarks Run.
(Photo: RCE Water Resources Program)

Foster Run (FR1)

No SVAP assessments were performed within the Foster Run subwatershed during this study.

Harrow Run (Subwatershed HR1)

The Harrow Run subwatershed was assessed as “good” along three stream reaches (Table 2).

Table 2: SVAP assessment scores for the Upper Cohansey River Watershed.

Subwatershed	Date	Reference Location	Hydrologic Alteration	Channel Condition	Riparian Zone Left Bank	Riparian Zone Right Bank	Bank Stability Left Bank	Bank Stability Right Bank	Water Appearance	Nutrient Enrichment	Riffle Embeddedness	Barriers to Fish Movement	Instream Fish Cover	Pools	Invertebrate Habitat	Canopy Cover	Manure Presence	Overall Site Average
C1	7/18/05	Walter's Road	9	9	8	7	8	8	7	9	7	10	9	8	8	10	n/a	**8.5**
C1	7/18/05	Walter's Road	7	10	9	9	8	8	9	7	7	8	9	7	8	1	n/a	**7.5**
C1	7/18/05	Silverlake Road	8	7	10	8	9	9	6	8	n/a	10	6	2	3	2	n/a	**6.3**
C1	7/19/05	Seeley Road	9	9	8	7	7	5	6	7	6	9	8	7	9	9	n/a	**7.7**
C1	7/19/05	Seeley Road	9	9	9	9	6	6	7	8	3	6	8	7	7	9	n/a	**7.3**
C1	7/19/05	Seeley Road/Lake	6	7	8	7	6	6	6	7	7	4	6	5	6	9	n/a	**6.4**
C2	6/22/05	Harmony Road near John Dare Road	9	8	7	7	10	6	9	5	n/a	n/a	5	n/a	7	10	n/a	**7.6**
C2	7/19/05	n/a	8	7	9	9	8	8	9	9	n/a	5	8	7	7	9	n/a	**7.8**
C4	6/1/05	Biels Mill Road	9	9	10	10	10	10	3	8	2	10	10	10	10	10	n/a	**8.4**
C4	6/17/05	Off of Center Road	10	10	10	10	3	3	3	7	n/a	8	7	8	10	8	n/a	**7.6**
C4	6/17/05	Trib to Cohansey south of Clarks Run, North of Har	10	10	10	10	9	9	1	1	n/a	10	7	1	10	10	n/a	**7.2**
C5	6/1/05	Deerfeild Road	8	7	10	10	8	4	2	9	n/a	10	9	7	8	10	n/a	**7.8**
C5	6/1/05	n/a	5	3	3	3	5	5	5	8	1	7	8	10	7	1	n/a	**5.3**
C5	6/7/05	Beals Road	9	7	9	6	7	6	9	9	5	7	8	7	7	10	n/a	**7.7**
C5	6/7/05	Beals Road	9	10	8	9	8	7	7	8	n/a	6	9	7	6	10	n/a	**8.0**
C5	6/7/05	Beal Road	9	10	10	10	9	9	8	7	n/a	9	7	9	10	10	n/a	**8.8**
C5	6/21/05	Tice's Lane off of Rt 77	5	4	5	7	4	4	3	2	n/a	10	6	1	2	10	n/a	**4.8**
C5	6/21/05	Off of Tices Road (off of Rt 77)	9	7	7	8	10	10	8	9	n/a	5	3	4	7	10	n/a	**7.2**
C5	6/21/05	Tice's Road (off of Rt 77)	9	8	9	9	8	8	7	8	n/a	8	6	6	7	9	n/a	**7.7**
C5	6/21/05	Center Road off of Tices Lanr across from Feaster's	6	4	1	1	3	3	4	9	n/a	10	3	1	4	1	n/a	**4.2**
C5	6/21/05	Directly across Center Road from r\each 6/21 R005	9	8	9	9	9	9	3	9	n/a	8	6	7	6	10	n/a	**7.6**
C5	7/3/05	Center 663, on bridge, below intersect w/Tices Lane	10	7	10	10	8	8	5	10	n/a	8	3	10	8	n/a	n/a	**7.9**
CL1	6/3/05	Coleman Road	9	5	3	6	8	6	10	10	5	7	10	3	10	7	n/a	**7.3**
CL1	6/3/05	n/a	2	2	2	6	3	4	7	10	n/a	4	9	7	10	n/a	n/a	**5.9**
CL1	6/3/05	n/a	9	6	1	4	7	5	7	7	n/a	10	10	7	10	3	n/a	**7.0**
CL1	6/5/05	Beals Road	9	8	9	7	8	6	7	8	n/a	8	6	8	7	9	n/a	**7.7**
CL1	6/15/05	Downstream of Coleman Road	9	8	8	9	6	6	8	9	7	7	8	7	8	10	n/a	**8.0**
CL1	6/15/05	Downstream of Coleman Road (deep into woods)	9	8	9	6	8	7	3	7	n/a	9	9	7	9	10	n/a	**7.8**
CL1	6/15/05	Downstream of Coleman Road	10	9	7	6	6	7	3	8	n/a	7	10	9	10	10	n/a	**8.1**
CL1	7/21/05	Willow Drive bridge near park	7	6	7	6	7	7	9	7	3	6	8	9	9	10	n/a	**7.3**
CL2	6/3/05	Coleman Road	6	6	6	8	5	5	8	10	8	10	10	9	8	10	n/a	**8.1**
CL2	6/15/05	Coleman Road	9	5	6	6	8	8	7	7	n/a	8	9	6	8	9	n/a	**7.5**
HR1	6/17/05	Harrow's Run & Center Road	7	8	10	8	7	7	10	10	n/a	9	10	1	10	10	n/a	**8.3**
HR1	6/17/05	Directly downstream in Harrow's Run & Center Road	10	10	10	10	5	5	9	10	n/a	8	10	2	10	10	n/a	**8.5**
HR1	6/17/05	Haven Hill Farm (157 Seeley Road)	9	7	10	10	6	4	10	10	n/a	8	10	7	10	10	na	**8.7**

Legend

(green)	Good = assessment score > 7
(yellow)	Fair = assessment score of 5 - 7
(orange)	Poor = assessment score < 5

Descriptions of each indicator are available in the U.S. Department of Agriculture Stream Visual Assessment Protocols (USDA, 1998).

Benthic Macroinvertebrates

The NJDEP Ambient Biological Monitoring Network (AMNET) maintains four benthic macroinvertebrate stations in the Upper Cohansey River Watershed (Figure 12). These stations were monitored in 1995, 2000, and 2006 (Table 3). To supplement this data, the RCE Water Resources Program sampled four stations in the fall of 2006 (Figure 12; Table 3). Full details on methods for each can be found in the data report (RCE Water Resources Program, 2009a).

The AMNET macroinvertebrate results show moderate impairments to biological communities within the watershed (Table 3). This is also seen in the RCE collected macroinvertebrate data (Table 3). 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 suboptimal habitat conditions, which may explain the observed impaired benthic macroinvertebrate community (Table 3). Habitat quality may be low due to physical alterations as observed during SVAP assessments conducted throughout the watershed (Table 2). The overall quality of the streams was assessed as “good” but individual SVAP element scores ranged from “fair” to “good” (Table 2). The bank stability scores obtained during SVAP assessments may signal increased erosion rates in the Upper Cohansey River Watershed which may cause filling in of habitat necessary for macroinvertebrates.

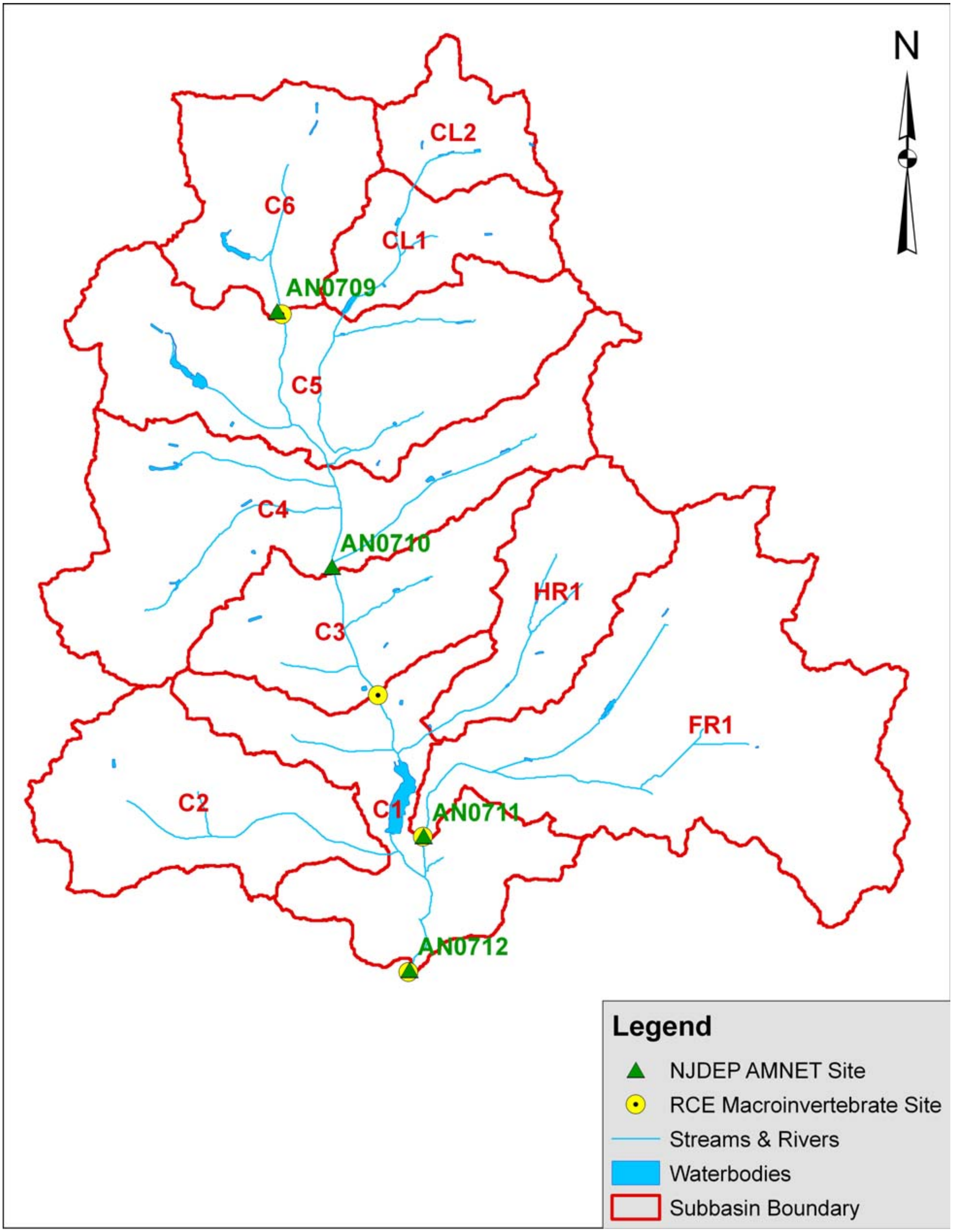


Figure 12: Benthic macroinvertebrate stations in Upper Cohansey River Watershed.

Table 3: Benthic macroinvertebrate results for Upper Cohansey River Watershed.

Agency	Station	Date Sampled	Impairment Status	Habitat Analysis
NJDEP	AN0709	10/19/1995	Non-Impaired	N/A
NJDEP	AN0709	10/17/2000	Moderately Impaired	Optimal/Excellent
NJDEP	AN0709	10/24/2006	Non-Impaired	Suboptimal/Good
NJDEP	AN0710	10/19/1995	Moderately Impaired	N/A
NJDEP	AN0710	10/17/2000	Moderately Impaired	Suboptimal/Good
NJDEP	AN0710	10/24/2006	Moderately Impaired	Suboptimal/Good
NJDEP	AN0711	10/19/1995	Severely Impaired	N/A
NJDEP	AN0711	10/17/2000	Severely Impaired	Suboptimal/Good
NJDEP	AN0711	10/24/2006	Moderately Impaired	Suboptimal/Good
NJDEP	AN0712	9/26/1995	Moderately Impaired	N/A
NJDEP	AN0712	9/19/2000	Moderately Impaired	Optimal/Excellent
NJDEP	AN0712	11/28/2006	Moderately Impaired	Suboptimal/Good
RCE Water Resources	C1	10/24/2006	Moderately Impaired	Suboptimal/Good
RCE Water Resources	FR1	10/24/2006	Severely Impaired	Suboptimal/Good
RCE Water Resources	C3	10/25/2006	Severely Impaired	Suboptimal/Good
RCE Water Resources	C6	10/25/2006	Moderately Impaired	Suboptimal/Good

Water Quality Parameters

To identify the cause(s) of impairment observed through both the SVAP assessment results and biological sampling, water quality monitoring began in June 2006. As per the NJDEP-approved Quality Assurance Project Plan (QAPP), *in situ* measurements of pH, dissolved oxygen (DO), and temperature were collected. Stream velocity and depth were measured across stream transects at each sampling station. Using this information, flow (Q) 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 TP, dissolved orthophosphate phosphorus, ammonia-nitrogen, total Kjeldahl nitrogen (TKN), nitrate-nitrogen, nitrite-nitrogen, total suspended solids (TSS), and fecal coliform.

Ten water quality stations (Figure 5) were monitored for three different types of sampling events. Regular monitoring, which included analysis for all parameters, occurred from June 14, 2006 through November 15, 2006. These events were monitored for all *in situ* parameters, velocity and depth, and TP, dissolved orthophosphate phosphorus, ammonia-nitrogen, TKN, nitrate-nitrogen, nitrite-nitrogen, TSS, and fecal coliform. Bacteria-only monitoring was conducted in the summer months of July through September 2006. This entailed collecting three additional samples per month for fecal coliform analysis, as well as *in situ* parameters, and velocity and depth to calculate flow. In addition, water samples from three storm events were collected from September through November 2006. Four samples were collected over the course of each storm event for all parameters at all ten monitoring locations.

Since the release of the *Upper Cohansey River Watershed Restoration and Protection Plan: Data Report* (RCE Water Resources Program, 2009a), the water quality standard for pH in the Upper Cohansey River has been modified. It was previously required that pH levels be between 6.5 and 8.5 SU, with the new standard set so that pH levels should be between 4.5 and 7.5 SU (NJDEP, 2009b; Table 4). Updated pH graphs are presented in Appendix A. All other water quality standards previously reported are unchanged (Table 4).

The NJDEP's Integrated Water Quality Monitoring and Assessment Methods advises that if water quality results exceed the water quality criteria twice within a five-year period, then the waterway's quality may be compromised (NJDEP, 2009c). NJDEP has further stated that a minimum of eight samples need to be collected to confirm the quality of waters, with quarterly samples over a two-year period being ideal (NJDEP, 2005; NJDEP, 2009c). Therefore, if a waterbody has a minimum of eight samples collected 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 Cohansey 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, and fecal coliform). The number of samples exceeding state water quality standards is given in Table 5.

Nitrate

While the focus of water quality issues in this plan is on fecal coliform and phosphorus impacts due to the currently established TMDLs, other parameters were monitored as part of this study. Nitrate concentrations at the ten monitoring stations were below the water quality standard (10 mg/L) except for station C2. Nine of the twelve samples analyzed at this site were above the water quality standard. Potential sources of nitrate include fertilizers, animal feedlots, septic systems, and animal waste. Many of the implementation projects recommended for the

Upper Cohansey River Watershed (Appendix B) are targeted to reduce bacteria, phosphorus, and TSS, but may also have the ancillary benefit of reducing some levels of nitrate in surface waters.

The primary impacts of concern due to nitrate are on groundwater and drinking water supplies. Three groundwater monitoring wells are located within the Upper Cohansey River Watershed, two of which are maintained by USGS (Wells #111212 and #111214) and one by NJDEP (Well #110692) (Figure 13). Nitrate in these wells ranges from 7.83 mg/L to 16.0 mg/L, but these results, however, are from only one sampling event. These concentrations may be indicative of potential problems due to groundwater discharge to surface waters, or if groundwater is used for crop irrigation. These situations may partly explain the nitrate levels detected during this study. Additional studies on nitrate occurrences in groundwater and drinking waters in the Upper Cohansey River Watershed are in order, but are beyond the original scope of this study. Future work could also include implementation practices specifically designed to reduce nitrate levels within subwatershed C2.

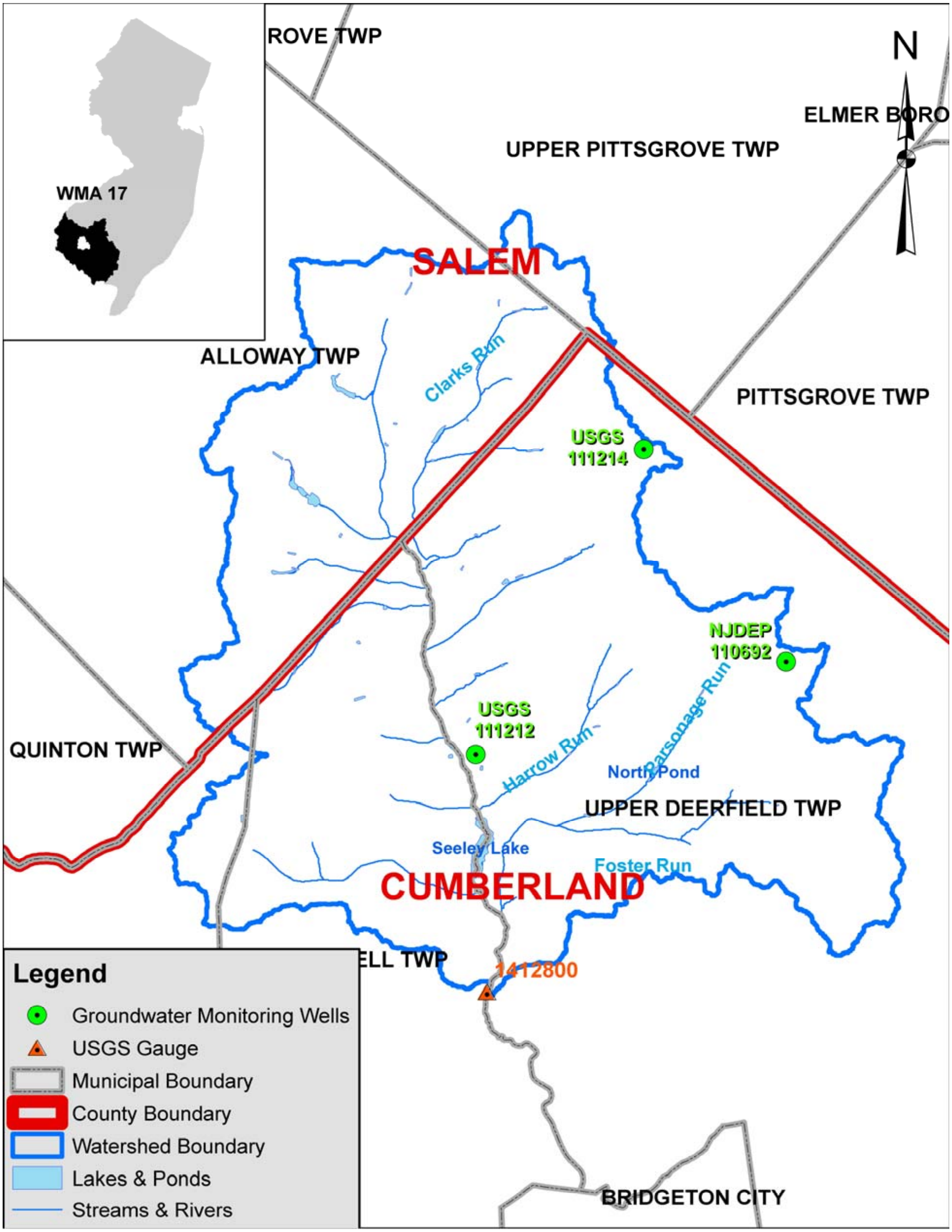


Figure 13: Location of groundwater monitoring wells within the Upper Cohansey River Watershed.

Table 4: Water quality standards for Upper Cohansey River Watershed (NJDEP, 2009b). Bold items are new as of publication of the *Upper Cohansey River Watershed Restoration and Protection Plan: Data Report* (RCE Water Resources Program, 2009a).

Substance	Surface Water Classification	Criteria
pH (SU)	**FW2**	**4.5 – 7.5**
TP (mg/L)	FW2 Streams	Except as necessary to satisfy the more stringent criteria in accordance with "Lakes" (above) 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.
TSS (mg/L)	FW2-NT	Non-filterable residue/suspended solids shall not exceed 40.
Bacterial counts (col/100 mL): Fecal Coliforms	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.

Table 5: Number of samples that exceed state water quality standards.

	Select Monitoring Parameters			
Station	**pH***	**TP**	**TSS**	**Fecal coliform****
C1	2	10	1	5
C2	0	5	2	5
FR1	0	13	0	9
HR1	0	6	2	9
C3	0	7	1	5
C4	0	8	1	3
C5	0	8	1	8
CL1	0	9	1	2
C6	0	6	0	6
CL2	0	7	0	7

**Based upon the new standard of 4.5 – 7.5 S.U. established in November 2009 (NJDEP, 2009b).*
***For fecal coliform, the number of samples higher than the 400 col/100ml standard was calculated.*

pH

With modification of the pH water quality standard for the Upper Cohansey River, many of the exceedances reported in the *Upper Cohansey River Watershed Restoration and Protection Plan: Data Report* (RCE Water Resources Program, 2009a) are no longer evident. Mean pH levels for all stations were within the state's water quality standard (Figure 14). The data indicate two exceedances at one location, station C1 (Table 5). This station is located on the Cohansey River at USGS 01412800 at Seeley Lake (also AMNET station AN0712) (Figure 1; Figure 5). While two exceedances would normally indicate impaired waters for this parameter, pH levels exceeded the water quality with far less frequency than other pollutants of concern (i.e., TP and fecal coliforms) (Table 5).

The standard error of the mean is indicated on data graphs by error bars (Figure 14; Figure 15; Figure 17). The standard error of the mean is an estimate of the amount that an obtained mean may be expected to differ by chance from the true mean. The general rule of thumb is that the smaller the error of a sample set, the less spread out the data is from the mean sample size. Also, the larger the error, the more spread out the samples are distributed from the mean. The standard error on pH levels (Figure 14) was small and ranged from 0.04 to 0.15.

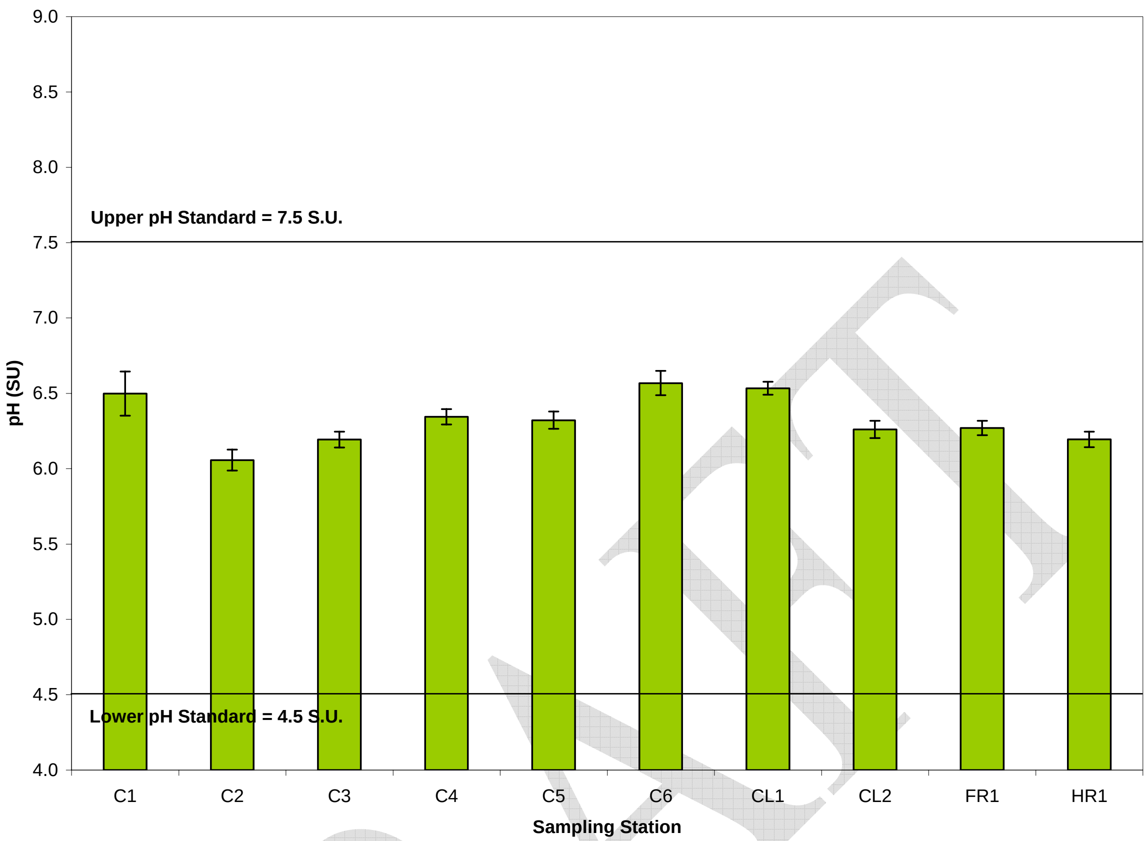


Figure 14: Mean pH levels for RCE monitored stations in Upper Cohansey River Watershed. (Error bars indicate standard error of the mean.)

Total Phosphorus (TP)

All water quality monitoring stations exceeded the 0.05 mg/L standard more than twice during the sampling season (Table 5). This indicates elevated TP levels are causing impairments throughout the watershed. Stations FR1 (Parsonage Run) and C1 exceeded the 0.05 mg/L standard most frequently (on 13 and 10 occasions, respectively) (Table 5). Stations C2, which is an unnamed tributary to the Cohansey River, and CL2 in the headwaters of Clarks Run (Figure 5) had the highest single concentrations of TP over the course of the monitoring period (1.21 mg/L and 0.92 mg/L, respectively). Both occurred on June 28, 2006, during a precipitation event of 1.59 inches of rain. Results from station C6 were significantly higher than usual on August

30, 2006, when TP equaled 0.80 mg/L, following two days of rainfall. Standard error of the mean for TP ranged from 0.03 to 0.09 (Figure 15).

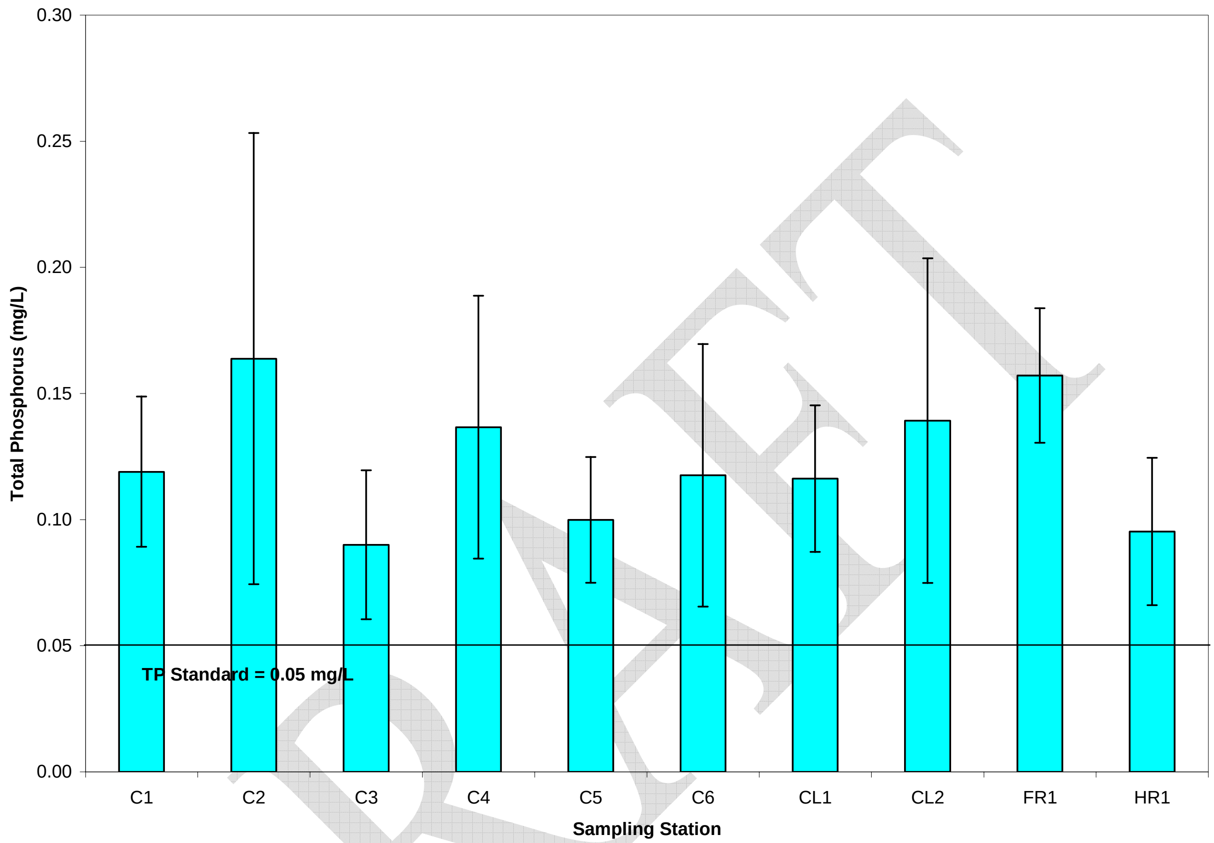


Figure 15: Mean total phosphorus (TP) concentrations for RCE monitored stations in Upper Cohansey River Watershed. (Error bars indicate standard error of the mean.)

For the analysis of TP data, wet and dry weather loads were compared. TP loads were calculated for both dry weather and wet weather events by multiplying concentrations by the flow measured at each station. Wet and dry dates were distinguished from each other by utilizing the USGS hydrograph separation model (HYSEP). HYSEP estimates the groundwater, or base flow, component of stream flow through one of three methods: fixed interval, sliding interval, or local minimum (Sloto and Crouse, 1996). The local minimum method was used in the Upper Cohansey River Watershed. Baseflow is calculated in this method and any flows measured during the course of this project that are above the calculated baseflow are considered "wet" events, while those below are considered "dry" events (Sloto and Crouse, 1996). In addition, downstream stations had upstream station loads subtracted from their total load in order to determine the contribution of individual subwatersheds. In some cases, this can lead to negative loads at a station due to there being a larger load upstream of that station. By using these methods, subwatersheds FR1 and C1 were found to have the largest mean TP loads in the Upper Cohansey River Watershed for both dry and wet weather events (Figure 16). These subwatersheds have the greatest impact in regards to TP results at the most downstream monitoring point for the project area (station C1; Figure 5) and may be contributing to the high concentrations measured during monitoring. High nutrient loading from the large drainage area to FR1 and in the immediate subwatershed to C1 are priorities for water quality management.

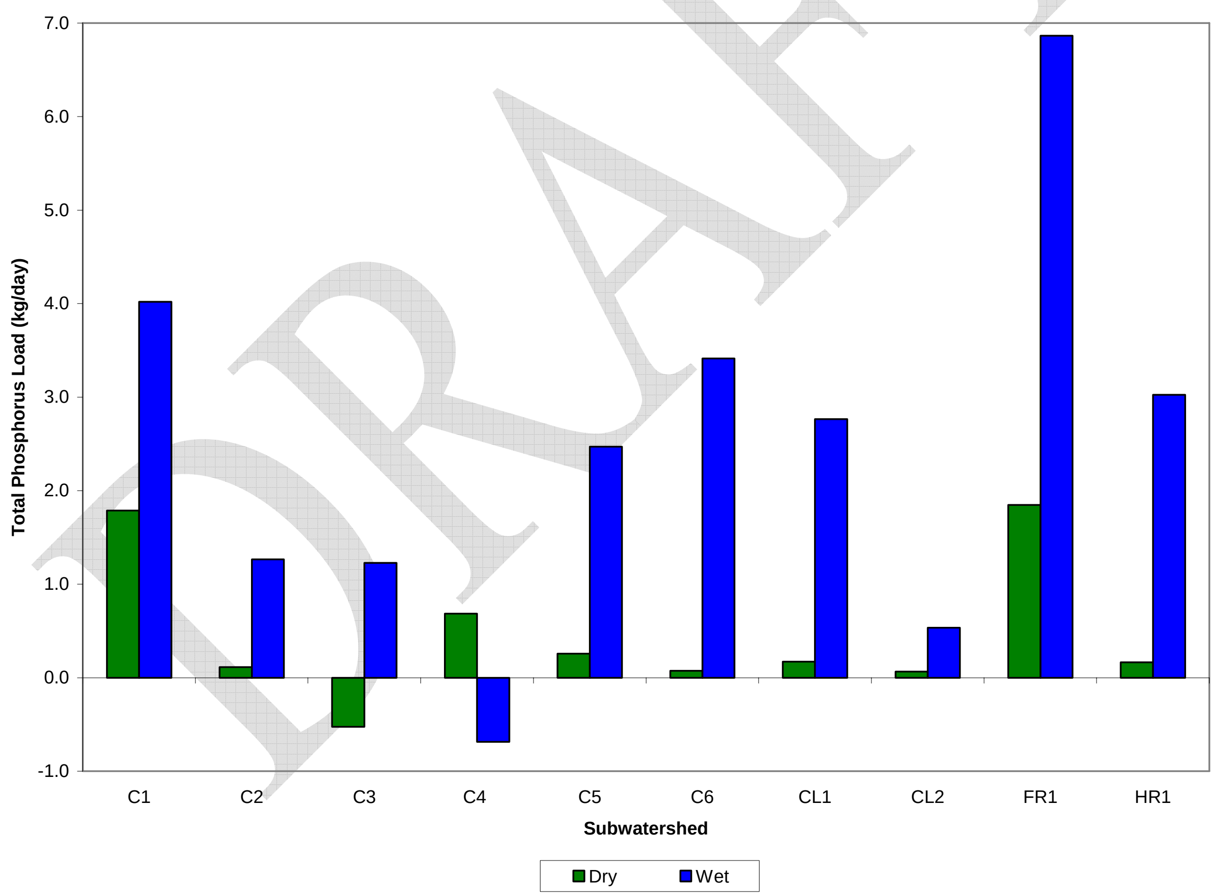


Figure 16: Comparison of daily total phosphorus (TP) loads per subwatershed under dry and wet conditions.

TP loads were also estimated using the Soil and Water Assessment Tool (SWAT) to model nutrient dynamics in the Upper Cohansey River Watershed (RCE Water Resources Program, 2009b). TP loads were calculated from each subwatershed on an annual basis for 2005 and 2006, and then normalized by subwatershed area to compare subwatershed loading rates (Table 6). These rates were compared to areal loading coefficients used by the NJDEP for TP. Areal loading coefficients for agricultural land uses, low density residential, and natural lands are 0.60, 0.30, and 0.05 kg/acre/year, respectively (NJDEP, 2004). Normalized total annual TP loading rates predicted using the SWAT model for 2005 (1.70 kg/acre) and 2006 (0.85 kg/acre) (Table 6) are higher than the NJDEP coefficient for agriculture (0.60 kg/acre/year). This may be due to higher soil erodibility, high watershed slopes, and different agricultural practices used in the Upper Cohansey River Watershed as opposed to those watersheds used to develop the NJDEP coefficients. If these higher values are representative of conditions in the Upper Cohansey River Watershed, the need for water quality improvement is reinforced in this project.

Under existing conditions, the subwatersheds that produced the largest TP loads were C4 and C2 in 2005 and C4 and C1 in 2006 (Table 6). When normalized by area, the largest loading occurred in subwatersheds C2 and C6 in both 2005 and 2006 (Table 6).

Table 6: Estimated subwatershed TP loadings from Cohansey SWAT model.

	Total Phosphorus (kg)		**Total Phosphorus (kg/acre)**	
Subwatershed	**2005**	**2006**	**2005**	**2006**
CL1	435	235	1.83	0.99
CL2	524	316	1.70	1.02
C6	1,158	620	2.29	1.23
C5	777	388	1.60	0.80
C4	2,964	1,189	1.84	0.74
C3	715	277	1.28	0.50
HR1	258	131	0.54	0.27
FR1	944	637	0.81	0.55
C2	1,999	789	3.12	1.23
C1	1,493	888	2.03	1.21
Watershed Total	11,267	5,470	1.70	0.85

Fecal Coliform

The former surface water quality standard for bacterial quality of FW2 surface waters was that the geometric mean of samples not exceed 200 counts of organisms (colonies) per 100mL (col/100mL). Since initiation of this project, the indicator organism has changed for freshwaters in New Jersey to the use of *Escherichia coli* (*E. coli*). For this report, however, the former standard for fecal coliform will be applied to data collected in the Upper Cohansey River Watershed since it is a fecal coliform TMDL that is the driver of this effort (Table 4). In the Upper Cohansey River Watershed, five stations exceeded a geometric mean of 200 col/100 mL over the course of data collection with maximum fecal coliform concentrations exceeding 600 col/100 mL at least once at all stations throughout sampling (Figure 17; Table 5). The geometric mean of fecal coliform concentrations was above the standard at stations C5, C6, CL2, FR1 and HR1 (Figure 17). In addition, all stations exceeded the 400 col/100 mL standard at least once during the sampling season (Table 5). Station FR1 had the highest fecal coliform count across all stations over all events (8,000 col/100 mL). Standard error of the mean was large, and ranged from 41.70 to 360.25 (Figure 17), indicating large variability in the fecal coliform levels.

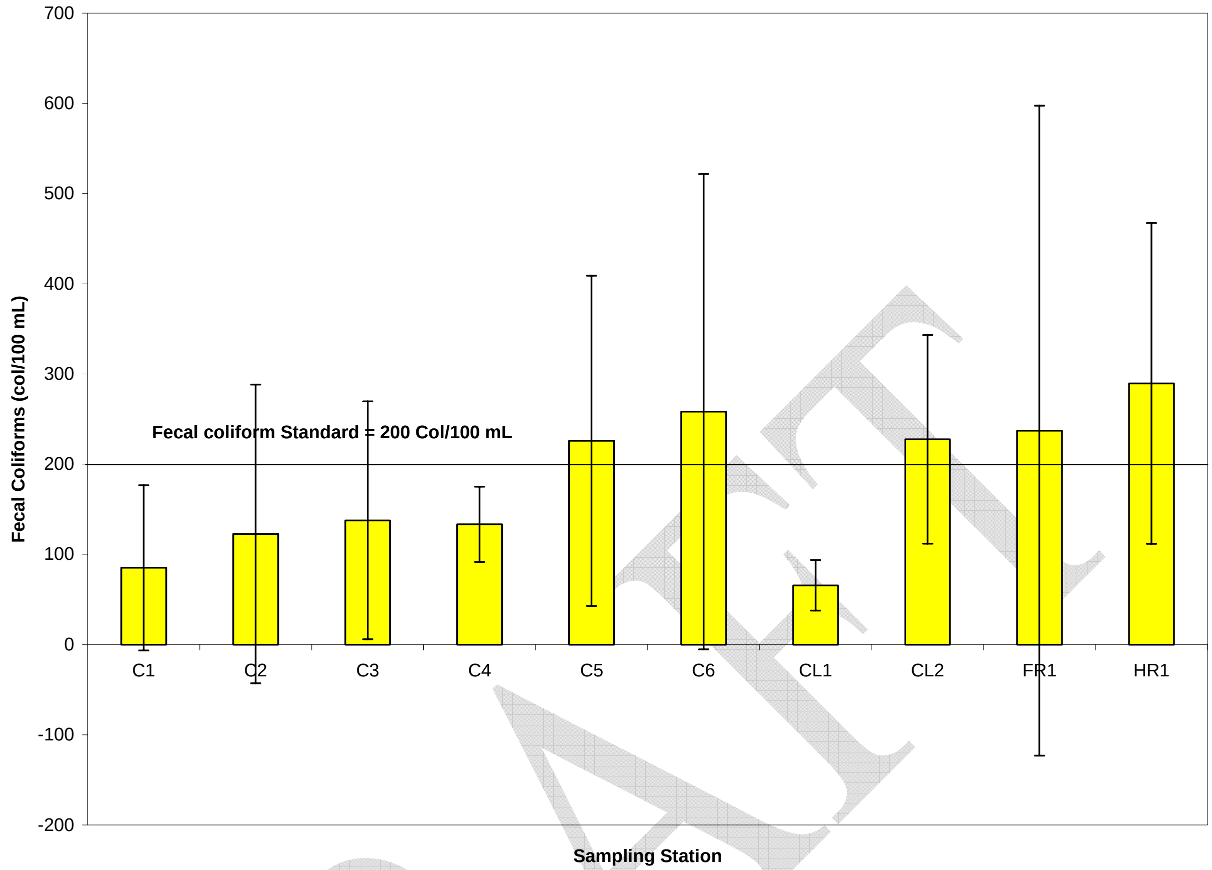


Figure 17: Geometric mean fecal coliform (FC) concentrations for RCE monitored stations in Upper Cohansey River Watershed. (Error bars indicate standard error of the mean.)

As stated in the TMDL, occurrences of high fecal bacteria in surface waters are largely due to storm events (NJDEP, 2003a). Fecal coliform loads were calculated in the same manner as TP loads and were also compared between wet and dry events. Fecal coliform loads were greater in almost every subwatershed during sampling events when stream volume was greater than baseflow (wet weather events; Figure 18). Only subwatersheds C1 and C4 had lower loadings during wet events (Figure 18). Assimilation, predation, or some other loss of FC may be occurring prior to these locations. The FR1 subwatershed was found to have the greatest influence on water quality at C1, where the USGS gauge 01412800 is located (Figure 1). The FR1 subwatershed is a priority for controlling pathogens in the Cohansey River, as are C3 and C5 subwatersheds, which have a strong impact on the downstream pathogen results in dry and wet weather (Figure 18).

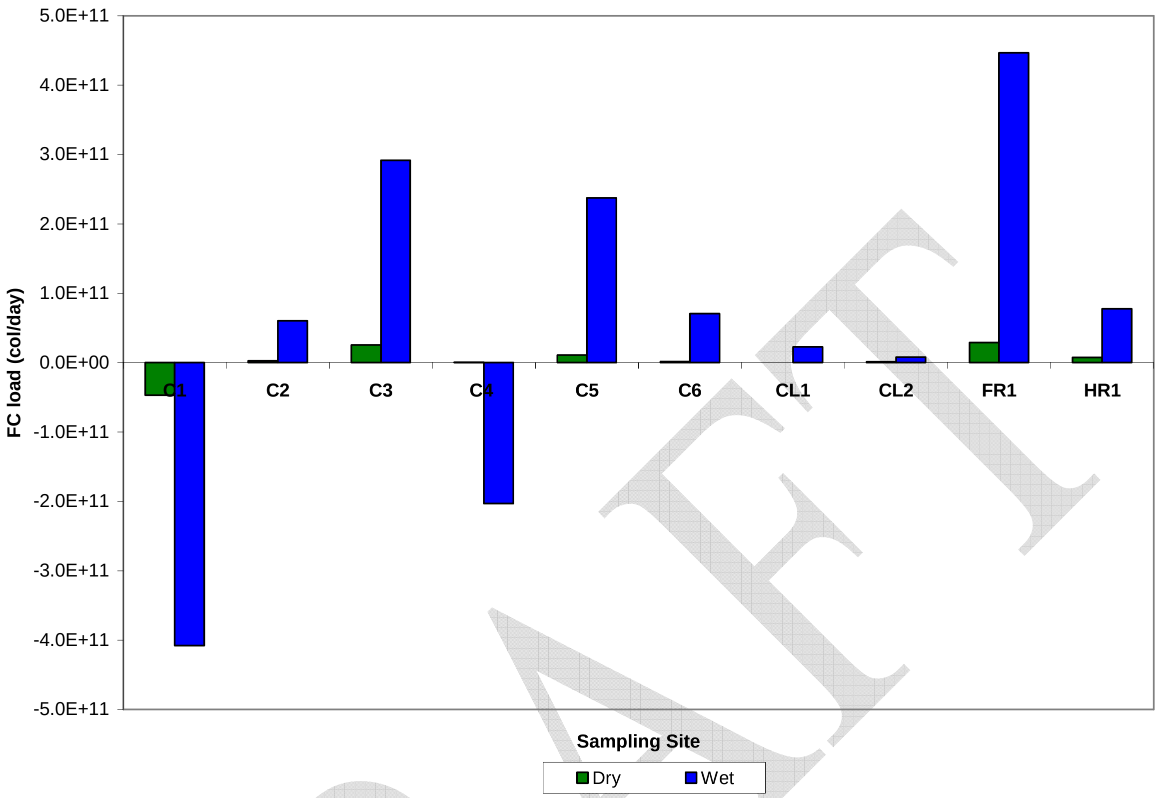


Figure 18: Comparison of daily fecal coliform load by subwatershed under dry and wet conditions.

Source Identification of Pollutants of Concern

Due to the extent and frequency of violation of applicable water quality standards, both TP and fecal coliform pollution are of primary concern in the Upper Cohansey River Watershed (Table 7). Elevated levels were seen at all stations during the course of this study (Figure 15; Figure 17). As stated earlier, TMDLs have been established to reduce TP and fecal coliform levels in the watershed, indicating the importance of addressing these parameters and their impact on water quality. Control and reduction of pollutants, however, are only effective when their sources have been determined and targeted efforts are used.

Table 7: Pollutants of concern (marked with an ✕) for each subwatershed in the Upper Cohansey River Watershed.

Subwatershed	pH	Total Phosphorus	Fecal coliform
C1	✕	✕	✕
C2	-	✕	✕
C3	-	✕	✕
C4	-	✕	✕
C5	-	✕	✕
C6	-	✕	✕
CL1	-	✕	✕
CL2	-	✕	✕
FR1	-	✕	✕
HR1	-	✕	✕

Total Phosphorus (TP)

Fertilizers, domestic animal and livestock wastes, failing septic systems, and crop residues are potential agricultural and residential nonpoint sources of phosphorus carried by stormwater runoff and groundwater. Road runoff during storm events may also carry high concentrations of TP to streams and rivers (Flint and Davis, 2007).

Correlations with TSS and TP were conducted at each sampling station to determine the relationship between sediments and nutrients. For all stations, the correlation coefficient (R^2) was calculated as 0.81, indicating a strong relationship between TSS and TP (Table 8). At all stations other than C5, the correlation between TP and TSS yielded an R^2 value greater than 0.65 (Table 8). This relationship may indicate that phosphorus is likely attached to suspended sediments as they tend to occur together (Table 8). Erosion is leading to suspended sediments in streams and high phosphorus concentrations in the water column. This behavior is similar under both wet and dry conditions, as illustrated by station C1 (Figure 19).

Table 8: Correlation between TP and TSS by monitoring station.

Station	Correlation Coefficient (r)	R^2
C1	0.84	0.71
C2	0.96	0.92
C3	0.87	0.76
C4	0.87	0.76
C5	0.23	0.05
C6	0.92	0.85
CL1	0.84	0.71
CL2	0.81	0.65
FR1	0.82	0.66
HR1	0.93	0.86
All Stations	**0.81**	**0.65**

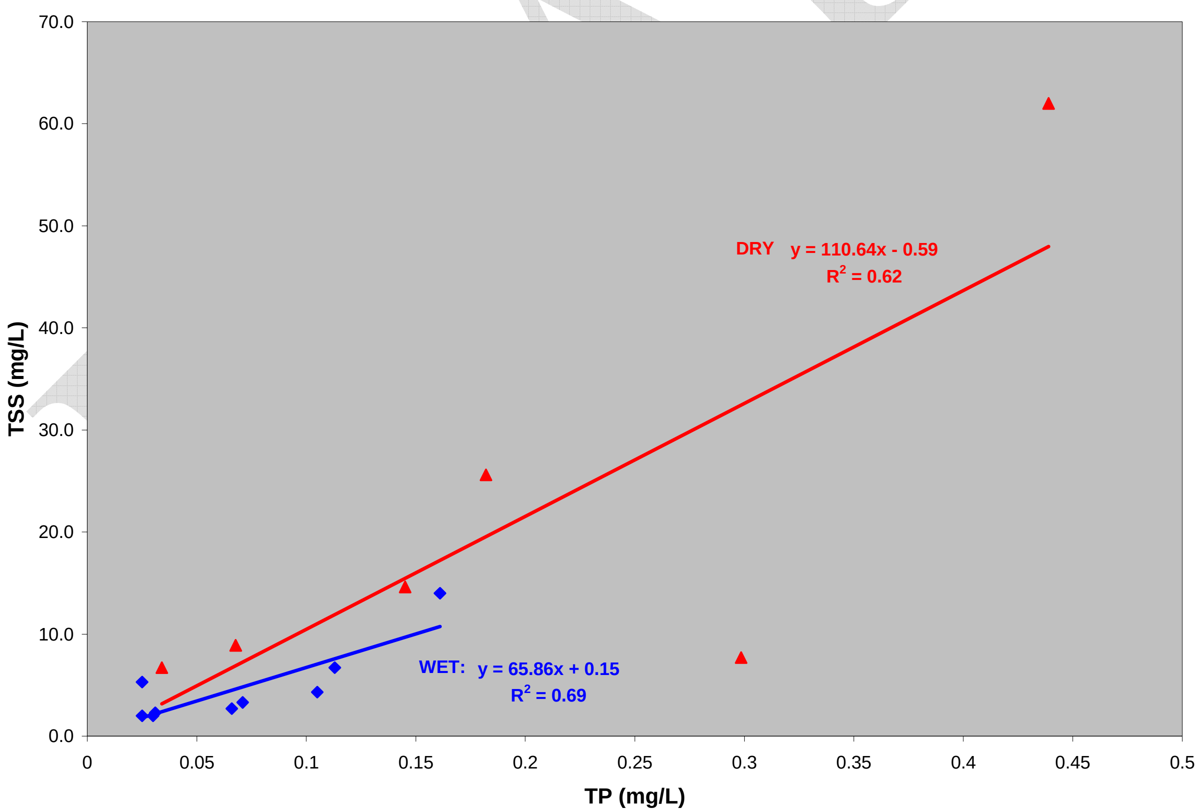


Figure 19: Plot of TP versus TSS concentrations at station C1 for wet and dry events.

At station C5, there is no correlation between suspended sediments and TP (Figure 20). TSS is relatively unchanging, even when TP is elevated and when samples were collected under storm conditions. TSS averaged 6.41 mg/L in dry conditions and 14.11 mg/L in precipitation events. In addition, TSS levels only violated the state water quality standard once throughout sampling (RCE Water Resources Program, 2009a). TSS levels may be low due to a lack of erosion of soils into the stream, as indicated by the high scores for C5 obtained during SVAP data collection for stream bank stability and the health of the riparian zone (Table 2). Therefore, there may be a source of phosphorus within the C5 subwatershed independent of suspended sediments in the Upper Cohansey River.

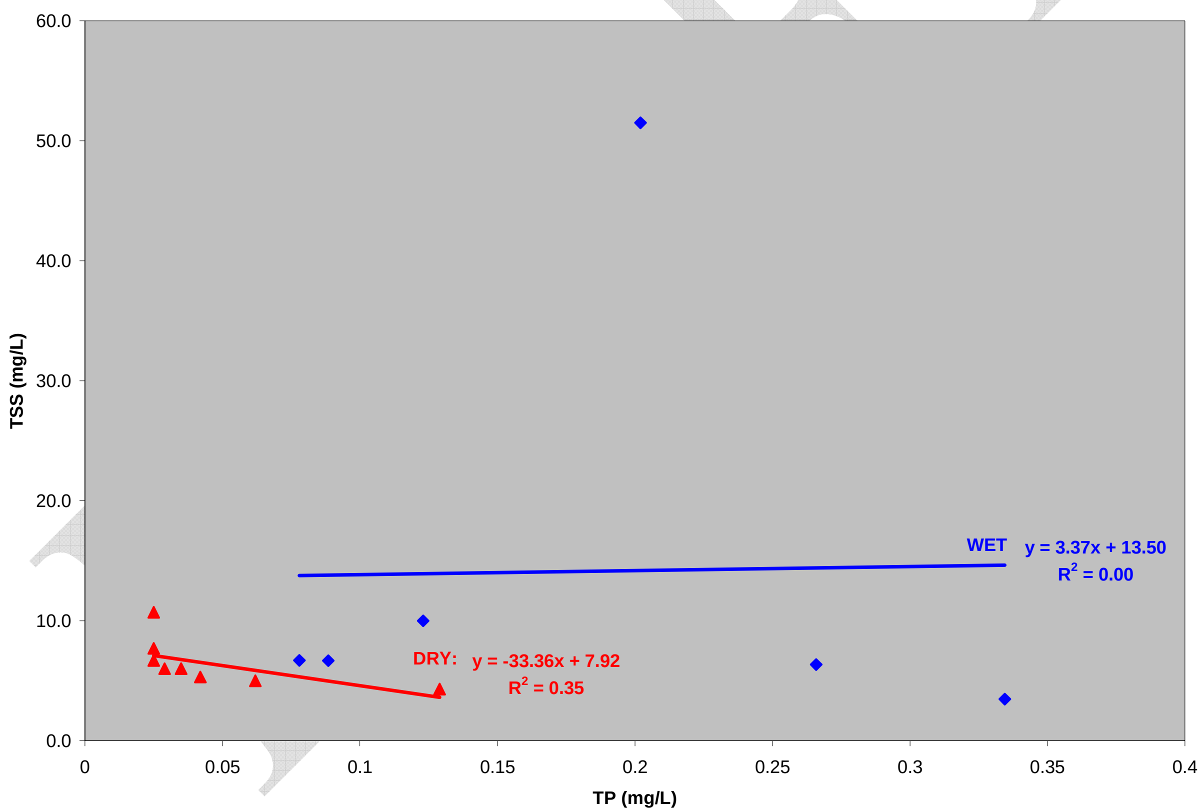


Figure 20: Plot of TP vs. TSS concentrations at station C5 for wet and dry events.

The HR1 subwatershed (Harrow Run) has proved to be affected by runoff events. The average TSS results are eight times higher during precipitation events than dry weather. At this station, TP and TSS correlate well (R^2 = 0.86; Table 8). SVAP scores for bank stability are low in HR1, indicative of high levels of erosion in this subwatershed (Table 2). Controlling storm-induced runoff and erosion are important goals for this subwatershed so that TP can be reduced and TMDL targets achieved.

In addition, there are a number of man-made impoundments and lakes along the Cohansey River (Figure 1). These areas may be accumulating sediments and sediment-bound phosphorus and harboring potential sinks for these pollutants. If the lakes are functioning as a sink for water quality contaminants, then it is likely that the water quality of the lake and its sediments are impacted. Nutrients that are accumulating in these waterways can create eutrophic conditions represented by algal growth, loss of dissolved oxygen, and lake filling. Study on the lakes and any accumulated sediment and sediment-bound phosphorus is beyond the current scope of this project, but further research would be necessary to determine the impact of these impoundments on water quality within the Upper Cohansey River Watershed. Water quality of these lakes may ultimately indicate that the expensive option of dredging is necessary to maintain watershed health and improve water quality.

Fecal Coliform

Using an indicator organism like fecal coliform to solve pathogen problems in surface waters presents several challenges. First, fecal coliform is solely an indicator of fecal pollution and not a direct measure of fecal contamination. Second, the measurement of fecal coliform concentration does not identify sources of fecal pollution. Therefore, it is imperative that prior to any remediation strategies the potential sources of pollution be identified. With more than 95% of the Upper Cohansey River Watershed without centralized wastewater treatment (Figure 6), failing septic systems are one potential source of fecal contamination. For those areas serviced by a centralized wastewater treatment plant, failing infrastructure could be a hazard that would result in waters impaired by bacteria.

Other sources throughout the Upper Cohansey River Watershed include wildlife (deer, raccoons, muskrats) and waterfowl (ducks, Canada geese, snow geese). Agricultural practices including the spreading of manure and its use as a fertilizer could potentially lead to runoff of fecal-related pathogens. Two confined feed operations exist in the watershed, and manure management is important at these facilities to prevent runoff. Livestock access to waterways can also lead to direct impacts on streams, and locations where livestock have access to surface waters have been identified through field visits. Equine facilities also require manure management; there are a few of these facilities in the lower reaches of the watershed. Improper disposal of domestic pet wastes are also a potential source of pathogen pollution. Recently, dumpsters have been recognized as a source of pathogens in stormwater runoff due to birds using dumpsters as feeding locations; this is also true of rodents (Central Coast Water Board, 2006).

Microbial source tracking (MST) was employed to determine bacterial sources within the Upper Cohansey 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).

Based on the frequency of bovine- or human-related *Bacteroides* occurrences in water quality samples, some conclusions can be drawn in regards to the sources of pathogen pollution in-stream. Human-related sources of fecal bacteria were measured in higher frequencies than bovine-related sources (Figure 21). The highest frequency of human *Bacteroides* (HuBac) was 40% in the C1 subwatershed, followed by 30% of samples from subwatersheds C2, C4, and HR1 (Figure 120). Bovine *Bacteroides* were less frequently detected in samples. The C3 subwatershed had the highest occurrence of bovine-related *Bacteroides* at 20% (Figure 21). This would indicate that the majority of fecal contamination within the Upper Cohansey River Watershed is from human sources.

The presence of human fecal matter in-stream is a serious public health threat and needs to be addressed, especially in the C1 subwatershed. Surface waters contaminated with human feces may also carry enteric pathogens including the hepatitis A virus, *Salmonella enterica* serovar Typhi, Norwalk group viruses, and others. Therefore, the control of human sources of pathogens in the C1, C2, C4, and HR1 subwatersheds is imperative for both ecological health and human health.

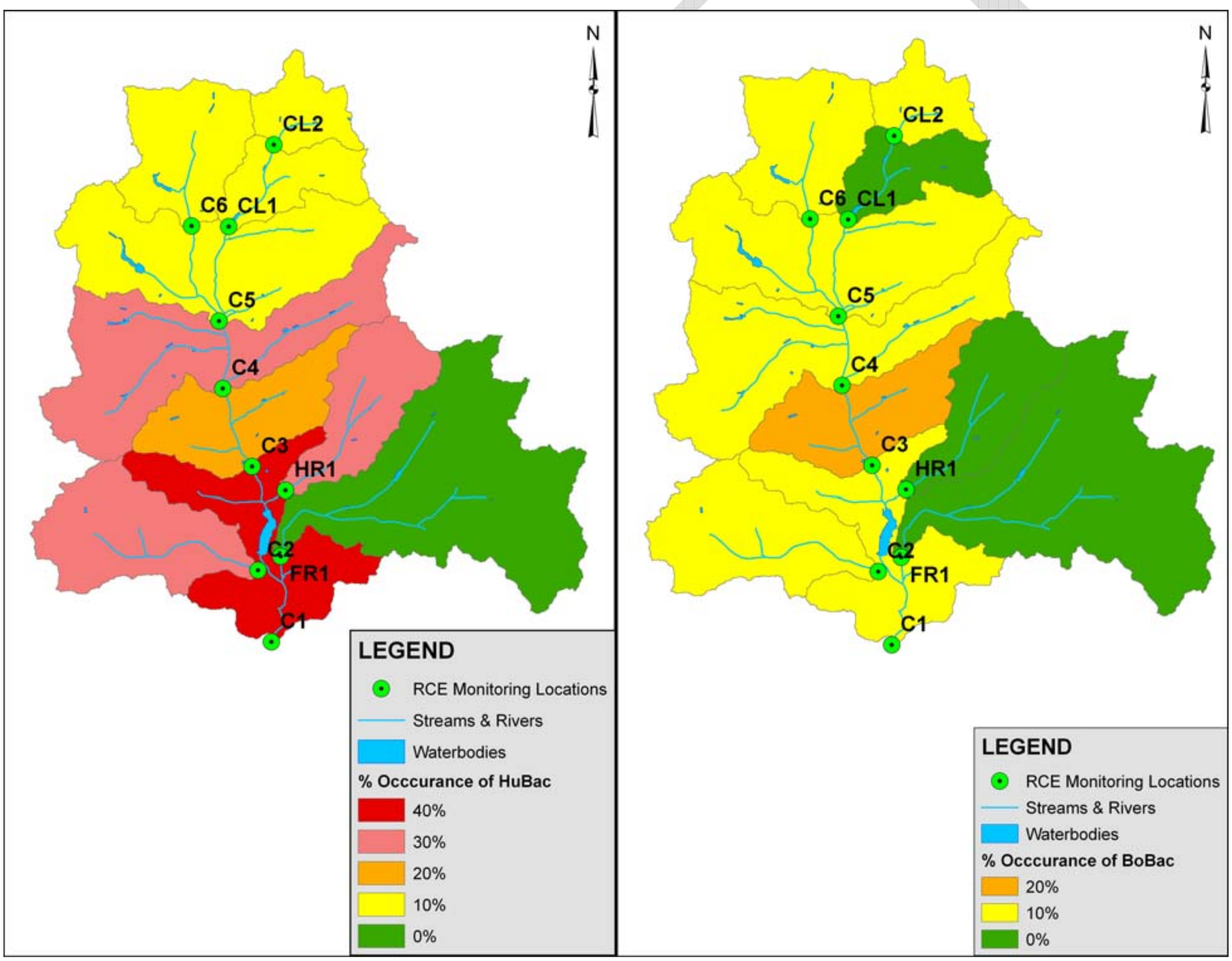


Figure 21: Percent occurrence of human (HuBac) and bovine (BoBac) *Bacteroides* by subwatershed over 10 sampling events.

Addressing Pollutants of Concern

The Upper Cohansey River Watershed Restoration and Protection Plan is dedicated to projects and efforts to control nonpoint source pollution. In the Upper Cohansey River Watershed, fecal coliform and TP are of concern. Implementation of the suggested projects will aid in achieving the goals set up in the appropriate TMDLs. Project details include the following information:

- Summary of current conditions at the location or in the watershed
- Descriptions of the implementation efforts
- Anticipated pollutant removal
- An estimate of cost
- Potential funding sources and project partners
- Proposed monitoring

These projects have been prioritized based on percent removal of pollutants, need on a subwatershed basis, impact on the watershed's discharge quality, overall cost-effectiveness, and best professional judgment.

In an effort to recommend realistic, cost-effective management strategies that will be welcomed by communities in the watershed, project partners held several meetings with members of the local farming community (representing grain, nursery, field crops, sod, and livestock industries), County Health Departments, Cumberland and Salem County governments, municipal governments, and environmental commission representatives. Information gained from these meetings was essential to the development of plans that lead to action and water quality improvement. The recommendations referenced in this Watershed Restoration and Protection Plan include the information learned and feedback received from these meetings.

Identification of Priority Implementation Efforts

Phosphorus and fecal coliform are moved primarily by surface runoff (both storm-driven flows and irrigation) in the Upper Cohansey River Watershed. Therefore, implementation projects have been identified and prioritized based on the water quality improvement that will result from their implementation and the cost-benefit of proposed solutions in dealing with surface runoff. Identified projects have also been developed based on water quality data collected for this project. Some projects are already underway; however, the urgency of their implementation has been highlighted below for the purposes of attracting funding sources and expediting their implementation schedule.

The following is a list of recommended implementation efforts to improve the water quality within the Upper Cohansey River Watershed. Details on each of the efforts identified below can be found in Appendix B.

1. Sewer Infrastructure Repair in the Parsonage Run Subwatershed
2. Decentralized and Centralized Wastewater Management Options Along the East Shore of Seeley Lake
3. Nursery Operations Best Management Practices Outreach and Education
4. Minimum Till Drill Program
5. Vegetated Buffers
6. Decentralized Wastewater Treatment Outreach and Education
7. Bioretention Basin and Vegetation Swale in the Harrow Run Watershed
8. Detention Basin Retrofit Designs
9. Addressing Livestock Fencing Needs.

Schedule for Implementation of Management Measures

Implementation of projects listed herein obviously requires some level of funding. The RCE Water Resources Program, local environmental commissions, municipalities, and citizen action groups need to work together to begin implementation of this plan. The following is a schedule for implementation provided funding is available (Table 9). In addition, estimated reductions in pollutants of concern if improvement projects are enacted and are effective at their targeted pollutant removals is given (Table 10).

Table 9: Implementation strategy for water quality improvement projects in the Upper Cohansey River Watershed.

Applicable BMPs	Subwatershed	Target % Removal of TP	Target % Removal of TSS	Target % Removal of FC	Estimated Potential Cost	Implementation Schedule
Sewer Infrastructure Repair in the Parsonage Run Subwatershed	FR1	85%	85%	85%	To Be Determined	Currently Underway
		95%	95%	95%		
		100%	100%	100%		
Decentralized and Centralized Wastewater Management Options Along the East Shore of Seeley Lake	C1	85%	85%	85%	To Be Determined	December 31, 2015
		95%	95%	95%		
		100%	100%	100%		
Nursery Operations Best Management Practices Outreach and Education	All	50% - 100%	50% - 100%	50% - 100%	$325,000	December 31, 2015
Minimum Till Drill Program	All	22%	30%	95%	$241,000	December 31, 2015
Vegetated Buffers	C1, C3, C4, C5, C6,CL1, CL2, HR1	30%	60% - 80%	95%	$64,900	December 31, 2015
Decentralized Wastewater Treatment Outreach and Education	All	50% - 100%	50% - 100%	50% - 100%	$26,500	December 31, 2015
Bioretention Basin and Vegetated Swale in the Harrow Run Watershed	HR1	94%	90%	95%	$70,000	December 31, 2015
Detention Basin Retrofit Designs	FR1	60%	90%	95%	$95,000 – $475,000	December 31, 2015
Addressing Livestock Fencing Needs	C6	30%	80%	95%	$1 - $2/linear foot	December 31, 2015

Table 10: Estimated annual reductions (in kilograms per year; kg/yr) of select pollutants for each recommended water quality improvement project.

Applicable BMPs	Subwatershed	Estimated TP Reduction	Estimated TSS Reduction (kg/yr)	Estimated FC Reduction (col/100ml/yr)
Sewer Infrastructure Repair in the Parsonage Run Subwatershed	FR1	1,129	51,037	4.8×10^{13}
		1,262	57,041	5.4×10^{13}
		1,328	60,044	5.7×10^{13}
Decentralized and Centralized Wastewater Management Options Along the East Shore of Seeley Lake	C1	802	40,220	N/A
		896	44,952	N/A
		943	47,318	N/A
Nursery Operations Best Management Practices Outreach and Education	All	1,991 – 3,982	182,943 – 365,885	3.6×10^{13} – 7.2×10^{13}
Minimum Till Drill Program	All	876	109,765	6.8×10^{13}
Vegetated Buffers	C1, C3, C4, C5, C6,CL1, CL2, HR1	739	174,171 – 239,229	7.4×10^{12}
Decentralized Wastewater Treatment Outreach and Education	All	1,991 – 3,982	182,943 – 365,885	3.6×10^{13} – 7.2×10^{13}
Bioretention Basin and Vegetated Swale in the Harrow Run Watershed	HR1	57	66,351	1.1×10^{13}
Detention Basin Retrofit Designs	FR1	797	54,039	5.4×10^{13}
Addressing Livestock Fencing Needs	C6	154	30,912	9.5×10^{12}

Information and Education Component

The RCE helps the diverse population of New Jersey adapt to a rapidly changing society and improve their lives through an educational process that uses science-based knowledge. We focus on issues and needs relating to agriculture and the environment; management of natural resources; food safety, quality, and health; family stability; economic security; and youth development. RCE is an integral part of the New Jersey Agriculture Experiment Station and Rutgers, The State University of New Jersey, and is funded by the United States Department of Agriculture, the State of New Jersey, and County Boards of Chosen Freeholders.

The Water Resources Program is one of many specialty programs under RCE. The goal of the Water Resources Program is to provide solutions for many of the water quality and quantity issues facing New Jersey. This is accomplished through research, project development, assessment and extension. In addition to preparing and distributing fact sheets, we provide educational programming in the form of lectures, seminars, and workshops as part of our outreach to citizens. With New Jersey Agriculture Experiment Station funding and other State and Federal sources, we conduct research that will ultimately be used by stakeholders to improve water resources in New Jersey.

Programs listed below are a small sample of educational opportunities available in New Jersey. The RCE Water Resources Program plays an important role offering programs delivered to municipalities and working with local stakeholders to educate them on specific concerns in their area. Along with the RCE Water Resources Program, the USEPA and NJDEP offer newsletters, brochures and other outreach materials that can be used to supplement programs that educate stakeholders.

For more information on the RCE Water Resources Program and its educational opportunities, please visit http://water.rutgers.edu/.

Stormwater Management in Your Backyard

This program provides in-depth instruction on stormwater management. It introduces the factors that affect stormwater runoff, point and nonpoint source pollution, impacts of development (particularly impervious cover) on stormwater runoff, and pollutants found in stormwater runoff. An overview of New Jersey's stormwater regulations is presented including who must comply and what is required. Additionally, TMDLs are introduced along with various other requirements of the Federal Clean Water Act that have serious implications on New Jersey. Different types of best management practices (BMPs) are presented and how these BMPs can be used to achieve the quality, quantity and groundwater recharge requirements of New Jersey regulations are illustrated. BMPs discussed include bioretention systems (rain gardens), sand filters, stormwater wetlands, extended detention basins, infiltration basins, manufactured treatment devices, vegetated filters, and wet ponds.

The program also discusses various management practices that homeowners can install including dry wells, rain gardens, rain barrels, and alternative landscaping. Protocols for designing these systems are reviewed in detail with real world examples provided. A step by step guide is provided for designing a rain garden so that homeowners can actually construct one on their property. Students have an opportunity to bring in sketches of their property for review and discussion of various BMP options for each site. The course also provides a discussion of BMP maintenance focusing on homeowner BMPs. The course concludes with a discussion of larger watershed restoration projects and how students can lead these restoration efforts in their communities. The course is very interactive and ample time is set aside for question and answer sessions.

Environmental Stewards Program

RCE partnered with Duke Farms in Hillsborough, NJ to create a statewide Environmental Stewardship certification program. Participants learn land and water stewardship, BMPs, environmental public advocacy, and leadership. Each group meets twenty times for classroom and field study. They are taught by experts from Rutgers University and its partners. Students are certified as Rutgers Environmental Stewards when they have completed sixty hours of classroom instruction and sixty hours of a volunteer internship. Classes are held throughout New Jersey including at the Essex County Environmental Center in Roseland, Duke Farms, and the Rutgers EcoComplex in Bordentown, Burlington County. Partners ask students to provide volunteer assistance to satisfy their internship requirements.

Graduates of this program become knowledgeable about the basic processes of earth, air, water and biological systems. They gain an increased awareness of techniques and tools used to monitor and assess the health of the environment. They gain an understanding of research and regulatory infrastructure of state and federal agencies operating in New Jersey that relate to environmental issues. Unlike some programs, they are also given an introduction to group dynamics and community leadership. Participants are taught to recognize elements of sound science and public policy while acquiring a sense of the limits of our current understanding of the environment. The goal of the Rutgers Environmental Stewards program is to give graduates knowledge to expand public awareness of scientifically based information related to environmental issues and facilitate positive change in their community.

New Jersey Watershed Stewards Program

The statewide program New Jersey Watershed Stewards (NJWS) was developed by the RCE Water Resources Program in 2009. The idea of the NJWS program was developed as a result of the Water Resources Program faculty and staff attending the National Water Conference in St. Louis in February 2009. The Water Resources Program faculty and staff learned about the successful Watershed Stewards programs of other states, such as Maine and Texas. The success of these programs inspired the Water Resources Program faculty and staff to develop a Watershed Stewards program for New Jersey.

The NJWS program is designed to raise awareness and empower stakeholders to solve problems of nonpoint source pollution in watersheds throughout New Jersey. As part of the NJWS program, stakeholders complete in-class training as well as participate in a watershed-scale apprenticeship in order to obtain the title of a "New Jersey Watershed Steward." Inducted stewards become instrumental in continuing participation in watershed projects in New Jersey and improve the water quality of New Jersey watersheds.

The first NJWS program was offered in spring 2010 at the Rutgers EcoComplex located in Bordentown, New Jersey. The program includes four modules: one on the NNJWS program, the second on watershed definition and classification, one on watershed impairments, and a final one on watershed approaches and solutions to watershed impairments. In addition to these modules, class activities are implemented to engage trainees in the program. Upon completion of a one day training program, trainees are required to participate in a NJWS apprenticeship project where they will participate in a watershed-scale project (e.g., installing rain gardens, visually assessing streams, assembling rain barrels, etc.).

The goals of the NJWS program are to increase stakeholder involvement in Watershed Protection Plan and/or TMDL development processes by educating and organizing local citizens; promote healthy watersheds by increasing citizen awareness, understanding, and knowledge about the nature and function of watersheds, potential impairments, and watershed protection strategies to minimize non-point source pollution; enhance interactive learning opportunities for watershed education across the state and establish a larger, more well-informed citizen base; empower individuals to take leadership roles involving community and watershed level water resource issues; integrate watershed assessment research, education, and extension; and, deliver local solutions to community and watershed level water resource issues.

Additional Education Programs

The educational programs described above are on-going opportunities for residents, landscape professionals, and other concerned stakeholders and are applicable to the Upper Cohansey River Watershed. In addition to these opportunities, education programs specific for the needs addressed in this Watershed Restoration and Protection Plan are Decentralized Wastewater Treatment Outreach and Education and Nursery Operations Best Management Practices Outreach and Education. Additional information regarding these two educational opportunities for the Upper Cohansey River Watershed is given in Appendix B.

Decentralized Wastewater Treatment Outreach and Education

During this study, it became apparent that many areas within the Upper Cohansey River Watershed service their wastewater onsite, with septic systems. These systems themselves are not the primary concern, but it is the fact that older systems that are failing may still be in place and may not have been detected. Failing onsite wastewater treatment systems have the ability to emit not only bacteria and associated viruses, but may also contribute to the excess nutrient pollution within a watershed. Education and outreach would be conducted with homeowners to describe proper maintenance and operation of their septic systems.

Nursery Operations Best Management Practices Outreach and Education

Many agricultural areas throughout the Upper Cohansey River Watershed are nurseries providing vegetation for landscapers, homeowners, or other property owners. The acreage devoted to nursery production is relatively stable and should be fairly resistant to erosion but additional practices such as covering with weed cloth, using gravel or shells to keep soil in place, and growing cover crops. Targeted efforts on these properties would be to inventory nursery operations in the watershed and provide them with manuals describing agricultural management practices to reduce erosion, manage fertilizer use, and provide information in irrigation options (see Appendices C and D for these manuals).

Interim Measurable Milestones

Development of this Watershed Restoration and Protection Plan is the result of analyzing previously collected data, collecting 300 water quality samples and several biological samples, gathering input from local stakeholders, and modeling the watershed. This multi-year and multi-step process is based on data collected in the spring, summer, and fall of 2006 and follow-up field work completed in 2007 and 2008. It is expected that since the time of data collection, some conditions in the watershed may have changed, either benefiting water quality or worsening conditions.

With this in mind, projects that have been identified are expected to have the most effective impact on water quality in the Upper Cohansey River Watershed. This Watershed Restoration and Protection Plan was developed using a holistic perspective, recommending projects and implementation efforts that will benefit local water quality beyond just what is mandated by TMDLs, including other parameters that may have yet been identified as impairing the watershed.

Projects that involve cessation of human-related pathogens are clearly the top priority, followed by all pathogen management measures, erosion and sedimentation concerns, and low cost-high benefit projects. It should be noted that many of these projects will entail several years of implementation before a project fully achieves its goals. Therefore, it is important that this Watershed Restoration and Protection Plan remain dynamic and its implementation an evolving process. Regular meeting with municipalities, counties, and stakeholder groups should be held to solicit information on the ever-changing needs of the watershed so additional projects can be added to this plan and targeted to those expressed needs. This document should be consulted during the decision-making process for municipal and county governments as they proceed to plan for growth, keeping watershed protection and water resource protection an utmost priority.

Monitoring Component

Implementation of management measures will result in water quality improvements while minimizing flooding, promoting groundwater recharge or reuse, and other benefits. Both modeling and monitoring can be conducted to quantify these improvements.

Monitoring can be conducted to also quantify the improvements to the Upper Cohansey River and its watershed that result from implementation of this plan. NJDEP does maintain four benthic macroinvertebrate stations on the Upper Cohansey River (Figure 12). These stations can provide continued information on improvement of water quality and its effects on aquatic biota. Moreover, water quality samples can be collected at established stations throughout the system and analyzed for various pollutants that are a concern within the watershed, such as nutrients and bacteria. These stations include the USGS gauge located at the outlet of the Upper Cohansey River Watershed (Figure 1). Suggestions for monitoring can be found in the descriptions of individual BMPs described in Appendix B.

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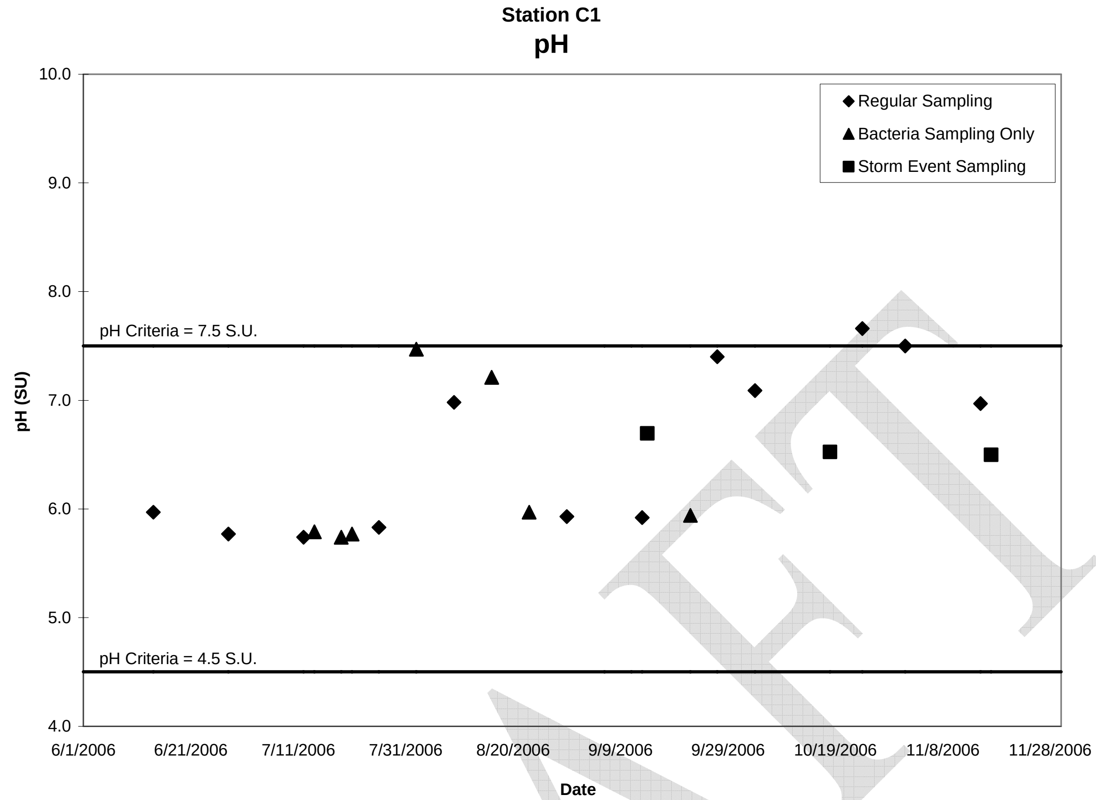
APPENDIX A: PRESENTATION OF pH IN-STREAM CONCENTRATIONS IN GRAPHS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Bacteria Sampling Only
Storm Event Sampling
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pH (SU)
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9.0
8.0
7.0
6.0
5.0
4.0
6/1/2006
6/21/2006
7/11/2006
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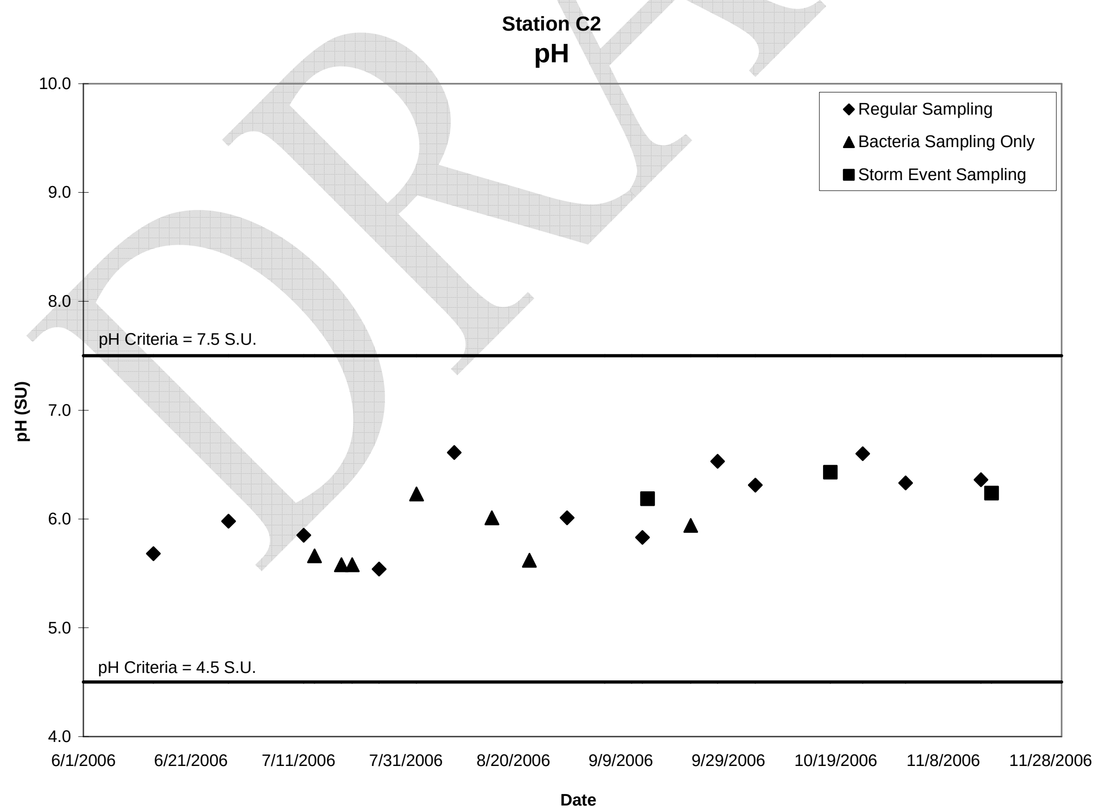
11/8/2006
11/28/2006
Date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Regular Sampling
Bacteria Sampling Only
Storm Event Sampling
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pH Criteria = 4.5 S.U.
pH (SU)
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9.0
8.0
7.0
6.0
5.0
4.0
6/1/2006
6/21/2006
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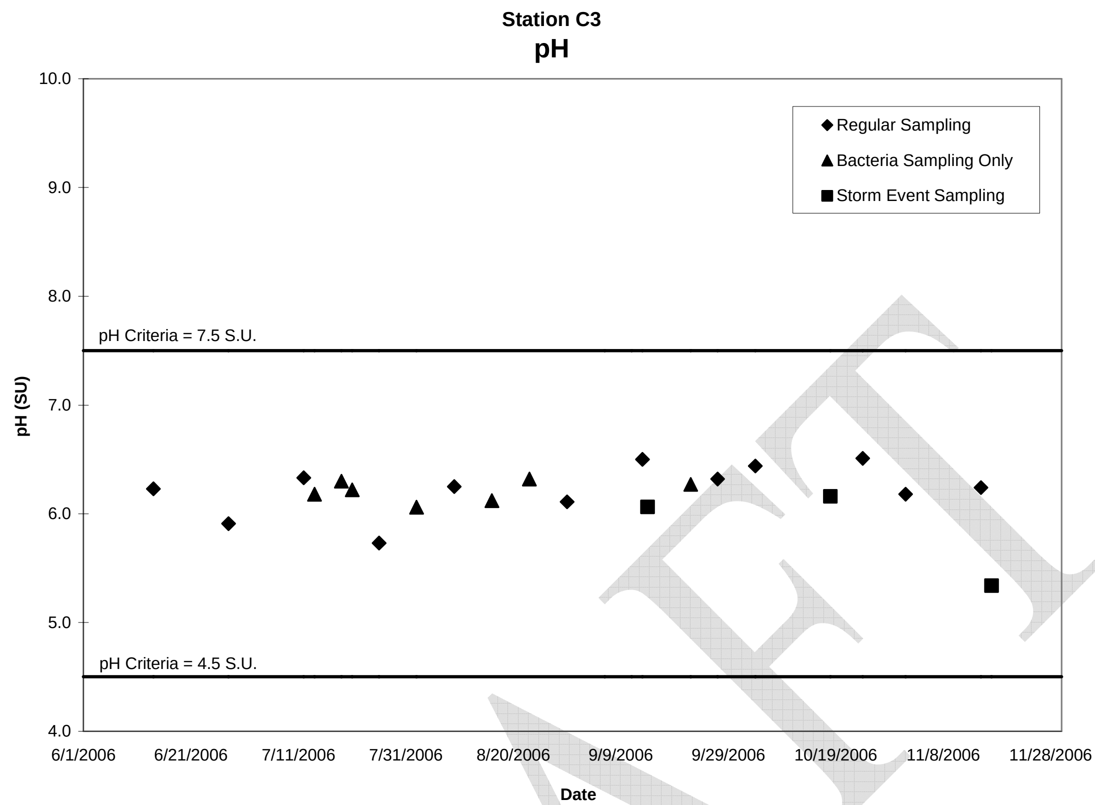
11/8/2006
11/28/2006
Date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Bacteria Sampling Only
Storm Event Sampling
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8.0
7.0
6.0
5.0
4.0
6/1/2006
6/21/2006
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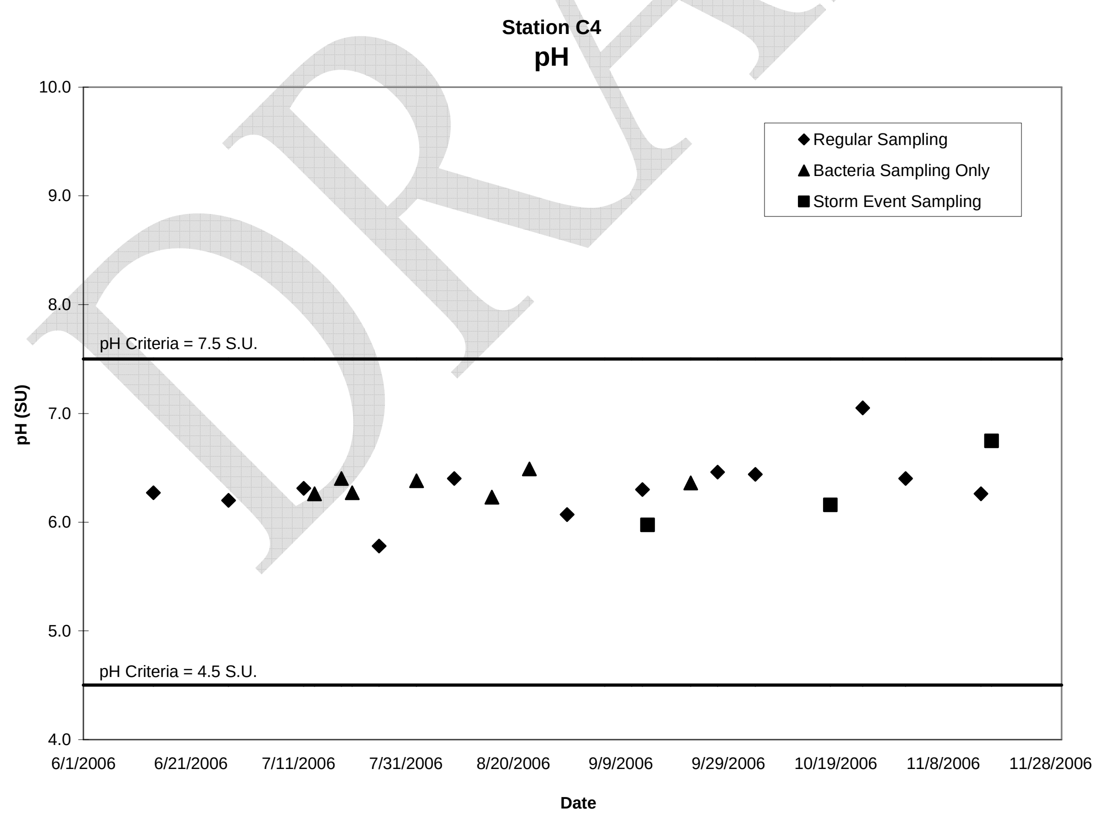
11/8/2006
11/28/2006
Date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7.0
6.0
5.0
4.0
6/1/2006
6/21/2006
7/11/2006
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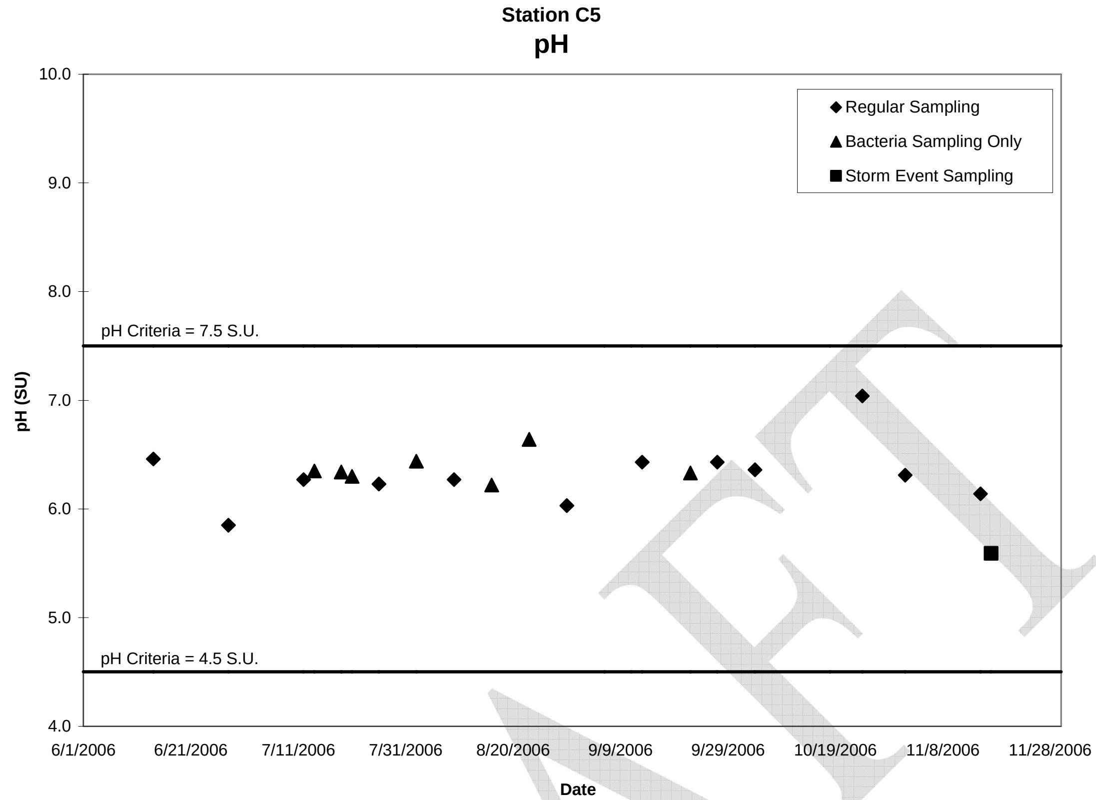
11/8/2006
11/28/2006
Date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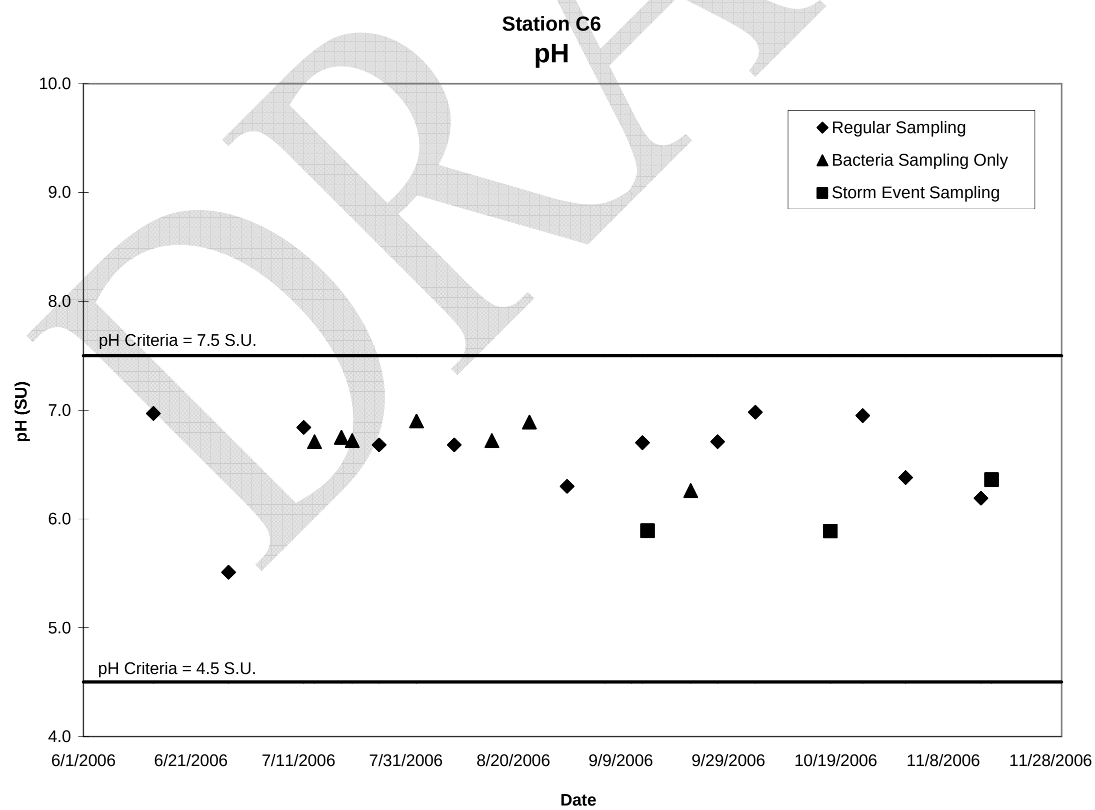
Regular Sampling
Bacteria Sampling Only
Storm Event Sampling
pH Criteria = 7.5 S.U.
pH Criteria = 4.5 S.U.
6/1/2006
6/21/2006
7/11/2006
7/31/2006
8/20/2006
9/9/2006
9/29/2006
10/19/2006
11/8/2006
11/28/2006
Date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4.0
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Bacteria Sampling Only
Storm Event Sampling
pH Criteria = 7.5 S.U.
pH Criteria = 4.5 S.U.
6/1/2006
6/21/2006
7/11/2006
7/31/2006
8/20/2006
9/9/2006
9/29/2006
10/19/2006
11/8/2006
11/28/2006
Date

APPENDIX B: IMPLEMENTATION PROJECTS TO ADDRESS KNOWN WATER QUALITY IMPAIRMENTS IN THE UPPER COHANSEY RIVER

Sewer Infrastructure Repair in the Parsonage Run Subwatershed

Current Conditions

Based on feedback received from Upper Deerfield Township, sanitary sewers dating back to earlier than the 1940's are leaking in the Seabrook region of the Township. This region of town is serviced by the Cumberland County Utilities Authority (CCUA), and a decrease in volume of wastewater to the treatment plant has raised attention to this engineering and public health problem. This area of the watershed falls within subwatershed FR1, where coliform counts have been as high as 8,000 col/100mL (Figure B-1). Sewer lines were replaced in the 1990's in some sections of this high density residential area (Figure B-2); however, easement issues and funding have prevented the final sections of pipe to be replaced and repaired. More than 20 homes could be discharging wastewater to a failing sewer line. Furthermore, nitrogen loading in this watershed is extremely high compared to loadings documented by other researchers (Mostaghimi *et al.*, 1997); this can also be considered a public health risk since the residents of the watershed rely on private wells for drinking water.

On two dates, water quality samples were collected immediately downstream of this high density residential development at two locations (PR1 and FR2) in addition to downstream monitoring at FR1 on Parsonage Run. Fecal coliform results were non-detect and at or below surface water standards at all locations (Figure B-3). Given the infrastructure issues, these fecal results are relatively low. However, these stations were only monitored on two occasions and are deemed as inconclusive evidence of the impacts of failing infrastructure on Parsonage Run water quality.

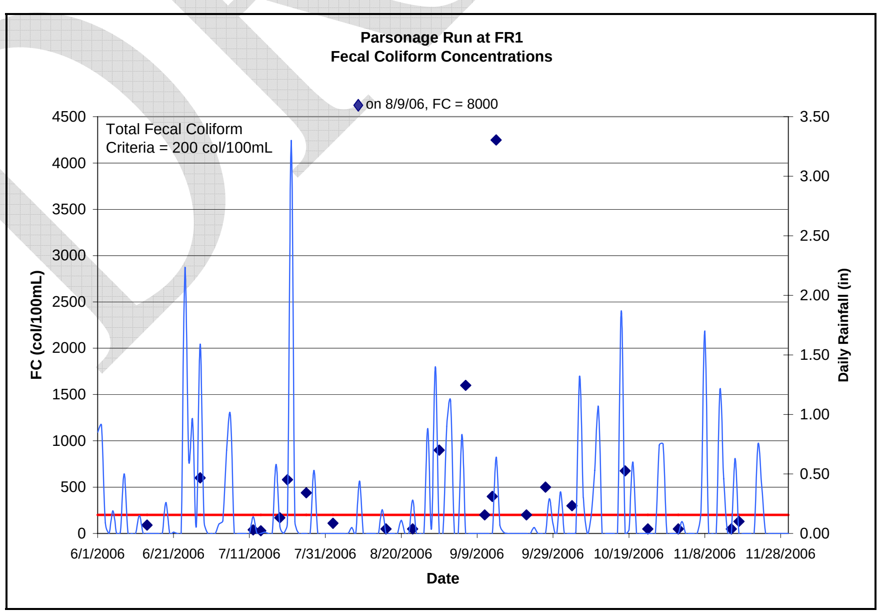

Figure B-1: Fecal coliform results at FR1 and precipitation patterns.

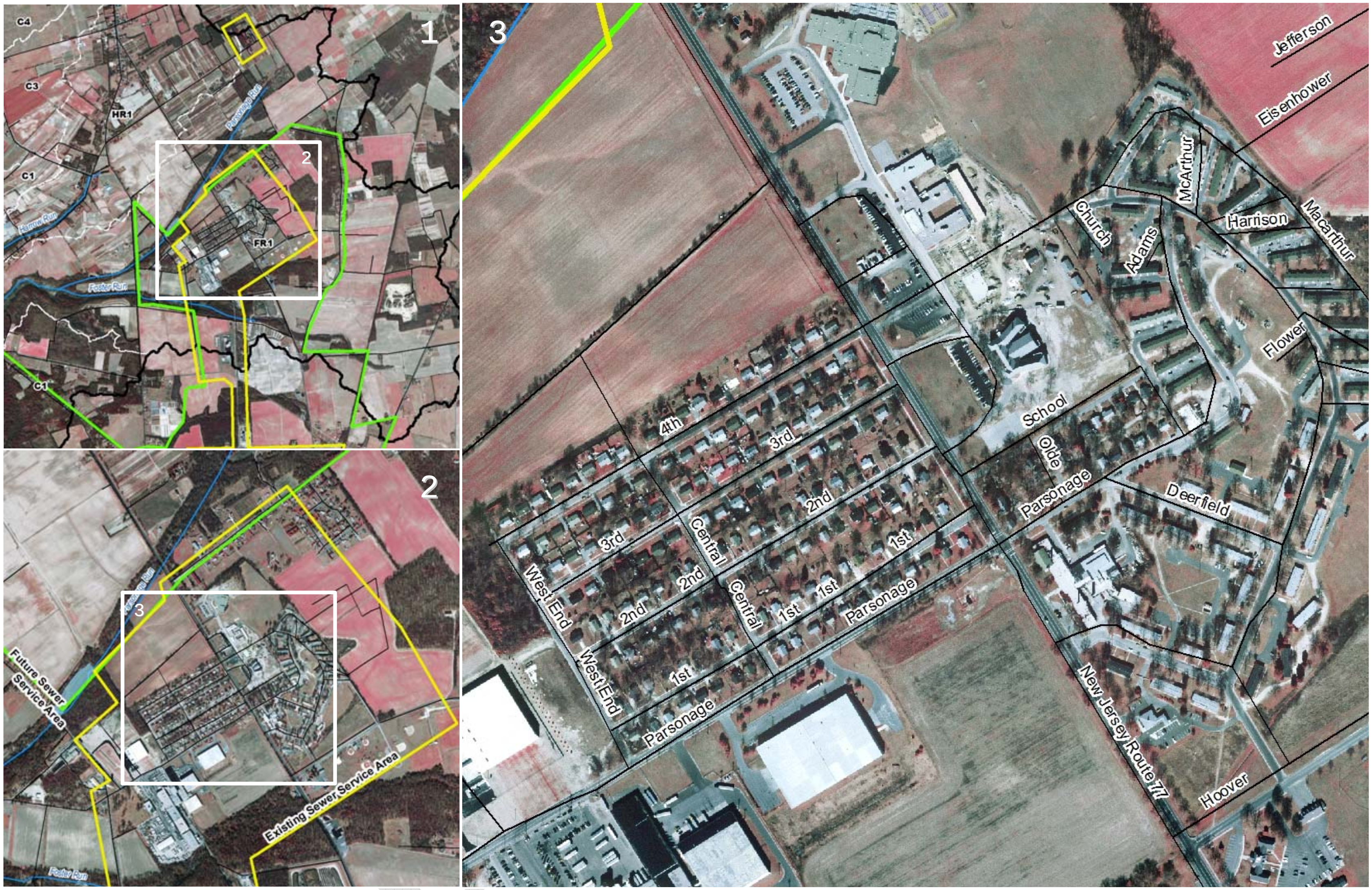

Figure B-2: Region of Upper Deerfield (FR1 subwatershed) with infrastructure failure.

	Fecal Coliform Monitoring Results (orgs/100mL)	
	10/24/2006	11/1/2006
FR1	ND	ND
FR2	100	200
PR1	ND	100

ND refers to < 100 orgs/100mL

Figure B-3: Monitoring locations downstream of failing infrastructure and fecal coliform results.

Implementation

Upper Deerfield started repairs to this sewer pipeline in late 2009 with grant support from the New Jersey Small Cities Community Development Block Grant, a funding source administered by the NJ Department of Community Affairs and from the US Department of Housing and Urban Development. With replacement of the failing infrastructure, it is believed that much of the pathogen and TP pollution will be removed from this subwatershed area, which is a subwatershed that highly impacts the final watershed discharge at the USGS gauging station.

Raw sewage is typically in the magnitude of 10^6 – 10^7 col/100mL for fecal coliform (Metcalf and Eddy, 1991; Overcash and Davidson, 1980). Since these densities are not corroborated by our water quality monitoring data, it can be concluded that die-off and other mechanisms may be at work, limiting the transport of pathogens from the Seabrook area to the monitoring station at FR1. It is not possible to predict the benefits that fixing this sewer line will have on the monitoring station; however, fixing the sewer line will decrease pathogen concerns in this subwatershed, as well as public health-related issues.

Post Construction Monitoring

Since improved water quality management in this subwatershed will have a definitive impact on water quality at the USGS gauge below Seeley Lake, it is recommended that water quality continue to be monitored on Parsonage Run at PR1 and on Foster Run at FR1 and FR2. Monitoring should target both wet and dry weather samples and should occur five (5) times per month in June, July, and August following the pipeline repair in order to determine that the infrastructure functions properly. Stream discharge at all locations should be measured, and laboratory analyses should be conducted for fecal coliform, *E. coli*, total nitrogen, and TP.

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Decentralized and Centralized Wastewater Management Options along the East Shore of Seeley Lake

Current Conditions

The current sewer service area for the Cumberland County Utilities Authority extends only to Columbia Highway and Finley Road in Upper Deerfield, just south of Seeley Lake. Outside of the sewer service area, between Seeley Road and Seeley Lake, are several large residences along the pond's shoreline (Figure B-4). Given that there is no sewer service in this area, it can be deduced that wastewater from these homes is serviced by a septic system or a cesspool. There are wastewater concerns that should be addressed along this waterbody:

- Several of these properties are narrow, with homes set close to the road. The front and side areas of the homes are limited for space for septic system disposal; therefore, if a disposal field does exist, it must be along the lake.
- A property across from the lake on the other side of Seeley Road has a mounded septic system. This need for a mounded system is evidence of a high water table in this area, which leads to failure in a traditional septic system and poses immediate health risks. Properties along the shoreline must also be within the high water table extent and experiencing leach field failure.

This region of the watershed is within subwatershed C1, which terminates at the USGS gauging station below Seeley Lake. Water quality at C1 exceeded the former water quality standard for fecal coliform on five monitoring events and had results as high as 2,000 col/100mL. Moreover, 40% of the MST samples collected and analyzed contained human-related *Bacteroides*. There are few other areas in this subwatershed that could be contributing to human-related pathogen contamination discovered during monitoring. Considering the vulnerability of septic systems and cesspools along the shoreline and the risk to surface water in close proximity, it has been determined that improving the current wastewater management strategy along Seeley Road is a priority for pathogen and TP control in the Cohansey River. This may include funding for alternative treatment units or extending sewer service lines to this region.

Figure B-4: Seeley Lake and its spillway to the Cohansey River.

Implementation

With the sewer service area extended to this region of Upper Deerfield, it is believed that pathogen pollution exhibited in this watershed will be greatly reduced, allowing the Cohansey River to more fully meet the requirements of its designated uses. If extending the sewer line is excessively costly or will promote unwanted growth in Upper Deerfield, then alternative treatment systems should be considered. Due to limited space on the properties for adsorption fields, other systems that require less absorption field area are viable options. These include aerobic pre-treatment units or recirculating sand filters. With the installation of new, working alternative units, nutrients and pathogens released from the failing septic systems will be removed. Cycling of phosphorus within the lake, however, will continue to impact water quality at the USGS gauge long after septic systems discontinue releasing high nutrients.

State revolving funds could be an option for the Township of Upper Deerfield and could expedite extending sewer service areas. The Environmental Infrastructure Trust Financing Program offers traditional financing at a rate as low as 2.13%. As for alternative treatment units, Upper Deerfield can utilize the state revolving fund to provide low interest loans to homeowners to replace failing septic systems or cesspools. Repayment of this loan can be extended over a 20-year period and paid back as part of a tax assessment on the property. More information on state revolving funds and this financing option can be found at www.njeit.org. The Environmental Infrastructure Trust specifically has stated its commitment to solving septic management issues in New Jersey (NJEIT, 2008).

Post Construction Monitoring

Following extension of sewer service to Seeley Road for the portion parallel to the shoreline of Seeley Lake or installation of alternative treatment units, water quality should be collected at monitoring station C1. Data collection at this location can be less frequent because of the USGS gauging station 01412800 at the same location on the Cohansey River. Fecal coliform and *E. coli* should be monitored, as well as TSS, TP, and nitrogen. *In situ* parameters should also be monitored. It is recommended that samples be collected year-round one time per month, except in June, July, and August when samples should be collected five times per month for fecal coliform and *E. coli*.

References

New Jersey Environmental Infrastructure Trust, 2010, *Other Projects*. http://www.njeit.org/otherprojects.htm, Last updated January 28, 2010.

Nursery Operations Best Management Practices Outreach and Education

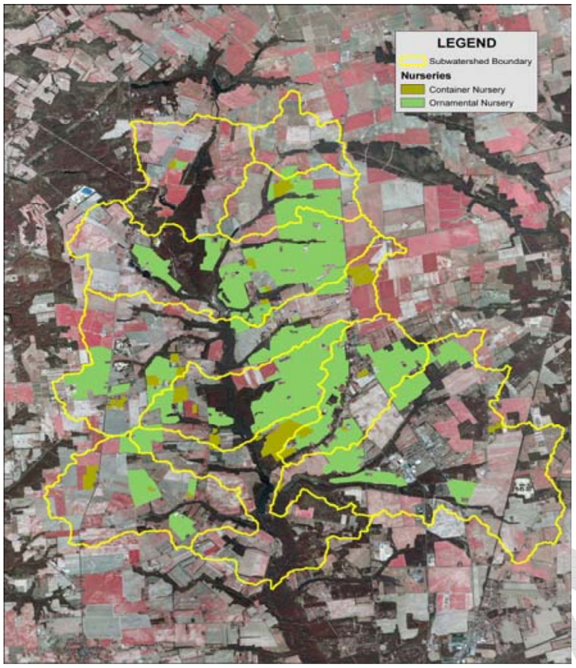


Figure B-5: Location of nursery operations.

Current Conditions

A large portion of the agricultural lands within the Upper Cohansey River Watershed are nursery operations (Figure B-5). Most of the acreage devoted to nursery production is relatively stable and should be fairly resistant to erosion. Practices currently protecting nursery lands include production areas and roads covered with weed cloth, gravel, or shells (Figure B-6). Additionally, grass strips between beds (Figure B-7), and tailwater recovery basins that collect stormwater runoff should prevent movement of sediment in most cases (Figure B-8).

Figure B-6: Nursery with weed cloth and gravel to reduce runoff and erosion.

One area in particular for education is in the promotion and use of cover crops as a means of erosion control. Cover crops act to hold soils in place and prevent their loss from surface runoff. In addition, they have the capability to reduce flow rates of runoff and lower the concentration of pollutants found within this runoff.

A second area for education is in water reuse. Overdevest Nurseries in Bridgeton, NJ provides an excellent example of how the nursery industry can maximize its water reuse. They have been reusing over 75% of their water since 2000 and continue to expand this practice rapidly approaching 100% reuse. Overdevest Nurseries could be used as a model upon which to build other systems in the Upper Cohansey River Watershed. Information regarding their systems, including initial and maintenance costs, sizing of systems, and ease of use, would be gathered and shared with other nurseries. Materials specific to these topics would be developed (if not already in existence) and incorporated into education programs.

A third area for education is the disconnection of impervious surfaces. Many green house roofs, roadways, and other impervious areas can be disconnected from flowing off-site and rerouted to a tailwater recovery system for reuse or simply directed to pervious areas for filtering and infiltration. This practice is very inexpensive and very effective at reducing stormwater runoff volumes for smaller storm events.

Implementation

Despite nursery acreage being protected from erosion, other management practices can affect phosphorus contribution to waterbodies from nurseries. Container and field nurseries will be surveyed with a peer-reviewed questionnaire (Newman et al., 2008) modified for applicability for New Jersey operations. This would document good agricultural management practices and determine if any deficiencies exist.

Agricultural management practice (AMPs) manuals developed by Rutgers New Jersey Agricultural Experiment Station for container and field nurseries would be distributed to operations in the watershed (Appendix C; Appendix D). A shorter quick reference guide would be created of these AMP Manuals for use in the field. Support could be given for studies further characterizing the contribution of nutrients to surface water bodies from nurseries, and for the further implementation of agricultural management practices where appropriate. Participation by nursery operators in this type of research, documentation, and implementation should be considered significant cost share on the part of the growers.

Figure B-7: Grass filter strips between rows of nursery plants.

Figure B-8: Basins collect runoff from nursery acreage.

This outreach campaign will begin with the operator's surveys to better understand the current AMPs (if any) being conducted at nursery areas in the watershed. Feedback from this survey will direct educational opportunities adapted and/or developed to aid in increasing the use of AMPs. The educational/outreach programs that are highlighted through the needs survey will be developed to target the nurseries of Cumberland and Salem Counties. Demonstration AMPs will be constructed at various nurseries throughout the watershed and used as educational tools for outreach programming.

Following this initial educational campaign, a web-based follow-up survey will be launched to identify the effectiveness of this outreach program. Results of this survey will be compared to original survey results and determine possible reductions in fertilizer and pesticide use. Newspaper articles will be written to announce the program's effectiveness, and a final implementation report will summarize the results of this work.

Estimated Project Costs

Completing the Homeowner Needs Survey:	$ 6,000
Production of Educational Programs:	$ 5,000
Publication of Educational Materials:	$ 5,000
Consultation with Nursery Operations:	$ 25,000
Construction of Demonstration AMPs:	$250,000
Outreach Workshops to Encourage adoption of AMPs:	$ 25,000
Survey of Program Effectiveness:	$ 6,000
Development of Implementation Report:	$ 3,000

The total direct cost of implementation is estimated at **$325,000**. This is the most significant land use in the watershed and this program will have a very substantial impact on improving water quality in the Cohansey River as well as the surrounding waterways.

Post Implementation Monitoring

As indicated above, post-implementation monitoring will be conducted as part of this implementation project. Success will be measured in terms of use of additional AMPs in the watershed and number of operators enrolled in the program. Success will also be measured by long-term correspondence with the nursery operators using these techniques.

This can be related to water quality using the USGS monitoring station 01482500, Cohansey River at Seeley Lake, or through addition monitoring of pre- and post-management of nursery lands. It is expected that improvement will be demonstrated through this monitoring. The USGS monitoring station would require no additional cost.

References

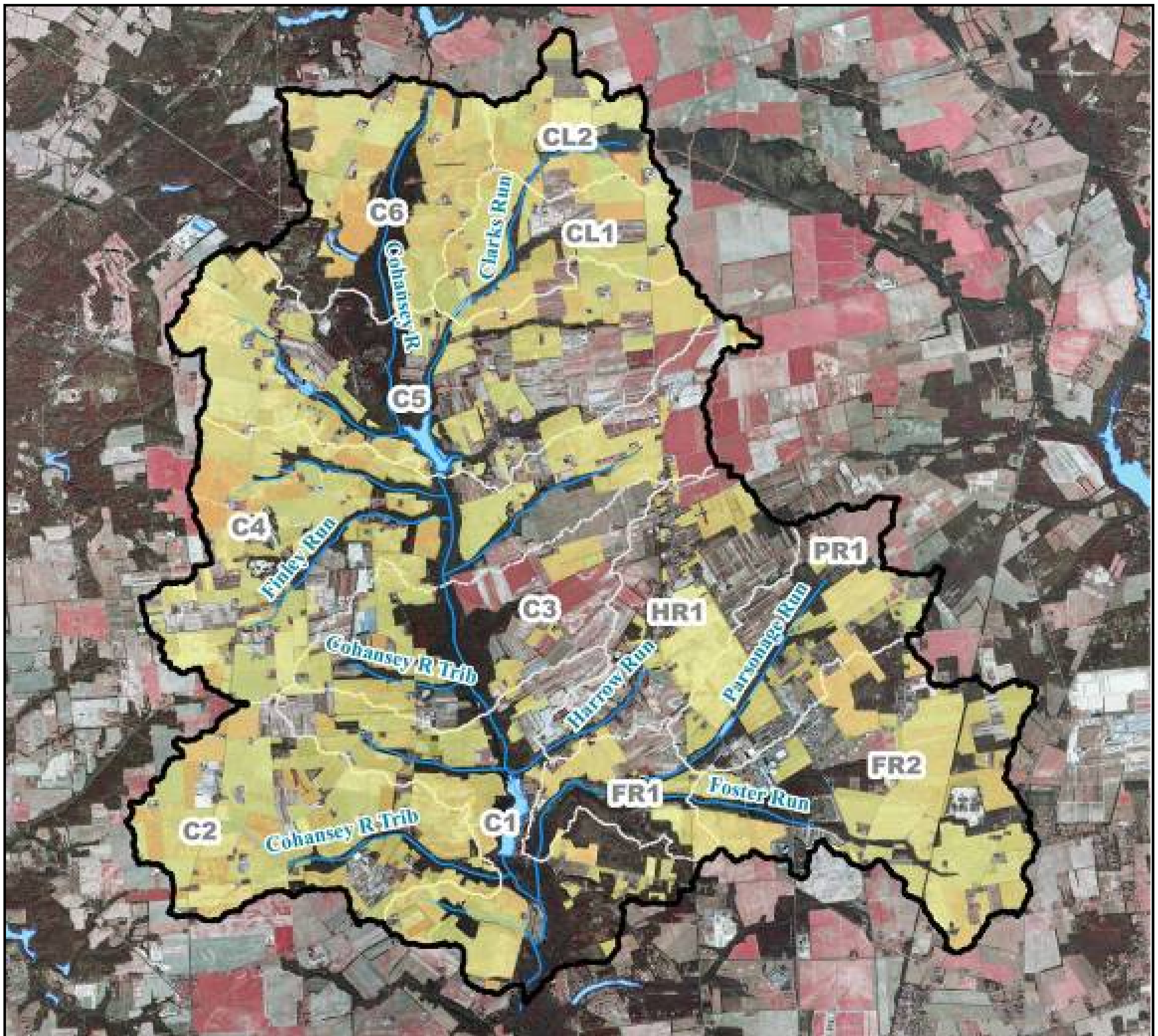
Newman, J., V. Mellano, K. Robb, and D. Haver, 2008, Conducting an environmental audit, Chapter 9. In Greenhouse and Nursery Management Practices to Protect Water Quality Univ. of Calif. Div. of Agric. and Nat. Resources. Publication 3508. Oakland, CA.

Minimum Till Drill Program

Current Conditions

Based on water quality monitoring data, suspended sediments are highly correlated with total phosphorus results; therefore, erosion has been highlighted as a major concern in all but one of the ten subwatersheds in the Upper Cohansey River Watershed. Due to the agricultural nature of the watershed (86% agriculture), low till, no till, and other till methods have been investigated as management options to reduce sediment loss on agricultural lands, such as the sediment loss from agricultural ponds (Figure B-9). According to feedback from the agricultural community, a minimum till drill used in bi-annual rotation is an effective tool to conserve valuable top soils, decrease erosion and transport of nutrients, and still produce a crop undiminished by a change in till methods. This is a realistic implementation opportunity that will be successful, according to the feedback received from the agricultural community in and around the watershed. Also, due to the large areas of the watershed covered by cropland and pastureland, this agricultural management practice has great potential to improve water quality and soil protection (Figure B-10).

Figure B-9: Turbid discharge from agricultural pond in the Upper Cohansey River Watershed.



Refers to cropland and pastureland agricultural land uses (NJDEP, 2007)

Figure B-10: Cropland and Pastureland Land Uses in the Project Watershed

Implementation

The project team proposes that two minimum till drills be purchased and housed at the Salem County RCE office. Farmers will be paid $15 per acre to utilize this equipment and participate as a partner in this minimum till effort. Farmers will have the option of using this equipment on an annual or biannual basis. The Salem County RCE office, Cumberland County RCE office, and Cumberland-Salem Conservation District (CSCD) will be responsible for providing advice and consultations with farmers to encourage this program's success and make this a positive, stronger relationship with landowners. Farmers' participation and feedback during this project will result in a document and final report that includes the following information:

- Comparison of crop yields from regular till to minimum till;
- Cost comparison of regular versus minimum till for fertilizers, pesticides, hours in the field, and equipment;
- Comments on equipment use, erosion control, and lessons learned.

This will be the first document of its kind specific for New Jersey farmers.

The final report will also include a photo log of regular till versus minimum till. An outreach campaign will also be developed and implemented that will include feedback from the agricultural community and feedback from those working in the minimum till program. The feedback and open discussions will lead to shared advice and increased production at a lower cost to farmers.

It is the goal of project partners that farmers will initially be paid for their participation in the data gathering process. After five years, equipment will be leased and maintained at the Salem County RCE office for those interested in utilizing minimum till on their properties.

Estimated Project Costs

Purchase of Two Minimum Till Drills:	$70,000 ($35,000 per unit for two units)
Equipment Maintenance Costs:	$10,000
Oversight of Operations/Feedback Surveys:	$75,000 ($15,000 per year for five years)
Payment for Farmer Participation:	$36,000
Water Quality Monitoring Costs:	$35,000
Outreach Program Materials:	$5,000
Final Report and Documentation:	$10,000

Total direct cost of this implementation project is **$241,000**.

Post Implementation Monitoring

Sampling stations used in this project will be monitored as farmers join the program in that particular subwatershed. Water quality monitoring should be conducted bi-weekly and during storm events and should include TSS and nutrients (nitrogen and phosphorus), as well as indicators of pesticide runoff. Water quality monitoring should initiate when the farmer agrees to participate and before fields are planted. Monitoring should continue for six months after planting.

Post-implementation monitoring will also include an analysis of buffer widths surrounding the till and minimum till fields, and water quality data's correlation to buffer width and health. This will ensure that appropriate buffer widths are being utilized to prevent pesticide runoff from harming nearby surface waters.

References

New Jersey Department of Environmental Protection (NJDEP), 2007, NJDEP 2002 Land Use/Land Cover Update, WMA-17. Trenton, NJ.

Vegetated Buffers

Current Conditions

Considering the amount of agricultural lands within the Upper Cohansey River Watershed, there are many opportunities for implementation of this agricultural buffer program. An ideal location for a vegetative buffer has been identified and is featured in Figure B-11. The thick orange line is the proposed vegetative buffer. Above that line is the drainage area to the vegetative buffer. The land use of the 25-acre drainage area treated by the proposed vegetative buffer strip is agriculture row crops and a small amount of greenhouse nursery land use. The site is located in the subwatershed HR1 which is classified as a priority subbasin for TP management and buffer implementation, as identified in the SWAT model developed for this project.

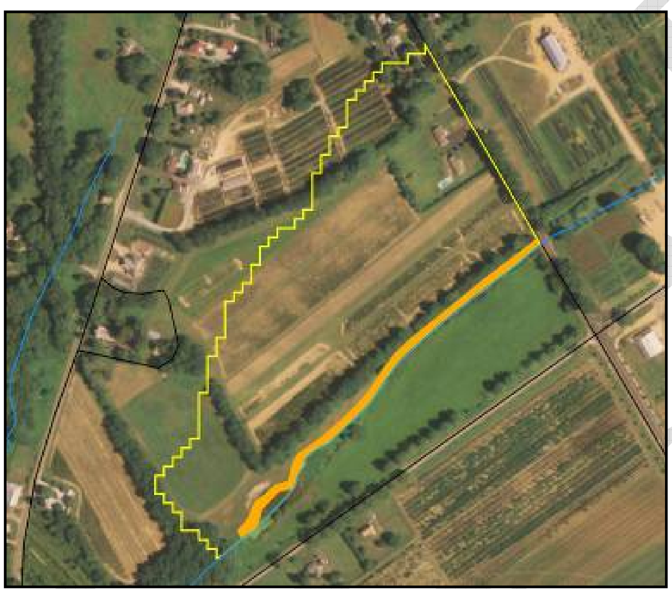


Figure B-11: Aerial View of Acres Treated by Agricultural Buffer Strip (USDA, 2006)

Description

A vegetative filter is an area designed to remove suspended solids and other pollutants from stormwater runoff flowing through a length of vegetation called a vegetated filter strip. The vegetation planted in a filter strip typically can be turf grasses, native grasses, herbaceous vegetation and woody vegetation, or some combination of these. It is important to note that all runoff to a vegetated filter strip must enter and flow through the strip as sheet flow. Failure to do so can severely reduce and even eliminate the filter strip's pollutant removal capabilities.

A vegetated filter is intended to remove pollutants from runoff flowing though it. Vegetated filter strips can be effective in reducing sediment and other solids and particulates, as well as associated pollutants such as hydrocarbons, heavy metals, and nutrients. The TSS removal rate for vegetative filters will depend upon the vegetated cover in the filter strip, but is reported to range from 60 to 80% (NJDEP, 2004). The pollutant removal mechanisms include sedimentation, filtration, adsorption, infiltration, biological uptake, and microbial activity. Vegetated filter strips have a removal rate of 30% for phosphorus and nitrogen (NJDEP, 2004). Vegetated filter strips with planted or indigenous woods may also create shade along water bodies that decrease aquatic temperatures, provide a source of detritus and large woody debris for fish and other aquatic organisms, and provide habitat and protective corridors for wildlife (Figure B-12).

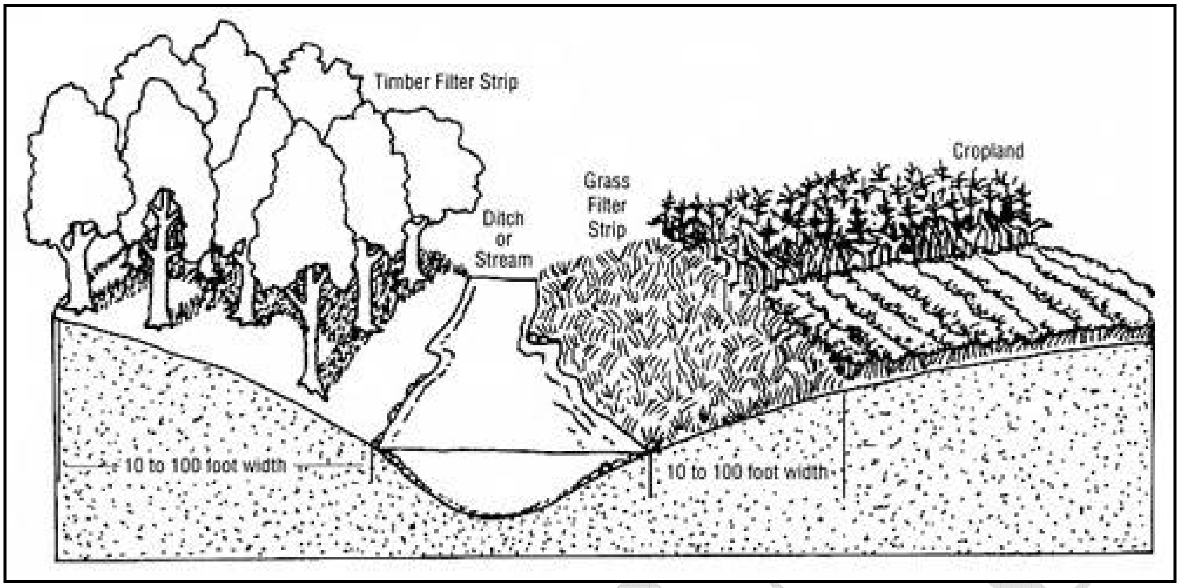


Figure B-12: Typical profile of a vegetated buffer in agricultural areas (FISRWG, 1998).

Location

Potential locations for vegetated stream buffers are found throughout the Upper Cohansey River Watershed (Figure B-13). The criteria used to determine each site are very simple; any portion of a stream or water body that was surrounded by agricultural land from the 2006 NJDEP aerials was chosen as a potential site for this BMP. This project could result in approximately 69,500 feet (13.2 miles) of additional vegetated buffer.

Implementation

The Cumberland-Salem Conservation District (CSCD) developed and implemented an agricultural buffer program, which installed 35 acres of vegetated buffers along agricultural lands in the Upper Cohansey River Watershed (Figure B-14). The program was very attractive to farmers for several reasons – the application and paperwork was not cumbersome, money was paid directly to the farmer in a timely manner, and seeds were provided for the buffer planting. The feedback from the farmer advisory committee about this program was always positive.

The agricultural buffer program developed by the CSCD paid landowners per acre to plant and maintain 30 foot wide agricultural buffers along fields to trap sediment and nutrients for an agreed upon number of years. The design of the CSCD program supplied the landowner with the seed mix for the vegetative filter strip and maintained communication with the landowners to ensure the success of the buffer.

Landowners involved in the program, appreciated the minimum amount of paper work, and waiting time for implementation and payment. Vegetative buffers are excellent management practices for agricultural areas because they require little space and are successful at controlling impacts of runoff.

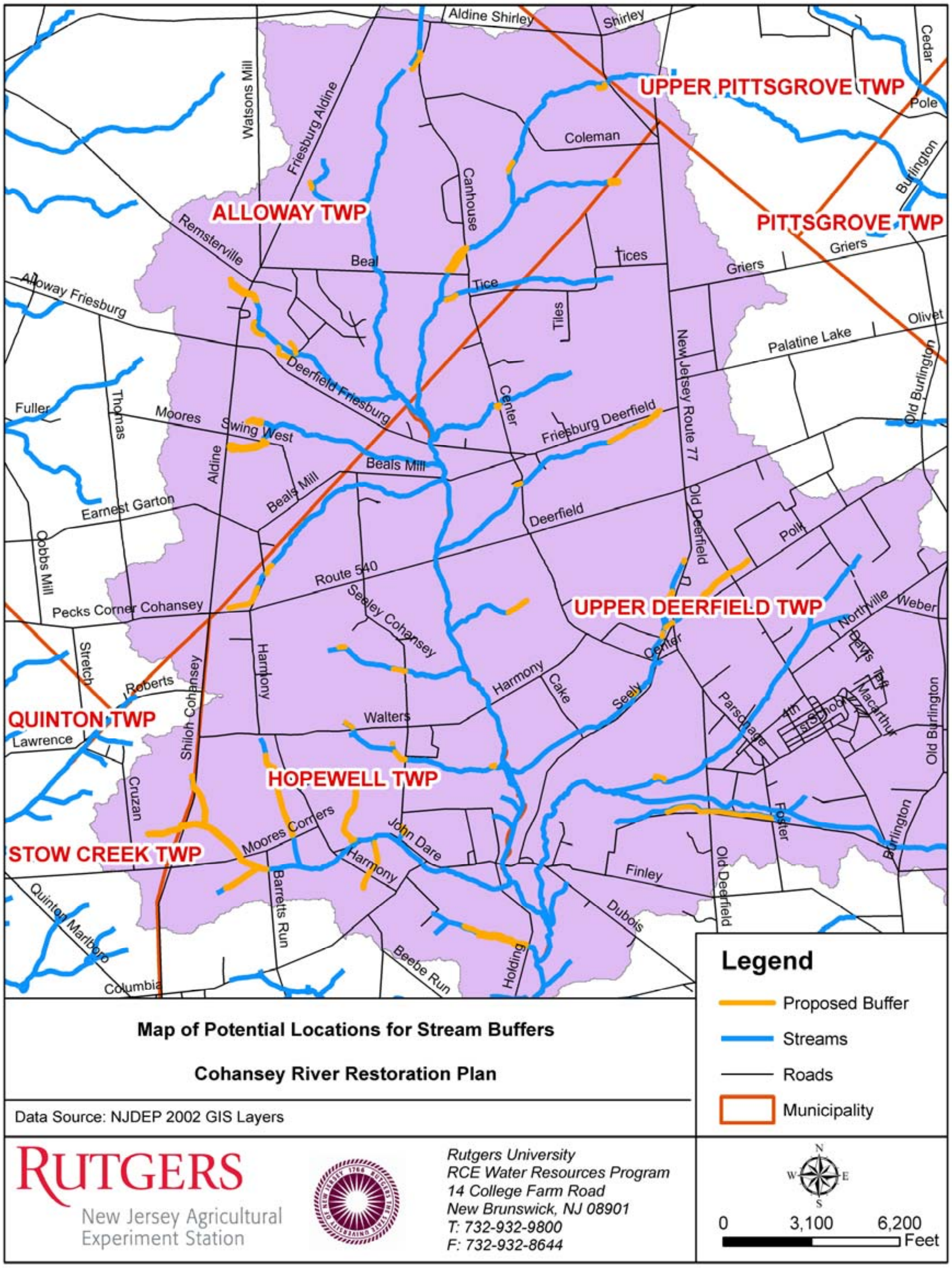


Figure B-13: Potential locations for vegetated buffers within the Upper Cohansey River Watershed.

A farmer who was interested in the program would apply to enter the program. The application included where the buffer will be, the existing slop of the land, and a proposed width of the buffer. After application is approved the farmer should be supplied with the appropriate amount of seed to create the buffer. The farmer will use the same practices that he or she uses for planting his or her crops to install the buffer. Clear the land of existing vegetation, plant the seed and allow time to grow. The agency that manages the program should be stay in contact with the farmer while he or she participates in the program and the status of the buffer should be checked from time to time to ensure the farmer is maintaining the buffer to allow it to function properly.

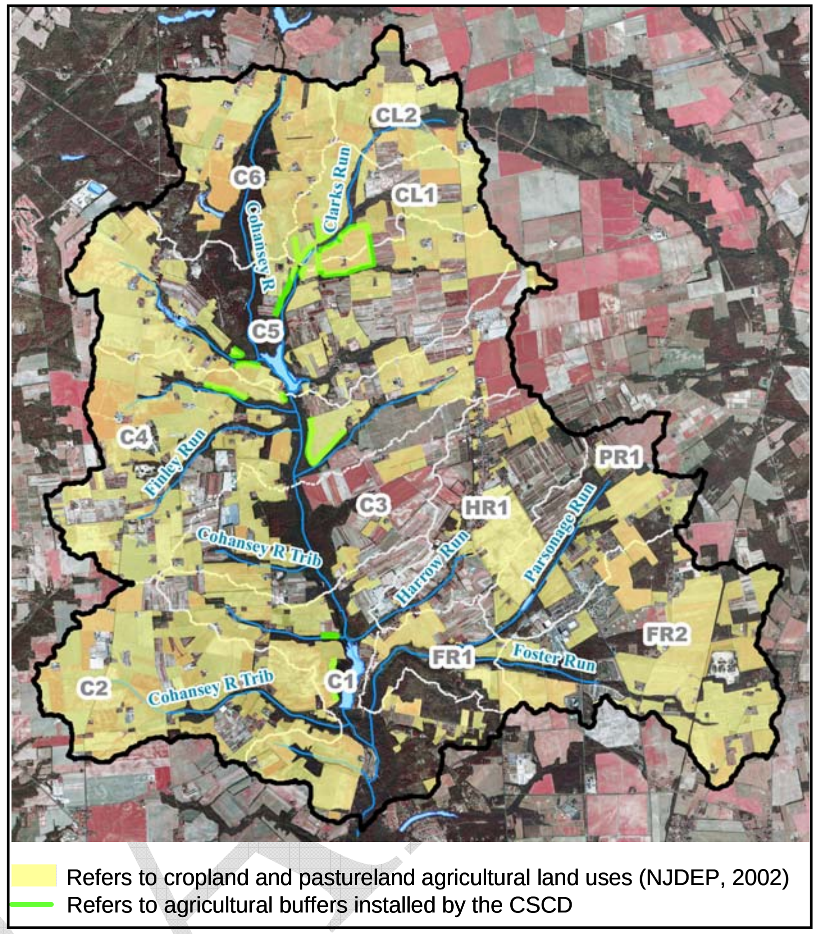


Figure B-14: Vegetated agricultural buffers installed by the CSCD.

This program should be started for the Upper Cohansey River Watershed as soon as possible.

Maintenance

Vegetated filter strips are expected to trap debris and sediment therefore they must be inspected for clogging and excessive debris and sediment accumulation at least four times annually and after every storm exceeding 1 inch of rainfall. Sediment removal should take place when the filter strip is thoroughly dry. Disposal of debris and trash should be done only at suitable disposal/recycling sites and must comply with all applicable local, state, and federal waste regulations. (NJDEP, 2004)

Mowing of filter strip must be performed on a regular schedule based on specific site conditions (typically once every six months is the minimum). Turf grass should be mowed at least once a month during the growing season. Vegetated stream buffers must be inspected at least annually for erosion and scour. Vegetated buffer areas should also be inspected at least annually for unwanted growth, which should be removed with minimum disruption to the planting soil bed and remaining vegetation. When establishing or restoring vegetation in the stream buffer, biweekly inspections of vegetation health should be performed during the first growing season or until the vegetation is established. Once established, inspections of vegetation health, density, and diversity should be performed during both the growing and non-growing season at least twice annually. All use of fertilizers, mechanical treatments, pesticides and other means to assure optimum vegetation health must not compromise the intended purpose of the vegetative filter. All vegetation deficiencies should be addressed without the use of fertilizers and pesticides whenever possible. All areas of the filter strip should be inspected for excess ponding after significant storm events. Corrective measures should be taken when excessive ponding occurs. (NJDEP, 2004)

Cost

The cost of this program and project in particular is from the filter strip program that existed in this watershed. It will cost $600 for seed, and administrative fees or about $0.42 per linear foot of a 30 foot wide strip. The farmers will be paid $200 a year to maintain each acre of filter strip or $0.14 per linear foot of a 30 foot wide strip.

Prioritization

This program is on a volunteer basis by the land owner. As shown by the involvement of farmers in the first round of vegetated buffers installed with the CSCD, there is a strong interest in willing participation with this form of water quality improvement. Priority sites will be chosen in cooperation with the CSCD.

Expected Results

Following the designs standards outlined in this document the vegetative buffers installed should remove 70% of the TSS in the runoff that it filters throughout the year and 30% of the nitrogen and phosphorus in the runoff. There is no removal rate of bacteria for vegetative filter strips, but it is fair to assume that the bacteria act as particles much like fecal coliform and the removal rate should be similar because the same mechanism expected to reduce TSS will reduce Bacteria.

References

Federal Interagency Stream Restoration Working Group (FISRWG), 1998, Stream Corridor Restoration: Principles, Processes, and Practices. GPO Item No. 0120-A; SuDocs No. A 57.6/2:EN3/PT.653. ISBN-0-934213-59-3.

New Jersey Department of Environmental Protection (NJDEP), 2002, NJDEP Aerial Photography of Salem County. Trenton, NJ.

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New Jersey Department of Environmental Protection (NJDEP), 2006, NJDEP Aerial Photography of Salem County. Trenton, NJ.

Decentralized Wastewater Treatment Outreach and Education

Current Conditions

Outdated systems, lack of maintenance, and improper use have been identified as reasons for failure of onsite wastewater treatment systems in this region. According to community feedback and discussions with local inspectors/pumpers, education is needed on how to maintain and care for decentralized treatment systems. Through partnership with county health departments, an effort will be undertaken to educate homeowners with support from municipalities, identification of appropriate public service announcements, and K-12 education materials. Also distribution of educational materials can be administered with the help of pumping/inspecting companies that operate in the watershed, tax mailers, and newspaper articles. Working with septic-related businesses in the watershed will help to correct misconceptions and misuse that are currently in practice at some residences.

Overall, the majority of the watershed's homeowners rely on septic for wastewater treatment (Figure B-15). It is estimated that more than 600 residences rely on septic systems and cesspools for wastewater treatment in the Upper Cohansey River Watershed. The USEPA reports that septic system failure rates typically range from 10-20%, which would be 61-121 residences per year dealing with septic system failure. Failure has been defined by the USEPA as wastewater ponding on the surface or backing up into the home (USEPA, 2002). In neighboring states such as New York, the reported failure rate is 4% (Nelson, Dix, and Shepard, 1999). With appropriate targeted education and availability of resources, this 4% failure rate could be achieved in the Upper Cohansey River Watershed, which would reduce the number of failing systems in the Upper Cohansey River Watershed to 24 systems, resulting in a significant reduction in pathogens and nutrients impacting surface waters. Currently, the pathogen load in the Upper Cohansey

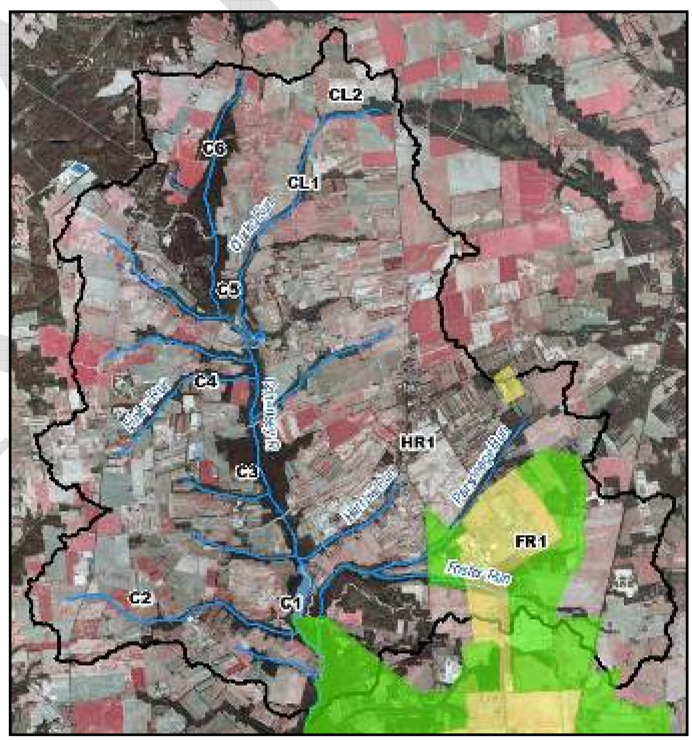

Figure B-15: Areas served by centralized wastewater treatment.

River ranges from 10^7 – 10^9 col/day during dry weather and 10^9 – 10^{11} col/day during wet weather.

Table B-2: Fecal coliform load per subwatershed based on 2006 water quality monitoring.

Individual Catchments	Dry Weather Mean FC Load	Wet Weather Mean FC Load
	col/day	*col/day*
C1	-4.70E+10	-4.08E+11
C2	2.54E+09	6.01E+10
C3	2.55E+10	2.92E+11
C4	7.10E+08	-2.03E+11
C5	1.11E+10	2.37E+11
C6	1.52E+09	7.07E+10
CL1	7.15E+07	2.27E+10
CL2	1.12E+09	7.90E+09
FR1	2.89E+10	4.47E+11
HR1	7.51E+09	7.75E+10

Septic systems from typical residential units will discharge 10^6 – 10^8 most probable number (MPN) of fecal coliforms per 100 mL (Bauer *et al.*, 1979; Bennett and Linstedt, 1975; Laak, 1975; Sedlak, 1991; Tchobanoglous and Burton, 1991), and a reported volume of wastewater from a toilet is 70 liters per person per day (Mayer *et al.*, 1999). Even with a failing septic system, unless the wastewater is being trenched illegally directly to the stream, the effluent will undergo some die-off naturally through soil infiltration and biological degradation. A worst-case scenario for water quality is pooled wastewater from a failing system mobilized by rainfall, entering the stream. This would result in effluent high in nutrients, pathogens and metals impacting local water quality.

In addition to water quality protection yielded from improved septic education and use, this project should engage municipalities in investigating management goals and opportunities. Management programs should be tailored to a municipality's capabilities, as well as their needs. Management programs typically are more stringent with increasing risks to public health and the environment. Management programs should include specific program goals, public education tasks, record management, technical guidelines for site evaluation, construction, and operation/maintenance, system inspections and maintenance monitoring, and may also include licensing and certification of inspectors, installers, and pumpers (USEPA, 2002). Consultation will be given to municipalities to identify their goals for decentralized management and approaches to reach those goals. Management, though initially difficult to discuss, is a long-term solution to decentralized wastewater problems, management will provide both a strategy and funding source for improving current conditions.

Implementation

This outreach campaign will begin with a homeowner survey to better understand the homeowners' understanding of how a septic system works and the care and maintenance required. Feedback from this survey will direct educational materials that are adapted and/or developed and methods used to effectively reach homeowners. Educational materials will be re-tooled or developed to fit the population's needs. If educational programs are highlighted through the needs survey, then an evening program will be developed to target the residents of Cumberland and Salem Counties.

Following this initial educational campaign, a web-based follow-up survey will be launched to identify the effectiveness of this outreach program. Results of this survey will be compared to original survey results. Newspaper articles will be written to announce the program's effectiveness, and a final implementation report will summarize the results of this work.

Estimated Project Costs

Completing the Homeowner Needs Survey:	$6,000
Adaptation and Development of Educational Programs:	$8,000
Consultation with Municipalities:	$5,000
Survey of Program Effectiveness:	$6,000
Development of Implementation Report:	$1,500

The total direct cost of implementation is estimated at **$26,500**, which includes production and distribution of educational materials tailored to meet the area's needs.

Post Implementation Monitoring

As indicated above, post-implementation monitoring will be conducted as part of this implementation project. Success will be measured in terms of improved understanding of working septic systems and number of homeowners educated. Success will also be measured by long-term correspondence with the septic inspectors and pumpers working in these communities.

This can be related to water quality using the USGS monitoring station 01482500, Cohansey River at Seeley Lake. It is expected that improvement will be demonstrated at this monitoring station, which requires no additional cost.

References

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Bioretention Basin and Vegetated Swale in the Harrow Run Watershed

Current Conditions

The land use of the 117 acres treated by the proposed bioretention basin and swale is agriculture row crops and field nursery. The proposed project site is located in the HR1 subwatershed, which has been identified as a priority subwatershed for TP management (Figure B-16). Currently, runoff from the nursery flows through a mowed grassed channel, but rapid flow and a bend in the channel are leading to erosive conditions and undercutting at the road (Figure B-17).

Figure B-16: Photograph of site.

Description

A bioretention system consists of a soil bed planted with native vegetation located above an underdrain sand layer. Bioretention can be in the form of a swale or a basin. A swale is a grassed channel that routes water from one point to another while the water is flowing over the swale it will infiltrate. A bioretention basin is a small depression in the ground that holds water in place while it infiltrates. Basins are sized to hold the runoff from one to five acres of land; they can be used in succession for drainage areas larger than 5 acres. Stormwater runoff entering the bioretention system is filtered first through the vegetation and then the sand/soil mixture before being conveyed downstream by the underdrain system or discharged to groundwater (Figure B-18). Runoff storage depths above the planting bed surface are typically shallow. The accepted TSS removal rate for bioretention systems is 90% (NJDEP, 2004).

Bioretention systems are used to remove a wide range of pollutants, including TSS, nutrients, metals, hydrocarbons, and pathogens from stormwater runoff. They can also be used to reduce peak runoff rates and increase stormwater infiltration when designed as a multi-stage, multi-function system. Bioretention systems have estimated removal efficiencies of 60% and 30% for TP and TN, respectively (NJDEP 2004). A bioretention column study found removal efficiencies averaging 91.5% for TSS and 91.6% for fecal coliform (Rusciano and Obropta, 2007).

The areas proposed for bioretention and swale installation are shown in orange on Figure B-17. This is an estimation from visual inspections of the natural and unnatural drainage of the site with existing stormwater controls. Runoff from row crops in the northeastern area of the site drains towards the three areas of proposed bioretention. Stormwater is then piped under the road and flows overland to the tailwater recovery pond. Visual inspections of the tailwater recovery pond indicate eutrophication even during cold weather, indicative of excessive nutrients discharging to the pond.

The Cohansey River Watershed typically has very porous soil, which is advantageous to this project, avoiding the need for construction of an underdrain in this bioretention retention system.

Figure B-17: Aerial View of Acres Treated (NJDEP, 2006)

Implementation

- Construction of bioretention systems can cost between $3 to $15 per square yard (Lake Superior, 2005). For the demonstration project outlined in this document, the cost would range from $20,000 to $100,000. This estimated cost is probably lower because there will be no underdrain in this system
- Potential Funding Sources:
  - NJDEP 319 (h) Grants (http://www.state.nj.us/dep/watershedmgt/319grant_sfy2005_projects.htm);
  - Watershed Institute Grants Program (http://www.thewatershedinstitute.org/resources/twig/);
  - Watershed Protection and Flood Prevention Program (http://www.nrcs.usda.gov/programs/watershed/);
  - Clean Water State Revolving Fund (http://www.epa.gov/owm/cwfinance/cwsrf/index.htm);
  - Infrastructure Trust Fund (http://www.njeit.org/).
- Checklist for construction:
  - Soil Erosion Sediment Control Permit (minimum of $820) available through the CSCD;
  - Heavy equipment to clear, excavate and re-grade site;
  - Plants (herbaceous plugs);
  - Soil stabilizing material (mulch or coconut or straw matting).

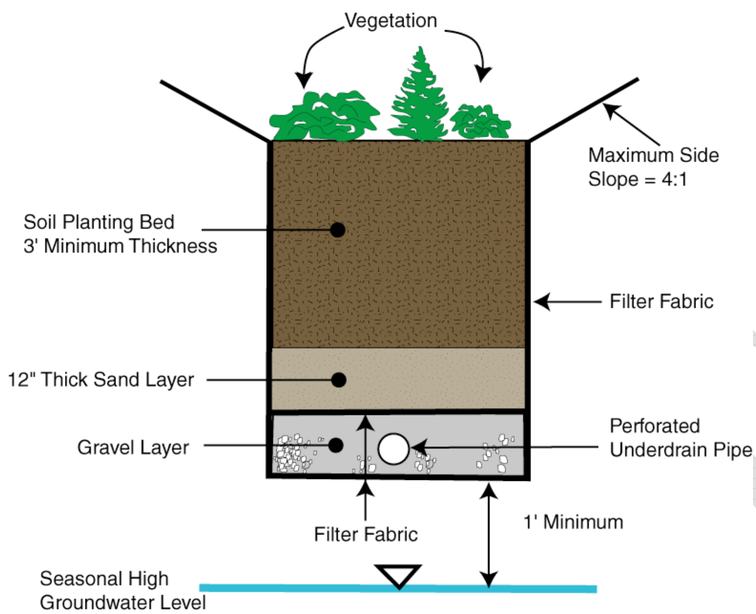

Figure B-18: Typical Profile of a bioretention system with optional underdrain system (NJDEP, 2004)

Post Construction Maintenance

Bioretention systems must be inspected for clogging and excessive debris and sediment accumulation at least four times annually as well as after every storm exceeding 1 inch of rainfall. Sediment removal should take place when the basin is thoroughly dry. Disposal of debris, trash, sediment, and other waste material should be done at suitable disposal/recycling sites and in compliance with all applicable local, state, and federal waste regulations. (NJDEP, 2004)

Mowing of bioretention system can be performed on a regular schedule based on specific site conditions (once every six months is the minimum). Grass should be mowed at least once a month during the growing season. Vegetated areas must be inspected at least annually for erosion and scour. Vegetated areas should also be inspected at least annually for unwanted growth, which should be removed with minimum disruption to the planting soil bed and remaining vegetation. When establishing or restoring vegetation, biweekly inspections of vegetation health should be performed during the first growing season or until the vegetation is established. Once established, inspections of vegetation health, density, and diversity should be performed during both the growing and non-growing season at least twice annually. All use of fertilizers, mechanical treatments, pesticides and other means to assure optimum vegetation health must not compromise the intended purpose of the vegetative filter. All vegetation deficiencies should be addressed without the use of fertilizers and pesticides whenever possible. The bioretention system should be inspected for excess ponding after significant storm events. Corrective measures should be taken when excessive ponding occurs (NJDEP, 2004).

The system's drain time should be evaluated after rain storms larger than 1". If the drain time is longer than 72 hours, they system needs to be evaluated to find a way decrease the drain time to at least 72 hours, which is the maximum drain time allowed by NJDEP (NJDEP, 2004).

References

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Detention Basin Retrofit Designs

Current Conditions

The Cohansey River Watershed has been listed in the New Jersey Integrated Water Quality Monitoring and Assessment Report, which includes the 305(b) Report and 303(d) List, as impaired for phosphorus, total suspended solids (TSS) and bacteria. Stormwater runoff from developed areas is a primary source of these pollutants. Although runoff from some developed sites is managed with detention basins, these systems are mainly designed to reduce downstream flooding and do little to address water quality. In most cases, detention basins can be retrofitted to enhance their pollutant removal capabilities and achieve water quality improvements.

Many of these detention basins can be altered or retrofitted to improve their ability to remove TSS and phosphorus loads from stormwater runoff and achieve water quality improvements. If these improvements are made correctly, they could improve water quality, as well as reduce maintenance costs. There are only a few detention basins in the Cohansey River watershed but they are found in subwatershed that has been identified as a significant source of pollution for the watershed. This document reviews several recommendations to improve the water quality of a detention basin's effluent. These recommendations can be incorporated into future designs of proposed detention basins because there is still development in the Cohansey River Watershed.

Detention Basin Retrofit Design Alternatives

The rainfall event used to analyze and design stormwater best management practices (BMPs) for water quality improvements is the "water quality storm" of 1.25 inches of rain over two hours. This storm can be used to compute runoff volumes and peak rates to ensure that stormwater quality BMPs, whether they are based on total runoff volume or peak runoff rate, will provide a standard level of stormwater pollution control. Since approximately 90% of storms in New Jersey are typically smaller than the water quality storm, BMP designs and retrofits that treat these small storms will have a significant impact on improving water quality in the watershed.

Low Flow Vegetated Channel

A common design feature for detention basins is a low flow concrete channel that carries runoff from the inlets to the outlet structure of the detention basin. This feature is intended to force water to quickly pass through the basin during small storm events to avoid ponding and maintenance issues. Due to sediment and debris accumulation in these channels and the lack of regular maintenance, these channels frequently tend to clog, causing ponding of water in the channel. The small stagnant ponds become ideal mosquito breeding habitat, thereby creating a problem they originally intended to avoid.

Low flow concrete channels act as an impediment to improving water quality in a detention basin. It is recommended to remove the concrete channel and replace it with a vegetated swale (see attached detail). The swale should have a 0.1% side slope to ensure easy maintenance and a slope not exceed 3%. The swale should be seeded with native grasses to minimize maintenance.

Where possible, replacement soils should be installed with the top 1.5 feet of soil composed of a bioretention soil mix to encourage infiltration (see detail). Below this infiltration media, a 6" layer of 3/4" diameter clean stone should be installed. The native vegetation in the swale should be cut once or twice a year.

Dense native vegetation creates friction along the flow path of runoff through the detention basin. This friction slows the water allowing sediment to settle out. Water will be held in the detention basin longer increasing infiltration and allowing the vegetation to take up nutrients carried in stormwater runoff. Finally, native vegetation that is allowed to grow taller will develop a deep root structure allowing a much greater infiltration rate than soil with short turf grass. The channel should be designed to infiltrate and pass water through within 48 hours after a storm to prevent mosquito breeding.

Low Flow Rip-Rap Channel

This design is similar to the vegetated channel but instead of vegetation, the channel is filled with rip-rap stone. The channel should not be any wider than 10 feet with the bottom at least three feet above the seasonal-high groundwater elevation. The channel should be designed to hold the runoff volume of the water quality storm from the detention basin's drainage area. The infiltration rate of the soil where the channel will be installed should be taken into consideration before sizing. The channel will infiltrate any storm equal to or smaller than the water quality storm within 48 hours.

When retrofits are installed, the concrete channel should be completely removed.

¾" Stone Filled Sock

Many municipalities are hesitant to remove the low flow concrete channel in detention basins. There is an alternative method that will yield similar results that requires alterations be completed for only a small section of the low flow concrete channel to work; the section is approximately 8" wide. Contractors can fill an 8" diameter sock with ¾" clean stone that is then set in the detention basin and surrounds the outlet of the detention basin. Any runoff must pass through the sock before it enters the outlet. Since, the v-shape of the low flow concrete channel will not allow the sock to rest on the bottom of the channel; water will be able to pass underneath the sock. Therefore, only a section as wide as the sock should be removed from the low flow concrete channel. This will ensure that all the runoff entering the basin must pass through the sock before it exits the basin.

The purpose of the sock is to acts a check dam in the basin. The stone filled sock will reduce the speed of the run off in the basin and promote more ponding of stormwater. This will provide the stormwater a larger contact area with the bottom of the basin promoting more infiltration and treatment. The stone-filled sock will act as a rough filter to removing sediment and nutrients attached to the sediment from the water column and allow to pond to slowly drain to the outlet structure. Higher flows will overtop the sock and make its way to the outlet structure, maintaining the flow control capacity of the basin.

<u>Native and Low Maintenance Grasses and Vegetation</u>

Detention basins with turf grass provide for minimal infiltration. Turf grass has a shallow root structure that does not open up the soil below the surface allowing water to infiltrate. By introducing native grasses and reducing the frequency of mowing from once a week to once or twice a year (in the winter), native grasses develop a deep root structure. The height of grass is directly proportional to the depth of the root structure. Limiting mowing and allowing the grass to grow taller will ensure development of a deep root structure. This method reduces maintenance costs due to less mowing and improves water quality through increases in infiltration and subsequent decreases in stormwater discharges to nearby waterways.

Additionally, many basins throughout New Jersey are over-compacted, thereby limiting their infiltration capacity. Although the root structure of native vegetation may increase infiltration rates, some of these over-compacted basins may need to be deep-tilled to loosen up the soil, and soil amendments may need to be added. Promoting infiltration in these basins is important to improve water quality in the watershed.

Location

Only four detention basins are to be located within the Upper Cohansey River Watershed (Figure B-19).

Implementation

The modifications of the detention basins should take a short amount of time. Although heavy equipment may be needed to remove the concrete channel and install the vegetative channel, precautions should be taken to avoid over-compacting the basin. Deep-tilling may be needed to loosen the soil in areas where heavy equipment is driven. The native grass will be seeded in the basins after the turf grass in the basin has been eliminated with an herbicide. Seed will need to be covered and protected from erosion.

The detention basins must be inspected for excessive debris and sediment accumulation at least four times annually, as well as after every storm exceeding one inch of rainfall. Sediment removal should take place when the basin is thoroughly dry. Disposal of debris, trash, sediment, and other waste material should be done at suitable disposal/recycling sites and in compliance with all applicable local, state, and federal waste regulations (NJDEP, 2004).

Mowing of these newly vegetative basins must be performed on a regular schedule based on specific site conditions (once every six months). Vegetated areas must be inspected at least annually for erosion, scour and unwanted growth, which should be removed with minimum disruption to the planting soil bed and remaining vegetation. When establishing or restoring vegetation, biweekly inspections of vegetation health should be performed during the first growing season or until the vegetation is established. Once established, inspections of vegetation health, density, and diversity should be performed during both the growing and non-growing season at least twice annually. Use of fertilizers, mechanical treatments, pesticides and other means to assure optimum vegetation health must not compromise the intended purpose of the vegetative filter. Vegetation deficiencies should be addressed without the use of fertilizers and pesticides whenever possible. The vegetative detention basin system should be inspected for excess ponding after significant storm events. Corrective measures should be taken when excessive ponding occurs (NJDEP, 2004).

Cost

The cost of the detention basin will vary depending on the amount of work that needs to be done to improve the detention. If the detention basin needs to be excavated and replanted the cost would be approximately $2 to $4 per square foot of the detention basin. When a detention basin needs to be re-vegetated the cost to improve the detention basin is $0.25 to $2 per sq. ft. The cost estimates vary because the designs to improve the detention basins have so much flexibility to them. The cost to remove a low flow concrete channel is approximately $100 per linear foot of low flow channel.

Expected Results

Retrofit designs should target infiltration of runoff generated from the water quality storm. Since approximately 90% of all storms in each year in New Jersey come in storms smaller than the water quality storm, this will have a dramatic effect on water quality in the watershed. While it is hard to measure the exact effect, the basins will have many of the same characteristics as a vegetated filter strip. It is difficult to estimate the reductions for each pollutant because many of the functions of the basin will be enhanced by the proposed changes. Targeted reductions in TSS, total nitrogen and total phosphorus are expected to be 90%, 60% and 30%, respectively. Depending on the final design of the detention basin, it will function like a bioretention basin or a wetland. The removal rates for bioretention basins and wetlands are at or above 90% for fecal coliform (Karathanasis 2003; Rusciano and Obropta, 2007). Since drainage areas for each basin were not readily available it is impossible to estimate the total pounds of pollutants removed by retrofitting the detention basins in the Neshanic River Watershed.

References

Karathanasis, A. D., C. L. Potter, and M. S. Coyne, 2003, Vegetation Effects on Fecal Bacteria, BOD, and Suspended Solid Removal in Constructed Wetlands Treating Domestic Wastewater. *Ecological Engineering,* 20(2): 157-69.

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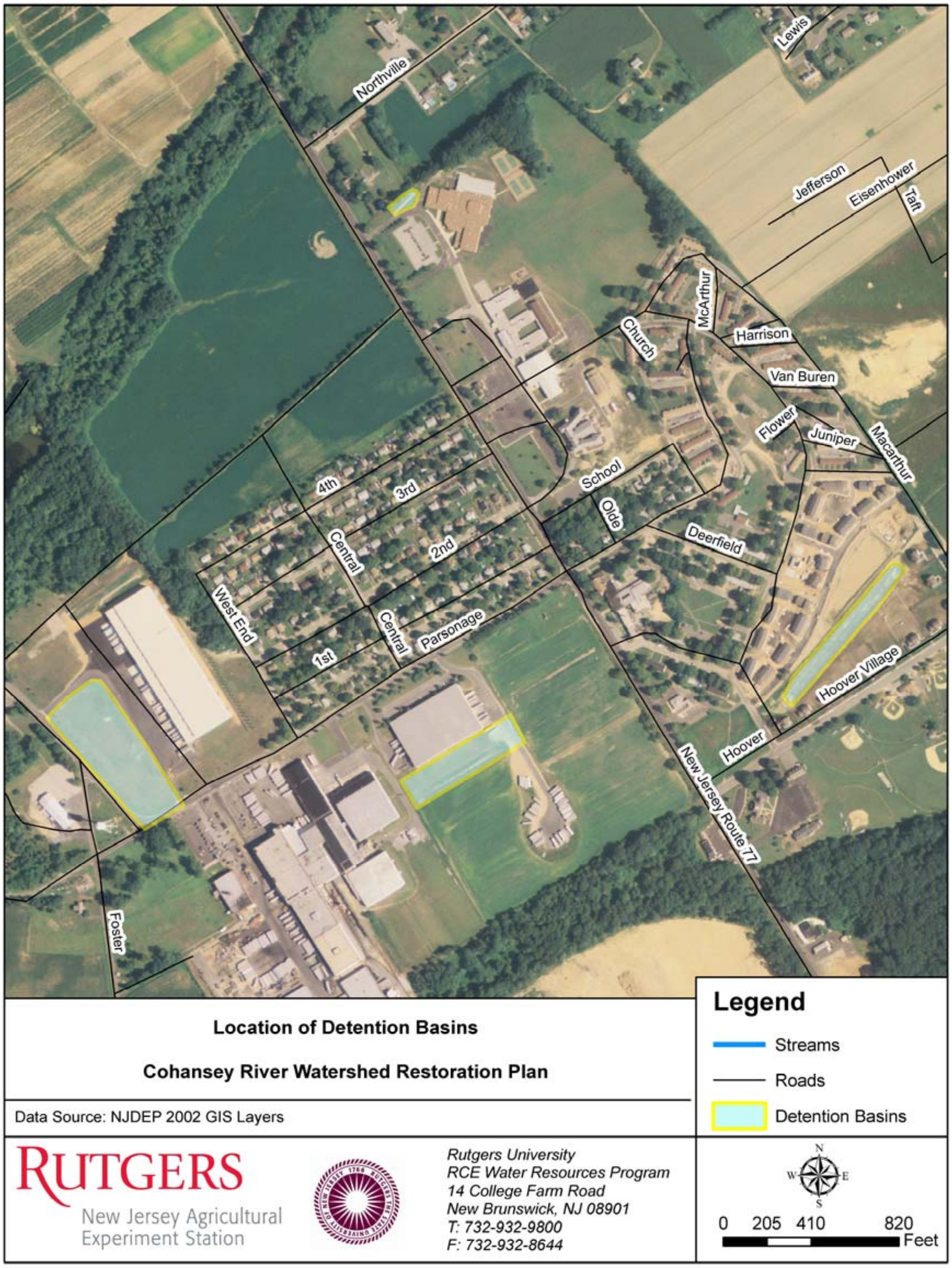

Figure B-19: Location of detention basins in subwatershed FR1 of the Upper Cohansey River Watershed.

Addressing Livestock Fencing Needs

Current Conditions

Livestock-related runoff and direct discharge of waste can be a major pathogen and nutrient concern, as well as impact other water quality parameters and stream conditions. To remediate this issue, livestock fencing around rivers and streams can prevent livestock from having direct access and reduce the potential for pathogens to enter surface waters. Fencing also provides a physical space between livestock and the waterway where vegetated filter strips should be installed to filter and treat runoff, as well as improve ecological diversity and stream stability. There are not many situations that call for animal fencing in the Upper Cohansey River Watershed but they are suspected to be large sources pathogens.

By restricting livestock access to the surface waters with fencing, landowners can quickly eliminate direct discharges of pathogens and nutrients to surface waters. With fencing setbacks, there will be ample room for a vegetated filter strip to buffer contaminants entering the stream from overland flow, as well as improve stream stability at the location where livestock are currently entering the river. Vegetative filter strips have a removal efficiency of 30% for phosphorus and nitrogen and 80% removal efficiency for TSS (NJDEP, 2004). The one major concern for the landowner and livestock owner is finding an alternative water supply for the animals. Water and feed should be provided for the livestock at the opposite corner of the property at the highest elevation, so that runoff can be minimized.

Location

The location of potential livestock fencing projects is shown in Figure B-20. The criteria for site selection were any portion of stream or water body that was surrounded by agricultural land and appeared to hold livestock from the 2006 NJDEP aerials was chosen as a potential site for this BMP. This is projected to result in approximately 3,600 feet of livestock fencing in the Upper Cohansey River Watershed (Figure B-20).

Prioritization

There are only three sites for the entire watershed that have been selected for this watershed. The RCE Water Resources Program did not rank any of these projects above another because of the small number of projects proposed. The RCE Water Resources Program would recommend the most northern site as the first to implement. This project would serve as a great demonstration project due its high visibility.

Cost

There are several different types of fencing that can be used in this project (electrified polywire, high tensile electrified wire, high tensile non-electrified wire, barbed wire or woven wire) and each have similar costs. The cost for installing a fence can range from $1.00 to $2.00 per linear foot (Meyer and Olsen, 2005); with an estimated 3,600 linear feet of lands needing fencing, a total of $3,600.00 to $7,200.00 would be needed to fence all projected areas within the Upper Cohansey River Watershed. These costs do not include any additional costs accrued due to the inclusion of a vegetated buffer to improve water quality (see Vegetated Buffers section in Appendix B for more information on costs).

Expected Results

If livestock fencing alone is installed, benefits to water quality would be expected but previous research has not quantified those benefits. Providing an alternate watering source for livestock, in addition to fencing, has been estimated to reduce TSS by 90%, total nitrogen by 54%, and TP by 81% (Agouridis *et al.*, 2005). Following state0 design standards, vegetative buffers installed in areas between the fencing and the waterway should remove 70% of the TSS in the runoff that it filters throughout the year and 30% of the nitrogen and phosphorus in the runoff (NJDEP, 2004). There is no removal rate of bacteria for vegetative filter strips, but it is fair to assume that the bacteria act as particles much like fecal coliform and the removal rate should be similar because the same mechanism expected to reduce TSS will reduce bacterial concentrations. Livestock fencing in North Carolina in conjunction with tree plantings reduced TSS by 82.3% and TP by 78.5% (Agouridis *et al.*, 2005).

References

Agouridis, C.T., S.R. Workman, R.C. Warner, and G.D. Jennings, 2005, Livestock Grazing Management Impacts on Stream Water Quality: A Review. J. of Amer. Water Res. Assoc. 41(3): 591-606.

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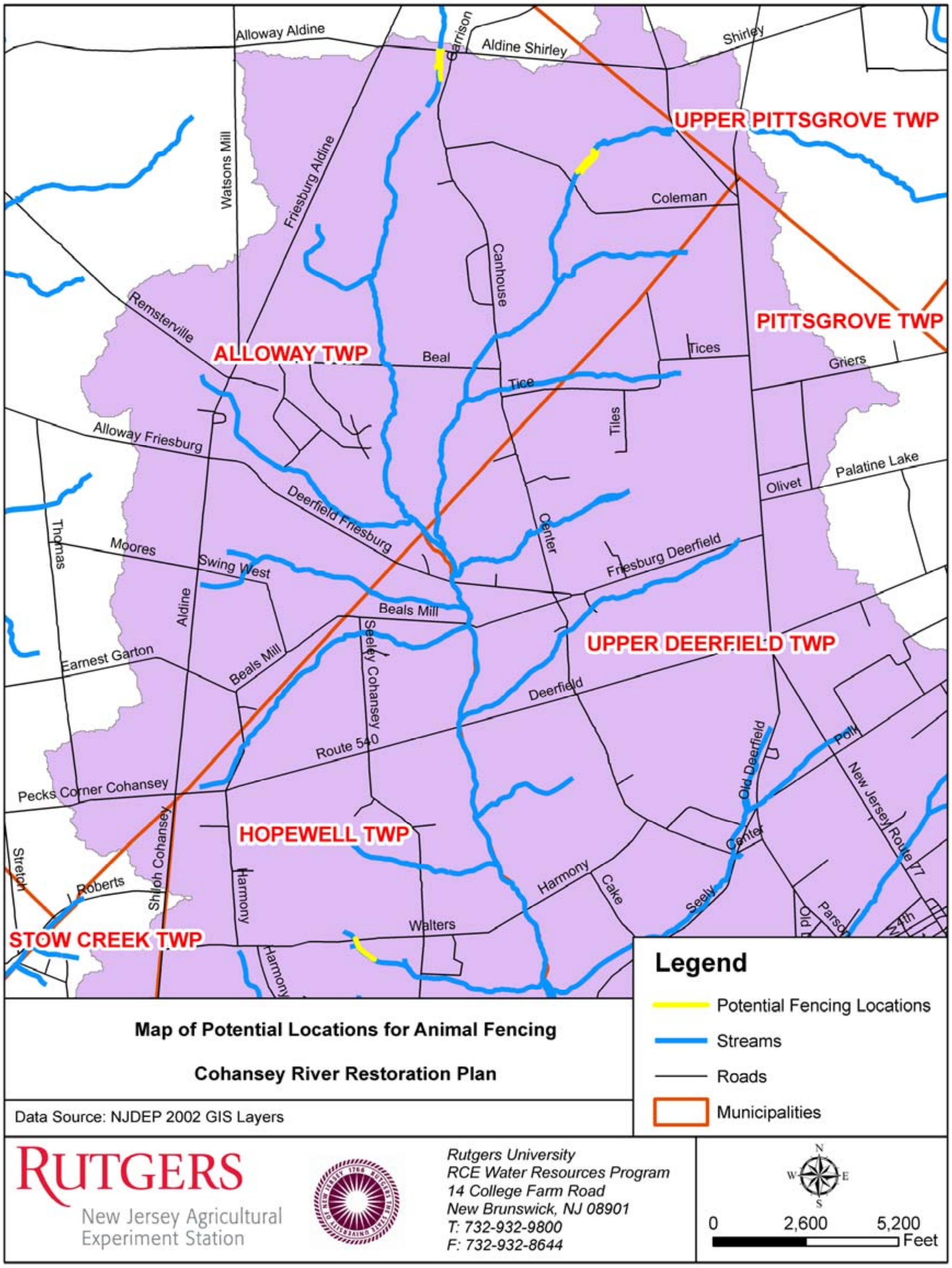


Figure B-20: Potential locations for livestock fencing in the Upper Cohansey River Watershed.

APPENDIX C: ENGINEERING PLANS FOR IMPLEMENTATION PROJECTS TO ADDRESS KNOWN WATER QUALITY IMPAIRMENTS IN THE UPPER COHANSEY RIVER

NOTES:

1. THE SITE SHOW TO THE RIGHT IS LOCATED IN THE COHANSEY RIVER WATERSHED. IT HAS A LARGE AMOUNT OF IMPERVIOUS SURFACE. THE DRAINAGE PLAN FOR THIS SITE ALLOWS THE STORMWATER RUNOFF TO DISCHARGE TO A STORM SEWER SYSTEM AND THE FORESTED AREA DOWNSTREAM OF THE SITE. THIS PLAN IS THE BEGINNING OF DECREASING THE AMOUNT OF STORMWATER RUNOFF GENERATED FROM THE SITE.

2. THIS DESIGN CAPTURES THE RUNOFF GENERATED BY SMALL BUT FREQUENT STORMS FROM THREE ROOFTOPS. THE DESIGN CAPTURES, TREATS AND INFILTRATES STORMWATER RUNOFF THE NEW JERSEY STORMWATER QUALITY (1.25 INCHES OF RAIN OVER 2 HOURS).

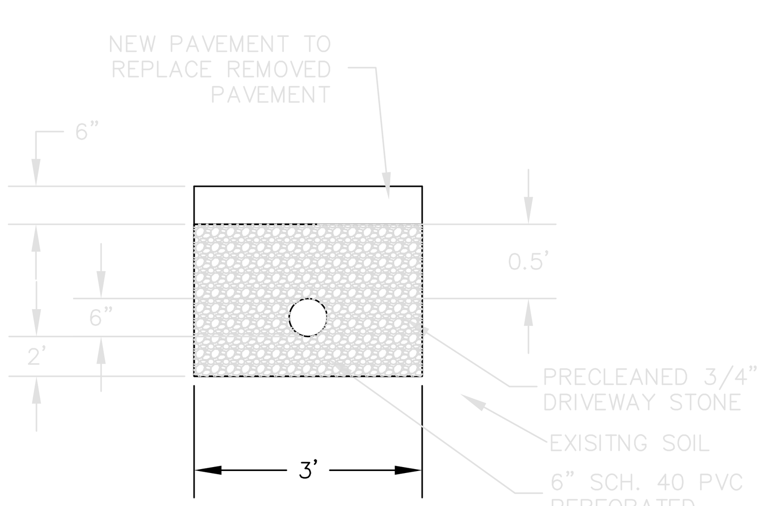
3. THE STORMWATER RUNOFF EXITS THE ROOFS VIA ROOF DRAINS. THESE ROOF DRAINS DISHCARGE ON TO THE PARKING LOT OF THE SITE. THIS DESIGN EXTENDS THE ROOF DRAINS TO PRIMARILY DISCHARGE INTO A INFILTRATION TRENCH UNDERGROUND. THE INFILTRATION TRENCH IS 3 FT BY 3 FT WITH A 6" POROUS PVC PIPE RUNNING THROUGH THE TRENCH. THE ROOF DRAINS ARE CONNECTED TO THE PIPES IN THE TRENCH. AS THE WATER IS DISCHARGED TO THE PIPES, THE WATER IS NOT CONTAINED IN THE PIPES BECAUSE THEY ARE PERFORATED. THE RUNOFF ENTERS THE STONE FILLED INFILTRATION TRENCH WHERE IT INFILTRATES INTO THE GROUND. DURING VERY LARGE STORMS, THE INFILTRATION TRENCH WILL BE FILLED AND WATER WILL DISCHARGE OUT THROUGH THE PIPE VERY QUICKLY. IF THE TRENCH BECOMES TOO FULL THE TRENCH WILL OVERFLOW ONTO THE PARKING LOT (SEE DETAILS BELOW).

6. THIS WILL REMOVE 90% OF THE RUNOFF FROM 11.35% OF THE IMPERVIOUS SURFACE OF THE SITE. PREVENTING 6.22 ACRE-FEET OF WATER A YEAR OF RUNOFF FROM THE SITE.

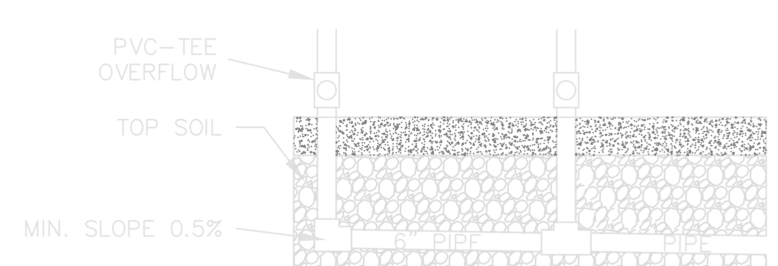
7. TO IMPROVE THE WATER QUALITY OF THE RUNOFF FROM THE PARKING LOT, IT IS RECOMMENDED THAT THE PARKING LOT BE CLEANED BY A STREET SWEEPER OR VACUUM TRUCK AT LEAST ONCE EVERY SIX MONTHS.

MATERIAL	UNIT	AMOUNT REQUIRED
6" PVC POROUS PIPE	FEET	
¾" CLEAN STONE	CUBIC YARDS	
CONSTRUCTION FABRIC	SQ. FEET	
MATERIAL REMOVED FROM SITE	CUBIC YARDS	

AREA (LABEL)	DRAINAGE AREA (ACRES)
ROOF A	2.369
ROOF B	0.436
ROOF C	0.883
ROOF D	0.645
ROOF E	0.448
PARKING LOT	12.917



CROSS SECTION TRENCH DETAIL
NOT TO SCALE



TRENCH PROFILE
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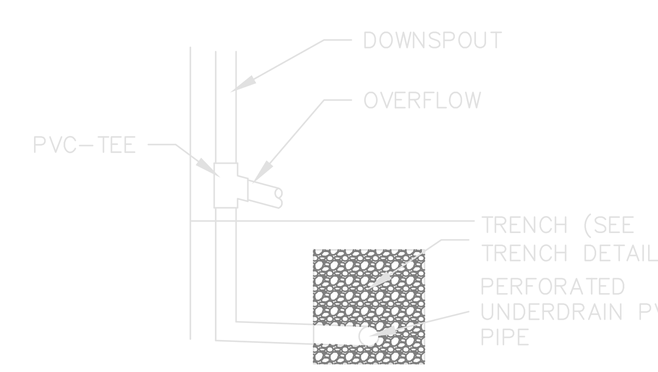


UNDERDRAIN CONNECTION DETAIL
NOT TO SCALE

CHRISTOPHER C. OBROPTA, Ph.D., P.E.
PROFESSIONAL ENGINEER - NJ LICENSE # 37532

DESIGNED DCY | CHECKED CCO | APPROVED | DATE

COHANSEY RIVER WATERSHED RESTORATION PLAN
NJ DEPARTMENT OF ENVIRONMENT PROTECTION

PROPOSED BMP DEMONSTRATION PROJECT
BIORETENTION POND AND INFILTRATION TRENCHES

RUTGERS COOPERATIVE EXTENSION
WATER RESOURCES PROGRAM
14 COLLEGE FARM ROAD
NEW BRUNSWICK, NJ 08901
WWW.WATER.RUTGERS.EDU

RUTGERS
New Jersey Agricultural Experiment Station

JOB XXXXXXXX | SHEET # XX | B/D XX | TOTAL XX

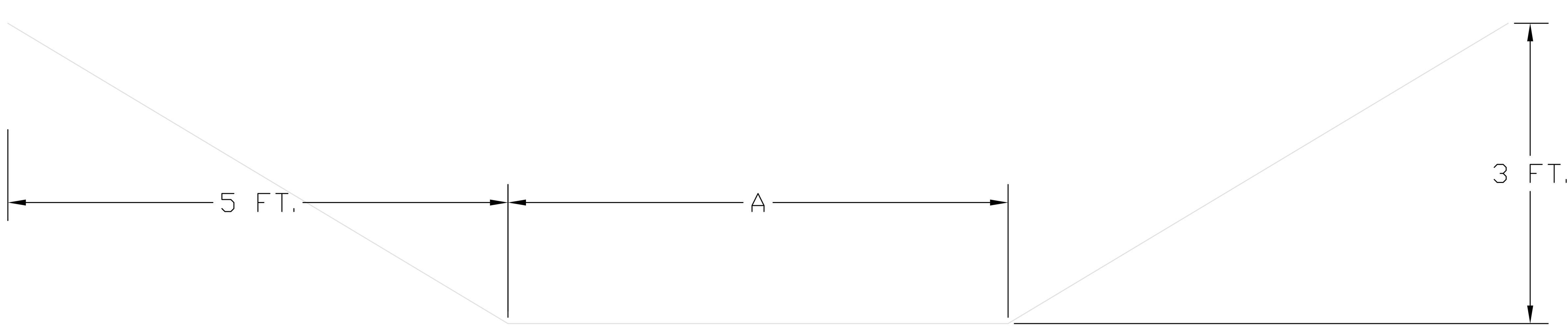
NOTES:

1. THIS PROJECT WAS SELECTED TO BE SWALE DEMONSTRATION PROJECT. DURING VISITS OF THE WATERSHED, THIS AREA SHOWED EVIDENCE OF SIGIFICANT EROSION ALONG THE FARMS EXISTING STORMWATER SWALES. THIS PROJECT IS TO UPGRADE THE EXISTING SWALE. THE SWALES WILL HAVE CHECK DAMS INSTALLED, RE-GRADED AND RE-VEGETATED.

2. THE SWALES WILL BE RE-GRADED TO MATCH THE DIMENSIONS SHOWED IN THE CROSS SECTIONS DETAILS BELOW. THESE CROSS SECTIONS ARE DESIGNED TO CONTROL THE FLOW UP TO A 25 YEAR STORM. AFTER THE SWALES HAVE BEEN RE-GRADED THEN THE SOIL WILL BE SEEDED WITH AN ANNUAL RYE GRASS AND NATIVE WARM SEASON GRASS SEED MIX. THE ENTIRE SURFACE OF THE SWALES WILL BE COVERED BY EROSION CONTROL MATTING TO PREVENT EROSION WHIILE THE VEGETATION IS ESTABLISHING ITSELF.

3. GABION BASKET CHECK DAMS ARE RECOMMENDED EVERY 250 FEET IN EACH SWALE. A CROSS SECTION OF THE CHECK DAM IS ONE OF THE DETAILS FOUND AT THE BOTTOM OF THIS SHEET. THE GABION BASKETS SHOULD BE ONE FOOT HIGH. THE CHECK DAMS SHOULD BE CONSTRUCTED OF GABION BASKETS FILLED WITH RIP-RAP. THE CHECK DAMS WILL REDUCE THE FLOW OF WATER AS IT TRAVELS THROUGH THE SWALE REDUCING THE EROSION OCCURING IN THE CHANNEL OF THE SWALE.

4. THIS DESIGN IS EXPECTED TO DRASTICALLY REDUCE EROSION FROM THE SWALE AND TO REMOVE 70% OF THE SEDIMENT IN THE STORMWATER RUNOFF FROM THIS SITE.



CROSS SECTION OF SWALE
(NOT TO SCALE)

MEASUREMENT FOR A

WEST SWALE = 5 FT.

EAST SWALE = 5 FT.

BOTTOM SWALE = 15 FT.

CROSS SECTION OF GABION CHECK DAM
(NOT TO SCALE)

CHRISTOPHER C. OBROPTA, Ph.D., P.E.
PROFESSIONAL ENGINEER - NJ LICENSE # 37532

DESIGNED SPW CHECKED CCO APPROVED DATE

COHANSEY RIVER WATERSHED RESTORATION PLAN
NJ DEPARTMENT OF ENVIRONMENT PROTECTION

PROPOSED BMP DEMONSTRATION PROJECT
EROSION CONTROL SWALE PROJECT

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JOB COHANSEY
SHEET # 01
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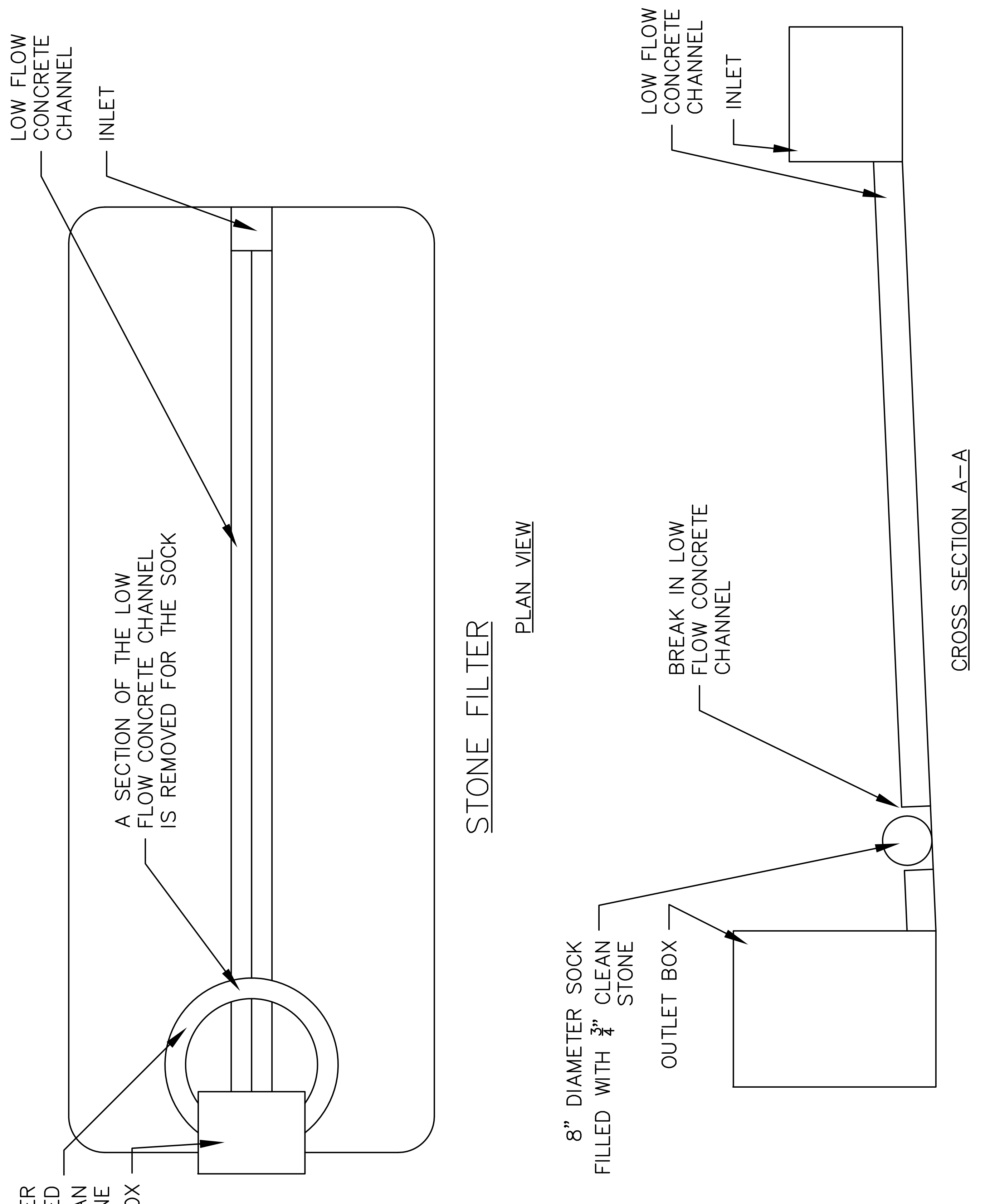

COHANSEY WATERSHED RESTORATION
NEW JERSEY DEP

RECOMMENDED MANAGEMENT MEASURES
DETENTION BASIN MODIFICATION DETAILS

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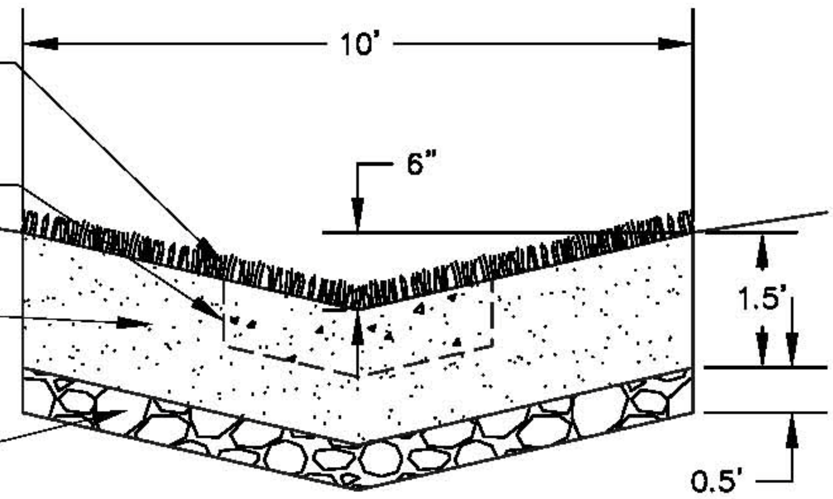
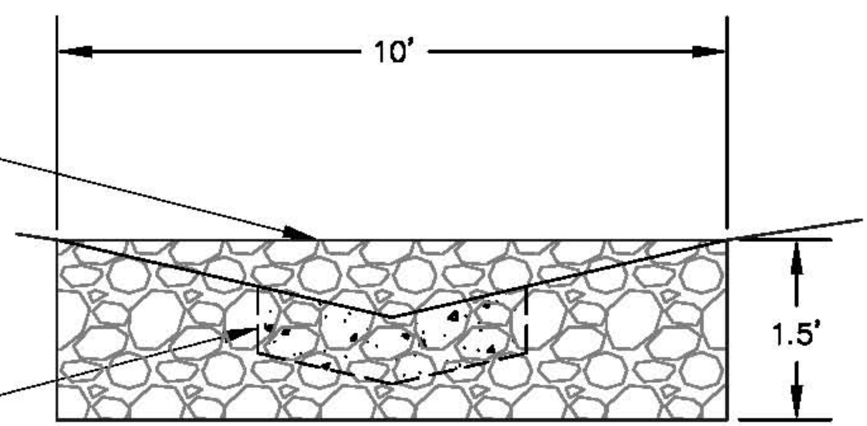


LOW FLOW VEGETATED CHANNEL

NOT TO SCALE



LOW FLOW RIP RAP TRENCH

NOT TO SCALE

BIORETENTION MEDIA MIX NOTES:

1. 87 % SAND. A WASHED, MEDIUM, SAND IS SUFFICIENT.
2. 8 % FINES. FINES INCLUDE BOTH CLAY AND SILT.
3. 5% ORGANIC MATTER.

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COHANSEY WATERSHED RESTORATION
NEW JERSEY DEP

RECOMMENDED MANAGEMENT MEASURES
DETENTION BASINS MODIFICATIONS DETAILS

APPENDIX D: SOIL, WATER, NUTRIENT AND PESTICIDE AGRICULTURAL MANAGEMENT PRACTICES FOR FIELD NURSERIES IN THE UPPER COHANSEY RIVER WATERSHED

Rutgers New Jersey Agricultural Experiment Station

Soil, Water,
Nutrient and Pesticide
Agricultural Management Practices
for
Field Nurseries
in the
Upper Cohansey River Watershed

James Johnson
Agricultural Agent
Cumberland County

Dr. Salvatore Mangiafico
Environmental and Resource Management Agent
Cumberland & Salem Counties

Table of Contents

Introduction

Within New Jersey, the Cumberland/Salem/Gloucester area accounts for nearly half the nursery acreage in the state while the Monmouth/Burlington area adds over 25% more. The Southern region of Cumberland, Salem and Gloucester Counties has continued to expand while areas north have either remained stable or decreased in acreage.

New Jersey has many attributes that make it an ideal spot to produce nursery plants. The marketing potential is great since it is geographically located in the center of the BosWash megalopolis. The conglomeration of cities that makes up the megalopolis is around 500 miles long from the areas of Boston, Massachusetts to Washington, DC and has a population of approximately 44 million people. That represents about 16% of the total population of the United States.

Soils, water resources and environmental factors make Southern New Jersey optimal for nursery plant production. Soils are somewhat variable from very sandy to silt loams. This allows a wide range of plant material to be grown. Southern New Jersey sits atop the Cohansey aquifer. It is one of the largest aquifers on the East coast of the US. The environment is moderated by the Atlantic Ocean and the Delaware Bay. As a consequence, it has a similar hardiness zone to central North Carolina.

New Jersey is an expensive state in which to conduct business. The cost of land and higher than average operational costs force producers to find ways to maximize production while also protecting the environment. These factors provide significant challenges that require good managerial leadership. Profitability has a direct relationship to the time it takes to produce the crop and plant population density.

Interest in planting field-grown nursery stock has seen resurgence in recent years. This is the result of growers identifying a potentially profitable niche. It may be that the niche is there because there is a potential for increased sales of similar material, similar material of higher product quality, new or different material, or a myriad of other reasons. The marketing skills of an individual will largely determine the difference between success and failure. It has become very difficult for a business to survive for an extended period of time by just being nursery stock growers.

In a perfect world, nurseries would be designed for maximum efficiency with minimal environmental impact. In reality, few nurserymen have financial resources adequate to complete installation of an ideal facility when they are starting out in the business. However, many practices can be adopted which both increase profitability and minimize environmental impacts. If an established nursery moves to a new site, one should take advantage of the opportunity. The result of not designing from the ground up is the need for retrofitting existing nurseries that may end up costing more than a nursery built from the ground up. Planning is critically important for every nursery. No matter where one is financially, one should always plan for the future while building for the present.

When designing the nursery, pay special attention to water movement that minimizes environmental impact. Runoff water is typically higher in nutrient content than surface or groundwater. Because of the need to have minimal environmental impact, it is increasingly important to use turf between plant rows and in waterways to reduce erosion and capture nutrients. Depending on the site, a bio-filter may be important to install to enhance water quality before it leaves the nursery during significant rain events. A bio-filter uses vegetative plant material to remove pollutants from the water before it enters ground or surface waters. Wetlands plants have been shown to be quite effective at removing nutrients in biofilters while being resilient to varying water conditions.

Grouping plants by water or nutrient needs can help reduce water and nutrient use. Grouping by pesticide requirement is usually difficult but where possible may enhance pesticide use safety. Recommendations for pesticide use on nursery stock can be found in Rutgers Cooperative Extension Publication #E036: Pest Control Recommendations for Shade Trees and Commercial Nursery Crops (available online at the website listed in the References section of this document).

Nursery Design

Site Selection

The ultimate success of a field nursery is highly dependent on soil characteristics. While soils in field nurseries can be amended with organic matter, native soil characteristics such as texture, drainage, profile and slope need to be suitable for production of perennial crops. Most field-grown nursery crops are produced on 1 to 7 year cycles. Knowing the history of the field including previous crops grown, types of pesticides applied (especially herbicides) and types of organic soil amendments are important since each can affect plant growth.

Field-grown nursery stock production can range from multiplication of stock material and liners that are bare-rooted to digging large material that is balled and burlapped. When producing balled and burlapped material, field soils need to be cohesive enough to maintain an intact ball. Root balls that are excessively sandy may fall apart during handling. Ideally, soils should be relatively free of large rocks and deep enough to allow easy digging. The American Standards for Nursery Stock (ANSI Z60.1) includes standard dimensions for harvesting root balls according to the size of the plant (available online at the website listed in the References section of this document).

Balled and burlapped material may be hand dug or dug by machine. Machine digging is much faster than hand digging for intermediate-sized plant material and requires less-trained individuals. With trained personnel, hand digging is usually faster with small plant material and typically becomes the only option, as root balls get very large.

Soil drainage should be considered when selecting a site. Try to avoid soils that have poor internal drainage or that are subject to flooding. Nursery stock that has been flooded is often weakened and predisposed to increased disease and insect problems. Fields being considered for nursery stock production should have a minimum of 8 to 10 inches well-drained profile but this requirement varies based on which plants are to be grown. A soil probe can be used to investigate the soil profile, in order to determine the depth and texture of soil layers and see if there are layers that may restrict root growth or water drainage. Even sandy soils can have poor drainage if there is an impervious layer, as is common in many fields. At the other extreme, deep sandy soils have relatively little water holding capacity and generally require an irrigation system to ensure successful field production. A penetrometer can be used to determine the strength of soil layers. Soil layers that require a strong force for the insertion of a penetrometer may limit root growth or water infiltration. These hard layers can be the result of soil compaction or tillage practices, or may be natural hard pans in the soil.

While flat, non-flooding fields are optimal for mechanical production practices, some slope can offer enhanced air and water drainage. As the slope increases, one should consider contour planting and the use of turf plantings between rows to reduce erosion potential. A good place to start in determining soil potentials are the “Soil Surveys” for each county prepared by the Natural Resources Conservation Service. Paper copies of some county Soil Surveys were produced as recently as 2008 but the internet-based Web Soil Survey is now the official soil survey document. Websites for these resources are listed in the References section of this document.

It is critically important to have water available to irrigate crops. Nursery transplants are expensive and avoidable losses need to be minimized. Growers also need to maximize growth to be profitable. The use of irrigation can shorten the production cycle by 1 to 2 years over non-irrigated crops. It is important to choose field production land with good water resource access. When locating a field nursery near surface bodies of water, withdrawals for irrigation should not have a negative effect on nearby surface bodies of water. The nursery also bears a responsibility to protect the surface waters from field erosion sediment and nutrient contamination.

Site Development and Layout

Natural features of the land should be considered when developing a field nursery site. Consider all production operations when laying out the fields. Set them up for the best efficiency of plant maintenance, irrigation, harvesting and maneuvering sprayers, tractors and wagons. Consider contour plantings on sloped land and plan for turfgrass waterways and field edge buffer strips to reduce erosion. Grass strips can effectively slow runoff and trap sediment, thereby reducing soil losses by 30 to 50 percent compared to bare soil. A grass strip will slow runoff water, allowing silt to settle out. Buffer strips should be established between production areas and surface water bodies including streams and lakes. The first 3 to 4 feet of buffer strips do most of the filtering. As slope increases, the number of strips needed increases and the distance between them needs to decrease. Grasses for buffer strips and grass waterways should be able to withstand wet growing conditions and still produce an aggressive root system that will take abuse and maintain a good grass mat to slow runoff and catch sediment.

What's most important in choosing grass species for use as a buffer is to identify a species or mixture that will maintain a dense stand in the conditions of your site. Different species will thrive in different site conditions, including soil drainage, available moisture, and fertility. While some turfgrasses are more demanding in terms of water and fertilizer, tall fescue and creeping red fescue, for examples, are two rhizomatous species that may be more tolerant of drought, lower fertility and higher salts. If areas have poor drainage or will be wetted continually with runoff, other grasses or appropriate wetland plants should be chosen. A guide for choosing appropriate grass species can be found in the Rutgers fact sheet Turfgrass Seed Selection for Home Lawns (available online at the website listed in the References section of this document).

Mow grass strips to keep the grass from seeding and to encourage a thicker stand. Since these grasses accumulate nutrients from runoff, grass clippings should be removed and the organic matter used to amend field soils. To keep grass waterways and buffer strips vigorous, avoid frequent traffic over them and lift implements above the ground before crossing. Monitor growth to determine if supplemental fertilization is required.

Few fields are uniform in slope, drainage (air and water), and fertility. Determine optimal conditions for growth of plant material and plant accordingly. As examples, plants that will tolerate wetter soils include red maple, river birch, bald cypress, willows, sweet gum and black gum. Crape myrtle will thrive in moist locations but should be planted on well-drained sites because they tend to grow too long in the fall and may be damaged by frost when planted on moist sites. Dogwoods require very well-drained locations. Avoid frost pockets with crops such as flowering cherries and Colorado blue spruce, which begin growth early in the spring. A few degrees difference could damage early cherry and plum flowers or destroy the first flush of growth.

Irrigation Management

Water quantity and quality

It is important to secure good water resources when considering a new nursery site. Generally, nursery crops require between one and two inches of water per week. Natural rainfall will reduce the need for other water resources. If water quantity is limited, consider lower water use irrigation systems (drip or trickle irrigation, center pivots, travelers, etc.).

Micro-irrigation (drip or trickle irrigation) is a low volume, low-pressure system that applies water directly to the soil surface over extended periods of time. It results in less water lost to evaporation or run off. There are several benefits derived from the use of micro-irrigation.

1. Micro-irrigation applies water only to the root zone of the nursery crop so roots tend to concentrate within the zone wet by the micro-irrigation. That forces more roots into the ultimate root ball.
2. Fewer weeds tend to germinate since water is distributed over a smaller surface area than with overhead irrigation. Less weed competition can increase the effectiveness and reduce costs of pre-emergent herbicides and directed post-emergent herbicides management programs, which also reduces the need for frequent tilling.
3. Since only a small surface area is wetted when using micro-irrigation, field operations can continue with fewer interruptions.

Overhead irrigation is especially useful when using lower quality water and when it is necessary to make frequent cropping changes. Including infrastructure needs, the initial investment of an overhead irrigation system is typically lower than a trickle system but operational costs may be higher.

Micro-irrigation requires clean water, free of sediment and minerals. Well water generally requires little or no filtration. Surface water from rivers or ponds generally requires sand media filters so emitters don't plug. If fertilizer is applied with micro-irrigation, the amount of fertilizer applied to a crop can be reduced while increasing growth due to improved fertilizer use efficiency. Fertilizer use in field crops can be cut in half from traditional fertilization and overhead irrigation methods.

Water Use Certification

Without access to an adequate quantity and quality of water, the nursery industry and agriculture in general is not viable. In an effort to monitor and regulate water use in the state of New Jersey, the Department of Environmental Protection (DEP) has created a water use certification program. For crop needs in excess of 3,100,000 gallons per month, growers are required to have water diversions certified for use by the DEP. A second threshold is the composite farm pumping rate capability. When the combined total pumping capacity for wells exceeds 70 gallons per minute, certification is also required. The process requires a certification of need by the local Agricultural Agent, information on water sources, specific locations of diversions, crops grown, and public notification that allows area resident input. Annual reporting of actual use is required along with a five-year recertification cycle. Uses under the aforementioned levels should be registered with DEP in a similar process but lacking the public notice requirement.

The cost of doing business in New Jersey is high. Because of this, it is necessary to maximize growth and yields of nursery plants. A requirement for maximizing growth is that plants receive optimal amounts of water. History has proven that anticipated natural rainfall is never a sure thing. Avoid delays in irrigating crops. It is better to start irrigation as soon as crops need the water rather than delay watering in anticipation of a rain event. If one gets behind in supplying plants water, it may be nearly impossible to catch up without a significant rain event. Remember that although heavier soils dry out more slowly than sandy soils, when they dry down to a certain point they are difficult to re-wet.

Water system design

The irrigation system should be designed during the planning stage of the business and should be definitely considered prior to property purchase. Identify how much water, practically and legally, will be available to you and from what sources. Decide what types of irrigation systems will be placed in each field. If possible, design for flexibility in case there are changes in crop and/or irrigation system needs. The main irrigation trunk lines should be buried, usually along roads, with the valves located at convenient intervals. Irrigation lines are susceptible to damage caused by winter freezing. When possible, plan for a gravity method of draining the lines so they don't have to be blown out.

Recognize water use differences and crop response to overhead versus micro-irrigation systems and the associated costs of installation and use. If considering overhead irrigation, understand that water cannons are not the only option. When conditions for installation are good, center pivots and travelers can provide a gentle rain-like effect while using less water than do water cannons. Center pivots and travelers also produce less soil compaction and consequent water runoff. There are many types of irrigation systems available, many of which are specifically tailored to certain types of production. Be sure to evaluate the options.

Water treatment

Treatment of water for irrigation purposes is generally unnecessary when using well water. When using surface water sources such as rivers and ponds, water should be evaluated to determine the need for water treatment. If there is the opportunity to use recycled water, the probability of needing to treat water to eliminate pathogens increases.

If using a source of water that has the potential for problems, carefully observe plant material for disease symptoms and dieback. Presently, most water treatment systems for pathogen control at nurseries are using chlorine. Realize that chlorine can be toxic to humans and some plants and that training and caution are needed when using chlorine. Other options include the use of ultraviolet radiation (UV), ozone, heat treatment, bromine, and copper. The combination of UV and ozone treatments may offer the most effective water treatment of any system. Costs of the systems vary widely.

Remember that each treatment option has strengths and weaknesses, and evaluate them accordingly. Copper is a known root inhibitor and bromine is in the same family as chlorine. When using these treatments, be vigilant in looking for negative effects on plants. UV radiation is the only treatment listed above that does not directly add potentially harmful chemicals to the treated water. One source of information to help evaluate treatments is found in the publication entitled "Management Practices to Protect Water Quality: A Manual for Greenhouses and Nurseries." It can be found at http://ceventura.ucdavis.edu/files/32117.pdf.

Water system management

When to irrigate

Avoid getting behind! Growers should rely on natural rainfall as the basis for nursery crops water needs but recognize that natural rainfall will either be inadequate in quantity or timing during the growing season. Many growers have a tendency to delay irrigation in anticipation of rain events. Unfortunately, rainfall is not entirely timely or reliable. When irrigation gets behind, virtually all plant material may be in need of water. If the need for water exceeds the nursery's water resources or the capacity of the water distribution system, choices will have to be made as to what will be watered and what will wait. There are economic costs no matter what the decision.

Be sure to understand how the physical properties of the soils in your nursery affect the water holding capacity of the soils and how quickly soils will dry out and require irrigation. Review NRCS soil survey information to help determine which types of soils you have in which location on the nursery. The available water capacity of a soil will depend on its texture and organic matter content. Sandy soils hold less plant-available water than do loamy and heavier soils. The desired frequency of irrigation will also depend on the rooting depth of the plants and the rate at which plants and soils are transpiring water. The evapotranspiration rate increases as solar radiation, temperature and wind increases and as humidity decreases. Plants will require more frequent irrigations in hot, dry, windy weather. It is also important to understand how dry of a soil your particular crop will tolerate without suffering water stress or decreased yield. Check with your local agricultural agent if you have questions. Remember, heavier soils dry more slowly but when dry are difficult to re-wet.

Cyclic irrigation

Cyclic irrigation uses shorter but more frequent irrigation cycles to conserve water. It is a system that wets and then re-wets soils but uses lower amounts of water so runoff is limited. Where micro-irritation systems are not appropriate, it offers the opportunity for an effective method of irrigation water reduction using the same irrigation equipment. Field soils may exhibit a similar benefit, especially in cases where irrigation rates would exceed the infiltration capacity of the soil or not allow uniform wetting of the soil profile if cyclic irrigation were not used. Remember to consider field operations scheduling prior to using cyclic irrigation because the field will be irrigated more than once each irrigation cycle.

Irrigation for heat or cold protection

For crops that initiate growth early in the spring and those that grow late into the fall it is critically important to have overhead irrigation available to protect from late and early freezes respectively. To have water freeze, a great deal of energy is required to be released in what is called the "heat of fusion." Essentially, when temperatures drop below freezing, water will cool to approximately 32°F and will stay at that temperature for an extended time until it freezes solid. The ice temperature will then drop to near the ambient air temperature. All the time the water remains at the freezing point it offers protection to plant material on which it is located. As long as water keeps running, the temperature should never drop below freezing.

On a practical basis, irrigation systems should be started prior to when the air temperature drops below freezing and remain on until the temperature rises above freezing and ice formed on the plants disappears.

Micro-irrigation

Micro-irrigation (drip or trickle irrigation) is an irrigation system that applies water very slowly over a longer time period than with overhead irrigation. The result is a small wetted profile on the surface that expands outward and downward as it moves through the soil profile. A heavier soil will have a wider profile than a lighter soil.

Benefits of using this type system include lower water consumption, an effective irrigation of the root profile, reduced weed problems, reduced disease problems, good access to field operations with equipment since the area between rows is not wetted, and a lower cost of operation than with overhead irrigation. Drawbacks include an inability to protect from freezes, the need for higher quality water resources, the need to have set planting blocks and patterns in the field to allow for infrastructure and a higher cost of initial installation.

Nutrient Management

The concept of soil quality includes assessing a soil for its ability to grow plants, cycle nutrients, and percolate and hold water. In nursery production, a healthier soil will have a greater ability to maximize plant growth. The factors that help determine a soil's productivity include the cation exchange capacity, the water holding capacity, drainage characteristics and slope. Depending on the crops to be grown and production systems, different soils will be more or less desirable for nursery production. Soil survey information is available from the Natural Resources Conservation Service on line at: http://soils.usda.gov/survey/

Soil Fertility

Soil testing forms the basis for all fertility recommendations. Conduct soil tests prior to each crop cycle to determine nutrient status. Sampling needs to be representative of the field so the number of soil tests required per field will vary with the size and uniformity of the field. Unless there are specific areas of concern, submit composite samples of the field for testing. Take vertical cores of the soil profile that are 6 to 8 inches in depth. Separately sample areas that have differing field textures, colors and drainage characteristics.

The soil pH and nutrient content may vary considerably, thus requiring varied amendment practices. It is important to take soil tests well in advance of any cultivation, because of the time it takes to conduct the tests, evaluate the results, plan the most economical and effective program for crop production, apply treatments and allow time for the treatments to integrate into the soil. Lime and phosphorus applications should be completed well before planting. These materials should be thoroughly mixed with the top 6 to 8 inches of soil during normal soil preparation practices. Complete soil test results will also indicate if other soil nutrients are required as pre-plant adjustments.

Optimal management practices for fertilizer applications focus not only on maximizing growth of nursery stock but also the potential for excess fertilizer to be lost from fields through runoff, leaching, and soil erosion.

These losses can negatively impact surface water bodies and groundwater. Nitrogen and potassium applications should take place close to the time of planting.

Nursery stock sold with a root ball includes soil necessary to stabilize roots and ensure transplanting success. Preventing further loss of soil and rebuilding soil in fields is very important. Each cropping cycle for field grown nursery crops generally requires one to seven years. Therefore, nursery professionals need to implement growing practices that maintain and improve soil quality characteristics during fallow periods, as well as during field preparation for planting and during the production cycle.

Organic matter, along with naturally occurring silt and clay, serves as a nutrient buffer for soils. Organic matter, silt and clay have high cation exchange capacities that allow a soil to hold some applied nutrients and make them slowly available to plants. While the amount of silt and clay in soils cannot be effectively modified, the organic matter content of a soil can be increased through management practices.

Most soils benefit from the addition of organic matter. Benefits include improving soil structure, water retention, drainage and aeration. The quality of nursery stock grown is typically improved and digging is usually easier in mineral soils that have been amended with organic matter. Some nursery species also develop a more fibrous root system as the amount of organic matter is increased.

Soil Amendments

The long-term health and productivity of soil is a major concern for field nurseries. The loss of soil and nutrients from fields due to environmental conditions such as wind and rain are responsible for major losses. Normal farming practices can result in losses under adverse environmental conditions. Tillage operations that are followed a short time later with significant wind or rain events results in loose soil that will blow and/or wash away. Tillage can also result in soil compaction that will reduce water penetration and moisture holding characteristics. Because of reduced water penetration into the soil, it can increase the formation of washes and gullies.

Costs may prohibit transporting significant quantities of bark, yard waste compost, mushroom soil or other organic amendments to any but the most intensively cultivated sites like seedbeds or transplant production beds. Light application of animal wastes can be applied to field soils but recognize there can be weed issues later. Apply only 1/4 to 1/2 inch and incorporate as soon as practical following application. If wastes are incorporated, 75 to 100 percent of the nitrogen in the waste may be available the first year. Rate of application should be based on nutrient analysis of animal wastes. Particular attention should be given to the metal content of animal wastes. Zinc and copper levels may be high enough to raise these elements to toxic levels if repeated applications are made over a number of years. Foliar tissue analysis of fully expanded leaves collected from crops early in the growing season can provide valuable information about the efficiency of the animal waste application and determine if any supplement is required.

Growers should check to see if composts from municipal yard wastes are affordable organic source for amending fields. Application rates of stabilized composted wastes range from 50 to 200 tons per acre and with nitrogen contents ranging from 0.2 to 0.5 percent, nutrient loss is of less concern. The 50 tons per acre application rate represents approximately 1/2-inch coverage over a 1-acre area, while the 200 tons per acre would be approximately a 2-inch depth.

An alternative to applying organic materials over the entire field is to incorporate the organic matter in planting rows only. If rows in the field are spaced 12 feet apart and the root zone area of plants is considered to be 2 feet on each side of the stem, a 4-foot strip would receive the organic matter, thus reducing the amount of organic matter applied in the field by two-thirds. Planting rows would need to remain in the same location each year for this to have long-term benefit.

Non-crop Area Management During Production

Semi-permanent turf-type grass cover established between rows in a field nursery is an important component of minimizing soil losses and maintain long-term soil productivity. Grass sod also makes it easier to move equipment through fields when they are wet or snow covered. Grassed contour strips slow down and direct flow of water across a slope and serve as a buffer and a biological filter to remove excess nutrients before water leaves the nursery. Turf-type fescues are probably the most effective grasses. They are vigorous, don't readily seed, are somewhat drought tolerant and provide some biomass when plowed down. Nursery planting rows should be kept clean or mostly weed free with pre-emergence or post-emergence herbicides while maintaining grass cover between rows.

Grass should be mowed regularly to avoid seed formation. An option to mowing is to use chemical mowing techniques. Sub-lethal rates of herbicides and/or growth regulators can be used to slow growth of grass but not kill it. For example, tall or fine fescues or a mix of the two grasses will be suppressed for eight to ten weeks by spraying in early spring when there are four to five new leaves or seven to ten days after mowing with 1 pint / acre of sethoxydim (Vantage), a selective grass herbicide. Another alternative is to use glyphosate (Roundup 4L) at the rate of 4 to 8 ounces per acre as a directed spray. The 4-ounce rate usually gives six weeks of suppression; the 8-ounce rate gives about 10 weeks of suppression. Glyphosate needs to be applied as a directed spray between the nursery stock rows. Use no more than 25 gallons of the final spray mix per broadcast acre. Chemical mowing will result in chlorotic (yellow) grass for up to 30 days.

Soil Conservation

Conservation efforts are needed to reduce soil and nutrient loss resulting from wind erosion and storm water movement. Soil stabilization and erosion control management practices include:

- Contoured layout of fields (planting across slopes)

- Use of cover crops between crops
- Fallowing land (letting it rest without a crop for a year or more)
- Use of vegetation in aisles, row ends, drive roads, field border strips & waterways
- Use of sediment dams in waterways
- Installation of swales to collect soil in runoff water
- Installation of wetlands areas to collect nutrients
- Use of irrigation practices that do not increase erosive washes
- Use of trickle irrigation to reduce the wetted surface area thereby reducing the need for tillage to help control weeds.

Most practices used to reduce soil loss involve planting and maintaining vegetation cover while growing nursery crops. The physical effect of cover crops protecting the surface of the ground has a direct beneficial effect on reducing soil loss. Growing cover crops may be one of the most important management tools to improve soil productivity.

As an example, integrating a cover-cropping plan that maintains or increases soil productivity into a three-year crop rotation plan requires four acres annually for every three acres of productive area. In a traditional crop cycle where a field of plants would be sold by April, following harvest, the field would immediately be prepared for planting. The field would be plowed, fertilized, and sown with a sorghum-Sudan hybrid. The cover crop would be mowed as many times as necessary to avoid seed-head formation and then the field would be plowed under in September. A small grain winter cover crop such as rye should then be planted for winter soil stabilization and as a source of additional organic matter. The rye or other winter cover crop should be plowed down in the spring prior to planting a nursery crop.

This use of sequential planting of grasses and small grains reduces sediment and nutrient losses and potentially increase the soil organic matter levels. Sudan hybrids can be grown all summer and are killed by freezing temperatures. Small grains make an excellent winter cover crop. Seeding rates and planting dates are shown in Table 1. To avoid a serious weed problem grasses should be mowed or killed with herbicides prior to seed formation. The residue should be plowed down.

Table 1: Ground Cover Crops

Species	Seeding Rate	Weight (pounds/bushel)	Planting Date
Barley	2.0 bu/A	48.0	Aug.- Oct.
Rye (annual)	1.5 bu/A	56.0	Aug. – Oct.
Ryegrass (annual)	2.0 bu/A	24.0	Aug. – Oct.
Oats	1.5 bu/A	32.0	Aug. – Oct.
Buckwheat	1.5 bu/A	45.0	Aug. – Oct.
Wheat	25.0 lb/A	60.0	Aug. – Oct.
Crimson Clover	20.0 lb/A	60.0	Aug. – Oct.
Sorghum-Sudan Hybrids	25.0 lb/A	50.0	April – May

The presumed increase of the organic matter in soils may not be the most significant benefit of cover crops. One of the most important physical property improvements is an increased size of soil aggregates in the 1-2 mm size range. An increase in the larger aggregates helps water infiltration and retention, provides a better biological habitat and provides a better rooting environment. Regular incorporation of organic residue is needed or improvements can be lost quickly under conditions of frequent tillage.

Vegetative filter strips between the production site and surface waters are recommended management practices to reduce movement of soil and nutrients off site. Cool season grasses used as filter strips are most effective during critical erosion periods in fall, winter and spring seasons when rain is frequent and during excessive storm run-off events. Filter strips collect sediment and nutrients by trapping and binding nutrients to the vegetative matter in the filter strip. To maximize the benefits of a filter strip, grass should be dense with at least 70% surface coverage. The width of the filter strip necessary will vary based on slope. A study conducted in Indiana indicated little additional benefit when the strip was wider than 8'. Another study completed in Iowa indicated benefits were maximized at a width of 30'.

During major rain events runoff can be expected no matter what system is employed to reduce impact. Storm water ponds and constructed wetlands used as natural filters can be designed to provide even greater retention of sediment and nutrients than can be accomplished with filter strips. Contact Rutgers Cooperative Extension or your local Soil Conservation District for more information on design.

All systems that capture nutrients and sediment require maintenance. Filter strips should be mowed and the residue removed. The residue will be nutrient-rich, so application on and incorporation into production fields will benefit not only the filter strip but also subsequent crops. Depending on surface cover, slope and environmental factors, sediment retention basins will require cleaning as often as every 2 years. The use of a sediment trap that can be easily cleaned and located upstream from the retention basin will prolong the time between cleanouts of the basin.

Fertilization

Perform soil testing regularly to identify fertilization needs and to develop a historical record of soil pH and nutritional status. If the field does not have a historical record, test for several years annually. When soil pH and phosphorus levels have stabilized, one can test less frequently.

When possible, plan to use split applications of fertilizers. Plants will use nitrogen and other nutrients more efficiently when applied in smaller doses, more frequently. Split applications will also reduce the potential for nutrient runoff. Remember that a number of other nutrients, as recommended by soil tests, should be incorporated into the soil before planting.

Side dressing plants rather than broadcast fertilization places fertilizers in proximity to the root zone. When plants are spaced out, nitrogen application should be based on an amount of nitrogen per plant rather than pounds of nitrogen per acre. When plants are closely spaced in rows, adjust the amount of fertilizer used to reflect the area actually fertilized. (If the row spacing is at 6 feet while the root zone is about 1 foot, use 1/6 the amount of fertilizer usually recommended.) Doing so maximizes growth with a minimum amount of fertilizer.

When using a two-way split application, the initial fertilization should take place before bud break. A second application should generally be applied by mid-June. When the total fertilizer requirement is split three ways, the final application should be administered no later than mid-August. With a two-way split application, the first application should use about 65% of the total for the year. For plants that normally have a single annual flush of growth, 65% of the total annual rate should be applied before bud break.

Slower-growing cultivars or species should be fertilized at the lower rates. Vigorous plants require higher rates of fertilizer to maximize growth. Excessive fertilization has been shown to reduce growth and can contribute to nutrient runoff, negatively affecting water quality. The use of controlled-release fertilizers is an optional method of applying nutrients. While initial costs are generally higher than using a granular fertilizer, there may be cost savings of time and equipment use since one application will last the entire growing season.

A combination (N, P, K) fertilizer may be the appropriate selection based on results of a soil test. Generally, applying combination or complete fertilizers has been less expensive than applying nutrient-specific fertilizers (e.g. urea (46-0-0), ammonium nitrate (33-0-0), potassium chloride (0-0-60), etc.). When a certain nutrient in the combination is not needed, however, negative environmental impacts may be greater. Phosphorus is usually the nutrient found to be most in excess for agricultural production. The pollution risk associated with phosphorus is generally related to soil particulate movement that occurs during significant rain events. When phosphorus-laden runoff water enters surface waters, the result can be algal blooms and fish kills.

Fertigation is the process of injecting fertilizers into irrigation water. It can be a good method of applying nursery crop fertilizers since it allows plant material to be "spoon fed" as the season progresses. It can also be effectively used to quickly address crop nutrient deficiencies. Care must be taken to avoid runoff during fertigation.

Fertigation Procedures:

1. Fully charge the irrigation system. When the system is fully charged, water should be coming out of the emitter farthest from the injection point. Record the amount of time required from when the irrigation is turned on until water is flowing from the farthest emitter, then add a couple of minutes safety margin. Using this figure during each fertigation event can save time walking to check the end of the system during each cycle.
2. Begin injection. The length of time required to inject the fertilizer should be at least as long as it took to fully charge the system.
3. After all fertilizer solution is injected, run the system for at least as long as it took to charge the irrigation system to be sure all fertilizer solution has been flushed from the system. This is a good time to walk the system to make sure emitters are not clogged.

Pest Management

Plants produced in the nursery require careful attention during production to maintain suitable plant quality. Plants may be grown under conditions that often favor development of pests that can adversely affect plant growth. These pests may include weeds, insects, and diseases. In the past, pest control utilized preventative pesticide (herbicides, fungicides, or insecticides) applications. Newer pesticides have been developed minimize environmental impact and to target specific pests or groups of pests. As newer pesticides have been developed, the cost of pest control applications have increased. To help contain costs associated with pest control, scouting nurseries for pests on a regular basis is necessary. Upon finding suspected pests, identification is necessary and then selection of appropriate control measures. Rotating chemical classes is important to reduce the probability of pest resistance.

Pest Management Planning

Certain pest problems can be anticipated by knowing the crop history of a field. If a field has been in sod, for instance, grubs might be expected. When sod is killed, root-feeding grubs remain and will feed on roots of liners planted into the field unless control measures are taken. In the case of certain nematode-sensitive crops like American boxwood, soil testing for presence of harmful nematodes is prudent. Contact your Extension Agricultural Agent for assistance in taking a nematode assay sample.

Pest management should be a primary consideration in designing the layout of a field nursery. Any practice that reduces stress on the plant will help promote healthy, vigorous growth and reduce pest problems. Ensure good air drainage by removing windbreaks or barriers to the downhill flow of cold air, plant on the contour to help maintain uniform soil moisture and maintain plants in optimal nutritional condition. Also, control weed growth and keep plants free of damaging insects and diseases.

Give careful consideration to crop rotation practices. Avoid plants with allelopathic relationships. Allelopathy is the inhibition of growth in one species of plants by chemicals produced by another species and can occur by just having leaf residues over the root areas of susceptible plants. The most familiar example of allelopathy is suppression of many plants within the root zone areas of black walnut trees. Growers have reported similar problems when planting deciduous shrubs after boxwoods, yews after yews, oaks after oaks, poplars after poplars, and many rosaceous crops such as cotoneaster, pears, mountain ash, hawthorn or quince in rotations.

Crops with complementary pest problems should not be grown in the same fields or fields close to each other. An awareness of these instances can help reduce pest problems such as cedar-apple rust in crabapple and cedars. Pesticides used on neighboring crops may negatively affect other crops. For instance, Burford holly is very sensitive to and can be defoliated by dimethoate (Cygon).

Rules and Regulations

- Pesticide Use Certification Program
    - All agricultural businesses that use pesticides must possess a pesticide applicator license. If the business applies pesticide only for their own business they should have a private license.
        - To receive a license, one must pass a test administered by the New Jersey Department of Environmental Protection (NJDEP).
        - Licenses are good for five years but need to be renewed annually. During the five-year license period one is expected to receive 8 credits of core and 16 credits of category recertification training.
- Employee requirements
    - Employees may apply pesticides as a "handler." Annual training is required. A roster of trained handlers must be maintained.
    - Employees are required to receive EPA-approved Worker Protection Safety training every five years and have a current verification card in their possession.
- Agricultural Worker Protection
    - Employers are required to "assure that each worker has received a employee orientation at least once each year for each agricultural establishment on which the worker is employed, on the first day of their employment, or at least one day prior to any work in a field which has been treated within the past 30 days"
- Reporting
    - Businesses need to inventory stored pesticides annually and submit a copy to the local fire company by May 1.
    - It is required that an annual use report be submitted to the NJDEP Pesticide Control Program office.
- A complete set of rules and regulations can be found on the Internet at: http://www.nj.gov/dep/enforcement/pcp/pcp-regs.htm.

Monitoring pest populations

Pest management strategies should be used to minimize the amount of pesticides applied. That entails the application of pesticides based on need and requires monitoring to make that determination. In addition, pesticides should be applied efficiently and at times when runoff losses are unlikely.

Scouting is a key element of pesticide management. Traditional pest management programs identify pest problems and then establish a threshold (a tolerable pest population) after which control measures are started. A significant difference for the nursery industry is that there is a zero threshold requirement for plant material stock that is shipped, as established by law. Essentially that means that all plant material shipped interstate must be pest-free. The following is a list of pest management strategies:

- Establish a scouting program to monitor pest problem outbreaks. Scouting can include direct observation or trapping with sticky cards or pheromone traps. Trained employees or professional pest control advisors should do scouting. Records of scouting results should be maintained and there should be a designated person for making pest management decisions.
- Apply insecticides, miticides and fungicides based on need. Only apply in anticipation of a pest problem when methods of predicting outbreaks have been documented. The major exception is that some disease pathogens require preventative sprays on susceptible crops.
- Apply weed control agents based on control characteristics of specific herbicides (pre-emergence or post-emergence).
- When possible, use pesticides that are effective but less environmentally persistent, toxic, or mobile.
- Maintain records on past pest problems, pesticide use, environmental and other information for treatment areas.

- Use control options that help maintain pest predators. Use narrow-spectrum pesticides that affect only target organisms and apply pesticides only to affected plants or areas.
- Evaluate the use of pheromones for monitoring populations, for mass trapping, for disrupting mating or other behaviors of pests and to attract predators or parasites.
- Destroy pest breeding, refuge and overwintering sites. Remove plant debris from plant growing areas or the nursery. Inspect and quarantine newly introduced plant material. When possible, choose plant species or cultivars that are known to be more resistant to common pests and diseases.
- Use spreader/stickers with fungicides and insecticidal sprays to increase efficiency and reduce losses due to rain or irrigation.

Pesticide Applications

When the application of pesticides is necessary, growers need to identify and evaluate pesticide options. Growers should develop a schedule that provides a rotation between pesticide classes to help reduce pest resistance to the controls. When a choice of registered materials exists, producers are encouraged to choose the most environmentally benign pesticide products. Consider persistence, toxicity runoff and leaching potential of products along with other factors.

Growers need to be licensed to use pesticides and meet the requirements of federal and state laws that regulate use of pesticides. Users must apply pesticides in accordance with the instructions on the label of each pesticide product and wear appropriate protective equipment. Farm-worker safety requirements should also be reviewed and met. A checklist of some pesticide safety needs follows:

- Calibrate pesticide spray equipment annually.
- Use backflow protection devices on hoses used for filling tank mixtures.
- Evaluate the soil and physical characteristics of the site. Locate mixing, loading and storage in areas that have a low potential leaching or runoff of pesticides. In situations where the potential for pesticide loss is high, emphasis should be given to practices and/or management practices that will minimize these potential losses. Recognize physical characteristics that may be impacted by pesticide movement and take steps to reduce the risk of an incident occurring.
    - Proximity to surface water
    - Runoff potential
    - Wind erosion and prevailing wind direction
    - Highly erodible soils
    - Highly permeable soils
    - Shallow aquifers
    - Wellhead protection areas
    - Proximity to dwellings
- When possible, use pesticides with a low solubility in water (5 ppm or less) or a low potential risk for leaching.
- Use pesticides with a short half-life to reduce the persistence of the pesticide in the soil and thus the opportunity for leaching.
- Time the pesticide application as far in advance as possible of irrigation and unfavorable weather conditions. The interval between pesticide application and irrigation or rain is closely related to the amount of pesticide runoff and leaching loss. It also relates to pesticide efficacy against the pest.
- Use efficient application methods, e.g., banding of pesticides or applying chemicals when containers are jammed (containers spaced pot-to-pot), or stagger applications.

Fumigation

Fumigation kills most insects, disease, nematodes and weeds, and may be the most practical solution for a valuable, pest-prone crop. Because fumigation kills by using toxic chemicals, it is important that care be given to each stage of the fumigation process to ensure the safety of the fumigator and the effectiveness of the treatment.

Fumigants are highly toxic chemicals. Purchase and application in many states requires certified applicator licensing.

Maximum effectiveness may be achieved when the treated area is covered with plastic sheeting. The plastic helps ensure that certain fumigants remain in the soil long enough to be effective before escaping into the atmosphere. Cultivate the treated area seven days after application. Do not plant until 14 to 20 days after treatment. If the soil is cold and/or wet you will have to wait longer. ***Always refer to the product label for details and precautions.***

Regardless of the fumigant you use, soil preparation is the key to successful sterilization. Soil should be cultivated twice to a depth of 6 to 8 inches: once 7 to 10 days before fumigation and once immediately before fumigation. Tillers and rotavators are excellent for this purpose. At treatment time, the soil should be free of clods and fresh organic debris, moist enough for seed germination and have a temperature greater than 55^{o}F at the 6-inch depth. Most fumigants are less effective when organic material (such as roots, stumps, leaves, and grass) have not decomposed. Either remove organic debris or allow it to decompose before fumigation.

Fall is an excellent time to fumigate because soils are warm and proper moisture levels are easier to attain. Investigate fumigant options prior to use for best effect. If you have never fumigated soil before, have an experienced pesticide applicator help the first time you fumigate. Fumigants are highly toxic chemicals that must be handled properly to be both safe and effective.

Operation and Maintenance of Pesticide Application Equipment

All pesticide application equipment should be maintained in good working condition. Make a checklist of known replacement, repair and wear items. Calibrate spray equipment with clear water prior to the start of the spray application season. All sprayer tanks should be labeled to identify what types of pesticides can be used with the specific equipment. Lock the tanks when not in use to avoid possible contamination of spray materials.

Storage

Chemical storage facilities must be designed or located such that weather conditions or accidental spills or leakage will not impact soil, water, air or plants. Chemical storage facilities should be posted with adequate safety warning signs and chemicals in storage must be reported to the local fire department annually. Store pesticides in their original containers in environmentally safe and secure locations. Storage should be secure and include proper ventilation and control for any potential chemical leakage that may contaminate water sources or be a detriment to living organisms. Designs for chemical storage and handling facilities can be obtained through Rutgers Cooperative Extension or through your local Natural Resources Conservation Service office.

Mixing and Rinsing Stations

Research has indicated that one of the greatest potentials for ground water contamination from pesticides comes from spills that may occur during the mixing and loading process. The location and design of proper mixing and rinsing equipment stations, relative to the potential contamination of ground or surface water sources should be considered.

To protect against ground water contamination, mixing, loading and cleaning operations should be done on an impervious surface covered with a roof and surrounded by impervious curbing. Wash water and waste products used in cleaning of pesticide application equipment should be disposed of in a safe manner. Rinse water from equipment and containers should be stored and used in the following batch mixture where possible. Where disposal is necessary and allowed by laws and regulations, it should be performed avoiding high runoff and leaching areas such as ponds, lakes, streams, and other water bodies. Disposal of empty pesticide containers should follow instructions provided on the container.

All operations should be performed at a safe distance (100 ft.) from any well. When wells are in close proximity, extreme care must be exercised when mixing or applying chemicals. Anti-siphoning devices should always be used to prevent backflow into the well.

Pre-Planting Weed Management Planning

The most important weed management tasks are done before planting. Good site preparation includes scouting for perennial weeds and controlling the difficult species such as multi flora rose, Canada thistle, mugwort and field bindweed before planting. Controlling perennial weeds requires killing the root system, since most perennial weeds will re-grow if only the top is destroyed. There are few effective options for controlling perennial weeds in crop areas. Fumigation is not an option and the control spectrum for systemic post-emergence herbicides is generally limited. Cultivation is a possible control technique and it can be effective against perennial weeds using multiple cultivations over a period of several months to control the root systems. Timing of the application is critical to ensure satisfactory perennial weed control. Fumigant information is indicated above.

Planting sequential cover crops and allowing the land to remain fallow can help to reduce some weed and insect problems. The intense shading, mowing and competition created in a cover crop program will greatly reduce, if not eliminate, certain weed problems.

Growing individual species of nursery crops in separate blocks allows for more options in weed control. Another management consideration is herbicide carryover from one season to another. When planning new fields, obtain the herbicide history because some herbicides remain in the soils and cause problems for new crops.

Pesticide Considerations

- Follow label guidelines:
  - Use recommended rates
  - Use recommended methods of container disposal
  - Follow all instructions as indicated on the pesticide label.
    - Re-entry interval
    - Worker protection standards, etc.
- Mix only the amount of pesticide needed:
  - Plan ahead and be sure to use all mixed pesticides.
  - Spay all material on labeled plants to avoid water quality problems.
- Comply with Worker Protection Standards:
  - Train workers on "Worker Protection Standards"
    - Train nursery workers and pesticide handlers to use correct procedures: applications, mixing, loading, handling, posting, record-keeping, re-entry of treated areas, use of personal protective equipment (PPE), and emergency assistance.
    - Document all training sessions.
    - Provide decontamination sites and post necessary information in a central location.
- Stagger herbicide applications whenever possible:
  - Most herbicide runoff occurs during irrigation or rain events shortly after application. Avoid making a pesticide application to the entire nursery to reduce peak loading of the runoff water.
- Avoid injecting pesticides into the overhead irrigation system.
- Select pesticides with lower water solubility.
- Participate in pesticide recycling programs.

Guidelines for using pre-emergence herbicides

Most pre-emergence herbicides can be used after the soil is settled around the transplants. They must be applied before weeds emerge. This prevents weed seeds from germinating from several weeks to months. As with any other tool, each herbicide has unique characteristics that should be considered when planning a weed management program. Always review labeled information prior to using pesticides. Consider the following during decision-making.

- Rate of application (The correct rate will vary with weed pressure, organic matter content of the soil and ornamental species.)
- Residual (length of time the herbicide will provide effective weed control)

- Activation (For maximum effectiveness, herbicides need to be watered with 1/2-inch of irrigation water or rain into the soil surface within a specified time.)
- Mechanism of action (how the herbicide kills weeds)
- Weed control spectrum (which weeds the herbicide will and will not control)
- Potential losses (leaching, runoff, and volatility)

Since pre-emergence herbicides will not control growing weeds, they should be applied before weeds germinate. In field production, pre-emergence herbicides should be applied on weed-free, stabilized soil after transplanting and then irrigated. Frequency of herbicide application will depend upon the herbicide's residual. Residual weed control will increase with increasing herbicide application rate; control decreases with increasing amounts of rainfall or irrigation, temperature, and organic matter. The proper herbicide for each situation will be dictated by the plant species, weed species, and future use of the field.

Guidelines for using post-emergence herbicides

Post-emergence herbicides can be classified as systemic or contact and selective or nonselective. Selective herbicides kill only specific plants while nonselective herbicides kill all plants. Systemic herbicides are absorbed and move through the plant. These are useful for controlling perennial weeds. For best control, the weeds must be actively growing so the herbicides can move throughout the plant. Contact herbicides kill only the portion of the plant on which the herbicide actually settles. Contact-type herbicides kill small annual weeds but only burn back perennial or large annual weeds. Good spray coverage is important. Check the label to determine the need to treat at a specific stage of weed growth.

All post-emergence herbicides need to dry on the plant to maximize effectiveness. Specific drying times range from 30 minutes to 8 hours and are specified on the label. This is the length of time that needs to pass after herbicide application before irrigation or rain to ensure that the herbicide has had adequate time to affect the plant. Although post-emergence herbicides labeled for field production remain in the soil for a short length of time after application, they have no residual and little or no soil activity; therefore, multiple applications are needed for perennial weeds. The majority of herbicides registered for post-emergence weed control in field production are used either for grass control or for nonselective weed control. Products that provide nonselective weed control should not be applied to the foliage of ornamental plants as severe injury or plant death may occur.

Post-emergence herbicide considerations:

- Apply at correct rate.
- Remember that multiple applications are usually required to control perennial weeds.
- Use the type and amount of surfactant specified on the label.
- Apply when the air temperature is above 50^{o} F and the comfort index (temperature in ^{o}F plus humidity) is below 140.
- Treat weeds at proper growth stage.
- Avoid mowing three or four days before and after herbicide application.
- Allow adequate time for treated plants to die before disturbing the soil.
- When there is a potential for losses through leaching, runoff, and/or volatility, check the label and consider another option if necessary.

Guidelines for weed control without the use of herbicides

Herbicides cannot always be used, nor are they effective in controlling all weeds. In these situations, cultivation and hand pulling may be the only available options. Cultivation works well on small annual weeds. Perennials will often re-grow from the roots even if the top is removed. Also, remember cultivation can stimulate successive flushes of germinating weeds by bringing new weed seeds to the soil surface. Check for emerging weeds on a two- to three-week cycle if you are routinely cultivating. If pre-emergence herbicides have been applied and activated, they form a chemical barrier that must be left undisturbed to be effective. Cultivation disrupts this barrier and lessens the effectiveness of the herbicide. Therefore, avoid cultivating if using pre-emergence herbicides.

Cultivation is not without other drawbacks. Cultivated soil is very susceptible to erosion since there is little to no vegetation to hold the soil in place. In addition, implements such as in-row weeders, which cut off weeds 1 inch below the soil surface, can build up ridges. Ridged soil around the stem collar of newly set liners tends to suffocate them just as if they had been planted too deeply.

It is important to develop a weed management strategy that encompasses all 12 months of the year and uses all available options. This strategy should include preventative measures such as pre-emergence herbicides, as well as sanitary practices that prevent weed seeds and vegetative parts from spreading.

Glossary

AMP - the Agricultural Management Practices include schedules of activities, prohibitions, maintenance procedures and structural or other management practices found to be the most effective and practicable methods to prevent or reduce the discharge of pollutants to the air or waters of the United States. Best management practices also include operating procedures and practices to control site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage.

Cation Exchange Capacity (CEC) – the total of exchangeable cations (positively charged ions) that a soil can adsorb. Mineral particles and organic matter in the soil are able to exchange cations adsorbed to their surfaces with other cations in the soil solution, acting as a store for nutrients and buffering against changes in pH. Some cations of interest are ammonium (NH_4^+), potassium (K^+), calcium (Ca^{2+}), and magnesium (Mg^{2+}), all of which serve as plant nutrients, and hydrogen ions (H^+), which cause soil acidity.

Constructed wetland - a shallow bed filled with selected vegetation, such as cattails, into which runoff water is diverted and which serve as a biological filter for removing chemicals from the water. Constructed wetlands are designed to slow moving water, allowing time for treatment, and can use a variety of substrates, from native soil to sand or gravel. They can be designed to have the water level above the substrate surface or so that the water is kept below the surface.

Controlled-release fertilizer (CRF) - a formulation of fertilizer where release time is controlled by the thickness of the coating (i.e. resin) or the amount of the release agent in the coating that dissolves in water to form pores in the coating (i.e. plastic). CRFs have the advantages of slowly but continually feeding crops and not exposing plants to a large dose of salt at one time (as using some granular fertilizers may).

Cyclic irrigation –an irrigation schedule in which a plant's daily water allotment is divided up and applied in a series of irrigation and rest intervals throughout the day.

Emitter - a device used to apply water in the form of spray or drops to the soil surface. It is a general term that can be applied to drip stakes, micro-sprinklers, misters, etc.

Half-life - the time required for a substance to degrade by one-half. Pesticides with a long half-life are considered *persistent*.

Lime - a material containing carbonates, oxides, and/or hydroxides, and used to neutralize substrate acidity. Dolomitic limestone contains calcium and magnesium.

Nematode - very small worms abundant in many soils and important because many attack and destroy plant roots.

Pathogen - a causal agent of disease. The term can refer to funguses, bacteria, viruses, or other disease-causing organisms.

Permeability - the capacity of porous rock, sediment or soil to transmit water.

Pesticide - any form of chemical or substance used to control pests. Pesticides include fungicides, herbicides, and insecticides.

pH - a measurement, ranging from 0 to 14, of the concentration of hydrogen ions (H^+) in a solution. A pH of 7 is neutral, a pH below 7 is acidic, and a pH above 7 is alkaline or basic.

Pheromone – a naturally occurring or synthetically produced substance that can result in specific reactions of organisms. Pheromones are notably used by insects for communication, and so can be used in pest management to scout for, trap, or disrupt mating in insect pests.

Runoff - the portion of precipitation or irrigation on an area that is discharged from the area. Runoff which is lost without entering the soil is called surface runoff and that which enters the soil is called ground water runoff or seepage flow. Managing runoff is critical in the nursery industry because it can carry sediment, fertilizers, pesticides and other pollutants to surface water bodies or groundwater.

Soil – a natural body composed of unconsolidated minerals, organic matter, air, water and organisms. Considering plant growth, soils serve to provide a plant with support, water, nutrients and air for its roots. Soils also provide important environmental functions including regulating water movement in a watershed, sequestering carbon from the atmosphere, and removing pollutants from water and air. In nursery production, care is necessary to conserve soil by preventing erosion and promoting soil health in order to preserve these functions and encourage healthy and vigorous plants.

Substrate - organic and inorganic materials, often bark, peat and sand, used as growing media in a container to support the plant and contain the root system.

Water holding capacity - the amount of water a soil can hold after being fully wetted and allowed to drain. In soils, the term *field capacity* is also used. Because some water will be held too tightly by the soil for plants to use, the term *available water capacity* is used to designate the amount water a soil can hold that can be used by plants. A soil's water holding capacity is affected by soil texture and organic matter content. An understanding of the water holding capacity of your soil is important because it determines how frequently you should irrigate and how much water should be applied.

Useful References

- Archived historical soil survey publications for New Jersey counties. http://soils.usda.gov/survey/online_surveys/new_jersey/
- Best Management Practices Guide 2.0. Order through the Southern Nursery Association, Inc. http://www.sna.org/forms/SNAProductOrderForm.pdf
- "Management Practices to Protect Water Quality: A Manual for Greenhouses and Nurseries". http://ceventura.ucdavis.edu/files/32117.pdf.
- New Jersey Department of Environmental Protection rules and regulations can be found on the Internet at: http://www.nj.gov/dep/enforcement/pcp/pcp-regs.htm
- Pest Control Recommendations for Shade Trees and Commercial Nursery Crops. By A. B. Gould, S. Hart and J. Lashomb. NJAES pub. #E036. http://njaes.rutgers.edu/pubs/publication.asp?pid=e036
- Pruning Field Grown Shade and Flowering Trees. By T. E. Bilderback, R.E. Bir and M.A. Powell. Horticultural Information Leaflet NO. 406. http://www.ces.ncsu.edu/depts/hort/hil/hil-406.html
- Soil quality information is available from the Natural Resources Conservation Service on line at http://www.statlab.iastate.edu/survey/SQI/sqiinfo.shtml
- The American Standards for Nursery Stock. ANSI 60.1. American Association of Nurserymen. 1250 I Street N.W. Suite 500, Washington D.C. 20005. http://www.jerseygrown.nj.gov/jgstandards.pdf
- "Water Quality Handbook for Nurseries". http://osuextra.okstate.edu/pdfs/e-951.pdf
- Web Soil Survey website. http://soils.usda.gov/survey/

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Appendix 1: Fertilizer Application Record Sheet

Date	Field Location	Fertilizer Analysis	Brand Name	Amount Applied	Plant Name	Environmental Conditions

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Appendix 2: Fertilizante Aplicación Tablero

Fecha	Área	Análisis de fertilizante	Nombre del Producto	Cantidad total usada	Planta	Condiciones ambiental

Appendix 3: Pesticide Application Record Sheet

Date	Field Location	Plant	Wind	Product Name	Pounds per Section	Total Used	Length of Control	Pests Not Controlled	General Plant Health

Appendix 4: Peste Aplicación Tablero

Fecha	Área	Planta	Viento	Nombre del Producto	Libras por la sección	Cantidad total usada	Longitud del Control	Pestes (Plagas) no controladas	Salud de Planta General

APPENDIX E: SOIL, WATER, NUTRIENT AND PESTICIDE AGRICULTURAL MANAGEMENT PRACTICES FOR CONTAINER NURSERIES IN THE UPPER COHANSEY RIVER WATERSHED

Rutgers
New Jersey Agricultural
Experiment Station

Soil, Water,
Nutrient and Pesticide
Agricultural Management Practices
for
Container Nurseries
in the
Upper Cohansey River Watershed

James Johnson
Agricultural Agent
Cumberland County

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Introduction

New Jersey has many attributes that make it an ideal spot to produce nursery plants. The marketing potential is great since it is geographically located in the center of the "BosWash" megalopolis. The megalopolis is around 500 miles long from the areas of Boston, Massachusetts to Washington, DC and has a population of approximately 44 million people. That represents 16% of the total population of the United States.

Unfortunately, New Jersey is also an expensive state in which to conduct business. The cost of land and higher than average operational costs force producers to find ways to maximize production in a way that also protects the environment. While these factors are generally considered to be negative, they also provide opportunities for the good manager and a container operation.

In a perfect world, nurseries would be designed for maximum efficiency with minimal environmental impact. In reality, few nurserymen have financial resources adequate to complete the planning and installation of such a facility when they are starting out in the business. If an established nursery moves to a new site, one should take advantage of the opportunity. The result of not designing from the ground up is the need for retrofitting existing nurseries. One should remember, however, that lack of finances to build a state-of-the-art nursery doesn't mean one should not plan for that nursery. Nurseries should plan for the future while building for the present.

Infrastructure efficiency of plant and support materials handling is critical to profitability. One must maximize space use and minimized the number of times plants are moved. One should examine and evaluate everything. Included would be identifying where raw materials are stored, where substrate (container media) is prepared, the potting location, how plant material is moved within the nursery, and how plant material is sold off the nursery to include site selection of transportation docks and handling facilities.

When designing the nursery, there should be special attention toward water movement that minimizes environmental impact. Runoff water is typically higher in nutrient content than surface or groundwater and can carry sediment and pesticides. Because of the need to have minimal environmental impact, it is important to capture and re-use excess irrigation water. The need to also capture a certain amount of water from rainfall is a compounding factor. The reason for capturing water from rainfall is that there is typically a nutrient load that comes from the nursery associated with the early stages of a rain event. Optimally, nurseries should develop the capability to capture the first inch of a rain event.

A system for capturing and treating excess irrigation and rainfall water may include a biofilter, an impoundment and a filtration system. A biofilter is an area of vegetation where runoff is slowed, allowing sediment to be removed from the water. Plants and microbes in the biofilter help reduce nutrient content in the water. An impoundment is a natural or constructed basin that captures and stores runoff. Water in the impoundment can be recycled, which entails treatment and reuse for irrigation. When water from an impoundment is used for irrigation, a filtration system may be necessary to reduce water particulate matter so sprinklers won't plug. Because impoundments may overflow during significant rain events, an additional biofilter can be placed to further remove pollutants from the water leaving the nursery before it enters ground or surface waters.

Plant grouping is encouraged to help reduce water or nutrient use or to enhance pesticide use safety. A partial list of species with low, medium, or high irrigation requirements is included in Appendix 2. Foliage characteristics (dense vs. sparse leaves, and branching) will affect water use by plants. Certain plant species will channel more overhead water into a container than others; this is a lesser consideration if using micro-irrigation. Water use is also affected by plant growth. During rapid growth (usually spring and summer), the plants require more water than during times of slower growth (winter). A partial list of plants with low, medium, or high nutritional requirements when container-grown is included in Appendix 3. If fertilizer is applied through the irrigation system or it is applied overhead, many of the plant environment characteristics noted for irrigation requirements will apply. Grouping by pesticide requirements is usually much more difficult. Recommendations for pesticide use on nursery stock can be found in Rutgers Cooperative Extension Publication #E036: Pest Control Recommendations for Shade Trees and Commercial Nursery Crops (available online at <http://njaes.rutgers.edu/pubs/publication.asp?pid=e036>)

Irrigation Management

Water Use Certification

Prior to starting a nursery, it is important to establish the right to use water in the state of New Jersey. The New Jersey Department of Environmental Protection (NJDEP) administers the water use certification program. It is required that one be certified for water use when there is a water need in excess of 100,000 gallons per day or one has the capability to pump water at a rate over 70 gallons per minute. Remember that a permit to drill a well is not a permit to use the water from that well. It is increasingly important to use the most efficient methods of irrigation because of limits being placed on allowable water use. Factors that have increased water regulation include the need to conserve water in designated critical areas with limited water supplies and perceived overuse of water resources. One can get additional information on the water certification program through your local Rutgers Cooperative Extension Agricultural Agent or through the NJDEP.

Water Quality

High quality water is necessary for nursery industry success. Water should be evaluated for pH and soluble salts. If salts are elevated, water should also be checked for sodium. Iron and sulfur may also be of importance, especially in regard to their cosmetic effect on many species of plants (leaf discoloration). For container irrigation, it is generally preferable to use a groundwater source rather than surface water. If surface water is used, it may be necessary to filter it to prevent the clogging of irrigation nozzles, misters, or micro-irrigation emitters. If the pH of the water is elevated, pesticide labels should be carefully reviewed to determine the potential for pesticide deactivation.

Water Quality Monitoring

1. Water quality should be monitored at least twice a year (preferably during extended periods of wet and dry weather). More frequent monitoring may be needed to adjust production practices in response to changes in water quality.
2. Water quality should always be monitored prior to locating a new nursery, moving to a new site, or using a new water source. Test the water quality to ensure that the concentration of chemical constituents is acceptable for plant growth according to guidelines.

Irrigation Water Quality Guidelines

Table 1: General irrigation water quality guidelines for container plant production.

	Degree of Problem		
Characteristic	None	Increasing	Severe
Potting Substrate pH Maintenance			
pH	6.5 – 7.0	> 7.0	
Bicarbonate (ppm alkalinity)	< 61	61 – 214	> 214
Bicarbonate (meq/L)	< 1.0	1.0 – 3.5	> 3.5
Soluble Salts			
Electrical Conductivity (EC, dS/m)	< 0.75	0.75 – 1.4	> 1.4
Toxicity - Root Absorption *(Sensitive Crops)*			
Sodium (Sodium Adsorption Ratio (SAR))	< 3	3 – 9	> 9
Chloride (ppm)	< 70	70 – 345	> 345
Toxicity - Foliar Absorption			
Sodium (ppm)	< 70	> 70	-
Chloride (ppm)	< 100	> 100	-
Foliar Residues			
Bicarbonate (ppm hardness)	< 40 – 90	90 – 520	> 520
Bicarbonate (meq/L)	< 0.7 – 1.5	1.5 – 8.5	> 8.5
Iron (ppm)	< 3	> 3	-
Permeability - Organic Potting Substrate			
Sodium (Sodium Adsorption Ratio (SAR))	< 35	> 35	-

Table 2: Irrigation water quality guidelines for micro-irrigation.

	Degree of Problem		
Characteristic	None	Increasing	Severe
Hydrogen Sulfide (H_2S) (ppm)	< 0.1	0.1 – 0.5	> 0.5
Iron (Fe^{++}) (ppm)	< 0.2	0.2 – 0.3	> 0.3
Tannins, Phenolics, Humic Acids (ppm)	-	-	> 2.0
Total Dissolved Solids (TDS, ppm)	< 525	525 – 2100	> 2100
Suspended Solids (ppm)	< 50	50 – 100	>100

Water Treatment

Treatment of irrigation water may be necessary if the water quality is poor. In New Jersey there is usually no need to change the water pH. If it is necessary to reduce the pH, the addition of an acid to the water will work. Remember that acidification will not reduce the salt concentration of water with a high soluble salt content. Deionization and reverse osmosis can be used to remove salts from irrigation water. These water treatments are used if soluble salts, especially sodium, are high enough to cause plant damage. These are expensive treatments and so are generally limited to high value crops.

Water System Design and Management

Designing an Irrigation System

Irrigation systems should be designed to maximize the amount of irrigation water reaching the plant substrate while minimizing water that lands away from plant material. Test them with a water collection system to measure the amount of water applied and the uniformity of application. The water collection system can be as simple as placing same sized containers in various locations within the plant growing area, running the irrigation system and then measuring differences between water quantities collected in the containers. Different sprinkler heads will result in widely different dispersal patterns. Be sure to test when there is little air movement as well as when there is increased wind. Determine the maximum wind speed under which plant material can be effectively irrigated.

When to Irrigate

The amount of irrigation water needed per application depends on container size, growing substrate, plant species, and weather conditions. A substrate's water absorptive capacity is similar to that of a sponge. When relatively moist, there is a low water absorption capacity. When relatively dry, there is a high water adsorption capacity. Organic media tend to become hydrophobic when they get excessively dry, will tend to allow irrigation water to run through resulting in very little adsorption and will hold be quite difficult to re-wet. If the substrate is too wet, it will also hold very little water.

Growers can get a feel for the amount of water needed by checking the water content of the substrate as well as taking into consideration weather conditions since the previous irrigation. By adjusting the irrigation amount according to the amount of water lost since the last irrigation, growers can greatly reduce the amount of water they use and reduce the amount of fertilizer exiting containers through excess leaching.

Increasing the substrate's water-holding capacity can decrease the frequency of irrigation. Substrates with a higher proportion of fine particles, including water-holding organic materials like peat and coir, will retain more water. An increase in water-holding capacity of substrate must be balanced with the need to maintain air-filled pore space in the substrate. A substrate with insufficient air-filled pore space will be excessively wet and have a higher potential for the incidence of diseases such as *Phytophthora* or *Pythium*. Materials such as vermiculite, perlite or rice hulls are added to substrate mixes to increase air-filled pore space.

Cyclic Irrigation

Most nurseries irrigate on a daily basis with water being applied in a single, continuous application. An alternative approach to help increase the water-holding capacity is cyclic irrigation in which the daily water allotment is applied in more than one application with timed intervals between applications. For example, using cyclic irrigation, one might apply three 0.1-inch doses of water lasting about 20 minutes each. The first hour 0.1 inch would be applied, one hour later another 0.1 inch and the final 0.1 inch of water would be applied one hour after the last application. This would replace a single application of 0.3 inch in 1 hour.

Compared to continuous irrigation, cyclic irrigation has been shown to reduce the volume of irrigation runoff by 30% and the amount of nitrate leached from containers by as much as 41% (Fare et al. 1994). Growers have also indicated that the amount of water applied per cycle can be reduced because of better wetting characteristics, resulting in a net water savings. Cyclic irrigation can be used with both overhead and micro-irrigation systems. Using timers and solenoid valves is desirable when applying cyclic irrigation because manual control can become cumbersome.

Electronic control of irrigation systems has been developed using several different soil moisture sensing devices appropriate for use in containers. These systems can be used to indicate when to irrigate and how much water to apply. While they have been used successfully in nursery situations, an understanding of the limitations of individual sensors is important since many have some limitations such as erroneous readings caused by elevated salt levels in the substrate. A successful approach is to use more than one system, so that the strengths of one system offset the weaknesses of the other.

Micro-irrigation

Micro-irrigation is a method of irrigating where water is applied at a relatively slow rate and usually directly to the container substrate. While a variety of emitters can be used, point source emitters (in-line emitters, spray stakes, spaghetti drippers, etc.) are generally used for container production. Irrigating container-grown plants with micro-irrigation can result in water, fertilizer and pesticide savings as compared to overhead irrigation. Additional savings are realized because micro-irrigation systems require smaller pumps and pipe sizes. However, micro-irrigation systems generally have higher initial and maintenance costs. Use of micro-irrigation also affords the opportunity to harvest crops shortly after irrigation because most of the soil is not wetted.

Sub-irrigation

Use of a sub-irrigation system is another irrigation option. A capillary mat system employs a water-conducting porous plastic mat to conduct water to plants. The ebb-and-flow system uses a flooded bed in which the base of the container is submerged in water during the flood cycle and water is absorbed by the substrate through capillary action. Following irrigation, water drains from the production area into a reservoir. Sub-irrigation has become increasingly important in greenhouse production systems. Advantages include eliminating runoff leaving the production area and conserving water and fertilizer. Care must be taken to avoid salt accumulation in container substrate and disease transmission among plants through recycled water.

Irrigation Uniformity

The uniformity of water application and efficiency of an irrigation system tends to decrease over time because of wear. Maintenance is required to retain efficiency and that justifies the need to test the system annually at the start of the season. Use the same water collection system as described in the “Designing an Irrigation System” section. When irrigation uniformity decreases and water is wasted, disease problems tend to increase and crops become less uniform. Be sure to keep baseline information developed when the system was new for comparison during annual inspections. As irrigation uniformity becomes less acceptable, repairs, replacements and adjustments must be performed.

Management of Irrigation Systems

1. Irrigation should be scheduled (both when to initiate irrigation and the duration) based on plant demand. Schedules can be determined by container weight, color or feel of substrate, or electronically measuring substrate moisture content. Remember, when plants show moisture stress growth has been lost.
2. A substrate’s water-holding capacity is related to the pre-irrigation substrate water content. Substrates that are moist will require less irrigation water to complete wetting than a substrate that has excessively dried.
3. Irrigation should be managed to minimally exceed the water-holding capacity of the substrate. Be sure there is enough water applied to have 15% of the water leach through the substrate to control soluble salts. It is helpful to occasionally measure the actual volume of the leachate to avoid insufficient or excessive leaching. When attempting to limit water use during extended periods of limited rainfall, soluble salts can build up in the center portion of containers. Leaching is critical to avoid plant injury.
4. When using timer-controlled automated systems, a main shutoff device should be used to prevent irrigation system operation during significant rainfall events.
5. Where practical, use substrate moisture sensors or a class A evaporation pan calibrated to plant demand to help schedule irrigation applications.
6. Where practical, use cyclic irrigation to decrease the amount of water and nutrients exiting the container.
7. Micro-irrigation should be used for large containers (7 gallons and larger) to minimize water loss between containers.
8. When practical, the irrigation system should be separated into zones to match plant irrigation

needs. If possible, plants with similar irrigation requirements should be grouped into the same irrigation zone.

9. Irrigation should be scheduled to allow the maximum time following pesticide applications.
10. When practical, irrigation should be applied during time of minimal wind.
11. Personnel need to be trained in irrigation management, procedures for recording water use and problem reporting.
12. Avoid irrigating areas without plants, considering both non-crop areas like roads and walkways and crop areas where plants have been removed. Consolidate plants from partially filled irrigation zones.
13. When using overhead irrigation, keep plant spacing close to minimize water falling between pots, while leaving enough space between pots to allow sufficient air flow around foliage.
14. Use a well-designed irrigation system and keep it maintained. Maintain water pressure appropriate for sprinklers to maintain desired drop site. Use identical emitters within a zone. Maintain filters and inspect the performance of the irrigation system. Space overhead sprinklers to achieve head-to-head coverage.

Irrigation for Heat or Cold Protection

1. Water application should be initiated as the air temperature nears the critically hot temperature for plant injury. Intermittent syringing of the foliage is important to avoid serious wilting. One must carefully consider not only the temperature, but also the wind speed and relative humidity, as they will increase plant stress as winds increase and the relative humidity decreases.
2. Water application should be initiated as the air temperature nears critically cool temperatures for plant injury. When irrigation is started for cold protection, it should continue until ice has melted off the plant material. Review weather forecast. Irrigating for cold protection is only effective for relatively short cold snaps.

Runoff Water Management

Erosion Control

Water erosion is the process by which the land surface is worn away by water flowing over exposed soil. In the process, water picks up detached soil particles and debris that may contain chemicals harmful to receiving waters. Erosive forces increase as the velocity of flowing water increases resulting in small channels and eventually gullies of varying widths and depths. Soil erosion, therefore, should be avoided for two reasons: first, because it entails a loss and degradation of soil onsite; second, because the sediment and chemicals associated with the sediment particles can be harmful if it enters surface water bodies. Sedimentation is the process where soil particles settle out of suspension as the velocity of water decreases. Larger and heavier particles (gravel and sand) settle out more rapidly than fine silt and clay particles. It is difficult to totally eliminate the transportation of these fine particles even with the most effective erosion control program. A well-designed nursery facility will help reduce erosion from both irrigation and rain events.

Each container nursery should develop a plan for erosion and sediment control. Personnel from the local Natural Resources Conservation Service (NRCS) and Soil Conservation District (SCD) can help with design planning. The plan should address: 1) preventing slope soil erosion by using vegetative cover and other means; 2) a system to capture excess irrigation water; 3) a method to remove sediment from excess irrigation water; 4) a designed biofilter to remove nutrients and other chemicals from the water (e.g.: vegetated buffers, wetland areas, or grassed waterways).

Most slopes can be stabilized with a permanent vegetative cover. A temporary cover can be used for quick establishment until a permanent cover can be established. While grasses will form the basis for stabilization, woody plant material can be incorporated to reduce wind, noise and dust as appropriate.

Ground covers can also be used in the stabilization scheme, especially on slopes where mowing is not feasible or in shaded areas where grass establishment is difficult.

Mulching includes using a protective layer of straw, plant residues, stone, or synthetic materials to protect the soil surface from the forces of raindrop impact and overland flow. Mulch fosters the growth of vegetation and reduces evaporation. Organic mulches such as straw, wood chips and shredded bark have been found to be the most effective materials. A variety of erosion control blankets have been developed in recent years for use as mulch, particularly in critical areas such as waterways and channels. Jute mesh or various types of netting are very effective in holding mulch in place on waterways and slopes before grasses become established.

A filter strip is an area of vegetation that removes sediment, organic matter and other contaminants from runoff and wastewater. They do this by filtration, deposition infiltration, absorption, decomposition and volatilization, thereby reducing pollution and protecting the environment. Often they do not filter out soluble materials. This type of filter is often wet, difficult to maintain and should not be used as travel lanes.

A vegetated buffer strip is a form of a filter strip. It is usually viewed as a protective barrier to a sensitive area such as a river. It should be retained in its natural state if created along the banks of water bodies. Vegetated buffers prevent erosion, trap sediment, filter runoff and function as a floodplain during periods of high water. Design of filter strips should be site specific because of topographic differences in sites. Slope, soil type, vegetative cover and other runoff control measures may differ for different sites. It is important in the design of the slope that buffer strips do not cause flow concentrations that will result in erosion or carry sediment across the buffer.

Collection

A water collection basin or impoundment is a primary means of reducing potential water quality problems. It should be the goal of each container nursery operation that no irrigation water leaves the property.

During the irrigation season, to the maximum extent practicable, all irrigation return flows should be recycled with no discharge back to public waters. As a general rule, newly constructed water collection and recycling facilities should be designed to accommodate the irrigation return flow.

Basins are typically constructed with an emergency overflow to prevent dike damage that can result from storm water overtopping. Basins or other structures that are planned for construction must have all permits. Where rainwater is allowed to discharge from the property, it must be considered in the design of the water collection basin. The Natural Resources Conservation Service and/or the local Soil Conservation District can provide design criteria and expertise to help develop the best plans for the nursery collection or retention basin.

Systems should be designed to collect a certain amount of storm water runoff in addition to irrigation water. Some locations require that the first inch of storm water be collected. Storm water runoff should not be discharged directly into surface or ground waters. Runoff should be routed over a longer distance, through grass waterways, wetlands, vegetative buffers and other places designed to increase overland flow. These components increase infiltration and evaporation, allow suspended solids to settle, and remove potential pollutants before they are introduced to other water sources.

Wetlands

A constructed wetland is an aquatic ecosystem with rooted emergent hydrophytes designed and managed to treat agricultural wastewater. The plants extract water and nutrients and add oxygen to the root zone to help in the treatment process. There are a number of attractive herbaceous and woody plants that are adapted to permanently saturated soil conditions including species of cattails, bulrushes, iris, oak, willow, rose, hibiscus and lobelia. A constructed wetland used to treat runoff typically includes an impervious subsurface barrier, a suitable substrate for the hydrophytic vegetation, the plants, wastewater or runoff flowing at a slow velocity through the system and the structural components needed to contain and control the flow. The system can be designed as either 1) a free-water or surface flow system or 2) a subsurface-flow system. The wetland concept has been identified as a beneficial filter for environmental contaminants. The Natural Resources Conservation Service may be able to assist in design.

Recycling Water

Water collected in an impoundment can potentially be recycled. Use of recycled water may require some treatment because elevated soluble salts or concerns about disease organisms. Reduction of soluble salts is most cost-effectively addressed by blending recycled water with clean water. Blending also offers safety benefits if concerns exist with regard to residual farm chemicals in the water.

Techniques used to reduce biological organisms in the water include use of chlorine, bromine and ozone or treatment with UV light. Chlorine has been used most extensively in the past, but bromine has been reported to have a broader spectrum of activity on plant pathogens. Bromine in the form of tablets is also safer and easier to handle than chlorine gas. Ozone and UV lighting has been tested with apparent success in nurseries for treating recycled water. Ozone generators can treat large quantities of recycled water faster and safer than chlorine or bromine. It is important to check with the NJDEP to determine if there are any use restrictions on treatment options. Local officials should also be contacted regarding proper notification and reporting when using acid, chlorine, bromine or ozone.

Limited investigation into possible problems with traces of organic chemicals remaining in recycled water has not confirmed that this is a significant concern. A brief review of the subject was prepared (2). It is presently available on the Internet. Even with limited risk it is important to be observant for possible damage to plants from chemical residues in recycled water, especially considering that most nurseries produce a wide variety of plant materials and that some types will be more sensitive than others.

Nutrient Management

The goal of a nutrient management program is to apply the minimal amount of fertilizer that will result in the maximum desired growth rate, flower production, foliage color enhancement, or expected plant quality. The amount of fertilizer needed to achieve the desired response is impacted by container irrigation management practices, as previously discussed, and properties of the substrate, which is discussed below. Considering these factors, nursery operators can develop a nutrient management plan and achieve minimal fertilizer losses from containers.

Substrates

Many terms, including *soil*, *soil-less media*, *potting mix*, *container mix* and *substrate* are used to describe potting materials for growing plants. However, many of these terms are imprecise or can be confusing. *Container mix* and *potting mix* imply that more than one component is used. The term *substrate* avoids much of the confusion of other terms and is descriptive of the entire composition. *Substrate* is the term used in Europe and most other parts of the world to describe the components of the root rhizosphere within containers.

Many materials are used as nursery container substrates. The predominant components in the New Jersey and the mid-Atlantic area are pine bark, sphagnum peat moss, vermiculite and sand. Many other materials have been used with varying levels of success. The wetability, stability, chemical and physical characteristics tend to limit the portion of alternative materials that can be used in a potting substrate. Organic components that have not been aged are not stable and may decompose rapidly, causing what is referred to as “shrinkage”. Containers that were full at the potting can rapidly lose substrate volume resulting in a change in characteristics of that substrate. Some composted materials lack the coarse large particles necessary for adequate aeration and limit their use as a container substrate. Some composted materials have high salt levels.

Use of a line-mixer for blending components of the substrate is the optimal method. If blending on the ground, use a concrete slab that does not allow for standing water. In all cases, be sure areas surrounding substrate preparation and storage are kept mowed to prevent weed seeds from contaminating the substrate. Sanitation is the first step toward a weed-free nursery.

When choosing a container substrate, determine ones that are best adapted to plant growth and management. Use stable substrate components that do not decompose rapidly. Check potential organic substrates for weed seed, nematodes, pathogens and chemical contaminants.

Preparing Substrates

Substrate preparation (mixing) systems used in Southern New Jersey include pad mixing, paddle mixing and line mixing. While each has their strengths and weaknesses, all mixing systems have the potential for releasing particulate matter to the air. The pad, tumble and line mixers are the primary types used in commercial operations, although the paddle type of mixer has been used for starting nurseries and for small batch mixing.

Of the three systems used commercially, line mixing generally results in the best media quality and consistency. This is because they produce a uniform product and they tend to have fewer problems breaking down medium components. Breaking down medium components reduces porosity and ultimately can increase the incidence of root diseases.

All mixing systems will generate dust. There are things one can do to minimize worker exposure. Requiring use of a dust mask can dramatically reduce worker exposure. The following are some infrastructure changes that may help and should be evaluated.

- Install a sprinkler system on the mixer to settle dust that might be generated.
- Install a semi-permeable screen to reduce the effect of wind on any dust that might be generated (semi-permeability reduces turbulence effects that may occur as wind wraps around a non-permeable structure).
- Mix during times of the day when there is less wind.

Further reductions can be accomplished by locating the mixing site away from property borders. If centralizing the location is either not practical or wind continues to move dust, windbreaks may be planted near property boundaries. Windbreaks should contain both deciduous and evergreen species. Be sure to evaluate movement of dust during the various times of the year one may be mixing since wind direction changes seasonally.

Container Substrate Physical Properties

The physical characteristics of container substrate dictate how much water and oxygen are available to roots. The characteristics that have the majority of impact on plant growth are bulk density, air space and container moisture capacity. Achieving a fundamental understanding of these physical characteristics is essential to proper irrigation and fertilization management.

The bulk density refers to the weight of substrate per unit volume of substrate particles (usually expressed in grams per cubic centimeter, g/cc). Bulk density values for pine bark range from 0.19 to 0.24 g/cc depending on the particle size distribution of the pine bark. The bulk density for peat ranges from 0.05 to 0.5 g/cc. Particle size distribution refers to sizes of particles (dust-like to chunks) that compose a substrate.

The particle size distribution, particle density and nesting of substrate component particles greatly influence the size and distribution of pore spaces in the substrate and therefore the amount of water and air the wetted substrate will hold. Many sizes of pine bark are available ranging from fine to coarse; the size to be used is dependent on the type of crop and grower practices. Generally, coarse particles are better for peat and vermiculite while one should avoid bark that is either too small or too large. Experience is usually the best judge of which to use.

Pore spaces exist between substrate particles and within particles. When the substrate is fully wetted and allowed to drain, some pores will hold water and some will hold air. Water-filled pore space is critical in a substrate because these pores hold the water that will be taken up by the plants. Air-filled pore space is critical because these pores hold oxygen that is essential for root growth. The term "total porosity" refers to the total volume of pore space in a substrate and is expressed as a percentage of the total substrate volume. Recommended total porosity values range from 50 to 85 %. The term "air space" refers to the fraction of air-filled large pores (macropores) from which water drains following irrigation. Air space values are also expressed as a percentage of the total substrate volume and recommended values range from 10 to 30 %.

In general, a substrate with a relatively high proportion of micropores will have a high water-holding capacity due to the attraction of water for the walls of small pores. Also, such a substrate will have a relatively low total porosity value since small particles tend to nest or settle within each other. Substrates with a high proportion of micropores are substrates with a high proportion of fine particles.

Container capacity is the maximum volume of water that a substrate can retain following irrigation and drainage and is a measure of the potential water reservoir of a container. The term "water-holding capacity" is used synonymously. An area of saturation, called a perched water table, exists at the bottom of a container following irrigation and drainage. The height of the saturated area is greater for a fine textured (small pores) substrate than for a coarse textured (large pores) substrate. Above the perched water table there is a gradient of air-filled pore spaces. The amount of air-filled pores increases with the distance above the perched water table.

Container capacity is expressed on a volume basis as the percent of water retained relative to the substrate volume. Recommended container capacity values range from 45 to 65 %. The water in a substrate can also be classified as "available" or "unavailable." Available water is that fraction of the water that can be absorbed by roots. Unavailable water (hygroscopic water) is that fraction of water that is held tightly to particles and is unavailable to roots.

Container dimensions can affect the air space and container capacity. For example, a typical bark- filled 1-gallon container (6 inches tall) might have a perched water table that is 1 inch tall. Thus, the perched water table occupies 1/6 (17 %) of the container volume. Using the same substrate, a flat (3 inches tall) will also have a 1 inch perched water table; however, the water table will occupy 1/3 (33 %) of the flat volume. Bilderback and Fonteno, 1987, discuss further information on how container dimensions influence substrate characteristics.

The physical properties of a substrate are also affected by amending the principle substrate with another ingredient. Amending pine bark with sand increases the amount of available water and bulk density but decreases unavailable water, total porosity and air space. Adding peat moss to pine bark also increases the amount of available water. The water-holding capacity of the substrate must be balanced with the air-filled pore space. Insufficient air-filled pore space in the substrate will promote root rot diseases. Conversely, the substrate should have sufficient water-holding capacity to keep plants well supplied with water and avoid excessive leaching. The desired balance between water-holding capacity and air-filled pore space in a substrate can vary with the plant species to be grown.

A substrate with a high proportion of coarse particles has a high air space and a relatively low water-holding capacity. Consequently, leaching of pesticides and nutrients is likely to occur. Always test the physical characteristics of the substrate and use the substrate initially on a trial basis.

Table 3. Recommended physical characteristics for container substrates*:

Physical Characteristic	Recommended Range
Total Porosity	50 to 85 %
Air Space	10 to 30 %
Container Capacity	45 to 65 %
Available Water Content	25 to 35 %
Unavailable Water content	25 to 35 %
Bulk Density	0.19–0.70 g/cc.

*Following irrigation & drainage as a % of volume

Fertilization

The cation exchange capacity (CEC) indicates how well a substrate holds positively charged ions (cations) such as ammonium, potassium, calcium and magnesium against leaching. Typical CEC values (in milliequivalents per 100 milliliters of substrate, meq/100 ml) for several container substrate components are: aged pine bark, 10.6; sphagnum peat moss, 11.9; vermiculite, 4.9; and sand, 0.5.

The role of the CEC in soil-less substrates as related to plant nutrient uptake and leaching continues to be important. The pH continues to influence nutrient availability as it does in field soils. The optimum release rates, however, occur at a lower pH than in mineral soils. Research has indicated optimal nutrient availability to occur between a pH of 4 and 5 in bark and peat/bark substrates as opposed to a pH of 6 and 7 in mineral soils (1). The ability to hold nutrients in the substrate is also necessary to maintain plant nutrition and reduce leaching. Research has shown that nitrogen and phosphorus leach readily from container substrates (3, 4). A partial solution to reduce leaching is to use of controlled-release fertilizers as a basis for fertility programs.

The container system requires frequent irrigations because of the limited water volume that can be held by the substrate. Consequently, irrigation is a predominate factor in controlling container substrate nutrient levels. Soluble fertilizers injected frequently through the irrigation system or controlled-release fertilizers are used to provide a continuous supply of nutrients at optimal levels, but in small quantities necessary to minimize nutrient loss due to leaching. Specific nutrient levels and pH required for container substrates are discussed in the section on Interpretation of Substrate Extract Levels.

Pre-Plant Substrate Amendments

Dolomitic Limestone

Dolomitic limestone supplies calcium (Ca) and magnesium (Mg) and neutralizes the acidity of the growth substrate. The quantity of dolomitic limestone added to the substrate depends on irrigation water alkalinity and Ca and Mg content, initial pH of growth substrate and the plant species grown. In mineral soils, hollies, azaleas and other ericaceous plants grow best in substrates from pH 4.5 to 5.5, while Nandina, junipers, boxwood and many flowering shrubs require a substrate pH of 5.5 to 6.5. In organic substrates, the nutrient availability curve is lower than that in a mineral soil and optimal uptake of nutrients occurs approximately 1 pH unit below that of mineral soils. Plants requiring a lower pH range (e.g. ericaceous) continue to perform well in the pH of 4.5 to 5.5 while non-acid loving plant material continues to do well at pH reading down to 5.5. The dolomitic limestone requirement will vary based on substrate components. Typically, a bark-based substrate will require less Dolomitic lime to correct pH imbalance than a peat-based substrate. The pH should be monitored to determine how well the substrate pH is being maintained through the growing season.

Micronutrients

Micronutrients are essential for plant growth, but only small quantities are required. There are several micronutrient fertilizers sold commercially. These fertilizers usually contain the essential micronutrients and are added to the container substrate as an amendment. Micronutrient amendments are usually effective for up to two growing seasons unless irrigation water alkalinity is high, in which case additional applications of micronutrients may be needed. Micronutrients are also available commercially as a component of the macronutrient fertilizers. If composted yard debris or composted biosolids are 10 % or greater by volume of the substrate, then micronutrient needs may be met by these components.

Superphosphate

Phosphorus leaches rapidly from a soilless container substrate. Complete controlled-release fertilizers applied during the growing season should supply adequate phosphorus. Superphosphate should not be added to the container substrates when controlled-release fertilizers are used.

Fertilizer Applications

The preferred nutrient ratio for fertilization of container-grown plants during the growing season is approximately 3:1:2 ($N:P_2O_5:K_2O$). Fertilizer can be applied with one or more applications of a controlled-release fertilizer (CRF) or with a fertilizer solution through the irrigation system (fertigation).

Controlled-release fertilizers supply essential plant nutrients for an extended period of time (months). Fertilizers are available that contain different mechanisms of nutrient release and contain various components. CRF's can be applied to the substrate surface or incorporated into the substrate prior to potting. High temperatures can result in excessively high soluble salt levels, so monitoring is important. If the CRF is incorporated, be sure to use it within a few days to prevent excessive soluble salt build-up. Avoid broadcasting CRF fertilizer on spaced containers.

Liquid fertilization should be applied at the frequency of application dependent on nutrient concentration in the substrate solution. When fertilizer is injected in the overhead irrigation system it will be necessary to take steps to capture the nutrient loaded runoff water so it will remain on-site. Fertilizing through the irrigation water is appropriate for low-volume irrigation systems in which irrigation water is delivered into the container. Even then, care should be taken to minimize leaching from the container to prevent nutrient laden runoff from entering surface or ground water.

Fertilizer Application Rate

The goal of a fertilizer program is to apply the least amount of fertilizer for the desired growth so that nutrient leaching is minimized. Fertilizer application rates will vary from product to product but will also depend on species and container size.

As a general rule, one should apply CRF's at the manufacturer's recommended rate. Reapplication of a fertilizer should occur when substrate solution nutrient status is below desirable levels (see section on Monitor Container Substrate Nutrient Status).

Studies have shown that plant growth using 75% of the recommended rate of CRF are not significantly different than full CRF rates. Rates of CRF at 50% of the recommended rate combined with low rate fertigation have resulted in increased growth rates. Even when using lower rates of CRF, there remains the need to capture nutrient-rich runoff water for re-use.

Monitoring Container Substrates for Nutrient Status

To ensure adequate nutrient levels in the growth substrate, nursery operators should monitor the container substrate nutrient status and use the results to determine fertilizer reapplication frequency. Periodic monitoring is important because plant growth will be reduced when excessive or inadequate nutritional levels are present. Many times, this reduced growth may not be expressed by visual symptoms.

High concentrations of soluble salts can result from substrate components, inadequate irrigation frequency and duration, water source and/or fertilizer materials and application methods. Container substrate soluble salt levels may also accumulate during the overwintering of plants in polyhouses when fertilized with CRF's. Excessive nutrient concentrations injure roots, ultimately restricting water and nutrient uptake. That combination ultimately compounds the problem because the plant will remove fewer nutrients from the substrate. Conversely, rainfall and excessive irrigation can leach nutrients from the container substrate resulting in inadequate nutritional levels and threaten water quality.

How Often to Monitor

Substrate used for long-term crops should be tested at least monthly. Biweekly monitoring during the summer may be necessary to track fluctuations in electrical conductivity (EC). The EC level is a measurement of soluble salts in the substrate and is used as a relative indicator of the nutritional status. Even when controlled-release fertilizers are used, substrate nutritional levels will gradually fall during the growing season to levels that may not support optimal growth.

High temperatures in overwintering structures can result in nutrient release from controlled-release fertilizers. Monitor substrate electrical conductivity two or three times during the winter to ensure levels are not toxic.

Nutrients may accumulate in specific locations in substrate due to irrigation patterns and fertilization methods. Therefore, one isolated sample will not give an accurate representation of the nutrient status of the substrate.

Substrate Sampling Methods for Nutrient Extraction

Several procedures have been used to extract the nutrient solution from the container substrate. The liquid extracted or sample of liquid extracted is needed for nutritional analyses. The Virginia Tech Extraction Method (VTEM, also referred to as the pour-through or leachate collection method) enables rapid sample collection.

The Virginia Tech Extraction Method should be conducted about an hour or two after irrigation (so that the growth substrate has drained). Uniform moisture levels are critical for obtaining consistent results with time. The container is then placed in a collection pan with the bottom of container elevated above bottom of the pan.

The bottom or sides of the container do not need to be wiped before collecting leachate. The elevated container does not allow the container to come in contact with the liquid collected in the pan and thereby avoids contaminating the liquid. Apply water (in a circular motion) to the substrate surface to yield about 50 ml (1.5 oz) of leachate (liquid) from the container. Leachate should be collected from five to ten containers per production bed or area to obtain an average value for the five to ten individual samples. This average value should be representative of the growth substrate nutritional status. This method of leachate collection allows for nursery operators to make quick determinations of leachate electrical conductivity and pH. For additional analyses, samples can be sent to a laboratory for determination of elemental concentrations. All laboratories do not use the same procedures, so test results can differ between laboratories. Consequently, interpretation of results by the testing lab is very important.

Interpretation of Substrate Extract Levels

Container substrate nutritional levels in Table 2 may be used for interpreting levels obtained with the Virginia Tech Extraction Method. If nutritional levels that result from application of controlled-release fertilizers should drop below desirable levels during periods of active plant growth, then re-application should be considered to maintain optimal levels. Most fertilizers (except urea) are salts and when fertilizers are in solution they conduct electricity. Thus, the electrical conductivity of a substrate solution is indicative of the fertilizer level that is available to plant roots.

- Desirable container substrate electrical conductivity levels are 0.5 – 1.0 mmhos/cm for solution fertilizer only, controlled-release fertilizers or the combined use of controlled-release and solution fertilizer. Ranges given in Table 2 correspond to most container-grown landscape plants. However, adjustments must be made for plants known to be sensitive to fertilizer additions.
- Plants with a low nutrient requirement (Appendix 2) may grow adequately with nutrient levels lower than those given in Table 2.
- Measure the irrigation water electrical conductivity. The irrigation water electrical conductivity will allow you to know the contribution of your water to the extracted liquid or leachate electrical conductivity and this should be considered when interpreting the substrate electrical conductivity.

Table 4: Desirable nutritional substrate levels for container plants with high nutritional requirements. (Levels are for interpretation of the Virginia Tech Extraction Method when fertilizing with solution or liquid fertilizer alone or in combination with controlled-release (CR) fertilizer or using only controlled-release fertilizer.)

Analysis	Desirable levels: Solution only or CR and solution	Desirable levels: CR fertilizer only
pH	5.0 to 6.0	5.0 to 6.0
Electrical conductivity, dS/m (mmhos/cm)	0.5 to 1.0	0.2 to 0.5
Nitrate-N, NO_3–N mg/L (ppm)	50 to 100	15 to 25
Phosphorus, P mg/L	10 to 15	5 to 10
Potassium, K mg/L	30 to 50	10 to 20
Calcium, Ca mg/L	20 to 40	20 to 40
Magnesium, Mg mg/L	15 to 20	15 to 20
Manganese, Mn mg/L	0.3	0.3
Iron, Fe mg/L	0.5	0.5
Zinc, Zn mg/L	0.2	0.2
Copper, Cu mg/L	0.02	0.02
Boron, B mg/L	0.05	0.05
Levels should not drop below these during periods of active growth. Plants with low nutritional requirements may grow adequately with lower nutrient levels. See Appendix 2 for various plant nutritional requirements.		

Supplemental Fertilization

When nutritional monitoring indicates the need for additional fertilizer, apply supplemental fertilizer to return the desired nutritional levels. The two application options are to apply fertilizer by injecting fertilizer into irrigation water or placing fertilizer on the surface of container substrate. When injected fertilizer is applied through an overhead irrigation system, runoff water will have a nutrient load and should be collected in an impoundment for reuse. It is recommended that one inject an individual element or a combination of elements in concentrations slightly less than desirable levels to be maintained in the growth substrate (Table 3).

Surface-applied fertilizer should be applied to specific blocks or groups of plants, thus minimizing nutrient loss and nutrient loading of runoff water. Broadcast fertilizer applications should be avoided whenever possible unless containers are closely spaced.

It is important to record all fertilizer applications. Good current and past records are valuable to help identify production problems. They also to help identify why things went better than expected and can be used to help fine-tune an already good program. Record as much information as possible. At a minimum, information should include fertilizer product name and analysis, date and location applied, and general notes about plant and environmental conditions. See Appendix 4 for a sample record sheet of fertilizer applications.

Foliar Analyses

Foliar analyses may be used to verify or diagnose deficiencies or toxicities during the growing season. They are also used to determine the elemental status of plant tissue in fall or winter prior to spring flush of growth. Where a problem exists, it is typically necessary to sample a “good” plant as well as a “bad” plant for basis of comparison. It is important to maintain good records of foliar analyses. Ideally, photographs of sampled plants should also be included. That will help form a database of desired nutritional levels for future plant production. A well-designed fertility program can eliminate the need for tissue testing.

Tissue Sampling Considerations

Generally, plants grown under similar conditions can be treated as a group when sampling, although samples from different species or cultivars should not be mixed. A tissue sample must be representative of plants sampled. An acre of plants of the same species that had been treated similarly would require only one to three composite samples while plants of the same species that have been grown under different cultural or environmental conditions, should be sampled separately.

Taking Tissue Samples

Take samples just before new flush of growth develops. Each sample should be composed of 20 – 30 uppermost mature leaves (or shoot tips) selected randomly from the group of plants. Only one or two leaves for broadleaf evergreens or one or two shoot tips (1-inch long) for narrow-leaved evergreens should be removed from a single plant to obtain a sample of green tissue that weighs from 10 to 30 grams (approximately one ounce). When sampling for diagnostic purposes, collect three samples of tissue that are the same age from abnormal or problem tissue and three samples of "normal tissue." Samples that represent different stages of the problem should be obtained to determine whether tissue elemental content changes as the problem progresses. Collect tissue samples in brown paper bags (not plastic lined) and mark with appropriate identification and sampling date.

Interpretation of Tissue Analyses

Elemental ranges for uppermost mature leaves of woody ornamental plants are given in Table 4. Compare the magnitude of Table 4 values with test results as well as the ratio between elements. Seldom are all elemental test values within the ranges given in Table 4, but these values are intended to be guidelines. Maintain tissue test records for they are valuable aids when making fertility management decisions and you will be able to refine the guidelines in Table 4 based on your experience and for your crops and growing conditions.

Table 5. Elemental ranges for uppermost mature leaves of woody ornamentals.

Element	Percent*	Element	Parts Per Million (ppm)
Nitrogen	2.0–2.5	Iron	100–200
Phosphorus	0.2–0.4	Manganese	50–100
Potassium	1.5–2.0	Zinc	20–75
Calcium	0.5–1.0	Copper	5–10
Magnesium	0.3–0.8	Boron	20–30
* Percent of leaf dry weight		Molybdenum	0.1–1.0

Pest Management

Plants produced for the landscape require careful attention during production to maintain suitable plant quality. Container-grown landscape plants are grown under conditions that often favor development of pests that adversely affect plant growth. These pests may include weeds, insects and diseases. In the past, pest control utilized preventative pesticide (herbicides, fungicides or insecticides) applications. Current pest control involves scouting for pests on a regular basis, identifying the pest and selecting appropriate chemicals that are environmentally friendly and target existing pest problems. Other good management practices include using low volume applicators and maintaining proper sprayer calibration and nozzle adjustments.

Rules and Regulations

- Pesticide Use Certification Program
  - All agricultural businesses that use pesticides must possess a pesticide applicator license. If the business applies pesticide only for their own business they should have a private license.
    - To receive a license, one must pass a test administered by the New Jersey Department of Environmental Protection (NJDEP).
    - Licenses are good for five years but need to be renewed annually. During the five-year license period one is expected to receive eight (8) credits of core and sixteen (16) credits of category recertification training.

- Employee requirements
    - Employees may apply pesticides as a "handler". Annual training is required. A roster of trained handlers must be maintained.
    - Employees are required to have received EPA-approved Worker Protection Safety training every five years and have a current verification card in their possession.
- Reporting
    - Businesses need to inventory stored pesticides annually and submit a copy to the local fire company by May 1.
    - It is required that an annual use report be submitted to the NJDEP Pesticide Control Program office.
- A complete set of rules and regulations can be found on the Internet at: http://www.nj.gov/dep/enforcement/pcp/pcp-regs.htm.

Nursery Pest Management (NPM)

Pest management strategies should be used to minimize the amount of pesticides applied. That entails the application of pesticides based on need and requires monitoring to make that determination. In addition, pesticides should be applied efficiently and at times when runoff losses are unlikely.

Use of NPM strategies is a key element of pesticide management. NPM strategies follow many of the practices established by integrated pest management programs. The significant difference is that nursery stock is governed by a zero threshold requirement. That requirement is necessary to meet laws established for shipment of nursery plant material. The following is a list of NPM strategies:

- Apply insecticides and fungicides based on need. A scouting program to monitor pest problems is a necessary component of a NPM program. Only apply in anticipation of a pest problem when established environmental factors are present that predicts an outbreak. The major exception is that some disease pathogens require preventative sprays on susceptible crops.
- Use regular scouting to determine pest problems. Scouting can include direct observation or trapping with sticky cards or pheromone traps. Trained employees or professional pest control advisors should do scouting. Records of scouting results should be maintained, and there should be a designated person for making pest management decisions.
- Use effective pesticides, but choose those that are less environmentally persistent, toxic, or mobile.
- Maintain records on past pest problems, pesticide use, environmental and other information for treatment areas.
- Use control options that help maintain pest predators. Use pesticides that affect only target organisms and apply pesticides only to affected plant species or areas.
- Evaluate the use of pheromones:
    - For monitoring populations
    - For mass trapping
    - For disrupting mating or other behaviors of pests
    - To attract predators/parasites
- Destroy pest breeding, refuge and overwintering sites. Remove plant debris and keep them in a sealed container until disposal. Inspect and quarantine newly introduced plant material. When possible, choose plant species or cultivars that are known to be more resistant to common pests and diseases.
- Use spreader/stickers with fungicides and insecticidal sprays to increase efficiency and reduce losses due to rain or irrigation.

Pesticide Applications

When pesticide applications are necessary, growers should identify and evaluate pesticide options. Growers should develop a schedule that provides a rotation between pesticide classes to help reduce pest resistance to the controls. Where a choice of registered materials exists, producers are encouraged to choose the most environmentally benign pesticide products. Consider the persistence, toxicity, runoff and leaching potential of products along with other factors.

Growers should be licensed to use pesticides and meet the requirements of federal and state laws that regulate use of pesticides. Users must apply pesticides in accordance with the instructions on the label of each pesticide product and wear appropriate protective equipment. Farm-worker safety requirements should also be reviewed and met. A checklist of some pesticide safety needs follows:

- Calibrate pesticide spray equipment annually.
- Use backflow protection devices on hoses used for filling tank mixtures.
- Evaluate the soil and physical characteristics of the site. Locate mixing, loading and storage in areas that have a low potential leaching or runoff of pesticides. In situations where the potential for pesticide loss is high, emphasis should be given to practices and/or management practices that will minimize these potential losses. Recognize physical characteristics that may be impacted by pesticide movement and take steps to reduce the risk of an incident occurring.
    - Proximity to surface water
    - Runoff potential
    - Wind erosion and prevailing wind direction
    - Highly erodible soils
    - Highly permeable soils
    - Shallow aquifers
    - Wellhead protection areas
    - Proximity to dwellings
- When possible, use pesticides with a low solubility in water or a low potential risk for leaching.
- Use pesticides with a short half-life to reduce the persistence of the pesticide in the soil and thus the opportunity for leaching.
- Time the pesticide application as far in advance as possible of irrigation and unfavorable weather conditions. The interval between pesticide application and irrigation or rain is closely related to the amount of pesticide runoff and leaching loss. It also relates to pesticide efficacy against the pest.
- Use efficient application methods, e.g., banding of pesticides or applying chemicals when containers are jammed (containers spaced pot-to-pot), or stagger applications.

Operation and Maintenance of Pesticide Application Equipment

All pesticide application equipment should be maintained in good working condition and have known replacement, repair and wear items identified. Calibration of equipment should be conducted prior to the mixing and loading of pesticides, and at a minimum, prior to each season of application or when a change in pesticide application is made. All sprayer tanks should be locked when not in use to avoid possible contamination of spray materials. Even small quantities of herbicides in a spray tank not intended to contain those products can result in significant plant damage.

Storage

Chemical storage facilities must be designed or located such that weather conditions or accidental spills or leakage will not impact soil, water, air or plants. Chemical storage facilities should be posted with adequate safety warning signs and chemicals in storage must be reported to the local fire department annually. Store pesticides in their original containers in environmentally safe and secure locations. Storage should be secure and include proper ventilation and control for any potential chemical leakage that may contaminate water sources or be a detriment to living organisms. Designs for chemical storage and handling facilities can be obtained through Rutgers Cooperative Extension or through your local Natural Resources Conservation Service office.

Mixing and Rinsing Stations

Research has indicated that one of the greatest potentials for ground water contamination from pesticides comes from spills that may occur during the mixing and loading process. The location and design of proper mixing and rinsing equipment stations, relative to the potential contamination of ground or surface water sources should be considered.

To protect against ground water contamination, mixing, loading and cleaning operations should be done on an impervious surface covered with a roof and surrounded by impervious curbing. Wash water and waste products used in cleaning of pesticide application equipment should be disposed of in a safe manner. Rinse water from equipment and containers should be stored and used in the following batch mixture where possible. Where disposal is necessary and allowed by laws and regulations, it should be performed avoiding high runoff and leaching areas such as: ponds, lakes, streams and other water bodies. Disposal of empty pesticide containers should follow instructions provided on the container.

All operations should be performed at a safe distance (100 ft.) from any well. When wells are in close proximity, extreme care must be exercised when mixing or applying chemicals. Anti-siphoning devices should always be used to prevent backflow into the well.

Other Pesticide Considerations

- Follow label guidelines:

  Pesticide applicators need to follow recommended rates, use recommended methods of container disposal and follow all other instructions (re-entry interval, worker protection standards, etc.) as indicated on the pesticide label.
- Mix only the amount of pesticide needed:

  Plan ahead and mix only the amount of pesticide needed. Disposal of excess pesticides often presents water quality problems.
- Comply with Worker Protection Standards:

  Worker Protection Standards training sessions need to be conducted (and documented) to train nursery workers and pesticide handlers to use correct procedures for pesticides: applications, mixing, loading, handling, posting, record-keeping, re-entry of treated areas, use of personal protective equipment (PPE) and emergency assistance. Provide decontamination sites and post necessary information in a central location.
- Stagger herbicide applications whenever possible:

  Since the major herbicide runoff from container nurseries occurs in the first 6 irrigations after application, staggering the herbicide applications over small areas should reduce peak loading of the system. Staggering applications would be preferable to one application over a large area.

- Apply pesticides to containers that are spaced optimally. Excessively wide spacing wastes pesticides and raises the potential for runoff.
- Avoid injecting pesticides into the overhead irrigation system.
- Select pesticides with lower water solubility.
- Participate in pesticide recycling programs.

System Integration: Grouping Plants

The content of this document is a review of recommended practices for production of container nursery plant material. It has been divided into the major categories of water management, nutrient management and pest management and it is recommended to group plants based on those categories for optimal efficiency.

There will always be reasons to modify grouping schemes within each category. As an example, when using controlled-release fertilizer for basal plant needs it may be more important to group according to the need for supplemental fertilization. It becomes increasingly important if the supplemental fertilizer is injected in irrigation water.

The larger challenge for growers is to balance the grouping needs between the water management, nutrient management and pest management categories. As an example, there will be often be times when grouping based on water will not be the best when considering either pesticide use or fertilization requirements. There is not just “one way” of doing things. Growing plants is a series of compromises.

As a grower, one must look for the best workable option. The ability to group plants based on all three management categories is highly improbable if not nearly impossible. One will need to develop a prioritized listing of critical needs. The management area that is most critical for optimal plant growth should be rated highest and should generally form the basis of one’s management program. As an example, if a plant is susceptible to root rots, watering may be the critical management area since plants will die if over-watered.

As a final thought, an agricultural management plan is a series of tools. It is the grower’s responsibility to choose the best tools for success in the nursery business. There is a combination that will maximize profitability while minimizing environmental impact for your business.

Glossary

Absorption - to take in through pores or membranes (such as water) or to hold within.

Acid - a substance that tends to give up protons (hydrogen ions) to some other substance.

Acidity - hydrogen ion activity measured and expressed as a pH value. A substance is considered acidic if the pH is less than 7.

Adsorption - the attraction of ions or compounds to the surface. Substrate particles can adsorb large amounts of ions and water.

Air space - the percentage of container volume occupied by air-filled large pores from which water drains following irrigation.

Alkalinity - concentration of bases often expressed as carbonate or bicarbonate equivalents. An alkaline substrate will have a pH greater than 7.

AMP - the Agricultural Management Practices (AMP's) include schedules of activities, prohibitions, maintenance procedures and structural or other management practices found to be the most effective and practicable methods to prevent or reduce the discharge of pollutants to the air or waters of the United States. Practices also include operating procedures and practices to control site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage.

Anion exchange capacity – the sum total exchangeable anions (negatively charged particles) that a soil or substrate can adsorb. Anionic compounds include sources of phosphorus (PO_4^{3-}), nitrogen (NO_3^-), and sulfur (S^- and SO_4^{2-}).

Base - a substance that tends to accept protons (hydrogen ions) from some other substance. Soil or water is considered basic if the pH is greater than 7.

Bicarbonate/carbonate - salts of carbonic acid that formed when carbon dioxide dissolves in water. In combination with sodium, calcium, and magnesium ($NaHCO_3$, $CaCO_3$ and $MgCO_3$), they have an alkalizing effect.

Biofilter – a living system of plants, including natural and constructed wetlands, located within a watercourse that uses nutrients in runoff water, captures sediment, and degrades other chemicals, thereby enhancing water quality.

Bulk density - the weight of dry substrate per unit volume of substrate (expressed in grams per cubic centimeter, g/cc).

Carbonate - see bicarbonate.

Cation Exchange Capacity (CEC) - total of exchangeable cations (positively charged ions) that a substrate can adsorb. Some cations of interest include ammonium (NH_4^+), potassium (K^+), calcium (Ca^{2+}), and magnesium (Mg^{2+}), all of which serve as plant nutrients, and hydrogen ions (H+) that cause soil acidity.

Collection basin (pond) – an enclosed body of water to collect excess water from irrigation or storm events.

Constructed wetland - a shallow bed filled with selected vegetation, such as cattails, into which runoff water is diverted and which serve as a biological filter for removing chemicals from the water. Constructed wetlands are designed to slow moving water, allowing time for treatment, and can use a variety of substrates, from native soil to sand or gravel. They can be designed to have the water level above the substrate surface or so that the water is kept below the surface.

Container capacity - the maximum volume of water that a substrate can retain following irrigation and drainage. It is a measure of the water reservoir in the container.

Controlled-release fertilizer (CRF) - a formulation of fertilizer where release time is controlled by the thickness of the coating (i.e. resin) or the amount of the release agent in the coating that dissolves in water to form pores in the coating (i.e. plastic). CRFs have the advantage over granular fertilizers of slowly but continually feeding crops and not exposing plants to a large dose of salt at one time.

Cyclic irrigation –an irrigation schedule in which a plant's daily water allotment is divided up and applied in a series of irrigation and rest intervals throughout the day.

Deionization - a technique used to remove ions (charged particles) from irrigation water. Systems are available that combine pre-filtration, mixed-bed resins, activated carbon and final filtration.

Electrical conductivity (EC) - the measure of salt content of water based on the flow of electrical current. When the salt content increases, there is greater the flow of electrical current. EC is measured in mmhos/ cm or deciSiemens/m (dSm), which are numerically equivalent.

Emitter - a device used to apply water in the form of spray or drops to the substrate surface. It is a general term that can be applied to drip stakes, micro-sprinklers, misters, etc.

Half-life - the time required for a substance to degrade by one-half. Pesticides with a long half-life are considered persistent.

Leachate - solution that drains from container substrate during and after irrigation and may contain nutrients and pesticides from the substrate solution.

Nematode - very small worms abundant in many soils and important because they may attack and destroy plant roots or infest foliar portions of the plant.

Pathogen - a causal agent of disease. The term can refer to funguses, bacteria, viruses or other disease-causing organisms.

Perched water table – in container production, a saturated zone of water above the bottom of a container.

Permeability - the capacity of porous rock, sediment or soil to transmit water.

Pesticides - any form of chemical or substance used to control pests. Pesticides include fungicides, herbicides and insecticides.

pH - a measurement, ranging from 0 to 14, of the concentration of hydrogen ions (H^+) in a solution. A pH of 7 is neutral, a pH below 7 is acidic and a pH above 7 is alkaline or basic.

Reverse osmosis - process where water is forced under pressure through a semi-permeable membrane to remove dissolved and suspended constituents.

Rhizosphere - the vicinity of the roots.

Runoff - the portion of precipitation or irrigation on an area that is discharged from the area. Runoff which is lost without entering the soil is called surface runoff and that which enters the soil is called ground water runoff or seepage flow. Managing excess irrigation water and rainfall is critical in the nursery industry because it can carry sediment, fertilizers, pesticides and other pollutants to surface water bodies or groundwater.

Sedimentation - particles settling out from suspension.

Sodium Adsorption Ratio (SAR) - the concentrations of calcium and magnesium relative to that of sodium. Sodium is often responsible for salinity problems when linked to chloride (Cl^-) or sulfate (SO_4^{2-}). The SAR can be determined for irrigation water or in soils. The following formulation is used to calculate the adsorption ratio:

$$SAR = \frac{Na}{\sqrt{\frac{(Ca + Mg)}{2}}}$$

Soluble salts - see electrical conductivity.

Substrate - organic and inorganic materials, often bark, peat, and sand, used as substrate components in a container to support the plant and contain the root system.

Total porosity - total volume of pore space in a substrate.

Transpiration – the loss of water vapor from plants, mostly through stomata (a pore in the epidermis of a leaf or young stem) and lenticels (an opening in the cork of roots and stems).

Virginia Tech Extraction Method (VTEM) - a technique used to monitor container nutrient status.

Water-holding capacity - the amount of water a substrate can hold after being fully wetted and allowed to drain. In containers, the term *container capacity* is also used. Because some water will be held too tightly by the substrate for plants to use, the term *available water capacity* is used to designate the amount water a substrate can hold that can be used by plants. An understanding of the water-holding capacity of your containers is important because it determines how frequently you should irrigate and how much water should be applied.

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Acknowledgments:

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Appendix 1:

A partial list of container-grown plants with low, medium, or high water requirements.

LOW WATER REQUIREMENT
Arctostaphylos spp., Bearberry
Berberis thunbergii, Japanese Barberry
Cornus spp., Dogwood
Cytisus scoparius, Scotch Broom
Euonymus japonicus 'Albo-Marginata'
Hedera helix, English Ivy
Juniperus chinensis 'Blue Vase'
Juniperus chinensis 'Parsonii'
Juniperus chinensis 'Torulosa'
Juniperus conferta, Shore Juniper
Juniperus horizontalis Blue Rug (`Wiltonii')
Leucophyllum frutescens, Texas Sage
Mahonia fortunei, Fortune's Mahonia
Tilia spp., Linden

MEDIUM WATER REQUIREMENT
Abelia X *grandiflora*, Glossy Abelia
Buxus microphylla, Japanese Boxwood
Callistemon spp., Bottlebrush
Camellia japonica, Camellia
Chaenomeles speciosa, Flowering Quince
Cortaderia selloana, Pampas Grass
Crataegus spp., Hawthorn
Forsythia spp.
Gardenia jasminoides, Gardenia
Hemerocallis spp., Daylily
Hibiscus syriacus, Shrub Althaea
Ilex X *attenuata*, East Palatka Holly
Ilex cornuta 'Burfordii Compacta', Dwarf Burford Holly
Ilex crenata, Japanese Holly
Ilex crenata 'Compacta'
Ilex crenata 'Helleri'
Ilex vomitoria, Dwarf Yaupon Holly
Ilex vomitoria 'Schelling's Dwarf'
Illicium parviflorum, Anise
Juniperus chinensis var. sargentii
Lantana montevidensis, Trailing Lantana
Ligustrum japonicum, Wax-Leaf Ligustrum
Ligustrum sinense, Japanese Privet
Liriope muscari, Lilyturf
Liriope 'Evergreen Giant'
Magnolia grandiflora, Southern Magnolia
Malus spp., Crab Apple
Myrica cerifera, Waxmyrtle
Nandina domestica, Heavenly Bamboo
Pennisetum setaceum, Red Fountain Grass
Philadelphus coronarius, Mock Orange
Photinia X *fraseri*, Fraser's Photinia
Pittosporum tobira, Pittosporum
Platanus spp., Plane Tree
Platycladus spp., Arborvitae
Podocarpus macrophyllus, Podocarpus
Pyrus spp., Pear
Quercus laurifolia, Laurel Oak
Quercus virginiana, Live Oak
Rhododendron spp., Kurume Azalea
Spiraea spp.
Ulmus parvifolia, Chinese Elm
Zelkova spp., Japanese Zelkova

HIGH WATER REQUIREMENT
Acer rubrum, Red Maple
Betula spp., Birch
Buddleia davidii, Butterfly-Bush
Cercis spp., Redbud
Cotoneaster spp.
Hibiscus rosa-sinensis, Hibiscus
Hydrangea macrophylla, Hydrangea
Juniperus chinensis var. procumbens
Juniperus chinensis 'San Jose'
Juniperus horizontalis 'Plumosa Compacta'
Juniperus virginiana 'Grey Owl' Eastern Redcedar
Lagerstroemia indica, Crape Myrtle
Pyracantha spp., Pyracantha
Rhododendron spp., Indica Azalea
Salix spp., Willow
Spiraea spp.
Viburnum odoratissimum, Sweet Viburnum
Viburnum plicatum var. tomentosum 'Shasta', Doublefile Viburnum
Vitex agnus-castus, Chastetree

Plant water requirements will vary depending on growth rate desired and cultural conditions.

Appendix 2:

A partial list of plants with low, medium, or high nutritional requirements when container-grown.

LOW NUTRIENT REQUIREMENT
Camellia japonica, Camellia
Camellia sasanqua, Sasanqua Camellia
Cortaderia selloana, Pampas Grass
Hydrangea macrophylla, Hydrangea
Lantana montevidensis, Trailing Lantana
Leucophyllum frutescens, Texas Sage
Liriope spp. `Evergreen Giant'
Myrica cerifera, Waxmyrtle
Pennisetum setaceum, Red Fountain Grass
Pinus spp., Pine
Prunus caroliniana, Cherry Laurel
Rhododendron spp., Azalea, Rhododendron
Rhododendron austrinum, Florida Flame Azalea
Rhododendron canescens, Pinxter Azalea
Taxodium distichum, Bald Cypress

MEDIUM NUTRIENT REQUIREMENT
Abelia X *grandiflora*, Glossy Abelia
Acer rubrum, Red Maple
Buxus microphylla, Japanese Boxwood
Dietes vegeta, African Iris
Gardenia jasminoides, Gardenia
Hedera helix, English Ivy
Hemerocallis spp. Daylily
Ilex X *attenuata*, East Palatka Holly
Illicium parviflorum, Anise
Juniperus chinensis `Blue Vase'
Juniperus chinensis `Parsonii'
Juniperus chinensis `Torulosa'
Lagerstroemia indica, Crape Myrtle
Liriope muscari, Lilyturf
Magnolia grandiflora, Southern Magnolia
Mahonia fortunei, Fortune's Mahonia
Nandina domestica, Heavenly Bamboo
Photinia X *fraseri*, Fraser's Photinia
Pittosporum tobira, Pittosporum
Podocarpus macrophyllus, Podocarpus
Quercus laurifolia, Laurel Oak
Quercus virginia, Live Oak
Ulmus parvifolia, Chinese Elm
Washingtonia robusta, Washington Palm
Zamia floridana, Coontie

HIGH NUTRIENT REQUIREMENT
Buxus sp. `Wintergreen' Boxwood
Callistemon spp., Bottlebrush
Euonymus spp., Euonymus
Hibiscus rosa-sinensis, Hibiscus
Hibiscus syriacus, Shrub Althaea
Ilex cornuta `Burfordii Compacta' Dwarf Burford Holly
Ilex crenata, Japanese Holly
Ilex vomitoria, Dwarf Yaupon Holly
Ligustrum japonicum, Wax-Leaf Ligustrum
Lonicera spp., Honeysuckle
Spiraea spp., Spiraea

Plant requirement will vary depending on growth rate desired and cultural conditions.

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Appendix 3:

Fertilizer Application Record Sheet

Date	Field Location	Fertilizer Analysis	Brand Name	Amount Applied	Plant Name	Container Size	Environmental Conditions

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Appendix 4: Fertilizante Aplicación Tablero

Fecha	Area	Análisis de fertilizante	Nombre del Producto	Cantidad total usada	Planta	Volumen de Maceta	Condiciones Ambiental

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Appendix 5: Pesticide Application Record Sheet

Date	Location	Plant	Wind	Product Name	Pounds per Section	Total Used	Length of Control	Pests Not Controlled	General Plant Health

Appendix 6: Peste Aplicación Tablero

Fecha	Area	Planta	Viento	Nombre del Producto	Libras por la sección	Cantidad total usada	Longitud del Control	Pestes (Plagas) no controladas	Salud de Planta General