Cedar Grove Brook Watershed Restoration and Protection Plan

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New Jersey Department of Environmental Protection

Office of Policy Implementation and Watershed Restoration

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I. ACKNOWLEDGEMENTS

This project was a collaborative effort of the New Jersey Water Supply Authority, the New Jersey Department of Environmental Protection, Franklin Township, Somerset County and the project committee. TRC Omni Environmental was contracted to perform water quality sampling, investigate best management practices, and develop potential projects. SWM Consulting, P.A. was retained as a subconsultant by TRC Omni.

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II. Executive Summary

A. Project Background/Development

The Delaware and Raritan (D&R) Canal transfers water from the Delaware River Basin to the Raritan River Basin, where the raw water is treated to become drinking water for approximately 600,000 customers living in and near the Raritan Basin. Since 1997, several of the Canal's water purveyors have reported increased concentrations of total suspended solids in the raw water during and immediately after precipitation events, requiring increased chemical use for treatment and increasing residual sludge generation. In addition, a 1999 study by the United States Geological Survey (USGS) reported that turbidity does not decrease in the Canal reach between Ten Mile Lock and the Route 18 spillway (the final 11 miles of the Canal) as would be expected due to low water velocities in this reach, indicating that settling solids are replaced by particulates from influent streams and stormwater discharges to the Canal. Field observations downstream of the Canal's confluence with Cedar Grove Brook confirm this, noting the formation of a sand bar indicating that Cedar Grove Brook contributes sediment-laden stormwater to the Canal.

The New Jersey Water Supply Authority (NJWSA) identified a total of 68 infalls or stream and stormwater discharges to the Canal between Amwell Road and Landing Lane, where the Canal discharges into the Raritan River. The report titled "Delaware and Raritan Canal Tributary Assessment and Nonpoint Source Management Project: Watershed Restoration and Protection Plan" [1] described those infalls, estimated pollutant loads and provided preliminary recommendations for best management practices. Implementation of those recommendations is now underway.

The Cedar Grove Brook (also known as Al's Brook) watershed drains 1,788 acres in northeastern Franklin Township, Somerset County and discharges directly into the Canal approximately three miles upstream of the Canal's terminal spillway located near Landing Lane in the City of New Brunswick. The Cedar Grove Brook watershed is the fourth largest direct drainage to the Canal, and the largest within the last eleven miles of the Canal. The Cedar Grove Brook watershed was excluded from the original D&R Canal NPS study due to its size, and was made the focus of a separate nonpoint source management project.

The Cedar Grove Brook Stormwater Management and Watershed Restoration Project began as a regional stormwater management plan funded by a Section 319(h) Nonpoint Source Pollution Control Grant from the New Jersey Department of Environmental Protection (NJDEP). One aspect of a regional stormwater management plan is the development of new municipal ordinances or design standards if additional stormwater management is required to protect water resources. During the characterization and assessment phase of the project it became evident that the watershed is essentially built-out. In addition, the 2004 NJDEP stormwater regulations and strict development controls imposed by the Delaware and Raritan (D&R) Canal Commission are

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[1] A major restoration project (Delaware and Raritan Canal Nonpoint Source Implementation Project) is currently underway by NJWSA to reduce sediment loads to the Canal from the many stormwater infalls between Amwell Road and the Route 18 spillway.

expected to be protective of water quality from the impacts of future development. Lastly, the watershed is relatively small and located wholly within Franklin Township, Somerset County which has adopted ordinances and land use regulations which are protective of water resources.

As a result, the project focus was shifted from the development of additional performance standards for new development to the identification of management measures to address impacts from existing nonpoint source pollution problems concentrating on stormwater issues. The work included inventorying stream conditions, evaluating existing management practices and determining retrofit opportunities and remedial actions for existing stormwater problems. In addition, a monitoring program was implemented to track down sources of turbidity and identify best management practices (BMPs) to address likely sources of sediment.

B. Project Committee

A project committee of interested stakeholders was formed at the beginning of the project. The stakeholders included representatives from the NJDEP, Somerset/Union Soil Conservation District, Somerset County, Franklin Township, D&R Canal Commission, and NJWSA. The group met periodically throughout the project to provide feedback on various issues, including project identification.

C. Water Quality Monitoring and Modeling

Water quality monitoring and WinSLAMM modeling were used to help identify potential sources of sediment in the Cedar Grove Brook watershed. A series of stream visual assessments was also performed. The continuous turbidity monitoring results suggest that Cedar Grove Brook can significantly increase the turbidity peaks in the D&R Canal that occur during larger storm events. Water quality sampling in both Cedar Grove Brook and the D&R Canal demonstrate that high values of turbidity occur together with high values of total suspended solids (TSS); it is therefore likely that measures to reduce TSS loads to the Canal will also reduce turbidity.

There are three significant pond structures in the watershed – the Golf Coruse Pond, the Ukrainian Village Pond and the Lower Pond. The WinSLAMM analysis indicated that these ponds are providing significant sediment removal during normal and low flow conditions, resulting in Cedar Grove Brook currently discharging far less sediment to the D&R Canal than it would without the presence of those structures. These pond structures also act as sediment sources due to the resuspension of accumulated sediment under certain high flow storm conditions.

D. Recommended Management Measures

Several potential structural and non-structural nonpoint source management measures were evaluated for the Cedar Grove Brook watershed. The recommended measures include:

Structural Management Measures:

- Quail Brook Golf Course Pond – Outlet structure modification and addition of flowpath baffles
- Ukrainian Village Pond – Outlet structure modification
- Lower Pond – weir modification
- Riparian Restoration (multiple locations)
- Stormwater Basin Retrofits (multiple locations)
- Residential Stormwater Management – Rain barrels and rain gardens

Non-structural Management Measures

- River-Friendly Programs – Golf courses, businesses, schools and residents
- River-Friendly Communities

Detailed information on each of these proposed projects can be found in Section VIII.

E. Nine Minimum Elements of a Watershed Restoration Plan

The United States Environmental Protection Agency (EPA) identified nine significant elements that are critical for achieving improvements in water quality and that must be included in all watershed restoration plans funded with Clean Water Act Section 319(h) funding. The nine elements are listed below with a discussion of pertinent points from the Cedar Grove Brook watershed restoration plan that relate to each specific element. The elements do not occur sequentially.

Element 1: Identification of causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions, and any other goals identified in the watershed plan.

Element 1 includes mapping, characterization and assessment of the watershed (**Section IV Watershed Characterization and Assessment** and **Section V Visual Assessment**) and an accounting of nonpoint sources that cause impairment in the watershed (**Section VI Pollutant Source Assessment**). A correlation shall be made between the sources of pollution and the extent to which they cause water quality impairment.

The relative contribution from any land use type is a function of:

1) the percent of the watershed comprised of the land use type; and

2) the contribution (pounds per acre) generated by the land use type in terms of pollutant load.

The dominant developed land use in the Cedar Grove Brook watershed is residential, comprising 43% of the watershed. Commercial, industrial and institutional land uses comprise small amounts of the developed land area, forest and brush/shrub land comprise 20%, wetlands comprise 18% and agriculture approximately 1% of the watershed.

The WinSLAMM modeling indicated that approximately 38% of the solids load originates on residential properties, and the majority of that load is generated by vegetated areas. Although vegetation such as lawn and forest is generally considered to be more protective of water resources than impervious areas such as driveways and roofs, these areas do generate sediments and other pollutants.

An additional sediment source that must be considered is the resuspension of sediment from the three existing pond structures during large storm events.

Element 2: An estimate of the load reductions expected from management measures.

A total maximum daily load (TMDL) has not been prepared for Cedar Grove Brook, and the watershed is not identified on the State's 2008 List of Impaired Waters. The watershed has been observed to contribute TSS and associated turbidity to the D&R Canal and water purveyors with downstream water intakes have reported higher treatment needs during and after storm events.

As the Canal and Cedar Grove Brook are not listed as impaired for sediment, a targeted endpoint or specific load reduction for the watershed was not identified. The goal of this project is to reduce the sediment load in the stream and thereby reduce sediment loads in the Canal. The anticipated load reduction from each recommended management measure is, however, specified in the restoration plan (**Section VIII Nonpoint Source Management Measures** and **Appendix G Project Detail Sheets**).

Element 3: A description of the nonpoint source management measures that will need to be implemented to achieve load reductions and a description of the critical areas in which those measures will be needed to implement this plan.

This restoration plan describes the management measures that are recommended in order to achieve the reduction of sediment entering Cedar Grove Brook and ultimately the D&R Canal. These measures include:

Structural Management Measures:

- Quail Brook Golf Course Pond – Outlet structure modification and addition of flowpath baffles
- Ukrainian Village Pond – Outlet structure modification
- Lower Pond – weir modification
- Riparian Restoration (multiple locations)
- Stormwater Basin Retrofits (multiple locations)
- Residential Stormwater Management – Rain barrels and rain gardens

Non-structural Management Measures

- River-Friendly Programs – Golf courses, businesses, schools and residents
- River-Friendly Communities

Details on each of these projects are included in **Section VIII Nonpoint Source Management Measures** and **Appendix G Project Detail Sheets.**

Element 4: Estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement this plan.

This section describes the financial and technical assistance necessary to implement the entire watershed restoration plan. Items that are included are implementation, construction, maintenance, monitoring and evaluation. Organizations that could potentially be responsible for various projects and tasks shall also be identified. In the Cedar Grove Brook watershed, these organizations may include NJWSA, Somerset County and Franklin Township. Funding opportunities that may be utilized include Section 319(h) funds, Corporate Business Tax funds, Natural Resources Conservation Service funds, Partners for Fish & Wildlife, and NJWSA's source water protection fund. A discussion of potential funding sources and lead organizations is provided in **Section IX Technical and Financial Assistance**.

Element 5: An information and education component used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.

Outreach and education may occur through many different existing programs. Franklin Township's municipal stormwater management plan requires them to conduct a yearly educational event and distribute brochures provided by the NJDEP[2]. Additional information about this project can be distributed in conjunction with the required mailing. Web sites maintained by the Township, NJWSA and Raritan Basin Watershed Alliance (RBWA) can be vehicles for the dissemination of the plan and information about the management measures. The plan and resulting projects can be highlighted in the RBWA "Basin Bulletin". Both the D&R Canal Commission and D&R State Park can be a valuable ally in distributing literature on the project. See **Section XI Education**.

Element 6: Schedule for implementing the nonpoint source management measures identified in this plan.

A schedule for implementation of the management measures recommended in the plan shall be developed. The schedule will be modified depending on funding opportunities and the potential for management measures to be included in other projects. Some of the management measures recommended in this plan can be implemented with a minimum of planning and funding. For instance, NJWSA is currently implementing the River-Friendly suite of programs in this watershed, and could easily expand that work. Other projects will require the identification of a

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[2] See NJPDES Master General Permit for Tier A municipalities

lead entity and funding. A tentative schedule for implementation is provided in **Section X Implementation Schedule and Milestones.**

Element 7: Milestones- A description of interim measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.

Information regarding the project schedule is provided in **Section X Implementation Schedule and Milestones.**

Element 8: Performance Criteria-A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.

The primary criteria to be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards will be TSS reduction (lbs/yr) as estimated by periodic reexamination of the WinSLAMM model and application of the Step-L model. Additional information regarding monitoring and performance criteria is provided in **Section XII Project Monitoring**.

Element 9: A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established above.

Direct water quality monitoring is not planned in the Cedar Grove Brook. A continuous water quality and flow data monitoring station is planned for the D&R Canal at Landing Lane, approximately three miles downstream. This new facility will be constructed and maintained by the USGS and NJWSA. Those data will be used to assess the overall success of the nonpoint source management measures implemented through the D&R Canal Nonpoint Source Implementation Project, and will also be pertinent for this project.

Additional information regarding monitoring and performance criteria is provided in **Section XII Project Monitoring**.

III. Introduction

The Delaware and Raritan (D&R) Canal transfers water from the Delaware River Basin to the Raritan River Basin, where the raw water is treated to become drinking water for approximately 600,000 customers living in and near the Raritan Basin. Three water purveyors maintain water intakes downstream of the project area on the D&R Canal: Middlesex Water Company, East Brunswick Township and the City of New Brunswick. Since 1997, several of the Canal's water purveyors have reported increased concentrations of total suspended solids in the raw water during and immediately after precipitation events, requiring increased chemical use for treatment and increasing residual sludge generation. Studies and field observations confirmed that the Cedar Grove Brook watershed is a source of sediments to the Canal.

The New Jersey Water Supply Authority (NJWSA) identified a total of 68 infalls or stream and stormwater discharges to the Canal between Amwell Road and Landing Lane, where the Canal discharges into the Raritan River. The report titled "Delaware and Raritan Canal Tributary Assessment and Nonpoint Source Management Project: Watershed Restoration and Protection Plan" [3] described those infalls, estimated pollutant loads and provided preliminary recommendations for best management practices. Implementation of those recommendations is now underway.

A. Cedar Grove Brook Watershed & Water Quality Issues

The Cedar Grove Brook watershed (Figure 1) is the fourth largest direct drainage to the Canal, and the largest within the last eleven miles of the Canal. The Cedar Grove Brook watershed was not included in the original D&R Canal NPS study due to its size, and was made the focus of a separate nonpoint source management project.

The Cedar Grove Brook (also known as Al's Brook) watershed drains 1,788 acres in northeastern Franklin Township, Somerset County and discharges directly into the Canal approximately three miles upstream of the Canal's terminal spillway located near Landing Lane in the City of New Brunswick. A1999 study by the United States Geological Survey (USGS) reported that turbidity does not decrease in the Canal reach between Ten Mile Lock and the Route 18 spillway (the final 11 miles of the Canal) as would be expected due to low water velocities in this reach, indicating that settling solids are replaced by particulates from influent streams and stormwater discharges to the Canal. Field observations downstream of the Canal's confluence with Cedar Grove Brook confirm this, noting the formation of a sediment bar indicating that Cedar Grove Brook contributes sediment-laden stormwater to the Canal.

[3] A major restoration project (Delaware and Raritan Canal Nonpoint Source Implementation Project) is currently underway by NJWSA to reduce sediment loads to the Canal from the many stormwater infalls between Amwell Road and the Route 18 spillway, the last 11 miles of the Canal.

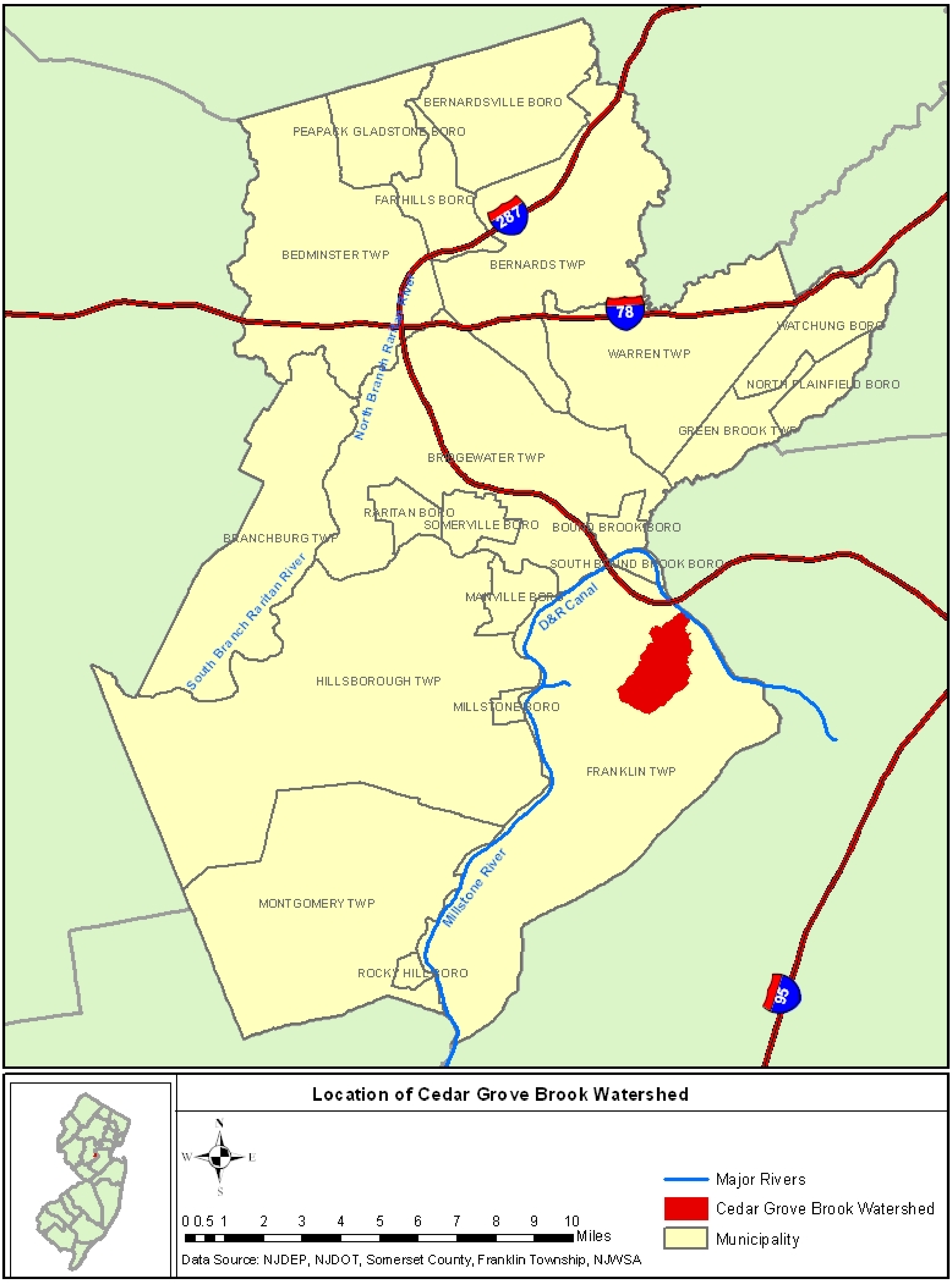

Figure 1. Location Map

The water supply purveyors reported increased levels of total suspended solids (TSS), turbidity, and total organic carbon (TOC) in the Canal during and immediately after precipitation events, requiring increased chemical use in the treatment process and increased sludge generation from residuals. There are no permitted ground water or surface water discharges in this watershed based on 2002 and 2006 NJDEP NJPDES data, so the source of pollution is 100% nonpoint. A United States Geological Survey (USGS) study from 1998 and 1999 (Appendix A) reported that turbidity and sediments were entering the Canal from influent streams and discharges to the Canal between 10 Mile Lock and Landing Lane Bridge and pointed to Cedar Grove Brook as a likely contributor.

B. Cedar Grove Brook Watershed Restoration Plan

The Cedar Grove Brook Stormwater Management and Watershed Restoration Project began as a regional stormwater management plan funded by a Section 319(h) Nonpoint Source Pollution Control Grant from the New Jersey Department of Environmental Protection (NJDEP). One aspect of a regional stormwater management plan is the development of new municipal ordinances or design standards if additional stormwater management is required to protect water resources. During the characterization and assessment phase of the project it became evident that the watershed is essentially built-out. In addition, the 2004 NJDEP stormwater regulations and strict development controls imposed by the Delaware and Raritan (D&R) Canal Commission are expected to be protective of water quality from the impacts of future development. Lastly, the watershed is relatively small and located wholly within Franklin Township, Somerset County which has adopted ordinances and land use regulations which are protective of water resources.

As a result, the project focus was shifted from the development of additional performance standards for new development to the identification of management measures to address impacts from existing nonpoint source pollution problems concentrating on stormwater issues. The work included inventorying the stream conditions, evaluating existing management practices and determining retrofit opportunities and remedial actions for existing stormwater problems. In addition, a monitoring program was implemented to track down sources of turbidity and identify best management practices (BMPs) to address likely sources of sediment.

C. Cedar Grove Brook Watershed Restoration Plan Components

1. Watershed Characterization and Assessment

A characterization and assessment of the watershed was performed. Various data were analyzed for the watershed, including hydrography, land use, land use changes, preserved lands, ground water and soils. Section IV contains the Watershed Characterization and Assessment.

2. Water Quality Monitoring and Modeling

As part of the Delaware & Raritan Canal Tributary Assessment and Nonpoint Source Management Study, NJWSA reviewed water quality data from the USGS study, New Jersey American Water Company, Middlesex Water Company and NJWSA. The data reviewed covered various portions of the time period from March 1998 to October 2004, and indicated that all of the data were below the surface water quality standard of 40 mg/l.

The average water velocity in the Canal is very low, and particles that cause turbidity are typically not transported significant distances. Turbidity is therefore expected to decrease through a particular reach as suspended solids settle out. USGS suggested that the expected decrease in turbidity within most reaches was not being observed because the expected decrease was being offset by turbid water entering the Canal from influent streams and stormwater discharges.

To examine the water quality problems reported by water purveyors and the issues found in USGS's report, NJWSA contracted with Omni Environmental, LLC (OMNI) to conduct water quality sampling and characterize sediment loads, and utilize a watershed computer model (WinSLAMM) to predict turbidity and total suspended solids (TSS) loading. These data were used to target areas within the watershed for nonpoint source management measures.

Omni prepared a Quality Assurance Project Plan (QAPP) (Appendix F), as required by the NJDEP, to obtain the necessary data for evaluating targeted pollutants with respect to flow conditions, seasonal variations and pertinent weather conditions. The sampling plan was designed to assess water quality impacts due to sediment loading. The water quality sampling was performed in accordance with the QAPP for six (6) stormwater locations, six (6) low flow locations, and eight (8) intensive stormwater locations to evaluate the targeted pollutants. The parameters measured during this study were total suspended solids (TSS) and turbidity. Omni submitted an initial report, "Cedar Grove Brook Watershed Water Quality Characterization and Assessment" (Appendix B) in July 2006.

Omni's initial report concluded the overall in-stream criteria for Cedar Grove Brook are regularly met for TSS and turbidity and concentrations and loads are relatively low throughout the watershed. When concentrations are elevated, it appears that the issue resolves itself before the stream's confluence with the Canal due to a high settling rate in the stream. The observed concentrations of TSS and turbidity were low enough that it appeared that Cedar Grove Brook may not be a large contributing factor to TSS and turbidity problems in the Canal. The sampling results indicated that the three pond structures in the watershed act as sediment sinks during low and normal flow conditions, but may act as sediment sources in high flow events.

Overall, the sampling results were not sufficient to exclude the possibility that Cedar Grove Brook delivers a substantial turbidity load affecting water quality in the Canal; nevertheless, the lack of direct sampling confirmation left open the possibility that efforts to minimize TSS and turbidity loads in the Cedar Grove Brook watershed may not address the water quality problems observed at the water supply intakes in the Canal.

To further investigate the water quality issues, turbidity was monitored continuously during a variety of flow conditions for a three week period from October 28 to November 18, 2008. Furthermore, data from the most upstream and downstream locations in the Canal (Ten Mile Lock and Route 18 Spillway at Landing Lane, respectively) were used to confirm the observations made previously by USGS (USGS, 2001) that identified Cedar Grove Brook as a likely source of turbidity to the Canal. These data at the upstream and downstream boundaries of the segment of interest in the Canal also provide a context in which to evaluate the impact of Cedar Grove Brook on the Canal. This additional data confirmed that Cedar Grove Brook is in fact, contributing a significant pollutant load to the Canal, particularly during high flow events.

3. Stream Visual Assessment

NJWSA utilized the United States Department of Agriculture-Natural Resources Conservation Service Stream Visual Assessment Protocol (SVAP) to collect baseline stream health data for this project. Fourteen SVAP locations were chosen based on preliminary visual assessments and accessibility. Various impairments were observed, including eroded streambanks, disconnection of the stream from the floodplain and degraded riparian zones. Section V provides the details of the visual assessments.

4. Recommended Management Measures

Several potential structural and non-structural nonpoint source management measures were evaluated for the Cedar Grove Brook watershed. The recommended measures include:

Structural Management Measures:

- Quail Brook Golf Course Pond – Outlet structure modification and addition of flowpath baffles
- Ukrainian Village Pond – Outlet structure modification
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- Riparian Restoration (multiple locations)
- Stormwater Basin Retrofits (multiple locations)
- Residential Stormwater Management – Rain barrels and rain gardens

Non-structural Management Measures

- River-Friendly Programs – Golf courses, businesses, schools and residents
- River-Friendly Communities

Detailed information on each of these proposed projects can be found in Section VIII.

IV. Watershed Characterization and Assessment

Appendix C contains the full Watershed Characterization and Assessment report.

A. Physical and Natural Features

Cedar Grove Brook (also known as Al's Brook), an FW2-NT (Fresh water Category 2, non trout) water body, is a significant tributary to the Delaware & Raritan Canal, one of New Jersey's major water supply facilities. The watershed encompasses a drainage area of approximately 1,788 acres and is the fourth largest direct drainage area to the Canal. The brook is located in Franklin Township, Somerset County and discharges to the Canal approximately three miles upstream from the water supply intakes for Middlesex Water Company, the Township of East Brunswick and the City of New Brunswick near Landing Lane. Figure 2 presents an aerial view of the watershed.

The Cedar Grove Brook including all its tributaries is 3.6 miles long and rises from the wooded wetlands near Amwell Road in Franklin Township. It flows northeast through residential, commercial and forested areas before discharging to the D&R Canal at Easton Avenue.

The elevation in the watershed ranges from six feet to 132 feet above mean sea level. Contour data was obtained from Franklin Township; Figure 3 presents the contours within the watershed. Inspection of the contours demonstrates the gentle slope of the watershed as well as the steeper sloped areas. Most of the banks along the Cedar Grove Brook are between five and 10 percent slope. As the gradient or percent of slope increases, the velocity of runoff water increases, which increases its erosive power.

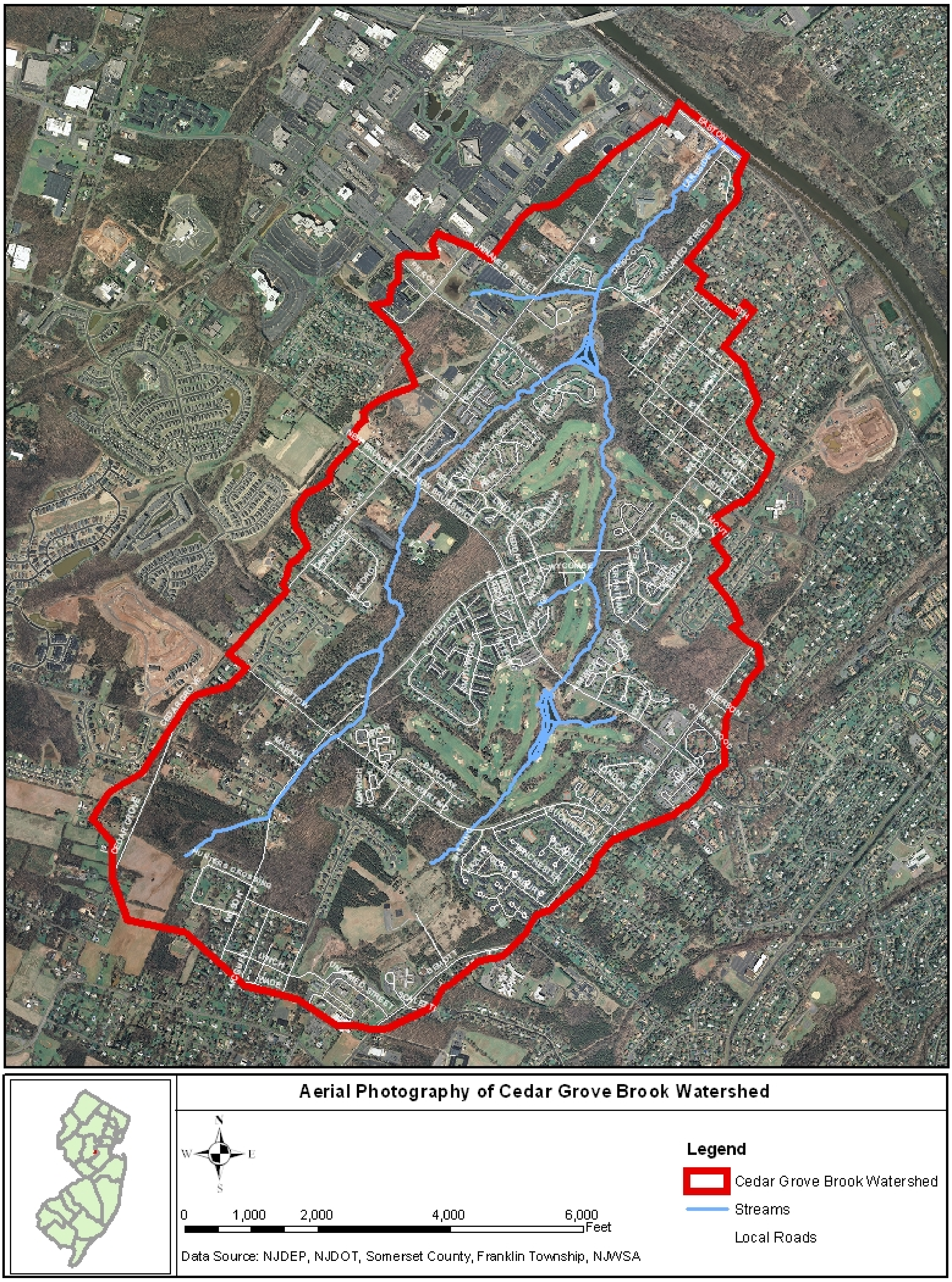

Figure 2. Aerial Map

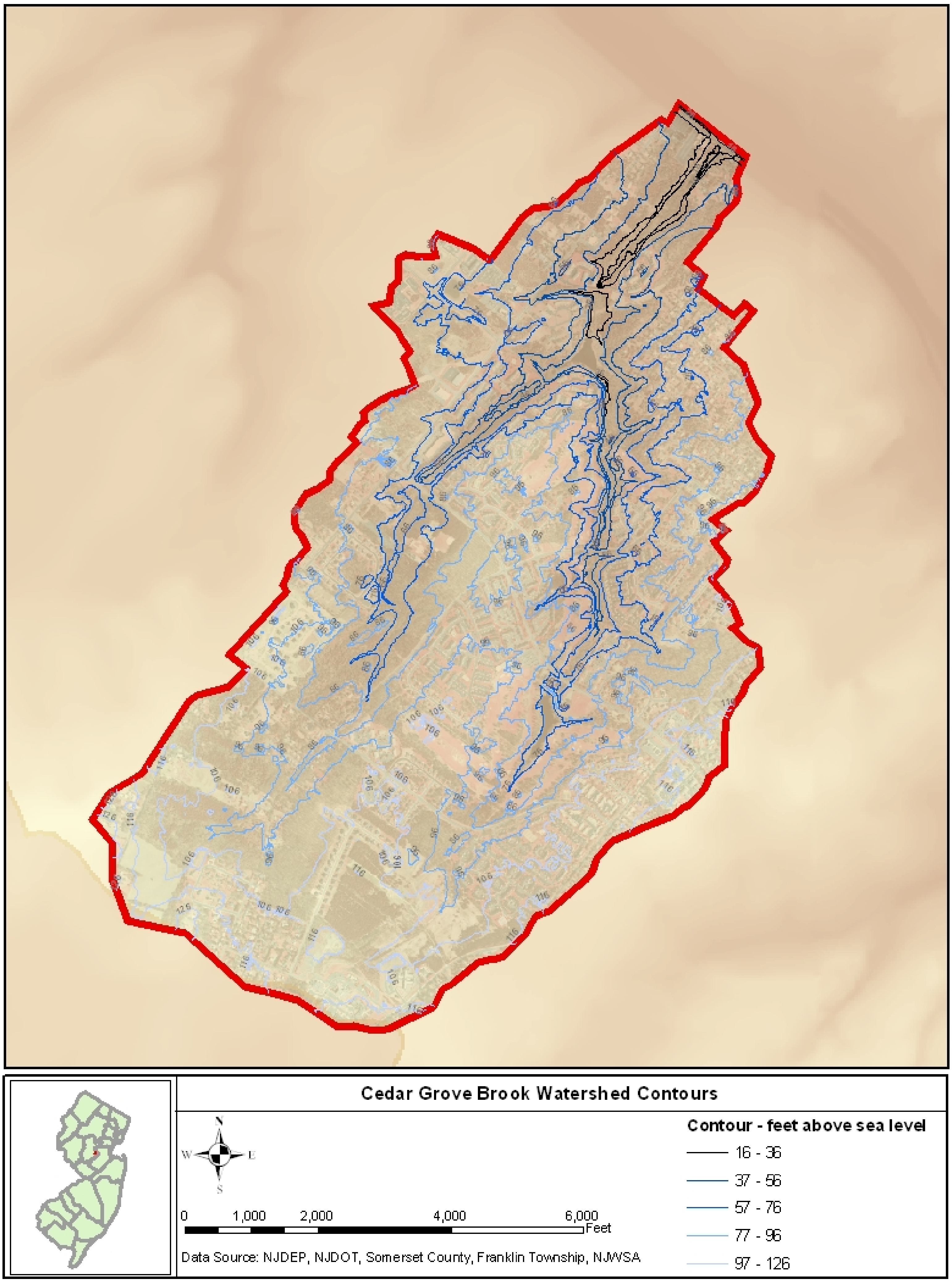

Figure 3. Watershed Contours

B. Land Use and Land Cover

NJWSA performed an analysis of land use based on the NJDEP land use/land cover data from 1986 to 2006. Additional refinement of the land use data was performed based on aerial photographs and field reconnaissance in 2009 for the D&R Canal Nonpoint Source Management Project and incorporated here. The dominant land use in the watershed was urban (60%), including residential (43%), commercial (6.6%), industrial ((0.4%) and recreational (10%) land uses. Forest and shrub/brush comprised approximately 20% of the watershed, wetland comprised approximately 18% and agriculture 1.3%.

During the 20-year period from 1986 to 2006, a total of 430.97 acres were converted to urban land. During the same period 318.02 acres of wetlands, 308.60 acres of forest, 24.56 acres of agriculture, and 7.09 acres of water were lost to development (Table 1 and Figure 4).

The pattern of land use change during that 20-year period was analyzed as well. The period between 1986 (Figure 5) and 1995 (Table 2) exhibited the most significant land use change in the watershed. Urban land use grew by 290.14 acres. All other land uses (with the exception of +2.39 ac. water[4]) lost area to development. The area experienced significant residential growth during this time period. Between 1995 and 2002 (Figure 6) development slowed; however, an additional 113.46 acres were converted to urban land use (Table 3). Additional residential growth as well as commercial development along Cedar Grove Lane was responsible for the change. Between 2002 and 2006, 27.37 acres were converted to urban land use (Table 4).

As of 2002, the impervious surface cover in the Cedar Grove Brook watershed was 19.5% , or 348 acres, based on the 2002 NJDEP land use/land cover data. According to Schueler (1992) [5], the hydrologic and pollutant loading in a watershed is directly related to the amount of impervious cover. Once the amount of impervious cover exceeds 5%, stream health is adversely impacted. Impervious surfaces also decrease natural groundwater recharge and convey a variety of pollutants that are detrimental to water quality, including sediment, nutrients, road salts, heavy metals, pathogens, and petroleum hydrocarbons.

As of 2009, the Cedar Grove Brook watershed was mostly developed (60%); however, there are opportunities for limited growth. Any additional storm water runoff is likely to have a negative impact on water quality in the watershed.

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[4] The retention pond at Quail Brook Golf Club is likely responsible for the increase to the water category.

[5] Schueler, T.R. 1992. *Mitigating the Adverse Impacts of Urbanization on Streams: A Comprehensive Strategy for Local Government*. In Watershed Restoration Sourcebook. Publication #92701 of the Metropolitan Washington Council of Governments.

Table 1. Land Use Change from 1986 to 2006

Land Use Type	Acres 1986	Percent 1986	Acres 2006	Percent 2006	Acreage Change from 1986 to 2006	Percent Change from 1986 to 2006
Agriculture	52.80	2.95	24.56	1.37	-28.24	-1.58
Forest	393.77	22.02	308.60	17.26	-85.17	-4.76
Urban	698.77	39.08	1129.74	63.18	430.97	24.10
Water	4.70	0.26	7.09	0.40	2.39	0.13
Wetlands	554.28	31.00	318.02	17.79	-236.26	-13.21
Barren Land	83.69	4.68	0.00	0.00	-83.69	-4.68
Total	1788.00	100.00	1788.00	100.00	0.00	0.00

Table 2. Land Use Change from 1986 to 1995

Land Use Type	Acres 1986	Percent 1986	Acres 1995	Percent 1995	Acreage Change from 1986 to 1995	Percent Change from 1986 to 1995
Agriculture	52.80	2.95	49.14	2.75	-3.65	-0.20
Forest	393.77	22.02	354.60	19.83	-39.18	-2.19
Urban	698.77	39.08	988.91	55.31	290.14	16.23
Water	4.70	0.26	7.09	0.40	2.39	0.13
Wetlands	554.28	31.00	384.47	21.50	-169.81	-9.50
Barren Land	83.69	4.68	3.80	0.21	-79.89	-4.47
Total	1788.00	100.00	1788.00	100.00	0.00	0.00

Table 3. Land Use Change from 1995 to 2002

Land Use Type	Acres 1995	Percent 1995	Acres 2002	Percent 2002	Acreage Change from 1995 to 2002	Percent Change from 1995 to 2002
Agriculture	49.14	2.75	24.56	1.37	-24.59	-1.38
Forest	354.60	19.83	316.39	17.70	-38.20	-2.14
Urban	988.91	55.31	1102.37	61.65	113.46	6.35
Water	7.09	0.40	7.09	0.40	0.00	0.00
Wetlands	384.47	21.50	330.08	18.46	-54.38	-3.04
Barren Land	3.80	0.21	7.51	0.42	3.71	0.21
Total	1788.00	100.00	1788.00	100.00	N/A	N/A

Table 4. Land Use Change from 2002 to 2006

Land Use Type	Acres 2002	Percent 2002	Acres 2006	Percent 2006	Acreage Change from 2002 to 2006	Percent Change from 2002 to 2006
Agriculture	24.56	1.37	24.56	1.37	0.00	0.00
Forest	316.39	17.70	308.60	17.26	-7.79	-0.44
Urban	1102.37	61.65	1129.74	63.18	27.37	1.53
Water	7.09	0.40	7.09	0.40	0.00	0.00
Wetlands	330.08	18.46	318.02	17.79	-12.07	-0.67
Barren Land	7.51	0.42	0.00	0.00	-7.51	-0.42
Total	1788.00	100.00	1788.00	100.00	N/A	N/A

Table 5. Land Use- 2009

Land Use Type	Acres 2009	Percent 2009
Agriculture	24.04	1.34
Forest	359.39	19.85
Urban	1068.74	60
Water	7.47	0.42
Wetlands	323.69	18.03
Barren Land	0	0
Total	1783.33	100.00
Note: Total acreage 2009 is slightly different due to the use of data calculated through the D&R Canal NPS Project.		

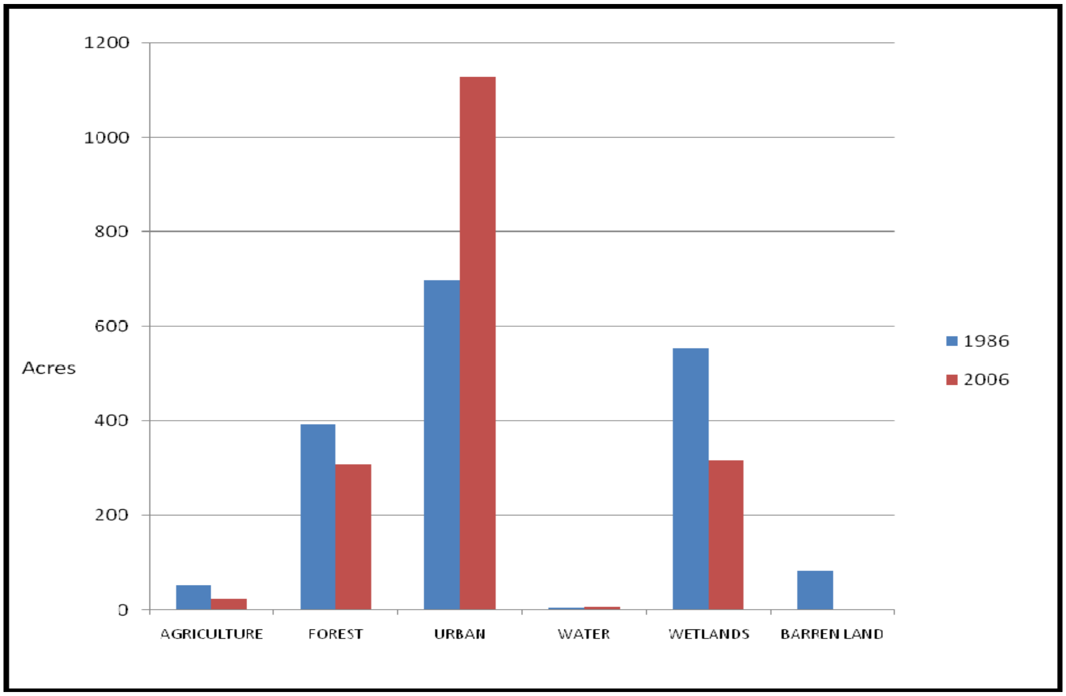


Figure 4. Land Use Comparison 1986 to 2006

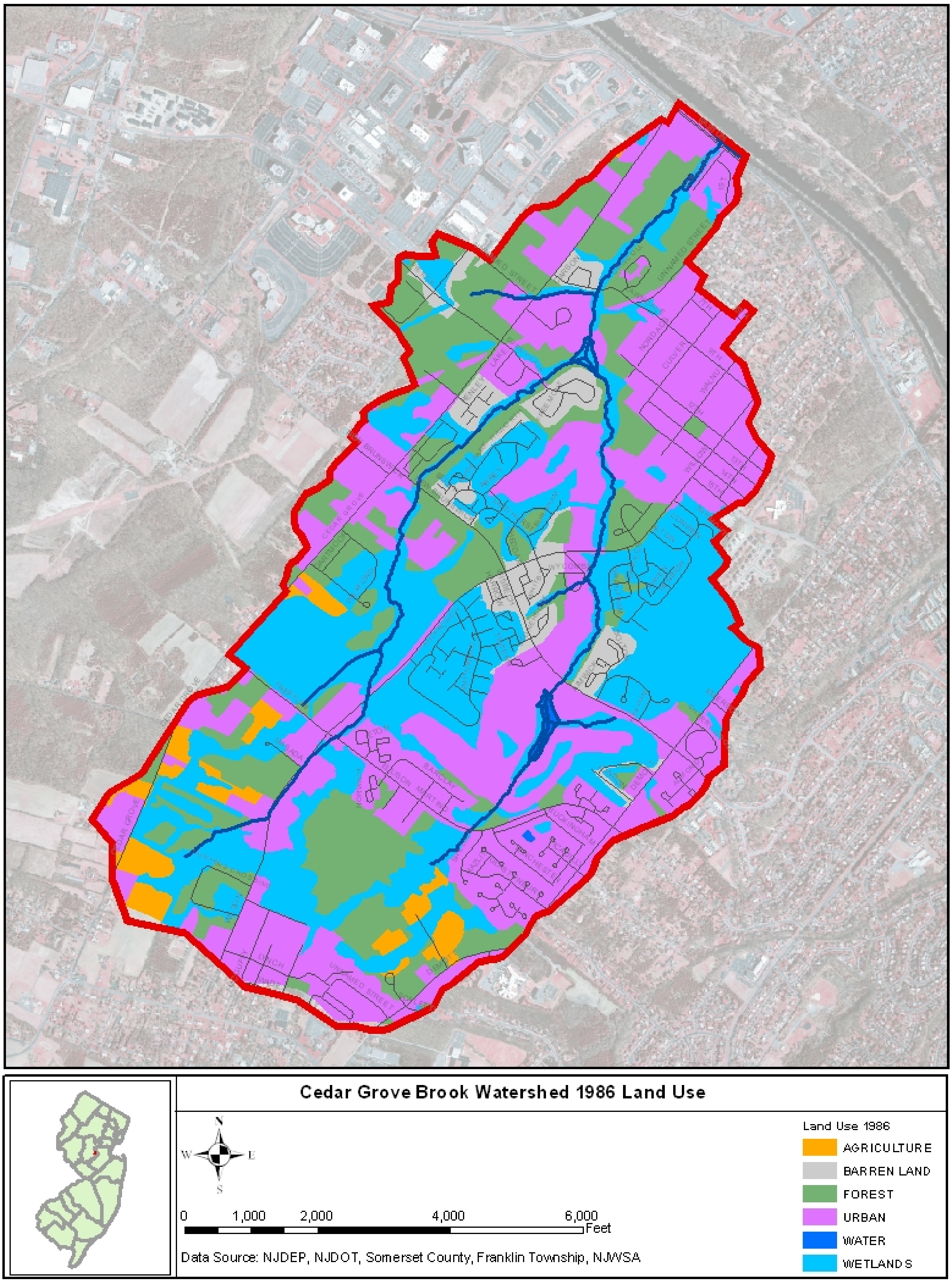


Figure 5. 1986 Land Use

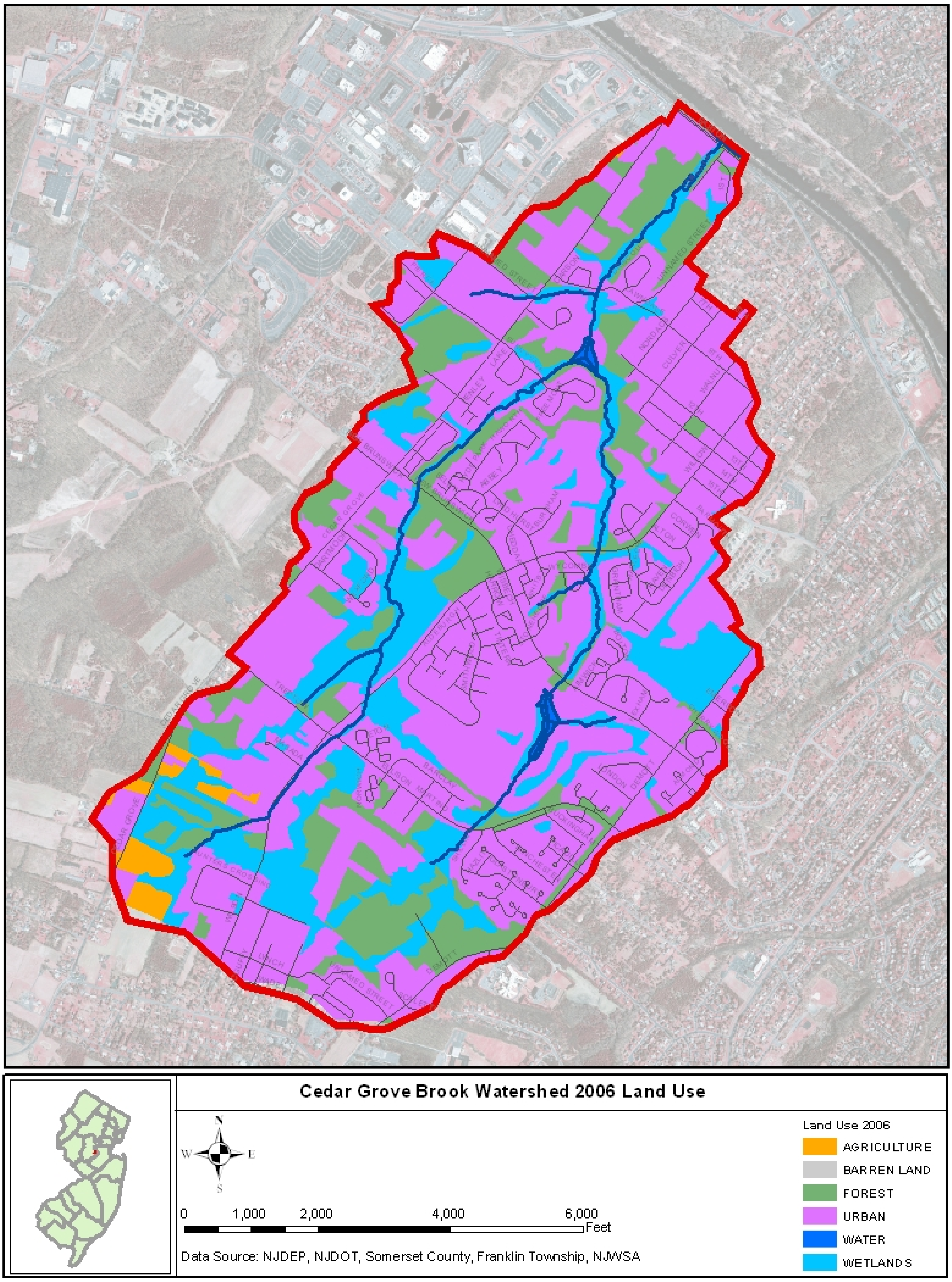


Figure 6. 2006 Land Use

C. Open Space and Preserved Lands

Preserved open space is beneficial to the health of a watershed. Open space, particularly that which is kept in a natural state, slows the movement of stormwater, provides areas for ground water recharge and can act as a filter of surface water pollutants. Preserving open space can also decrease flooding and erosion, increase biodiversity and habitat, provide recreational opportunities, enhance the quality of life and increase nearby land values.

Franklin Township and Somerset County have utilized the various open space funding programs that exist in New Jersey and have adopted open space and farmland preservation plans with a dedicated tax to finance acquisitions.

The total preserved open space in the Cedar Grove Watershed was 447 acres in 2009, or 25 percent of the total watershed area (Figure 7). Quail Brook Golf Course is owned by Somerset County, most of the rest of the open space in the watershed is owned by Franklin Township. There are isolated pockets of privately-owned open space in the larger residential developments which are maintained by homeowner associations.

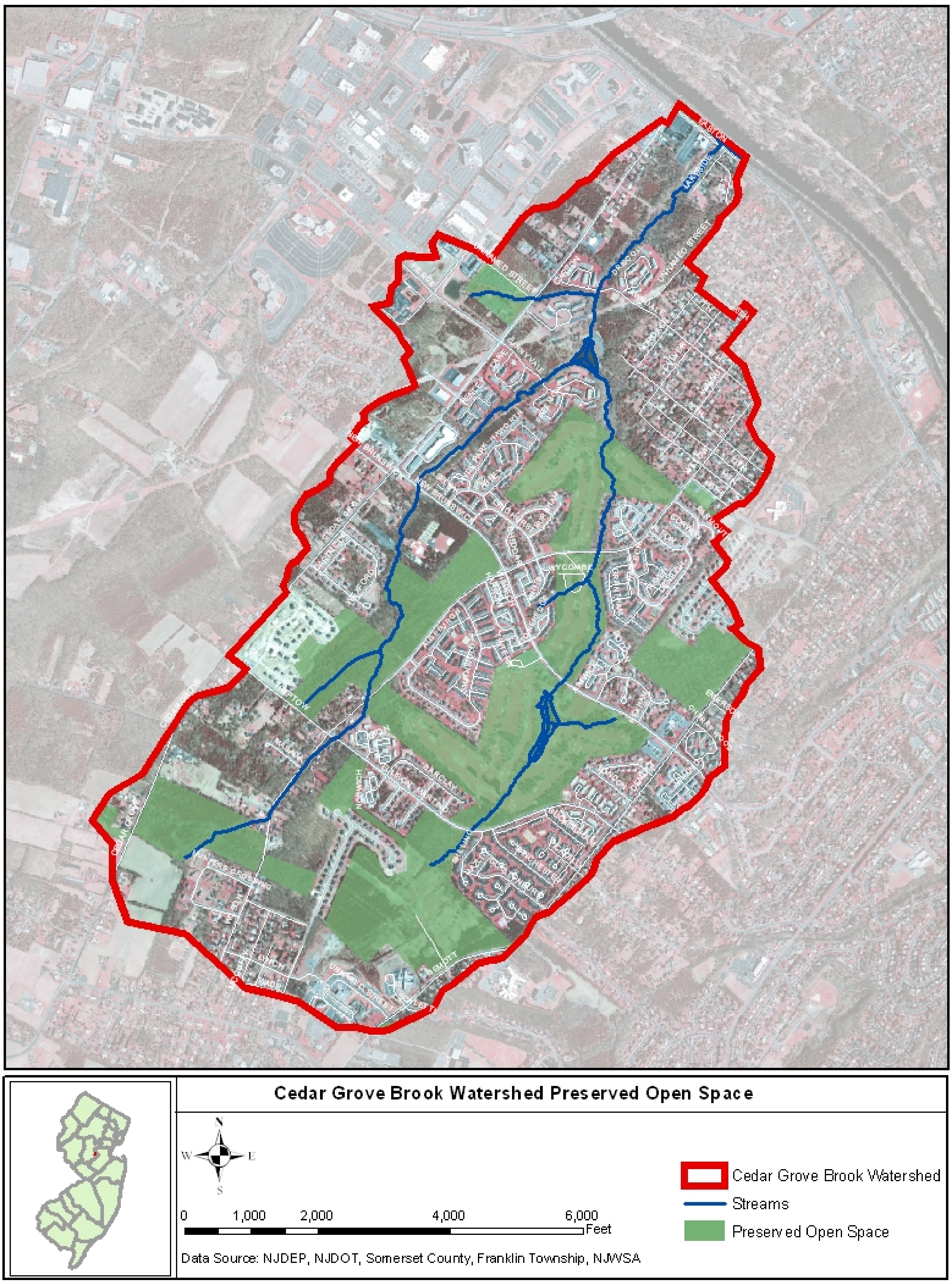


Figure 7. Preserved Lands

D. Ground Water

Cedar Grove Brook depends on ground water to maintain base flow during periods of low or no precipitation. Ground water can be contaminated by a wide variety of sources including accidental spills, and fertilizer and pesticide applications. Ground water recharge can be reduced through changes in soil permeability (e.g., impervious surfaces, soil compaction), soil aspect (e.g., slope, surface roughness), and vegetation. Relative to land use, recharge rates in forests are much higher than those in urban areas (Heath, 1983). This is because urban areas have large areas covered with impervious surfaces, hastening runoff to surface water, instead of allowing precipitation to percolate into the ground.

A ground water recharge area is the land area that allows precipitation to seep into the saturated zone. These areas are generally at topographically high areas with discharge areas at lower elevations, commonly at streams or other water bodies (i.e. the ground water returns to surface water). Groundwater recharge areas provide base flow to streams that support both aquatic ecosystems and surface water supplies. Estimating the relative recharge rates of various land areas provides a way by which the most critical ground water recharge areas can be mapped and protected through various mechanisms, including zoning, development regulation and land preservation.

Recharge rates are expressed in terms of the amount of precipitation that reaches the aquifer per unit of time (e.g. inches/year). Recharge rates vary from year to year, depending on the amount of precipitation, its seasonal distribution, air temperature, land use and other factors. The estimated recharge rates of this watershed from the NJGS 95/97 dataset indicate that the maximum recharge rate in non-drought conditions is 15.75 inches per year, with the highest infiltration rates predicted to occur in the downstream forest area along the Cedar Grove Brook (Figure 8).

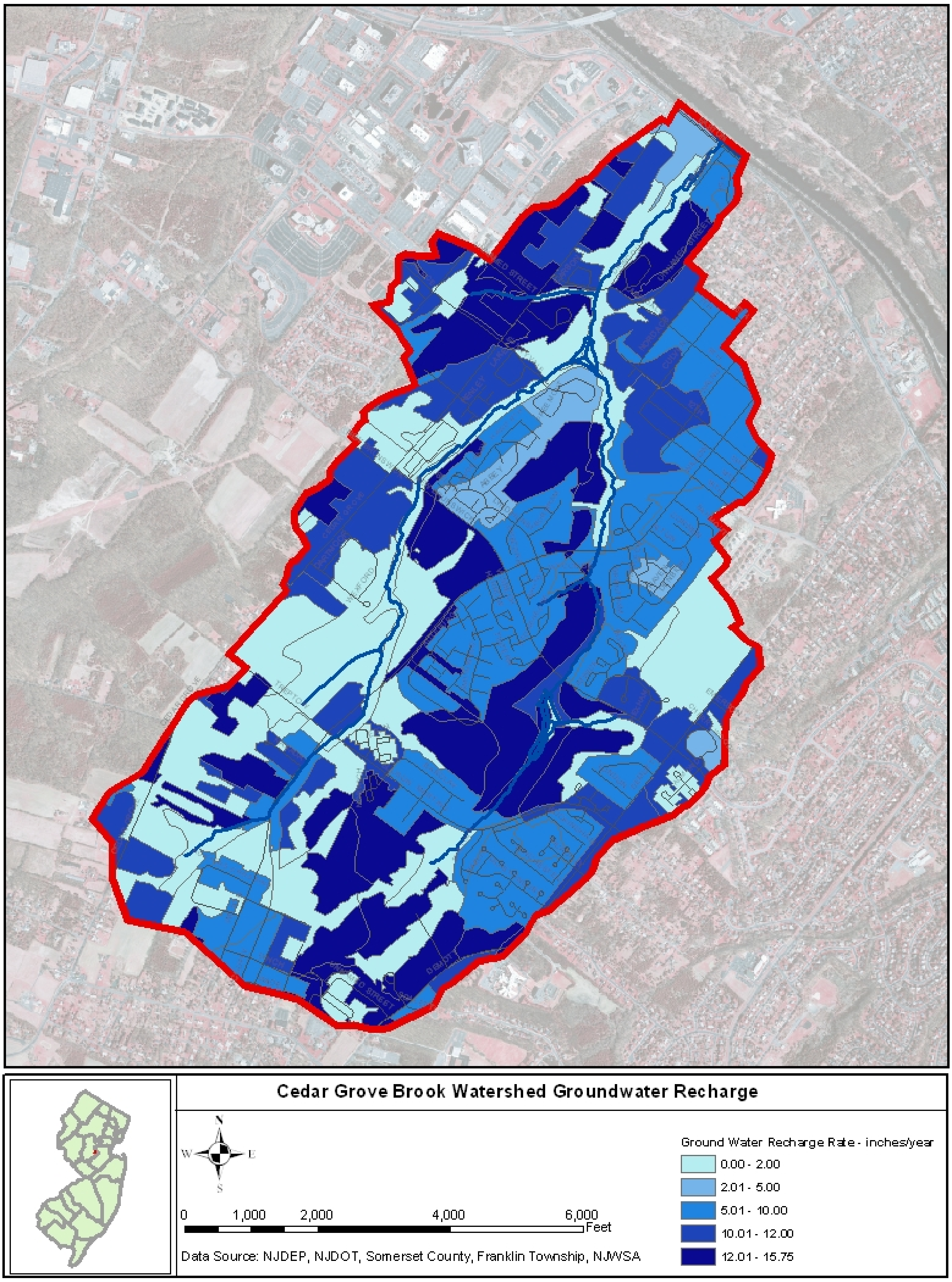


Figure 8. Groundwater Recharge

E. Soils

Soil is the unconsolidated mineral material on the immediate surface of the earth which serves as the medium for growth of land plants. The characteristics of each soil type have developed over time (usually many thousands of years) under the influence of the parent material, climate (including moisture and temperature regimes), macro- and microorganisms, and topography. Soil is a basic resource for food production, in addition to its essential role in collecting and purifying water before it enters the ground water; however, soil itself can be a pollutant as dust in the air or as sediment in water.

The US Department of Agriculture Natural Resources Conservation Service (USDA-NRCS) develops soil surveys to determine soil characteristics and capabilities. The Somerset County soil survey was updated in 2006. The soil survey separates the landscape into segments that have similar use and management requirements. Therefore, this data set is not designed for use as a primary regulatory or management tool, but may be used as a broad scale reference source.

The soil characteristics vary from place to place in slope, depth, drainage, erodibility and other properties. The hydrologic soil grouping describes the rate that water infiltrates into the ground. The majority of the Cedar Grove Brook watershed contains Class C soils, which have slow infiltration rates (Table 6 and Figure 9).

Table 6. Hydrologic Soil Group

Class	Definition	Acres	Percent within the watershed
A	High infiltration rates. Soils are deep, well drained to excessively drained sands and gravels.	0	0%
B	Moderate infiltration rates. Deep and moderately deep, moderately well and well drained, soils that have moderately course textures.	14.7	0.8%
C	Slow infiltration rates. Soils with layers impeding downward movement of water, or soils that have moderately fine or fine textures.	1760.5	97.9%
D	Very slow infiltration rates. Soils are clayey, have a high water table, or are shallow to an impervious layer.	17.7	1%
Unknown		3.9	0.2%
Source: NRCS Soil Survey Geographic (SSURGO) Database.			

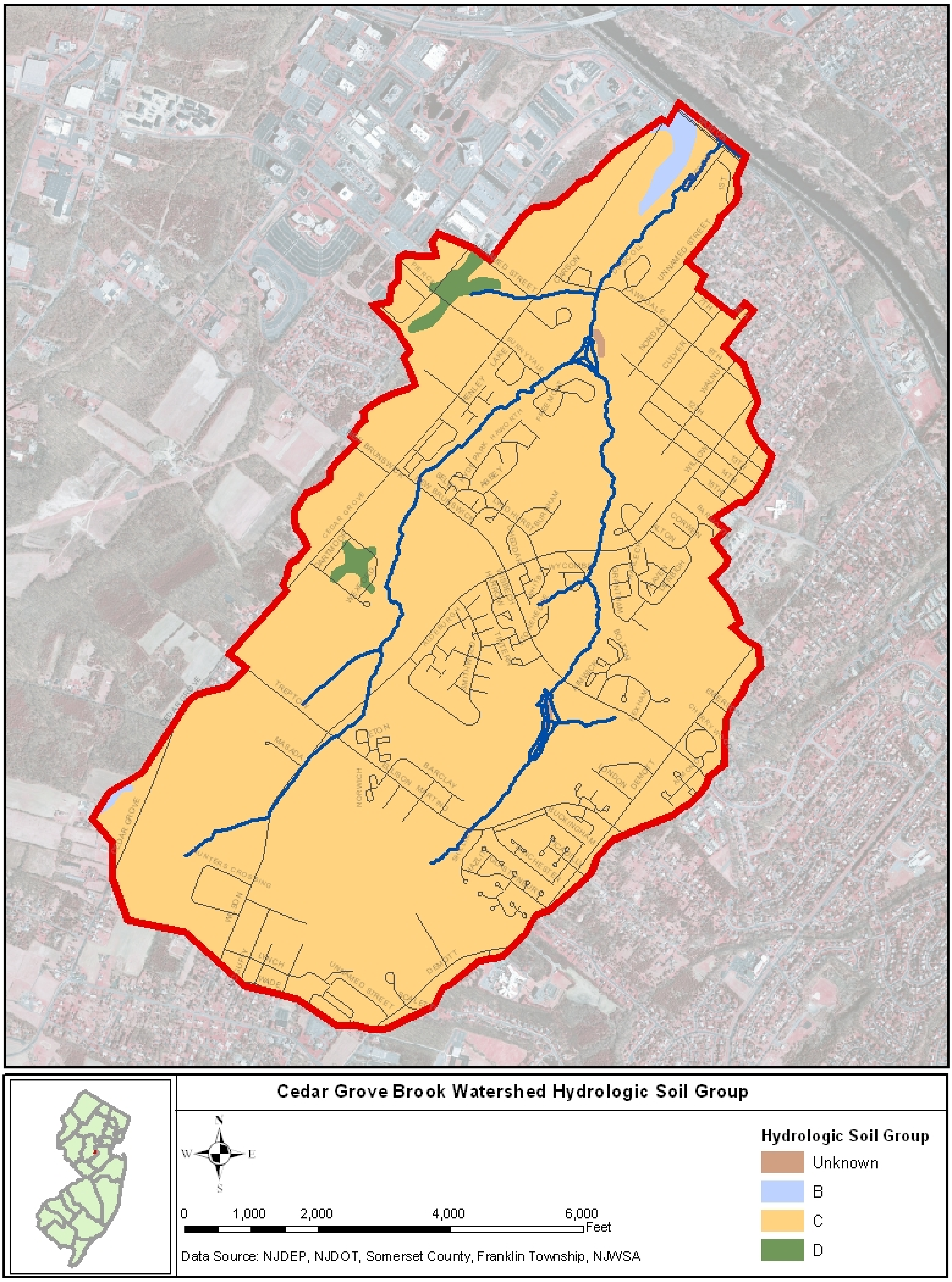


Figure 9. Hydrologic Soil Group

F. Known Contaminated Sites

A "known contaminated site" is a location where contamination of soil or ground water has been confirmed at levels greater than the applicable soil cleanup criteria, ground water quality standards and/or maximum contaminant levels of the Safe Drinking Water Standards and where remediation is either underway or pending. Contamination is typically identified at a site through sampling of the soil, sediment, surface water and/or ground water.

NJDEP maintains a master list for the cleanup of all hazardous discharge sites throughout the State. The master list, called the Contaminated Sites List (of which the Known Contaminated Sites list is a sub-list), includes an inventory of the sites that have been cleaned up, that have been identified as in need of cleanup, and that will be cleaned up. The list of sites used in this report is based on the most recent GIS coverage (April 2008 Known Contaminated Sites list) obtained from the NJDEP Site Remediation Program. Remedial levels are based on the NJDEP Site Remediation Program's 1989 Case Assignment Manual, which determines levels based on the overall degree of contamination at a site.

Table 7 and Figure 10 show three known contaminated sites within the Cedar Grove Brook watershed that are classified as level C2[6]. Known contaminated sites do not pose a significant threat to the Cedar Grove Brook watershed.

Table 7. Known Contaminated Sites within the Cedar Grove Brook Watershed

Tracking Number	Address	List Date	Type	Remediation Level & Status
162135	300 Cedar Grove Lane	8/14/2002	HO-UST	C2: Formal Design – Known Source or Release with GW Contamination – Closed 6/2006 – no detail
164971	302 Cedar Grove Lane	9/30/2002	N/A	C2: Formal Design – Known Source or Release with GW Contamination
031476	Quail Brook Golf Course – 621 New Brunswick Ave	12/17/2001	UST-Unleaded Gasoline	C2: formal Design – Known Source or Release with GW contamination. Closed – 10/1997 – 1,000 gallon tank removed
HO = Homeowner, UST = Underground Storage Tank Data from NJDEP's 2008 Known Contaminated Sites GIS coverage and Data Miner				

[6] A remedial action that consists of a formal engineering design phase, and is in response to a known source or release. Since the response is focused in scope and addresses a known, presumably quantifiable source, this remedial level is of relatively shorter duration than responses at sites with higher remedial levels. Usually involves cases where ground water contamination has been confirmed or is known to be present.

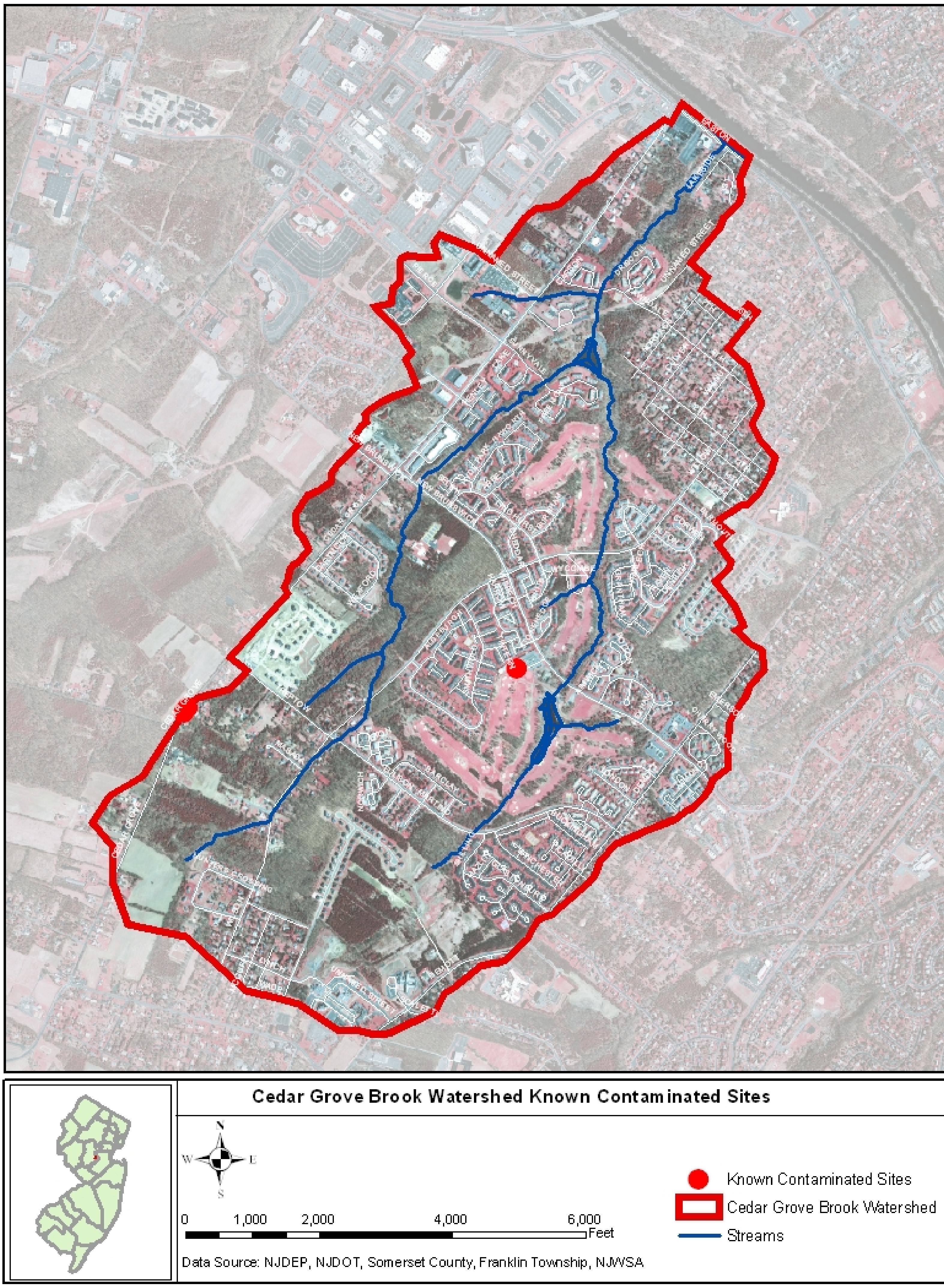


Figure 10. Known Contaminated Sites

V. Visual Assessment

A. Preliminary Visual Assessments

The Raritan Basin Watershed Alliance Road Crossing Protocol, developed by NJWSA and the Raritan Basin Watershed Alliance (RBWA), was utilized to collect information on each road crossing within the watershed. The information collected included land use, type of crossing, suitability for stream assessment (with respect to channel size, accessibility and safety) and the need for riparian buffer restoration. Photographs were taken at each crossing. From that list, NJWSA selected a subset of sites for stream visual assessment.

B. Stream Visual Assessments

In the fall of 2008 and winter of 2009, staff from the NJWSA and an ambassador from DEP's AmeriCorps program conducted a comprehensive stream visual assessment of the Cedar Grove Brook Watershed. NJWSA used the United States Department of Agriculture – Natural Resources Conservation Service (USDA-NRCS) Stream Visual Assessment Protocol (SVAP) to gather baseline data for this project. The SVAP is used to score a site based on a set of 15 indicators, including:

- Channel condition: Natural vs. altered channel (e.g. channelization; installation of riprap, dikes or levees; or downcutting or incision).
- Hydrologic alteration: Connectivity to the floodplain (e.g., structures or channel incision that limit the stream's access to the floodplain).
- Riparian zone: Stream's buffer area (e.g., a perfect score requires natural vegetation to extend at least two active channel widths on each side of the stream. A lower score, for instance a 5, is given when natural vegetation extends only half the active channel width on each side of the stream).
- Bank stability: Bank condition (banks are either level with the floodplain and stable or are higher and eroding; banks have exposed roots or slope failures present within the reach).
- Water appearance: Water clarity (clear with visible bottom or cloudy/murky).
- Nutrient enrichment: Presence of dense algal and/or aquatic macrophyte growth (A stream with a diverse plant community and clear water scores a 10; a stream with greenish water and an overabundance of algae and/or macrophytes scores a 3).
- Barriers to fish movement: Withdrawals, culverts, dams or diversions both up and downstream of the reach.
- Instream fish cover: Available cover types for fish habitat (e.g., woody debris, riffles, pools, and cobble).
- Pools: Abundance and depth of pools within the reach.
- Invertebrate habitat: Number of cover types available as habitat.
- Canopy cover: Coldwater versus warmwater fisheries. The project area is considered a coldwater fishery, thus a reach that is well shaded would score high, whereas a reach that is minimally shaded would score low.
- Manure presence: Evidence of livestock in or near the stream; it was not scored for any of the project sites.
- Salinity: Non-applicable for the project watershed.

- Riffle embeddedness: Embeddedness of cobble or gravel in sediment.
- Macroinvertebrates observed: Type and diversity of species present. A site with a good diversity of pollution intolerant species received a score of 15, while a site dominated by more pollution tolerant organisms might receive a 6. It should be noted that several of the SVAPs were performed during the winter months, which are not ideal months for the observation of macroinvertebrates. This parameter was not scored at all of the sites.

Once the team chose a segment for assessment, the active channel width was measured. A reach that was 12 times the active channel width was then scored from one to 10 (one to 15 for macroinvertebrates observed and one to five for manure presence) based on the 15 parameters described above; any parameter that was not applicable to a particular site was not scored. In the project watershed, salinity was determined to be not applicable; manure presence was not identified and thus not scored at any sites. The scores for each parameter were summed and divided by the total number of parameters scored to yield the SVAP score.

The SVAP relies heavily on relative comparison of sites, rather than a rigorous quantitative analysis; it is a screening assessment tool rather than a site-specific monitoring protocol, and therefore is subjective. Each parameter is scored based on the assessor's observations of a particular reach. For this reason, NJWSA ensured consistency of assessors among all of the sites.

The SVAP provided a great deal of useful information regarding the Cedar Grove Brook watershed. The shortfall of the protocol is that it fails to provide a mechanism for identifying the cause of identified problems.

The full SVAP report is provided in Appendix D. The 14 SVAP locations were chosen based on the preliminary visual assessments, tributary patterns and accessibility. The objective was to collect enough information to assess overall stream health. The stream assessment team identified areas of impaired stream systems throughout the watershed, and documented major detention basins and associated outfalls. Observed impairments included:

- Destabilization and erosion of stream banks
- Disconnection of the stream from the floodplain due to downcutting of the stream channel and man-made embankments;
- Inadequate riparian zones and overabundance of invasive species;
- Excessive sediment deposition due to a loss of stream transport capacity;
- Presence of algae in moderate to high densities during time of assessments (December).

Detailed surveys of detention basins in the watershed were conducted using the NJDEP Volunteer Monitoring Program Visual Assessment Pipe and Drainage Ditch Inventory. Detention basins were targeted by the NJWSA staff managing the Cedar Grove Brook project. Observed impairments included:

- Concrete low flow channels in each detention basin;
- Sediment accumulation at the outlet of each detention basin;
- Abundant scat accumulation from wildlife (geese and deer) in each detention basin;
- Erosion of stream banks at the outfall of four out of six basins surveyed.

Overall scores ranged from 4.70 (Poor) to 7.80 (Good). The scores for each parameter varied widely, e.g. from a low of four in the riparian zone category to a high of nine. Figure 11 shows the 14 SVAP locations; the data are summarized in Table 8.

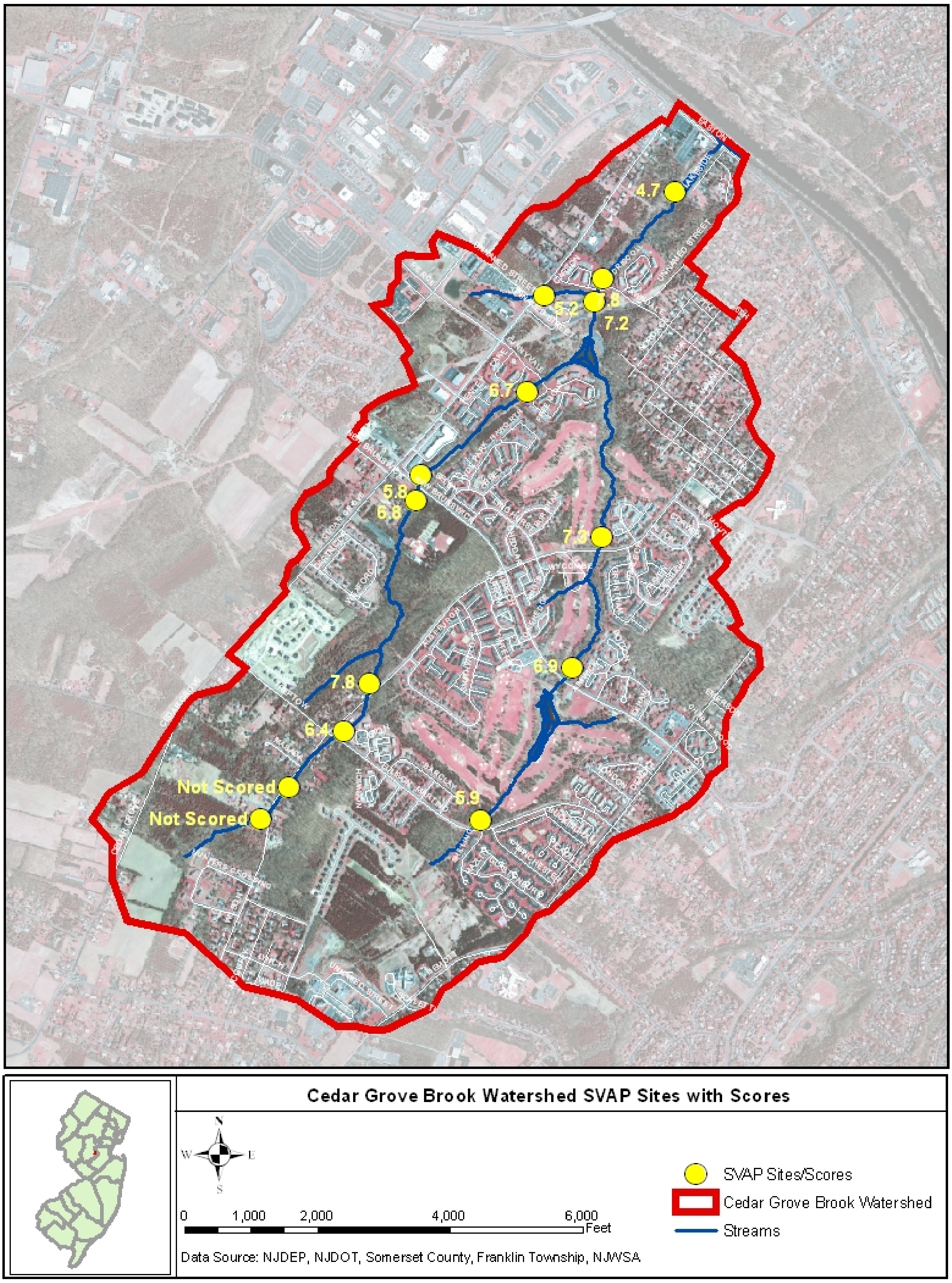


Figure 11. Stream Visual Assessment Locations and Scores

Table 8. Summary of Stream Visual Assessment Results

SVAP #	CGB-1	CGB-2	CGB-3	CGB-4	CGB-5	CGB-6	CGB-7	CGB-8	CGB-9	CGB-10	CGB-11	CGB-12	CGB-13	CGB-14
Assessment Scores:														
Channel condition	3	7	9	8	6	9			9	8	9	8	9	3
Hydrologic alteration	3	8	10	8	6	9			10	8	9	7	9	2
Riparian zone	4	6	8	6	6	4			4	6	9	8	8	6
Bank stability	5	7	7	7	6	7			10	7	8	7	9	3
Water appearance	7	7	8	6	7	7			8	7	8	7	7	7
Nutrient enrichment	7	7	4	7	6	7			8	9	3	7	8	3
Barriers to fish movement	3	1	3	3	3	3			3	3	9	3	3	5
Instream fish cover	5	8	10	5	4	8			5	10	9	5	8	8
Pools	6	8	9	8	3	7			3	5	6	3	9	3
Invertebrate habitat	8	10	10	7	7	10			7	10	10	7	10	7
Canopy cover	7	7	5	7	8	3			3	4	7	6	3	5
Manure presence	n/a	n/a	n/a	n/a	n/a	n/a			n/a	n/a	n/a	n/a	n/a	n/a
Salinity	n/a	n/a	n/a	n/a	n/a	n/a			n/a	n/a	n/a	n/a	n/a	n/a
Riffle embeddedness	3	10	10	8	7	7			n/a	6	7	3	5	4
Macroinvertebrates observed	7	na	na	na	na	na			na	na	na	na	na	na
Overall Score (Total divided by number scored) Poor = <6.0; Fair = 6.1 - 7.4; Good = 7.5 - 8.9; Excellent = >9.0	**5.2**	**7.2**	**7.8**	**6.7**	**5.8**	**6.8**	not scored	not scored	**6.4**	**6.9**	**7.8**	**5.9**	**7.3**	**4.7**
Rating	Poor	Fair	Good	Fair	Poor	Fair	na	na	Fair	Fair	Good	Poor	Fair	Poor

Four SVAP locations scored poor in the stream visual assessment process:
CGB-1: This location, with a score of 5.2, had low scores for channel condition, hydrologic alteration, riparian zone, barriers to fish movement and riffle embeddedness. The stream was confined by high banks associated with multi-family residential development on the left bank, and Lawndale Drive on the right bank. The left bank averaged 15 feet, the right bank averaged eight feet. Both banks were actively eroding. A headcut migration to bedrock provided evidence that the reach has been actively down cutting. This reach conveys considerable storm water runoff from a regional detention basin located at the southeast intersection of Pierce Street and Worlds Fair Drive.

The riparian corridor was inundated with invasive species. There was a lack of native species regeneration and virtually no native understory species population. There was an inline detention basin upstream of the Cedar Grove Lane road crossing. A large population of geese was observed. There was no riparian buffer upstream of the road crossing, only lawn. This site was identified as a potential location for riparian buffer improvement**.**

CGB-5: This location, with a score of 5.8, had low scores for barriers to fish movement and pools. The average bank height within the reach was one to two feet. The floodplain was steep and the reach was relatively straight. The upper portion of the reach was dominated by bedrock, the lower portion contained more silt and cobble. The substrate was >25% embedded at the lower end of the reach. Attached algae were moderately dense and completely covered the channel substrate.

The riparian corridor was 50 to75 feet wide on the left bank and 30 feet wide on the right bank. The corridor lacked a native understory and multi-flora rose was abundant. Land use in the vicinity of the site included commercial development and an access road.

CGB-12: This site scored 5.9, and had low scores for barriers to fish movement, instream fish cover and riffle embeddedness. The average bank height through the reach was one to two feet. The reach was dominated by small riffles and shallow pools. Sediment deposition was observed throughout the reach. A small tributary on the left bank was contributing sediment to the channel. Some erosion was occurring in proximity to a debris jam at the top of the reach.

The riparian corridor was 100 feet wide on the left bank and approximately 50feet on the right bank. The corridor contained a large population of invasive species, particularly multi-flora rose. Native species regeneration was absent. The land use in the vicinity of the site included multi-family residential and forest on the left bank, and Quail Brook Golf Course on the left bank.

CGB-14: This location had the lowest score of all the SVAP sites, a 4.7. It scored low for channel condition, hydrologic alteration, bank stability, nutrient enrichment, pools and riffle embeddedness. The stream meanders through an extensive sediment bar and may be a source of TSS during storm events.

The height of the banks within the reach ranged from one to two feet, and was as high as eight feet. The stream had access to the floodplain during storm events in some portions of the reach; in other areas the floodplain was steeply sloped.

The substrate was dominated by fine sediment in the lower portion of the reach; bedrock and cobble were observed at the upstream end where the gradient was steeper and riffles were more abundant. The upper portion of the reach had a meandering pattern with riffles, glides and shallow pools occurring frequently. Large, old sediment deposits inhabited by mature vegetation were observed. Recent deposition formed numerous sediment bars along straight areas, on the inside of meander bends and mid-channel. Bank erosion was observed on the outside of meander bends most often associated with large sediment deposits along the opposite bank.

The downstream end of the reach was dominated by large meanders, side channels and backwater pools . Large amounts of sediment were deposited within this portion of the reach. Some sediment bars were two feet above the water surface elevation and actively eroding. Attached algae were abundant and completely covered the substrate through most of the reach.

The riparian corridor on the left bank averaged less than 50 feet in width. The corridor on the right bank was approximately 50 feet wide in the lower and upper portion of the reach and greater than 100 feet mid-reach. The corridor on both banks was inundated with invasive species and lacked native species regeneration and native species in the understory. The land use in the vicinity of the site included roadway, forest and multifamily residential on the right bank and roadway, commercial development and multifamily residential on the left bank.

C. Stormwater Basin Survey

GIS layers identifying stormwater basins in the watershed were obtained from Somerset County and the Somerset-Union Soil Conservation District. A total of 15 basins were identified from the GIS layer and field observations. There may be other basins within the watershed that were not identified in this effort. General observations are included in Table 9, locations are shown in Figure 39.

Table 9. Stormwater Basins

	Basin Identifier	Street Location/ Block/Lot	Responsible Party/Owner	Notes/Observations
1	Lower Pond	1730 Easton Ave./ Block 424.02/Lot 24	Cretan Bull Restaurant Corp.	See Section VIII(A)(3)
2	Candlewood Hotel Co./ First Industrial L.P.	Block 468.09/Lot 47	First Industrial L.P. 311 South Wacker Dr., Chicago, IL 60606	Very large detention basin, 3 inlets, low flow channels, grass with some areas of exposed soil on basin floor
3	Ukrainian Village/Lakewood Townhomes	Sunnyvale Court/ Block 424.02/ Lot 11.96	Lakewood Townhouse Association 35 Clyde Road, Suite 102, Somerset, NJ	See Section VIII(A)(2)
4	Stonehenge Estates	19 Wexford Way/ Block 424.12/Lot 4.13	Stonehenge HOA, 315 Raritan Avenue, Highland Park, NJ	Low flow channels, 3 inlets, outfall 50 feet from channel, sediment source to stream, grass floor of basin
5	Franklin Twp. 1/Renoir Way	186 Cedar Grove Lane/ Block 424.12/Lot 2.32	Franklin Twp. 475 De Mott Lane	Near Renoir Way, 3 inlets with concrete low flow channels, wet basin floor, muddy, holding water after storm events
6	Hunter's Crossing	Block 423.01 Lot 40.07	Hunter's Crossing HOA, 12 Hunter's Crossing Road, Somerset, NJ 08873	Drains storm drain off Hunter's Crossing Road, 1 inlet concrete low flow channel, 3 inch hole partially blocked by sediment, sediment in low flow channel, riprap in stream at outfall, holding water after storm events – inlet under water
7	Franklin Twp. 3/Gauguin Way	Block 417.01 Lot 22.01	Franklin Twp. 475 De Mott Lane	Grass floor detention basin
8	Franklin Twp. 2	Block 417.01 Lot 5.04	Franklin Twp. 475 De Mott Lane	Very large detention basin at municipal complex. 1 inlet, 2 low flow channels, adjacent wetland area. Very wet and muddy by outlet structure
9	Somerset AL Holdings #1	473 De Mott Lane/	Somerset AL Holdings, 473	Unmowed basin – a lot of herbaceous and some woody

		Block 417.01/Lot 4.02	Demott Lane, Somerset, NJ	vegetation. Low flow channels.
10	Somerset AL Holdings #2	473 De Mott Lane/ Block 417.01/Lot 4.02	Somerset AL Holdings, 473 Demott Lane, Somerset, NJ	Small detention basin draining parking lot of assisted living facility. No low flow channel, grass mowed floor
11	Quail Brook Golf Course	625 New Brunswick Road/ Block 424.04/ Lot 63.02	Somerset County Park Commission	See Section VIII(A)(1)
12	Community Baptist Church	211 De Mott Lane/ Block 424.08/Lot 58.01	Community Baptist Church of Somerset	Receives stormwater from parking lot of Church Center via concrete swale and curb cuts. Low flow channel and mowed grass basin floor.
13	Franklin Township #4/147	Block 424.08/Lot 368	Franklin Township	Receives stormwater from approximately 35 houses on Rue Chagall and Picasso Court. Basin floor not regularly mowed
14	Paddock Estates	Block 423.01/Lot 17.10	Paddock Estates, LLC 1065 Route 22 West, Bridgewater, NJ	Two inlets with low flow channels. Mowed basin floor with some landscaping along berm. Discharges to stream along Wilson Ave.
15	Jain Center	111 Cedar Grove Lane/Block 468.07/Lot 45	Jain Center of NJ, 24A Chatham St., North Plainfield, NJ	Three concrete low flow channels.

VI. Pollutant Source Assessment

The Delaware & Raritan Canal transfers water from the Delaware River Basin to the Raritan River Basin, where the raw water is treated to become drinking water for approximately 600,000 customers living in and outside the Raritan Basin. Since 1997, several of the Canal's water purveyors reported increased concentrations of total suspended solids in the raw water during and immediately after precipitation events, requiring increased chemical use for treatment and increasing residual sludge generation.

A 1999 study by the United States Geological Survey (USGS) reported that the turbidity does not decrease in the Canal reach between Ten Mile Lock and the Route 18 spillway as would be expected due to low water velocities in this reach, indicating that settling solids are replaced by particulates from influent streams and stormwater discharges to the Canal. Field observations downstream of the Canal's confluence with Cedar Grove Brook confirm this, noting the formation of a sand bar indicating that Cedar Grove Brook contributes sediment-laden stormwater to the Canal.

The Cedar Grove Brook watershed is the fourth largest direct drainage to the Canal. NJWSA's D&R Canal Nonpoint Source Management Study focused on the last eleven miles of the D&R Canal; however, the Cedar Grove Brook watershed was excluded from that study due to its size, and was made the focus of this report.

The initial phase of this project included water quality sampling to assess the TSS and turbidity levels in Cedar Grove Brook, and to estimate watershed runoff rates and volumes and associated sediment loads. The results of this initial phase were published in the "Cedar Grove Brook Water Quality Characterization and Assessment" (Appendix B, TRC Omni, 2006).

The results of the initial sampling phase did not confirm that TSS and particularly turbidity loads from Cedar Grove Brook were substantially impacting the water quality of the D&R Canal at the water supply intakes downstream of Cedar Grove Brook. The sampling results were not sufficient to exclude the possibility that Cedar Grove Brook delivers a substantial turbidity load affecting water quality in the Canal; nevertheless, the lack of direct sampling confirmation left open the possibility that efforts to minimize TSS and turbidity loads in the Cedar Grove Brook watershed may not address the water quality problems observed at the water supply intakes in the Canal. Additional monitoring for the Cedar Grove Brook watershed was therefore designed to complement the restoration efforts that are currently underway in the Canal and to better understand the impact of Cedar Grove Brook on the turbidity in the Canal.

A. Quantification of Potential Sediment Loads – WinSLAMM Modeling

As part of the D&R Canal NPS Project, NJWSA and Princeton Hydro/SWM Consulting used the WinSLAMM source area data and results to estimate the particulate solids and particulate phosphorus loads from each infall drainage area. WinSLAMM allows the user to divide each land use (residential, commercial, industrial, other urban/open space, institutional and freeway) into source areas (parking areas, roof, landscaped areas, driveways, undeveloped, etc.). Additional information such as the length of road within the land use and a general estimate of drainage system characteristics are also entered. The model calculates how much of the pollutant load originates from each land use and each source area within the drainage area. Estimates are given for each rainfall event in the model run.

Based on the WinSLAM results, NJWSA ranked the infalls within the last 11 miles of the Canal based on the sediment and phosphorus loads. The Cedar Grove Brook watershed ranked first among all of the infalls. The WinSLAMM results based on the D&R Canal model are shown in Table 10.

Table 10. WinSLAMM Results - Sediment Load (lbs) from the Cedar Grove Brook Watershed

Land Use	Sediment load (lbs)
Residential	26,360,000
Institutional	9,042,000
Commercial	3,011,000
Industrial	121,338
Other Urban	31,700,000
Freeway	0
Total	70,230,500

For the Cedar Grove Brook project, the watershed was then divided into three subwatersheds, based on the areas draining to the Golf Course Pond, the Ukrainian Village Pond and the Lower Pond. The subwatershed delineations are shown in Figure 12.

Table 11 and Figure 13 show the results of the WinSLAMM modeling for the sediment load from each land use for the three subwatersheds. The relative contribution from any source area is a function of: 1) the percent of the watershed comprised of the source area; and 2) the potency (pounds per acre) of the source area in terms of sediment load contribution.

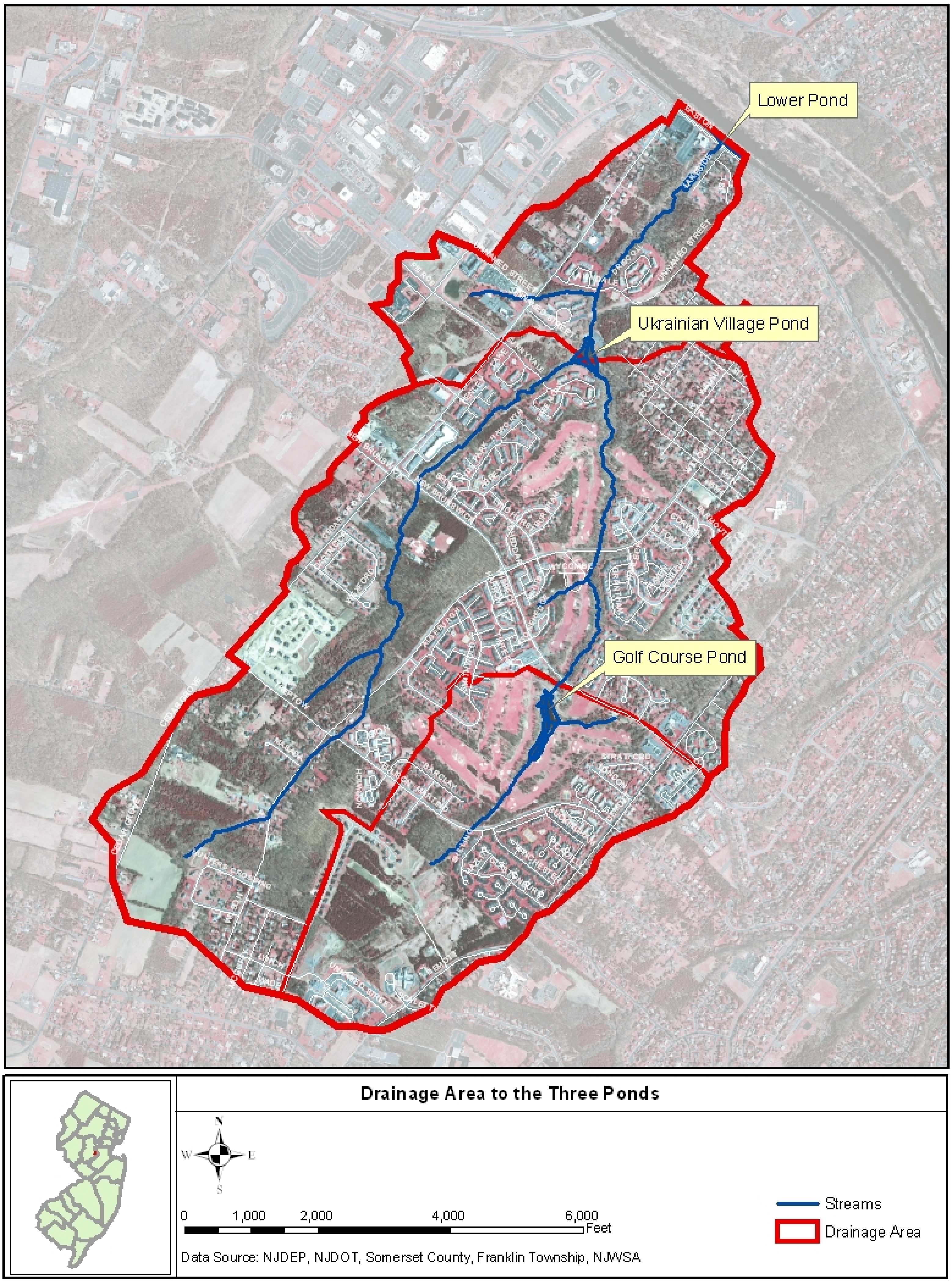


Figure 12. Subwatersheds

Table 11. Sediment Load (lbs) from the Three Subwatersheds

Land Use	Golf course Pond	Ukrainian Pond	Lower Pond	Total
Residential	3,730,000	14,410,000	2,188,000	20,328,000
Institutional	2,942,000	3,277,000	261,757	6,480,757
Commercial	1,062,000	678,539	1,562,000	3,302,539
Industrial	0	169,043	0	169,043
Other Urban	1,748,000	18,460,000	4,822,000	25,030,000
Freeway	0	0	29,910	29,910
Total	12,480,000	37,000,000	8,864,000	58,344,000
Note: The total sediment loads for the entire watershed (Table 10) and the 3 subwatersheds (Table 11) are slightly different due to slight modifications in the WinSLAMM model between the D&R Canal and Cedar Grove Brook projects.				

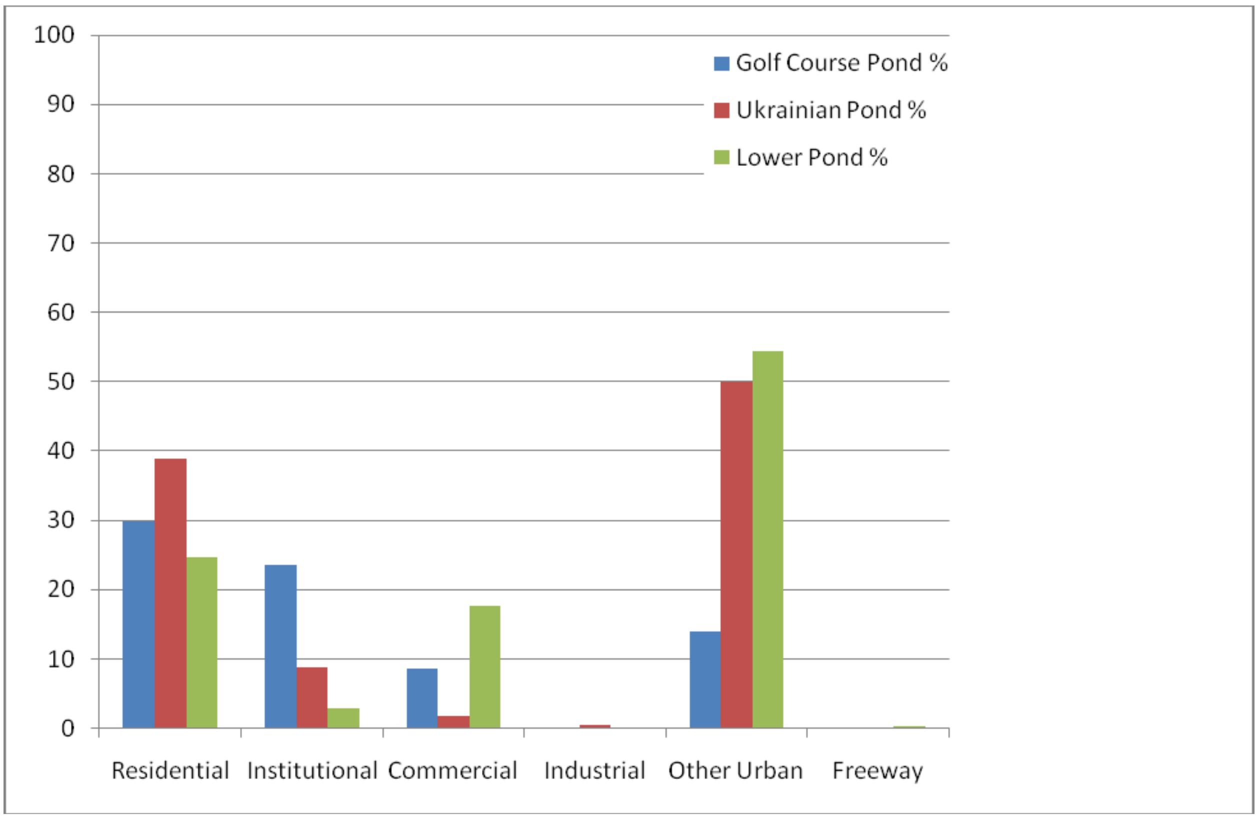


Figure 13. Percentage of Total Particulate Load by Land Use for Three Subwatersheds

The WinSLAMM modeling indicated that the largest sediment loads are typically generated from residential properties (approximately 38%) and the "other urban" land use. The "other urban" land use is the term that WinSLAMM uses for forests, brush/shrub land, wetlands and agriculture. Although vegetation such as lawn and forest is generally considered to be more protective of water resources than impervious areas such as driveways and roofs, these areas do generate sediments and other pollutants.

In order to better characterize the sediment load from the residential areas, the source areas for that land use were analyzed. WinSLAMM estimates the pollutant load coming from each source area within a land use; for residential land those source areas include roofs, driveways, paved parking areas, unpaved parking areas, streets and small landscaped areas. The results for the three subwatersheds are provided in Figure 14. The WinSLAMM modeling indicated that the majority of the residential sediment load is generated by small landscaped areas, typically lawns and gardens, with some forested areas.

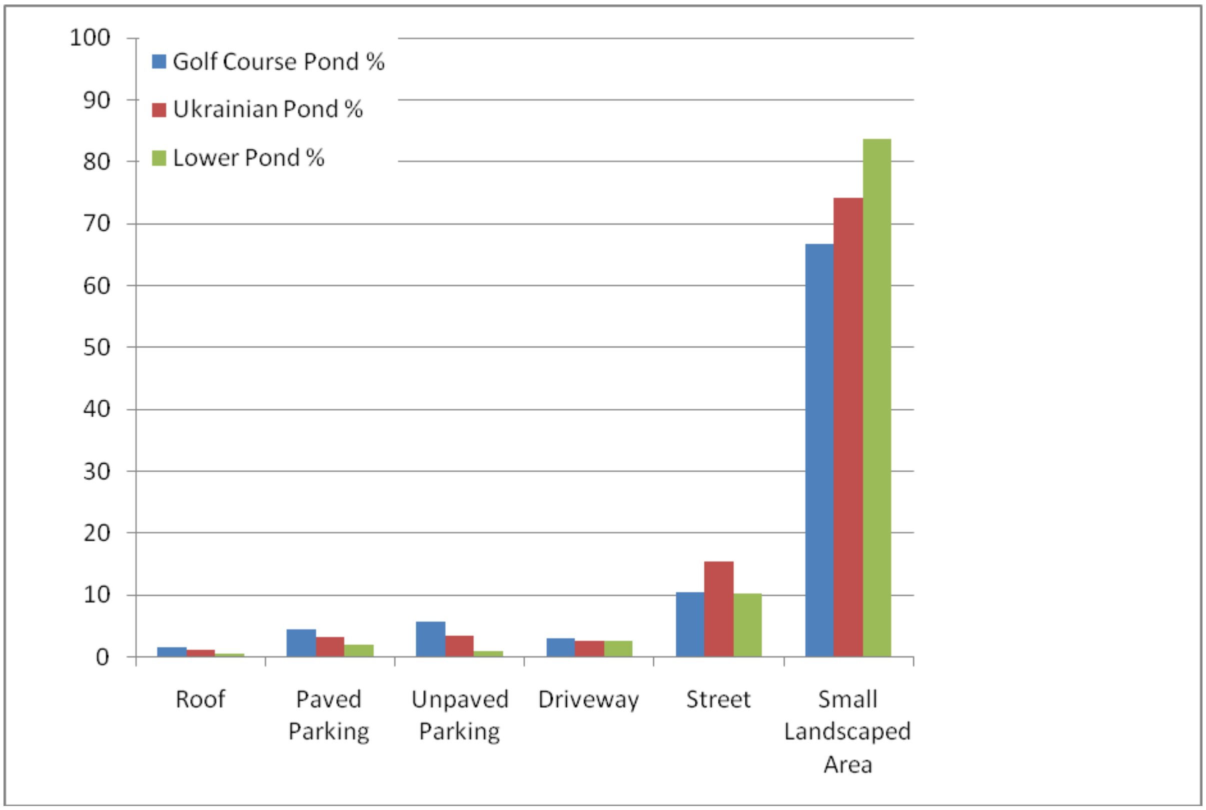


Figure 14. Percentage of Total Particulate Load by Residential Source Area for Three Subwatersheds

B. Historical Water Quality Data Summary (1998-2004)

In the late 1990's, water quality purveyors reported that after storm events, additional chemical treatment was necessary to remove suspended solids from the raw Canal water. This resulted in additional chemical costs and additional costs for removing additional sludge and/or residuals. USGS conducted a water quality study during 1998 and 1998 to determine if changes in water quality along the length of the Canal were related to storm events. USGS found that between Ten Mile Lock and the Route 18 spillway, the mean and median of measured turbidity changed very little during the study period.

The average water velocity in the Canal is very low, and particles that cause turbidity are typically not transported significant distances. Turbidity is therefore expected to decrease through a particular reach as suspended solids settle out. USGS suggested that the expected decrease in turbidity within most reaches was not being observed because the expected decrease was being offset by turbid water entering the Canal from influent streams and stormwater discharges.

USGS measured the velocity between Ten Mile Lock and the Route 18 Spillway at 0.22 ft/s, the lowest average velocity of the six reaches that were measured. The USGS study found a very small decrease in turbidity between Ten Mile Lock and the Route 18 Spillway. If there were no stormwater inputs of turbidity in this reach, a large decrease in turbidity would be expected as water travelled through the reach. Since that large decrease was not observed, USGS believed that turbidity was being added from influent streams and stormwater discharges. The Cedar Grove Brook (referred to as Al's Brook in the USGS study) drainage area was the largest in that reach, and was believed to be the source of "significant amount of stormwater runoff that carried turbidity" to the Canal (USGS, 1999). In addition, USGS observed a large sand bar just downstream of the confluence of Cedar Grove Brook with the Canal, indicating that Cedar Grove Brook has contributed stormwater-generated sediment to the Canal.

As part of the Delaware & Raritan Canal Tributary Assessment and Nonpoint Source Management Study, NJWSA reviewed water quality data from the USGS study, New Jersey American Water Company, Middlesex Water Company and NJWSA. The data reviewed covered various portions of the time period from March 1998 to October 2004, and indicated that all of the data were below the surface water quality standard of 40 mg/l. The USGS data indicated a decreasing trend in average turbidity upstream to downstream, and a similar trend for total suspended solids. The Middlesex Water Company data (4 sites) indicate that turbidity was approximately the same at all of their sampling sites. The NJWSA grab sample data indicated that average turbidity increased from Ten Mile Lock to Cedar Grove Brook and then decreased between Cedar Grove Brook and Landing Lane and Route 18. Turbidity samples taken at the Cedar Grove Brook confluence with the Canal were up to four times the levels of those taken at other locations, particularly during storm events.

C. Quantification of Potential Sediment Loads – TRC Omni Water Quality Sampling (2005)

The initial water quality data collected by TRC Omni (2005) suggested that the actual sediment loads from Cedar Grove Brook are much lower than the WinSLAMM model developed for the D&R Canal project predicted.

The three impoundments in the watershed (Golf Course Pond, Ukrainian Village Pond and Lower Pond) appear to act as sediment sinks and mitigate the potential impact of sediment generated in the Cedar Grove Brook watershed. In order to quantify the existing impact of the Golf Course Pond (Quail Brook Golf Course Pond) and Ukrainian Village Pond, a refined WinSLAMM (Version 9.3.0) simulation of the Cedar Grove Brook watershed was developed. The refined WinSLAMM simulation incorporated improved source terms from the stormwater sampling performed for the D&R Canal NPS Project in small subwatersheds that drain specific land use areas. Simulations were developed for the July 2005 and October 2005 storms (1.4 and 3.8 inches, respectively) that were sampled previously (TRC Omni, 2006). Predicted and observed loads were compared in order to understand the accuracy and limitations of both the model and the observed estimates. The refined WinSLAMM model was used then to assess the benefits of potential BMPs in terms of reduced sediment loads.

WinSLAMM simulations predict total volumes and pollutant loads to a single outlet over a storm based on individual watershed characteristics, most importantly soil type and land use. A low particle size distribution was assumed for all subwatersheds; since heavier particles settle faster, assuming a low particle size provides a conservative simulation of sediment removal rates. Predicted and observed comparisons were performed for both total runoff volumes and sediment removal rates at each of the three ponds during both 2005 storms. The predicted runoff volumes and removal rates were based on the output of the WinSLAMM simulations; the observed runoff volumes and removal rates represent best estimates based on continuous depth and discrete water quality measurements.

Estimates of the observed runoff volumes during the 2005 storms were calculated based on continuous measurements of depth over the weirs at the Golf Course Pond (CG2) and the Ukrainian Village Pond (CG5) using pressure transducers. Meaningful flow calculations could not be performed at the watershed outlet (Lower Pond, CG6) because the depth of water in the Canal was over the height of the weir, producing backwater effects. There are no significant tributaries between the Ukrainian Village Pond and the watershed outlet; the volume at CG5 (Ukrainian Village Pond) was multiplied by 1.15 to account for the increased drainage area. A comparison between the runoff volume predicted by WinSLAMM for each storm and the estimated runoff volume based on field data is provided in Figure 15. The trends and magnitudes compare reasonably well, although the field estimation of volume was significantly lower than the model predictions during the July storm. Differences can be explained by model uncertainty (runoff models often overestimate volume), field estimation uncertainty, and differences between simulated and actual local rainfall.

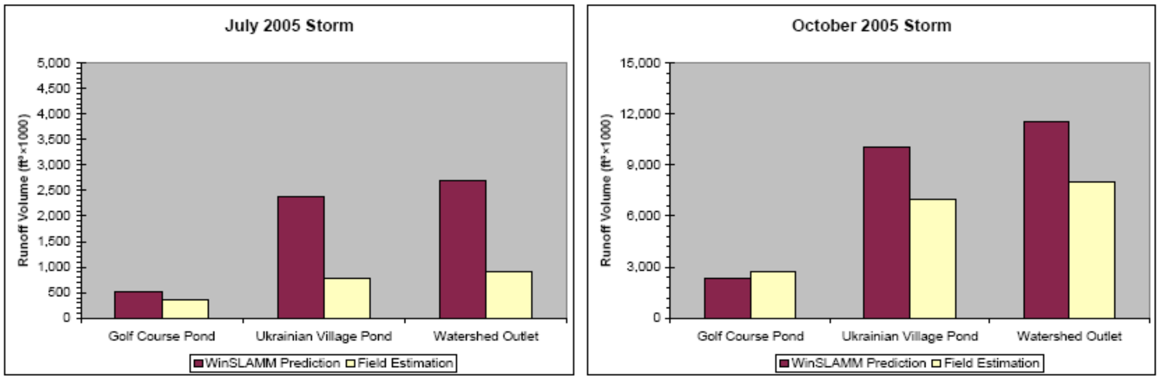
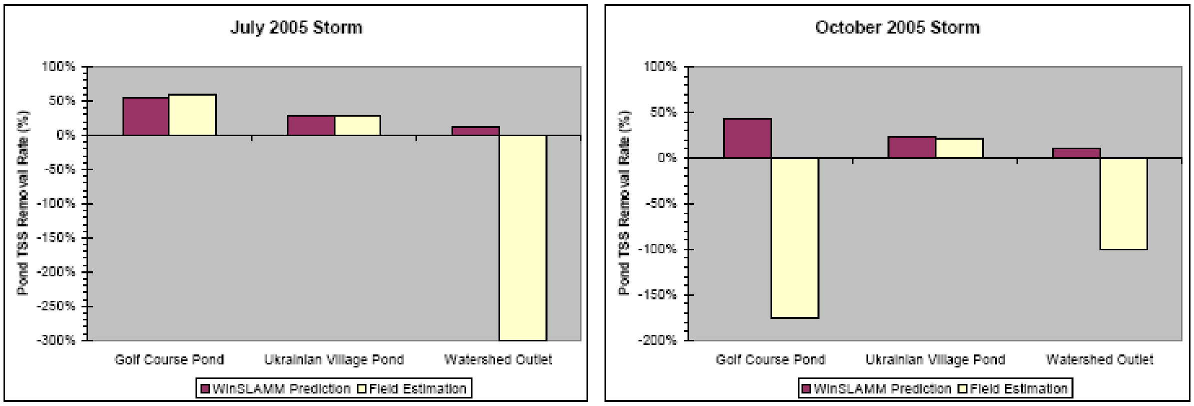


Figure 15. Runoff Volume Comparison

Estimates of the observed sediment removal rates during the 2005 storms were based on discrete water quality measurements at the inlet and outlet of each pond. The measured Total Suspended Sediment (TSS) concentrations at the inlet(s) and outlet were flow-weighted based on the estimated flow at the time of sampling in order to calculate Event Mean Concentrations (EMCs) for each storm. Since the total flow in and out of each pond is the same[7] over the course of each storm, the difference between the EMC at the outlet and the EMC at the inlet represents the pond removal rate. A comparison between the TSS removal rates predicted by WinSLAMM for each storm and the estimated removal rates based on field data is provided in Figure 16.

The removal rates compare extremely well, except that the Golf Course Pond and Lower Pond act as sources rather than sinks under certain conditions, apparently due to resuspension of bottom sediments. This is to be expected during the very large October 2005 storm event (3.8 inches); it indicates that sediment accumulates in the pond during the course of smaller, more typical events, but that large events can resuspend that sediment and cause an increase in TSS concentration. For instance, the EMC entering the Golf Course Pond at CG1 during the October 2005 storm was 4.7 mg/l of TSS; the EMC leaving the Golf Course Pond at CG2 during the same storm was 12.9 mg/l of TSS. The fact that the Lower Pond also increased TSS concentration during the much smaller July 2005 storm reflects the accumulated sediment behind the weir, leaving less than one foot of water beneath the crest of the existing weir.

[7] Hydrology for ponds is influenced by detention time that affects the amount of water evaporating as it passes through the pond, as well as the amount of rain that falls directly onto the pond. Loss of flow through evaporation, or increases from direct precipitation, may affect the outflow concentration.



*Negative "removal" rates indicate that the pond is adding TSS (due to resuspension) during a storm rather than removing it.

Figure 16. Pond TSS Removal Rate Comparison

These comparisons demonstrate the utility as well as the limitations of the WinSLAMM modeling tools for the Cedar Grove Brook watershed. Relative to all the other Canal contributions in the region, the Cedar Grove Brook represents a significant potential source of sediment and other pollutants. The three existing pond structures together are providing significant sediment removal, but also can act as sediment sources due to the resuspension of accumulated sediment under certain storm conditions.

D. Impact of Cedar Grove Brook on the D&R Canal

The D&R Canal NPS Implementation Project is focused on TSS loads, the underlying presumption being that TSS is related to turbidity and total organic carbon (TOC), both of which have been identified as water quality issues of concern for water supply uses in the Canal. Specifically, pulses of high turbidity and total organic carbon at the water supply intakes have been noted during storm events. Additional monitoring was performed in 2008 in order to understand the impact of Cedar Grove Brook on turbidity in the Canal and to understand the relationships among turbidity, TSS, and TOC under high and low flow conditions.

Continuous recording devices were equipped with turbidity sensors and installed in the following five locations (Figure 17):

- D&R Canal near Ten Mile Lock;
- Cedar Grove Brook at Easton Avenue near confluence with Canal;
- D&R Canal just upstream of Cedar Grove Brook confluence;
- D&R Canal just downstream of Cedar Grove Brook confluence; and
- D&R Canal near Route 18 spillway.

Turbidity was monitored continuously during a variety of flow conditions for a three week period from October 28 to November 18, 2008. Continuous monitoring data from Cedar Grove Brook and from the Canal upstream and downstream of Cedar Grove Brook were used to assess the impact of Cedar Grove Brook on turbidity in the Canal during a variety of flow conditions.

Furthermore, data from the most upstream and downstream locations in the Canal (Ten Mile Lock and Route 18 Spillway at Landing Lane, respectively) were used to confirm the observations made previously by USGS (USGS, 2001) that identified Cedar Grove Brook as a likely source of turbidity to the Canal. These data at the upstream and downstream boundaries of the segment of interest in the Canal also provide a context in which to evaluate the impact of Cedar Grove Brook on the Canal.

In addition to the continuous turbidity monitoring, water quality samples were collected from Cedar Grove Brook at Easton Avenue (upstream of weir near Canal confluence) and the D&R Canal at Five Mile Lock, which is near the Route 287 (Exit 10) bridge upstream of Cedar Grove Brook. Samples were collected under both low and high flow conditions, and analyzed for turbidity, TSS, and TOC. The grab sampling data were used to explore the relationships among TSS, turbidity, and TOC in Cedar Grove Brook and the Canal under various conditions. Eight grab sampling events were performed: four low-flow events, three high-flow events, and one medium flow event (two days after a rain event). Each event consisted of a single sample collected at both locations. The grab sampling in the Canal and in Cedar Grove Brook were used to assess the degree to which turbidity and TOC are related to TSS in this system. Figure 18 shows the flow and precipitation conditions prevalent during the monitoring period.

Flow was characterized using a nearby USGS stream gage (#01403150, West Branch Middle Brook near Martinsville). A small local stream was selected rather than the Canal gage at Port Mercer because the Canal gage is farther away and flow in the Canal is not as responsive to precipitation as a small stream, which would better characterize the response of Canal inlets and tributaries. Precipitation is shown in 15-minute increments based on data from the USGS rain gage in Somerville (#403410074364001). This station is approximately five miles from the sampling locations. The cumulative rainfall amounts for each storm event that occurred during the 2008 continuous monitoring period were as follows: 1.8 inches on 10/28, 0.31 inches on 11/5-11/6, and 1.27 inches on 11/13-11/15.

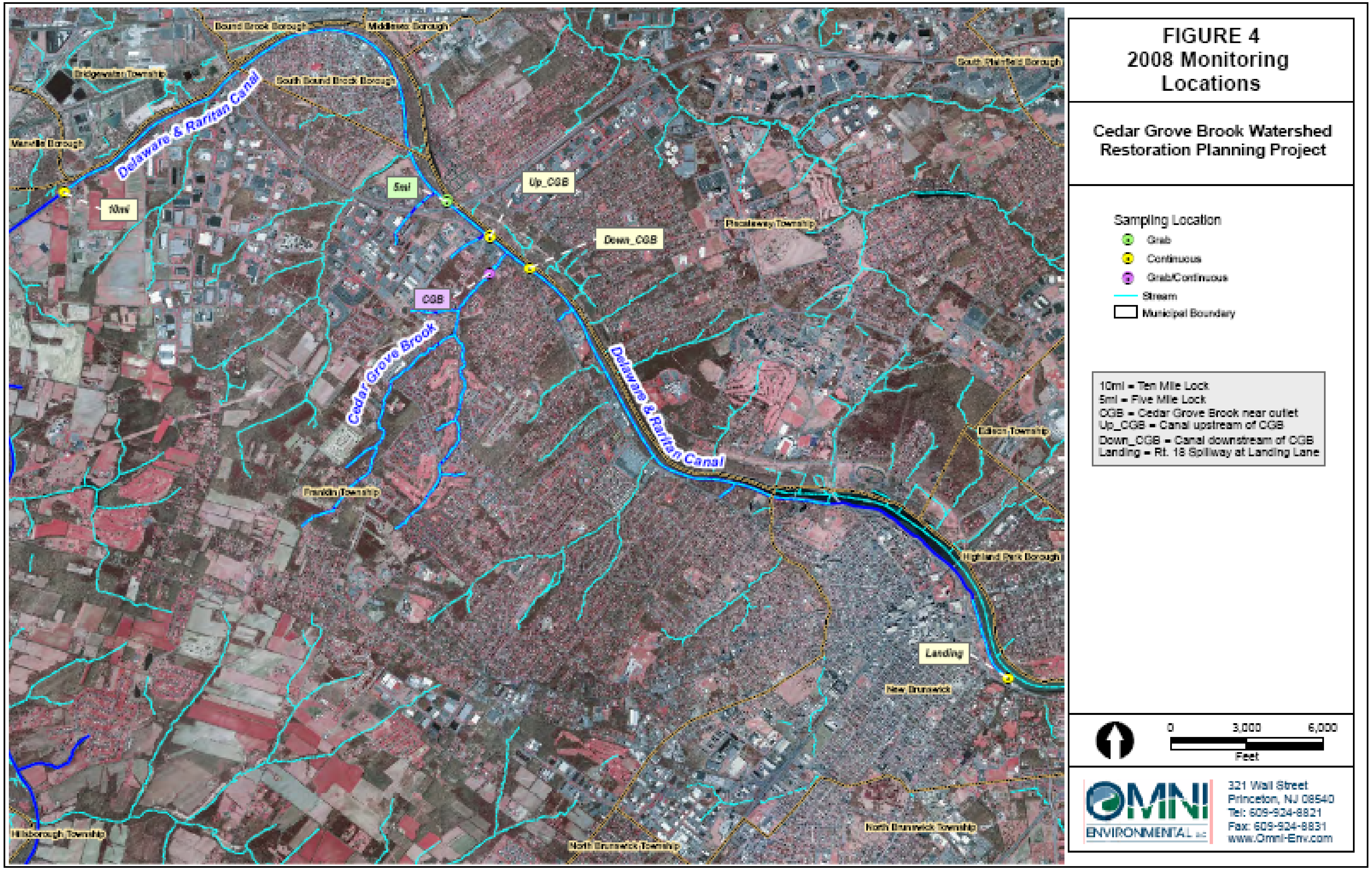


Figure 17. 2008 Monitoring Locations

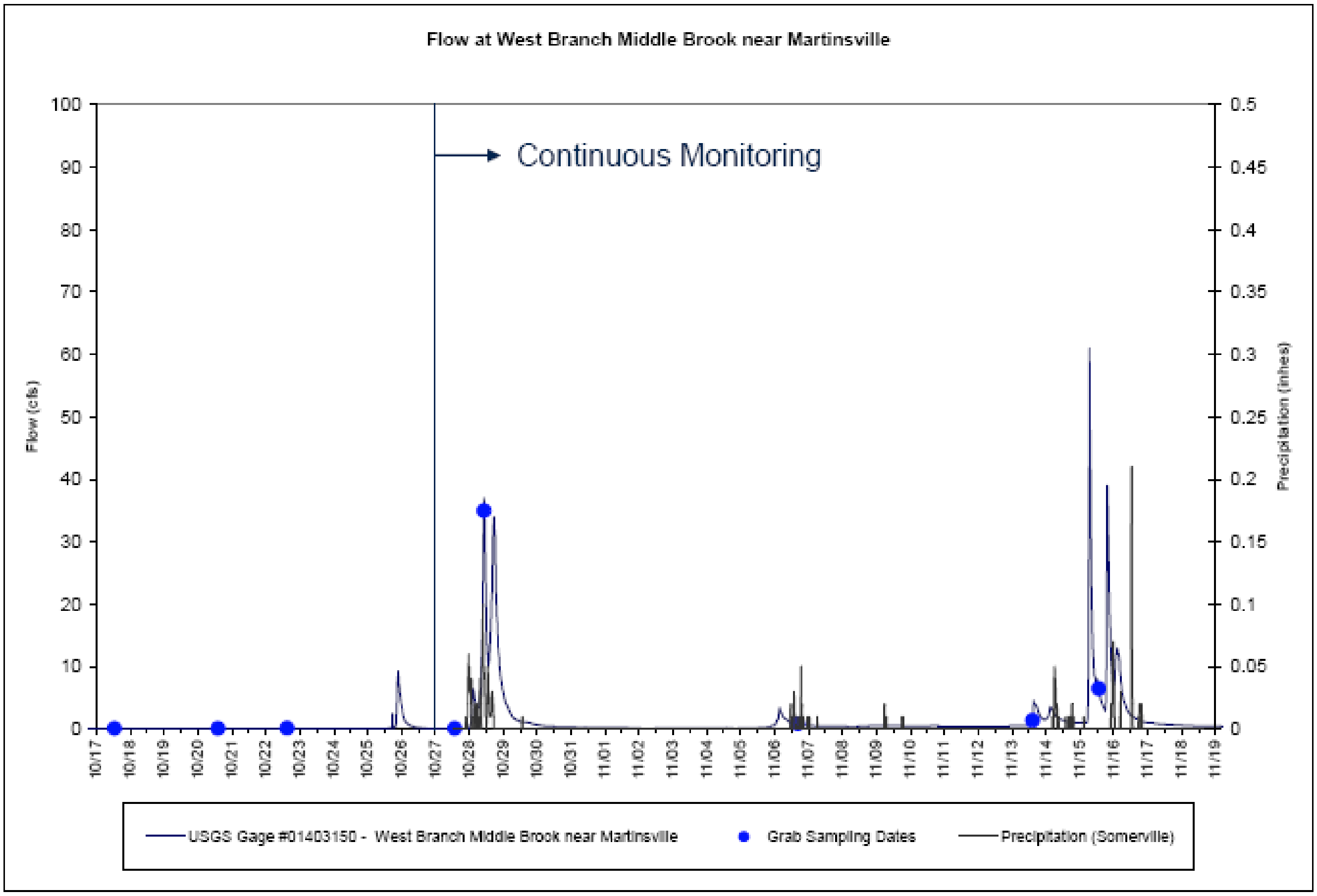


Figure 18. Flow and Precipitation Conditions During Monitoring Period

E. Turbidity Monitoring Results

Evaluating turbidity monitoring data from the four D&R Canal locations (10mi, Up_CGB, Down_CGB, and Landing) yielded some interesting results. Figure 19 zooms in on a low-flow period from November 3 to 8 and shows that at least some of the turbidity variation observed at the locations upstream and downstream of Cedar Grove Brook, as well as Landing Lane, can be explained simply by downstream propagation of the turbidity signature at the upstream study boundary at Ten Mile Lock. In fact, the turbidity peak at Ten Mile Lock was observed approximately 1.5 days later at the meters upstream and downstream of Cedar Grove Brook, and then again approximately 1 day after that at the downstream study boundary at Landing Lane (near Route 18 spillway). The total travel time of 2.5 days compares favorably with the expected travel time of 2 days 8 hours between Ten Mile Lock and the Route 18 Spillway as reported in the USGS study (USGS, 2001).

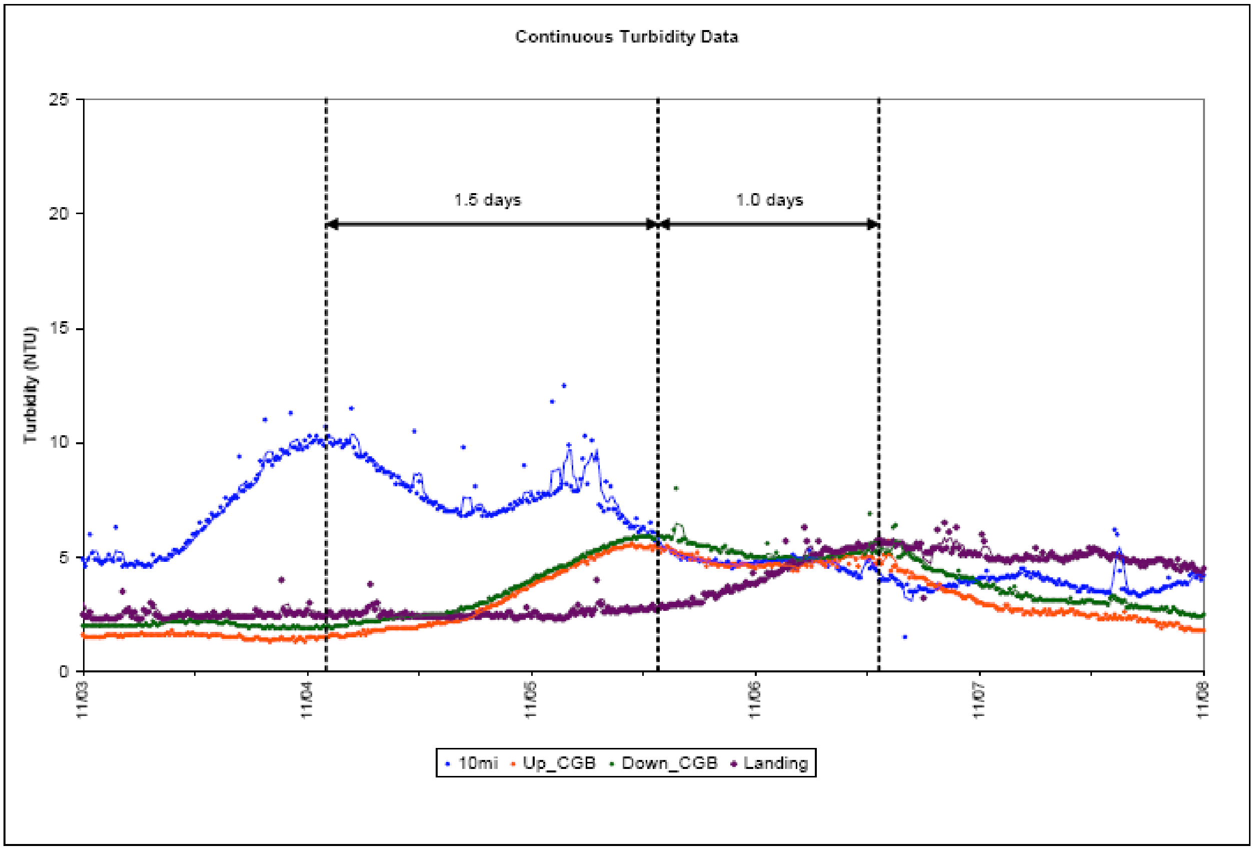


Figure 19. Travel Time of Turbidity in the D&R Canal

The continuous turbidity monitoring yielded one unexpected result: during low-flow periods, the D&R Canal at Ten Mile Lock exhibits clear diurnal turbidity variation (Figure 20) that appears to be natural in origin. The magnitude of the variation – about 1 Nephanolometric Turbidity Unit (NTU) – is not significant from a water quality perspective; however, it is consistent and definitely diurnal in nature, with peaks occurring at night (2:00–3:00AM) and troughs occurring in the mid-afternoon. Furthermore, as shown in Figure 20, the diurnal turbidity pattern exhibited at Ten Mile Lock is propagated downstream as well.

Traditionally, studies relating to diurnal variation in surface waters have focused on dissolved oxygen and pH; however, researchers are increasingly interested in diurnal variation of other surface water constituents, as evidenced by a recent symposium[8] sponsored by New Jersey Water Resources Research Institute entitled: "Diurnal (Diel) Cycling of Cedar Grove Brook Watershed Chemical Constituents in Surface Water and Related Media – Scientific and Regulatory Considerations." Researchers noted significant diurnal variations in arsenic and other metals, nutrients, hardness, organic carbon, and solids concentrations in surface waters, in addition to constituents that are more often associated with diurnal variations (e.g., temperature, pH, and

8 NJWRRI symposium: "Diurnal (Diel) Cycling of Chemical Constituents in Surface Water and Related Media – Scientific and Regulatory Considerations." Held December 12, 2008 at NJDEP in Trenton. http://www.njwrri.rutgers.edu/diurnal_cycling.html.

dissolved oxygen). The results of the continuous turbidity monitoring suggest that turbidity varies diurnally under some circumstances as well. Possible causes of diurnal variation include changes in flow, benthic macroinvertebrates activity, and temperature-related physical factors such as viscosity and sorption rates. The meter at Ten Mile Lock was deployed downstream of the lock itself, closer to the footbridge, and well past the area of turbulence associated with the lock. The smooth and consistent pattern suggests a natural diurnal phenomenon.

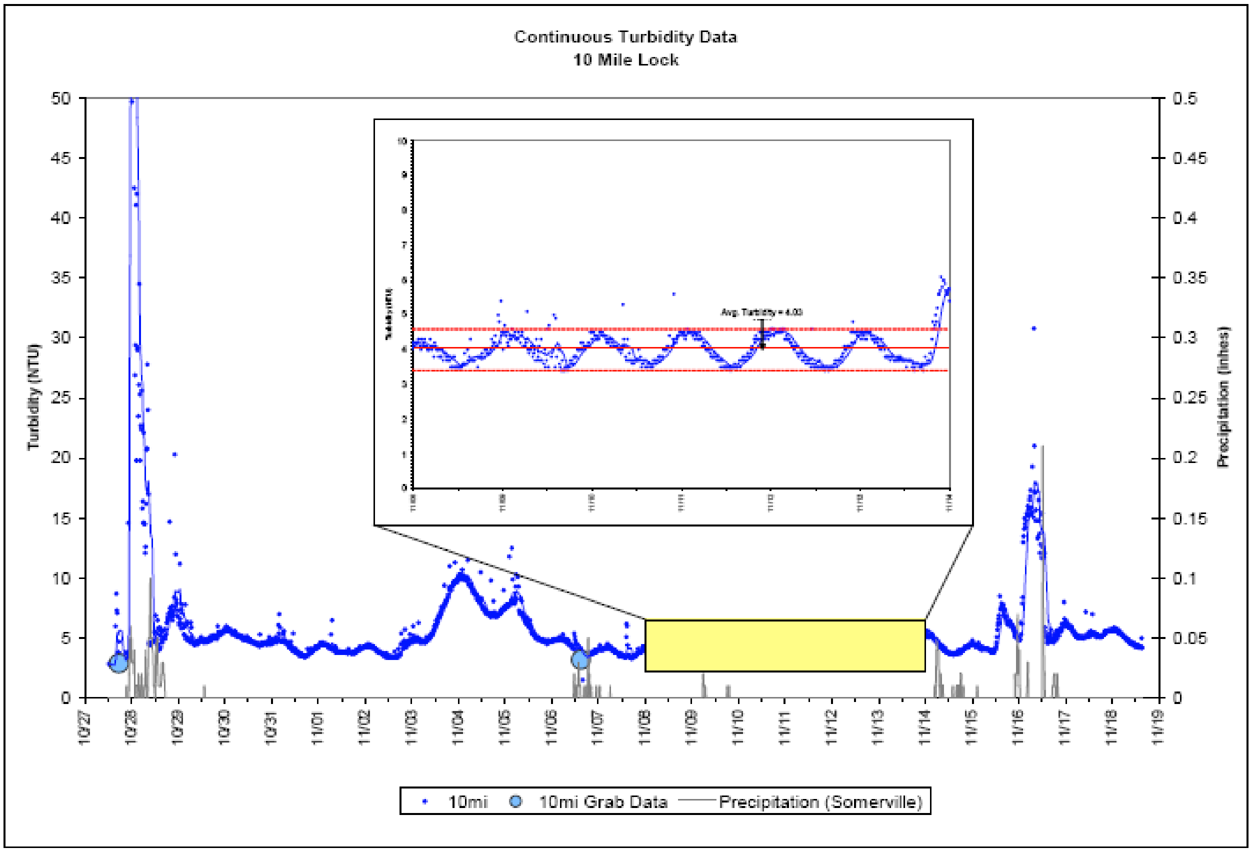


Figure 20. Diurnal Turbidity Variation Observed in the D&R Canal at Ten Mile Lock

The maximum, mean, and minimum turbidity values from the continuous turbidity data collected at the four D&R Canal locations are shown in Figure 21. The format and results are similar to that provided in the 2001 USGS study and can be compared directly. The USGS study was performed over a longer period of time (16 months), but did not include any turbidity measurements between Ten Mile Lock and the Route 18 Spillway. In terms of overall magnitude, the USGS average turbidity was approximately 9 NTU at Ten Mile Lock and the Route 18 Spillway locations, while the observed means during the 3-week survey in 2008 were 5.1 and 3.4 NTU at Ten Mile Lock and the Route 18 Spillway, respectively. The lower magnitude of the average can be attributed to the shorter time frame that included fewer major storms with high turbidity peaks. In fact, the highest maximum turbidity observed during the three-week survey in 2008 was 31 NTU at Ten Mile Lock, whereas the USGS long-term monitoring reported a maximum turbidity over 200 NTU at the same location. It is not surprising that the maximum recorded turbidity over a 16-month period would be substantially larger than that observed over a 3-month period.

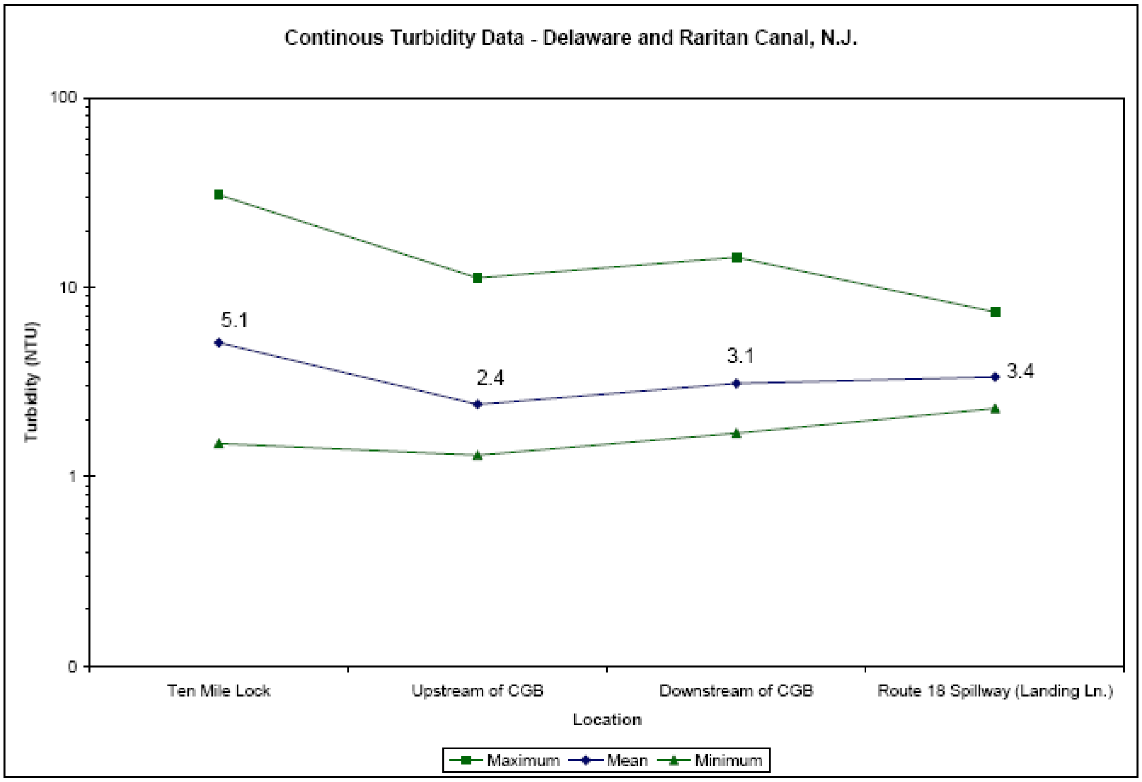


Figure 21. Turbidity Changes in the D&R Canal from Ten Mile Lock to the Route 18 Spillway

More importantly, the overall trends between Ten Mile Lock and the Route 18 Spillway were similar in both studies. The maximum recorded turbidity was significantly higher at Ten Mile Lock than at the Route 18 Spillway during both studies. Furthermore, the minimum recorded turbidity was very similar at both Ten Mile Lock and Route 18 Spillway locations during both studies. While the average turbidity during the 3-week survey in 2008 decreased by 1.7 NTU between the Ten Mile Lock and Route 18 Spillway locations (compared to only 0.1 NTU during the long term study by USGS), the observed average decrease was still much less than the 4 NTU that might be expected based on turbidity settling in other segments of the Canal (USGS, 2001). The turbidity trends at the Ten Mile Lock and Route 18 Spillway locations are similar between the two studies. It is evident from Figure 22 that Cedar Grove Brook does increase turbidity in the D&R Canal – maximum, average, and minimum turbidity all increase between the Canal monitoring locations upstream and downstream of the Cedar Grove Brook discharge point into the Canal; however, the magnitude of the increase in maximum, minimum, and average turbidity does not appear to be significant from a water quality perspective; for example, the maximum turbidity increased from 11 to 14 NTU due to the impact of Cedar Grove Brook. It is also worth noting that turbidity continues to increase between Cedar Grove Brook and the Route 18 Spillway, indicating that there may be another important discharge to the Canal in that segment.

In order to better assess the impact of Cedar Grove Brook on turbidity in the D&R Canal, it is helpful to zoom in on high and low flow periods. Figure 22 shows turbidity in the Canal upstream and downstream of Cedar Grove Brook, as well as in Cedar Grove Brook itself, during and after a storm event. Precipitation is also shown (in 15-minute intervals) along with grab turbidity sampling results that confirm the validity of the continuous turbidity results.

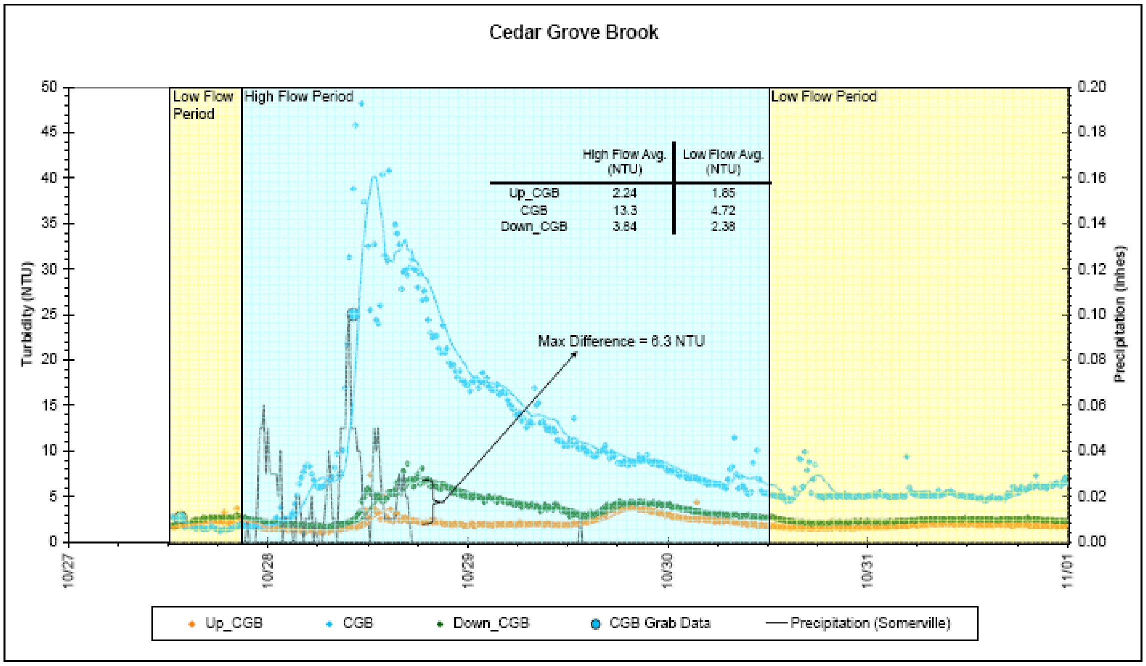


Figure 22. Turbidity Impact During High and Low Flow Periods

During the storm event, turbidity in Cedar Grove Brook peaked at over 40 NTU, whereas the turbidity in the Canal remained below 10 NTU. The maximum increase in turbidity in the Canal downstream of Cedar Grove Brook (e.g. difference between Up_CGB and down_CGB) was 6.3 NTU; furthermore, the impact of Cedar Grove Brook on the Canal was transient, with turbidity returning to pre-storm levels in about one day.

While the magnitude of the turbidity change due to Cedar Grove Brook was not that significant, it is worth noting that the turbidity peak in the Canal more than tripled during the storm due to the impact of Cedar Grove Brook. In addition, the long-term turbidity monitoring conducted by USGS recorded turbidity readings much higher than those observed during the 2008 monitoring period. Given the significant increase in the turbidity peak, the conclusion was made that Cedar Grove Brook increases the maximum turbidity peak in the Canal during large storm events.

Figure 22 also shows that the impact of Cedar Grove Brook on turbidity in the D&R Canal during low-flow periods is negligible. The difference in turbidity in the Canal immediately upstream and downstream of Cedar Grove Brook was less than 1 NTU during the low-flow period. It is clear from these data that the impact of Cedar Grove Brook on turbidity in the D&R Canal is limited to the turbidity peaks that occur during relatively infrequent, large storm events.

In summary, the continuous turbidity monitoring performed in 2008 yielded useful information regarding turbidity in the D&R Canal from Ten Mile Lock to the Route 18 Spillway and the impact of Cedar Grove Brook on this segment of the Canal. The first assessment based on the data is that turbidity in the D&R Canal from Ten Mile Lock to the Route 18 Spillway is generally fairly low in comparison to the turbidity criteria for freshwater in the Surface Water Quality Standards (N.J.A.C. 7:9B), namely a maximum 3- day average of 15 NTU and a maximum of 50 NTU at any time. Even during storm events, turbidity at the four Canal locations did not exceed these criteria during the 2008 monitoring period. The long-term monitoring performed in 1999-2000 (USGS, 2001) found a slightly higher average turbidity, likely driven by the substantially higher maximum peaks observed. It is unlikely that turbidity conditions have improved significantly between 2000 and 2008. It is more likely that the higher turbidity peaks occur during larger, less frequent storms, and perhaps also seasonally during summer phytoplankton growth periods in the Canal.

Cedar Grove Brook does appear to add some turbidity to the D&R Canal under typical and low-flow conditions, but the amount is not significant. This added turbidity is likely to reduce the amount of turbidity attenuation that occurs in this segment of the Canal. The average turbidity in the Canal at Ten Mile Lock is relatively low: approximately 5 NTU during the three-week survey in 2008 and approximately 9 NTU during the long-term monitoring performed in 1999-2000. The fact that, due to the impact of Cedar Grove Brook discharge, turbidity in the D&R Canal during typical and low-flow conditions does not decrease as much between Ten Mile Lock and the Route 18 Spillway may not be significant from a water quality perspective.

Although the typical and low-flow impact of Cedar Grove Brook on the turbidity in the Canal appears to be minimal, the continuous monitoring results do suggest that Cedar Grove Brook can significantly increase the turbidity peaks during larger storm events. This may be significant from a water treatment perspective, due to the proximity of Cedar Grove Brook to the water supply intakes. The fact that the 1.8 inch rainfall event that fell mostly on October 28, 2008 did not result in excessive turbidity in the Canal indicates that it is larger and less frequent storm events that must be driving the maximum turbidity events reported in the long-term study (USGS, 2001). To put this rainfall event in perspective, the idealized 2-year storm event for Somerset County is 3.3 inches over a 24-hour period. Furthermore, the idealized "water quality storm" is 1.25 inches of rain in a 2-hour period. While the October 28th storm totaled 1.8 inches of rain, no more than 0.5 inches fell in any 2-hour period.

F. Grab Sampling Results

As described previously, pairs of grab water quality samples from the D&R Canal (at Five Mile Lock) and Cedar Grove Brook (just upstream of the outlet to the Canal) were collected under a variety of flow conditions and analyzed for TOC, TSS, and turbidity. Results are provided in Table 12.

Table 12. Water Quality Sampling Data

Location	Flow Conditions	Date	Time	TOC (mg/l)	TSS(mg/l)	Turbidity (NTU)
D&R Canal at Five Mile Lock (5mi)	Low	10/17/2008	14:45	2.8	<2.5	2.1
		10/20/2008	15:00	3	<2.5	1.6
		10/22/2008	15:15	2.2	<2.5	2.8
		10/27/2008	14:30	6.5	<2.5	3.3
	Medium	11/6/2008	18:37	5.8	<2.5	4.2
	High	10/28/2008	12:00	2.9	3	3.1
		11/13/2008	14:30	5.6	3.5	5.8
		11/15/2008	13:40	4.9	3	3.1
Cedar Grove Brook (CGB)	Low	10/17/2008	12:50	3.9	9.5	2.2
		10/20/2008	14:00	3.1	<2.5	0.7
		10/22/2008	15:00	3	<2.5	0.9
		10/27/2008	12:00	8.7	<2.5	2.7
	Medium	11/6/2008	16:17	3.6	5	1.7
	High	10/28/2008	10”15	4.7	30	25
		11/13/2008	14:20	3.8	<2.5	2.8
		11/15/2008	13:20	5.2	5	9.7

The characterization of flow condition is qualitative. The sampling event on November 6th was intended to be a high-flow event, but the actual rainfall was less than expected and ended more than 24 hours before the sampling was performed. For this reason, the flow condition was characterized as “Medium” for that event. Eight pairs of water quality data were obtained under a variety of flow conditions that were available during the sampling period in 2008. In addition, TSS was analyzed along with confirmatory grab turbidity samples collected on November 6th at the four continuous turbidity monitoring locations in the Canal (Table 13).

Table 13. Additional TSS and Turbidity Samples at Canal Locations

Location	Date	Time	TSS (mg/l)	Turbidity (NTU)
D&R Canal at Ten Mile Lock (10mi)	11/6/2008	15:55	<2.5	3.2
D&R Canal upstream of Cedar Grove Brook (Up_CGB)		17:06	<2.5	5.9
D&R Canal downstream of Cedar Grove Brook (Down_CGB)		18:00	<2.5	5.1
D&R Canal near Route 18 Spillway (Landing)		18:15	91	11

Relationships among TOC, TSS, and turbidity were explored both in the Canal and in Cedar Grove Brook. The sample results did not include many high values, especially for TSS and turbidity; accordingly, statistical relationships were not developed. Instead, parameter values were plotted against each other and simple logarithmic regressions were fitted. Given the limited data range, the strength of the regression is not as important as the qualitative trend. For instance, Figure 23 shows turbidity versus TSS for D&R Canal locations and Cedar Grove Brook. In both cases the highest turbidity value occurred in the sample with the highest TSS concentration.

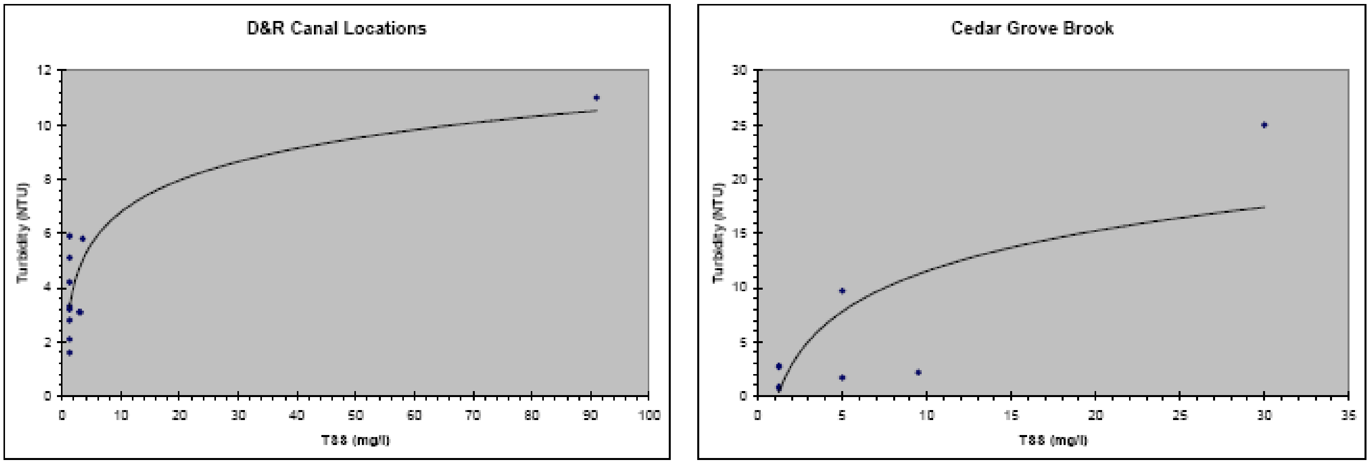


Figure 23. Turbidity vs. TSS in the D&R Canal and Cedar Grove Brook

On the other hand, TOC did not show any correlation with either turbidity or TSS, as shown in Figure 24; however, given the small number of high values, it is possible that a weak relationship exists that was not observed in this dataset.

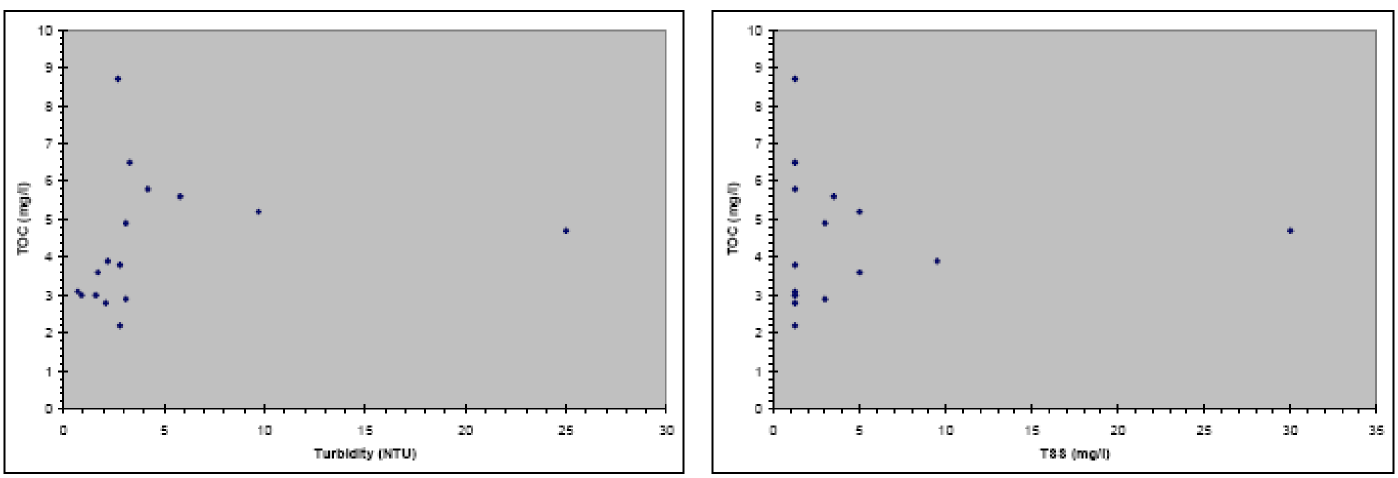


Figure 24. TOC vs. Turbidity and TOC vs. TSS

Because of the co-occurrence of high values of turbidity and TSS, it is likely that measures to reduce TSS loads to the Canal will also reduce turbidity, the parameter of concern for the D&R Canal Implementation Project. In this sense, TSS is a useful surrogate for elevated turbidity. The same cannot be said for TOC. Nothing in the data obtained for this study suggests that efforts to reduce TSS loads to the Canal will also reduce TOC.

VII. Regulatory Review

The State of New Jersey has adopted a number of rules which are designed to protect water resources. Franklin Township has also adopted a stream corridor ordinance which seeks to preserve the township's surface water resources. The existing regulations adequately protect the watershed from non-point source pollution which may result from future land development. Further, the watershed is almost entirely built-out. Accordingly, no further regulatory measures are recommended. Below are the key regulations which affect the watershed.

A. State Regulations

1. D&R Canal Commission Review Zone

http://www.dandrCanal.com/drcc/regulations.html

The entire Cedar Grove Brook Watershed is located in the D&R Canal Commission Review Zone. Areas within 1,000 feet of the Canal are within Zone A and the balance of the watershed is located within Zone B. The Cedar Grove Brook drains directly into the D&R Canal and is therefore afforded a no disturbance stream corridor protection zone which includes the 100-year flood plain plus 100 feet or a 300-foot buffer measured from the top of bank on either side of the stream, whichever is greater. The stream corridor starts from the point that the water course enters the Park at Easton Avenue, upstream to the point that the water course or its tributaries drain less than 50 acres. The Commission regulates all "major developments" in the watershed.

Major developments are reviewed for consistency with Commission regulations for stormwater runoff and water quality impact, stream corridor impact, visual, historic, and natural quality impact, as well as for traffic impact.

2. State Flood Hazard Area Rules

http://www.nj.gov/dep/landuse/se.html

The NJ Department of Environmental Protection adopted new Flood Hazard Area Control Act rules (N.J.A.C. 7:13) on November 5, 2007 in order to incorporate more stringent standards for development in flood hazard areas and riparian zones adjacent to surface waters throughout the State. The Department has adopted these new rules in order to better protect the public from the hazards of flooding, preserve the quality of surface waters, and protect the wildlife and vegetation that exist within and depend upon such areas for sustenance and habitat. Under the new rules Cedar Grove Brook is provided a 50-foot riparian zone.

3. State Freshwater Wetlands Protection Rules

http://www.nj.gov/dep/landuse/7-7a.pdf

Land disturbances in New Jersey wetlands are highly restrictive. In addition to the wetlands themselves, the regulations provide for a protective "transitional area" around identified wetlands. The wetlands in the Cedar Grove Brook watershed are generally of ordinary value which requires protection of an additional 50-foot transitional buffer adjacent to the wetland area. Field delineation may indicate other value wetlands.

4. Stormwater Management Rules

http://www.njstormwater.org/

Franklin Township is a Tier A community under NJDEP's stormwater management rules. The Tier A permit requires municipalities to develop, implement, and enforce a Stormwater Program. The stormwater program is described in the Franklin Township's written Stormwater Pollution Prevention Plan (SPPP). The Township is in compliance with the State's Stormwater Management Rules at the time of NJWSA's review.

B. Municipal Regulations

1. Franklin Township Stream Corridor Preservation Ordinance

http://www.ecode360.com/?custId=FR0703

All new lots in major and minor subdivisions and all building locations in site plans are required to provide sufficient areas outside of stream corridor preservation areas and within required setbacks to accommodate a structure for which it is being created as well as any normal accessory uses appurtenant thereto which would require disturbance. Stream corridors include four components: stream channels, floodplains, contiguous slopes of 12% or greater, and associated preservation areas.

2. Soil Removal and Deposit

http://www.ecode360.com/?custId=FR0703

In addition to the regulations of the Somerset/Union Soil Conservation District, Section 206 of the Franklin Township Codified Ordinance regulates the removal, import and disturbance of soil within the township. Permits are issued and the regulations are enforced by the Township Engineer. An exemption is provided for single family dwellings and structures accessory thereto, except on slopes of 10% or greater and within 50 feet of a stream, flood hazard area, or standing body of water or swamp.

VIII. Nonpoint Source Management Measures

Section VII discussed the WinSLAMM modeling and the water quality monitoring results. The WinSLAMM model indicated that the watershed has a significant proportion of residential land use, and that the largest sediment loads are generated from the residential land use and the "other urban" land use. The Quail Brook Golf Course is also a significant land use within the watershed. Vegetated areas within those land uses generate a significant portion of the sediment load. Although vegetated areas are generally considered to be protective of water resources, they do generate a pollutant load.

The USGS study (1999) suggested that the expected decrease in turbidity within most reaches was not occurring because the expected decrease was being offset by turbid water entering the Canal from influent streams and stormwater discharges. In the case of Cedar Grove Brook, the presence of a large sediment bar at the confluence of the stream with the Canal confirmed the stream's significance as a source of sediment to the Canal.

The TRC Omni water quality monitoring indicated that the three existing pond structures (Lower Pond, Ukrainian Village Pond and Golf Course Pond) provide sediment removal functions during normal flow and smaller storm events. These ponds appear to act as sediment sources during larger storm events, likely due to resuspension of sediment.

The TRC Omni water quality monitoring also indicated that while Cedar Grove Brook does not increase the magnitude of the turbidity in the Canal, it does impact the turbidity peaks that are observed.

Based on the land use data, WinSLAMM model, field reconnaissance and water quality monitoring results, the watershed was evaluated to identify potential nonpoint source management measures. Using those observations and the data described in the earlier sections of this report, several structural and non-structural nonpoint source management measures were identified for the Cedar Grove Brook watershed.

The recommended management measures focus on turbidity and total suspended sediment, as those two parameters were identified by the water purveyors as parameters of concern. The field observations, water quality monitoring and modeling indicated that storm events increase the turbidity peaks from Cedar Grove Brook and that the watershed is a source of sediment. The modeling that was conducted did not separate out land sources of sediment from in-stream sources (e.g. bank erosion). The recommendations contained in this restoration plan target land management, in order to reduce the amount of sediment washed from the land into streams, and also will reduce the volume of stormwater entering the streams, thereby reducing bank erosion.

The recommended management measures are described below; where appropriate, project detail sheets are provided in Appendix G.

A. Structural Measures

Seven structural management measures were identified for the watershed (Table 14).

Table 14. Summary of Structural Management Measures

Project	**Estimated Load Reduction**	**Estimated Cost**	**Cost/pound sediment removal**
Quail Brook Golf Course Pond Project 1- outlet modifications	40,000 lb/yr	$50,000	$1.25
Quail Brook Golf Course Pond Project 2- flowpath baffles	NA	$50,000	NA
Ukrainian Village Pond	59,941 lb/yr	$125,000	$2.08
Lower Pond	402,037 lb/yr	$500,000	$1.24
Riparian Restoration	Varies	Varies	Varies
Stormwater Basin Retrofits	Varies	Varies	Varies
Residential Stormwater Management (Rain Barrels, Rain Gardens)	Varies	Varies	Varies

Significant focus was given to improving the three primary pond structures (Golf Course Pond, Ukrainian Village Pond, and Lower Pond) to improve their water quality benefits. These ponds are providing significant sediment removal, and therefore preventing sediment from entering the D&R Canal. In some cases, such as in extreme storms, these ponds may also act as sediment sources due to the resuspension of accumulated sediments. Where appropriate, WinSLAMM was utilized to estimate sediment reductions from pond modifications.

Several additional structural management measures were also identified throughout the watershed. These measures are discussed below. In some cases, conceptual BMPs are provided; in other cases, where less information was readily available, those concepts must be developed in the future. Implementation will require detailed designs and plans. In addition, maintenance plans will be required for each management measure in order to ensure that it operates as intended. For instance, riparian buffers must be protected from mowing of adjacent areas and from animal damage. Replanting may be necessary. Stormwater basins may require maintenance such as mowing, sediment removal or cleaning of outlet structures.

1. Quail Brook Golf Course Pond

The most upstream of the pond features in Cedar Grove Brook is the Golf Course Pond (Figure 25).

Figure 25. Golf Course Pond

Two potential improvements to the Golf Course Pond were identified to increase the sediment removal rate and thereby reduce the sediment load to the downstream portion of Cedar Grove Brook:

1) modification to the outlet structure; and

2) flowpath routing baffles.

The existing outlet structure is a 3-foot long weir in the upstream side of an outlet box (Figure 26). The WinSLAMM simulation predicts an overall sediment removal rate of approximately 50%. Because the weir faces “upstream,” much of the pond volume appears to be short-circuited, which reduces the expected sediment removal rate.

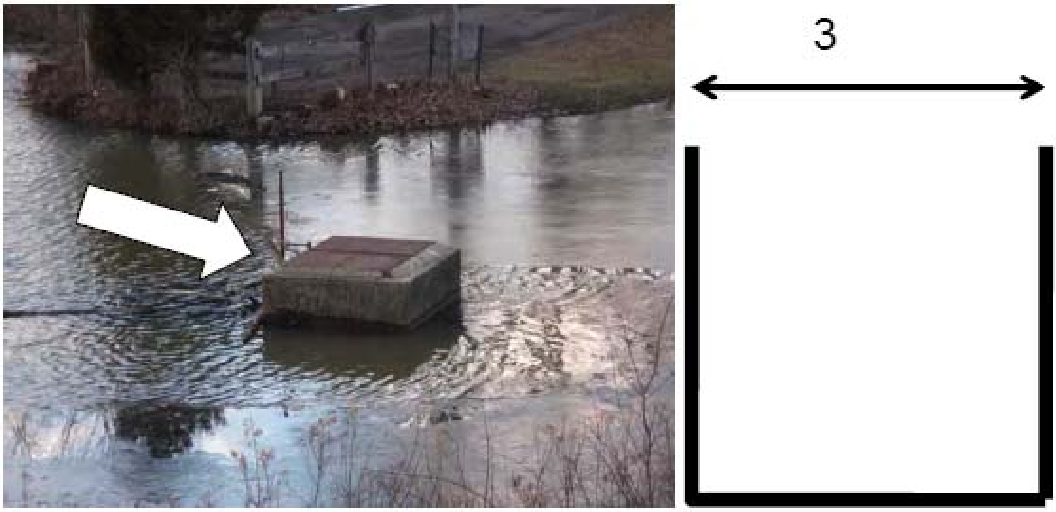


Figure 26. Golf Course Pond - Existing Outlet Structure

Two relatively simple changes to the outlet structure of the Golf Course Pond are proposed. The first is to face the outlet opening “downstream,” thereby increasing residence time in the pond, and allowing more time for settling to occur. In addition, adding a smaller outlet weir at the base of the existing 3-foot weir (Figure 27) will increase the residence time and increase the overall sediment removal rate of the pond feature. Various weir heights and widths were analyzed, and their associated long term sediment removal rates were estimated using WinSLAMM. The model indicated that sediment removal is more sensitive to weir width than weir height (Figure 28). Smaller weir widths would result in higher sediment removal rates. Adding a smaller weir between 3 and 6 inches wide and 6 to 12 inches high would substantially improve the sediment removal performance of the Golf Course Pond.

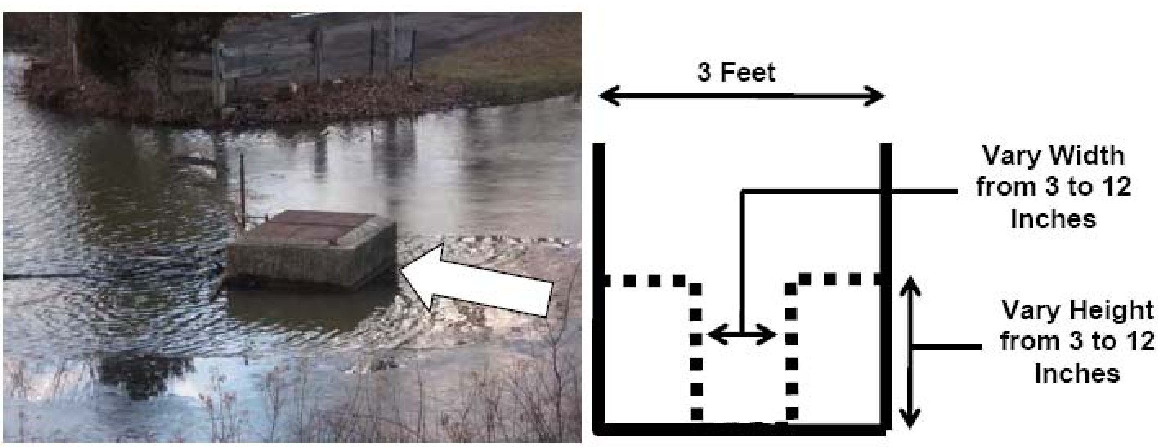


Figure 27. Golf Course Pond - Proposed Outlet Structure Modification

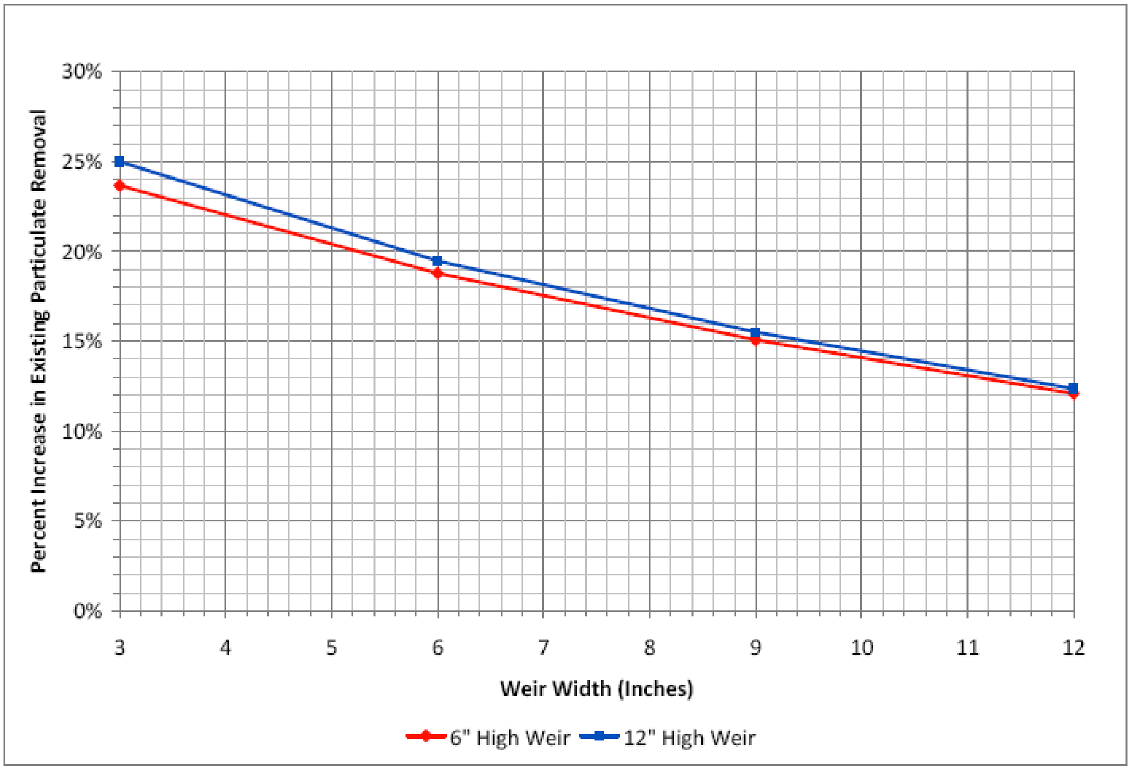


Figure 28. Golf Course Pond - Percent Change in Particulate Removal

The second proposed modification for the Golf Course Pond is to add flowpath baffles. The Golf Course Pond is somewhat linear, and the outlet is a straight flowpath from the inlet. As a result, the bulk of the pond volume is often short-circuited. The WinSLAMM modeling does not account for this phenomenon, and its importance is difficult to quantify. Adding flowpath baffles would force flow under most circumstances into more of the pond volume. This would increase residence time and therefore increase settling of sediment. Flowpath baffles, as proposed, are essentially concrete walls that extend downstream from the weir inlet in order to force water to circulate through more of the pond volume.

When improvements are made to the Golf Course Pond, sediment removal should also be performed. Stormwater basins require periodic maintenance, including sediment removal to maintain their hydrologic and water quality benefits. The stormwater monitoring results indicated that during large storm events, the TSS concentrations leaving the pond are higher than those entering the pond. This suggests that during larger storm events, accumulated sediment in the Golf Course Pond is being re-suspended and the pond is then acting as a sediment source rather than a sink.

2. **Ukrainian Village Pond**

The Ukrainian Village Pond (Figure 29) is downstream of the Golf Course Pond close to the center of the Cedar Grove Brook watershed. The Ukrainian Village Pond is an impoundment with two tributary inlets that discharges to Cedar Grove Brook. A relatively simple modification to the outlet structure is proposed to increase the sediment removal rate and thereby reduce the sediment load to the downstream portion of Cedar Grove Brook.

The existing outlet structure for the Ukrainian Village Pond is a 1-foot square weir within a larger 11-foot weir (Figure 30). According to the WinSLAMM simulations performed for the Ukrainian Village Pond, the existing overall sediment removal rate is approximately 33%.

Figure 29. Ukranian Village Pond

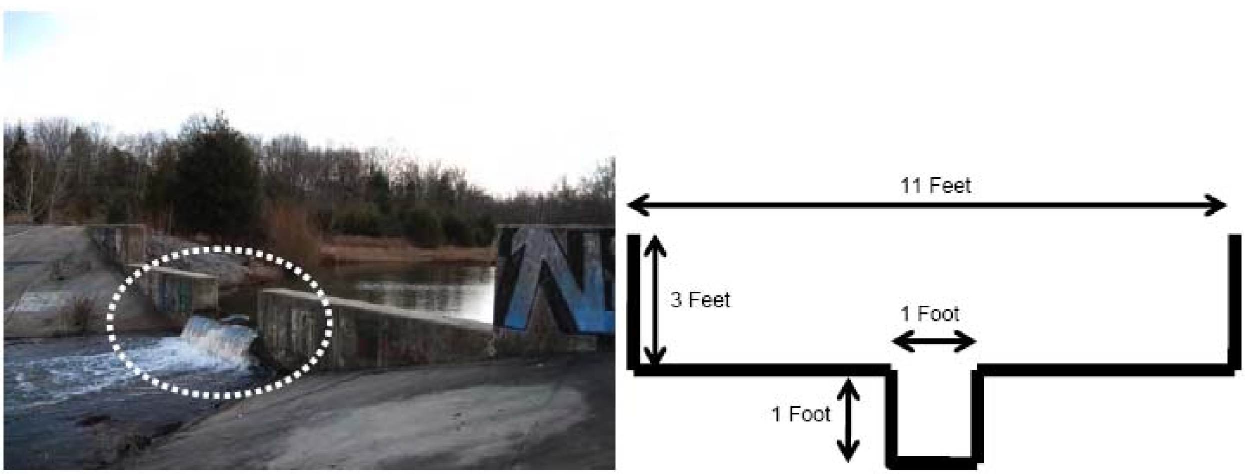


Figure 30. Ukranian Village Pond - Proposed Outlet Structure Modification

The existing 1-foot weir provides a negligible benefit in terms of sediment removal efficiency. Increasing the height of the existing weir, as shown in Figure 31, from 1 foot to 3 to 4 feet would improve the sediment removal by approximately 15% .

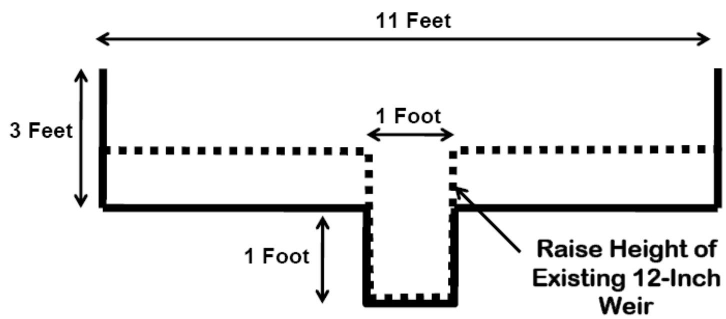


Figure 31. Ukrainian Village Pond - Proposed Modification to Outlet Structure

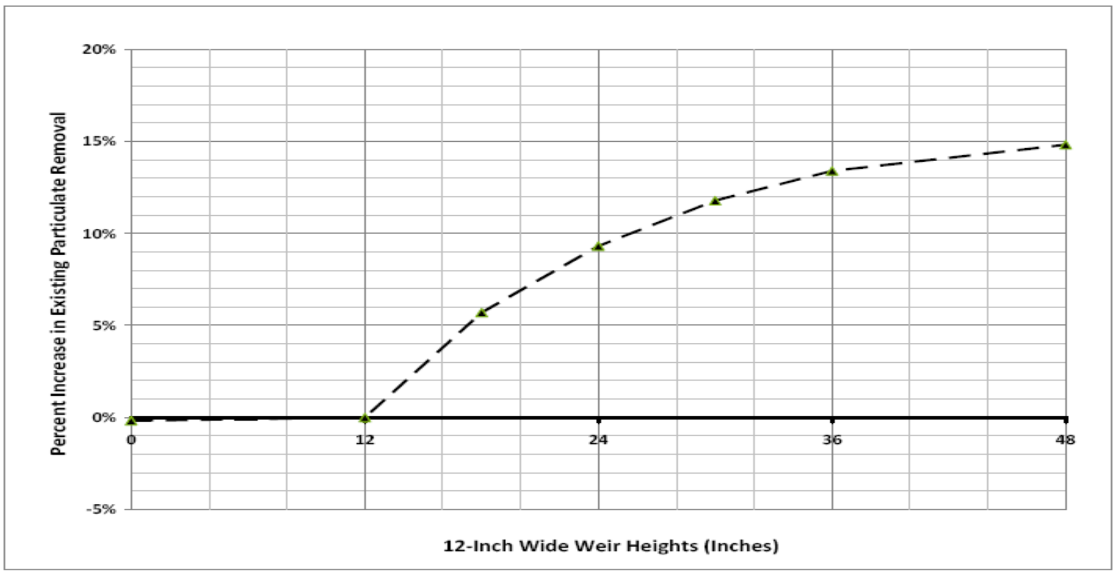


Figure 32. Ukrainian Village Pond - Percent Change in Particulate Removal

The 2005 stormwater monitoring did not show the Ukrainian Village Pond acting as a sediment source during either of the storm events that were monitored. It is possible that accumulated sediment in the pond is re-suspended and discharged to the watershed. When improvements are made to the pond, sediment removal should also be performed. This is a standard BMP maintenance action that must be performed on all stormwater ponds to maintain their hydrologic and water quality benefits.

3. Lower Pond

The outlet of Cedar Grove Brook (called "Lower Pond" for the purposes of this study) is impounded slightly by a dam structure just upstream of the Easton Avenue bridge with a weir that is generally submerged at the crest (Figure 33). Despite the dam structure, the outlet of Cedar Grove would not likely be identified by the casual observer as a pond under current conditions; one can see the bottom less than one foot below the weir crest. Nevertheless, the designation "Lower Pond" was adopted to reflect what this feature would become after the recommended restoration is complete. The reason is that the conceptual improvement identified for the outlet of Cedar Grove Brook to reduce the sediment load to the D&R Canal is a significant modification to the outlet structure. This modification would increase the height of the weir crest, resulting in a permanent pool of water 5 to 7 feet deep, thereby making it a more easily recognized pond feature.

Figure 33. Lower Pond - Cedar Grove Brook Outlet

A diagram of the existing outlet structure is shown in Figure 34. The current structure is not very useful from the standpoint of sediment removal. The WinSLAMM simulations indicate that the existing structure might be expected to remove approximately 3% of the sediment that reaches the outlet of Cedar Grove Brook. The WinSLAMM simulation does not account for the fact that the weir crest is generally submerged by Canal water, nor does it account for the resuspension of accumulated sediment. It is very likely that the outlet of Cedar Grove Brook provides a net source of sediments to the D&R Canal. The outlet structure could be improved substantially by increasing the elevation of the crest and decreasing the width of the smallest weir.

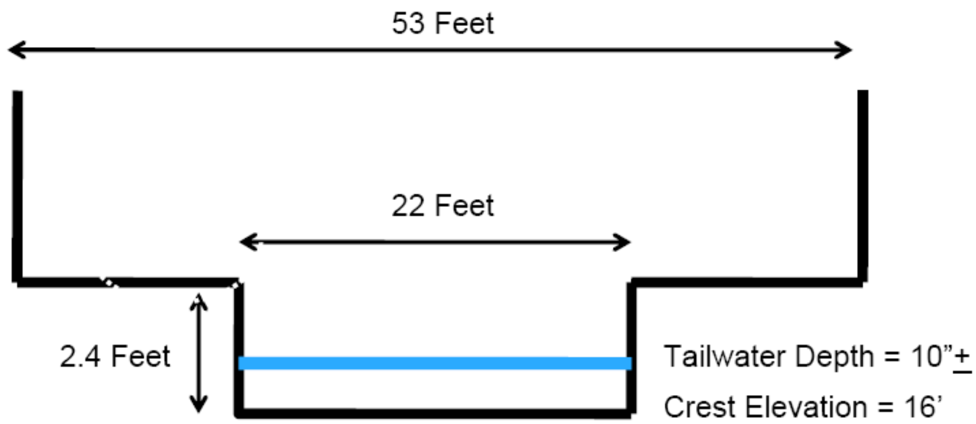


Figure 34. Lower Pond - Existing Outlet Structure

In terms of increasing the crest elevation, the flood plain at the Cedar Grove Brook watershed outlet is long and deep (Figure 35), providing plenty of room to significantly increase the crest elevation above the existing level. A new five foot wide weir (Figure 36) is proposed at a significantly higher crest elevation.

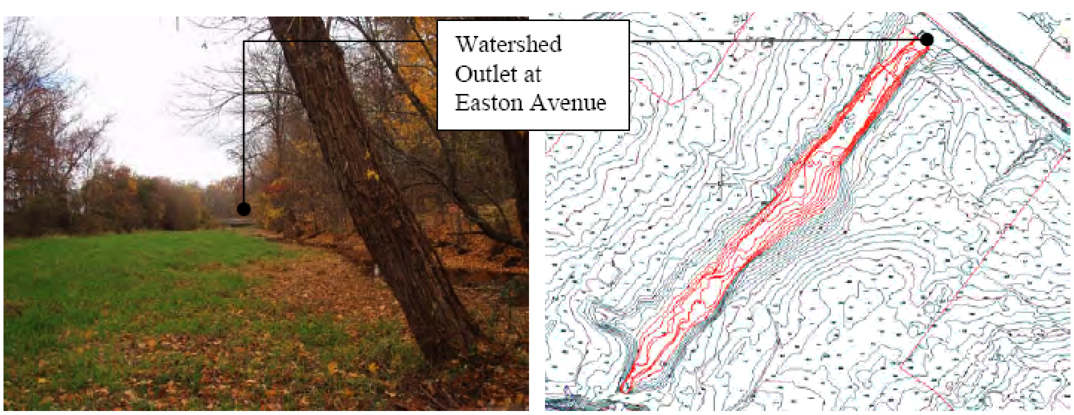


Figure 35. Lower Pond Floodplain

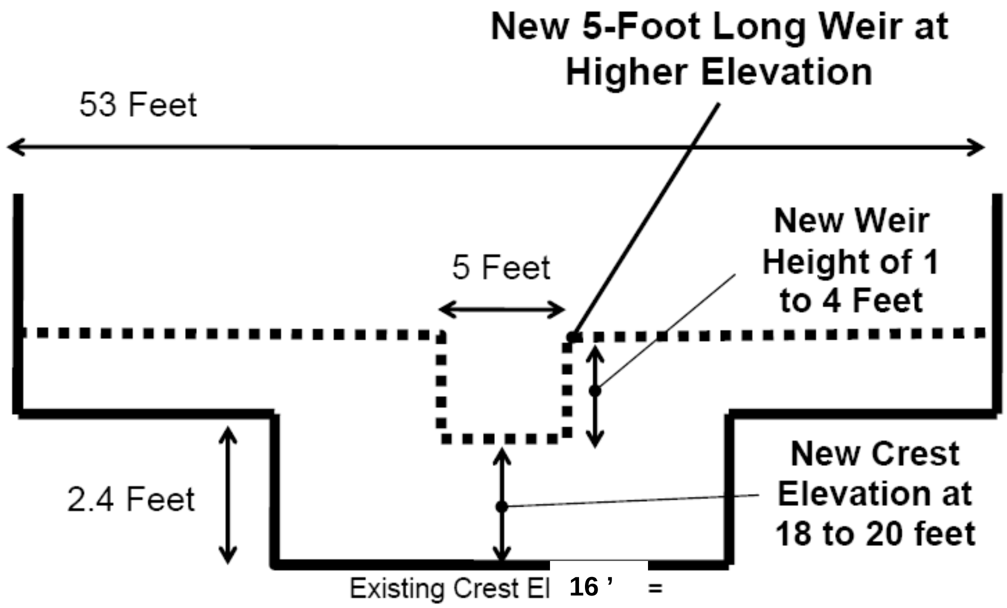


Figure 36. Lower Pond - Proposed Modification to Outlet Structure

The WinSLAMM model indicated that sediment removal is relatively insensitive to weir height at this location (figure 37). A 5-foot weir at a higher crest elevation will significantly improve the sediment removal rate of the outlet structure. Increasing the crest elevation will provide the most benefit of the elevation options explored, increasing the overall sediment removal rate to approximately 30%. This does not account for the fact that the weir crest would no longer be submerged by Canal water, or the additional benefit of reduced sediment resuspension.

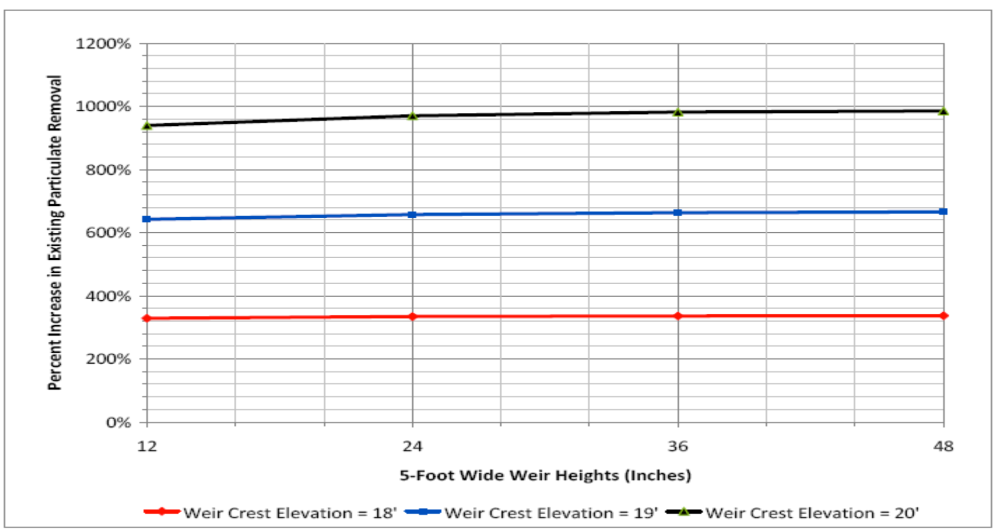


Figure 37. Lower Pond - Percent Change in Particulate Removal

4. Riparian Restoration

As detailed in Table 15 and Figure 38, eight sites were identified for riparian buffer restoration. The recommendations were developed based on the road crossing inventory and the stream visual assessments. Riparian buffer restoration may include forest and herbaceous plantings. Sediment removal rates and cost estimates were not detailed for each site, as those factors will be dependent on the width of the buffer and the plant species that are selected.

TSS removal rates for riparian buffers are reported to be 60 to 80%, depending on the width and type of vegetation. Removal rates for nutrients are typically lower than those for TSS. Riparian buffers also benefit streams from an ecological perspective, providing shade to moderate water temperature, and providing habitat and food for fish and other aquatic organisms.

A detailed planting plan must be developed for each site prior to implementation. In addition, permitting may be required for some projects.

Potential Riparian Buffer Restoration Sites

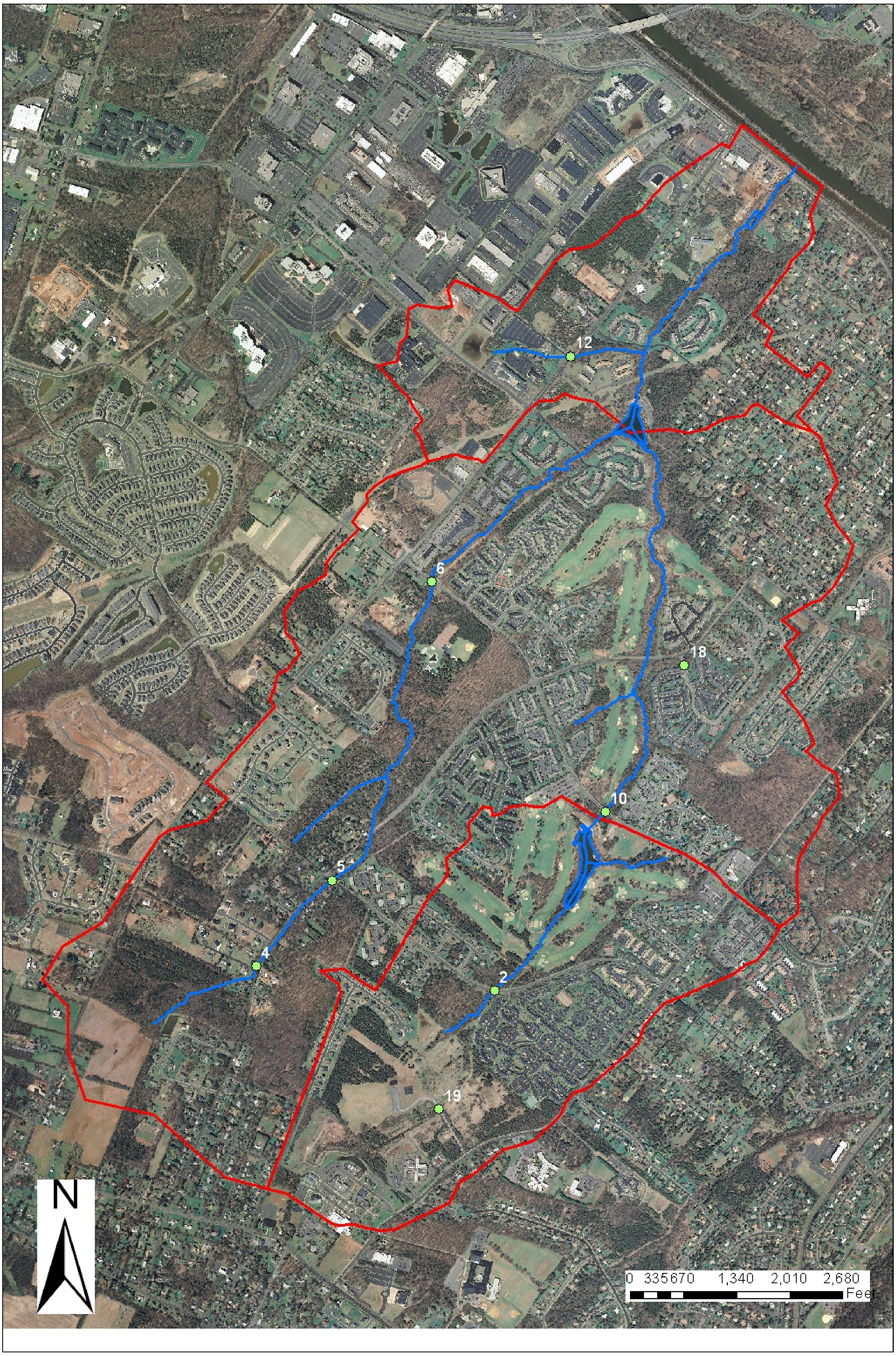


Figure 38. Potential Riparian Restoration Sites

Table 15. Cedar Grove Brook – Potential Riparian Restoration Sites

Road Crossing ID	SVAP #	Nearest Road	Notes
Cedar Grove Brook 2	NA	Martino Way	Upstream side of road crossing needs vegetation improvement near residential properties.
Cedar Grove Brook 4	CGB-7	Wilson Road	Municipal right of way present. Upstream of Wilson Road is good opportunity for buffer improvement, homeowner education.
Cedar Grove Brook 5	CGB-9	Martino Way	Canopy needs improvement to protect stream.
Cedar Grove Brook 6	CGB-6	New Brunswick Road	Upstream of road crossing needs vegetation improvement.
Cedar Grove Brook 10	NA	New Brunswick Road	Downstream of road crossing needs buffer improvement (golf course), no woody vegetation present.
Cedar Grove Brook 12	CGB-1	Cedar Grove Lane	Upstream of road crossing is good opportunity for buffer improvement – Rutgers Church on Cedar Grove Lane.
Cedar Grove Brook 18	NA	Denbigh	Area needs vegetation improvement, sections with exposed soil and no understory.
Cedar Grove Brook 19	NA	Middlebush Park Road	Good opportunity, on public property. No canopy, lawn to edge of stream. Utility line easement along right bank.

5. **Stormwater Retrofits**

Table 9 provides a listing of 15 stormwater basins in the watershed. That list includes the three ponds for which conceptual designs are included in this restoration plan. At this time, a detailed review of the design and function of the other 12 basins has not been performed; however, it is reasonable to anticipate that retrofits of at least some of those basins could improve their sediment removal capacity.

Many stormwater basins were designed with concrete low flow channels to force water to move quickly through the basin during smaller storm events. These channels can act as an obstacle to water quality treatment in those basins. Concrete low flow channels should, in most instances, be removed and replaced with vegetation or other stabilizing material. Most basins were also constructed with turf grass, which does not promote infiltration. By replacing turf grass with native grasses or other low maintenance vegetation, maintenance costs can be reduced (by reducing mowing needs) and infiltration can be increased.

Potential improvements include improved maintenance, removal of concrete low-flow channels and improvement of vegetation. It may also be appropriate to convert some of these basins to bioretention facilities or perform other modifications. Some of these retrofits can be accomplished at a relatively low cost, and may, in some cases reduce the required maintenance for the basin. Effective retrofits will reduce stormwater volume, increase sediment removal and can be used as a model and educational tool for township residents.

As with the riparian restoration projects, specific removal rates and costs for retrofit were not developed for these projects. Additional information, including detailed review of the existing design and the contributing drainage area for each basin must be developed in order to provide those estimates.

Figure 39. Key Stormwater Basins

6. **Residential Stormwater Management (Rain Barrels, Rain Gardens)**

Since the primary land use in the Cedar Grove Brook watershed is residential, a large impact can be made through the implementation of low-cost BMPs on private property. The installation of rain barrels and rain gardens on residential properties can help reduce the volume of runoff, promote infiltration of runoff and reduce the pollutant load entering the stormwater system. A Residential Stormwater Management Program will involve several components:

- Education and outreach for residents in targeted neighborhoods.
- Incentives to make a change in residential stormwater management.
- Technical support for installation of residential stormwater management practices.

Rain Barrels
A rain barrel can be constructed from a 55-gallon barrel, and is placed under a gutter's downspout next to a house, small sheds or other outdoor structures to collect rain water from the roof. The water can then be used in various ways including to water a garden. A rain barrel provides two important environmental functions:

- harvesting rain water provides an alternative to utilizing the drinking water supply for gardening and other uses, and
- the overflow from a rain barrel can be directed to a pervious area (an area where rain water can infiltrate into the ground) such as a lawn or garden and help replenish ground water supplies.

Rain barrels can be easily built and installed, but do require some maintenance.

1. Education & Outreach: Most residents are not familiar with the concepts of disconnecting impervious surfaces from the stormwater system and therefore rain barrels are not widely used. An educational component and support system for residents must be developed in order to provide that knowledge. This campaign could be led by Somerset County, Franklin Township, a local non-profit or NJWSA.
2. Identify target area: Targeting one sub-watershed or neighborhood within the Cedar Grove Brook watershed at a time may be a more feasible task than targeting the entire watershed at once.
3. Conduct rain barrel building workshop: Workshops can be held to assist people in building their own rain barrels for installation on their homes. The advantage of this type of system is that people are also provided with information regarding nonpoint source pollution and how they are contributing to improvement of the watershed. The disadvantage of this type of system is that it is very time intensive, from alerting residents about the workshop to obtaining barrels and conducting the workshop.
4. Develop rebate program: An alternative is to develop a rebate program, in which residents are reimbursed after they purchase and install a rain barrel. This rebate program could be coordinated with and administered through the municipality. If the rebate method is chosen, advertising and an educational presentation and program coordination meeting would still be needed to emphasize the importance of disconnecting impervious surfaces and reducing runoff.

Table 16. Cost Estimates for Rain Barrel Workshop

Item	Cost/Unit	Cost/Training
Rain Barrel	$50-$100	$1250 - $2500
Transportation of Barrels	varies	Varies
Parts (fixtures, caulk, screening)	$15-$20/barrel	$375 - $500
Tools (drill, pliers, wrench, saw)	$150-$200(purchase 1 set) $50-$75 (rental of power tools and purchase of manual tools)	$50 - $200
Direct Mailings	$.44/letter or $.29/postcard	$10-$20
Location	n/a	In-kind
Staff Time (prep time, set up, workshop, clean up)	n/a	40 hours
Total		$1700-$3500

The table estimates some of the costs associated with administering a rain barrel rebate program. The estimates assume the goal of providing rebates for approximately 300 barrels.

Table 17. Cost Estimates for Rain Barrel Rebate Program

Item	Cost
Administration of program	$500-$1000
Rebates for barrels (50% @ $100/barrel)	$15,000
Total	$16,000

Rain Gardens

Rain gardens are another example of a small scale BMP that can be implemented at the individual parcel level and have a large cumulative impact. A rain garden is a landscaped, shallow depression that allows for rain and runoff to be collected and then either infiltrated into the soil or evapotranspirated to the atmosphere. During rainstorms, much of the water quickly washes into the streets from yards, sidewalks, driveways, and parking lots. This water carries many pollutants including pesticides, fertilizers, animal waste, and chemicals. Excessive runoff can lead to flooding and can erode stream banks, adding sediment to waterways. Rain gardens reduce the quantity of water that reaches our waterways and improve the quality of water by filtering polluted runoff.

Rain gardens are designed to collect runoff from roofs, lawn, driveways, or sidewalks, or any combination of those. The size and depth of the garden will be determined by the volume of runoff that will reach the garden and the soil texture of the site. Rain garden plants should be native hardy perennial species that can survive in both wet and dry conditions. Some rain garden maintenance will be required, including weeding, pruning, and removing sediment that accumulates.

Rain gardens can treat and recharge a majority of the runoff from smaller, more frequent storms. This will reduce stormwater runoff volume, resulting in a reduction in streambank erosion and therefore a reduction in TSS loads.

This task targets residential properties, but rain gardens can also be installed on commercial or other parcels as well.

1. Education & outreach: As with rain barrels, most residents are not aware of the concept of rain gardens. An educational component must be developed to provide that information. Rutgers Cooperative Extension, Water Resources Program has many materials that can be used for this task. Advertising a demonstration rain garden at a public location is a great way to generate interest in rain gardens. The next step would be to teach interested parties in how to properly design a rain garden.
2. Identify target area: Targeting one sub-watershed or neighborhood within the Cedar Grove Brook watershed at a time may be a more feasible task than targeting the entire watershed at once.
3. Provide technical and (if possible) financial assistance for residents who are interested in installing a rain garden.
4. Follow-up.

Several factors can affect the cost of installing a rain garden including the size of the rain garden (based on how much stormwater it will be treating), how much the soil must be amended (to improve infiltration and provide nutrients to the plants), availability of volunteer labor, and the size of plants used to establish the rain garden. A safe estimate ranges from $2/square foot to $10/square foot. The cost of a demonstration rain garden can greatly be reduced through the usage of volunteer labor and donated plants and soil amendment materials.

Increasing the implementation of rain gardens and rain barrels throughout the residential and commercial areas of the Cedar Grove Brook watershed will help to reach the goal of reducing the total amount of sediment reaching the D&R Canal. These methods will help reduce runoff by collecting stormwater closer to the source and infiltrating into the ground. This will likely have a positive impact on existing structural stormwater BMPs such as detention basins and wet ponds. Rain gardens also provide an excellent first step toward educating communities about the stormwater issues in their neighborhoods.

B. Non-Structural Measures

1. River-Friendly Programs – Golf Courses, Businesses, Schools and Residents

The New Jersey Water Supply Authority (NJWSA, www.njwsa.org) implements a suite of River-Friendly programs, including those for Golf Courses, Businesses, Schools and Residents. These programs are based on those developed by the Stony Brook-Millstone Watershed Association. Through these programs, NJWSA works with landowners to improve water quality by implementing actions in four categories: Water Quality Management & Nonpoint Source Pollution Management, Water Conservation, Native Habitat & Wildlife Enhancement, and Education & Outreach. These programs are currently being implemented in the Cedar Grove Brook watershed.

The voluntary River-Friendly Golf Course, Business and School programs are a cooperative effort between the participants and NJWSA. They provide an opportunity for landowners to become local stewards, to showcase positive environmental actions they have already taken and to work with NJWSA to implement new practices. Participating landowners receive ongoing technical information, support and guidance for implementing environmental actions tailored to their unique location, resources and needs.

NJWSA is currently working with approximately 15 golf courses and businesses in the North & South Branch Raritan and Lower Raritan watershed management areas. Example accomplishments at one business facility include establishing a buffer along the Peter's Brook; expanding no-mow areas by 10 acres and thereby reducing lawn areas by 17%; and reducing irrigated areas by 33%.

These programs are mutually beneficial and they often reduce the operational cost of the facility, improve water quality conditions, and provide good public relation opportunities for the facility.

Quail Brook Golf Course was the first course to be certified as River-Friendly by NJWSA. During their time as a participant with the River-Friendly Golf Course Program, Quail Brook Golf Course has taken several actions to reduce their impact on the Cedar Grove Brook watershed. They installed a new irrigation system that allows staff to easily check for leaks on a daily basis. No-mow and low maintenance areas have been established throughout the course, providing buffers along waterways. An on site equipment wash facility was installed at the golf course and prevents fertilizer and pesticide rinsate, as well as potentially contaminated grass clippings from being washed into the stream. An Integrated Pest Management plan for the course has also be developed, which provides staff with a pragmatic plan to assess and treat turf problems by using the least amount of harmful chemicals as possible. A brochure containing River-Friendly tips is on display in the clubhouse, providing outreach to the patrons of the course.

Although Quail Brook Golf Course is the only golf course facility in the watershed, there are several other facilities that may be appropriate for inclusion in the River-Friendly programs, including businesses, assisted-living facilities, churches and parks.

Residents can fill out a self-certification questionnaire to receive recognition as a River-Friendly Resident. The questionnaire includes questions about lawn management practices, water conservation and septic system management, and represents a resident's pledge to manage their property in a responsible manner to help protect our drinking water resources and the environment. The questionnaire can be filled out online, or can be distributed through a variety of outlets. For example, municipalities could have the questionnaire available at the municipal buildings, or could distribute it, along with other information on nonpoint source pollution, at various community events.

The River-Friendly Farm program, administered by North Jersey Resource Conservation and Development Council (www.njriverfriendlyfarm.org) and the Raritan Watershed Agricultural Committee, uses a set of five criteria, including nutrient management, pest management, riparian buffers, soil loss and irrigation water management.

For more information on any of these programs, visit: www.raritanbasin.org and www.njriverfriendly.org.

2. River-Friendly Communities

There are several residential communities within the watershed that are managed by homeowner and condominium associations, which have a range of responsibilities. Associations may manage common open space or have maintenance responsibility for roads, stormwater systems, water supply systems, wastewater treatment systems, parks and more. Nonpoint source pollution from existing residential development in the Cedar Grove Brook watershed has been identified as a significant sediment source. By working with these associations through the established River-Friendly programs (e.g. River-Friendly Resident) and a new River-Friendly Communities program, pollutant loads from these communities may be reduced.

Similar to the River-Friendly Golf Course and Business programs, each participating association will complete a detailed application regarding their community and its maintenance practices. NJWSA will then work with each individual association to design a series of unique actions for certification. While some actions will be common to all properties, many will be unique to each particular association in order to meet the characteristics, constraints and needs of each property and association. Actions may be required in each of four areas:

- Water Quality Management,
- Water Conservation Techniques,
- Wildlife and Habitat Enhancement, and
- Education and Outreach.

The program will provide ongoing technical information, support and guidance for implementing environmental projects specific to the unique location, and the resources and needs of each association.

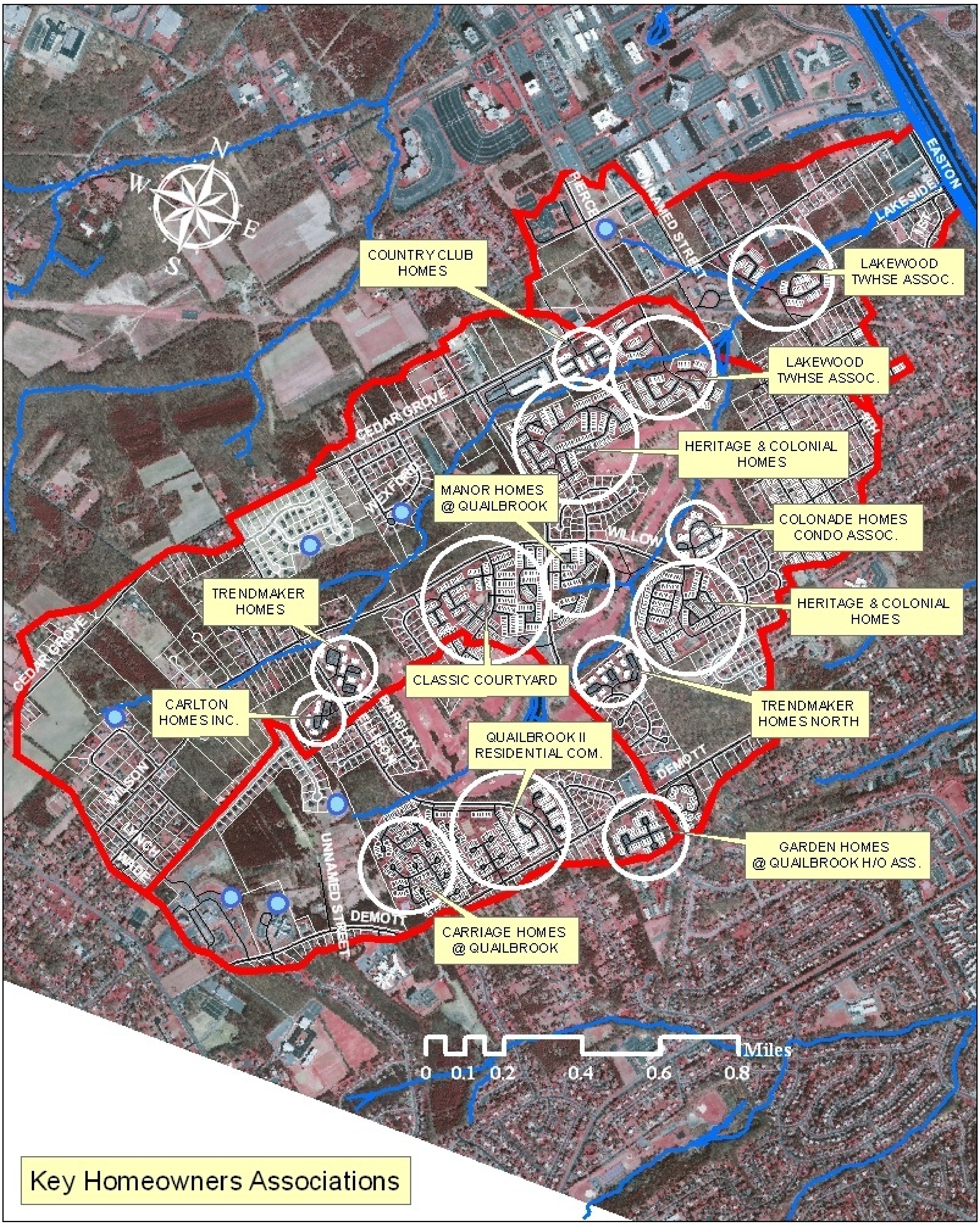
The River-Friendly Communities Certification Program will provide the following benefits:

- Protects natural resources and preserves New Jersey’s native landscapes.
- Provides public recognition for achievements through receipt of a plaque, an award presentation and media announcements.
- Reduces costs by decreasing use of fertilizers, pesticides and herbicides and decreasing use of equipment in ‘no-mow’ zones and ‘no-spray’ zones.
- Creates healthier landscaping.
- Maintains community aesthetics.
- Decreases water use.
- Increases natural habitat and attracts beneficial wildlife.
- Reduces resident exposure to pesticides and other chemicals.
- Promotes a positive relationship between the surrounding community and the association.

Figure 40 details the locations of key homeowner associations in the watershed. NJWSA will develop an outline and program documents for the River-Friendly Communities program with the help of the River-Friendly Technical Advisory Committee (TAC). The program materials are likely to be similar to those developed for the River-Friendly Business and Golf Course programs; however, appropriate adaptations for residential communities will be made.

Following development of the program materials, NJWSA will begin outreach to the associations and encourage them to join the program.

Key Homeowner Groups in the Cedar Grove Brook Watershed



(NJWSA / 1-28-09 / O'Neil)

Figure 40. Homeowner Groups in the Cedar Grove Brook Watershed

C. Prioritization of Nonpoint Source Management Measures

Several methods to prioritize the recommended projects were considered. Omni prioritized the structural modifications to the three main pond structures and the residential stormwater management measure; stakeholders also prioritized several of the management measures. NJDEP then requested that the Pennsylvania "Growing Greener" criteria be used. Those criteria include:

- Measurable water quality improvement (TMDL);
- Landowner participation;
- Permitting;
- Site constraints (topography, wetlands, stream encroachment, etc);
- Anticipated costs;
- Potential funding sources;
- Expected timeframe;
- Project partners needed;
- Ecological benefits; and
- Long term maintenance/monitoring.

These criteria were placed into two groups; one set was assigned scores from 1 to 5, and the second set was assigned to an 'other considerations' group that was not scored. The final prioritization score is a sum of the six scored criteria.

Scored criteria:

- Measurable water quality improvement (TMDL):
  - 1 = minimal benefit,
  - 3 = modest benefit,
  - 5 = substantial benefit;
- Landowner participation:
  - 1 = landowner participation anticipated to be difficult,
  - 5 = landowner participation already obtained or anticipated to be easily obtained;
- Permitting:
  - 1 = permitting anticipated to be difficult,
  - 3 = permitting anticipated to be required but obtainable,
  - 5 = no permitting required;
- Site constraints (topography, wetlands, stream encroachment, etc):
  - 1 = significant site constraints that will make design difficult,
  - 5 = no site constraints present obstacles to design;
- Anticipated costs:
  - 1 = cost/benefit ratio is high, e.g. significant cost per pound of pollutant removed,
  - 5 = cost/benefit ratio is low, e.g. low cost per pound of pollutant removed;
- Ecological benefits:
  - 1 = minimal additional benefit to overall habitat or water quality/quantity;
  - 5 = significant additional benefit to overall habitat or water quality/quantity.

Table 18. Prioritization of Nonpoint Source Management Measures

	Criteria						**Other considerations (not scored)**				
Projects	Measurable water quality improvement	Landowner participation	Permit	Site constraints	Antic. Cost	Ecological Benefits	Potential Funding Sources	Expected Time Frame	Partners Needed	Long Term Maintenance & Monitoring	**Score**
Quail Brook Golf Course Pond Project 1- outlet modifications	3	5	5	5	3	1	Available	Short	No	High	22
Quail Brook Golf Course Pond Project 2- flowpath baffles	2	5	5	5	3	1	Available	Short	No	High	21
Ukrainian Village Pond	3	3	3	3	3	2	Available	Medium	No	High	17
Lower Pond	5	4	3	4	3	2	Available	Medium	No	High	21
Riparian Restoration	2	3	4	4	5	4	Available	Short to Long	Yes	Low	22
Stormwater Basin Retrofits	3	3	4	4	3	4	Available	Short to Long	Yes	Moderate to High	21
Residential Stormwater Management (Rain Barrels, Rain Gardens)	2	3	5	5	4	1	Available	Short to Medium	Yes	Low	20
River-Friendly Programs	2	4	5	3	4	4	Available	Short	Yes	None	22
River-Friendly Communities	2	4	5	5	4	3	Available	Short	Yes	None	23

Based on the prioritization scheme, the recommended management measures were ranked as follows:

1. River-Friendly Communities
2. Quail Brook Golf Course Pond Project #1 – outlet modifications
2. Riparian Restoration
2. River-Friendly Programs
3. Quail Brook Golf Course Pond Project #2 – flowpath baffles
3. Lower Pond
3. Stormwater Basin Retrofits
4. Residential Stormwater Management
5. Ukrainian Village Pond

IX. Technical and Financial Assistance

The fourth minimum element of a watershed restoration plan includes an estimate of the amounts of technical and financial assistance needed. Table 14 and the project detail sheets in Appendix G provide estimated costs for the recommended management measures.

Potential project lead entities include:

- Somerset County Park Commission
- Franklin Township
- NJWSA
- Somerset-Union Soil Conservation District
- Homeowners Associations
- Rutgers Cooperative Extension, Water Resources Program

Technical assistance may be obtained from the organizations above, as well as the Natural Resources Conservation Service (NRCS), NJDEP, US Fish and Wildlife Service.

There are a variety of sources of funding that may be utilized for the projects detailed in this plan. Deadlines, funding amounts and application requirements change often for most of these programs, and the specific program website should be checked for current information.

- The NJDEP website provides a listing of funding sources at http://www.nj.gov/dep/grantandloanprograms/Information & Education. These programs include the Section 319(h) nonpoint source program and a variety of other potential funding sources.
- Franklin Township can include the projects recommended in the plan in their stormwater mitigation plan, making them eligible for implementation with funds collected when stormwater mitigation funds are collected from entities conducting development activities. Some of the management measures may be conducted as part of Franklin Township's NJPDES permit implementation activities.
- NJWSA maintains a source water protection fund. A portion of their water rate is allocated to source water protection activities. The River-Friendly programs are funded in this manner.
- The Natural Resources Conservation Service operates several funding sources, including the Wildlife Habitat Incentives Program (WHIP). See http://www.nj.nrcs.usda.gov/programs/fundingopportunities.html for more detailed information.
- USEPA has many grant programs, including their Environmental Education Grants and Five-Star Restoration Grants, that could potentially be applied to the recommended management measures. See http://water.epa.gov/grants_funding/shedfund/watershedfunding.cfm.
- The US Fish & Wildlife Service provides grants for a variety of habitat improvements, which could be incorporated into several of the recommended management measures. See http://www.fws.gov/grants/.

X. Implementation Schedule & Milestones

The sixth minimum element of a watershed restoration plan requires the development of a schedule for implementation. This schedule will be highly dependent on the availability of funding and organizations willing to accept responsibility for project planning, implementation and long-term maintenance. Some projects may be incorporated into the ongoing D&R Canal Implementation Project, which will facilitate implementation. NJWSA's River-Friendly programs are already being implemented, and increased outreach/implementation in the Cedar Grove Brook watershed can be easily accomplished.

A potential implementation schedule is provided in Table 19. Projects at Quail Brook Golf Course are anticipated to be easy to begin once funding is available, due to their participation in the River-Friendly Golf Course program. Quail Brook GC is owned and operated by the Somerset County Parks Commission. The background investigation work for those projects should be minimal.

The Ukrainian Village Pond and Lower Pond will require work with the landowners prior to beginning any design work. In addition, funding must be obtained for the projects. Design work and permitting will take significant time as well.

The riparian restoration projects and stormwater basin retrofits will require coordination with landowners, but should not require significant design time or permitting. Once funding is available, these projects are expected to progress relatively quickly.

Residential stormwater management projects, including rain barrels and rain gardens, can be implemented through ongoing initiatives of Rutgers Cooperative Extension and NJWSA. Additional funding and expansion of those programs will be required.

NJWSA's River-Friendly Golf Course and Business programs are currently being implemented in the Cedar Grove Brook watershed. Outreach regarding the River-Friendly Resident program can be expanded to the watershed as well. The River-Friendly School program can be implemented in the watershed as funding and NJWSA staff time is available.

The River-Friendly Communities program is a new program that will be developed and implemented by NJWSA as part of the River-Friendly suite of programs. Development of the program will begin during 2011.

Table 19. Potential Implementation Schedule

Projects	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Ongoing
Quail Brook Golf Course Pond Project 1- outlet modifications		x	x	x							
Quail Brook Golf Course Pond Project 2-flowpath baffles		x	x	x							
Ukrainian Village Pond				x	x	x	x				
Lower Pond					x	x	x	x			
Riparian Restoration		x	x	x	x	x	x	x	x	x	
Stormwater Basin Retrofits			x	x	x	x	x	x			
Residential Stormwater Management (Rain Barrels, Rain Gardens)	x	x	x	x	x						
River-Friendly Programs	x	x	x	x	x	x	x	x	x	x	x
River-Friendly Communities	x	x	x	x	x	x	x	x	x	x	x
Monitoring & Maintenance			x	x	x	x	x	x	x	x	x

XI. Education

Outreach and education may occur through many different existing programs. Franklin Township's municipal stormwater management plan requires them to conduct a yearly educational event and distribute brochures provided by the NJDEP. Additional information about this project can be distributed in conjunction with the required mailing. Web sites maintained by the Township, NJWSA and Raritan Basin Watershed Alliance (RBWA) can be vehicles for the dissemination of the plan and information about the management measures. The plan and resulting projects can be highlighted in the RBWA "Basin Bulletin". Both the D&R Canal Commission and D&R State Park can be valuable allies in distributing information on the project.

XII. Project Monitoring

In order to evaluate the effectiveness of the nonpoint source management practices recommended in this plan, a monitoring plan is a necessary component.

In order to reduce overall monitoring costs, this plan will not seek to develop an end-of-pipe monitoring plan. In some cases, BMP-specific project monitoring may be recommended to determine the effectiveness of a particular BMP. For example, evaluating the residence time of stormwater in ponds before and after the recommended retrofit may provide sufficient data on whether or not it is functioning correctly and achieving the overall goal of sediment removal. Another example of site-specific monitoring could be visual inspections of naturalized detention basins. Survival rates of vegetation should be characterized and the presence or absence of erosion should be recorded. Monitoring efforts should be conducted during baseline conditions as well as during storm events.

Monitoring of the smaller BMPs such as rain gardens and rain barrels presents a challenge since these types of BMPs will generally be found on private properties. Developing a database of installed rain gardens and rain barrels where homeowners can register their small scale BMPs could provide enough data to estimate sediment reductions. Record keeping at rain barrel and rain garden trainings and outreach events will also provide information on the effectiveness of the outreach when compared to the number of rain gardens and rain barrels installed. Follow up correspondence will assist in data collection.

The WinSLAMM model that was developed as part of this project can also be utilized to help estimate load reductions achieved from the recommended management measures. Another model that can be used to document load reductions is the Spreadsheet Tool for Estimating Pollutant Load (STEPL). This simple spreadsheet model, which is approved for use by NJDEP and USEPA, can assist in quantifying the TSS reductions associated with implemented management measures and documenting progress made toward reducing TSS loads to the Canal. A USGS gauge on the D&R Canal at Landing Lane is scheduled for installation in 2011 as part of the D&R Canal NPS Implementation Project and NJWSA's overall early warning system for water purveyors. This gauge will provide overall turbidity/TSS data downstream of the Cedar Grove Brook inlet to the Canal. These data can be used to help evaluate the overall sediment and volume reduction efforts within the D&R Canal watersheds.

Lastly, the plan and the progress toward implementation of the recommended management measures should be evaluated over time. This evaluation will help to reprioritize projects, address specific shortcomings, and allow for adaptive management.

XIII. Summary

A review of existing GIS information and collection of stream visual assessment data and water quality data resulted in the identification of nine sets of nonpoint source management measures that should be implemented in the Cedar Grove Brook Watershed in order to reduce TSS loads to the Brook and ultimately to the D&R Canal. The management measures that were identified, in order of prioritization, are:

- River-Friendly Communities
- Quail Brook Golf Course Pond Project #1 – outlet modifications
- Riparian Restoration
- River-Friendly Programs
- Quail Brook Golf Course Pond Project #2 – flowpath baffles
- Lower Pond
- Stormwater Basin Retrofits
- Residential Stormwater Management
- Ukrainian Village Pond.

The United States Environmental Protection Agency (EPA) identified nine significant elements that are critical for achieving improvements in water quality and that must be included in all watershed restoration plans funded with Clean Water Act Section 319(h) funding. The nine elements are listed below with a discussion of pertinent points from the Cedar Grove Brook watershed restoration plan that relate to each specific element. The elements do not occur sequentially.

Element 1: Identification of causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions, and any other goals identified in the watershed plan.

Element 1 includes mapping, characterization and assessment of the watershed (**Section IV Watershed Characterization and Assessment** and **Section V Visual Assessment**) and an accounting of nonpoint sources that cause impairment in the watershed (**Section VI Pollutant Source Assessment**). A correlation shall be made between the sources of pollution and the extent to which they cause water quality impairment.

The relative contribution from any land use type is a function of:

1) the percent of the watershed comprised of the land use type; and

2) the contribution (pounds per acre) generated by the land use type in terms of pollutant load.

The dominant developed land use in the Cedar Grove Brook watershed is residential, comprising 43% of the watershed. Commercial, industrial and institutional land uses comprise small amounts of the developed land area, forest and brush/shrub land comprise 20%, wetlands comprise 18% and agriculture approximately 1% of the watershed.

The WinSLAMM modeling indicated that approximately 38% of the solids load originates on residential properties, and the majority of that load is generated by vegetated areas. Although vegetation such as lawn and forest is generally considered to be more protective of water resources than impervious areas such as driveways and roofs, these areas do generate sediments and other pollutants.

An additional sediment source that must be considered is the resuspension of sediment from the three existing pond structures during large storm events.

Element 2: An estimate of the load reductions expected from management measures.

A total maximum daily load (TMDL) has not been prepared for Cedar Grove Brook, and the watershed is not identified on the State's 2008 List of Impaired Waters. The watershed has been observed to contribute TSS and associated turbidity to the D&R Canal and water purveyors with downstream water intakes have reported higher treatment needs during and after storm events.

As the Canal and Cedar Grove Brook are not listed as impaired for sediment, a targeted endpoint or specific load reduction for the watershed was not identified. The goal of this project is to reduce the sediment load in the stream and thereby reduce sediment loads in the Canal. The anticipated load reduction from each recommended management measure is, however, specified in the restoration plan (**Section VIII Nonpoint Source Management Measures** and **Appendix G Project Detail Sheets**).

Element 3: A description of the nonpoint source management measures that will need to be implemented to achieve load reductions and a description of the critical areas in which those measures will be needed to implement this plan.

This restoration plan describes the management measures that are recommended in order to achieve the reduction of sediment entering Cedar Grove Brook and ultimately the D&R Canal. These measures include:

Structural Management Measures:

- Quail Brook Golf Course Pond – Outlet structure modification and addition of flowpath baffles
- Ukrainian Village Pond – Outlet structure modification
- Lower Pond – weir modification
- Riparian Restoration (multiple locations)
- Stormwater Basin Retrofits (multiple locations)
- Residential Stormwater Management – Rain barrels and rain gardens

Non-structural Management Measures

- River-Friendly Programs – Golf courses, businesses, schools and residents
- River-Friendly Communities

Details on each of these projects are included in **Section VIII Nonpoint Source Management Measures** and **Appendix G Project Detail Sheets.**

Element 4: Estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement this plan.

This section describes the financial and technical assistance necessary to implement the entire watershed restoration plan. Items that are included are implementation, construction, maintenance, monitoring and evaluation. Organizations that could potentially be responsible for various projects and tasks are also identified. In the Cedar Grove Brook watershed, these organizations may include NJWSA, Somerset County and Franklin Township. Funding opportunities that may be utilized include Section 319(h) funds, Corporate Business Tax funds, Natural Resources Conservation Service funds, Partners for Fish & Wildlife, and NJWSA's source water protection fund. A discussion of potential funding sources and lead organizations is provided in **Section IX Technical and Financial Assistance**.

Element 5: An information and education component used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.

Outreach and education may occur through many different existing programs. Franklin Township's municipal stormwater management plan requires them to conduct a yearly educational event and distribute brochures provided by the NJDEP[9]. Additional information about this project can be distributed in conjunction with the required mailing. Web sites maintained by the Township, NJWSA and Raritan Basin Watershed Alliance (RBWA) can be vehicles for the dissemination of the plan and information about the management measures. The plan and resulting projects can be highlighted in the RBWA "Basin Bulletin". Both the D&R Canal Commission and D&R State Park can be a valuable ally in distributing literature on the project. See **Section XI Education**.

Element 6: Schedule for implementing the nonpoint source management measures identified in this plan.

A schedule for implementation of the management measures recommended in the plan shall be developed. The schedule will be modified depending on funding opportunities and the potential for management measures to be included in other projects. Some of the management measures recommended in this plan can be implemented with a minimum of planning and funding. For instance, NJWSA is currently implementing the River-Friendly suite of programs in this watershed, and could easily expand that work. Other projects will require the identification of a lead entity and funding. A tentative schedule for implementation is provided in **Section X Implementation Schedule and Milestones.**

Element 7: Milestones- A description of interim measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.

Information regarding the potential project schedule is provided in **Section X Implementation Schedule and Milestones.** This schedule was developed based on NJWSA's experience in other watersheds. Each milestone is contingent upon funding and lead organization availability.

Milestones Year 1:

[9] See NJPDES Master General Permit for Tier A municipalities

- Continue and expand existing River-Friendly programs.
- Begin development of River-Friendly Communities program.
- Begin implementation of Residential Stormwater Management Programs

Milestones Year 2:

- Begin implementation of Quail Brook Golf Course pond modification projects.
- Begin implementation of River-Friendly Communities Program.
- Begin riparian restoration projects

Milestones Year 3:

- Begin stormwater basin retrofits.

Milestones Year 4:

- Complete Quail Brook Golf Course pond modification projects.
- Begin Ukrainian Village Pond project

Milestones Year 5:

- Begin Lower Pond project.
- Complete at least one stormwater retrofit project.
- Complete Residential Stormwater Management projects.

Milestones Year 7:

- Complete Ukrainian Village Pond project

Milestones Year 8:

- Complete Lower Pond Pond project

Milestones Year 10:

- Complete riparian restoration projects.

Ongoing:

- River-Friendly Programs
- Monitoring
- Maintenance

In addition, each project will require the establishment of tasks and milestones specific to the project.

Element 8: Performance Criteria-A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.

The primary criteria that will be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards will be TSS reduction (lbs/yr) as estimated by periodic reexamination of the WinSLAMM model and application of the Step-L model. Additional information regarding monitoring and performance criteria is provided in **Section XII Project Monitoring**.

Element 9: A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established above.

Direct water quality monitoring is not planned in the Cedar Grove Brook. A continuous water quality and flow data monitoring station is planned for the D&R Canal at Landing Lane, approximately three miles downstream. This new facility will be constructed and maintained by the USGS and NJWSA. Those data will be used to assess the overall success of the nonpoint source management measures implemented through the D&R Canal Nonpoint Source Implementation Project, and will also be pertinent for this project.

Additional information regarding monitoring and performance criteria is provided in **Section XII Project Monitoring**.

APPENDICES

Appendix A Water Quality of the Delaware and Raritan Canal, New Jersey, 1998-99, United States Geological Survey (USGS), 1999

Appendix B Cedar Grove Brook Watershed Water Quality Characterization and Assessment, TRC Omni, 2006

Appendix C Characterization and Assessment of the Cedar Grove Brook, NJWSA, 2009

Appendix D Cedar Grove Brook Stream Visual Assessment Results, NJWSA, 2009

Appendix E Cedar Grove Brook Watershed Restoration Planning Project, Omni Environmental, LLC, 2009

Appendix F Approved QAPP

Appendix G Project Detail Sheets

U.S. Department of the Interior
U.S. Geological Survey

WATER QUALITY OF THE DELAWARE AND RARITAN CANAL, NEW JERSEY, 1998-99

Water-Resources Investigations Report 01-4072

Prepared in cooperation with the

NEW JERSEY WATER SUPPLY AUTHORITY

science for a changing world

WATER QUALITY OF THE DELAWARE AND RARITAN CANAL, NEW JERSEY, 1998-99

By Jacob Gibs, Bonnie Gray, Donald E. Rice, Steven Tessler, and Thomas H. Barringer

U.S. GEOLOGICAL SURVEY

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2001

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U.S. DEPARTMENT OF THE INTERIOR

GALE A. NORTON, ***Secretary***

U.S. GEOLOGICAL SURVEY

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ILLUSTRATIONS

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TABLES

CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
acre	4,047	square meter
acre	0.4047	hectare
square foot (ft^2)	929.0	square centimeter
square foot (ft^2)	0.09294	square meter
square mile (mi^2)	259.0	hectare
square mile (mi^2)	2.590	square kilometer
	Volume	
gallon (gal)	3.785	liter
gallon (gal)	0.003785	cubic meter
cubic foot (ft^3)	0.02832	cubic meter
	Flow	
foot per second (ft/s)	0.3048	meter per second
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
cubic foot per minute (ft^3/min)	0.02832	cubic meter per minute (m^3/min)
mile per hour (mi/h)	1.609	kilometer per hour
gallon per minute (gal/min)	0.06308	liter per second
million gallons per day (Mgal/d)	0.04381	cubic meter per second
	Temperature	
degree Fahrenheit (°F)	°C = 5/9 x (°F-32)	degree Celsius (°C)

CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNITS--Continued

Vertical datum: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929-- a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Water-quality abbreviations:

µg	-micrograms	DOC	-dissolved organic carbon
mg	-milligrams	SOC	-suspended organic carbon
mg/L	-milligrams per liter	POC	-purgeable organic compound
µg/L	-micrograms per liter	TOC	-total organic carbon
µS/cm	-microsiemens per centimeter at 25 degrees Celsius	VOC	-volatile organic compound

Water Quality of the Delaware and Raritan Canal, New Jersey, 1998-1999

By Jacob Gibs, Bonnie Gray, Donald E. Rice, Steven Tessler, and Thomas H. Barringer

ABSTRACT

Since 1934, the Delaware and Raritan Canal has been used to transfer water from the Delaware River Basin to the Raritan River Basin. The water transported by the Delaware and Raritan Canal in New Jersey is used primarily for public supply after it has been treated at drinking-water treatment plants located in the Raritan River Basin. Recently (1999), the raw water taken from the canal during storms has required increased amounts of chemical treatments for removal of suspended solids, and the costs of removing the additional sludge or residuals generated during water treatment have increased. At present, action to control algae is unnecessary.

The water quality of the Delaware and Raritan Canal was studied for approximately 16.5 months from mid-January 1998 through May 1999 to determine whether changes in water quality along the length of the canal are associated with storms. Nine water-quality constituents, and field measured specific conductance and turbidity were statistically tested.

Instantaneous or grab samples of water were collected from the Delaware and Raritan Canal after five storms and during four nonstorm events. Median values of water-quality constituents in samples collected immediately after storms and during nonstorm conditions when statistically compared by sampling location were not significantly different. Therefore, the data were combined or aggregated to eliminate one of the two explanatory variables, either individual sampling sites or the two types of sampling events, in order to generate a sample population large enough to show statistically significant differences. After combining sampling events, only the median concentration of suspended organic carbon, and field measured specific conductance and turbidity, were significantly different among sampling sites. Median concentrations of total and filtered ammonia plus organic nitrogen, total phosphorous, turbidity, ultraviolet absorbance at 254 nanometers, and dissolved organic carbon in samples collected after storms were significantly greater than in samples collected during nonstorm conditions, when the sampling locations were aggregated in the statistical analysis. Methyl *tert*-butyl ether, the most frequently detected volatile organic compound (VOC), was detected in 55 of 80 samples. The highest concentration of methyl *tert*-butyl ether, 3.2 micrograms per liter, was measured in a sample collected during nonstorm conditions.

The median of the continuously monitored specific conductance during nonstorm conditions at Port Mercer, N.J., increased by approximately 3 to 4 μS/cm (microsiemens per centimeter) (1.5 to 2 percent of the median specific conductance) relative to that at the nearest upstream site, at Lower Ferry Road. The land use in the influent basins for this reach of the Delaware and Raritan Canal is primarily urban. One possible source of water with high specific conductance is either domestic or industrial wastewater that continuously discharges into pipes, then empties into the canal. Another possible source is ground water from an area within this reach where the elevation of the water table is higher than that of the water surface of the Delaware and Raritan Canal.

The median continuously monitored specific conductance measured during nonstorm conditions at the Route 18 Spillway site increased relative to that of the nearest upstream site, Ten Mile Lock, by approximately 3 to 4 μS/cm. The mean net change in continuously monitored specific conductance for this reach during storms also increased. Land use in the two largest influent

basins within this reach, the Borough of South Bound Brook and Als Brook, is predominantly urban.

The mean and median of continuously monitored turbidity varied along the length of the canal. In the reach between Raven Rock and Lower Ferry Road, the mean and median for continuously monitored turbidity during the study period increased by 7.2 and 6.2 NTU (nephelometric turbidity units), respectively. The mean of continuously monitored turbidity decreased downstream from Lower Ferry Road to Ten Mile Lock. Turbidity could increase locally downstream from influent streams or outfalls, but because the average velocity of water in the canal is low, particles that cause turbidity are not transported appreciable distances. In the reach between Ten Mile Lock and the Route 18 Spillway, the mean and median of the continuously monitored turbidity changed less than 0.5 NTU during the period of record. The small change in turbidity in this reach is not consistent with an average velocity for the reach; the average velocity in this reach was the lowest in all of the reaches studied. The expected decrease in turbidity due to settling of suspended solids is likely offset by turbid water entering the canal from influent streams or discharges from storm drains. Field observation of a sand bar immediately downstream from the confluence of Als Brook and the canal confirmed that the Als Brook drainage basin has contributed stormwater-generated sediment to the canal that could reach the monitor located at the Route 18 Spillway and the raw water intakes for two drinking-water treatment plants.

INTRODUCTION

The Delaware and Raritan Canal, which was put into operation in 1834, was originally constructed as a barge canal. In 1934, the State of New Jersey acquired the canal, and it is currently operated by the New Jersey Water Supply Authority (NJWSA). Since 1934, the canal has been used for interbasin transfer of water from the Delaware River Basin to the Raritan River Basin. Water purveyors, who are customers of the NJWSA, use the canal as a source of raw water that will be treated and distributed as public drinking water.

Since 1997, several water purveyors have noticed that the raw water withdrawn from the canal during precipitation events has required increased amounts of chemicals for the removal of suspended solids which, in turn, generates increased amounts of sludge or residuals. The increased use of chemicals in treating the water and removing additional sludge or residuals contributes to the increased cost of producing drinking water that meets the desired chemical quality and regulatory standards. Drinking-water purveyors are concerned that this worsening of water quality during storms could be part of a long-term trend of declining water quality and want to determine the possible sources or causes. To address these concerns, the U.S. Geological Survey (USGS), in cooperation with the New Jersey Water Supply Authority, conducted a study from mid-Janury 1998 through May 1999 to determine whether the water quality in the canal is affected by stormwater runoff from basins influent to the canal, and if so, to identify which of the canal reaches are the largest sources of the poorer water quality that the drinking-water-treatment plants are treating during storms. In order to effectively manage the logistics of conducting sampling along the 58-mile long canal during a storm, the collection of surface-water samples and analysis of water-quality data were divided into two projects. The first project, a reconnaissance of the entire length of the canal is designed to evaluate changes, statistically and qualitatively, in the quality of water at the ends of reaches of 10 miles or longer. The second project, which has not been conducted as of the publication of this report, will consist of collecting and analyzing samples from individual influent streams or pipes that discharge into the canal in those reaches of the canal where significant changes in water quality have occurred.

Purpose and Scope

This report describes the first project in a two-part study and characterizes the water quality of the Delaware and Raritan Canal over a period of approximately 16.5 months (mid-January 1998 through May 1999). Water samples were collected and analyzed to determine changes in the water quality of the canal associated with storms, and to compare the water quality related to storms to that of periods when no precipitation occurred, along the length of the canal.

Six continuous water-quality monitors were used to collect data along almost the entire length of the canal. Specific conductance, temperature, and turbidity were the water-quality characteristics that were continuously monitored.

Instantaneous water samples were collected at seven locations after the start of five storms and four times when there was no precipitation. The instantaneous water-quality samples were analyzed for nitrogen species (nitrite, nitrite plus nitrate, ammonia, and ammonia plus organic nitrogen in filtered samples, and ammonia plus organic nitrogen in whole water samples), phosphorous in filtered and unfiltered samples, total suspended solids, suspended organic carbon, dissolved organic carbon, ultraviolet absorbtion at 254 nanometers (UV 254), and 29 volatile organic compounds (VOCs). Specific conductance and turbidity were measured in the field. Results of these analyses and measurements are presented in tables and figures.

In addition, water-quality data obtained during the study were organized and formatted into a relational database. Geographic information system (GIS) files were created to represent the canal and cultural features associated with the canal, and land uses of the drainage basins influent to the canal.

Approach

The changes in the water quality along the length of the canal caused by stormwater runoff and continuous discharges to the canal from unknown sources, and the biological, chemical, and physical processes that occur in the canal, were evaluated by measuring constituents in instantaneous water samples collected at seven locations along the canal where width- and depth-integrated samples could be obtained. Instantaneous water-quality samples were collected after the start of five storms (after 0.5 inch of precipitation had fallen) and on four occasions when there had been no precipitation for the previous ten days (hereafter called a nonstorm event or condition). Continuous measurements of temperature, specific conductance, and turbidity were collected at six sites, at five of which instantaneous water samples also were collected. This arrangement of continuous water-quality monitoring locations divided the length of the canal into five reaches. The change in water quality along the length of the canal was determined by sampling at each instantaneous water-quality sampling site and subsequent analysis of the samples at the USGS National Water Quality Laboratory (NWQL) or the USGS New Jersey District laboratory, or by continuously measuring the changes in water quality in each reach at the continuous water-quality monitoring sites and subsequent evaluation of that data.

Previous Studies

The hydrology of watersheds flowing into and under the canal has been studied by Ebasco Services, Inc. (1988). Watersheds and watershed divides adjacent to the feeder part of the canal, which extends from the canal inlet on the Delaware River to Southard Street in the City of Trenton, N.J., are described in the report, and the watersheds that drain into or under the feeder part of the canal are identified. Maps containing information on influent basins to the feeder part of the canal were incorporated into geographic information system coverages generated in this study.

The plans and goals for the establishment and maintenance of a state park encompassing the canal and for a natural-resource inventory of the state park are contained in a report by the Delaware and Raritan Canal Commission (1977). Streams that flow into or under the canal, the drainage basins of those streams that flow into or under the canal, and areas of local runoff or overland flow that reach the canal were identified in the natural-resource inventory of the report.

Rutgers University (1980) conducted a study of the hydrologic, hydraulic, water-quality, and operational characteristics of the canal. The discussion of water quality is a snapshot of the water quality for 1974 through 1977. The Rutgers University report also contains a list of structures and their locations on canal property. This list was incorporated into geographic information system coverages generated for the present study.

Camp, Dresser, and McKee, Inc.(1986) evaluated seven ways to divert stormwater that flows into the U.S. Route 1 conduit of the canal to the Assunpink Creek. The diversion of stormwater to the Assunpink Creek would reduce the cost of repeated dredging to maintain the flow capacity of the conduit. The proposed alternatives were not adopted (Steven Nieswand, U.S. Geological Survey, oral commun., 1999). Camp, Dresser, and McKee, Inc. (1986) delineated the drainage areas from which stormwater originates, then flows into the canal and the U.S. Route 1 conduit. The spatial information on stormwater drainage basins that discharge into the conduit was incorporated into geographic information system coverages generated in the present study. Results of chemical analyses of sediment collected from seven storm drains that empty into the conduit for trace elements, polychlorinated biphenyls, and chlorinated pesticides also are reported.

NJWSA has no historical documentation or reports that conclude water-quality degradation associated with excessive algal growth occurred in canal water, and none of the water purveyors has complained to the NJWSA about the taste or odor of treated drinking water that might be attributable to algae in canal water (Edward Buss, New Jersey Water Supply Authority, written and oral commun., 1999).

Hickman and Barringer (1999) and Hay and Campbell (1990) discuss water-quality changes at the Delaware River at Lumberville, Pa. (USGS surface water-quality station 01461000) during 1986-95 and 1976-86, respectively. The Delaware River at Lumberville drains an area of 6,598 mi^2; water quality at this station can be used to represent the water quality at the intake of the canal on the Delaware River because this station is located approximately 0.7 miles downstream from the intake. Within the 0.7 miles, there is a negligible increase in the drainage area of the Delaware River. Thus, very little change in the water quality would be expected to occur within this reach. Hay and Campbell (1990) evaluated 22 constituents for trends at the Delaware River at Lumberville, Pa. The results of their analysis (at a statistical confidence level of 95 percent or greater) indicated that concentrations of total organic carbon decreased and pH increased during 1975-86, and that concentrations of sulfate decreased during 1979-86. Hickman and Barringer (1999) evaluated trends for 23 water-quality constituents. The results of their analyses (at a statistical confidence level of 95 percent or greater) indicated that biochemical oxygen demand increased, and total nitrogen, total ammonia nitrogen, organic plus ammonia nitrogen, total organic carbon, and fecal coliform (MPN) decreased during 1986-95.

Acknowledgments

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DESCRIPTION OF STUDY AREA

The study area consists of the Delaware and Raritan Canal and all drainage basins influent to the canal (fig. 1). The study area lies almost wholly within the Piedmont Physiographic Province in New Jersey. A small part of the area, part of the Duck Pond Run influent drainage basin, is in the Coastal Plain Physiographic Province.

Average annual precipitation in the study area ranges from 42 to 46 inches. The average annual runoff ranges from 21 to 23 inches (Schopp and Bauersfeld, 1985).

Delaware and Raritan Canal

The Delaware and Raritan Canal is approximately 58 miles long from the water intake on the Delaware River, 0.7 miles upstream from Raven Rock, to the end of the canal at the Route 18 Spillway, which empties canal water into the Raritan River at New Brunswick (fig. 1). The canal is entirely within the Piedmont Physiographic Province in New Jersey (Otto S. Zapecza, U.S. Geological Survey, oral commun., 1999).

The canal is roughly parallel to the Delaware River from the inlet on the Delaware River to Calhoun Street in Trenton, a distance of 21.8 miles. At Calhoun Street, the canal turns to the northeast, away from the Delaware River, and is roughly parallel to the Fall Line, the dividing line between the Piedmont and Coastal Plain Physiographic Provinces. Near Southard Street in Trenton, the canal goes underneath U.S. Route 1 in two identical 13 feet by 8 feet reinforced concrete rectangular conduits that extend approximately 1.15 miles to Mulberry Street in Trenton (Camp, Dresser, and McKee, Inc., 1986). The canal becomes an open channel again downstream from Mulberry Street and runs approximately parallel to U.S. Route 1 from Trenton City to the aqueduct over the Millstone River. After crossing the Millstone River, the canal follows the right bank (in the downstream direction) of the Millstone River until it reaches the confluence of the Millstone and Raritan Rivers. The canal then follows the Raritan River along the right bank and ends at the Route 18 Spillway in New Brunswick.

In 2000, there are eight historically certified locks on the Canal. These eight locks have been modified; the lock gates have been replaced with weirs and sluice gates that control the water level or, in the case of the Raven Rock lock, with a set of sluice gates only. Supplemental overflow weirs have been installed at five locks--Griggstown, Ten Mile, South Bound Brook, Five Mile (Rutgers University, 1980) and Kingston (John Petersen, New Jersey Water Supply Authority, oral commun., 1999).

The aqueduct that carries canal water over the Millstone River has a series of sluice gates to allow diversion of Millstone River water into the canal during periods of flooding in the Millstone River to maintain the structural stability of the aqueduct (Rutgers University, 1980) or to provide additional water to the canal during droughts in the Delaware River Basin.

Drainage Basins Influent to the Delaware and Raritan Canal

The total area of basins draining into the canal (hereafter called influent drainage basins) is 53,860 acres. The four largest influent drainage basins, which account for 76.2 percent of the total area of all the influent drainage basins, in descending order of drainage area, are Wickecheoke Creek (16,987 acres), Lockatong Creek (14,815 acres), Duck Pond Run (3,904 acres), and Als Brook (2,411acres), (Delaware and Raritan Canal Commission, 1977). Duck Pond Run flows into the canal between Port Mercer and Griggstown (fig. 1). Land use in the Duck Pond Run Basin is undergoing rapid change from agricultural to urban (fig. 2). The Als Brook Basin drains into the canal between Ten Mile Lock and Landing Lane Bridge about 1.5 miles from the Route 18 Spillway (fig. 3). The Als Run drainage basin contains a mixture of land uses, (urban, 48.1 percent; agriculture, 3 percent; and undeveloped, 48 percent) which was determined from the 1986 integrated terrain land use (ITU) coverage, (New Jersey Department of Environmental Protection, 1996). The Wickecheoke Creek and the Lockatong Creek Basins drain into the feeder part of the canal between the Raven Rock feed gates and Brookville (fig. 4). The predominant land use in the Wickecheoke Creek and the Lockatong Creek Basins is agricultural (60 percent of the total area of the two basins) (fig. 4).

METHODS OF INVESTIGATION

Eight sites were selected at locations along the canal, from the inlet on the Delaware River at Bull’s Island, N.J. (fig. 4), to the outlet at the Raritan River near

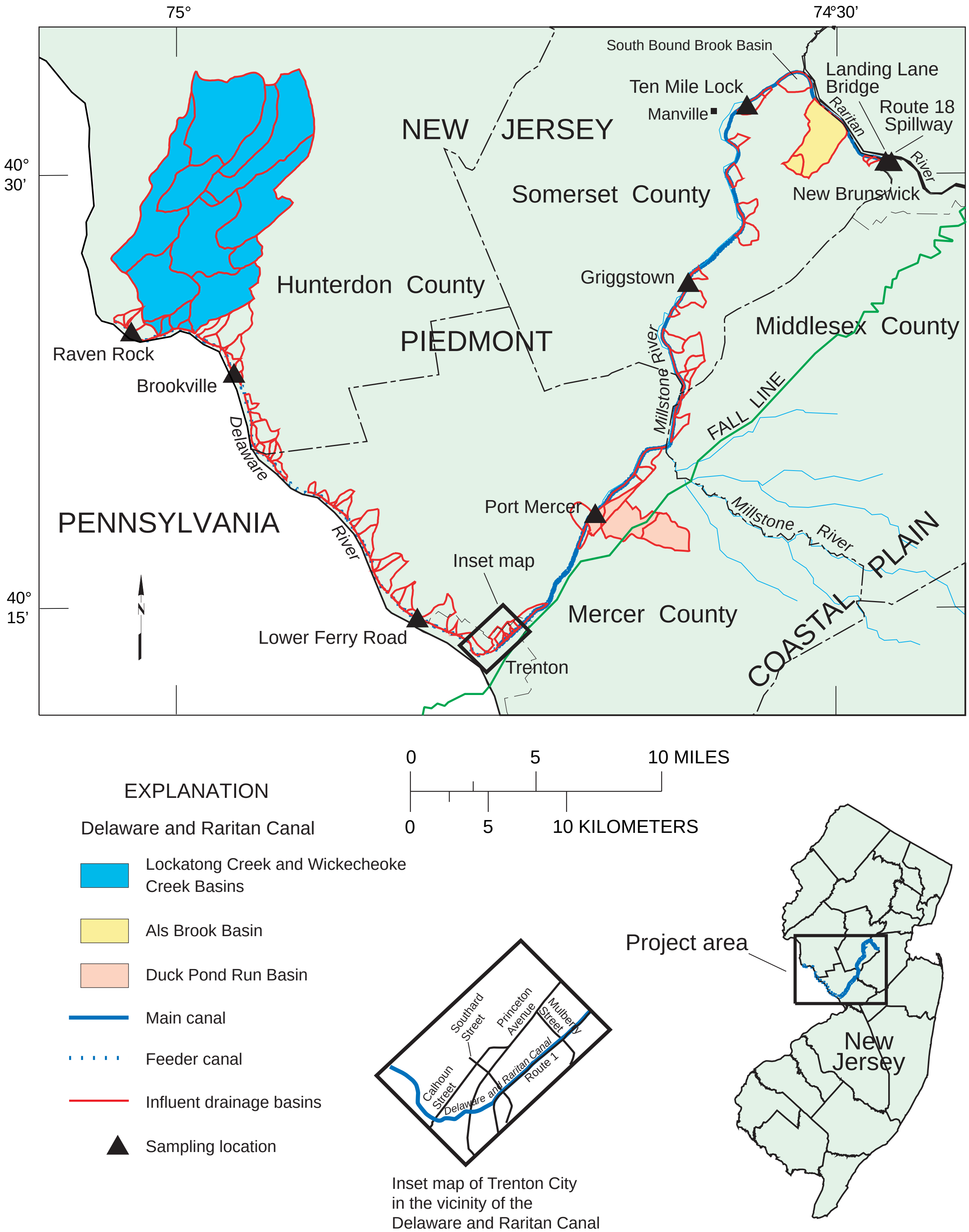


Figure 1. Locations of water-quality sampling sites and influent drainage basins along the Delaware and Raritan Canal, New Jersey.

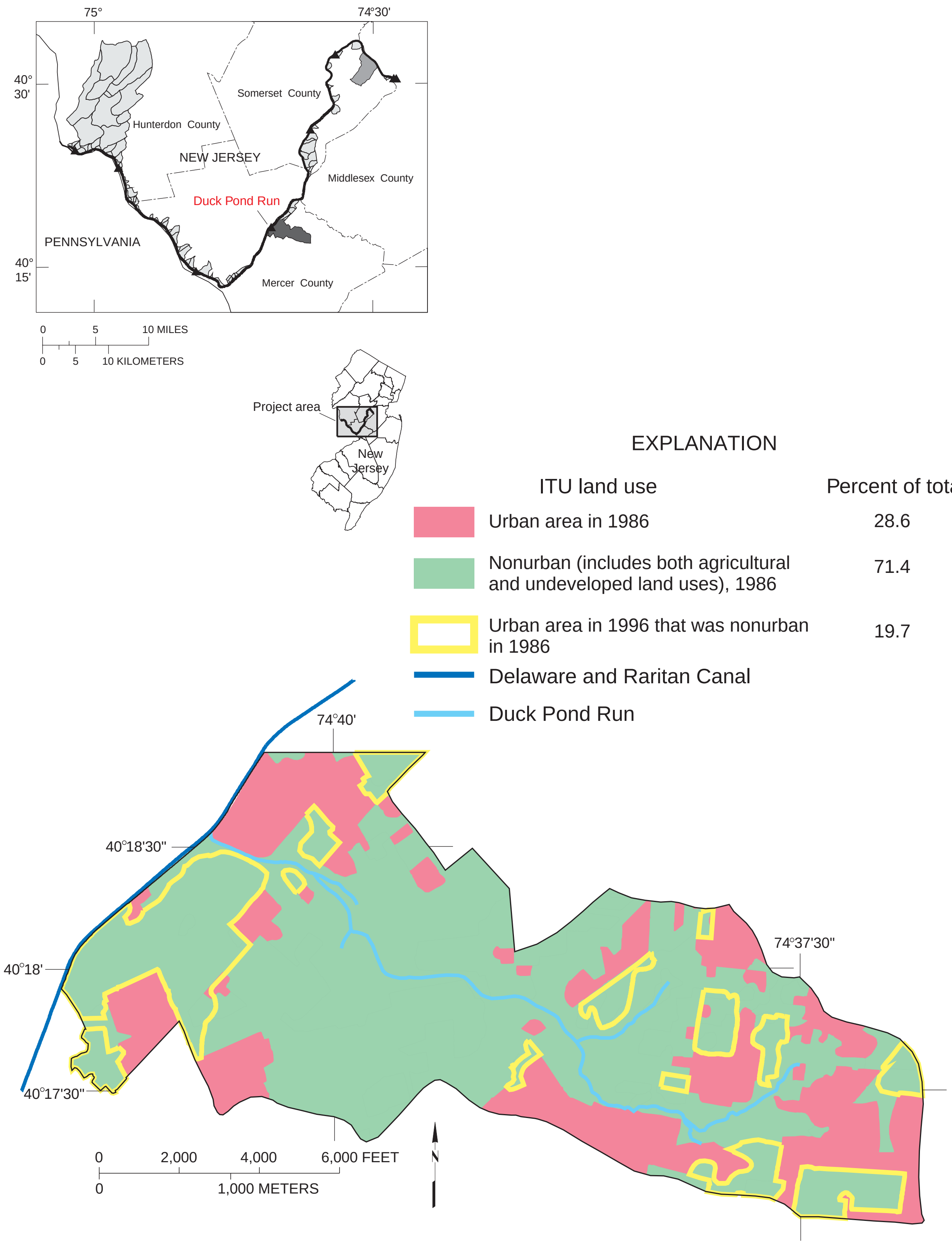


Figure 2. Land use in the Duck Pond Run drainage basin, New Jersey, in 1986 and 1996, based on Integrated terrain land use (ITU), as interpreted from U.S. Geological Survey 1996 digital infrared orthophoto.

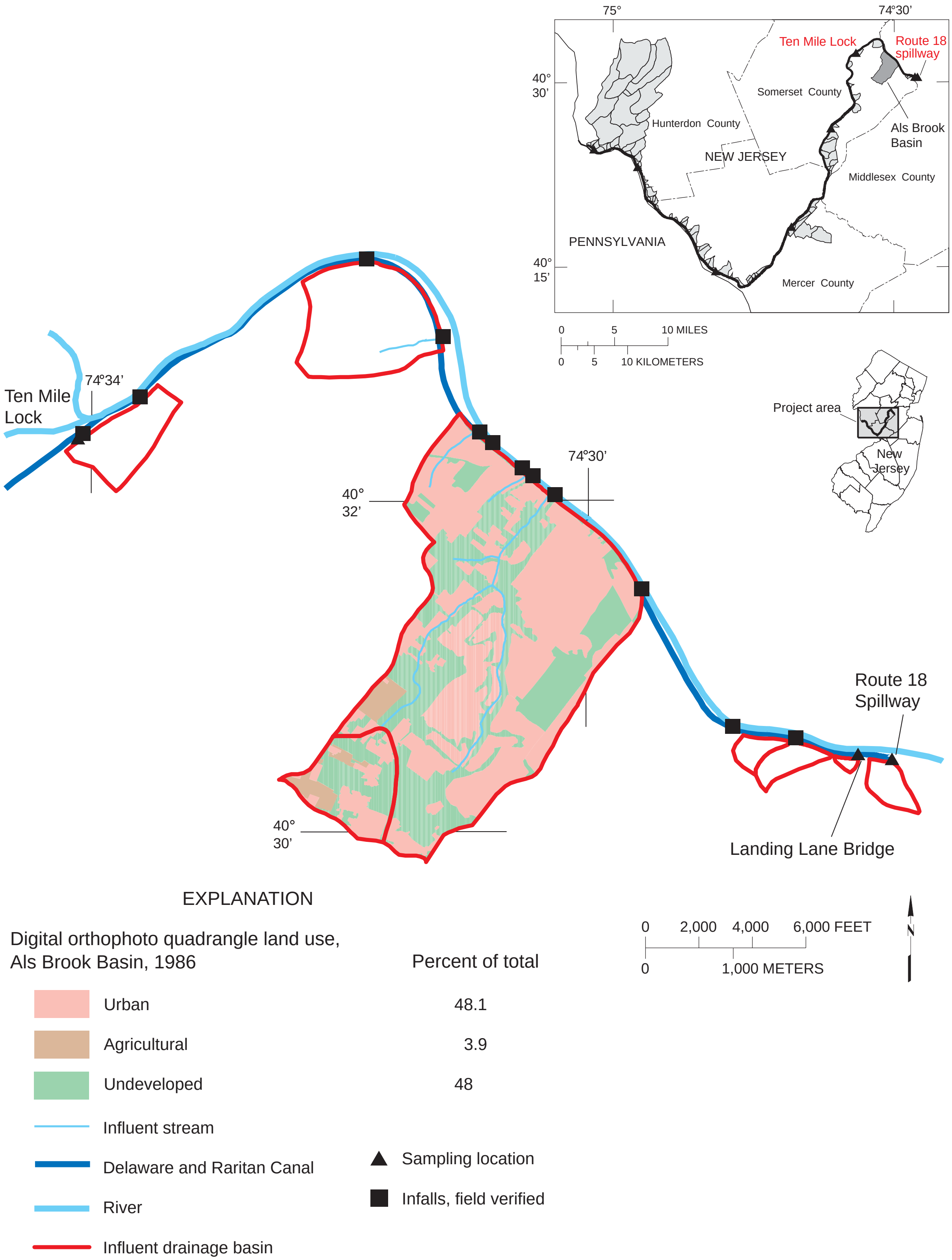


Figure 3. Land use within the Als Brook drainage basin and hydrologic infalls to the Delaware and Raritan Canal, Somerset County, New Jersey.

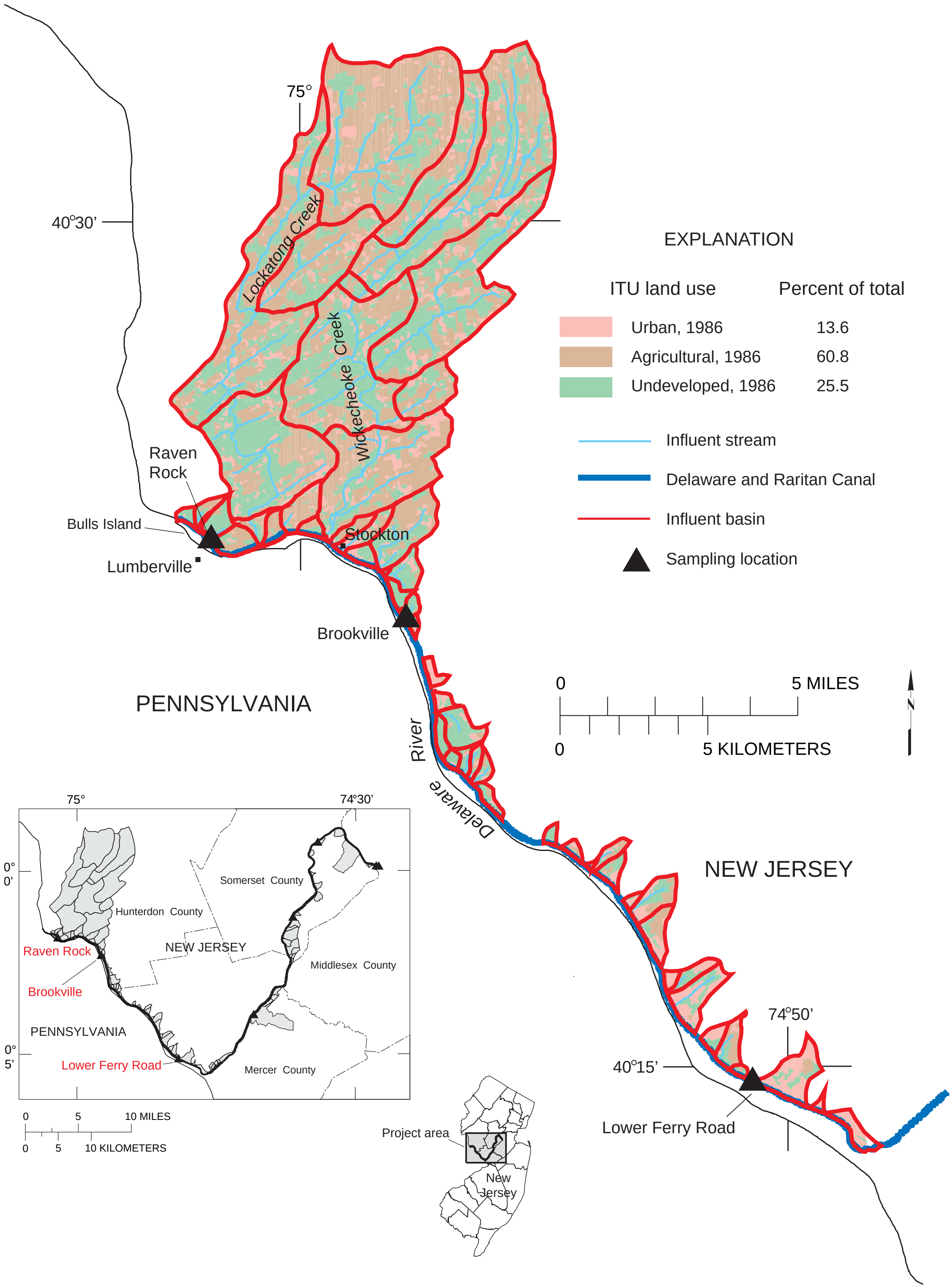


Figure 4. Drainage basins influent to the feeder section of the Delaware and Raritan Canal and 1986 integrated terrain land use (ITU), Hunterdon and Mercer Counties, New Jersey.

New Brunswick. Of the eight sites, six were equipped with continuous water-quality-monitoring equipment. Instantaneous water-quality samples also were collected at five of these sites. The other two sites were used to collect only instantaneous water-quality samples. One site was used only to continuously monitor water quality. Instantaneous samples were collected after more than a 0.5 inch of precipitation fell in the study area. Nonstorm samples were collected after a 10-day period with precipitation no greater than 0.5 inch falling in the study area. Water quality during storms and nonstorm conditions was compared to determine the changes caused by stormwater runoff that entered the canal.

Site Selection

The sites selected for the study are points along the canal that could be affected by runoff from influent basins upstream and the two points used to define the most upstream and downstream locations of the study area of the canal (fig. 1). The eight sites are described below in downstream order.

The Raven Rock site is in Hunterdon County (fig.1). It is 0.75 miles downstream from the Bulls Island inlet (fig. 4), which diverts water from the Delaware River into the canal. It is also the location of the feeder sluice gates that regulate the flow to the canal. The water quality at this site was considered to be an indicator of the quality of the water entering the canal from the Delaware River.

The Brookville site is also in Hunterdon County. It is 5.1 miles downstream from the feeder gates at Raven Rock at a bridge over the canal and is 1.8 miles south of Stockton (fig. 4). The spillway from the Wickecheoke Creek is located 2.3 miles upstream, and the Lockatong Creek spillway is located 3.9 miles upstream (fig.4). These are the two largest influent basins that drain into the canal. Their combined drainage area is 34,827 acres. A quarry, which is near the site, contributes stormwater runoff that enters the canal at a point just upstream from the site.

The Lower Ferry Road site is just upstream from Trenton City, Mercer County, at Lower Ferry Road at the bridge that crosses over the canal (fig. 4). It is 12.9 miles downstream from Brookville and 18 miles downstream from Raven Rock. Many spillways and culverts are located between the Brookville and Lower Ferry Road sites, approximately 10.9 miles downstream from the Lambertville feed gates. Land use in the influent basins between this site and the Raven Rock site is 13.6 percent urban, 60.8 percent agricultural, and 25.5 percent undeveloped (fig. 4).

The Port Mercer site is at Port Mercer in Mercer County at the Province Line (Quaker Bridge) Road bridge that crosses over the canal. It is 4.7 miles downstream from Trenton and 10.7 miles downstream from Lower Ferry Road. A small part of the canal runs through a culvert underneath U.S. Route 1, a major highway, for approximately 1.16 miles. This site is at the end of a reach that is surrounded by an urban area (Trenton) and at the beginning of a reach surrounded by land that was originally agricultural, but is rapidly becoming urban.

The Griggstown site is at the Griggstown causeway in Somerset County, where the causeway bridge crosses the canal. It is 11.3 miles downstream from Port Mercer (fig. 1). At this point, the canal extends in the northeastern direction parallel to the Millstone River. Some storm drains that carry water from a large quarry 3.7 miles upstream from this site empty directly into the canal. The land use in the influent basins downstream from the site and upstream from the next monitoring site is about 16 percent urban and 61 percent agricultural, as determined from the 1986 ITU land-use coverage.

The Ten Mile Lock site is in Somerset County. It is 8.9 miles downstream from Griggstown and 2 miles downstream from Millstone Borough across the canal and the Millstone River from Manville. This site is 0.3 miles upstream from the intake for one of the water purveyors. Land in the influent drainage basins downstream from this site is heavily urbanized.

The Landing Lane Bridge site is in New Brunswick, Middlesex County, approximately 7.5 miles downstream from Ten Mile Lock and 6.4 miles downstream from the town of South Bound Brook. The bridge at this site is the last one before the canal ends at the Route 18 Spillway, approximately 0.22 miles downstream. The drainage basin at the town of South Bound Brook (5.2 mi upstream from Landing Lane Bridge) consists primarily of road storm drains that discharge into the canal. The canal makes another sharp turn to the southeast and parallels the Raritan River. Als Brook Basin (fig.1) drains 2,411 acres and is the largest influent drainage basin located along the reach between Ten Mile Lock and Landing Lane Bridge.

The Route 18 Spillway site is at New Brunswick, Middlesex County. This continuous water-quality monitoring site is on the bank opposite the Route 18 Spillway; at this point on the left bank looking downstream, the canal empties into the Raritan River. The intakes of several water purveyors are on the canal just downstream from this site. One small influent basin with an area of 53 acres drains into the canal between Landing Lane Bridge and the Route 18 Spillway.

Continuous-Monitoring Sites

All sites except Brookville and Landing Lane Bridge were used for continuous monitoring. Brookville was not used because of the proximity of Raven Rock. The Landing Lane Bridge site was not used because of the difficulty of mounting the continuous water-quality monitor on the steel bridge. The continuous water-quality-monitoring sensors at all six sites were placed approximately 2 feet below the average surface elevation of the canal water. The depth of the sensors is about one-third of the average depth of water (approximately 6 feet) in the canal. The actual location of the continuous water-quality monitor differed in some cases from that of the instantaneous water-quality sampling site because the monitors measure water quality at a point, whereas the instantaneous water samples are depth- and width-integrated. For example, at Raven Rock the monitor was mounted on the left retaining wall of the canal 200 feet downstream from the feed gates so that the gates would protect the monitor from large debris such as tree limbs. At the Lower Ferry Road, Port Mercer, and Griggstown sites, the monitors were positioned near the midpoint of the canal on the downstream side of each bridge to protect the monitors from large debris. At the Ten Mile Lock site, the monitor was attached to the right retaining wall, 20 feet upstream from the weir. At the Route 18 Spillway site, the monitor is on the right retaining wall just upstream from the end of the canal, near the raw water intakes for two water-treatment plants.

Instantaneous Water-Quality Sample-Collection Sites

The water column in the canal was sampled at seven of the eight study sites. The Route 18 Spillway site could not be used for instantaneous water-quality sampling because flow was not uniform at this site. Also, water was almost always flowing at the Route 18 Spillway on the left bank, which promoted algal growth on the spillway during the study. Therefore, a good cross-section sample of water flowing over the Route 18 Spillway could not be obtained safely because algal growth made the surface of the spillway slippery.

Samples were collected at the centroid of flow upstream from the weir at Ten Mile Lock to avoid collecting a nonrepresentative, aerated sample. At Raven Rock, samples were collected from the upstream side of the bridge, upstream from the feed gates, also to avoid collecting a nonrepresentative, aerated sample. At both of these sampling sites, the canal narrows before water flows through gates or over a weir, which creates excellent stream mixing. At four of the five remaining sites, the samples were collected on the upstream side of the bridge; at the Port Mercer site, the samples were collected on the downstream side of the bridge because no walkway is present on the upstream side.

Water-Quality Sampling

A total of 63 samples were collected at all sites except the Route 18 Spillway during nine sampling rounds--five storms and four nonstorm events. The instantaneous water samples were analyzed for nitrogen species (nitrite, nitrite plus nitrate, ammonia, and ammonia plus organic nitrogen in filtered samples, and ammonia plus organic nitrogen in whole water samples), phosphorous in filtered and unfiltered samples, total suspended solids, suspended organic carbon, dissolved organic carbon, UV 254nm, and 29 VOCs; specific conductance and turbidity were measured in the field. Samples analyzed for VOCs were collected during four storms and four nonstorm events. Three additional sampling rounds were conducted during nonstorm conditions. These samples were analyzed for total suspended solids. Specific conductance, temperature, and turbidity were measured in the field when the three additional nonstorm samples were collected.

Storm condition samples were collected whenever there was sufficient precipitation to cause appreciable runoff into the canal. This criterion was met when more than 0.5 in. of precipitation fell in a 24-hour period over the entire study area. Storm sampling commenced toward the end of the precipitation, and all samples were collected at seven locations in less than 8 hours. The five storm-sampling rounds were conducted on September 8 and October 8, 1998, and on February 2, May 19, and May 25, 1999. Nonstorm sampling rounds were conducted on March 30, June 29, November 12, and December 21, 1998.

All sampling rounds, whether storm or nonstorm, were conducted at least 10 days apart to make each round independent of the others. The 10-day waiting period was not observed for the May 25, 1999, storm-sampling round because of a lack of precipitation during the study time period and the precipitation that occurred on May 19, 1999, was slightly greater than 0.5 inches. The approximate time needed for water to travel the length of the canal is 8 to 10 days.

Water-Quality Monitoring

The water-quality constituents selected for analysis in this study are those that are most likely to be affected by stormwater runoff and that could also affect drinking-water treatment. Maximum Contaminant Levels (MCLs) in drinking water have been issued by the State of New Jersey for nitrate, nitrite, and turbidity. MCLs also have been issued by the State for many of the VOCs analyzed for in canal water during this study (Shelton and Lance, 1999).

Specific conductance also is strongly influenced by precipitation and runoff from snowmelt and road deicing (Hem, 1992). Ammonia, organic nitrogen, suspended organic carbon, and total suspended solids affect drinking-water treatment. Dissolved organic carbon, UV254, and methyl *tert*-butyl ether (MTBE) (one of the 29 VOCs analyzed for) affect the color, taste, and odor of drinking water, which are aesthetic concerns of drinking-water treatment regulated by the State of New Jersey Secondary Maximum Contaminant Levels (Shelton and Lance, 1999). Phosphorous, both dissolved and whole water, is an essential nutrient for plants (Hem, 1992) and can enter the canal from the Delaware River and from precipitation runoff from influent basins. Excessive growth of algae can affect drinking-water taste and odor. Also, excessive growth of rooted plants can reduce the flow of water in the canal (Rutgers University, 1981).

Continuous On-Site Measurements

Turbidity, specific conductance, and temperature were measured by using a multi-parameter water-quality monitor (Yellow Springs Incorporated (YSI) 6000 UPG) with an internal battery source and data logging capability. Each water-quality monitor was programmed to record at 30-minute intervals for the first 3 months of the study period (mid-January 1998 through mid-April 1998), then at 15-minute intervals for the remainder of the study period. The continuous water-quality data were plotted, reviewed, and edited to correct erroneous values. After this review, the data were entered into the USGS

Automated Data Processing System (ADAPS) database, which is part of the USGS National Water Information System (NWIS).

Turbidity.--Turbidity is the measurement of suspended solids in a liquid. The unit of measurement is the nephelometric turbidity unit (NTU), which is determined by focusing a beam of light on the sample water, and then measuring the light that is scattered off the particles. The light source recommended for use by the International Standards Organization is a light emitting diode with a wavelength between 830 and 890 nanometers. The light is detected by a highly sensitive photodiode at a 90^{o} angle from the beam of light (Yellow Springs Incorporated, 1996).

The optical measurements are very susceptible to fouling. For this reason, the turbidity probe on the YSI 6000 UPG comes equipped with a mechanical wiper that rotates on the probe face. This discourages the build up of biological debris and the formation of bubbles from outgassing. The values are calculated from an average of eight readings taken at 4-second intervals (Yellow Springs Incorporated, 1996).

Specific Conductance.--Specific conductance is the ability of a substance to conduct an electrical current. It is the reciprocal of resistivity. The presence of charged ions allows a solution to conduct an electrical current. As the ion concentration increases, the conductance of the solution increases. For this reason conductance provides an indication of ionic strength (Hem, 1992).

The YSI 6000 UPG incorporates a cell with four pure nickel electrodes. Two of the electrodes are current driven, and two are used to measure the voltage drop. The voltage drop is then converted into a conductance value in millisiemens and multiplied by the cell constant to arrive at a value in microsiemens per centimeter (µS/cm) (Yellow Springs Incorporated, 1996).

Temperature.--The YSI 6000 UPG contains a thermistor of sintered metallic oxide which changes predictably in resistance with temperature variations. An algorithm is built into the YSI 6000 UPG software that converts the resistance to temperature in degrees Celsius, Kelvin, or Fahrenheit (Yellow Springs Incorporated, 1996).

Calibration Procedures

All continuous water-quality monitors were calibrated in the New Jersey District field laboratory a few hours prior to deployment in the field to ensure accurate measurements. Once the calibrated monitors were installed at a measurement site, the monitor readings were checked against calibrated portable field meter readings prior to unattended operation. Approximately every 2 weeks, the water-quality readings from the monitors were checked against portable field meter readings, then the monitors were replaced with newly calibrated monitors. This cycle was repeated for the duration of the project. If the difference between readings from the monitor and the field meter was not within acceptable limits, the difference was recorded and a correction or deletion was made to the continuous water-quality records after analysis of the data in the New Jersey District office.

Turbidity.--A two-point calibration, at 0 and 100 NTU, was performed just prior to deployment of the monitor. In most cases, this calibration range is sufficient because the majority of readings occur in this range and the calibration of the sensor is linear between 100 and 1000 NTU (Yellow Springs Incorporated, 1996). The standards were freshly prepared at the time of calibration. Filtered, de-ionized water was used for the 0 NTU standard, and the 4,000 NTU formazin was diluted to prepare the 100 NTU standard. Calibration was performed in the New Jersey District field laboratory, and not in the field, because turbidity is not temperature compensated and formazin turbidity standards change with temperature. The standards provided a means of determining whether adjustments were needed for the previously collected data as a result of calibration drift.

Specific Conductance.--The conductivity of solutions of ionic species is highly dependent on temperature. For this reason, the YSI 6000 UPG monitor uses temperature and raw conductivity values to generate a specific conductance value compensated to 25^{o} C (Yellow Springs Incorporated, 1996). A two-point calibration that bracketed the expected field values was performed in the New Jersey District field laboratory just prior to deployment of the monitor. The field laboratory provided a controlled environment for the monitor and the standards.

Temperature.--No calibration or maintenance of the temperature sensor is required (Yellow Springs Incorporated, 1996). Before initial deployment, a three-point thermistor check of the sensor was performed by using a National Institute for Science and Technology (NIST) traceable thermometer.

Instantaneous Water-Column Water-Quality Sampling

The four nonstorm sampling rounds were conducted by USGS personnel. The five storm sampling rounds were conducted by NJWSA. Employees of the NJWSA, who collected all storm samples, used the methods of collection and field measurements also used by the USGS. USGS personnel performed all sample processing. Both collection and processing were performed following the guidelines set forth in the USGS National Field Manual for the Collection of Water-Quality Data (Wilde and others, 1998). Analyses were performed at the USGS National Water Quality Laboratory (NWQL) in Lakewood, Colorado, with the exception of the analysis for UV254, which was performed at the USGS New Jersey District laboratory (NJWRDL). All water-quality data for the Delaware River at Lumberville, Pa., and at Trenton, N.J., were obtained as part of the USGS-New Jersey Department of Environmental Protection Cooperative Surface Water Quality Ambient Network and were used for comparisons with the water quality in the canal.

Sample collection.--Samples were collected using a weighted bottle sampler equipped with a 1-liter polyethylene bottle and suspended from a polyethylene rope. Samples were collected at equal increments across the canal using depth integration to produce a representative sample. At the Raven Rock and Ten Mile Lock sites, the samples were collected at the centroid of flow, upstream from either the sluice gates or the weir, respectively.

During nonstorm sampling, the sample water was collected at five increments across the canal, composited into a clean 10-liter churn splitter previously rinsed with canal water and taken back to the van for processing on site. During storms, the water was collected in field-rinsed, 1-liter polyethylene bottles and placed on ice to be processed the next day. The samples for organic carbon analysis were collected in baked, amber glass bottles at the centroid of flow about 1-foot below the water surface and placed on ice until processed. The samples for VOCs also were collected at the centroid of flow by using a vendor-certified precleaned disposable teflon bailer and immediately dispensed into baked, amber vials.The vials were examined to be certain that no air was present in the vials after filling; vials were then placed into an ice filled cooler.

Sample processing.--Samples were churned at a uniform rate of about 9 inches per second with care being taken not to break the surface of the water. The baffled piston of the churn was moved up and down a minimum of ten times to ensure proper mixing, and the sample was dispensed into polyethylene bottles that were pre-rinsed twice with de-ionized water (DI) and once with canal water prior to filling for analysis of unfiltered nutrient constituents. The unfiltered nutrient samples were preserved with sulfuric acid (H_2SO_4) to a pH of <2 and immediately chilled.

The sample water was then filtered through a 0.45-µm pore-size disposable Gelman filter pre-conditioned with 1 liter of DI water. The sample bottles also were rinsed twice with DI water and once with filtered canal water prior to filling. These samples were analyzed for dissolved (filtered) constituents. The filtered samples to be analyzed for nutrients were treated with sulfuric acid (H_2SO_4) to a pH of <2. The samples were then chilled.

The samples for analysis of organic carbon and UV254 were filtered in a stainless steel Gelman filter using a 0.45-µm pore-size silver filter. The sample water that passed through the silver filter was collected in baked glass amber bottles, then analyzed for dissolved organic carbon (DOC) and UV254. The suspended organic carbon (SOC) particles were retained on the silver filter, which was placed into a covered petri dish and chilled prior to analysis.

Samples collected during storms and nonstorm conditions were processed in the same manner; however, the storm samples were processed the next day at the USGS field laboratory. The processed samples were shipped overnight to the USGS NWQL. The analysis for UV254 was performed at the NJWRDL.

Laboratory and Field Analyses

Total suspended solids.--Total suspended solids are that part of total solids retained by a filter after drying. A well-mixed sample is filtered through a weighted standard glass-fiber filter, and the residue retained on the filter is dried to a constant weight in an oven at 103 to 105 ^{o}Celsius. The increase in weight of the filter represents the total suspended solids (Eaton and others, 1998).

Whole water and filtered nitrogen species.--The nitrogen species in the analyses included dissolved nitrite (NO_2) as N, dissolved nitrite plus nitrate ($NO_2 + NO_3$) as N, dissolved ammonia (NH_3) as N, and total and dissolved ammonia nitrogen plus organic nitrogen, also called Kjeldahl nitrogen. The whole water represents the total nitrogen species, and the dissolved species are that which pass through a 0.45-µm pore-diameter filter.

Whole water and filtered phosphorous.--Phosphorous is a rather common element in igneous rock and is fairly abundant in sediments. It is a component of sewage and is always present in animal metabolic waste (Hem, 1992). It is present in natural waters and in wastewaters almost solely as phosphate (Eaton and others, 1998). The whole-water sample represents the total phosphorous, and the dissolved phosphorous is that which passes through a 0.45 µm-pore-diameter filter.

Dissolved and suspended organic carbon.--Organic carbon is composed of a variety of organic compounds in various oxidation states (Eaton and others, 1998). Dissolved organic carbon (DOC) is the fraction of total non-volatile organic carbon (TOC) that passes through a 0.45-µm-pore diameter silver filter; suspended organic carbon (SOC) is the fraction of TOC that is retained by the filter.

The method used to measure the DOC is the ultraviolet-promoted persulfate oxidation method. The principle behind this method is that organic carbon is oxidized to carbon dioxide (CO_2) by persulfate in the presence of ultraviolet light. The CO_2 is purged from the sample, dried, and transferred with a carrier gas to a nondispersive infrared spectrometer for measurement (Eaton and others, 1998).

The SOC is detected by the wet-oxidation method. In this method, the sample is acidified, purged to remove inorganic carbon, and oxidized with persulfate in an autoclave to temperatures from 116 to 130 ^{o}C. The resultant CO_2 is then measured by a nondispersive infrared spectrometer (Burkhardt and others, 1997).

Specific conductance.--Specific conductance is the ability of an aqueous solution to conduct an electric current (conductance) of a body of unit length and unit cross-section at a specified temperature (Hem, 1992). The specific conductance measurements were performed both at the USGS NWQL and in the field. The standard temperature for laboratory measurement is 25 ^{o}C. All field measurements were made by using temperature compensated meters.

Ultraviolet absorbance at 254 nanometers.--Some dissolved organic compounds commonly found in water and wastewater strongly absorb ultraviolet (UV) radiation. Ultraviolet radiation is light that has a wavelength of between 100 and 400 nanometers. UV-absorbing organic constituents in a sample absorb UV light in proportion to their concentration. UV absorption is measured at 253.7 nanometers (UV254). Although UV absorption can be used to detect certain individual organic contaminants, UV254 is intended to be used to provide an indication of the aggregate concentration of UV-absorbing organic constituents in filtered sample water (Eaton and others, 1998).

Volatile organic compounds.--The method of analysis used for VOCs is purge and trap gas chromatography/mass spectrometry (GC/MS). This technique involves the transfer of the VOCs from an aqueous phase to a gaseous phase by bubbling an inert gas (such as helium) through a water sample contained in a purging chamber. The vapor is swept through a trap that adsorbs the target compounds or constituents. The trap is then heated and backflushed with the same inert gas to desorb the compounds onto a gas chromatographic column. The gas chromatograph is temperature-programmed to separate the compounds, which are then detected by a mass spectrometer (Connor and others, 1998). During this study, 29 target compounds or constituents were analyzed for in canal water. The analysis used for this project has 29 target compounds for which concentrations were reported and stored in NWIS.

Turbidity.--Turbidity measurements were performed in the field. Turbidity in water is caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, and plankton and other microscopic organisms. Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted with no change in direction or flux level through the sample. The nephelometric method was used during his study; thus the unit of measurement is the nephelometric turbidity unit (NTU). This method consists of using a beam of light to illuminate the sample and a photoelectric detector to indicate the intensity of light scattered at 90^{o} to the path of the incident light (Eaton and others, 1998).

Data Analysis

Continuous Water-Quality Data

All continuously monitored water-quality data collected during this study that met the data-quality objectives of the study are presented in Deluca and others (2000).

Data Preparation.--Continuously monitored turbidity and specific conductance data for the study period (mid-January 1998 to mid-April 1999) were retrieved from the USGS NWIS water-quality database (QWDATA). Initially, the data were electronically recorded at 30-minute intervals. After 3 months, the data were reviewed, and the data-recording interval was reduced to 15 minutes because of rapid changes in turbidity during storms. To make the data for the project compatible for the entire study period, every second value was eliminated from the 15-minute interval data for each site so that the data set would consist of values recorded at 30-minute intervals. Then the retained values were merged with the 30-minute interval data recorded during the first 3 months of the study. The data for all six continuous monitoring sites were then merged into one file to facilitate the analysis for the five stream reaches.

The data had two limitations. First, the continuous water-quality monitoring instruments were subject to failure from time to time, resulting in periods of lost observations throughout the period of this study. Second, a drought emergency was declared by the Delaware River Basin Commission from December 14, 1998, to February 2, 1999 (William E. Harkness, U.S. Geological Survey, written commun., 1998 and 1999), resulting in mandated flow reductions in two steps. Mandated flow was 85 million gallons per day beginning on December 14, 1998, and 70 million gallons per day beginning on December 23, 1998.

Normal flow resumed on February 2, 1999. The reductions in flow during the drought emergency increased the time of travel.

The first data limitation resulted in lost records of net change in a reach defined by upstream and downstream continuous monitoring sites because of instrument failure, which was random and rarely occurred for the same parcel of water passing each site. The upstream data were lagged in time so that the same parcel of water was measured by both the upstream and downstream water-quality monitors. The second limitation required the computation of time-lag values for the periods of unreduced flow, the period after the first flow reduction, and the period after the second flow reduction.

Analysis of the Change in Water Quality in a Reach.--The objective of the analysis of the continuously monitored water-quality data was to determine the mean and median net change in turbidity and specific conductance. A peak in the outflow at the downstream station of a reach was matched with the corresponding peak at the upstream station of a reach to determine the mean travel time in the reach; this travel time was used as the lag time to calculate the difference or net change in turbidity and specific conductance. This process was repeated for each reach for the periods of normal flow and for the period following the second flow reduction (70 percent of normal flow). This approach to interpreting continuously monitored data is possible because the flow rate in the canal is actively controlled to maintain a fairly constant rate within ± 10 percent over long periods of time (months), and relatively few data gaps break the continuous data record. During the drought emergency, the lag time for the short period of the first flow reduction was estimated by averaging the lag time of the normal flow and the lag time of the second flow reduction for each reach.

The mean and median[1] were computed for the series of values of net change for each reach. An estimate of the systematic value is the mean or median (Helsel and Hirsch, 1992). If the estimate of the time of travel is reasonably accurate, the systematic value of the net change in turbidity or specific conductance in a reach represents water quality in the canal altered by water from influent drainage basins, and the biological, chemical, and physical processes that occurred in a reach over long periods (months). The mean of net changes is more likely to be affected by extremely large values, either positive or negative, than is the median.

[1] The median is the value of the fiftieth percentile when the data are arranged in ascending magnitude.

Instantaneous Water-Quality Data

All instantaneous water-quality data were reviewed for sample consistency among related constituents. For example, the total phosphorous concentration should not be less than the filtered phosphorous concentration within a tolerance based on the laboratory analytical precision. All instantaneous water-quality data that passed this data review step were published in Deluca and others (2000) and were included in the statistical evaluation. The data are presented in box plots (Helsel and Hirsch, 1992) as a function of sampling location, water-quality constituent, and storm or nonstorm sample.

The hypothesis tested is that the quality of water in the canal was not affected by the sampling location along the length of the canal, or by storms or nonstorm events. All statistical hypotheses were tested by using nonparametric statistics at a significance level (α) of 0.05. Two types of nonparametric statistical tests were used, both using rank-transformed data--a two-way analysis of variance (ANOVA) (Helsel and Hirsch, 1992) and the Kruskal-Wallis nonparametric test of medians for three or more independent samples (Daniel, 1990). The Tukey multiple comparison test was used to determine whether the median concentration of a constituent at a particular sampling site and during either a storm or nonstorm event was significantly different from the median for another site, storm or nonstorm event when using either the ANOVA or the Kruskal-Wallis tests. First, the hypothesis was tested on the median value for a water-quality constituent by using a two-way ANOVA. The relatively small number of data values from a sampling site for storm or nonstorm event, a maximum of five values, meant that it was likely that for either sampling site or event type the null hypothesis that the medians are statistically the same would be accepted. If the null hypothesis was accepted, the nonsignificant effect was aggregated, and a Kruskal-Wallis nonparametric test was performed, followed by another Tukey multiple-comparison test. Only data that are statistically different are presented in box plots in this report.

Relational Database

For this study, water-quality data were reorganized and formatted into a relational database. Procedures were developed to export data from the NWIS into a fully normalized relational database (hereafter called CanalDB). This section describes the database structure and briefly summarizes the kinds of data it contains.

The water-quality database was structured around a data model that reflects the associations and relations among the various pieces of information that need to be stored and retrieved. The data model was then used to generate the physical database. The data model was designed using the CASE software package, ERwin (version 3.5.2, Platinum Technologies Inc.). Once the model was completed, ERwin was used to generate the physical database in Microsoft Access 97 format.

The CanalDB data model is described in appendix A. All table definitions, and field properties and definitions of the CanalDB, are listed in a data dictionary, which is the primary reference for tables and fields. An entity-relation diagram, which shows how data elements are linked, also is presented in Appendix A (fig. A1). Together, the model diagram and the data dictionary serve as the basic documentation for CanalDB.

Geographical Information System

A geographic information system (GIS) was used to examine the relations between water quality in the canal and drainage basins influent to the Delaware and Raritan Canal. Ellis and Price (1995) delineate drainage basins in New Jersey and identify those basins that are influent to the canal. Their information was augmented with information provided by Camp, Dresser & McKee (1986) and Ebasco (1988) for the feeder section of the canal. Site visits were made with NJWSA personnel to the main canal to verify that all the influent basins for that part of the canal were included in the GIS. The land use within the influent basins also was incorporated into the GIS. New Jersey Department of Environmental Protection (1996) integrated terrain unit (ITU) 1986 land use was used. Additionally, land use was directly interpreted from USGS digital infrared orthophoto quarter quads (DOQs) (U.S. Geological Survey, 2000) for the Als Brook and Duck Pond Run influent basins. For Duck Pond Run Basin, the DOQ source image dates were 1995 (Princeton-southwest and Hightstown-northwest) and 1997 (Princeton-northeast). For Als Brook basin the DOQ source image date was 1995 (Bound Brook-southeast and Plainfield-southwest).

WATER QUALITY OF THE DELAWARE AND RARITAN CANAL

The determination of which reaches of the canal were affected by stormwater runoff is based primarily on the analysis of continuous water-quality monitoring data and field trip observations because the results of the statistical tests were not significant at $\alpha \leq 0.05$.

Samples Collected During Storm and Nonstorm Events

Ammonia and nitrite concentrations in filtered samples from the canal were not compared statistically by using the Kruskal-Wallis nonparametric test for ranked data for the effect of location or storms because the concentrations were censored at the USGS

NWQL method reporting levels of 0.02 and 0.01 mg/L, respectively, for 25 of 62 and 20 of 62 sample analyses. The range of concentrations and median values of nitrite and ammonia for all the sampling sites on the canal during storm and nonstorm events are shown in table 1.

The hypothesis that the quality of water in the canal was not affected by sampling location, or by storms or nonstorm events, was tested for all constituents except ammonia and nitrite by using rank-transformed data in a two-way ANOVA. The two explanatory variables (treatments) were type of sampling event and sampling location. No statistically significant difference was indicated for the median of any constituent in a two-way ANOVA. A relatively small number of replicates in each cell of the ANOVA, a maximum of five values, resulted in a statistically significant difference for only one of the explanatory variables because of the relatively large range in concentrations. Therefore, the values of the nonsignificant explanatory variable with the largest significance level were aggregated, and the Kruskal-Wallis test (equivalent to a one-way ANOVA) was performed for each constituent except ammonia and nitrite.

Suspended organic carbon (SOC) was the only constituent for which the median concentration at each sampling site differed significantly ($\alpha \leq 0.05$) from that at the other six sites (fig.5). The median concentrations of SOC at the three sampling locations on the feeder part of the canal (Raven Rock, Brookville, and Lower Ferry Road) were significantly greater than that at Ten Mile Lock, which is on the main part of the canal. The median concentrations of SOC in samples collected at Port Mercer, Griggstown, and Landing Lane Bridge were not significantly different ($a > 0.05$) from those at the three sites on the feeder part of the canal or at Ten Mile Lock.

The interquartile range (the value at the 75th percentile less the value at the 25th percentile, shown as the upper and lower ends of the box in the box plot) of SOC for samples collected at the three sites on the feeder part of the canal is larger than the interquartile range for samples from the other sites on the main part of the canal, except for Landing Lane Bridge (fig. 5). The lowest average velocity, 0.22 ft/s, of the six reaches defined by continuous water-quality monitor sites was measured between Ten Mile Lock and the Route 18 Spillway. Therefore, the large

Table 1. Maximum, median, and minimum concentrations of nitrite and ammonia in storm and nonstorm samples from all sampling sites on the Delaware and Raritan Canal, N.J.

Constituent	Data summary descriptor	Concentration during event (mg/L)	
		Storm	Nonstorm
Nitrite as N	Maximum	0.028	0.023
	Median	.011	.0135
	Minimum	[1]<.01	[1]<.01
Ammonia as N	Maximum	.16	.093
	Median	.0375	.02
	Minimum	[1]<.02	[1]<.02

[1]Laboratory reporting level

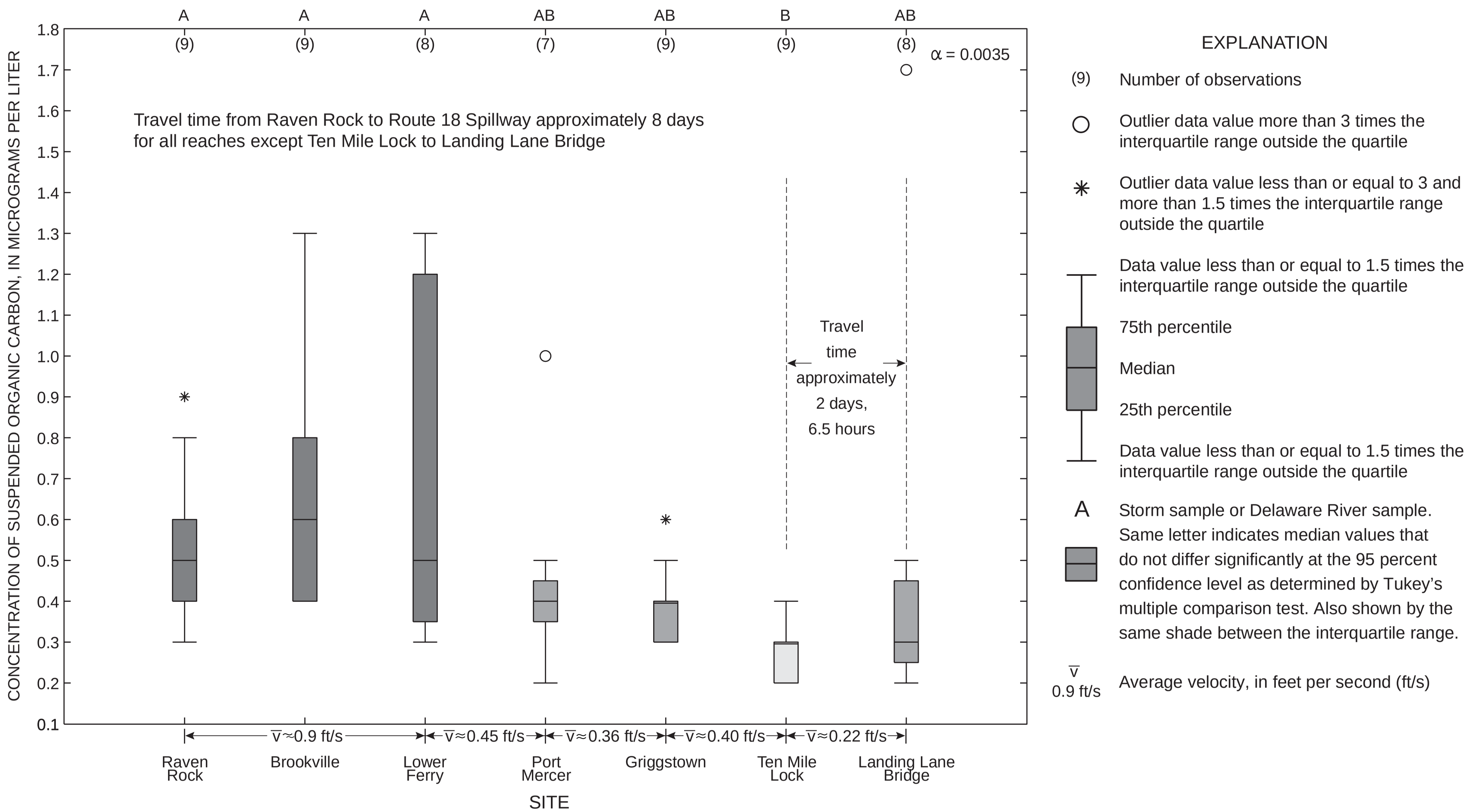


Figure 5. Distributions of concentrations of suspended organic carbon in samples collected during storms and nonstorm conditions at sites on the Delaware and Raritan Canal, N.J., 1998-99.

interquartile range for SOC in samples collected at Landing Lane Bridge would not be caused by inflows to the canal upstream from Ten Mile Lock because the particles that are larger than clay particles and that have a density greater than that of water would tend to settle and not be transported to Landing Lane Bridge in the approximately 2.27 days needed for canal water to go from Ten Mile Lock to Landing Lane Bridge, which is approximately 0.22 miles upstream from the Route 18 Spillway.

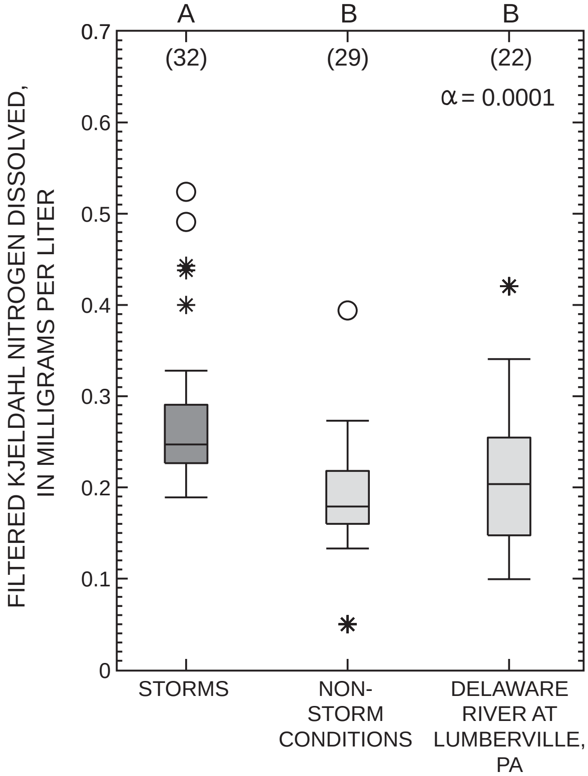
When compared statistically by using the Kruskal-Wallis test (Daniel, 1990), stormwater that entered the canal significantly ($\alpha < 0.05$) changed the median value of ammonia plus organic nitrogen (fig. 6), organic carbon (fig. 7), and UV254 (fig. 8; table 2) in filtered water samples collected during storms from that collected during nonstorm sampling. Median concentrations of nitrite plus nitrate (fig.9) and phosphorus (fig. 10; table 2) in filtered samples collected during storms were not significantly different ($\alpha > 0.05$) from those in filtered samples collected during nonstorm conditions.

The following water-quality constituents analyzed for in whole-water samples collected from the canal during storms had medians that were significantly larger ($a \leq 0.05$) than the medians of nonstorm samples: phosphorus (fig. 11), turbidity (fig.12), ammonia plus organic nitrogen (fig. 13) (table 2). The following constituents analyzed for in whole water or unfiltered samples collected during storms did not have medians that were significantly larger ($a > 0.05$) than the medians for samples collected during nonstorm events: specific conductance (fig. 14), suspended organic carbon (fig. 15), MTBE (fig. 16), and total suspended solids (figure 17; table 2).

Storms that produced runoff to the canal were shown to significantly affect the median concentrations of 6 of the 12 water-quality constituents that were statistically evaluated (table 2). Median concentrations of total and dissolved ammonia plus organic nitrogen increased during storms. Because concentrations of ammonia are relatively small, ammonia plus organic nitrogen is important to the quality of stormwater that enters the canal. The median concentration of total phosphorous increased during storms, and the median concentration of dissolved phosphorous did not (dissolved phosphorous concentrations were small). Thus, particulate phosphorous is an important factor in the quality of stormwater that enters the canal. The median concentration of total suspended solids did not increase during storms; however, the median concentration of turbidity did increase during storms. This seeming inconsistency in the results was probably caused by the poorer precision in measuring total suspended solids than in measuring turbidity. Total suspended solids are reported to one significant figure, and turbidity is reported to two significant figures.

A comparison was made of aggregated water-quality data from all sampling sites on the canal and data from the Delaware River near the intake of the canal, by constituent. The sampling site on the Delaware River at Lumberville, Pa., which is 0.7 miles downstream from the intake, is the site with water-quality data that is closest to the intake. Water-quality data for this site are available for all constituents studied, except for VOCs and field measured tubidity. The sampling site on the Delaware River, nearest the intake, with data on VOCs is the Delaware River at Trenton, N.J., which is approximately 20 miles downstream from the intake. Field measured turbidity data for the Delaware River were not available for comparison with the turbidity data for the canal.

Median values of all constituents except ammonia, nitrite, and dissolved phosphorous in nonstorm samples from the canal were not significantly different ($\alpha > 0.05$) from that in samples collected from the Delaware River at Lumberville, Pa., during a 5-year period (water years 1995 through 1999) during storms and nonstorm events. Storms with precipitation of more than 0.5 inches in one day are relatively rare and occurred at Trenton, N.J., for about 7 percent of the storms during the period of record for this rain gage, 1913-81 (R.D. Schopp, U.S. Geological Survey, written commun., 1999). Concentrations of ammonia, nitrite, and dissolved phosphorous in filtered water from



EXPLANATION

(29) Number of observations

Outlier data value more than 3 times the interquartile range outside the quartile

Outlier data value less than or equal to 3 and more than 1.5 times the interquartile range outside the quartile

Data value less than or equal to 1.5 times the interquartile range outside the quartile

75th percentile

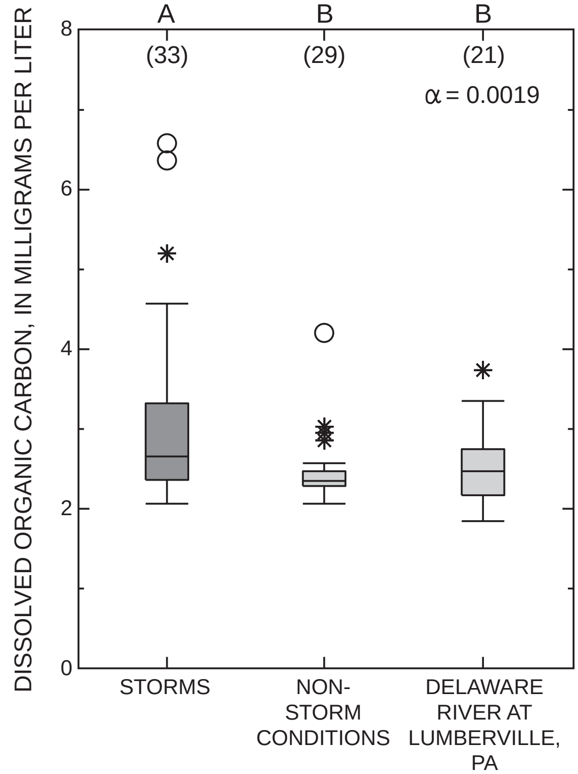
Median

25th percentile

Data value less than or equal to 1.5 times the interquartile range outside the quartile

A Storm sample or Delaware River sample. Same letter indicates median values that do not differ significantly at the 95 percent confidence level as determined by Tukey's multiple comparison test. Also shown by the same shade between the interquartile range.

Figure 6. Distribution of concentrations of ammonia plus organic nitrogen in filtered samples collected during storms and nonstorm conditions from the Delaware and Raritan Canal, N.J., and the Delaware River at Lumberville, Pa.



EXPLANATION

(29) Number of observations

Outlier data value more than 3 times the interquartile range outside the quartile

Outlier data value less than or equal to 3 and more than 1.5 times the interquartile range outside the quartile

Data value less than or equal to 1.5 times the interquartile range outside the quartile

75th percentile

Median

25th percentile

Data value less than or equal to 1.5 times the interquartile range outside the quartile

A Storm sample or Delaware River sample. Same letter indicates median values that do not differ significantly at the 95 percent confidence level as determined by Tukey's multiple comparison test. Also shown by the same shade between the interquartile range.

Figure 7. Distribution of concentrations of dissolved organic carbon in samples collected during storms and nonstorm conditions from the Delaware and Raritan Canal, N.J., and the Delaware River at Lumberville, Pa.

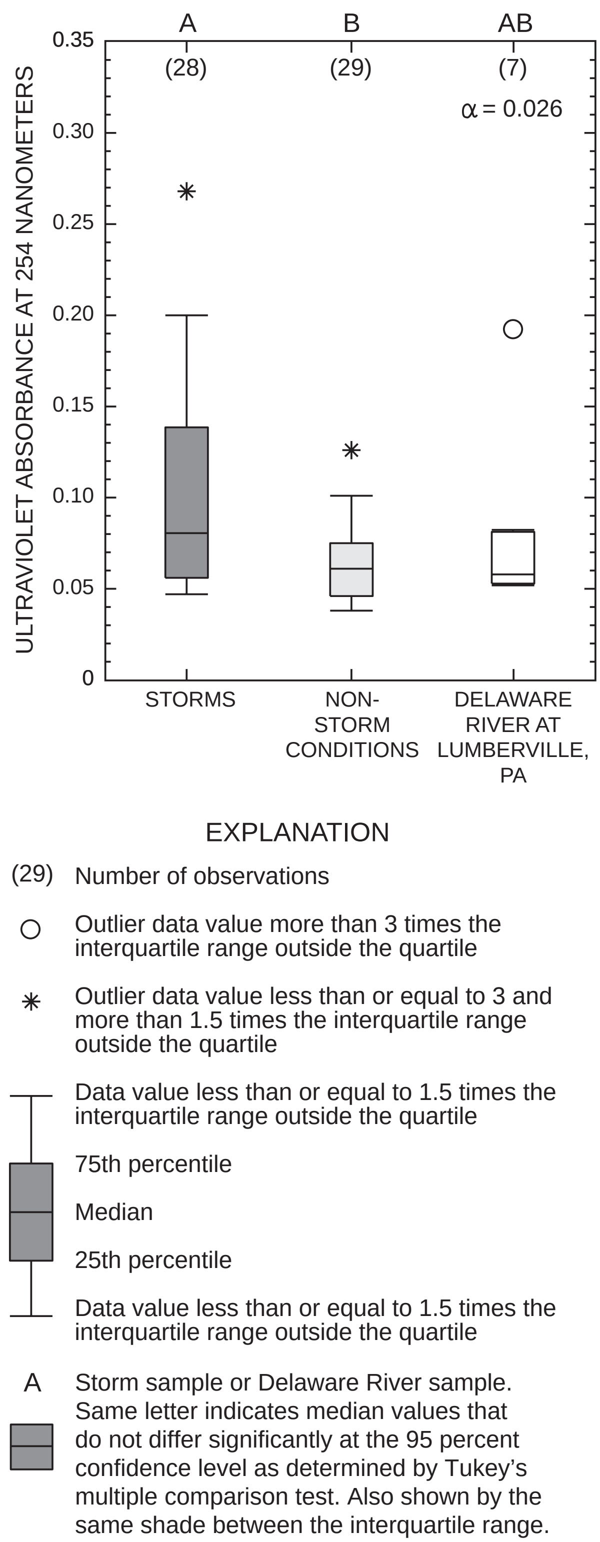


Figure 8. Distribution of ultraviolet absorbance at 254 nanometers in filtered samples collected during storms and nonstorm conditions from the Delaware and Raritan Canal, N.J., and the Delaware River at Lumberville, Pa.

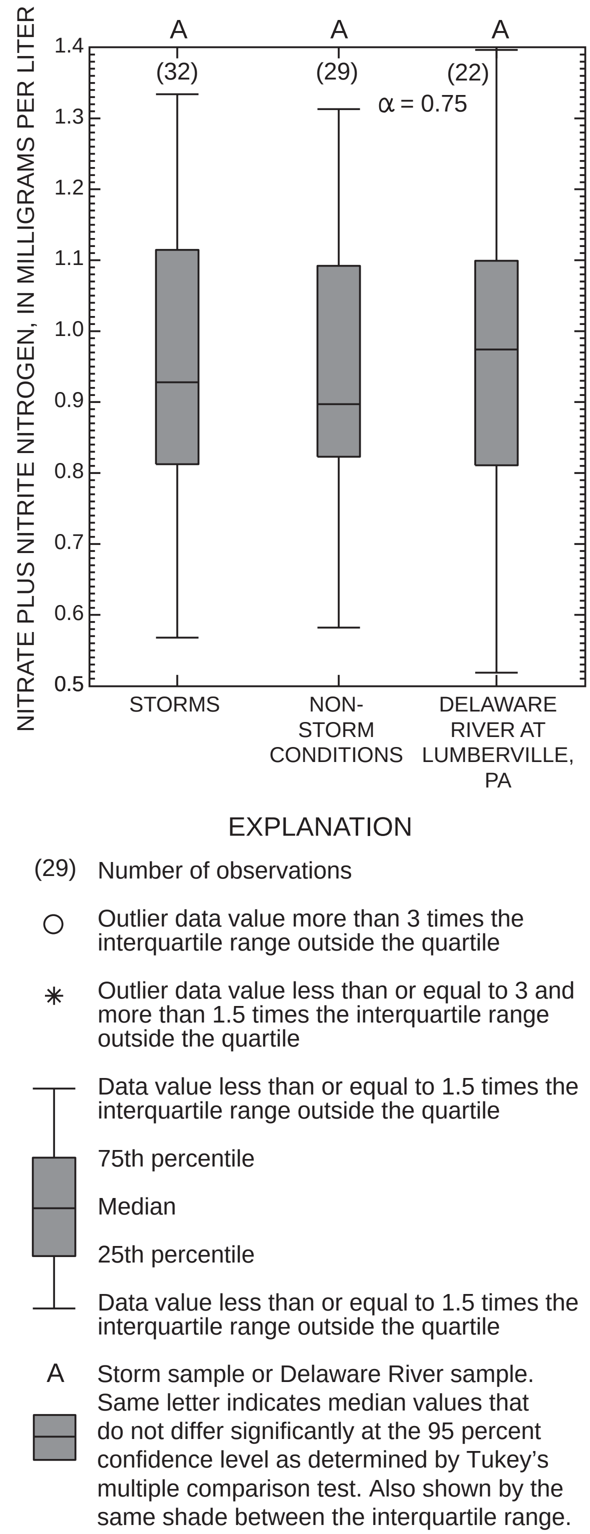


Figure 9. Distribution of concentrations of nitrate plus nitrite nitrogen in filtered samples collected during storms and nonstorm conditions from the Delaware and Raritan Canal, N.J., and the Delaware River at Lumberville, Pa.

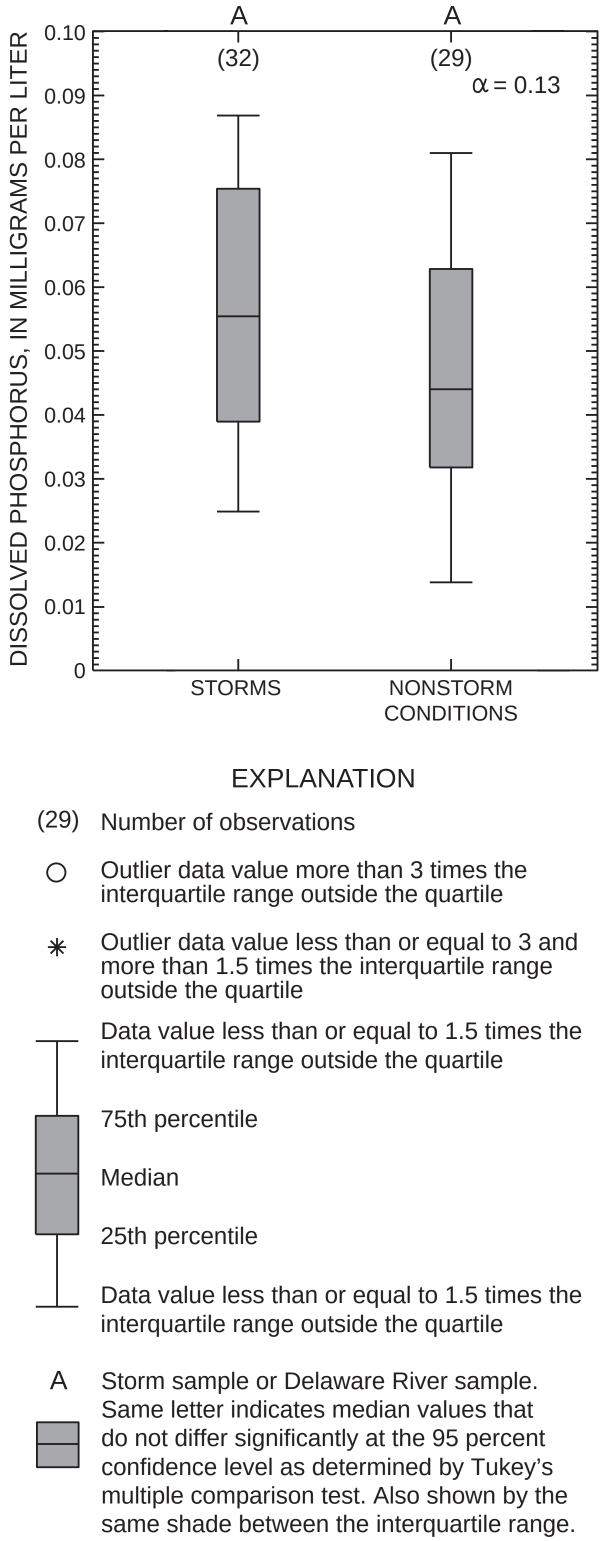


Figure 10. Distribution of concentrations of phosphorus in filtered samples collected during storms and nonstorm conditions from the Delaware and Raritan Canal, N.J.

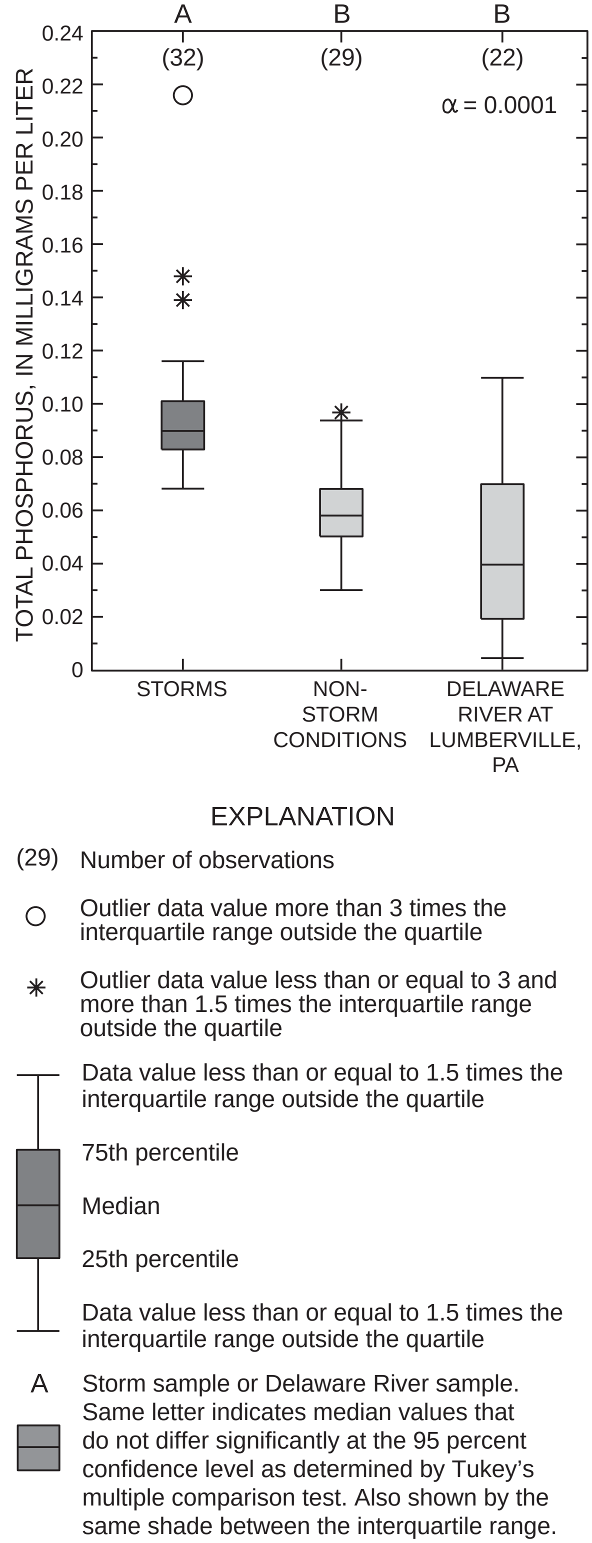


Figure 11. Distribution of concentrations of total phosphorus in samples collected during storms and nonstorm conditions from the Delaware and Raritan Canal, N.J., and the Delaware River at Lumberville, Pa.

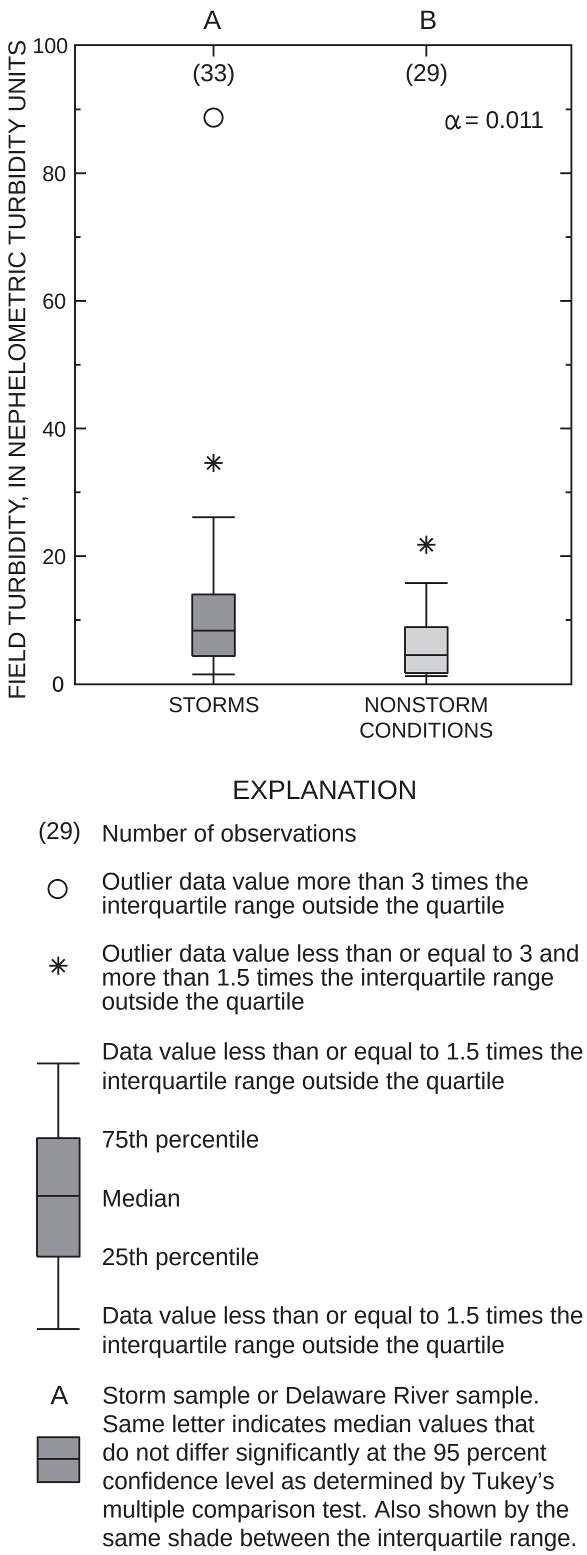


Figure 12. Distribution of field turbidity in samples collected during storms and nonstorm conditions from the Delaware and Raritan Canal, N.J.

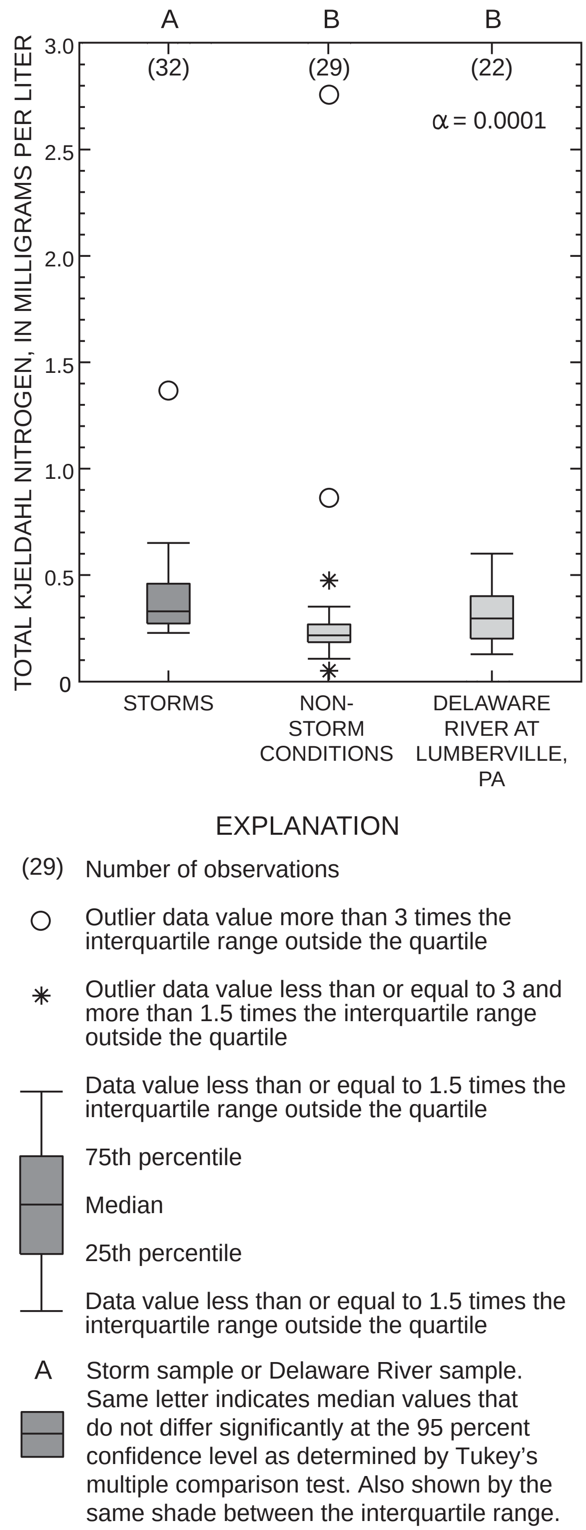
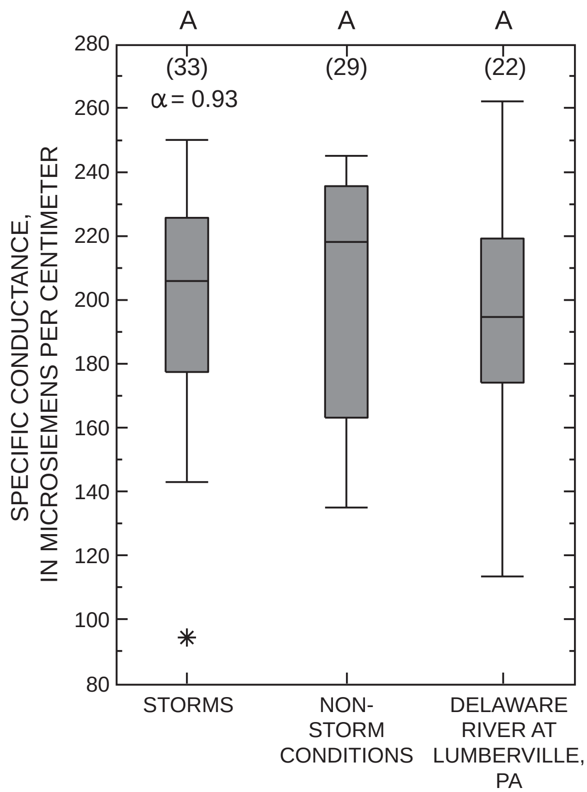


Figure 13. Distribution of concentrations of total ammonia plus organic nitrogen in samples collected during storms and nonstorm conditions from the Delaware and Raritan Canal, N.J., and the Delaware River at Lumberville, Pa.



EXPLANATION

(29) Number of observations

○ Outlier data value more than 3 times the interquartile range outside the quartile

✳ Outlier data value less than or equal to 3 and more than 1.5 times the interquartile range outside the quartile

Data value less than or equal to 1.5 times the interquartile range outside the quartile

75th percentile

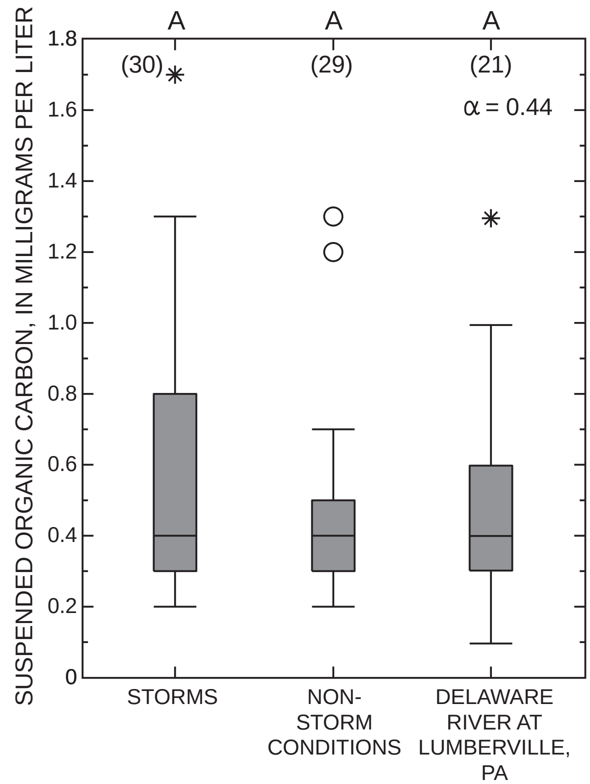
Median

25th percentile

Data value less than or equal to 1.5 times the interquartile range outside the quartile

A Storm sample or Delaware River sample. Same letter indicates median values that do not differ significantly at the 95 percent confidence level as determined by Tukey's multiple comparison test. Also shown by the same shade between the interquartile range.

Figure 14. Distribution of specific conductance in samples collected during storms and nonstorm conditions from the Delaware and Raritan Canal, N.J., and the Delaware River at Lumberville, Pa.



EXPLANATION

(29) Number of observations

○ Outlier data value more than 3 times the interquartile range outside the quartile

✳ Outlier data value less than or equal to 3 and more than 1.5 times the interquartile range outside the quartile

Data value less than or equal to 1.5 times the interquartile range outside the quartile

75th percentile

Median

25th percentile

Data value less than or equal to 1.5 times the interquartile range outside the quartile

A Storm sample or Delaware River sample. Same letter indicates median values that do not differ significantly at the 95 percent confidence level as determined by Tukey's multiple comparison test. Also shown by the same shade between the interquartile range.

Figure 15. Distribution of concentrations of suspended organic carbon in samples collected during storms and nonstorm conditions from the Delaware and Raritan Canal, N.J., and the Delaware River at Lumberville, Pa.

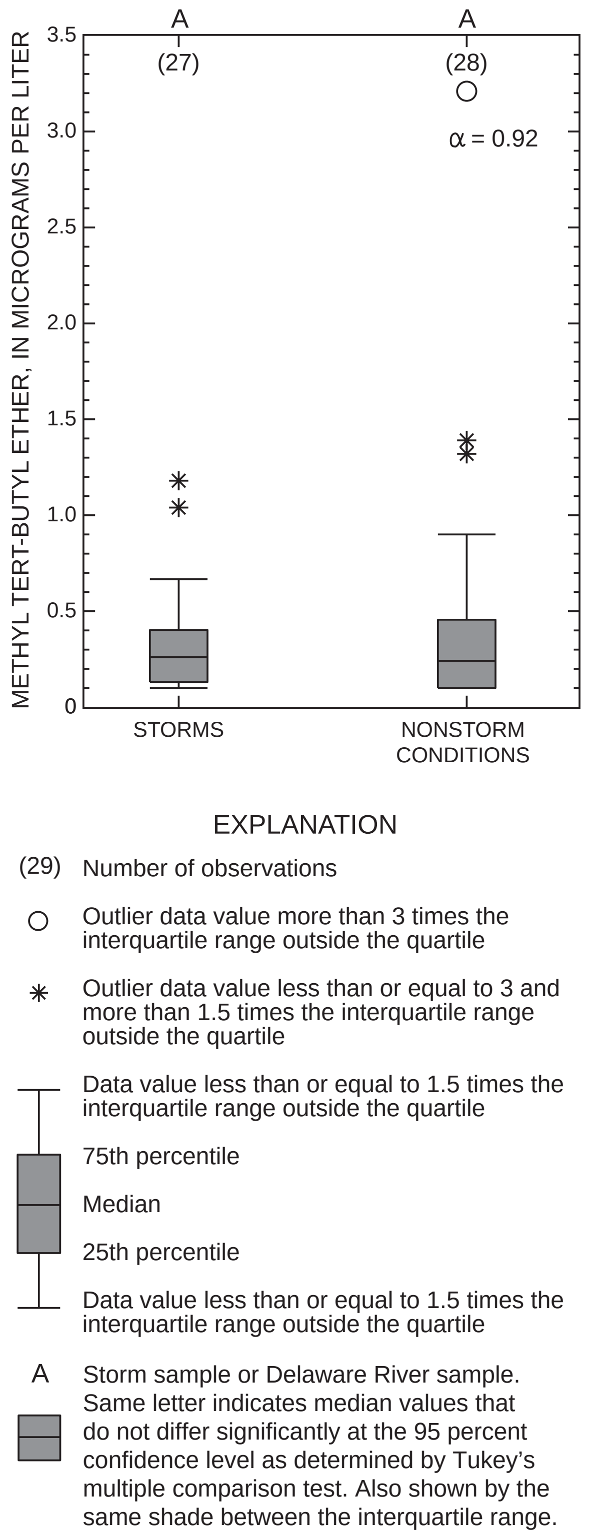


Figure 16. Distribution of concentrations of methyl tert-butyl ether in samples collected during storms and nonstorm conditions from the Delaware and Raritan Canal, N.J.

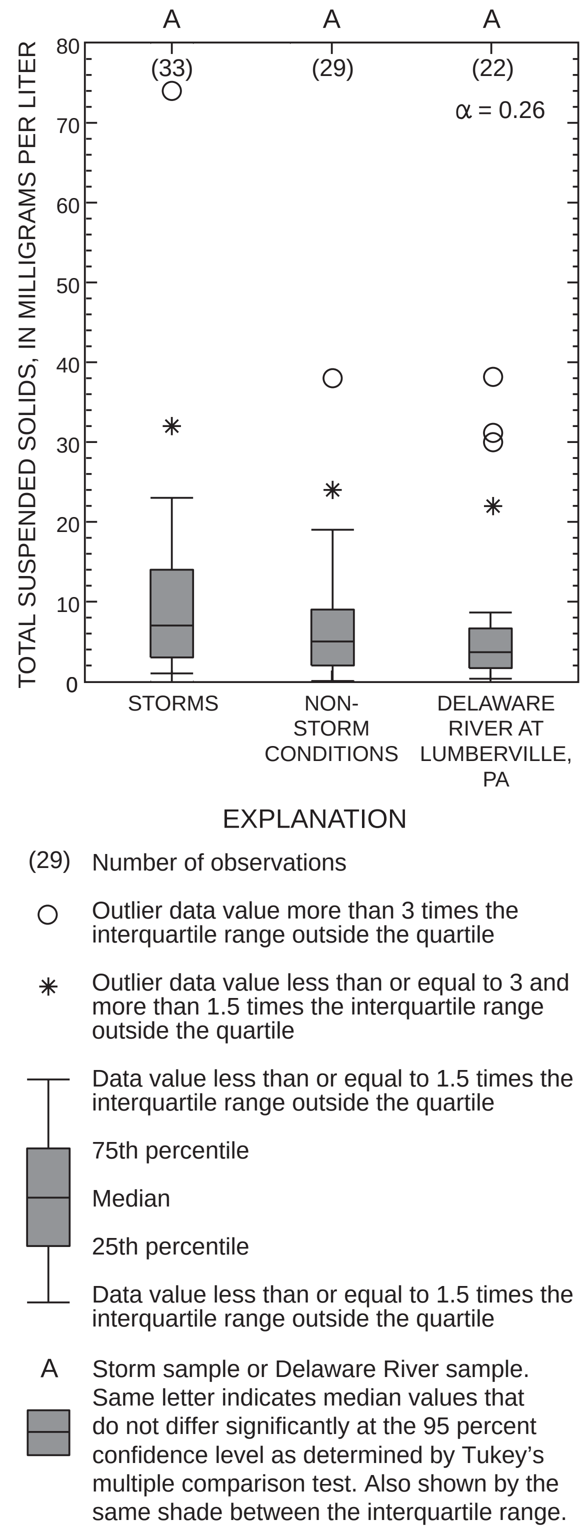


Figure 17. Distribution of concentrations of total suspended solids in samples collected during storms and nonstorm conditions from the Delaware and Raritan Canal, N.J., and the Delaware River at Lumberville, Pa.

Table 2. Results of the Kruskal-Wallis test on median values of constituents in storm and nonstorm samples from all sampling sites on the Delaware and Raritan Canal, N. J.
[--, no data; nm, nanometers]

Constituents in filtered water	Statistically significant difference in median values (storm median value was greater than nonstorm median value)	Kruskal-Wallis test, alpha value	Constituents in unfiltered or whole water	Statistically significant difference in median values (storm median value was greater than nonstorm median value)	Kruskal-Wallis test, alpha value
Ammonia	No statistical test	--	Ammonia plus organic nitrogen	Yes	.0001
Ammonia plus organic nitrogen	Yes	.0001	Methyl tert-butyl ether (MTBE)	No	.92
Nitrite	No statistical test	--	Phosphorus	Yes	.0001
Nitrite plus nitrate	No	.75	Specific conductance	No	.93
Organic carbon	Yes	.0019	Suspended organic carbon	No	.44
Phosphorus	No	.13	Total suspended solids	No	.26
Ultraviolet absorbance at 254 nm	Yes	.026	Turbidity	Yes	.011

the canal were not compared to that from the Delaware River at Lumberville because either the data were highly censored or the laboratory reporting levels were changed. Phosphorus in filtered-water samples was not statistically evaluated because the laboratory lower reporting level was increased from 0.01 to 0.05 mg/L on October 1, 1998 (the beginning of water year 1999) (U.S. Geological Survey, 1998). The percentage of censored values of phosphorous in filtered water to the total number of analyses of phosphorous in filtered-water samples collected from the Delaware River at Lumberville during water years 1995-99 is 4 percent. The change in laboratory reporting level resulted in an increase in the percentage of censored values of phosphorous analyzed for in filtered-water samples from the canal during 1998-99 to 8 percent.

Only 6 of 29 VOCs were detected in 55 samples of canal water by using purge and trap GC/MS analysis with a method reporting level of 0.2 µg/L. MTBE was detected in 43 samples; the highest concentration was 3.2 µg/L. Toluene was detected in five samples; the highest concentration was 0.7 µg/L. Chloroform was detected in four samples, and all the concentrations were approximately 0.1 µg/L. Methylene chloride, ortho-Xylene, and meta- plus para-Xylenes were detected once each at concentrations of 0.1, 0.2, and 0.5 µg/L, respectively. The highest concentration of MTBE and the greatest number of analytes were detected in a nonstorm sample collected at Brookville. None of the 55 samples contained a VOC concentration that exceeded U.S. Environmental Protection Agency or State of New Jersey Primary Drinking Water Maximum Contaminant Levels.

A statistical comparison was performed on concentrations of MTBE in samples from the canal and in samples from the Delaware River at Trenton collected during water years 1995-99 (fig. 18). Results of the statistical comparison of the medians of MTBE concentrations for the two sites indicated that they were not significantly different ($\alpha > 0.05$).

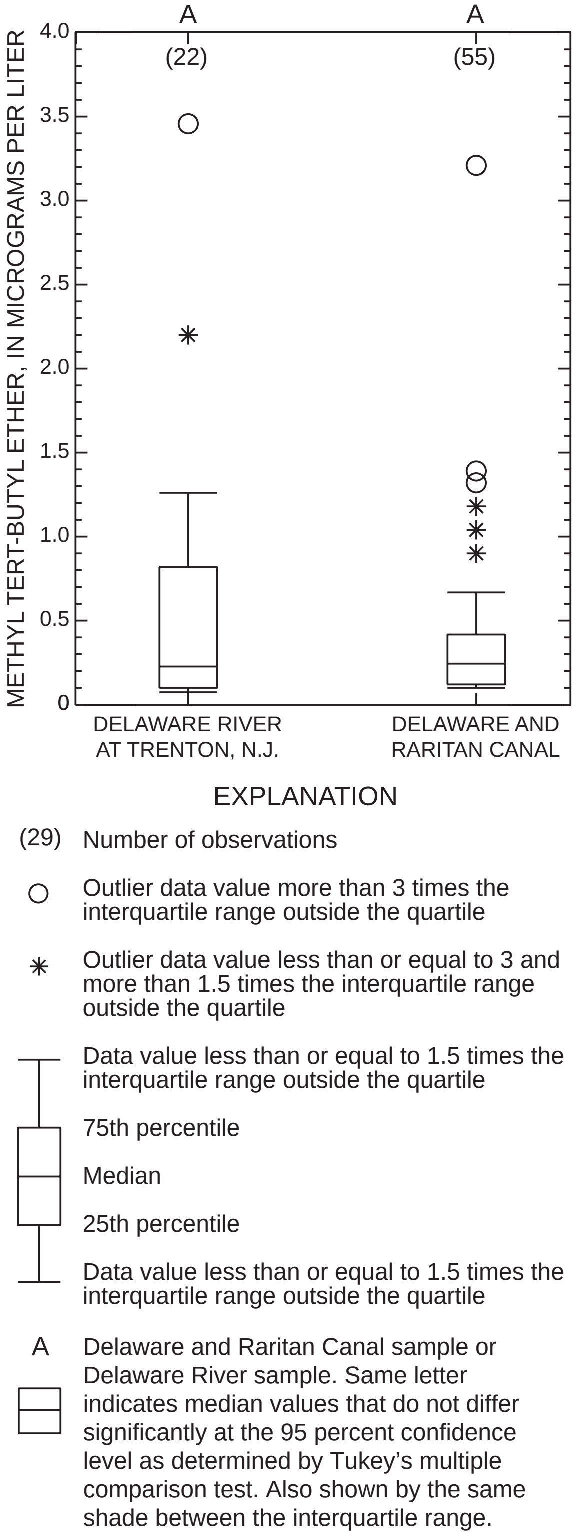


Figure 18. Distribution of concentrations of methyl tert-butyl ether in samples collected from the Delaware River at Trenton, N.J., during water years 1995-99 and the Delaware and Raritan Canal, N.J., during water years 1998-99.

The results of the nonparametric two-way ANOVA tests showed that the water quality at one sampling location was not more affected by stormwater runoff into the canal than at any of the other six sampling locations. The instantaneous water-quality data did not reveal a pattern of water-quality change that would narrow the focus of a future more detailed investigation into the effects of stormwater runoff on the water quality of a particular reach of the canal.

Continuous Water-Quality Monitoring

The six continuous water-quality monitoring locations divide the canal into five reaches that cover almost the entire length of the canal. Water temperature (T), specific conductance (SC), and turbidity were recorded every 30 minutes for approximately 1 year and 3 months, from February 1998 to May 1999. The data on SC are summarized in figure 19 and on turbidity in figure 20. Temperature was used solely to correct the specific conductance to the reference temperature of 25 ^{o}Celsius. Daily maximum, minimum, and mean of water temperatures are reported in Deluca and others (2000) and stored in CanalDB.

The data from an upstream location were lagged in time so that upstream and downstream sensors measured the same parcel of water. The upstream measurement value was subtracted from the downstream value to obtain the net change in turbidity or SC that occurred in each reach bounded by two continuous water-quality monitors. This approach to interpreting continuously monitored data is possible because the flow rate in the canal is actively controlled to maintain a fairly constant flow rate within $\pm$ 10 percent over long periods of time (weeks), and relatively few gaps break the continuous data record.

The population of net changes in turbidity or SC for the period of record of this study has a systematic value and plus or minus some amount of random variability. If the estimate of the time of travel is reasonably accurate, the systematic value represents turbidity or SC in a reach of the canal that has been altered by water from influent drainage

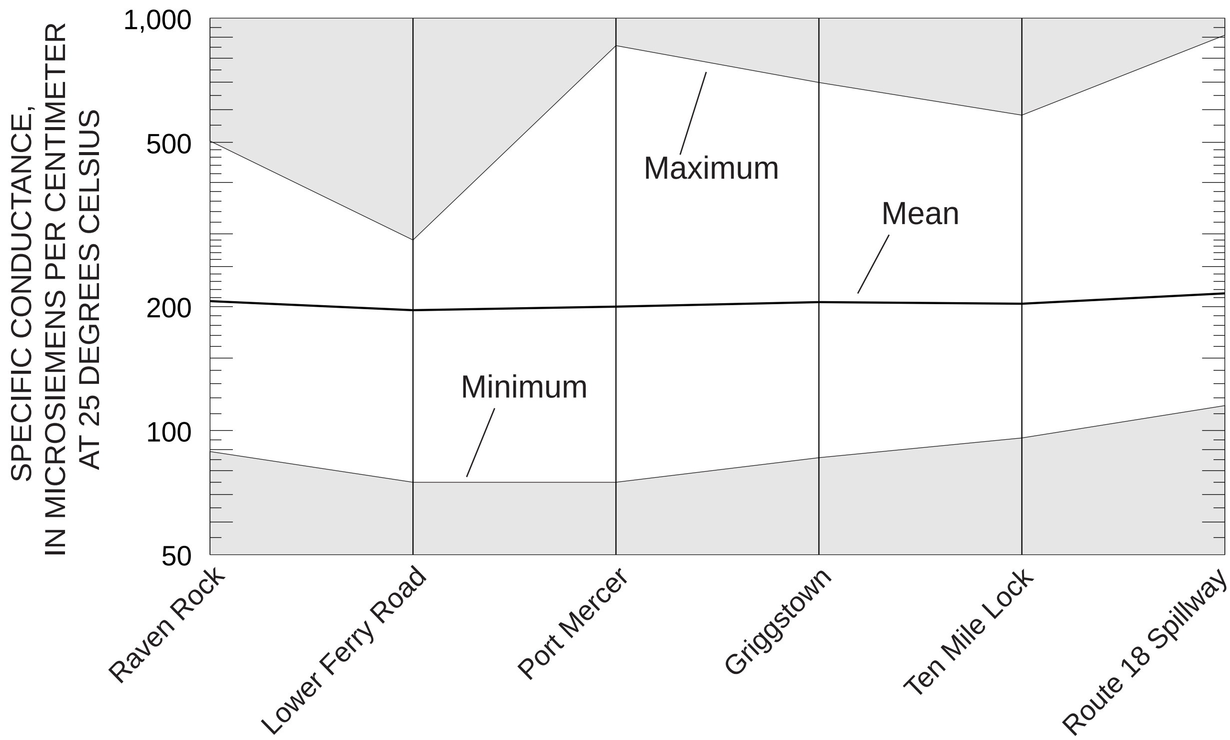


Figure 19. Minimum, maximum, and mean of continuously monitored specific conductance at six sampling locations along the length of the Delaware and Raritan Canal, N.J., February 1998 to May 1999.

basins, as well as the biological, chemical, and physical processes that occurred in a reach over long periods of time (months). The mean is more likely to be affected by extremely large values of net change than is the median.

A comparison of the mean and median of a population reveals information about the distribution of values of the population. If the mean and median values are not similar, then the population has a small percentage of extremely large or small values that affect the mean more than the median (Helsel and Hirsch, 1992). The relation between the mean and median of the population of net changes in turbidity or SC in a reach can be used to infer whether or not measurable effects of storms had occurred.

Specific Conductance

The range and mean of continuously monitored SC for the project period of record are shown in figure 19. The mean SC changed little along the length of the canal; during the period of record the mean ranged from 196 µS/cm at Lower Ferry Road to 215 µS/cm at the Route 18 Spillway. The minimum value of SC ranged from 75 µS/cm at Port Mercer to 115 µS/cm at Route 18 Spillway. The minimum values of SC for canal water can be compared to the SC of precipitation at Washington Crossing, N.J., which has a seasonal precipitation-weighted mean of 24 and 18 µS/cm for 1998 and 1999, respectively (National Atmospheric Deposition Program (NRSP-3)/National Trends Network 2000, 2000). Maximum SC is greater downstream from influent basins with a large percentage of urban land use, 858 µS/cm at Port Mercer and 991 µS/cm at Route 18 Spillway, than downstream from influent basins with a large percentage of non-urban land use, 290 µS/cm at Lower Ferry Road.

The mean and median of net changes in SC for the five reaches that constitute almost the entire length of the canal are shown

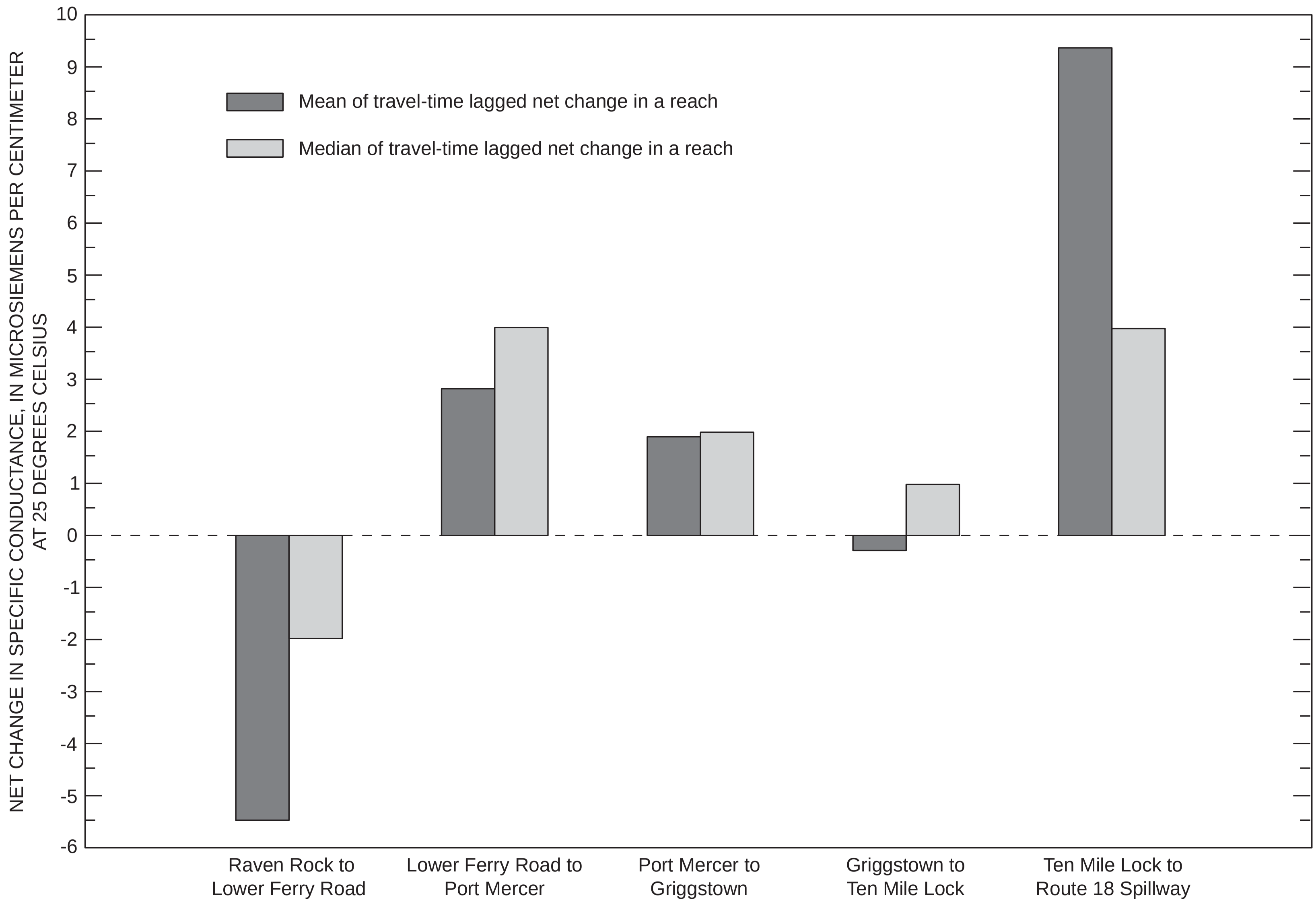


Figure 20. Mean and median of the travel-time lagged net changes in specific conductance in the five reaches of the Delaware and Raritan Canal, N.J., February 1998 to May 1999.

in figure 20. The change in SC in the reach between Raven Rock and Lower Ferry Road shows the effect of stormwater runoff from the influent basins of Lockatong and Wickecheoke Creeks. These two influent drainage basins with a combined drainage area of 31,802 acres compose the largest drainage area in the study area. When the water from the Lockatong and Wickecheoke Creeks that has a SC lower than the canal water enters the canal, the SC of canal water at Lower Ferry Road is reduced by approximately 5.5 μS/cm for the mean value and 2.5 μS/cm for the median value for the project period of record. The differing values of the mean and the median net change in SC in a reach indicate that a small number of extreme values of net change in SC have affected the mean more than the median; therefore, the decreases in SC are associated with storms and stormwater with a lower SC that enters this reach of the canal.

If a net change of 5 μS/cm were determined by a few field measurements, the net change would be within ± 3 percent of the reading, the accepted measurement accuracy for SC (Radtke and others, 1998). The mean net change in the reach between Raven Rock and Lower Ferry Road is significant because the mean is the central value of a population of tens of thousands of measurements. The continuous-monitoring mean SC is supported by the field measurements for SC at Brookville, which is immediately downstream from the confluence of the Wickecheoke Creek and the canal (fig. 4). The means of storm and nonstorm field measured SC values, which are based on five and four measurements, respectively, differed by approximately 15 μS/cm.

In the canal reach between Lower Ferry Road and Port Mercer, SC increased to a mean of 2.7 μS/cm and a median of 4μS/cm for the net changes. A review of the continuous data record of the lagged net changes showed that an increase in SC in this reach occurred mostly during nonstorm conditions. The net change in SC that occurred in this reach under nonstorm conditions can be deduced from the agreement between the mean and median values of the net change in SC (fig. 20). A possible source of high SC water in this reach is domestic or industrial wastewater that continuously discharges into pipes, which empty into the Delaware and Raritan Canal, and ground water that flows from areas within this reach where the water table is higher than the surface-water level of the Delaware and Raritan Canal.

The mean and median of the net change in SC between Port Mercer and Griggstown both increased about 1.9 μS/cm (fig. 20). Duck Pond Run is the largest influent drainage basin in this reach. During 1998-99, this basin was undergoing change from agricultural and forested land uses to urban land use.

Net changes in SC in the reach between Griggstown and Ten Mile Lock are small, -0.25 μS/cm for the mean and 0.9 μS/cm for the median. Only five small influent drainage basins with a total area of 1,038 acres drain into the canal in this reach.

The greatest net change in SC in the five reaches, an increase of 9.3 and 4.0 μS/cm for the mean and median values of the period of record of this project, respectively, occurred in the most downstream reach between the Ten Mile Lock and Route 18 Spillway. A mean value much larger than the median value of net change in SC indicates that the net change in SC is associated with precipitation runoff from the two largest influent basins in this reach, the Borough of South Bound Brook and Als Brook. The primary land use in the basins influent to this reach of the canal is urban, and many storm drains in this area empty road runoff into the canal. The fourth largest influent drainage basin, Als Brook, drains into the canal about 1.34 miles upstream from the Route 18 Spillway.

Turbidity

The maximum and minimum turbidity for the six continuous water-quality monitoring sites is 960 and 0.3 NTU, respectively (fig. 21). The mean value of the continuously monitored turbidity data for the duration of the study increased from

11.8 NTU at Raven Rock to 19.6 NTU at Lower Ferry Road, then gradually decreased downstream to 8.6 NTU at the Route 18 Spillway (fig. 21).

The mean and median of net changes in turbidity for the five reaches are shown in figure 22. The reach between Raven Rock and Lower Ferry Road shows the effect of the influent basins of Lockatong and Wickecheoke Creeks. When the water from the Lockatong and Wickecheoke Creeks with higher turbidity entered the canal, the turbidity at Lower Ferry Road increased over the turbidity at Raven Rock by approximately 7.3 NTU for the mean value and 6.1 NTU for the median value of the project period of record. The average velocity of the canal water in this reach was estimated to be 0.9 ft/s. This average velocity was less than the commonly accepted 1.5 ft/s needed to transport sand.

The canal water between Lower Ferry Road and Port Mercer underwent a net change in turbidity for the project period of record of -4 NTU for the mean and -3.4 NTU for the median. The average velocity of the canal water in this reach is estimated to be 0.45 ft/s. Significant attenuation of turbidity occurred in this reach. A new housing development was under construction near the canal about 0.25 miles upstream from the Port Mercer continuous water-quality monitor. After and during a storm, a plume of high-turbidity water was visible coming from a storm drain, which received overland flow from the construction site, and entering the canal on the right bank, then hugging the right bank. This source of turbid water will probably be

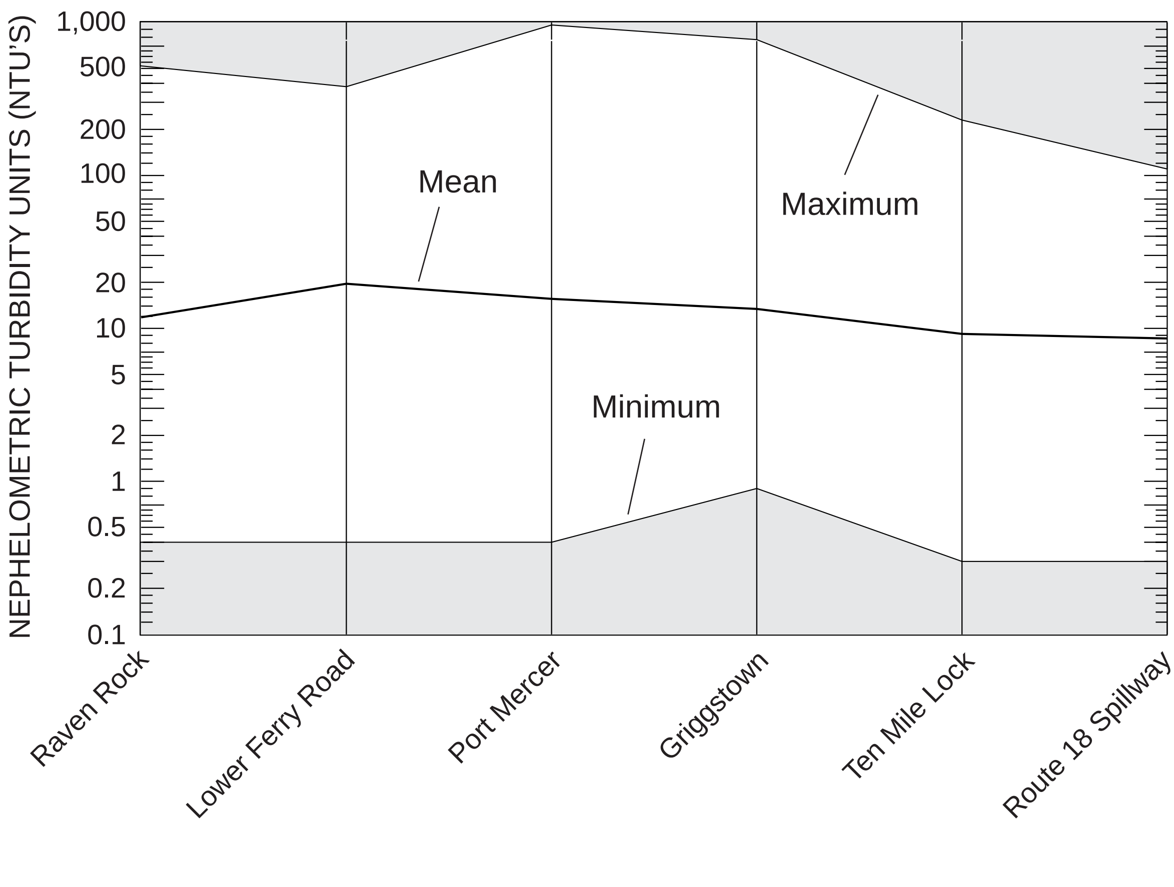


Figure 21. Minimum, maximum, and mean of continuously monitored turbidity at six sampling locations along the length of the Delaware and Raritan Canal, N.J., February 1998 to May 1999.

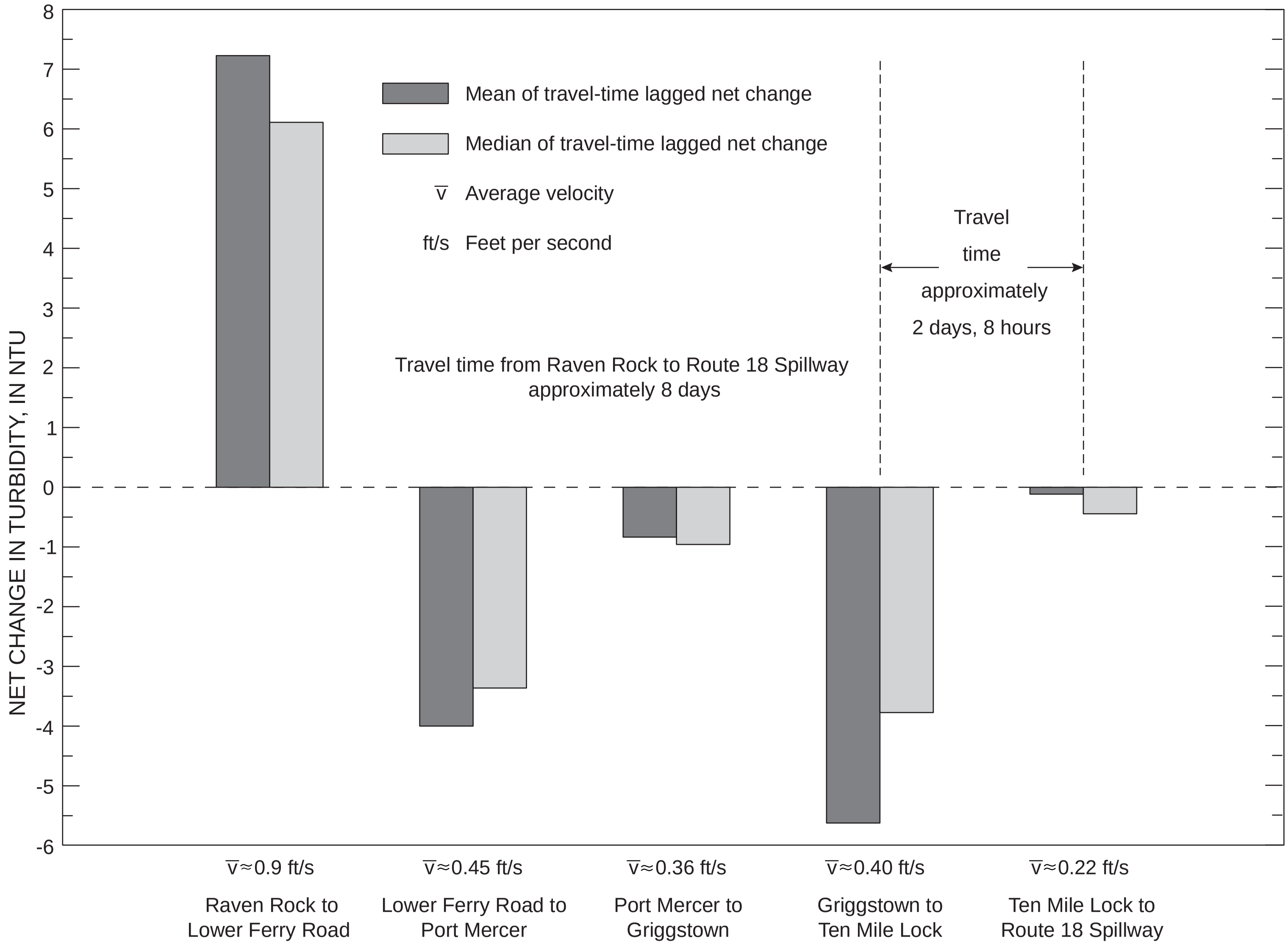


Figure 22. Mean and median of the travel-time lagged net changes in turbidity in the five reaches of the Delaware and Raritan Canal, N.J., February 1998 to May 1999.

eliminated once the housing development is completed. It is not apparent from a data review that the turbid water that entered the canal mixed sufficiently with the canal water in the 0.25 miles between the storm drain and the monitor to be detected by the continuous water-quality monitor located almost midway across the canal. The period of record mean values for turbidity at Lower Ferry Road and Port Mercer are 19.6 and 15.6 NTU, respectively (fig. 21).

The water in the reach between Port Mercer and Griggstown underwent a net change in turbidity for the project period of record of -0.8 NTU for the mean and -1.0NTU for the median between the start and end of the reach (fig. 22). Almost no change in turbidity occurred in this reach, which is an unexpected result, because the estimated average velocity of the canal water in this reach, 0.36 ft/s, was lower than the average velocity of the reach between Lower Ferry Road and Port Mercer.

The minimal reduction in turbidity in the reach between Port Mercer and Griggstown could have been caused by dredging of the canal in this reach during the project. A review of the turbidity values for the project period of record showed that the turbidity generated by the dredging was detected by the Griggstown continuous water-quality monitor. The Duck Pond Run Basin drains into the canal in this reach. Stormwater from this basin might increase turbidity in this reach. The confluence of Duck Pond Run and the canal is approximately 11.2 miles upstream from the Griggstown continuous water-quality monitor. Any settleable solids or turbidity that enters the canal from Duck Pond Run would settle in the canal during the 45.7 hours of travel time before being detected by the Griggstown continuous water-quality monitor. Only duck weed, which floats on the water surface, was observed in this reach during field trips to the study area. Algae were not observed in this reach.

The water in the reach between Griggstown and Ten Mile Lock underwent a net change in turbidity for the project period of record of -5.6 NTU for the mean and -3.8 NTU for the median (fig. 22). The average velocity of canal water in this reach was approximately 0.40 ft/s. Thus, the attenuation of the turbidity in this reach was caused by settling of the suspended particles because the velocity of the water was low.

The water in the reach between Ten Mile Lock and the Route 18 Spillway underwent a net change in turbidity for the project period of record of -0.1 NTU for the mean and -0.4 NTU for the median (fig. 22). The average velocity of the water in this reach was approximately 0.22 ft/s, which was the lowest average velocity of the six reaches, and the net change in turbidity was negligible. If little turbidity is added to the canal water from influent drainage basins, this reach would have measurably large decreases in turbidity similar to those in the reach between Ten Mile Lock and Griggstown because of the low velocity; however, water from Als Brook Basin, the fourth largest influent drainage basin, and the Borough of South Bound Brook drainage basin, which covers an area of 500 acres, enters the canal about 1.34 miles and 5.5 miles, respectively, upstream from the Route 18 Spillway. Because Als Brook is closer to the continuous water-quality monitor located at the Route 18 Spillway and has an area 5.8 times larger than the Borough of South Bound Brook Basin, it was more likely to be the source of a significant amount of stormwater runoff that carried turbidity into the canal. A deposit of sand and gravel is present at the confluence of Als Brook and the canal and extends almost one-third of the width of the canal. No sand and gravel deposits in the canal were observed near the Borough of South Bound Brook drainage basin.

SUMMARY

In general, the chemical composition of water in the Delaware and Raritan Canal in New Jersey during nonstorm conditions is not statistically different from that of the water near the intake of the canal, at the Delaware River at Lumberville, Pa. The results of statistical hypothesis testing of the instantaneous water-quality sampling data collected during the project period of record, mid-January 1998 to May 1999, did not identify specific locations along the canal at which statistically significant changes in median values of water-quality constituents were associated with storms. To determine statistically significant differences for all the water-quality constituents, one explanatory variable (either precipitation conditions or sampling locations) was removed by combining either storm and nonstorm data, or data from all sampling locations. Thus, the results of the analysis of the continuous water-quality monitoring data provided the information needed to identify water-quality changes related to storms in the five reaches of the canal.

The concentrations of ammonia and nitrite nitrogen were not statistically tested because about 40 and 32 percent, respectively, of the data values were less than the method reporting level. Concentrations of filtered phosphorous in water samples from the canal could not be statistically compared with concentrations in samples collected at the Delaware River at Lumberville, Pa., because of a change in the laboratory reporting level in 1999, from 0.01 to 0.05 milligrams per liter. The change in laboratory reporting level resulted in a greater percentage of censored data from the canal (8 percent) than from the Delaware River at Lumberville, Pa. (4 percent). The nonstorm median concentrations of nine water-quality constituents in canal water were not significantly different from the median concentrations in samples collected during water years 1994-99 at the Delaware River at Lumberville, Pa., nor was field measured specific conductance significantly different.

Only the median concentrations of suspended organic carbon differed significantly along the length of the canal after the storm and nonstorm data were aggregated. Median concentrations were significantly higher during and after storms than for nonstorm events for the following constituents: total and filtered ammonia plus organic nitrogen, total phosphorous, turbidity, ultraviolet absorbance at 254 nanometers, and dissolved organic carbon.

Only five volatile organic compounds (VOCs) were detected. Toluene was detected five times; the highest concentration was 0.7 μg/L (micrograms per liter). Chloroform was detected 4 times, and all the concentrations were approximately 0.1 μg/L (micrograms per liter). Methylene chloride, ortho-Xylene, and meta- plus para-Xylenes were detected once each at concentrations of 0.1, 0.2, and 0.5 μg/L, respectively. Methyl *tert*-butyl ether (MTBE) was the most frequently detected VOC. MTBE was detected in 55 of 80 samples. The median concentration of MTBE in canal water (0.25 μg/L) was not statistically different from that in water from the Delaware River at Trenton, N.J.

Stormwater runoff into the canal reach between Raven Rock and Lower Ferry Road reduced the continuously monitored specific conductance (SC) at Lower Ferry Road relative to that at Raven Rock during 1998-99. The largest basins that drain into the canal in this reach are the Wickecheoke Creek (16,987 acres) and Lockatong Creek (14,815 acres).

The median of the continuously monitored SC for the period of record during nonstorm conditions at Port Mercer increased by approximately 3 to 4 μS/cm (microsiemens per centimeter) (1.5 to 2 percent of the median specific conductance), relative to that of the nearest upstream site, Lower Ferry Road, during 1998-99. Land use in the influent basins for this reach of the canal is primarily urban.

The median continuously monitored SC for the project period of record during nonstorm conditions at the Route 18 Spillway site increased relative to that of the nearest upstream site, Ten Mile Lock, by approximately 3 to 4 μS/cm, during 1998-99. The mean of the net change for the period of record in continuously monitored specific conductance for this reach during storms also increased. Land use in the two largest influent basins, the Borough of Bound Brook and Als Brook, is predominantly urban.

Continuously monitored turbidity differed along the length of the canal. Between Raven Rock and Lower Ferry Road, the mean and median for continuously monitored turbidity increased by 7.2 and 6.2 NTU (nephelometric turbidity units), respectively, during 1998-99. The continuously monitored turbidity decreased downstream from Lower Ferry Road to Ten Mile Lock.

Turbidity increased locally downstream from influent streams or outfalls and was not transported appreciable distances because of the low average velocities of water in the canal reaches from Lower Ferry Road to the Route18 Spillway, which ranged from 0.45 to 0.22 ft/s. Turbidity that entered the feeder part of the canal from Raven Rock to Lower Ferry Road probably was transported greater distances than in the rest of the canal because the average velocity, 0.9 ft/s, was at least twice that in the rest of the canal.

In the reach between Ten Mile Lock and the Route 18 Spillway, little change was measured in the continuously monitored turbidity, which decreased less than 0.5 NTU for the mean and median during 1998-99. If no additional turbidity was introduced in the reach between Ten Mile Lock and the Route 18 Spillway, a reduction of approximately 4 NTU, which is similar to that in the reach between Griggstown and Ten Mile Lock, would be expected. The lack of a reduction in turbidity values for the reach between Ten Mile Lock and the Route 18 Spillway is not consistent with the average velocity for this reach, which is the lowest average velocity of all the reaches. Field observation of a sand bar immediately downstream from the confluence of Als Brook and the canal confirmed that the Als Brook drainage basin has contributed sediment carried by stormwater to the canal; the storm water and suspended solids could reach the monitor at the Route 18 Spillway and the raw water intakes for two drinking-water treatment plants.

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APPENDIX A. RELATIONAL DATABASE DESIGN

INTRODUCTION

The CanalDB data model is described in this section. A complete listing of all table definitions and field properties and definitions in the CanalDB database is presented in a Data Dictionary. The Data Dictionary is the primary reference for the tables and fields in the Access database. A entity-relationship diagram of the data model also is presented (fig. A1). Together, the diagram and the Data Dictionary serve as the documentation for the database.

The following statement summarizes the water-quality data model: Sites may have one or more Samples, and Samples may have one or more Results. The core tables in CanalDB are the three tables that physically represent that statement (figs. A1 and A2), and each has a prefix of tbl: tblSite, tblSample, and tblResult (tables A1, A2, A3, respectively). All other tables in the database are used to provide classification and qualification information to the core tables; these are referred to as domain tables because each supplies information about (or selection lists for) a particular subject domain (for example, method, equipment, or parameter). There are ten domain tables in CanalDB, and all have a prefix of tds. Seven of these tables serve the tblSample core table (tdsHydrologicEvent, tdsHydrologicCondition, tdsSampleMedium, tdsSamplingMethod, tdsSamplingEquipment, tdsSamplingIntervalGroup and tdsSampleType; tables A4-A10, respectively), two serve the tblResult core table (tdsParameter and tdsResultFlag; tables A11 and A12), and one (tdsAgency; table A13) serves both of those core tables by providing selections for sample collection and result-reporting agencies.

CORE ENTITIES IN THE DATABASE

Site

A Site is defined as the place or location where Samples were collected. For each Site, data can include the official USGS Station name, Station ID (STAID), latitude, longitude, New Jersey State Plane coordinates (NJSP83), watershed code (HUC), and a comment.

Sample

A Sample is generally considered to be either field data (for example, stage level or temperature) or material (water specimen) collected at a single Site on a particular date and time. Samples are explicitly defined within CanalDB as a unique combination of site, date/time, collection agency, sample medium, sampling method, sampling equipment, and sample type (for example, regular, spike, or replicate). Each Sample is also classified to a "sampling interval group" that informs the user about whether the Sample is part of a series, for example 15-minute-interval data from a continuous monitoring station. Sampling also is associated with (but not defined by) hydrologic events (for example, storm or hurricane) and hydrologic conditions (for example, rising stage of a storm event). Figures A1 and A2 illustrate how Samples and the associated domain tables fit into the model.

Result

A Result is the field measurement or laboratory analytical value pertaining to a single Parameter in a single Sample. In this appendix, Parameter refers to a characteristic or constituent. Each Sample can have many Results, but each Parameter can occur only once within a single Sample (for example, pH measured twice must be for different times or

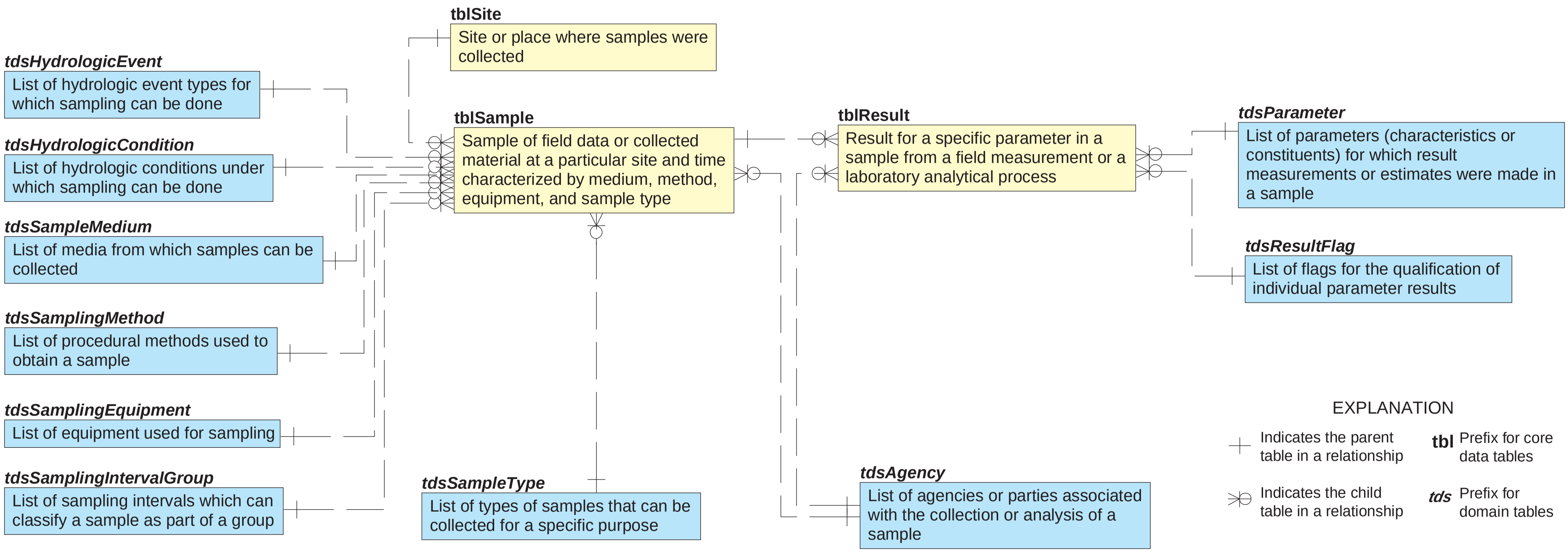

Figure A1. Data model for Delaware and Raritan Canal water-quality database (CanalDB) showing definitions for each table and their relationships.

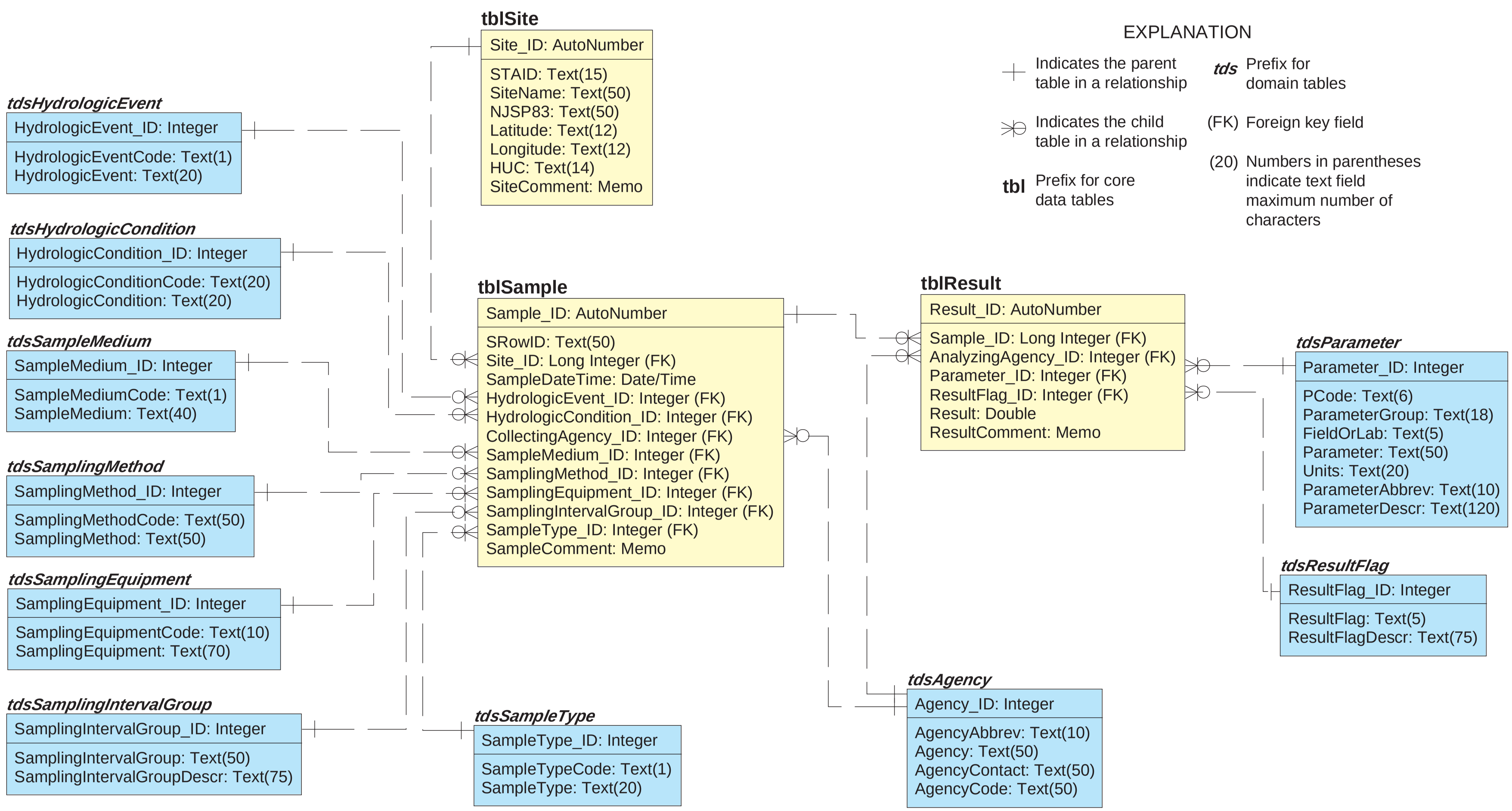

Figure A2. Structure of the Delaware and Raritan Canal water-quality database (CanalDB) showing fields in each table and selected properties (data type, text field size, foreign key designation (FK)).

sample types, collection agency, or method as defined for a different Sample). Results are further qualified by association with a Result Flag (for example, < or estimated) to aid in interpreting the integrity and accuracy of the reported value. Figures A1 and A2 illustrate how Results fit into the model.

Summary Table

At the writing of this report (March 2000), the CanalDB contains 10 Site records, 267,061 Sample records, and 766,711 Result records. Because most of the Samples/Results are 15-minute or 30-minute-interval continuous monitoring data, a new table, tblDailySummary (table A14) was created to summarize individual Parameters at a Site throughout a day. A total of 12,340 daily statistics (number of measurements (N), minimum, maximum, and mean) for individual parameters are stored in the table to allow efficient browsing. The reduction from 766,711 Result records to 12,340 summary records is due to compacting all 15-minute (N = 96 per day) and 30-minute (N = 48 per day) continuous monitoring data for each day. Measurements that are not part of a continuous series (instantaneous samples) are represented by a sample size (N) of 1.

The table tblDailySummary contains 17 identification/classification fields and 4 summary statistics fields (fig. A3). It is better suited to general browsing and queries of the data than is the individual Results table. It is also a more efficient link for Geographic Information Systems to display summarized values for spatial evaluation of parameters.

tblDailySummary

tblDailySummary
Site_ID: Long Integer STAID: Text SiteName: Text SampleDate: Date/Time CollectingAgency: Text HydrologicEvent: Text HydrologicCondition: Text SampleMedium: Text SamplingMethod: Text SamplingEquipment: Text SamplingIntervalGroup: Text SampleType: Text AnalyzingAgency: Text ParameterGroup: Text FieldOrLab: Text Parameter: Text Units: Text N: Long Integer Minimum: Double Maximum: Double Mean: Double

Figure A3. Fields in the table tblDailySummary and their data types.

DATA DICTIONARY

The Data Dictionary is a listing of table and field properties for the CanalDB. Information about each table is shown in a heading area at the top of the table:

- Table Name is self explanatory.
- #Fields is the number of fields in the table.
- #Recs is the current number of records at the time the dictionary was generated.
- Last Updated is the date of last update to the table at the time the dictionary was generated.
- Table Description is a description of the table contents or function.

Below the heading area, a numbered listing of each field in the table is accompanied by descriptive information:

- Field Name is self explanatory.
- PK is checked if the field is part of the primary key for the table.

- FK is checked if the field is a foreign key pointing to data in a “parent” table.
- Rqd is checked if the field is required to have a value for each record in the table; if unchecked the field is optional.
- Type is the data type of the field.
- Size is the size of the field (maximum number of characters for text fields; for other data types, it represents the number of bytes used for storage).
- Default is the default value for the field (usually refers to a foreign key value that represents a selection from a domain table).
- Description is a description of the field.

Table A-1. Characteristics of tblSite

Table Name	#Fields	#Recs	Last Updated:
tblSite	**8**	**10**	11/20/00 8:32:09 A

Table Description: **Site or place where samples were collected**

	Field Name	PK	FK	Rqd	Type	Size	Default	Description
1	Site_ID	☑	☐	☑	AutoNumber (Long)	4		Key that uniquely identifies a site (place) where sampling occurs
3	STAID	☐	☐	☐	Text	15		USGS site identification code
4	SiteName	☐	☐	☑	Text	50		Name by which site is known
5	NJSP83	☐	☐	☐	Text	50		New Jersey State Projection 1983 coordinate for site location
6	Latitude	☐	☐	☐	Text	12		Latitude in degrees-minutes-seconds format
7	Longitude	☐	☐	☐	Text	12		Longitude in degrees-minutes-seconds format
8	HUC	☐	☐	☐	Text	14		14-digit hydrologic unit code that identifies the watershed in which a site is located
9	SiteComment	☐	☐	☐	Memo	-		Comment about a site

Table A-2. Characteristics of tblSample

Table Name	#Fields	#Recs	Last Updated:
tblSample	**13**	**267061**	11/20/00 8:31:47 A

Table Description: **Sample of field data or collected material at a particular site and time characterized by medium, method, equipment, and sample type**

	Field Name	PK	FK	Rqd	Type	Size	Default	Description
1	Sample_ID	☑	☐	☑	AutoNumber (Long)	4		Key that uniquely identifies an individual sample of data or material
2	SRowID	☐	☐	☐	Text	50		Code representing the source and row number from the original USGS National Water Information System import file
3	Site_ID	☐	☑	☑	Number (Long)	4		Key that uniquely identifies a site (place) where sampling occurs
4	SampleDateTime	☐	☐	☑	Date/Time	8		Date and time at which a sample was collected, in the format yyyy-mm-dd hh:mm:ss
5	HydrologicEvent_ID	☐	☑	☑	Number (Integer)	2	0	Key that uniquely identifies a hydrologic event
6	HydrologicCondition_ID	☐	☑	☑	Number (Integer)	2	0	Key that uniquely identifies a hydrologic condition
7	CollectingAgency_ID	☐	☑	☑	Number (Integer)	2		Key that uniquely identifies an agency involved in collecting or analyzing samples
8	SampleMedium_ID	☐	☑	☑	Number (Integer)	2	9	Key that uniquely identifies a medium which is sampled

Table A-2. Characteristics of tblSample--continued

9	SamplingMethod_ID	☐	☑	☑	Number (Integer)	2		Key that uniquely identifies a sampling method used to collect a sample or make a measurement
10	SamplingEquipment_ID	☐	☑	☑	Number (Integer)	2		Key that uniquely identifies a type of equipment used for sampling
11	SamplingIntervalGroup_ID	☐	☑	☑	Number (Integer)	2		Key that uniquely identifies a sampling interval group
12	SampleType_ID	☐	☑	☑	Number (Integer)	2	9	Key that uniquely identifies a sample type
13	SampleComment	☐	☐	☐	Memo	-		Comment about a sample that assists with evaluating results

Table A-3. Characteristics of tblResult

Table Name	#Fields	#Recs	Last Updated:
tblResult	**7**	**766711**	11/20/00 9:36:52 A

Table Description: **Result for a specific parameter in a sample from a field measurement or a laboratory analytical process**

	Field Name	PK	FK	Rqd	Type	Size	Default	Description
1	Result_ID	☑	☐	☑	AutoNumber (Long)	4		Key that uniquely identifies a result of measurement or analysis for a single parameter from a sampling event
2	Sample_ID	☐	☑	☑	Number (Long)	4		Key that uniquely identifies an individual sample of data or material
3	AnalyzingAgency_ID	☐	☑	☑	Number (Integer)	2		Key that uniquely identifies an agency involved in collecting or analyzing samples
4	Parameter_ID	☐	☑	☑	Number (Integer)	2		Key that uniquely identifies a parameter (characteristic or constituent)
5	ResultFlag_ID	☐	☑	☑	Number (Integer)	2	0	Key that uniquely identifies a ResultFlag qualifying a result
6	Result	☐	☐	☐	Number (Double)	8		Result (value) for a parameter from a field measurement or laboratory analysis of a sample
7	ResultComment	☐	☐	☐	Memo	-		Comment for a result to provide information about a value not covered by other result qualifiers

Table A-4. Characteristics of tdsHydrologicEvent

Table Name	#Fields	#Recs	Last Updated:
tdsHydrologicEvent	**3**	**14**	11/20/00 9:05:31 A

Table Description: **List of hydrologic event types for which sampling can be done**

	Field Name	PK	FK	Rqd	Type	Size	Default	Description
1	HydrologicEvent_ID	☑	☐	☑	Number (Integer)	2		Key that uniquely identifies a hydrologic event
2	HydrologicEventCode	☐	☐	☑	Text	1		USGS code used to identify a hydrologic event
3	HydrologicEvent	☐	☐	☑	Text	20		Hydrologic event name

Table A-5. Characteristics of tdsHydrologicCondition

Table Name	#Fields	#Recs	Last Updated:
tdsHydrologicCondition	**3**	**7**	11/20/00 8:32:40 A

Table Description: **List of hydrologic conditions under which sampling can be done**

	Field Name	PK	FK	Rqd	Type	Size	Default	Description
1	HydrologicCondition_ID	☑	☐	☑	Number (Integer)	2		Key that uniquely identifies a hydrologic condition
2	HydrologicConditionCode	☐	☐	☑	Text	20		USGS code used to identify a hydrologic condition
3	HydrologicCondition	☐	☐	☑	Text	20		Description of a hydrologic condition

Table A-6. Characteristics of tdsSampleMedium

Table Name	#Fields	#Recs	Last Updated:
tdsSampleMedium	**3**	**35**	11/20/00 9:38:12 A

Table Description: **List of media from which samples can be collected**

	Field Name	PK	FK	Rqd	Type	Size	Default	Description
1	SampleMedium_ID	☑	☐	☑	Number (Integer)	2		Key that uniquely identifies a medium which is sampled
2	SampleMediumCode	☐	☐	☑	Text	1		USGS code used to identify a sample medium
3	SampleMedium	☐	☐	☑	Text	40		Sample medium name

Table A-7. Characteristics of tdsSamplingMethod

Table Name	#Fields	#Recs	Last Updated:
tdsSamplingMethod	**3**	**9**	11/20/00 8:35:17 A

Table Description: **List of procedural methods used to obtain a sample**

	Field Name	PK	FK	Rqd	Type	Size	Default	Description
1	SamplingMethod_ID	☑	☐	☑	Number (Integer)	2		Key that uniquely identifies a sampling method used to take a sample or make a measurement
2	SamplingMethodCode	☐	☐	☑	Text	50		USGS code used to identify a sampling method
3	SamplingMethod	☐	☐	☑	Text	50		Sampling method description

Table A-8. Characteristics of tdsSamplingEquipment

Table Name	#Fields	#Recs	Last Updated:
tdsSamplingEquipment	**3**	**114**	11/20/00 8:34:40 A

Table Description: **List of equipment used for sampling**

	Field Name	PK	FK	Rqd	Type	Size	Default	Description
1	SamplingEquipment_ID	☑	☐	☑	Number (Integer)	2		Key that uniquely identifies a type of equipment used for sampling
2	SamplingEquipmentCode	☐	☐	☑	Text	10		USGS code used to identify equipment used for sampling
3	SamplingEquipment	☐	☐	☑	Text	70		Equipment used for sampling

Table A-9. Characteristics of tdsSamplingIntervalGroup

Table Name	#Fields	#Recs	Last Updated:
tdsSamplingIntervalGroup	**3**	**4**	11/20/00 9:38:41 A

Table Description: **List of sampling intervals which can classify a sample as part of a group**

	Field Name	PK	FK	Rqd	Type	Size	Default	Description
1	SamplingIntervalGroup_ID	☑	☐	☑	Number (Integer)	2		Key that uniquely identifies a sampling interval group
2	SamplingIntervalGroup	☐	☐	☑	Text	50		Sampling interval group name
3	SamplingIntervalGroupDescr	☐	☐	☑	Text	75		Sampling interval group description

Table A-10. Characteristics of tdsSampleType

Table Name	#Fields	#Recs	Last Updated:
tdsSampleType	**3**	**12**	11/20/00 8:34:27 A

Table Description: **List of types of samples that can be collected for a specific purpose**

	Field Name	PK	FK	Rqd	Type	Size	Default	Description
1	SampleType_ID	☑	☐	☑	Number (Integer)	2		Key that uniquely identifies a sample type
2	SampleTypeCode	☐	☐	☑	Text	1		USGS code used to identify a sample type
3	SampleType	☐	☐	☑	Text	20		Sample type name

Table A-11. Characteristics of tdsParameter

Table Name	#Fields	#Recs	Last Updated:
tdsParameter	**8**	**61**	11/21/00 11:50:56

Table Description: **List of parameters (characteristics or constituents) for which result measurements or estimates were made in a sample**

	Field Name	PK	FK	Rqd	Type	Size	Default	Description
1	Parameter_ID	☑	☐	☑	Number (Integer)	2		Key that uniquely identifies a parameter (characteristic or constituent)
2	PCode	☐	☐	☑	Text	6		USGS code used to identify a specific parameter in the National Water Information System
3	ParameterGroup	☐	☐	☑	Text	18		Group to which a parameter belongs (such as nutrient)
4	FieldOrLab	☐	☐	☑	Text	5		Identifies whether a parameter value is determined in the field or in a laboratory
5	Parameter	☐	☐	☑	Text	50		Name of parameter
6	Units	☐	☐	☑	Text	20		Reporting units for a result of a parameter measurement or laboratory analysis
7	ParameterAbbrev	☐	☐	☑	Text	10		Parameter abbreviation
8	ParameterDescr	☐	☐	☑	Text	120		Parameter description

Table A-12. Characteristics of tdsResultFlag

Table Name	#Fields	#Recs	Last Updated:
tdsResultFlag	**3**	**10**	11/20/00 8:33:47 A

Table Description: **List of flags for the qualification of individual parameter results**

	Field Name	PK	FK	Rqd	Type	Size	Default	Description
1	ResultFlag_ID	☑	☐	☑	Number (Integer)	2		Key that uniquely identifies a ResultFlag qualifying a result
2	ResultFlag	☐	☐	☑	Text	5		Flag used to qualify a parameter result
3	ResultFlagDescr	☐	☐	☑	Text	75		Description of flag used to qualify a parameter result

Table A-13. Characteristics of tdsAgency

Table Name	#Fields	#Recs	Last Updated:
tdsAgency	**5**	**5**	11/20/00 8:29:30 A

Table Description: **List of agencies or parties associated with the collection or analysis of a sample**

	Field Name	PK	FK	Rqd	Type	Size	Default	Description
1	Agency_ID	☑	☐	☑	Number (Integer)	2		Key that uniquely identifies an agency involved in collecting or analyzing samples
2	AgencyAbbrev	☐	☐	☑	Text	10		Agency abbreviation or code
3	Agency	☐	☐	☑	Text	50		Agency name
4	AgencyContact	☐	☐	☐	Text	50		Agency contact information
5	AgencyCode	☐	☐	☐	Text	50		USGS numeric code for an agency in the National Water Information System

Table A-14. Characteristics of tblDailySummary

Table Name	#Fields	#Recs	Last Updated:
tblDailySummary	**21**	**12340**	11/21/00 11:50:56

Table Description: **Summary of daily values for each parameter at each site; this table is generated by a query and does not require integrity constraints which are already applied to the transactional database design**

	Field Name	PK	FK	Rqd	Type	Size	Default	Description
1	Site_ID	☐	☐	☐	Number (Long)	4		Key that uniquely identifies a site (place) where sampling occurs
2	STAID	☐	☐	☐	Text	15		USGS site identification code
3	SiteName	☐	☐	☐	Text	50		Name by which site is known
4	SampleDate	☐	☐	☐	Date/Time	8		Date on which samples were collected
5	CollectingAgency	☐	☐	☐	Text	10		Abbreviation or code of an agency involved in collecting or analyzing samples
6	HydrologicEvent	☐	☐	☐	Text	20		Hydrologic event name
7	HydrologicCondition	☐	☐	☐	Text	20		Description of a hydrologic condition
8	SampleMedium	☐	☐	☐	Text	40		Sample medium name
9	SamplingMethod	☐	☐	☐	Text	50		Sampling method description
10	SamplingEquipment	☐	☐	☐	Text	70		Equipment used for sampling
11	SamplingIntervalGroup	☐	☐	☐	Text	50		Sampling interval group name
12	SampleType	☐	☐	☐	Text	20		Sample type name
13	AnalyzingAgency	☐	☐	☐	Text	10		Abbreviation or code of an agency involved in collecting or analyzing samples

Table A-14. Characteristics of tblDailySummary--continued

14	ParameterGroup	☐	☐	☐	Text	18	Group to which a parameter belongs (such as nutrient)
15	FieldOrLab	☐	☐	☐	Text	5	Identifies whether a parameter value is determined in the field or in a laboratory
16	Parameter	☐	☐	☐	Text	50	Name of parameter
17	Units	☐	☐	☐	Text	20	Reporting units for a result of a parameter measurement or laboratory analysis
18	N	☐	☐	☐	Number (Long)	4	Number of measurements used in the daily summary statistics
19	Minimum	☐	☐	☐	Number (Double)	8	Minimum result value reported within the daily summary for a parameter
20	Maximum	☐	☐	☐	Number (Double)	8	Maximum result value reported within the daily summary for a parameter
21	Mean	☐	☐	☐	Number (Double)	8	Mean result value reported within the daily summary for a parameter

Cedar Grove Brook
Water Quality Characterization
and Assessment

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July 7, 2006

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List of Appendices

I. Project Description

The NJWSA is developing Stormwater Best Management Practice (BMP) strategies for the Cedar Grove Brook (also known as Al's Brook) watershed. This 2,300 acre watershed in Franklin Township, New Jersey conveys drainage to the Delaware and Raritan Canal, a major water purveyor supply conduit operated by the NJWSA in the Raritan River Basin. Increased levels of total suspended solids (TSS) and turbidity have been reported by the purveyors during and immediately after precipitation events. Recent studies and observations have confirmed that Cedar Grove Brook is a contributor of suspended sediments. Upon recognizing the need to quantify and control sediment loading, NJWSA and Franklin Township obtained a 319(h) nonpoint source grant to develop a regional stormwater management plan for the Cedar Grove Brook watershed.

The initial tasks required by NJWSA to develop this plan included field services and water quality sampling to determine watershed runoff rates and volumes and associated sediment loads. The field data will be used to assist NJWSA in the development of a watershed computer model that will be used to predict turbidity and TSS loadings and target areas within the watershed for remedial action. Technical assistance will then be provided to the NJWSA to identify and develop remedial measures that will be used by the NJWSA and Franklin Township to help reduce these TSS loadings and turbidity levels and achieve water quality goals both within the Canal and the Cedar Grove Brook Watershed.

II. Sampling Summary

A. Introduction

TRC Omni prepared a Quality Assurance Project Plan (QAPP) to obtain the necessary data to evaluate targeted pollutants with respect to flow conditions, seasonal variations and pertinent weather conditions. The sampling plan was designed to assess water quality impacts due to erosion and stormwater runoff in order to determine the effectiveness of BMP installations within the Cedar Grove Brook watershed. The field services and water quality sampling were performed in accordance with the QAPP for six (6) stormwater locations, six (6) low flow locations, and eight (8) intensive stormwater locations.

The parameters measured during this study were Total Suspended Solids (TSS) and turbidity. In water quality terms, suspended solids are those that won't pass through a 2-micron filter as opposed to dissolved solid which refers to ions and other particles that will pass through a 2-micron filter. Suspended solids also will settle within one hour in an Imhoff cone. High TSS can result in a high load of adsorbed toxics or bacteria and increase turbidity. It also can increase water temperature and inhibit productivity by blocking light. High TSS reduces the efficiency of wastewater treatment plants and industrial processes that use raw water. TSS is measured in milligrams per liter (mg/l) and the Fresh Water 2 Non-Trout surface water quality criteria for New Jersey is 40.0 mg/l non-filterable residue (Surface Water Quality Standards, N.J.A.C. 7:9B).

Turbidity is a measure of water clarity that describes the degree to which light passing through water is scattered. Turbidity is caused by fine suspended soil particles (0.004 mm to 1.0 mm), algae, plankton, and other substances, and affects the clarity of the water. Sources of turbidity include soil erosion, waste discharges, urban runoff, eroding stream banks, bottom feeding fish such as carp and excess algal growth. High turbidity can cause increased water temperatures as suspended particles absorb heat which can reduce dissolved oxygen concentrations. Highly turbid waters prevent light from penetrating and inhibit photosynthesis. The Fresh Water 2 water quality criteria for New Jersey is a maximum 30 day average of 15 nephelometric turbidity units (NTU), or a maximum of 50 NTU at any time (Surface Water Quality Standards N.J.A.C. 7:9B).

Stream sampling stations were selected so that the sources of nonpoint pollutants could be identified. Tributary stations were chosen in order to characterize substantial inputs into the Cedar Grove Brook study area. The following list describes the selected sampling stations (shown in Figure 1 in

Appendix A and in pictures 1 through 10 in Appendix C) for the two baseline events and the low flow events:

- CG1: Cedar Grove Brook, Upstream from Quail Brook Pond.
- CG2: Cedar Grove Brook, Effluent from Quail Brook Pond.
- CG3: Cedar Grove Brook, West Branch upstream from Ukrainian Village Pond.
- CG4: Cedar Grove Brook, East Branch upstream from Ukrainian Village Pond.
- CG5: Cedar Grove Brook, Effluent from Ukrainian Village Pond.
- CG6: Cedar Grove Brook, at weir south of Easton Avenue (near the confluence with the Delaware and Raritan Canal).

B. Baseline Storm Sampling

Baseline stormwater sampling events occurred on July 8, 2005 to July 9, 2005 and October 8, 2005 to October 10, 2005. During the first baseline stormwater event, samples were collected at approximately 8 am and 2:30 pm on July 8th, and at 7:30 am on July 9th. Samples were collected at the six (6) stations identified above and presented in Figure 1 in Appendix A. Approximately 1.8 inches of rain were recorded during the event. During the second baseline stormwater event, initial samples were collected on October 8th at approximately 7:00 am. The remaining samples were collected on October 8th at approximately 2:30 pm, October 9th at 7:45 am, and October 10th at 3:20 pm. Sampling for this event occurred at the same six (6) stations as the initial baseline storm event. Approximately 4.5 inches of rain were recorded during this event. A list of the baseline stations and descriptions follow and the data collected is presented in Table 1 in Appendix B.

C. Low Flow Sampling

Low flow sampling occurred on August 3, 2005. This event occurred when the measured flow at USGS station 01403150 (West Middle Brook near Martinsville) was below the stream flows that are exceeded 70% of the time (d70). Low flow grab sampling was performed at the same six (6) stations as the baseline stormwater sampling events. A summary of the data collected is found in Table 1 in Appendix B.

D. Intensive Storm

By analyzing the loading results for TSS and turbidity from the two baseline storm events, it was determined that the intensive stormwater event should target possible pollutant sources between CG5 and CG6 (stream reaches downstream of the Ukrainian Village Pond). Sampling stations for the intensive stormwater event were selected so that source inputs of nonpoint pollutants to Cedar Grove Brook could be identified (shown in Figure 1 in Appendix A). On November 11, 2005, TRC Omni staff conducted a survey of possible pollutant sources between these sites, identifying eight locations (IS1 through IS8) as described below to sample during the final intensive stormwater sampling event.

- IS1: Cedar Grove Brook, Effluent from Ukrainian Village Pond (also known as CG5).
- IS2: Ditch entering east side of Cedar Grove Brook, contains stormwater runoff from Overburden pile on Lawndale Drive.
- IS3: Tributary adjacent to Lawndale Drive that receives stormwater runoff from Pierce Street Detention Basin.
- IS4: Stormwater discharge pipe near Driscoll Court.
- IS5: Tributary receiving stormwater runoff from Carson Court.
- IS6: Discharge from Hidden Brook Senior Housing Detention Basin.
- IS7: Cedar Grove Brook, immediately downstream of discharge from Hidden Brook Senior Housing Detention Basin.
- IS8: Cedar Grove Brook, at weir south of Easton Avenue (also known as CG6).

Pictures of the eight sites are presented in Appendix C (Pictures 11 through 25) and rationale for sampling follow:

IS1, effluent from the Ukrainian Village Pond, was selected as a control based on the results of the baseline and low flow events. IS2 was chosen to gauge the impact of runoff from stockpiled overburden stored on Lawndale Drive. The overburden piles were created during an ongoing storm sewer project. (Picture 24,

Appendix C). Stormwater runoff from the overburden piles flows along a utility easement directly to the stream. In addition, the road leading to the stockpiled soil is covered with mud and silt (Picture 25, Appendix C). On a site visit on June 30, 2006 it was found that the overburden pile is no longer there and Lawndale drive is no longer covered with mud and silt (Picture 15, Appendix C). IS3 is the discharge of several hotels and apartment buildings. The base of the detention basin is not vegetated and consists mostly of exposed soil (Picture 26, Appendix C). IS4 and IS5 are surface discharges of two developments that discharge directly into the tributary and do not have detention ponds. IS6 is the detention pond discharge of a senior housing development. IS7 and IS8 were chosen to characterize stream bank erosion and the impact of construction occurring between the two sites (Pictures 27 and 28, Appendix C).

The intensive stormwater event occurred from April 22, 2006 to April 23, 2006 in accordance with the QAPP. Samples were taken on April 22nd first between 7:00 am to 8:30 am and second between 2:15 pm to 4:20 pm. The third set of samples was taken on April 23rd between 7:45 am to 9:00 am. A rain gage was set up at IS8 and the total rainfall was 2 inches for this event. A summary of the data results is presented in Table 2 in Appendix B.

E. Flow and Load Calculations

As part of the sampling and analysis, continuous flow was calculated using pressure transducers installed at sites CG2, CG5, and CG6 and HydroCAD's equation for flow over a weir defined as follows:

$$Q = (3.27 + 0.4\frac{H}{P})(L - \frac{nH}{10})H^{\frac{3}{2}},$$

where Q = Flow;

H = the head above the weir invert elevation;

P = the height of the crest above the approach channel;

L = the actual crest length; and

n = the number of end contractions = 2.

Flow was estimated at the inlet of Quail Brook Golf Course Pond (CG1), and at the inlets to Ukrainian Village Pond (CG3 and CG4) from the continuous flow data obtained from CG2 and CG5.

The continuous flows obtained during the two baseline storm events and the low flow event are displayed in Figures 1, 2, and 3 in Appendix D. These flows were used to calculate Total Suspended Solid (TSS) loading at the time each sample was collected. The TSS loadings obtained during each event are displayed on Figures 6, 9, and 14 in Appendix D. At sites CG3 and CG4, an average of the TSS concentrations was calculated and then multiplied by the flow observed at site CG5 to determine total TSS loading into Ukrainian Village Pond. Due to a pressure transducer battery failure at site CG2 during the second baseline stormwater event, the flow at this location was estimated as 80% of the flow at CG5 for all of the times that transducer readings were not available. The estimated flow for CG2 is displayed by the dashed line in Figure 2. The TSS loads and concentrations plots and the turbidity plots were used to determine target areas for the intensive stormwater event. Figures 5, 8, and 13 show the turbidity values for the three events.

III. Results

A. Baseline Water Quality Data

Figures 4, 5 and 6 in Appendix D are plots of the concentration and load of TSS and turbidity for the first baseline storm event. During the first baseline storm event on July 8, 2005, station CG3 exceeded the FW2-NT standard for TSS of 40 mg/l with concentrations of 72 mg/l for the first sample and 48 mg/l for the second sample. Also, station CG6 measured a TSS concentration of 110 mg/l for the second sample. CG3 and CG4 had higher concentrations of TSS and turbidity than the outlet of the pond CG5, suggesting that the stream may be a source of TSS and turbidity. Based on this data, settling appears to occur in the Ukrainian Village Pond which is serving as a sink for the system. After analyzing the load plots, an increase in TSS was found between CG5 (discharge of Ukrainian Village Pond) and CG6, near the confluence with the Delaware and Raritan Canal. Turbidity for all of these stations never exceeded the FW2-NT criterion of 50 NTU for any one sample.

Figures 7, 8 and 9 in Appendix D are plots of concentration and load of TSS and turbidity for the second baseline storm event. During the second baseline storm event sampling between October 8, 2005 and October 10, 2005, all measured results fell below the FW2-NT criterion for TSS and turbidity. Again, as in the first baseline storm results, the concentrations of TSS and turbidity for CG3 and CG4, the inlets of the pond, were higher than at CG5, the outlet of the pond. Again supporting the conclusion that the stream is a source of suspended solids and the Ukrainian Village Pond serves as a sink during high flow events. When the second baseline storm event TSS results were analyzed using calculated loads, again, an increase between CG5 and CG6 was again found and this area was targeted for the intensive storm event.

B. Settling Study

Figures 10 and 11 in Appendix D are graphs that display the results from the Settling Characterization study conducted on samples collected during the first baseline stormwater event. Samples obtained from stations CG3, CG4 and CG6, were shaken vigorously and transferred to Imhoff cones for a settleability study. Settling rates were observed and recorded during the study. The graphs depict the TSS and Turbidity at the beginning of the test zero (0) hours and four (4) hours later. As can be observed on the Settling Characterization study graphs, almost all of the solids quantified as TSS settle out within four (4) hours. The turbidity also is significantly decreased during this time period. This data indicates a moderately rapid settling rate for the solids present in the water column during storm events.

C. Low Flow

TSS and turbidity was measured once during the low flow event on August 3, 2005. All of the measured results for TSS at the low flow stations fell below the FW2-NT water quality standard of 40.0 mg/l except for station CG1, which had a TSS value of 88 mg/l (Figures 12 and 14 in Appendix D). This outlying result may be a result of very low flow and stagnant conditions at this site when the sample was collected. Also, turbidity for all stations fell below the FW2-NT water quality standard of 50 NTU for any one sample (Figure 13 in Appendix D). The measured concentrations for TSS and turbidity at CG3 and CG4 (inlets to the Ukrainian Village Pond) were lower than at CG5, the outlet of the pond. These data suggest that during low flow conditions, the lake is a source of TSS and turbidity likely due to the presence of phytoplankton growth in the pond (see photos). The data also indicate a decrease in TSS and turbidity between CG1 and CG2 and again between CG2 and CG4, suggesting a higher settling rate of suspended solids in the tributary stream. The data indicate that while no significant TSS or Turbidity issues occur in Cedar Grove Brook under low flow conditions, it appears that under these conditions the Ukrainian Village Pond serves a source of suspended solids and turbidity and the tributary streams serve as a sink.

D. Intensive

The measured TSS and turbidity results at the eight intensive storm stations all fell below the FW2-NT water quality standards for each sample set (Figures 15 and 16, Appendix D). The most significant concern was found at IS3, a site influenced by a non-vegetated retention basin flowing directly into the stream. A second issue was identified between IS7 and IS8 where the effects of stream erosion were clearly evident. The final concern was noted at IS2 where stormwater runoff from an overburden pile is flowing directly into the Cedar Grove Brook. This site contains a ditch that has very little flow so it is not expected to have a large influence over the stream even though concentrations for TSS and turbidity were significantly higher at this location. All other values appeared very low and therefore not expected to significantly impact stream quality. The results indicate that stormwater best management practices could benefit the stream, but may not improve the water quality of the canal significantly.

E. Results Conclusions

Overall, the sampling of Cedar Grove Brook showed that the in-stream criteria are regularly met for TSS and turbidity and that concentrations and loads are relatively low throughout the watershed. When concentrations are elevated, it appears that the issue resolves itself before the stream's confluence with the canal due to a high settling rate in the tributary. The observed concentrations of TSS and turbidity were low enough that it appears that Cedar Grove Brook may not be a large contributing factor to TSS and turbidity problems in the canal. During low flow conditions, Ukrainian Pond appears to be a source of TSS and turbidity due to its phytoplankton production. During high flow conditions moderate stream bank erosion and construction projects cause increased concentrations of TSS and turbidity in the Brook. This issue is partially resolved when the Ukrainian Village Pond settles suspended solids from upstream areas. Stream bank stabilization projects and buffer plantings downstream of the pond would aid in reducing TSS and turbidity near the streams confluence with the Canal. Further study of other potential causes of TSS and turbidity pollution in a larger watershed area may be necessary to clearly identify the TSS and turbidity issues in the canal.

APPENDIX A
Map of Sampling Locations

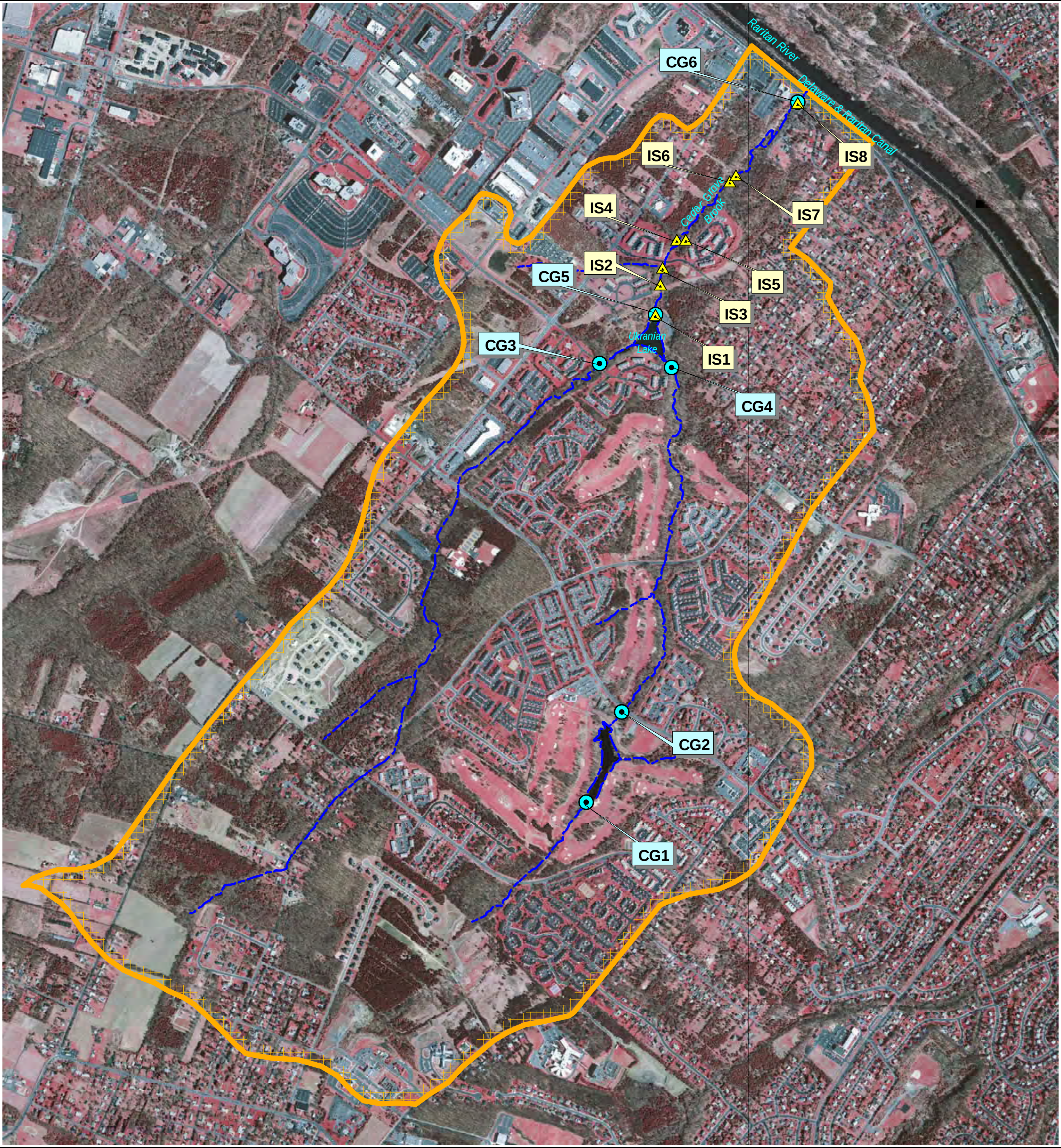


FIGURE 1: Sampling Locations

Cedar Grove Brook Water Quality Characterization & Assessment

TRC Omni

July 7, 2006

321 Wall Street
Princeton, NJ 08540
609-924-8821
www.TRComni.com

Baseline Stormwater & Low Flow Sampling Station

Intensive Stormwater Sampling Station

Watershed Boundary

1500 0 1500

Feet

APPENDIX B
Sampling Results

Table 1: Cedar Grove Brook Watershed, Data Summary

Station ID	Date/Time	Flow (cfs)	TSS (mg/l)	Turbidity (NTU)
CG1[1]	07/08/05 08:20 AM	4.28	22	17
	07/08/05 03:25 PM	4.72	4	7.6
	07/09/05 08:40 AM	1.76	3	2.9
	08/03/05 10:20 AM	0.01	88	39
	10/08/05 08:30 AM	22.67	3	8.7
	10/08/05 03:30 PM	53.88	5.5	12
	10/09/05 08:25 AM	30.91	3.3	10
	10/10/05 02:20 PM	2.14	1.5	3.1
CG2	07/08/05 08:05 AM	3.33	5	4.3
	07/08/05 03:40 PM	4.72	5	3.3
	07/09/05 08:15 AM	1.85	2	3.3
	08/03/05 10:10 AM	0.01	10	5.5
	10/08/05 08:15 AM	22.67	36	21
	10/08/05 03:40 PM	53.88	4	4.3
	10/09/05 08:35 AM	30.91	7	14
	10/10/05 02:30 PM	2.14	11	8.2
CG3[1]	07/08/05 07:55 AM	0.72	72	50
	07/08/05 03:15 PM	6.29	48	36
	07/09/05 08:00 AM	1.33	5	6.3
	08/03/05 10:45 AM	0.15	4.5	3.9
	10/08/05 07:45 AM	3.51	9	9.9
	10/08/05 03:15 PM	5.51	3.5	9.4
	10/09/05 08:10 AM	20.46	6.5	11
	10/10/05 02:45 PM	1.32	0.5	3.9
CG4[1]	07/08/05 07:50 AM	0.72	31	29
	07/08/05 03:00 PM	6.29	22	12
	07/09/05 07:50 AM	1.33	1.5	2.9
	08/03/05 10:35 AM	0.15	9	2.9
	10/08/05 07:30 AM	3.51	5	5.4
	10/08/05 03:00 PM	5.51	10	4.9
	10/09/05 08:20 AM	20.46	8	13
	10/10/05 02:55 PM	1.32	1	6.5
CG5	07/08/05 07:20 AM	1.22	22	18
	07/08/05 02:50 PM	13.66	25	23
	07/09/05 07:40 AM	2.67	7.3	12
	08/03/05 10:55 AM	0.31	19	13
	10/08/05 07:05 AM	8.45	4	13
	10/08/05 02:40 PM	11.02	7	9.2
	10/09/05 08:00 AM	40.92	5.5	13
	10/10/05 03:05 PM	2.55	3.3	7.7
CG6	07/08/05 06:50 AM	12.86	4	2.7
	07/08/05 02:30 PM	24.62	110	40
	07/09/05 07:25 AM	13.61	2	5.7
	08/03/05 11:10 AM	0.41	1.5	1.6
	10/08/05 06:50 AM	58.49	19	25
	10/08/05 02:20 PM	63.32	11	11
	10/09/05 07:45 AM	29.94	10	16
	10/10/05 03:20 PM	5.87	1	8.1

(green) = Low Flow Event
(blue) = Baseline Stormwater Event

[1] Flows are estimated.

Table 2. Cedar Grove Brook Intensive Stormwater Data Summary

Sample Location	Sample Round	TSS (mg/L)	Turbidity (NTUs)
IS1	A	13	12
	B	14	9
	C	10	10
IS2	A	*	*
	B	22	25
	C	33	37
IS3	A	12	9
	B	18	19
	C	4.5	9.4
IS4	A	2	2
	B	4	6.1
	C	2.5	7.7
IS5	A	4.5	4.8
	B	14	13
	C	2.3	8.8
IS6	A	4.5	11
	B	2.5	8.3
	C	2.5	9.8
IS7	A	1.5	2.4
	B	12	5
	C	8	11
IS8	A	5	3
	B	3.5	4.4
	C	21	15

APPENDIX C
Site Photographs

Picture 1: CG1 Inlet to Golf Course Pond

Picture 2: CG2 Culvert

Picture 3: GG2 Pressure Transducer

Picture 4: CG3 View from Top of Bridge

Picture 5: CG4 View from flooded banks

Picture 6: CG4 Downstream View

Picture 7: CG5 Dam discharge

Picture 8: CG6 during rain event

Picture 9: CG6 Pressure Transducer Location

Picture 10: Golf course pond and discharge

Picture 11: IS1/CG5 weir

Picture 12: IS1/CG5

Picture 13: IS2

Picture 14: Electrical easement near IS2

Picture 15: Lawndale Drive near IS2

Picture 16: IS3 Detention Pond

Picture 17: IS4

Picture 18: IS5

Picture 19: IS6

Picture 20: Detention Basin near IS6

Picture 21: IS7

Picture 22: Silt fences between IS7 and IS8

Picture 23: IS8/CG6

Picture 24: Overburden Pile on Lawndale Drive

Picture 25: Lawndale Drive

Picture 26: Pierce Street Detention Basin


Picture 27: Cedar Grove Brook Stream Bank Erosion


Picture 28: Construction near Easton Avenue

APPENDIX D
Data Analysis Figures

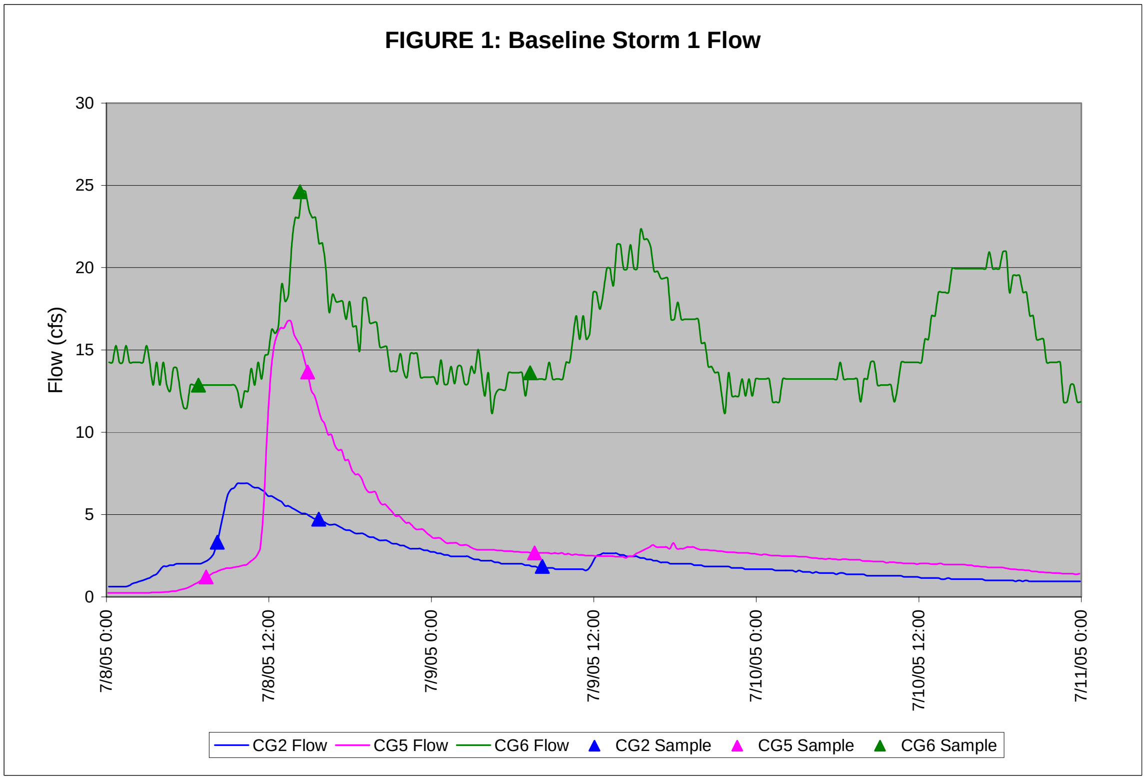


FIGURE 1: Baseline Storm 1 Flow
Flow (cfs)
30
25
20
15
10
5
0
7/8/05 0:00
7/8/05 12:00
7/9/05 0:00
7/9/05 12:00
7/10/05 0:00
7/10/05 12:00
7/11/05 0:00
CG2 Flow
CG5 Flow
CG6 Flow
CG2 Sample
CG5 Sample
CG6 Sample

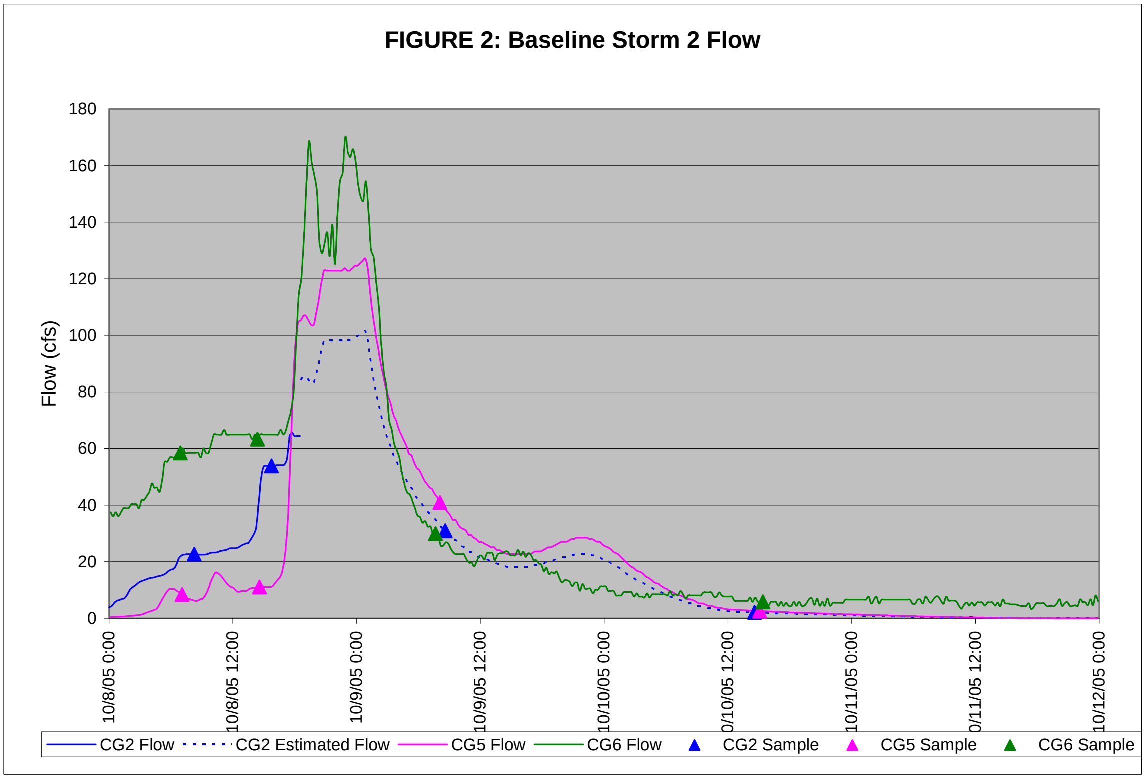


FIGURE 2: Baseline Storm 2 Flow
Flow (cfs)
180
160
140
120
100
80
60
40
20
0
10/8/05 0:00
10/8/05 12:00
10/9/05 0:00
10/9/05 12:00
10/10/05 0:00
0/10/05 12:00
10/11/05 0:00
0/11/05 12:00
10/12/05 0:00
CG2 Flow
CG2 Estimated Flow
CG5 Flow
CG6 Flow
CG2 Sample
CG5 Sample
CG6 Sample

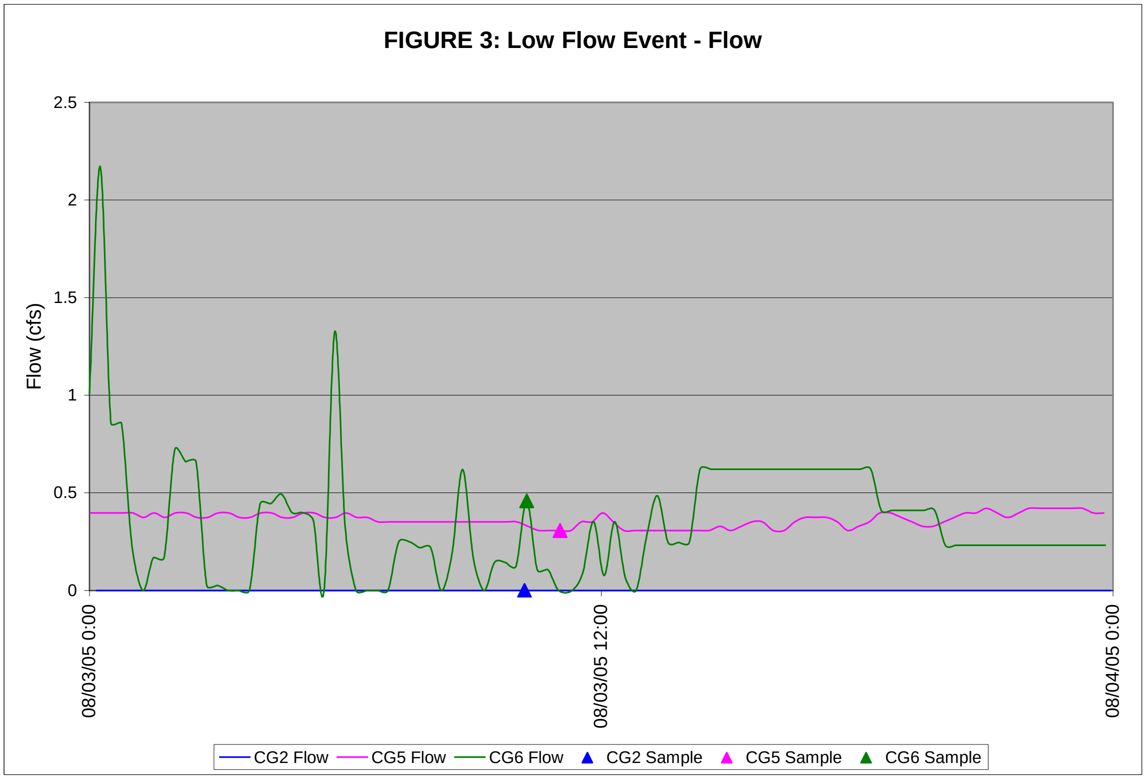


FIGURE 3: Low Flow Event - Flow
Flow (cfs)
2.5
2
1.5
1
0.5
0
08/03/05 0:00
08/03/05 12:00
08/04/05 0:00
CG2 Flow
CG5 Flow
CG6 Flow
CG2 Sample
CG5 Sample
CG6 Sample

FIGURE 4: Baseline Storm 1 - TSS Concentration

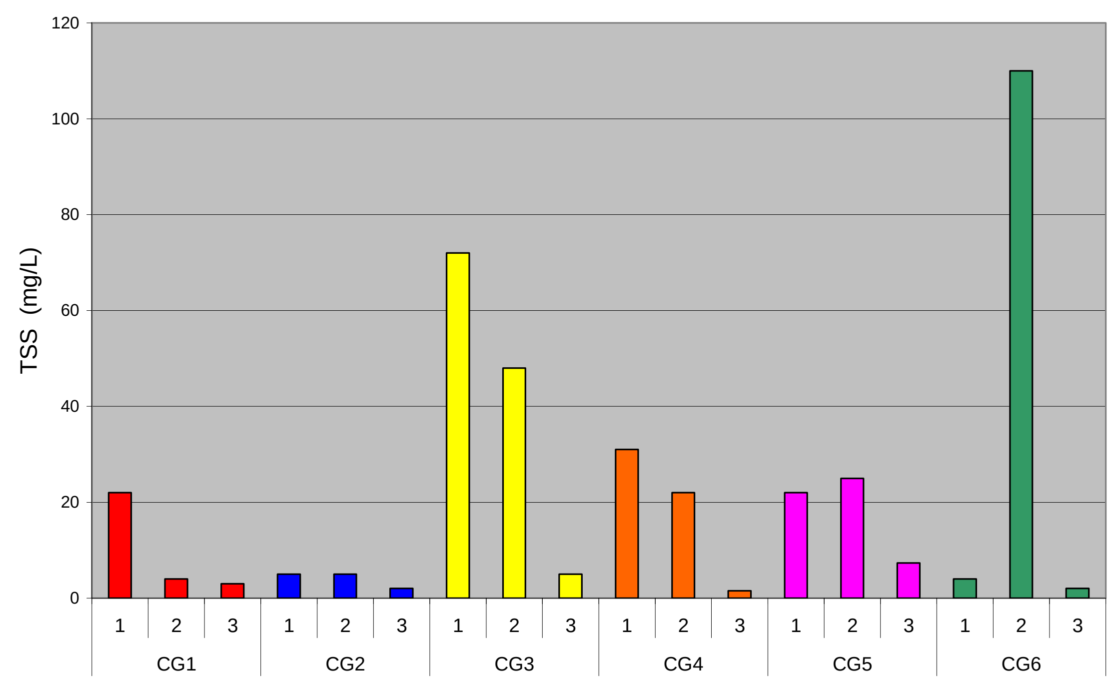


FIGURE 5: Baseline Storm 1 - Turbidity

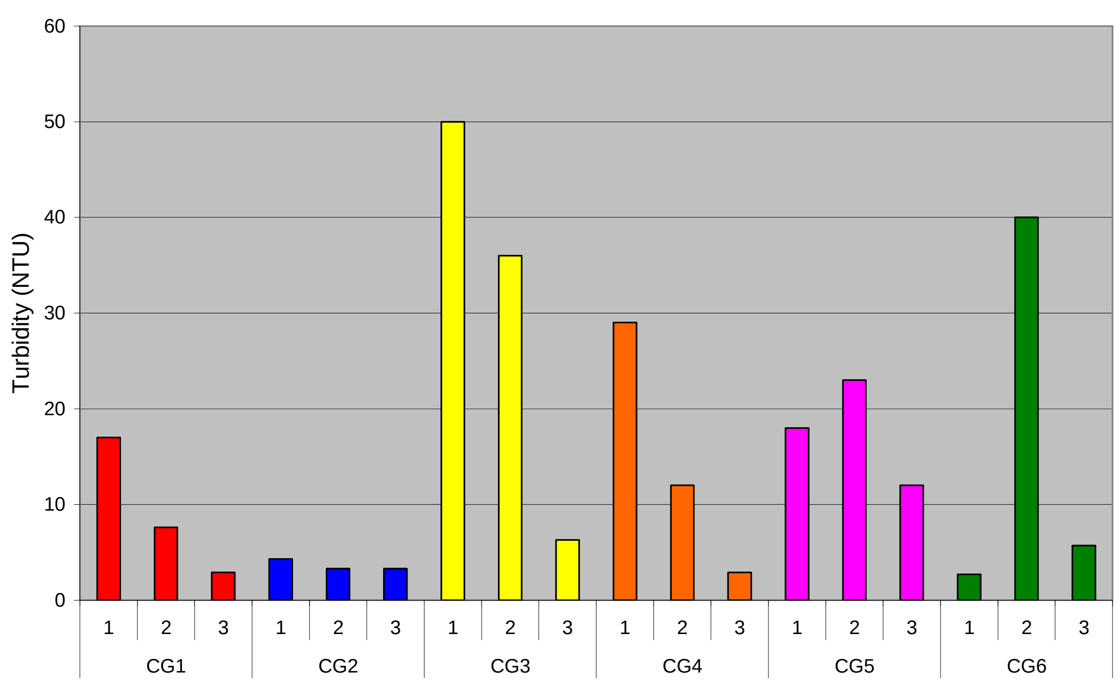


FIGURE 6: Baseline Storm 1 - TSS Loading

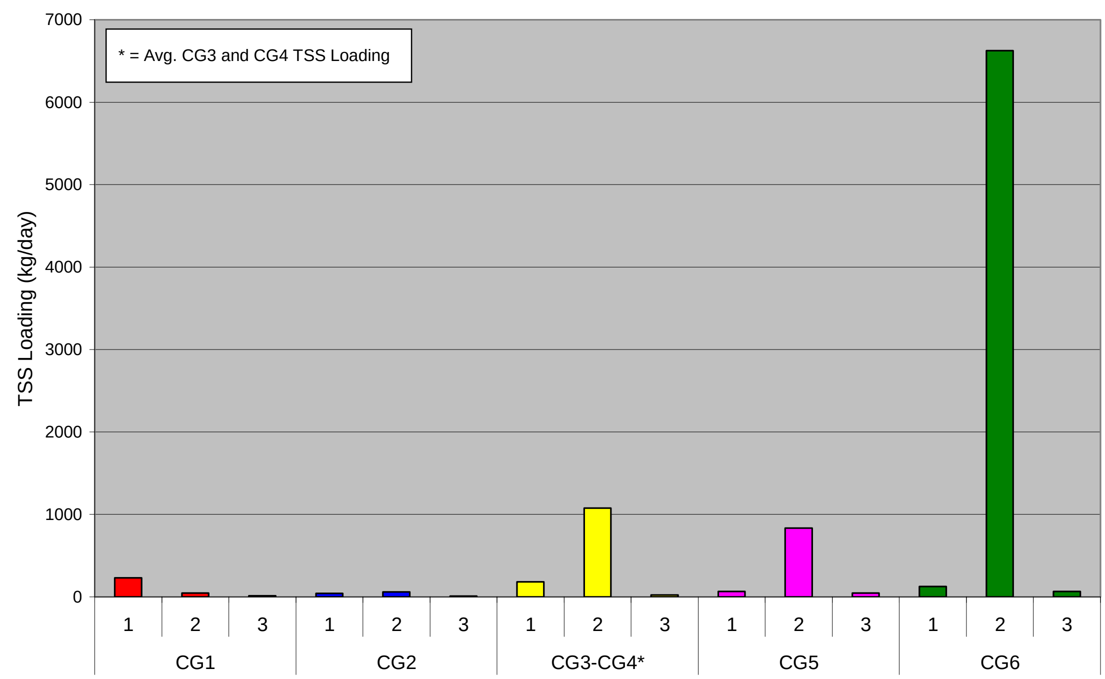


FIGURE 7: Baseline Storm 2 - TSS Concentration

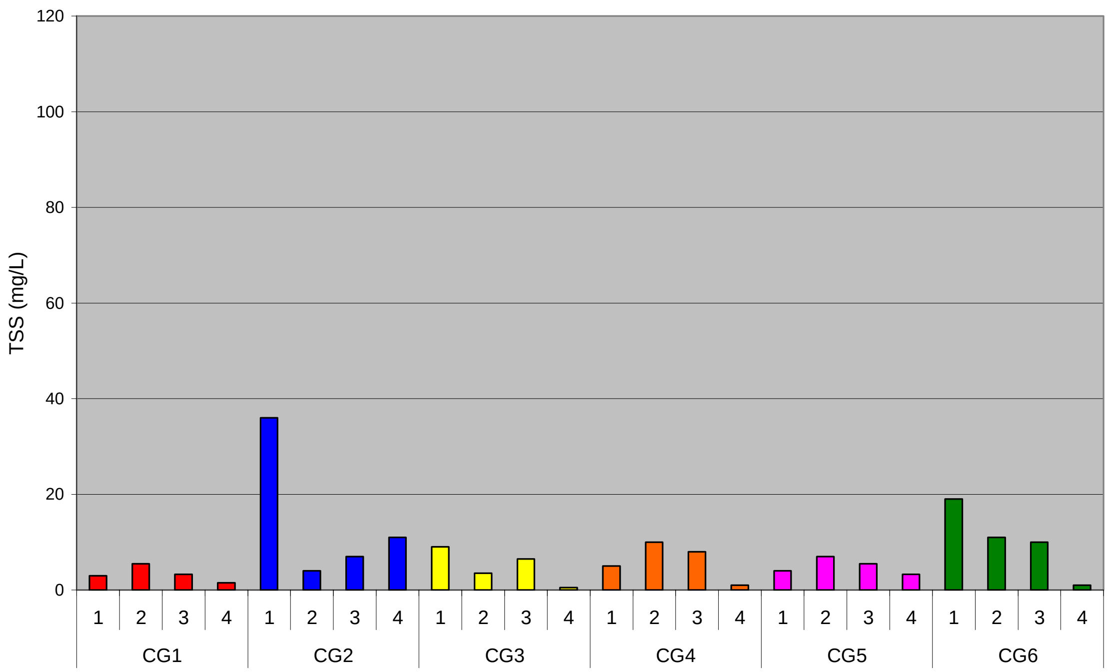
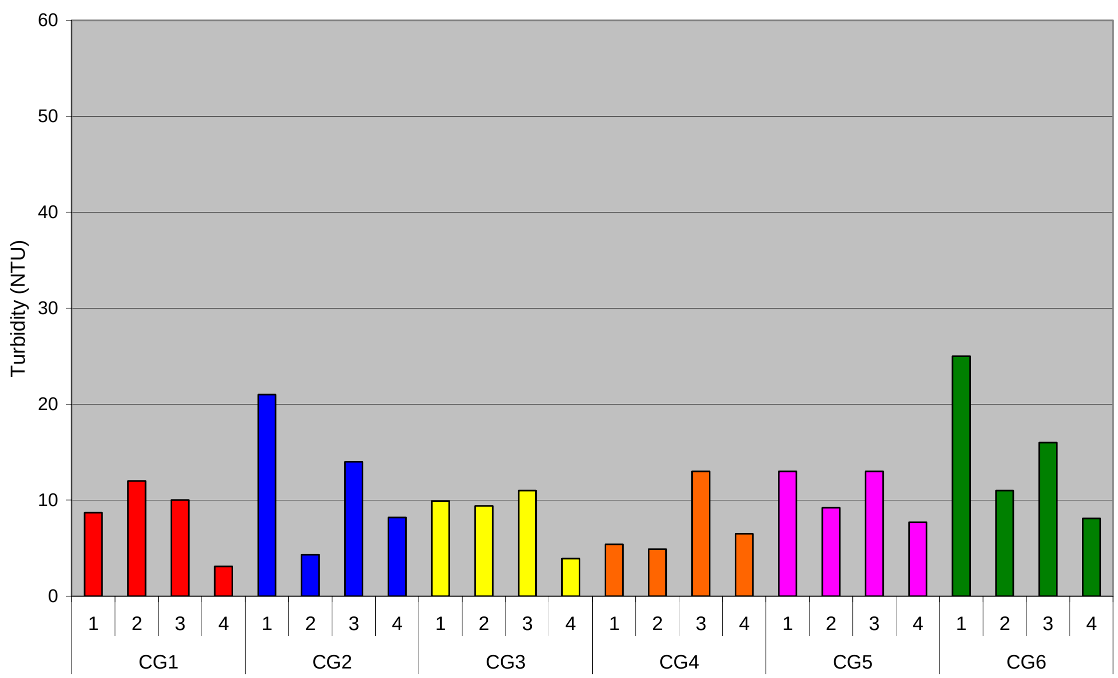


FIGURE 8: Baseline Storm 2 - Turbidity



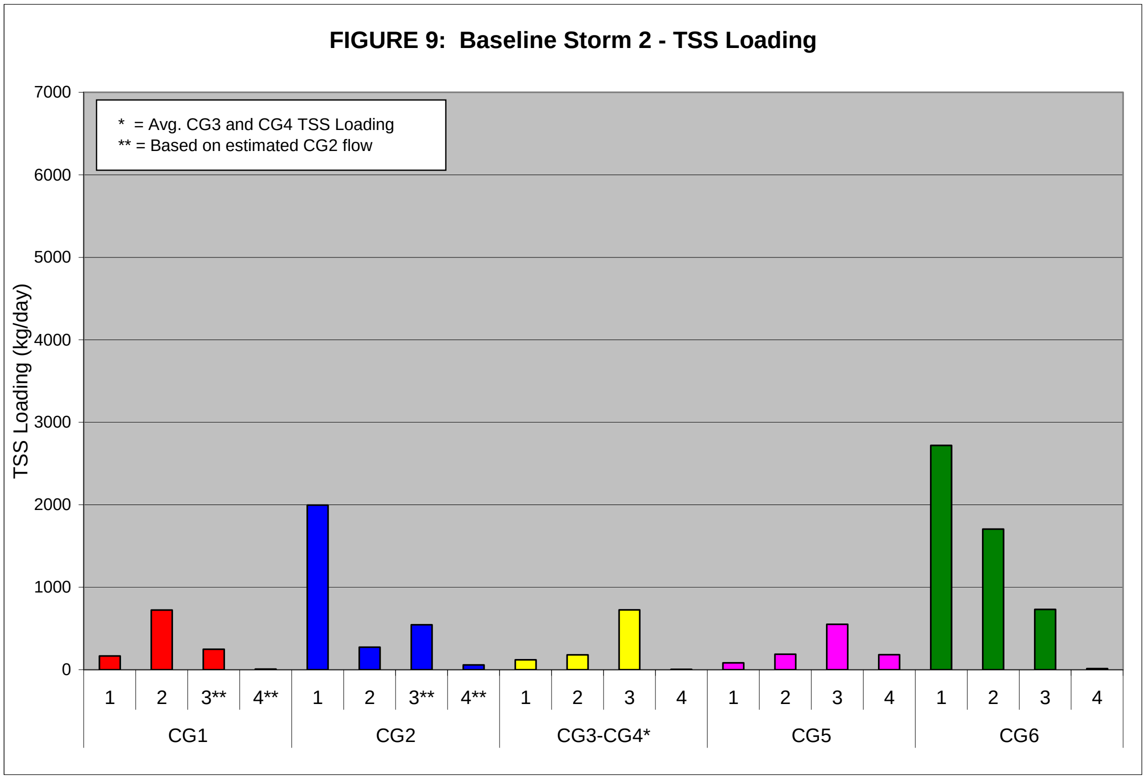


FIGURE 9: Baseline Storm 2 - TSS Loading
* = Avg. CG3 and CG4 TSS Loading
** = Based on estimated CG2 flow
TSS Loading (kg/day)
7000
6000
5000
4000
3000
2000
1000
0
1
2
3**
4**
1
2
3**
4**
1
2
3
4
1
2
3
4
1
2
3
4
CG1
CG2
CG3-CG4*
CG5
CG6

FIGURE 10: Baseline Storm 1- Settling Study (TSS)

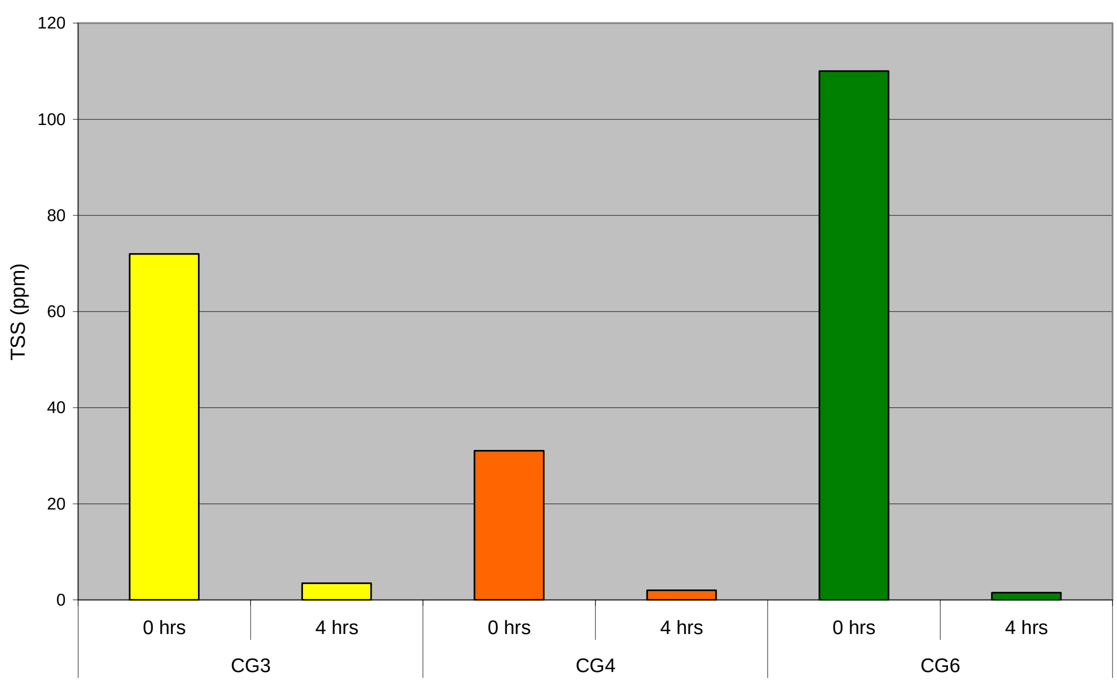


FIGURE 11: Baseline Storm 1 - Settling Study (Turbidity)

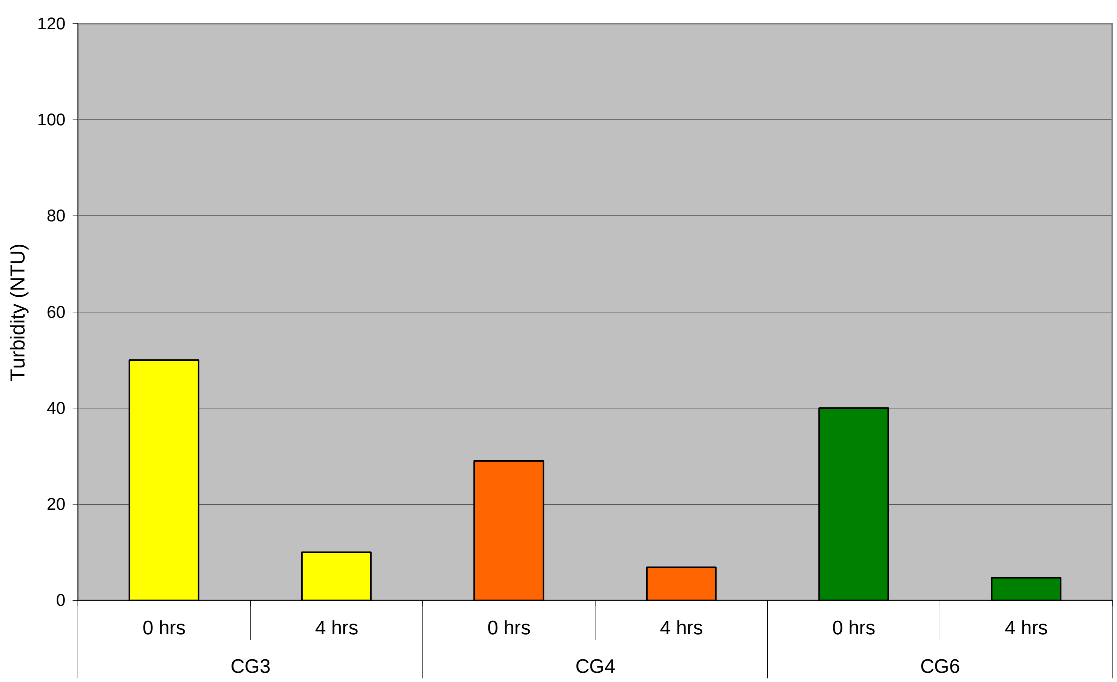


FIGURE 12: Low Flow Event - TSS Concentration

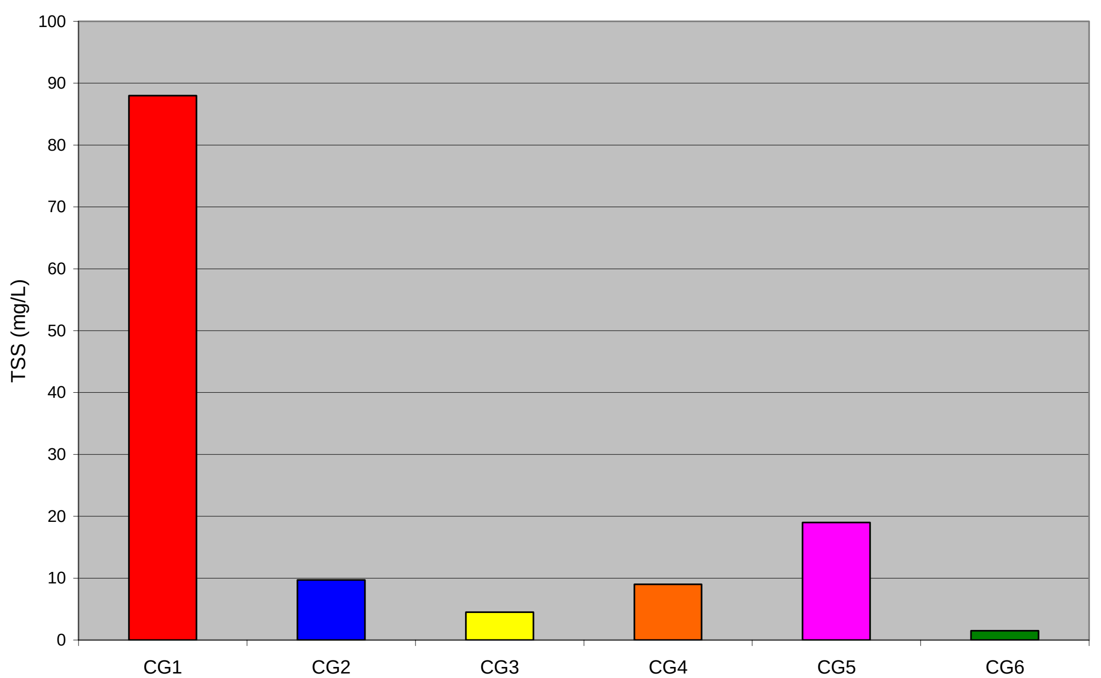


FIGURE 13: Low Flow Event - Turbidity

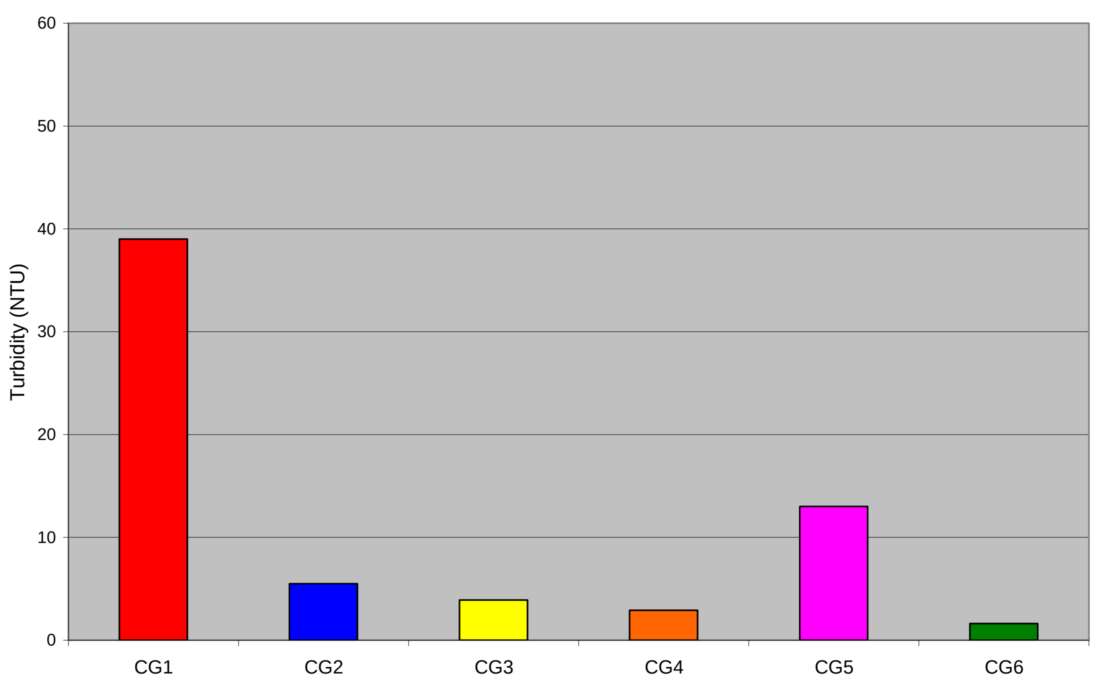
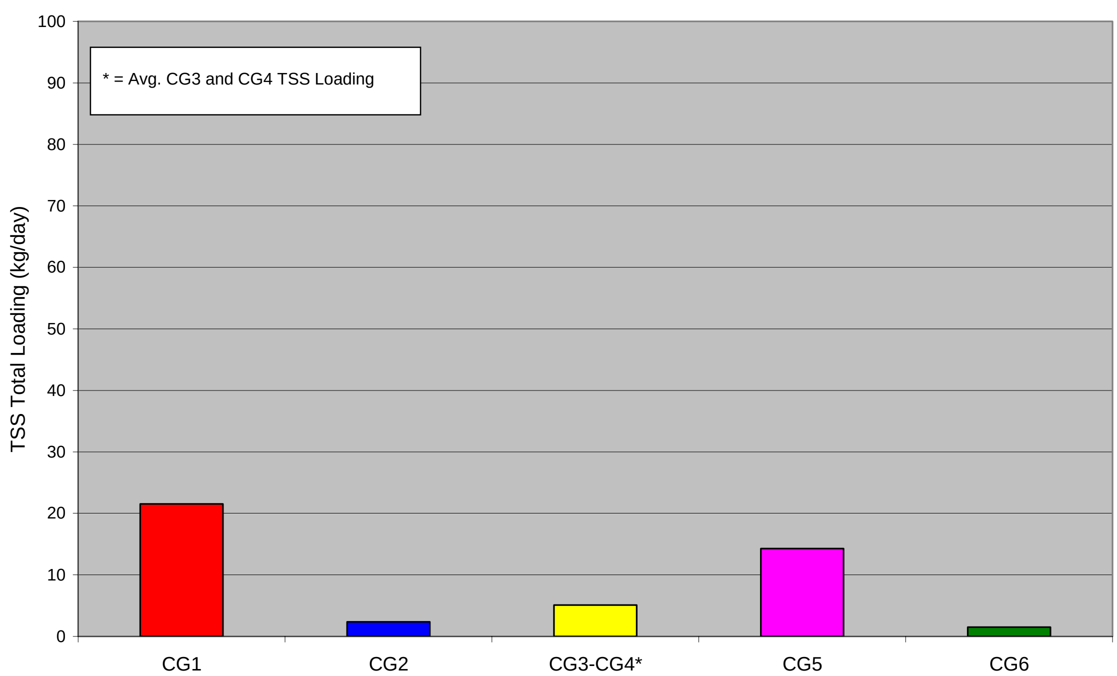


FIGURE 14: Low Flow Event - TSS Loading



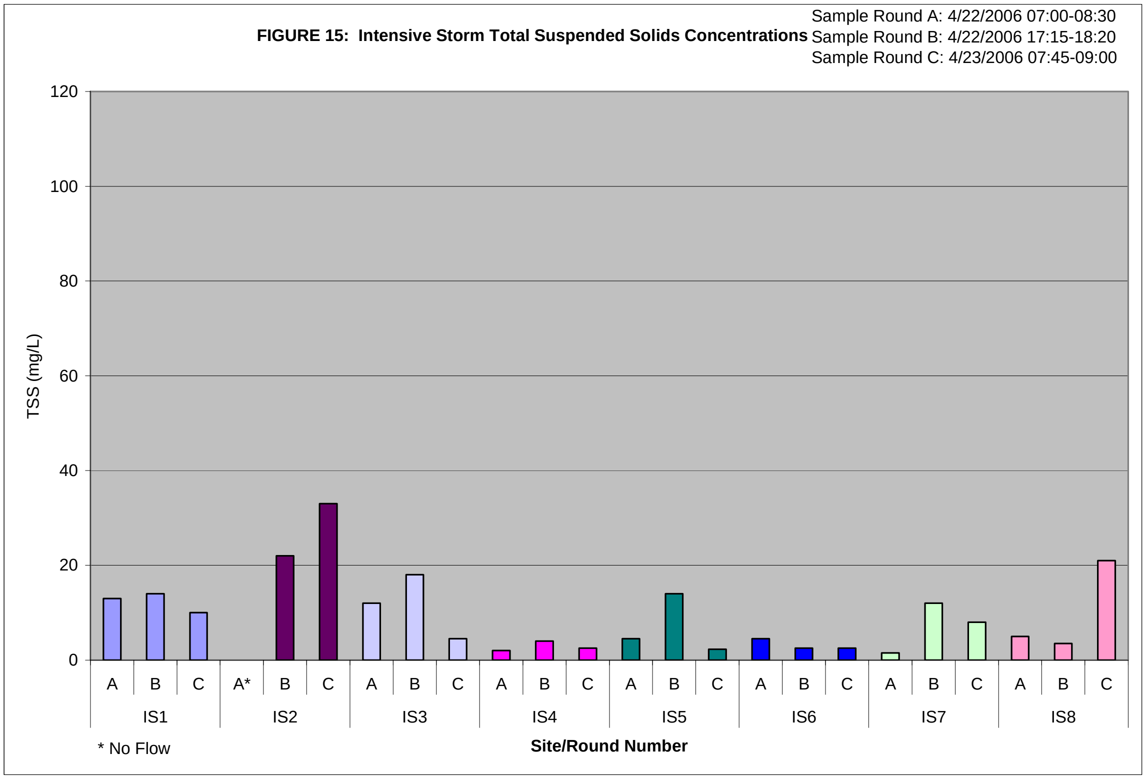


FIGURE 15: Intensive Storm Total Suspended Solids Concentrations
Sample Round A: 4/22/2006 07:00-08:30
Sample Round B: 4/22/2006 17:15-18:20
Sample Round C: 4/23/2006 07:45-09:00
TSS (mg/L)
0
20
40
60
80
100
120
A B C A* B C A B C A B C A B C A B C A B C A B C
IS1 IS2 IS3 IS4 IS5 IS6 IS7 IS8
Site/Round Number
* No Flow

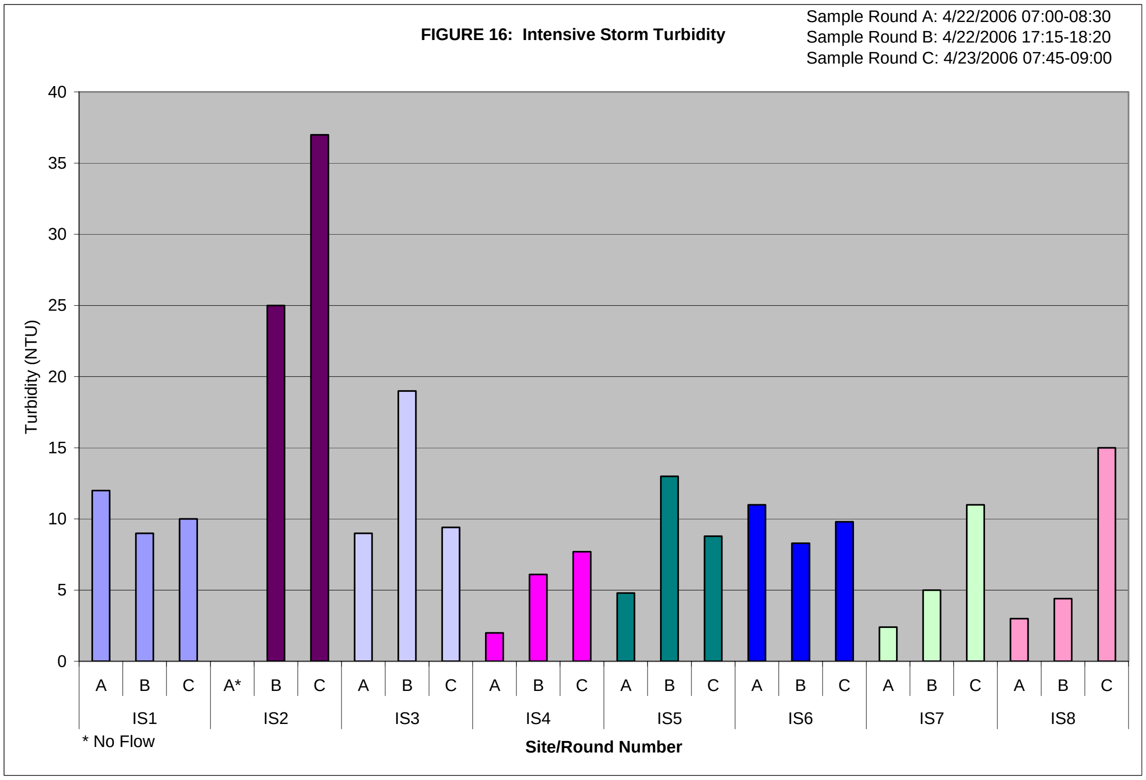


FIGURE 16: Intensive Storm Turbidity
Sample Round A: 4/22/2006 07:00-08:30
Sample Round B: 4/22/2006 17:15-18:20
Sample Round C: 4/23/2006 07:45-09:00
Turbidity (NTU)
0
5
10
15
20
25
30
35
40
A
B
C
A*
IS1
IS2
IS3
IS4
IS5
IS6
IS7
IS8
* No Flow
Site/Round Number

Characterization and Assessment of the Cedar Grove Brook Watershed

September 2009 – Final Draft

Jen Zhang, Watershed Protection Specialist
NJ Water Supply Authority

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FIGURE 6: CEDAR GROVE BROOK WATERSHED PRESERVED OPEN SPACE 11

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Project Background

In November 2003, the New Jersey Department of Environmental Protection Division of Watershed Management funded the New Jersey Water Supply Authority's (NJWSA) Section 319(h) Nonpoint Source grant proposal, "Stormwater Management Plan for the Cedar Grove Brook Watershed". NJWSA submitted this project with support from Franklin Township, Somerset County and the Somerset-Union County Soil Conservation District.

This project focuses on developing a watershed-based stormwater management plan to improve water quality problems caused by nonpoint source pollution and stormwater. Total NJDEP funding is $150,000 with a match of approximately $50,000 from NJWSA (using the Source Water Protection Fund and general budget funds) and in-kind support from the Franklin Township. The project will have beneficial results for the Delaware & Raritan Canal. As needed, watershed-specific criteria will be developed for stormwater management from new developments and potential projects will be identified for reducing the impact pollution from existing land uses. Through implementation of the Plan, pollutant loads to the Canal will be reduced and controlled, and stream baseflow to the Canal will be maintained.

The characterization and assessment will provide an in-depth characterization of the current conditions within the Cedar Grove Brook Watershed, and an evaluation and assessment of the findings to determine the short-term and long-term management measures that will be required to allow the stream to achieve full attainment of its designated uses. The characterization and assessment report is intended for preliminary assessments of the watershed and cannot substitute for on-site testing and evaluations.

Physical Setting of the Cedar Grove Brook Watershed

Cedar Grove Brook (also known as Al's Brook), an FW2-NT (Fresh water Category 2, non trout) waterbody, is a significant tributary to the Delaware & Raritan Canal, one of New Jersey's major water supply facilities. The Brook is located in Franklin Township, Somerset County and discharges to the Canal approximately 2 miles upstream of the water supply intakes for Middlesex Water Company, the Township of East Brunswick and the City of New Brunswick (**Figure 1**).

The Cedar Grove Brook encompasses a drainage area of approximately 1788 acres, located completely within HUC14 02030105-120-160[1], the Lower Raritan River from Mile Run to I-287 Piscataway, in the Lower Raritan Watershed Management Area (WMA 9).

The Cedar Grove Brook watershed is the fourth largest direct drainage area to the Canal, and is over 63 percent urban land coverage (as of 2006) with development continuing. The D&R Canal between Ten Mile Lock and Landing Lane Bridge receives excess loads of total suspended solids and turbidity causing sedimentation in the Canal and increased costs for drinking water

[1] HUC is a Hydrologic Unit Code is used for identifying watersheds. The number indicates the level to which the larger watersheds are subdivided.

treatment. Cost-effective stormwater and stream channel management to address problems caused by current and past development is needed.

The Cedar Grove Brook including all its tributaries is 3.6 miles long and rises from the wooded wetlands near Amwell Road in Franklin Township. It flows north through residential, commercial and forested areas before discharging to the D&R Canal at Easton Avenue (see aerial photography in **Figure 2**).

Because population estimates are done based upon political boundaries instead of watershed boundaries, the exact population within the watershed can only be estimated. According to the US Census Bureau, the population in Franklin Township increased from 42,780 in 1990 to 50,903 (19% increase) in 2002, to 58,461 (14.8% increase) in 2005. Much of the development activity in the watershed occurred between 1970 and 1990. There is however, continued in-fill development, particularly along Cedar Grove Lane.

Figure 1: Location of Cedar Grove Brook Watershed

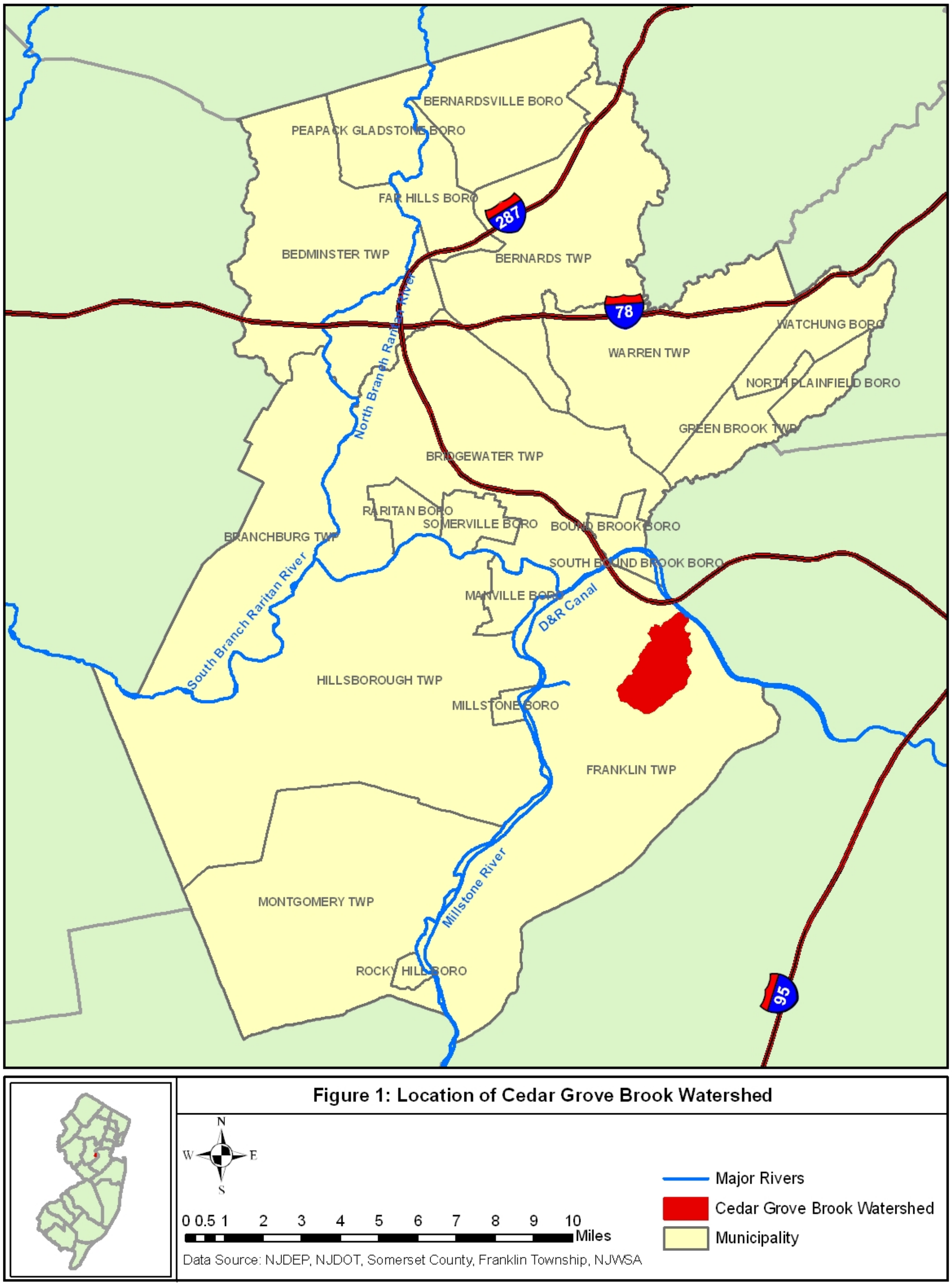
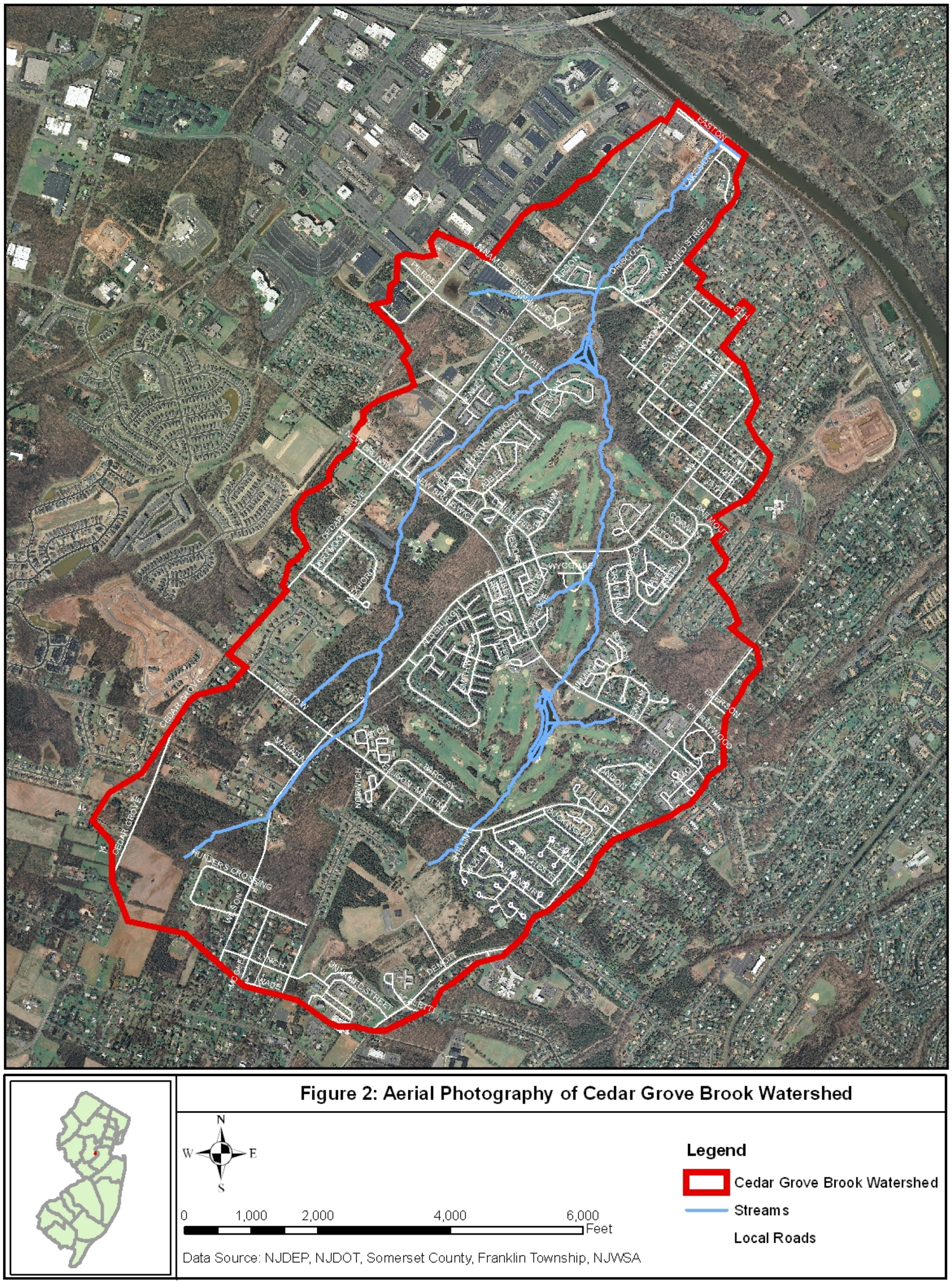


Figure 2: Aerial Photography of Cedar Grove Brook Watershed



Land Use Land Cover & Impervious Surface

The Cedar Grove Brook watershed is mostly developed; however, the riparian corridors are still forested in much of the watershed. Forested riparian corridors help to provide shade; stabilize stream banks and contribute to a stream's ability to support a variety of pollution sensitive species of aquatic life. Although at present the creek's corridors are lightly developed, pressure is mounting from the commercial development along Easton Avenue and highly populated residential areas within this watershed.

In November 2006, NJWSA staff revised the 2002 NJDEP land use land cover data based on field reconnaissance to analyze the pattern of land use change from 1986 to 1995, 1995 to 2002 and 2002 to 2006. Most of these changes may be characterized as impacts to natural habitats. These include (in order of frequency) a change from agriculture to residential use; forest to residential; wetlands to residential; forest to agriculture; and wetland to agriculture.

The Cedar Grove Brook watershed is primarily urban in nature (63% in 2006), with scattered forest and wetlands. By 2002, most of the area had already been developed, with only 27 acres converted to urban through 2006 (**Table 1**). While from 1995 to 2002, total 113 acres of new urban area has been added, developed in the previous forest, agriculture or wetland area (**Table 2**). An even faster development pace occurred during the period from 1986 to 1995 (**Table 3**), which added 290 acres of new urbanized area to this watershed. By sum, during the past 20 years from 1986 to 2006, a total of 431 acres have been converted to urban land in this watershed (**Table 4 and Figure 3, Figure 4 and 5**). Even though the development pace has slowed in the recent years, any new development could put further stress on the watershed.

A number of recent studies have shown that the hydrologic and pollutant loading in a watershed is directly related to the amount of impervious cover in that watershed[2]. Once the amount of impervious cover is greater than 5% to 10%, there is a drastic reduction in the health of a stream. Impervious surfaces do not allow rain and storm water to recharge naturally. Instead, this water becomes runoff, which is routed to the stream more quickly. Runoff from impervious areas can also contain a variety of pollutants that are detrimental to water quality, including sediment, nutrients, road salts, heavy metals, pathogenic bacteria, and petroleum hydrocarbons.

Currently the impervious surface in the Cedar Grove Brook watershed is 19.5% (total 348 acres of impervious cover according to the 2002 NJDEP land use/land cover data). Any future impervious cover development will further degrade this watershed.

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[2] Shueler, T.R. 1992. *Mitigating the Adverse Impacts of Urbanization on Streams: A Comprehensive Strategy for Local Government*. In Watershed Restoration Sourcebok. Publication #92701 of the Metropolitan Washington Council of Governments.

Table 1: Land Use Change from 2002 to 2006

Land Use Type	Acres 2002	Percent 2002	Acres 2006	Percent 2006	Acreage Change from 2002 to 2006	Percent Change from 2002 to 2006
AGRICULTURE	24.56	1.37	24.56	1.37	0.00	0.00
FOREST	316.39	17.70	308.60	17.26	-7.79	-0.44
URBAN	1102.37	61.65	1129.74	63.18	27.37	1.53
WATER	7.09	0.40	7.09	0.40	0.00	0.00
WETLANDS	330.08	18.46	318.02	17.79	-12.07	-0.67
BARREN LAND	7.51	0.42	0.00	0.00	-7.51	-0.42
SUM	1788.00	100.00	1788.00	100.00	0.00	0.00

Table 2: Land Use Change from 1995 to 2002

Land Use Type	Acres 1995	Percent 1995	Acres 2002	Percent 2002	Acreage Change from 1995 to 2002	Percent Change from 1995 to 2002
AGRICULTURE	49.14	2.75	24.56	1.37	-24.59	-1.38
BARREN LAND	3.80	0.21	7.51	0.42	3.71	0.21
FOREST	354.60	19.83	316.39	17.70	-38.20	-2.14
URBAN	988.91	55.31	1102.37	61.65	113.46	6.35
WATER	7.09	0.40	7.09	0.40	0.00	0.00
WETLANDS	384.47	21.50	330.08	18.46	-54.38	-3.04
SUM	1788.00	100.00	1788.00	100.00	0.00	0.00

Table 3: Land Use Change from 1986 to 1995

Land Use Type	Acres 1986	Percent 1986	Acres 1995	Percent 1995	Acreage Change from 1986 to 1995	Percent Change from 1986 to 1995
AGRICULTURE	52.80	2.95	49.14	2.75	-3.65	-0.20
BARREN LAND	83.69	4.68	3.80	0.21	-79.89	-4.47
FOREST	393.77	22.02	354.60	19.83	-39.18	-2.19
URBAN	698.77	39.08	988.91	55.31	290.14	16.23
WATER	4.70	0.26	7.09	0.40	2.39	0.13
WETLANDS	554.28	31.00	384.47	21.50	-169.81	-9.50
SUM	1788.00	100.00	1788.00	100.00	0.00	0.00

Table 4: Land Use Change from 1986 to 2006

Land Use Type	Acres 1986	Percent 1986	Acres 2006	Percent 2006	Acreage Change from 1986 to 2006	Percent Change from 1986 to 2006
AGRICULTURE	52.80	2.95	24.56	1.37	-28.24	-1.58
FOREST	393.77	22.02	308.60	17.26	-85.17	-4.76
URBAN	698.77	39.08	1129.74	63.18	430.97	24.10
WATER	4.70	0.26	7.09	0.40	2.39	0.13
WETLANDS	554.28	31.00	318.02	17.79	-236.26	-13.21
BARREN LAND	83.69	4.68	0.00	0.00	-83.69	-4.68
SUM	1788.00	100.00	1788.00	100.00	0.00	0.00

Figure 3: Land Use Acres Comparison between 1986 and 2006

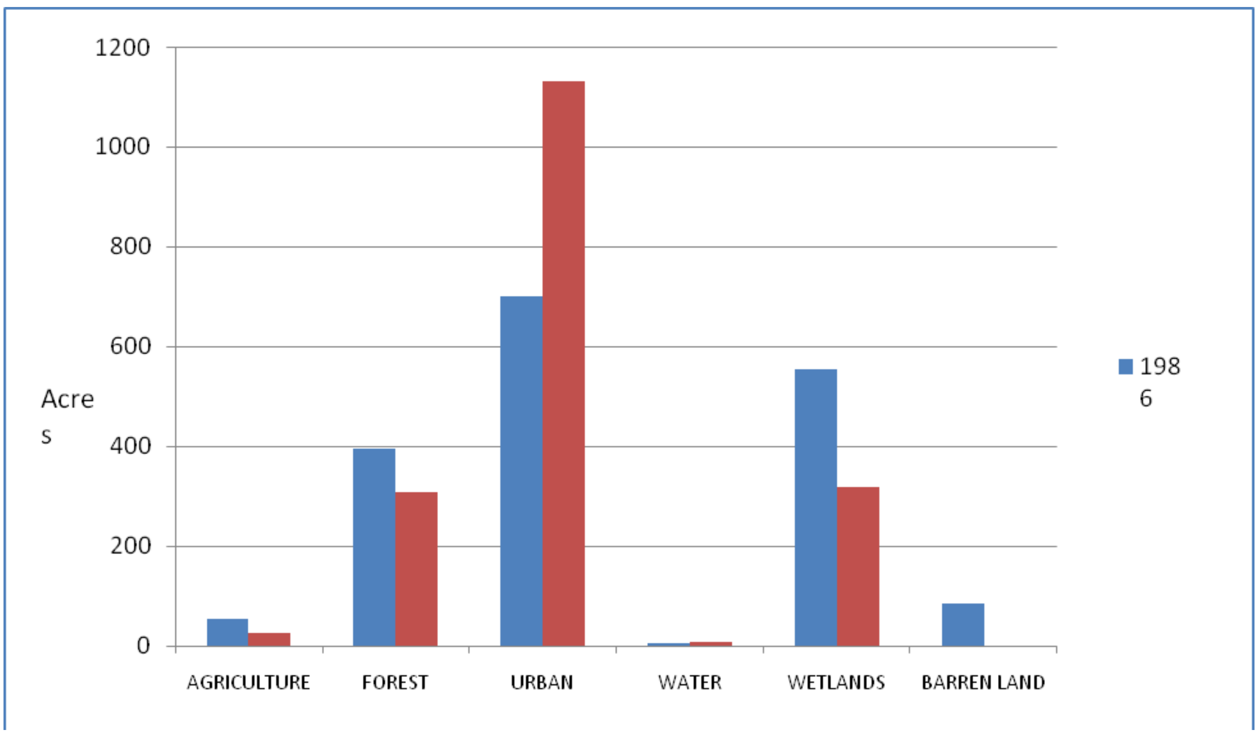


Figure 4: Cedar Grove Brook Watershed 1986 Land Use

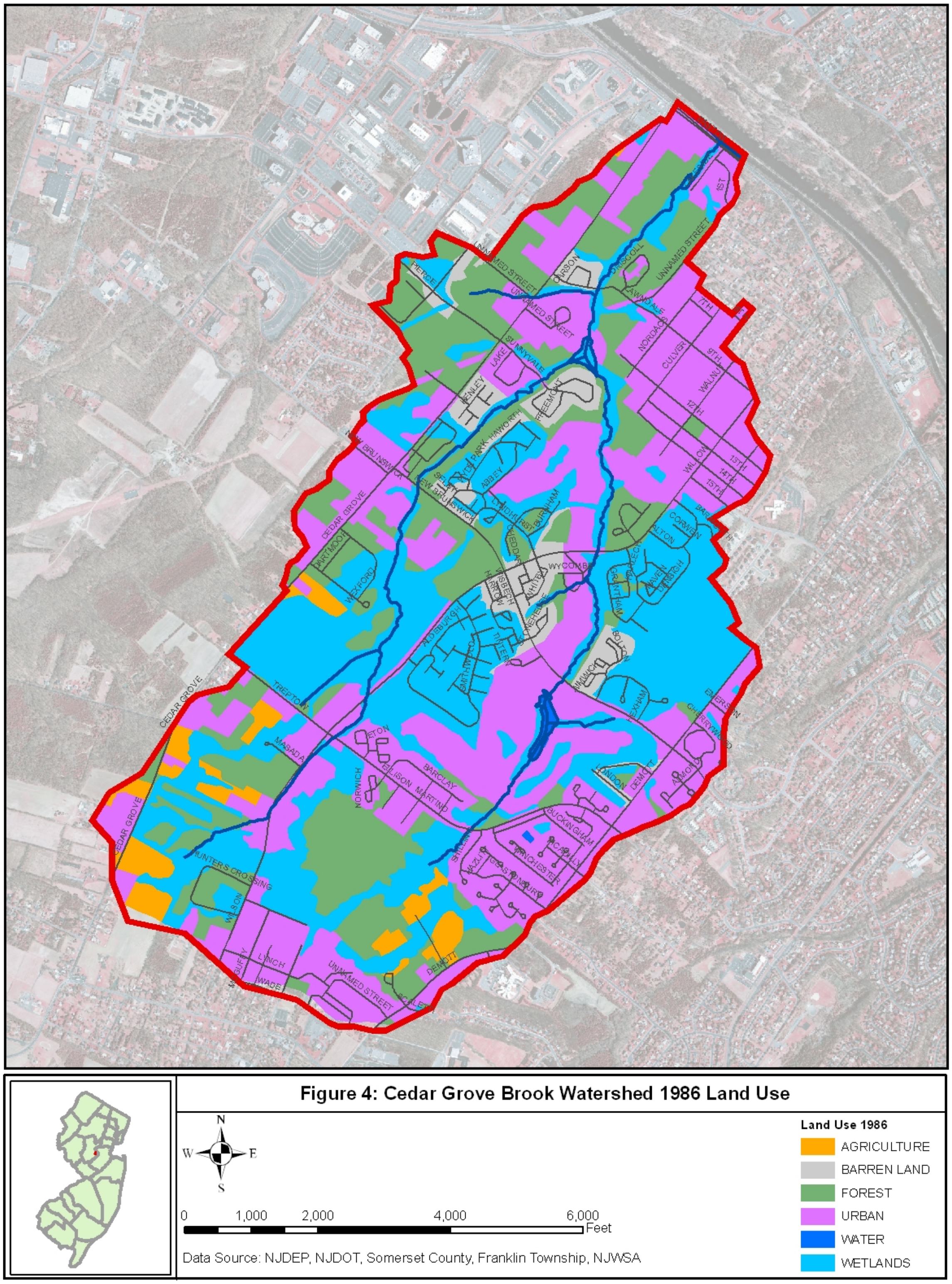
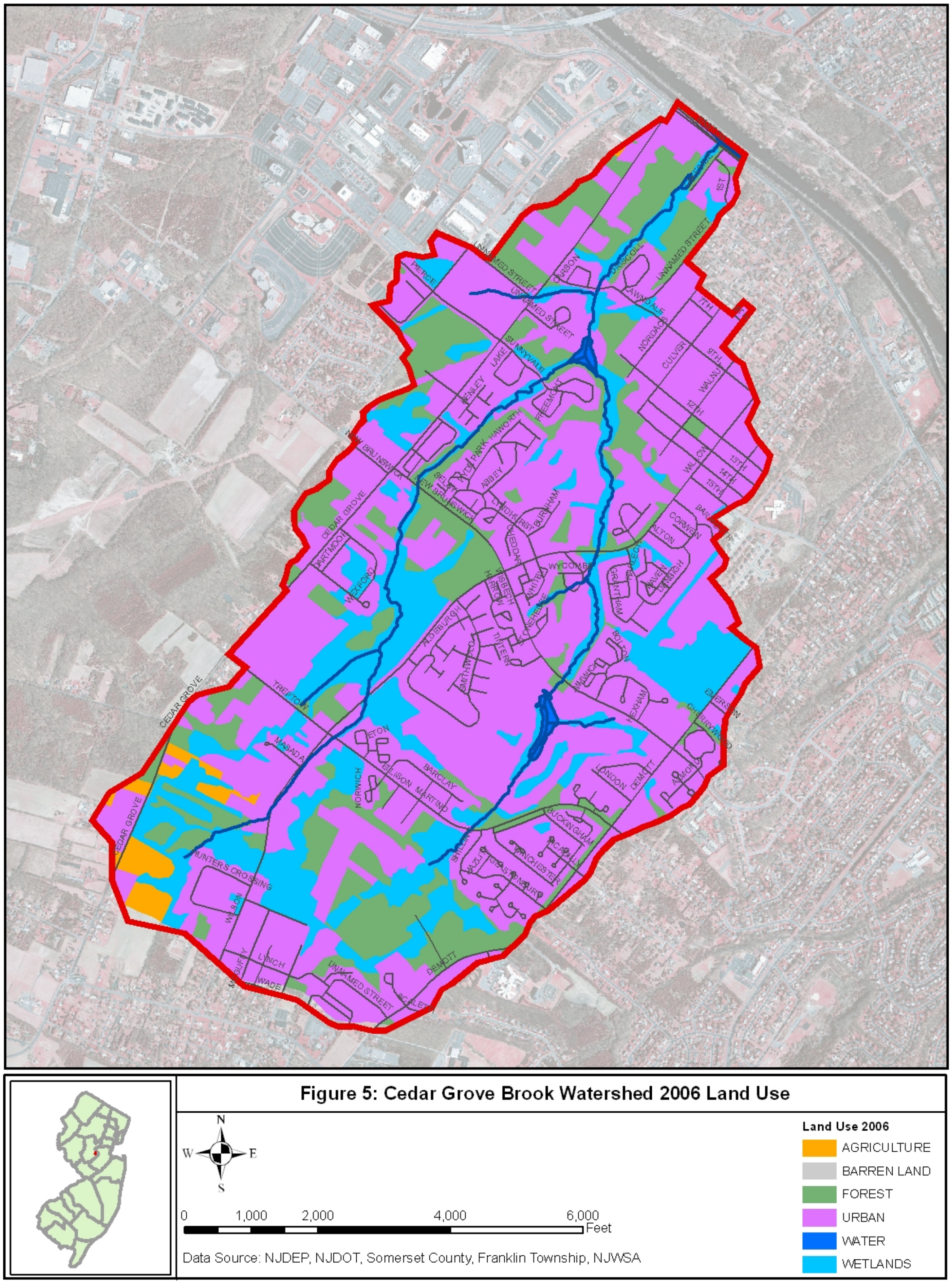


Figure 5: Cedar Grove Brook Watershed 2006 Land Use

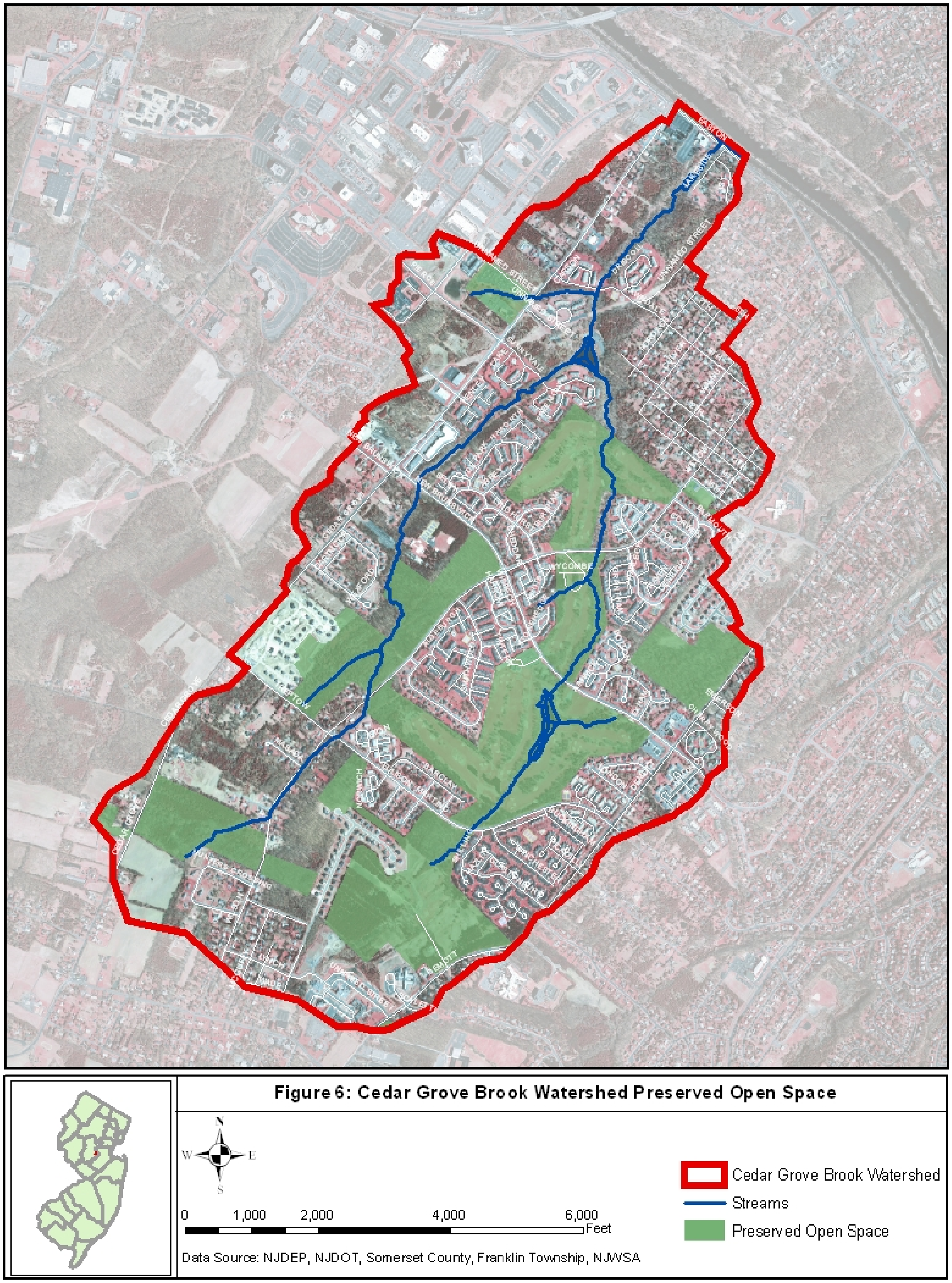


Open Space Preservation in the Watershed

The preservation of open space is beneficial to the health of our watersheds, and is perhaps the single most effective tool for protecting water quality and quantities. Open space, particularly those which are kept as forest or other vegetation, provides areas for natural infiltration of runoff and vegetation slows the movement of stormwater. The benefits of preserving land include limiting the amount of impervious cover in the landscape, increasing the infiltration of stormwater, decreasing flooding and erosion, decreasing non-point source pollution, providing habitat, increasing biodiversity, supporting agriculture, providing recreational opportunities, protecting quality of life and increasing nearby land values. Open space preservation should be conducted on a regional basis to avoid the creation of isolated islands of open space. New Jersey has taken a bold step with the creation of the Garden State Preservation Trust, which strives to save 1 million acres of open space and farmland. Franklin Township and Somerset County could take advantage of the funds from Garden State Preservation Trust, and have adopted open space and farmland preservation plans, and have dedicated taxes to finance acquisitions.

The total preserved open space in the Cedar Grove Watershed is 447 acres as of 2009, 25 percent of the total watershed area (**Figure 6**), there is no state owned open space in this watershed and Quail Brook Golf Course is owned by the County, all other open space belongs to Franklin Township. As of 2006, approximately 26 acres of farmland were present in the watershed, primarily along Cedar Grove Lane. These farms are surrounded by residential and other urban development. None are preserved through state or local programs, perhaps due to their small size.

Figure 6: Cedar Grove Brook Watershed Preserved Open Space



Water Quality

The Delaware and Raritan Canal transfers water from the Delaware River Basin to the Raritan River Basin, where the raw water is treated to become drinking water for approximately 600,000 people living in and outside of the Raritan Basin. The drinking water is treated and distributed by three water purveyors, Middlesex Water Company, the Township of East Brunswick and the City of New Brunswick. The entire length of the Canal is classified as FW2-NT.

The water supply purveyors have reported increased levels of total suspended solids (TSS), Turbidity, and total organic carbon (TOC) in the Canal during and immediately after precipitation events, requiring increased chemical use for removal and increased sludge generation from residuals. There are no groundwater or surface water discharges permitted in this watershed based on NJDEP NJPDES data, so the source of pollution is 100% nonpoint source pollution. A United States Geological Survey (USGS) study from 1998 and 1999 reported that turbidity and sediments were entering the Canal from influent streams and discharges to the Canal between 10 Mile Lock and Landing Lane Bridge and pointed to Cedar Grove Brook as a likely contributor.

To examine the water quality problems reported by water purveyors and the issues found in USGS's report, NJWSA contracted with Omni Environmental, LLC to provide field services and water quality sampling to determine watershed runoff rates and volumes and associated sediment loads, and then utilize a watershed computer model (WinSLAMM) to predict turbidity and total suspended solids (TSS) loading. These data were then used to target areas within the watershed for remedial actions.

TRC Omni prepared a Quality Assurance Project Plan (QAPP) to obtain the necessary data to evaluate targeted pollutants with respect to flow conditions, seasonal variations and pertinent weather conditions. The sampling plan was designed to assess water quality impacts due to erosion and stormwater runoff in order to determine the effectiveness of BMP installations within the Cedar Grove Brook watershed. The field services and water quality sampling were performed in accordance with the Quality Assurance Project Plan (QAPP) for six (6) stormwater locations, six (6) low flow locations, and eight (8) intensive stormwater locations to evaluate the targeted pollutants. The parameters measured during this study were Total Suspended Solids (TSS) and turbidity. Omni submitted an initial report in July 2006.

Omni's Cedar Grove Brook Watershed Water Quality Characterization and Assessment Report (July 2006) concluded the overall in-stream criteria for Cedar Grove Brook are regularly met for TSS and turbidity and concentrations and loads are relatively low throughout the watershed. When concentrations are elevated, it appears that the issue resolves itself before the stream's confluence with the Canal due to a high settling rate in the tributary. The observed concentrations of TSS and turbidity were low enough that it appeared that Cedar Grove Brook may not be a large contributing factor to TSS and turbidity problems in the Canal. During low flow conditions, Ukrainian Pond appeared to be a source of TSS and turbidity due to its phytoplankton production (**Figure 7**: Drainage Area to Three Ponds). During high flow conditions moderate stream bank erosion and construction projects cause increased concentrations of TSS and turbidity in the Brook. This issue is partially resolved when the Ukrainian Village Pond settles suspended solids from upstream areas. Stream bank stabilization projects and buffer plantings downstream of the pond would aid in reducing TSS and turbidity near the streams confluence with the Canal.

Overall, the sampling results were not sufficient to exclude the possibility that Cedar Grove Brook delivers a substantial turbidity load affecting water quality in the Canal; nevertheless, the lack of direct sampling confirmation left open the possibility that efforts to minimize TSS and turbidity loads in the Cedar Grove Brook watershed may not address the water quality problems observed at the water supply intakes in the Canal. To further investigate the water quality issues, continuous turbidity monitoring was performed in the fall of 2008.

The continuous turbidity monitoring results suggest that Cedar Grove Brook can significantly increase the turbidity peaks in the D&R Canal that occur during storm events. Since the long-term monitoring indicates that such turbidity peaks can be very high, the impact of Cedar Grove Brook on turbidity peaks in the Canal appears to be important from a water quality perspective, given the proximity to the water supply intake. Water quality sampling in both Cedar Grove Brook and the D&R Canal demonstrate that high values of turbidity occur together with high values of TSS; it is therefore likely that measures to reduce TSS loads to the Canal, which is the parameter of interest for the D&R Canal Nonpoint Source Implementation Project[3], will also reduce turbidity.

For the reasons stated above, the Cedar Grove Brook watershed was evaluated for potential stormwater BMP improvements. A windshield survey of the Cedar Grove Brook watershed was performed on January 8, 2009. A long-term WinSLAMM simulation was developed in order to evaluate potential BMPs to reduce the particulate load exported from Cedar Grove Brook to the D&R Canal.

According to the WinSLAMM model analysis, most of the sediment load in the Cedar Grove Brook watershed originates from pervious (wooded or landscaped), private residential areas. This limits the effectiveness of many structural and non-structural BMPs that might otherwise be contemplated in the watershed. Non-structural BMPs that would potentially yield a positive result in terms of improved water quality include public education aimed at local residents and improved fill management at the golf course. Efforts to reduce stormwater runoff from landscaped areas, such as the installation of rain gardens, would directly address the major source of sediment in the watershed.

The three existing pond structures in Cedar Grove Brook (Golf Course Pond, Ukrainian Village Pond, and Lower Pond) are providing significant sediment removal such that Cedar Grove Brook is currently discharging far less sediment to the D&R Canal than it would otherwise . However, these same pond structures also act as sediment sources due to the resuspension of accumulated sediment under certain storm conditions. Given the above considerations, the highest

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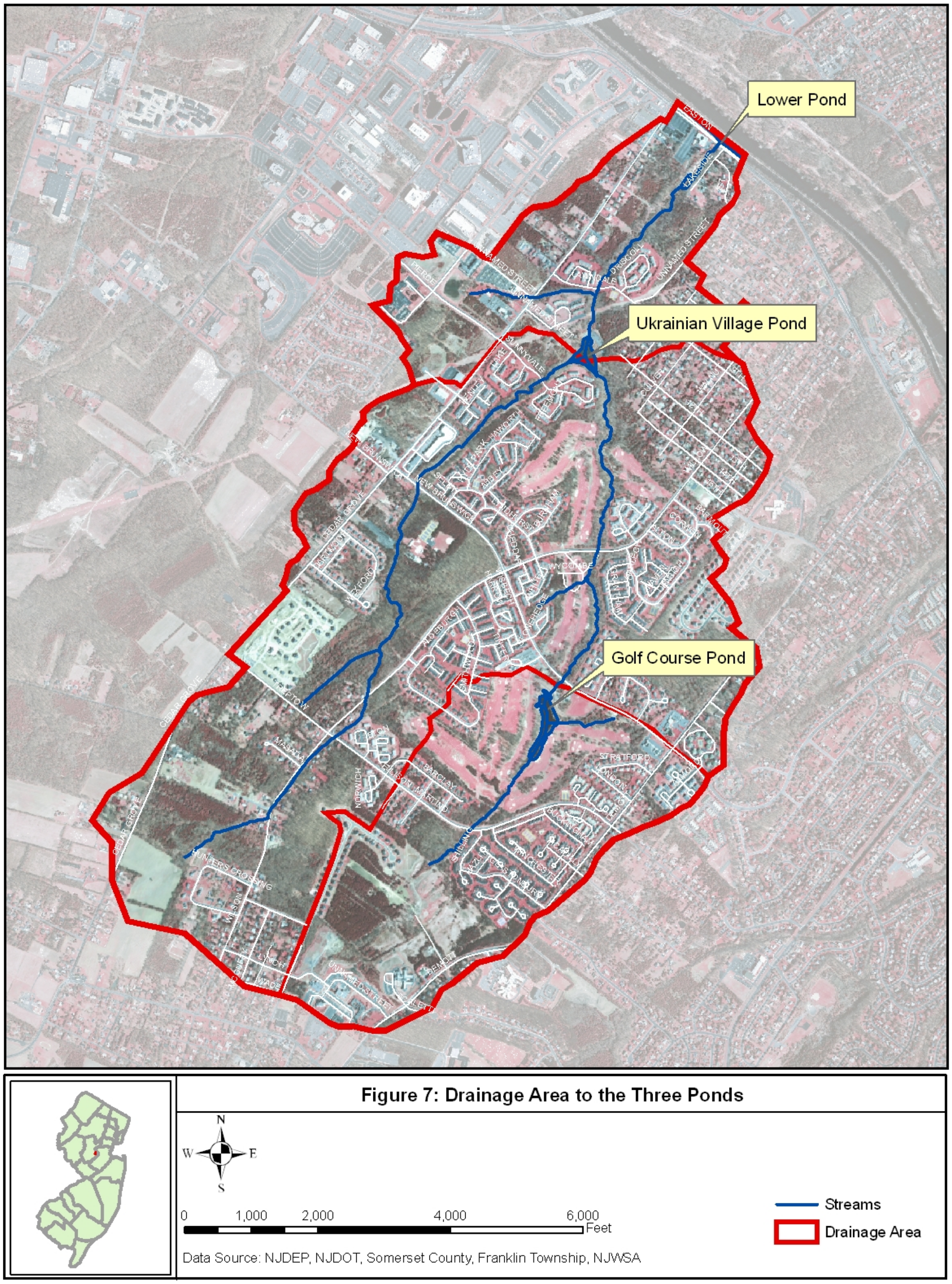
[3] A major restoration project (Delaware and Raritan Canal Nonpoint Source Implementation Project) is currently underway by NJWSA to reduce sediment loads to the Canal from the many stormwater infalls between Amwell Road and the Route 18 spillway, the last 11 miles of the Canal.

prioritization should be given toward improving the pond structures that already exist in order to optimize their water quality benefits. Each pond feature was evaluated for BMP opportunities, and the outlet structure of each pond was evaluated using long-term WinSLAMM simulations to explore possible modifications to enhance sediment removal.

The detailed information about the recommended structural BMPs for each of the existing pond structures can be found in Omni’s report “Cedar Grove Brook Watershed Restoration Planning Project” dated April 2009.

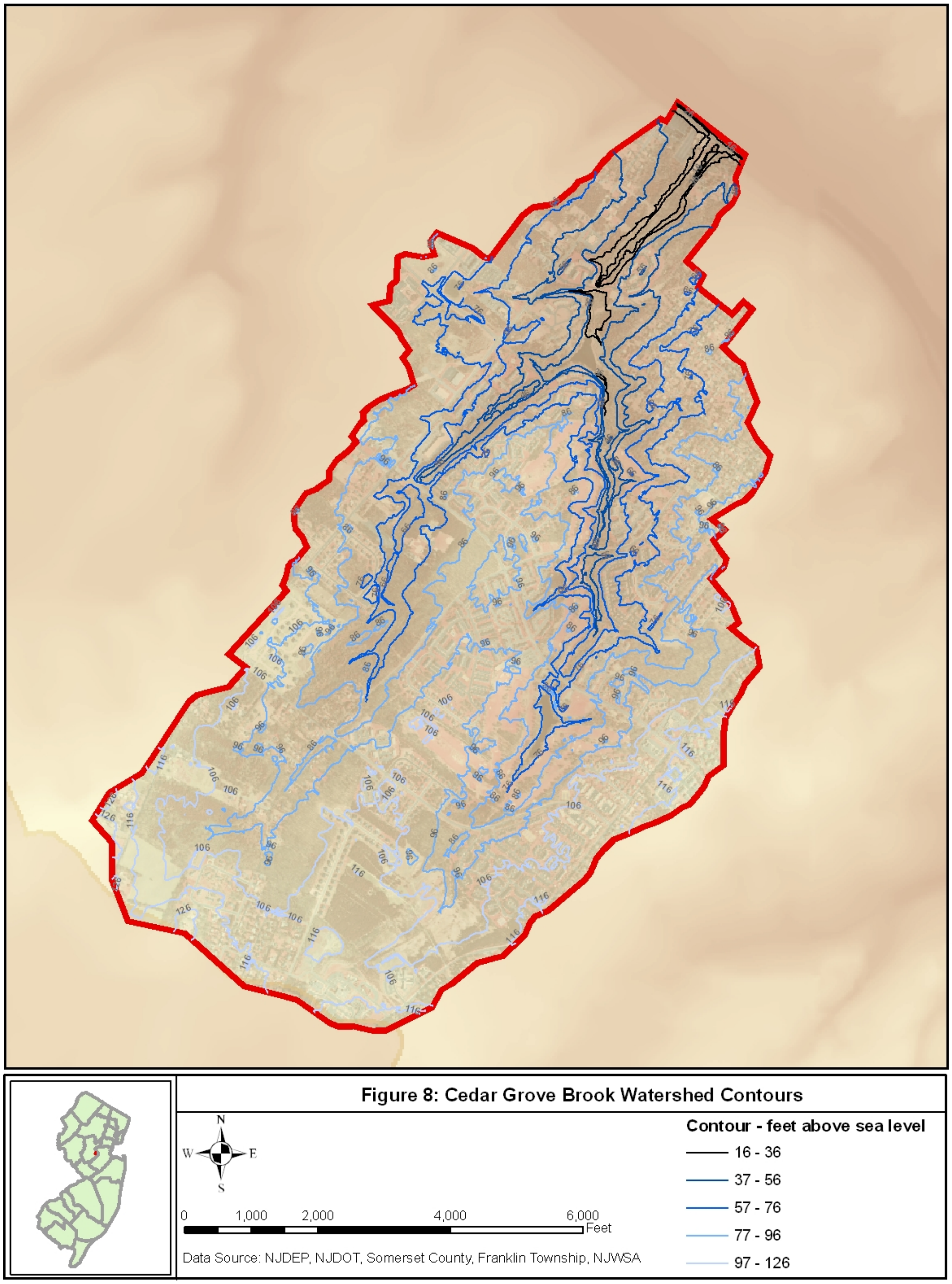
Figure 7: Drainage Area to the Three Ponds



Topography

The elevation in the Cedar Grove Brook watershed ranges from 6 feet to 132 feet above mean sea level. Contour data was obtained from Franklin Township; **Figure 8** presents the contours within the watershed. Inspection of the contours demonstrates the gentle slope of the watershed as well as the steeper sloped areas. Most of the banks along the Cedar Grove Brook are between 5 to 10 percent slope. As the gradient or percent of slope increases, the velocity of runoff water increases, which increases its erosive power. A doubling of velocity of runoff water increases the erosive power fourfold and causes 32 times the amount of material of a given particle size that can be carried (Foth, 1978).

Figure 8: Cedar Grove Brook Watershed Contours



Ground Water, Soil & Known Contaminated Sites

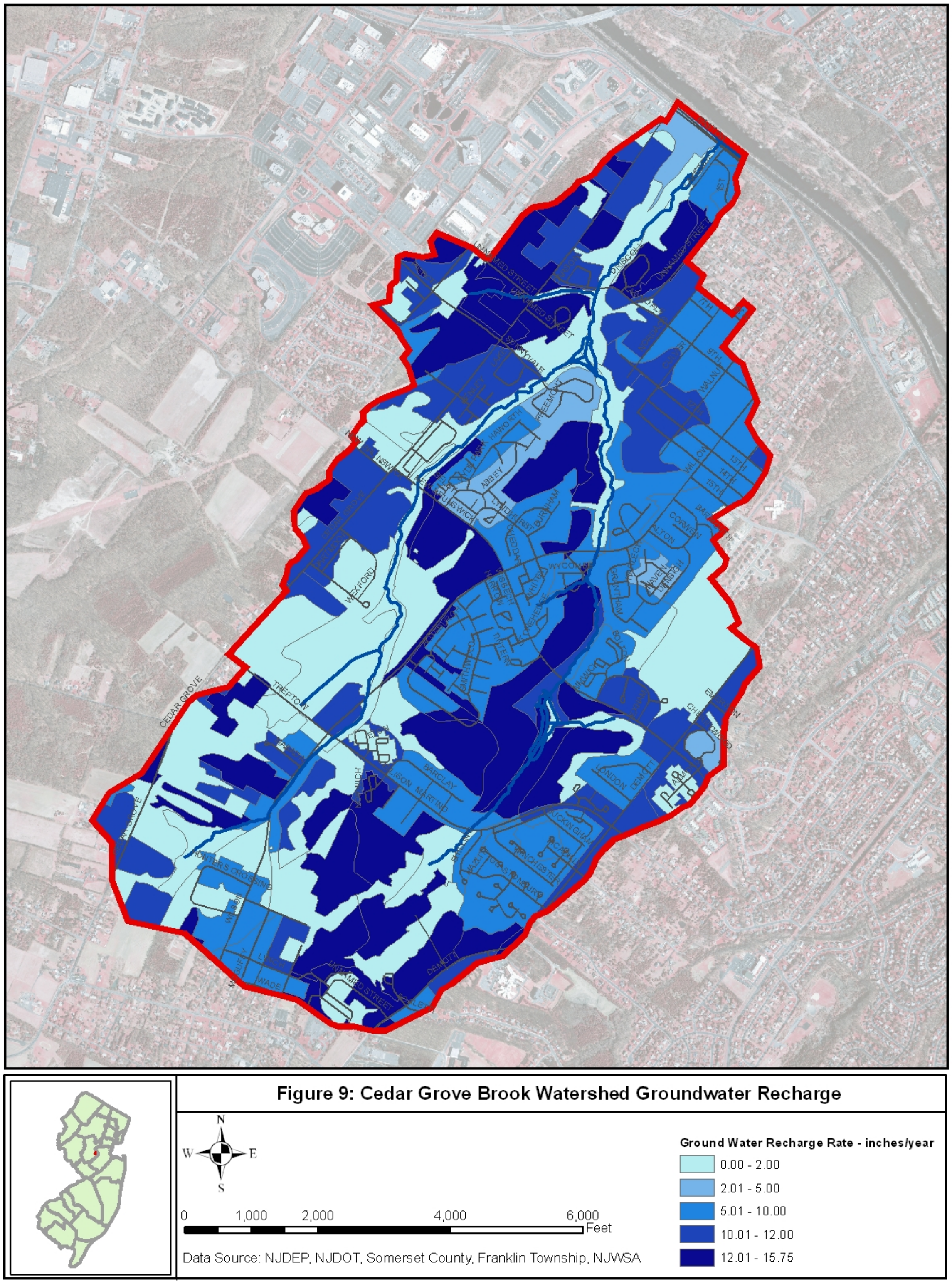
Ground Water

Ground water recharge is defined as water added to an aquifer (for example, precipitation that seeps into the ground). A ground water recharge area is the land area that allows precipitation to seep into the saturated zone. These areas are generally at topographically high areas with discharge areas at lower elevations, commonly at streams or other water bodies (i.e. the ground water returns to surface water). Groundwater recharge areas provide base flow to streams that support both aquatic ecosystems and surface water supplies. They also serve as a direct source of water supply for a wide variety of human uses, including potable water, industrial, agricultural and recreational supplies. Most ground water flows through the shallow layers of soil and weathered bedrock to the nearest stream. A smaller percentage penetrates deeper and recharges the aquifer. Aquifers often are used for water supply, and surface waters support both human water uses and aquatic ecosystems. Estimating the relative recharge rates of various land areas provides a way by which the most critical ground water recharge areas can be mapped and protected through various mechanisms, including zoning, development regulation and land preservation.

Recharge can be reduced through changes in soil permeability (e.g., impervious surfaces, soil compaction), soil aspect (e.g., slope, surface roughness), and vegetation. Recharge can be contaminated by a wide variety of intentional discharges (e.g., septic systems), accidental discharges (e.g., spills) and incidental discharges (e.g., fertilizer and pesticide applications targeted to specific targets that penetrated past the root zone, beyond those targets). Relative to land use, recharge rates in forests are much higher than those in urban areas (Heath, 1983). This is because urban areas have large areas covered with impervious surfaces, hastening runoff to surface water, instead of allowing precipitation to percolate into the ground. Cedar Grove Brook watershed is mostly developed; ground water resources are critical to this watershed.

Recharge rates are expressed in terms of the amount of precipitation that reaches the aquifer per unit of time (e.g. inches/year). Recharge rates vary from year to year, depending on the amount of precipitation, its seasonal distribution, air temperature, land use and other factors. The estimated recharge rates of this watershed from NJGS 95/97 dataset indicate that the maximum recharge rate in non-drought condition is 15.75 inches per year, with the highest infiltration rates predicted to occur in the downstream forest area along the Cedar Grove Brook (**Figure 9**).

Figure 9: Cedar Grove Brook Watershed Groundwater Recharge



Soil

Soil is the unconsolidated mineral material on the immediate surface of the earth which serves as the medium for growth of land plants. The characteristics of each soil type have developed over time (usually many thousands of years) under the influence of the parent material (the bedrock that has broken down into small fragments to form the soil), climate (including moisture and temperature regimes), macro- and microorganisms, and topography. Soil is a basic resource for food production, in addition to its essential role in collecting and purifying water before it enters the ground water. However, soil itself can be a pollutant as dust in the air or as sediment in water.

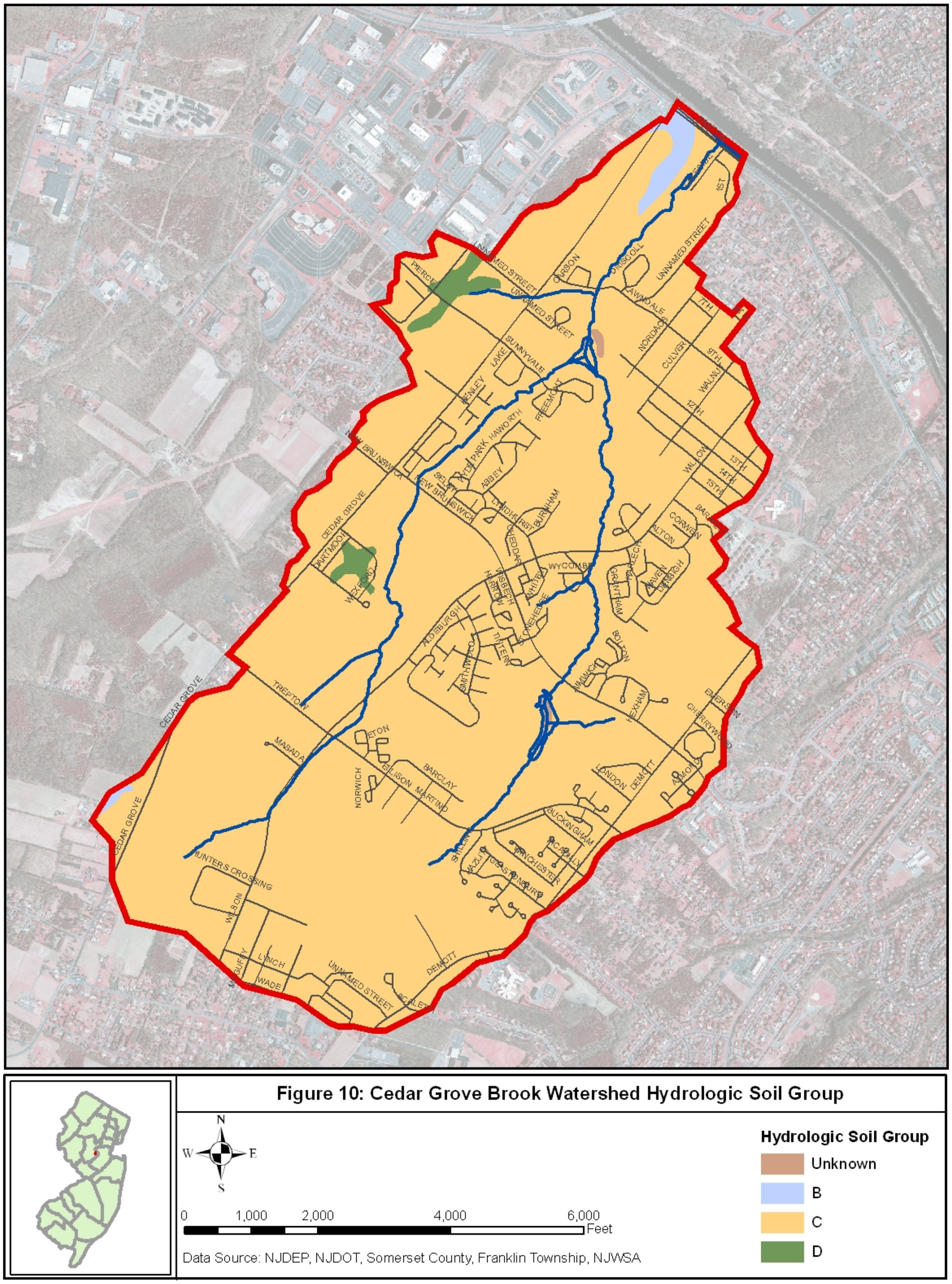
The US Department of Agriculture Natural Resources Conservation Service (USDA-NRCS) prepared soil surveys in 1974 to determine soil characteristics and capabilities and to help people understand soils and their uses. The soil survey was updated in 1986 and digitized into GIS in 1999, and then updated in 2006 to a Microsoft Access database with GIS format. The objective of soil mapping is to separate the landscape into segments that have similar use and management requirements. Therefore, this data set is not designed for use as a primary regulatory or management tool, but may be used as a broad scale reference source.

The soil characteristics vary from place to place in slope, depth, drainage, erodibility and other properties. The hydrologic soil grouping describes the rate that water infiltrates into the ground. The majority of the Cedar Grove Brook watershed has slow infiltration rates which fall into the class C soils (**Table 5** and **Figure 10**); these soils indicate a moderately risk for seepage to local surface and ground water resources.

Table 5: Hydrologic Soil Group

Class	Definition	Acres	Percent within the Watershed
A	**High infiltration rates. Soils are deep, well drained to excessively drained sands and gravels.**	**0**	**0%**
B	**Moderate infiltration rates. Deep and moderately deep, moderately well and well drained, soils that have moderately course textures.**	**14.7**	**0.8%**
C	**Slow infiltration rates. Soils with layers impeding downward movement of water, or soils that have moderately fine or fine textures.**	**1760.5**	**97.9%**
D	**Very slow infiltration rates. Soils are clayey, have a high water table, or are shallow to an impervious layer.**	**17.7**	**1%**
Unknown		**3.9**	**0.2%**
Source: NRCS Soil Survey Geographic (SSURGO) Database.			

Figure 10: Cedar Grove Brook Watershed Hydrologic Soil Group



Known Contaminated Sites

A “known contaminated site” is a place where contamination of soil or ground water has been confirmed and where remediation is either underway or pending. Known contaminated sites include those which have or had contamination present at levels greater than the applicable soil cleanup criteria, ground water quality standards and/or maximum contaminant levels of the Safe Drinking Water Standards. Contamination is normally identified at a site through sampling of the soil, sediment, surface water and/or ground water. There have also been instances where visual inspection has been used to confirm the existence of contamination (e.g., identification of floating hazardous substance or free product on water).

NJSA 58:10-23.16-17, the New Jersey statute on the discharge of petroleum products, debris and hazardous substances into waters, requires that the NJDEP prepare, adopt and update a master list for the cleanup of all hazardous discharge sites throughout the State. The master list, called the Contaminated Sites List (of which the Known Contaminated Sites list is a sub-list), must include an inventory of the sites that have been cleaned up, that have been identified as in need of cleanup, and that will be cleaned up. The list of sites used in this report is based on the most recent GIS coverage (April 2008 Known Contaminated Sites list) obtained from the NJDEP Site Remediation Program. Remedial levels are based on the NJDEP Site Remediation Program’s 1989 Case Assignment Manual, which determines levels based on the overall degree of contamination at a site.

Sites identified in the Known Contaminated Sites database can undergo a variety of activities, ranging from relatively simple soil removals to highly complex remedial activities. The sites included in this dataset are handled under various regulatory programs administered by the NJDEP’s Site Remediation Program, including the New Jersey Brownfield and Contaminated Site Remediation Act, Industrial Site Recovery Act, Solid Waste Management Act, Spill Compensation & Control Act, Underground Storage of Hazardous Substances Act, Water Pollution Control Act and the Federal Comprehensive Environmental Response, Compensation and Liability Act, Superfund Amendments and Reauthorization Act, and Resource Conservation and Recovery Act Corrective Action Program. A site can be regulated under more than one of these regulatory programs and often proceed through several remedial levels over time. Site remedial levels are classified as follows:

- “A” – An emergency action taken to stabilize an environmental and/or health threatening situation from sudden or accidental release of hazardous substances. Appropriate remedial actions involving a single phase of limited or short-term duration.
- “B” – A single phase remedial action in response to a single contaminant category effecting only soils. May be a sub-site of a more complex case. Does not include ground water investigation or remediation. Examples of level B cases include, but are not limited to “cut-n-scrape”; surface drum removals; fences; temporary capping.
- “C-1” – A remedial action that does not involve formal design where the source is known/identified. May include the potential for (unconfirmed) ground water contamination. Examples of C-1 cases are regulated or unregulated storage tanks containing gas or heating oil; septic tanks, etc.

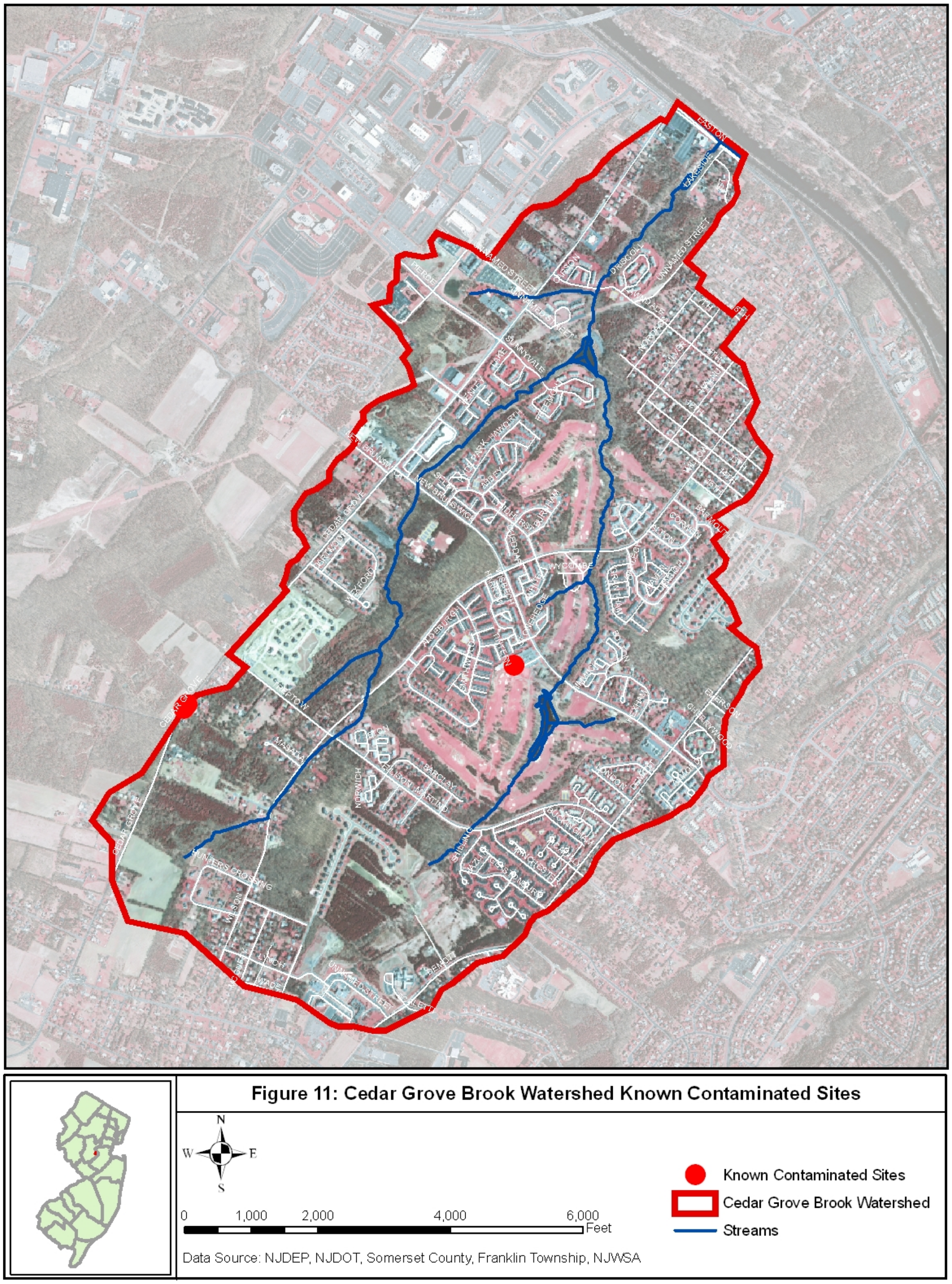
- "C-2" – A remedial action that consists of a formal engineering design phase, and is in response to a known source or release. Since the response is focused in scope and address a known, presumably quantifiable source, this remedial level is of relatively shorter duration than responses at sites with higher remedial levels. Usually involves cases where ground water contamination has been confirmed or is known to be present.
- "C-3" – A multi-phase remedial action in response to an unknown and/or uncontrolled source or discharge to the soils and/or ground water. In this remedial level, the contamination is unquantifiable (or presumed unquantifiable) and, therefore, no determinable timeframe for the conclusion of the remedial action is known.
- "C-4" or "D" – A multi-phase remedial action in response to multiple, unknown and/or uncontrolled sources or releases affecting multiple media which includes known contamination of ground water. In this remedial level, the contamination is unquantifiable (or presumed unquantifiable) and, therefore, no determinable timeframe for the conclusion of the remedial action is known.

Table 6 provides a listing of three known contaminated sites within the Cedar Grove Brook watershed that are classified as level C as defined above (**Figure 11**). Two of the known contaminated sites fall within major transportation corridors on the Cedar Grove Lane, very close to each other, while the third is within a parking lot. Additional information and identification of sites within a specified area are available from the NJDEP Site Remediation Program at www.state.nj.us/dep/srp.

Table 6: Known Contaminated Sites within the Cedar Grove Brook Watershed

TRACKING NUMBER	ADDRESS	LIST DATE	TYPE	REMEDIATION LEVEL AND STATUS
162135	300 CEDAR GROVE LANE	8/14/2002	HO - UST	C2: Formal Design - Known Source or Release with GW Contamination – CLOSED 6/2005 – no detail.
164971	302 CEDAR GROVE LANE	9/30/2002	N/A	C2: Formal Design - Known Source or Release with GW Contamination
031476	QUAIL BROOK GOLF COURSE - 625 NEW BRUNSWICK AVE	12/17/2001	UST – Unleaded Gas	C2: Formal Design - Known Source or Release with GW Contamination CLOSED – 10/1997 - 1,000 Gallon Tank Removed
HO=Homeowner; UST= Underground Storage Tank Data from NJDEPs 2008 known contaminated sites GIS coverage and data miner				

Figure 11: Cedar Grove Brook Watershed Known Contaminated Sites



Conclusions

Cedar Grove Brook Watershed is primarily an urbanized watershed with about two third of the area being built out. The predominant land use in the area is residential with a very high percent of impervious surface. Any development or redevelopment that does not address water quality or soil conservation strategies could have significant negative effects on the ecological health of the watershed, increase stormwater runoff and degradation to surface and ground water quantity and quality.

Pollutant loadings, particularly total suspended solids, in the surface waters of this watershed are primarily from nonpoint sources. Non-point source pollution is negatively affecting some areas of the watersheds, most likely due to development activities, which have not properly implemented soil conservation and best management practices. Construction activity, known sources of sediment loading, along with runoff from the suburban landscape and storm drains, known sources of nutrient and sediment loading, all contribute to the nonpoint source pollution in the Cedar Grove Brook watershed.

Franklin Township, Somerset County, the Delaware and Raritan Canal Commission and the New Jersey Water Supply Authority recognize the vulnerability of this watershed and its effects on the D&R Canal and should work together to protect the health of this waterway. The Cedar Grove Brook Watersheds Restoration and Protection Plan, currently in progress, will prioritize remediation strategies, and provide guidance for the long-term protection of this watershed.

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Cedar Grove Brook

Stream Visual Assessment Results

New Jersey Water Supply Authority

June 2009

Introduction

In 2005, the New Jersey Water Supply Authority (NJWSA) received a Section 319(h) Nonpoint Source Grant from the New Jersey Department of Environmental Protection (NJDEP) to develop a watershed restoration plan for Cedar Grove Brook. As part of that project, NJWSA performed stream visual assessments within the watershed to gain an overall assessment of stream health.

Stream Visual Assessment Protocol (SVAP)

NJWSA used the United States Department of Agriculture – Natural Resources Conservation Service (USDA-NRCS) Stream Visual Assessment Protocol (SVAP) to gather baseline data for this project. The SVAP is used to score a site based on a set of 15 indicators, including:

- Channel condition: Natural vs. altered channel (e.g. channelization; installation of riprap, dikes or levies; or downcutting or incision).
- Hydrologic alteration: Connectivity to the floodplain (e.g., structures or channel incision that limit the stream's access to the floodplain).
- Riparian zone: Stream's buffer area (e.g., a perfect score requires natural vegetation to extend at least two active channel widths on each side of the stream. A lower score, for instance a 5, is given when natural vegetation extends only half the active channel width on each side of the stream).
- Bank stability: Bank condition (banks are either level with the floodplain and stable or are higher and eroding; banks have exposed roots or slope failures present with the reach).
- Water appearance: Water clarity (clear with visible bottom or cloudy/murky).
- Nutrient enrichment: Presence of algae and/or aquatic macrophytes (A stream with a diverse plant community and clear water scores a 10; a stream with greenish water and an overabundance of algae and/or macrophytes scores a 3).
- Barriers to fish movement: Withdrawals, culverts, dams or diversions both up and downstream of the reach.
- Instream fish cover: Available cover types for fish habitat (e.g., woody debris, riffles, pools, and cobble).
- Pools: Abundance and depth of pools within the reach.
- Invertebrate habitat: Number of cover types available as habitat.
- Canopy cover: Coldwater versus warmwater fisheries. The project area is considered a coldwater fishery, thus a reach that is well shaded would score high, whereas a reach that is minimally shaded would score low.
- Manure presence: Evidence of livestock in or near the stream; it was not scored for any of the project sites.
- Salinity: Non-applicable for the project watershed.
- Riffle embeddedness: Embeddedness of cobble or gravel in sediment.
- Macroinvertebrates observed: Type and diversity of species present. A site with a good diversity of pollution intolerant species received a score of 15, while a site dominated by more pollution tolerant organisms might receive a 6. It should be noted that several of the SVAPs were performed during the winter months, which are not ideal months for the observation of macroinvertebrates. This parameter was not scored at all of the sites.

Once the team chose a segment for assessment, the active channel width was measured. A reach that was 12 times the active channel width was then scored from one to 10 (one to 15 for macroinvertebrates observed and one to five for manure presence) based on the 15 parameters described above; any parameter that was not applicable to a particular site was not scored. In the project watershed, salinity was determined to be not applicable; manure presence was not identified and thus not scored at any sites. The scores for each parameter were summed and divided by the total number of parameters scored to yield the SVAP score.

The SVAP relies heavily on relative comparison of sites, rather than a rigorous quantitative analysis; it is a screening assessment tool rather than a site-specific monitoring protocol, and therefore is subjective. Each parameter is scored based on the assessor's observations of a particular reach. For this reason, NJWSA ensured consistency of assessors among all of the sites.

The SVAP provided a great deal of useful information regarding the Cedar Grove Brook watershed. The shortfall of the protocol is that it fails to provide a mechanism for identifying the cause of identified problems.

Preliminary Visual Assessments
The Raritan Basin Watershed Alliance Road Crossing Protocol, developed by NJWSA, was utilized to collect information on each road crossing within the watershed. The information collected included land use, type of crossing, suitability for stream assessment (with respect to channel size, accessibility and safety) and the need for riparian buffer restoration. Photographs were taken at each crossing. From that list, NJWSA selected a subset of sites for stream assessment to perform an overall assessment of stream health in the watershed.

Summary of Results
The 14 SVAP locations were chosen based on the preliminary visual assessments, tributary patterns and accessibility. The objective was to collect enough information to assess overall stream health. The stream assessment team identified areas of impaired stream systems throughout the watershed, and documented major detention basins and associated outfalls. Observed impairments included:

- Destabilization and erosion of stream banks
- Disconnection of the stream from the floodplain due to downcutting of the stream channel and man-made embankments;
- Inadequate riparian zones and overabundance of invasive species;
- Excessive sediment deposition due to a loss of stream transport capacity
- Presence of algae in moderate to high densities during time of assessments (December).

Detailed surveys of detention basins in the watershed were conducted using the NJDEP Volunteer Monitoring ProgramVisual Assessment Pipe and Drainage Ditch Inventory. Detention basins were targeted by the NJWSA staff managing the Cedar Grove Brook project. Observed impairments included:

- Concrete low flow channels in each detention basin;
- Sediment accumulation at the outlet of each detention basin;
- Abundant scat accumulation from wildlife (geese and deer) in each detention basin
- Erosion of stream banks at the outfall of four out of six basins surveyed

Overall scores ranged from 5.20 (Poor) to 8.07 (Good). The scores for each parameter varied widely, e.g. from a low of four in the riparian zone category to a high of nine.

Detailed Stream Visual Assessment Results
Figure 1 shows the 14 SVAP locations; the data are summarized in Table 1.

SVAP CGB-1

SVAP CGB-1 (5.2/poor) was located downstream of the Cedar Grove Lane road crossing on a small tributary that drains to the main stem of Cedar Grove Brook. Assessment scores ranged from 3 for channel condition, hydrologic alteration and riffle embeddedness, to 8 for macroinvertebrate habitat.

The stream was confined by high banks associated with multi-family residential development on the left bank, and Lawndale Drive on the right bank. The left bank averaged 15 feet, the right bank averaged eight feet. Both banks were actively eroding. A headcut migration to bedrock provided evidence that the reach has been actively down cutting.

The riparian corridor was inundated with invasive species mainly multi-flora rose. There was a lack of native species regeneration and virtually no native understory species population. There was an inline detention basin upstream of the Cedar Grove Lane road crossing. A large population of geese was observed. There was no riparian buffer upstream of the road crossing, only lawn. This is a potential site for **riparian buffer improvement.**

SVAP CGB-2

SVAP CGB-2 (7.17/Fair) was located upstream of the Lawndale Drive crossing on the mainstem of Cedar Grove Brook. A dam was present at the top of the reach and a hardened sewer line crossing was present approximately mid-reach. Assessment scores ranged from 10 for macroinvertebrate habitat, 8 for hydrologic alteration, pools, and in stream fish cover to 1 for barriers to fish movement.

The average height of the left bank was 20 feet. It was void of understory vegetation and severely eroded in two areas. The average height of the right bank was one to three feet, allowing floodplain access for three to five year storm flows along the reach. Both banks displayed erosion.

A long continuous, deep glide two to three feet deep and a gradual meander bend were present from just below the dam to the grade control structure/hardened crossing at the sewer line crossing. The stream displayed a meandering pattern with a riffle/pool sequence below the hardened crossing.

The riparian corridor was inundated with invasive species, primarily multi-flora rose. There was a lack of native species regeneration and virtually no native understory species population. Rooted emergent and attached algae were moderately dense and completely covered the channel substrate.

SVAP CGB-3

SVAP CGB-3 (7.75/Good) was located downstream of the Lawndale Drive crossing on the main-stem of Cedar Grove Brook. Assessment scores ranged from 10 for in stream fish cover, hydrologic alteration, and invertebrate habitat, to 4 for nutrient enrichment and 3 for barriers to fish movement.

The average height of the banks was one to three feet, with the highest points on the outside of meander bends and the lowest points on the inside. The bankfull elevation was at the floodplain elevation on the inside of all meander bends, allowing floodplain access for all storm flows.

The stream reach displayed high sinuosity and was dominated by riffle/pool morphology. The abundance of large woody debris (LWD) was a contributing factor to the structural complexity of the channel. Pools were observed on the outside of most meander bends-two measured 3.5+feet deep. Erosion was observed on the outside of meander bends suggesting some lateral movement of the channel. Rooted and attached algae were dense and completely covered the channel substrate.

The riparian corridor was mostly vegetated, but contained a great deal of invasive species mainly multi-flora rose. There was a lack of dominant species regeneration and virtually no native understory species population. The land use in the vicinity of this reach included multifamily residential and forest.

SVAP CGB-4

SVAP CGB-4

SVAP CGB-4 (6.67/Fair) was located upstream of the Sunnyvale Road crossing on the west branch of Cedar Grove Brook. Assessment scores ranged from 8 for channel condition and hydrologic alteration to 5 for in stream fish cover.

The average height of the banks was approximately one foot on the inside of meander bends and two to six feet on the outside. The banks were much higher in some areas. The bankfull elevation was at the floodplain elevation on the inside of all meander bends, allowing for floodplain access for all storm flows in portions of the reach. Erosion was observed on the outside of meander bends, and some trees had exposed roots indicating scouring during high flows. Pools were observed on the outside of meander bends, and had average depths of one to two feet. The stream was sinuous and dominated by riffle/pool morphology.

The riparian corridor was approximately 50feet wide on the left bank and 75feet on the right bank. A large population of invasive species, particularly multi-flora rose and Japanese honeysuckle, was observed on both banks. There was a lack of species regeneration and a minimal population of native understory species. Damage from deer browse was apparent throughout the reach.

There was a large detention basin on the opposite side of Cedar Grove Lane draining into a side channel that crosses under Cedar Grove Lane and Sunnyvale Drive and joins Cedar Grove Brook downstream of the assessment reach. There was a large sediment deposit at the mouth of the side channel. The right bank of Cedar Grove Brook at the confluence was 10-15 feet high and was actively eroding. The riparian corridor in this area was ≤ 25 feet wide.

SVAP CGB-5

SVAP CGB-5 (5.75/Poor) was located downstream of the New Brunswick Road crossing on the west branch of Cedar Grove Brook. Assessment scores ranged from 8 for canopy cover to 3 for pools and barriers to fish movement.

The average bank height within the reach was one to two feet. The floodplain was steep and the reach was relatively straight. The upper portion of the reach was dominated by bedrock, the lower portion contained more silt and cobble. The substrate was >25% embedded at the lower end of the reach. Attached algae were moderately dense and completely covered the channel substrate.

The riparian corridor was 50 to75 feet wide on the left bank and 30 feet wide on the right bank. The corridor lacked a native understory and multi-flora rose was abundant. Land use in the vicinity of the site included commercial development and an access road.

SVAP CGB-6

SVAP CGB-6 (6.75/Fair) was located upstream of the New Brunswick Rd. crossing on the west branch of Cedar Grove Brook. Assessment scores ranged from 10 for invertebrate habitat to 3 for canopy cover. The riparian zone received a score of 4.

Cedar Hill Preparatory School was present on the left bank, approximately mid-reach. Residential development on the left bank also impacted the riparian zone.

The average height of the stream banks in the upper portion of the reach was 0.5to two feet, with the highest points on the outside of meander bends and the lowest points on the inside. The stream had access to the floodplain on at least one bank throughout the reach. The upper portion of the reach displayed high sinuosity and was dominated by riffle/pool morphology. Pools were observed on the outside of meander bends. No bank erosion was observed upstream of the school. The average bank height in the lower portion of the reach, downstream of the school, 0.5 to three feet. The stream was straight in this portion of the reach and some bank erosion was observed. A footbridge was constructed across the stream channel.

The riparian corridor was forested upstream of the school. Some invasive species were observed. At and below the prep school the riparian corridor on the left bank was predominantly lawn. The right bank had a canopy but lacked an understory, in part due to the school's ropes course. This reach has good potential as a **riparian buffer restoration site**.

A new stormwater outlet was observed on the school property. It was armored with riprap down to the stream channel.

SVAP CGB-7

SVAP CGB-7 was located upstream of the Wilson Road crossing. This reach was not scored due to the small size of the channel and its location through private property. The upper portion of the reach (and headwaters of the west branch) was forested. The average height of the banks within this portion of the reach was 0.5feet. The s**t**ream banks in the lower portion of the reach, where the stream comes into closer proximity to residential property and the road crossing, were approximately two feet high. The riparian corridor was mowed to the stream banks through the lower portion of the reach. This site is a potential site for a **riparian buffer improvement project.**

SVAP CGB-8

SVAP CGB-8 was located downstream of the Wilson Road crossing. This reach was not scored due to its location on private property.

The stream was channelized between Wilson Road. and residential lots. Bank erosion was observed along the reach in a majority of residential lots. The riparian corridor was comprised of lawn on the right bank and Wilson Road on the left bank. Invasive species dominated the riparian corridor where it was not managed by residents. A resident informed field staff that the stream floods the road every year during major storms. There was additional residential construction taking place at the top of the reach adjacent to the road.

SVAP CGB-9

SVAP CGB-9 (6.36/Fair) was located downstream of the Treptow Road crossing on the west branch of Cedar Grove Brook. Assessment scores ranged from 10 for bank stability to 3 for pools and canopy cover.

A significant amount of fine sediment was deposited just below the crossing. The average bank height was 0.5 to two feet allowing floodplain access during storm events. The reach was relatively straight, with only a few meanders. There was minimal diversity in the flow regime. Aquatic vegetation was abundant. The riparian corridor was dominated by a residential lawn on the left bank, and by forest and invasive species on the right bank. A pipe draining roof gutter runoff discharged into the stream from the left bank. The reach was a good candidate for a **riparian buffer improvement project.**

SVAP CGB-10

SVAP CGB-10 (6.92/Fair) was located downstream of the New Brunswick Road crossing on the east branch of Cedar Grove Brook. Assessment scores ranged from 10 for in-stream fish cover and invertebrate habitat to 4 for canopy cover.

Average bank height through the reach was 0.5-1.5 feet. The bankfull elevation on the inside of meander bends was at the floodplain elevation. There were some areas of bank erosion on the outside of meander bends, mainly on the right bank. In one area where the riparian corridor was the most narrow (35 feet wide), the right bank was high and actively eroding. The reach had high sinuosity and was dominated by riffle/pool morphology. Pools were observed on the outside of meander bends and had an average depth of 1.5 feet. The presence of LWD was a contributing factor to the structural complexity of the channel.

The land use in the vicinity of the site included forest and multifamily residential on the right bank and Quail Brook Golf Course on the left bank. QBGC was certified as a River-Friendly Golf Course by NJWSA in 2007.

The riparian corridor averaged 75 feet on the left bank and 50feet on the right bank. The golf course has a no-mow area approximately 40feet wide at the top of the reach where there was no canopy. Both banks have a large population of invasive species occupying the understory.

SVAP CGB-11

SVAP CGB-11 (7.83/Good) was located downstream of the Wilson Road crossing on the west branch of Cedar Grove Brook. A Franklin Township Preservation Area was present on the left bank. Assessment scores ranged from 10 for invertebrate habitat, 9 for channel condition and hydrologic alteration to 3 for nutrient enrichment.

The average height of the left bank was one to two feet, with some areas as high as five feet. The average height of the right bank was 0.5 to one feet, with some areas reaching three feet. The bankfull elevation was at the elevation of the floodplain allowing access to a wide floodplain during storm flows. Some erosion was occurring on the outside of meander bends. Some bank erosion was also observed where the stream straightened out, indicating high velocity during storm events.

The stream had a regular pool/riffle/glide sequence. Sediment deposition was observed in glides and pools along the reach. Rooted emergent and attached algae were dense and completely covered the channel substrate.

The riparian corridor was 100+ feet wide on each bank. There was an apparent lack of dominant species regeneration and a minimal population of native understory species. The land use in the vicinity of the site included forest on the right bank and residential on the left bank.

SVAP CGB-12

SVAP CGB-12 (5.92/Poor) was located downstream of the Martino Way crossing on the east branch of Cedar Grove Brook. Assessment scores ranged from 8 for channel condition and riparian zone to 3 for pools and riffle embeddedness.

The average bank height through the reach was one to two feet. The reach was dominated by small riffles and shallow pools. Sediment deposition was observed throughout the reach.

A small tributary on the left bank was contributing sediment to the channel. Some erosion was occurring in proximity to a debris jam at the top of the reach.

The riparian corridor was 100 feet wide on the left bank and approximately 50feet on the right bank. The corridor contained a large population of invasive species, particularly multi-flora rose. Native species regeneration was absent and the understory lacks native species population. The land use in the vicinity of the site included multi-family residential and forest on the left bank, and Quail Brook Golf Course on the left bank.

SVAP CGB-13

SVAP CGB-13 (7.33/Fair) was located at downstream of the Willow Road crossing on the east branch of Cedar Grove Brook. Assessment scores ranged from 10 for macro-invertebrate habitat, 9 for channel condition, hydrologic alteration and bank stability to 3 for canopy cover and barriers to fish movement.

The bank height averaged one to two feet. The elevation on the inside of meander bends was at the elevation of the floodplain allowing access during storm flows. The banks were mostly stable, with the exception of one area below a multifamily residential development where the riparian corridor was 10feet wide and the right bank was approximately eight feet high.

The reach was sinuous with a regular riffle/pool sequence. The pools averaged one to three feet deep, and some were deeper. An abundance of large woody debris contributed to the structural complexity of the channel, and provides abundant fish habitat. Fine sediment deposition was observed throughout the reach in pools and on the inside of meander bends.

The riparian corridor averaged 90 feet wide on the left bank and 50feet on the right bank. The land use in the vicinity of the reach included forest and multifamily residential on the right bank, and forest and Quail Brook Golf Course on the left bank.

A tributary from the golf course entering the main channel in this reach displayed no evidence of erosion or sediment input. In addition, a storm drain inflow from the residential development entered the reach on the right bank. The inflow was mostly armored and displayed little erosion.

SVAP CGB-14

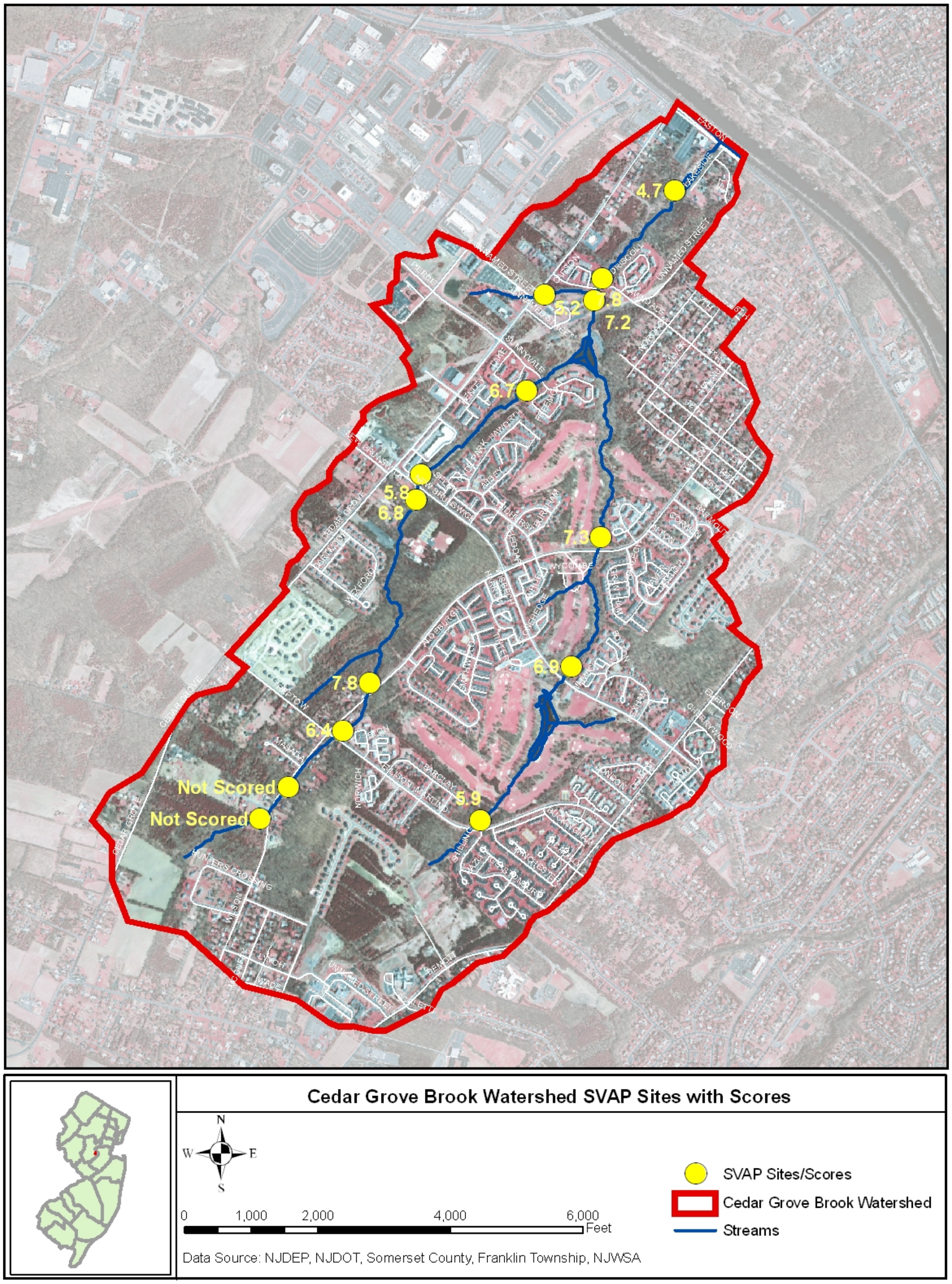
SVAP CGB-14 (4.7/Poor) was located upstream of the Easton Rd. crossing on the main stem of Cedar Grove Brook. Assessment score ranged from 8 for in stream fish cover to 3 for bank stability, nutrient enrichment and pools..

The height of the banks within the reach ranged from one to two feet, and some areas were as high as eight feet. The stream had access to the floodplain during storm events in some portions of the reach; in other areas the floodplain was steeply sloped.

The substrate was dominated by fine sediment in the lower portion of the reach; bedrock and cobble were observed at the upstream end where the gradient was steeper and riffles were more abundant. The upper portion of the reach had a meandering pattern with riffles, glides and shallow pools occurring frequently. Large, old sediment deposits inhabited by mature vegetation were observed. Recent deposition formed numerous sediment bars along straight areas, on the inside of meander bends and mid-channel. Bank erosion was observed on the outside of meander bends most often associated with large sediment deposits along the opposite bank.

The downstream end of the reach was dominated by large meanders, side channels and backwater pools . Large amounts of sediment were deposited within this portion of the reach. Some sediment bars were two feet above the water surface elevation and actively eroding. Attached algae were abundant and completely covered the substrate through most of the reach.

The riparian corridor on the left bank averaged less than 50feet in width. The corridor on the right bank was approximately 50feet wide in the lower and upper portion of the reach and greater than 100feet mid-reach. The corridor on both banks was inundated with invasive species and lacked dominant species regeneration and native species in the understory. The land use in the vicinity of the site included roadway, forest and multifamily residential on the right bank and roadway, commercial development and multifamily residential on the left bank.



Cedar Grove Brook Watershed SVAP Sites with Scores

Table 1. Summary of Stream Visual Assessment Results

SVAP #	CGB-1	CGB-2	CGB-3	CGB-4	CGB-5	CGB-6	CGB-7	CGB-8	CGB-9	CGB-10	CGB-11	CGB-12	CGB-13	CGB-14
Assessment Scores:														
Channel condition	3	7	9	8	6	9			9	8	9	8	9	3
Hydrologic alteration	3	8	10	8	6	9			10	8	9	7	9	2
Riparian zone	4	6	8	6	6	4			4	6	9	8	8	6
Bank stability	5	7	7	7	6	7			10	7	8	7	9	3
Water appearance	7	7	8	6	7	7			8	7	8	7	7	7
Nutrient enrichment	7	7	4	7	6	7			8	9	3	7	8	3
Barriers to fish movement	3	1	3	3	3	3			3	3	9	3	3	5
Instream fish cover	5	8	10	5	4	8			5	10	9	5	8	8
Pools	6	8	9	8	3	7			3	5	6	3	9	3
Invertebrate habitat	8	10	10	7	7	10			7	10	10	7	10	7
Canopy cover	7	7	5	7	8	3			3	4	7	6	3	5
Manure presence	n/a	n/a	n/a	n/a	n/a	n/a			n/a	n/a	n/a	n/a	n/a	n/a
Salinity	n/a	n/a	n/a	n/a	n/a	n/a			n/a	n/a	n/a	n/a	n/a	n/a
Riffle embeddedness	3	10	10	8	7	7			n/a	6	7	3	5	4
Macroinvertebrates observed	7	na	na	na	na	na			na	na	na	na	na	na
Overall Score (Total divided by number scored) Poor = <6.0; Fair = 6.1 - 7.4; Good = 7.5 - 8.9; Excellent = >9.0	**5.2**	**7.2**	**7.8**	**6.7**	**5.8**	**6.8**	not scored	not scored	**6.4**	**6.9**	**7.8**	**5.9**	**7.3**	**4.7**
Rating	Poor	Fair	Good	Fair	Poor	Fair	na	na	Fair	Fair	Good	Poor	Fair	Poor

Riparian Restoration Recommendations

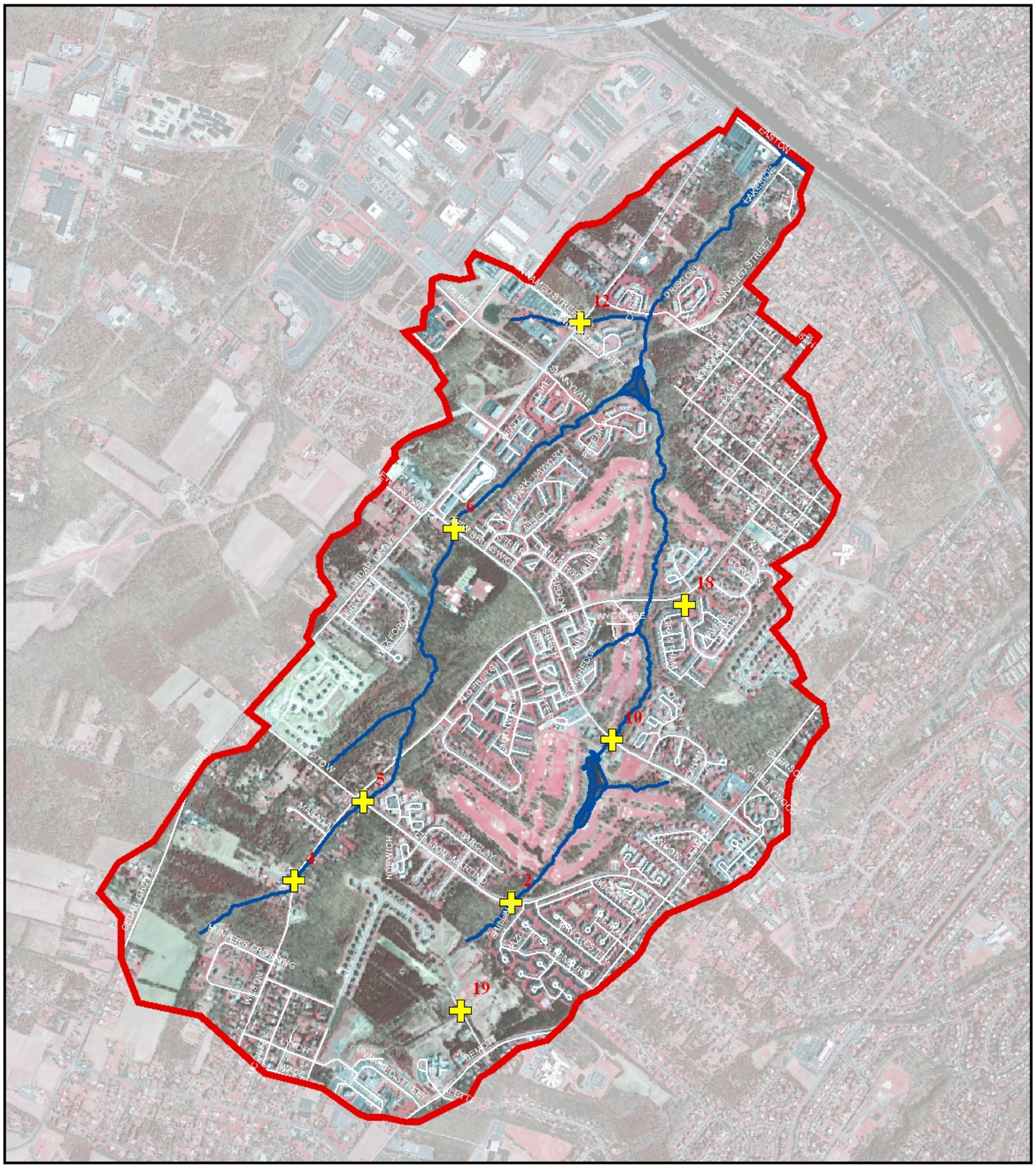
As detailed in Figure 2 and Table 2, eight sites were identified for riparian buffer restoration. The recommendations were developed based on the road crossing inventory and the stream visual assessments.

Riparian buffer restoration includes forest and herbaceous plantings. For each site, NJWSA recommends developing a planting plan prior to restoration. Potential funding sources include the Section 319(h) Nonpoint Source grant program, various programs led by the Natural Resources Conservation Service (NRCS, e.g. Conservation Reserve Enhancement Program, Conservation Reserve Program, Wildlife Habitat Incentives Program) and other similar programs.

Table 2.

Cedar Grove Brook – Recommended Riparian Restoration Sites

Road Crossing ID	SVAP #	Nearest Road
Cedar Grove Brook 2	NA	Martino Way
Cedar Grove Brook 4	CGB-7	Wilson Road
Cedar Grove Brook 5	CGB-9	Martino Way
Cedar Grove Brook 6	CGB-6	New Brunswick Road
Cedar Grove Brook 10	NA	New Brunswick Road
Cedar Grove Brook 12	CGB-1	Cedar Grove Lane
Cedar Grove Brook 18	NA	Denbigh
Cedar Grove Brook 19	NA	Middlebush Park Road



Cedar Grove Brook Watershed Buffer Sites from Road Crossing and SVAP Sites

N W E S

0 1,000 2,000 4,000 Feet

Buffer Sites

Cedar Grove Brook Watershed

Streams

Data Source: NJDEP, NJDOT, Somerset County, Franklin Township, NJWSA

CEDAR GROVE BROOK WATERSHED RESTORATION PLANNING PROJECT

PREPARED FOR:
NEW JERSEY WATER SUPPLY AUTHORITY
WATERSHED PROTECTION UNIT

PREPARED BY:
OMNI ENVIRONMENTAL LLC
PRINCETON, NJ

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I. BACKGROUND

The New Jersey Water Supply Authority (NJWSA) is developing stormwater Best Management Practice (BMP) strategies for the Cedar Grove Brook (also known as Al's Brook) watershed. This 1,784-acre watershed in Franklin Township, New Jersey conveys drainage to the Delaware and Raritan (D&R) Canal, a major water supply conduit operated by the NJWSA in the Raritan River Basin. The water supply purveyors have reported increased levels of total suspended solids (TSS), turbidity, and total organic carbon (TOC) in the Canal during and immediately after precipitation events. A study performed by the United States Geological Survey (USGS, 2001) pointed to Cedar Grove Brook as a likely contributor of suspended sediments and turbidity. NJWSA and Franklin Township obtained 319(h) nonpoint source grant funding to quantify and control sediment loading to the canal from the Cedar Grove Brook watershed.

The initial phase of the project included field services and water quality sampling to assess the TSS and turbidity levels in Cedar Grove Brook, and to estimate watershed runoff rates and volumes and associated sediment loads. The results of this initial phase were published in the Cedar Grove Brook Water Quality Characterization and Assessment (TRC Omni, 2006). The results of the initial sampling phase did not confirm that TSS and particularly turbidity loads from Cedar Grove Brook are substantially impacting the water quality of the D&R Canal at the water supply intakes downstream of Cedar Grove Brook. The sampling results were not sufficient to exclude the possibility that Cedar Grove Brook delivers a substantial turbidity load affecting water quality in the canal; nevertheless, the lack of direct sampling confirmation left open the possibility that efforts to minimize TSS and turbidity loads in the Cedar Grove Brook watershed may not address the water quality problems observed at the water supply intakes in the canal.

In addition, a major restoration project (hereafter referred to as the Canal Restoration Project) is ongoing concurrently by NJWSA to reduce sediment loads to the canal from the many stormwater infalls between Ten Mile Lock and the Route 18 spillway. The Canal Restoration Project is focused on TSS, while the relationships among TSS, turbidity, and total organic carbon (TOC) have not been well characterized in this system. Additional monitoring for the Cedar Grove Brook Watershed Restoration Planning Project was therefore designed to complement the restoration efforts that are currently underway in the canal and to better understand the impact of Cedar Grove Brook on the turbidity in the canal.

In addition to the diagnostic sampling component, the Cedar Grove Brook Watershed project involves the identification of stormwater BMP opportunities and the conceptual design of structural stormwater management system retrofits to minimize TSS and turbidity loading to the D&R Canal from Cedar Grove Brook. The field data were used in conjunction with watershed computer modeling to assess turbidity and TSS loadings, to target areas within the watershed for remedial action, and to develop conceptual remedial measures to help reduce these TSS loadings and turbidity levels in order to improve water quality within both the Canal and the Cedar Grove Brook.

II. QUANTIFICATION OF POTENTIAL SEDIMENT LOADS

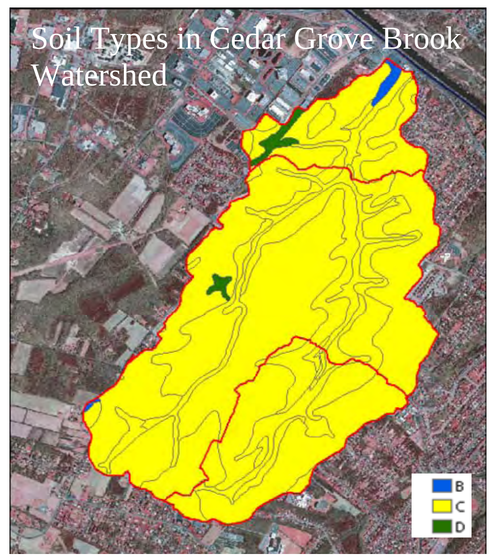
To evaluate the potential significance of stormwater pollutant loads to the D&R Canal from Cedar Grove Brook, estimated total particulate and particulate phosphorus loads from the Cedar Grove Brook were compared with similar estimates from the 59 canal infalls included in the N.J. Water Supply Authority's 2006 Tributary Assessment and Nonpoint Source Management Project. The project's area of study included the final eleven miles of the D&R Canal between Amwell Road in Franklin Township and Landing Lane in the city of New Brunswick. The combined drainage areas of the 59 Canal infalls in this project reach is approximately 1,500 acres in Franklin Township and South Bound Brook Borough. Following computation of estimated total particulate and particulate phosphorus loads using the WinSLAMM program[1], the 59 infalls were ranked based upon a combination of their total and unit area loadings to the Canal.

Using the same ranking system and version of WinSLAMM, similar load computations were performed for the Cedar Grove Brook watershed. Based upon the overall ranking system used in the 2006 project, the Cedar Grove Brook watershed was found to rank higher than any of the 59 infall watersheds included in the 2006 project. This result was driven primarily by the much larger size of the Cedar Grove Brook watershed which, at 1,784 acres, was approximately ten times larger than the largest infall watershed (172 acres). To address this disparity in areas, the ranking system was revised to be based only upon unit area loads. Under this ranking system, the Cedar Grove Brook watershed ranked seventh overall. This result indicates that the Cedar Grove Brook watershed can be considered a potentially significant source of stormwater pollutant loads to the Canal compared to all the infalls evaluated in the 2006 project.

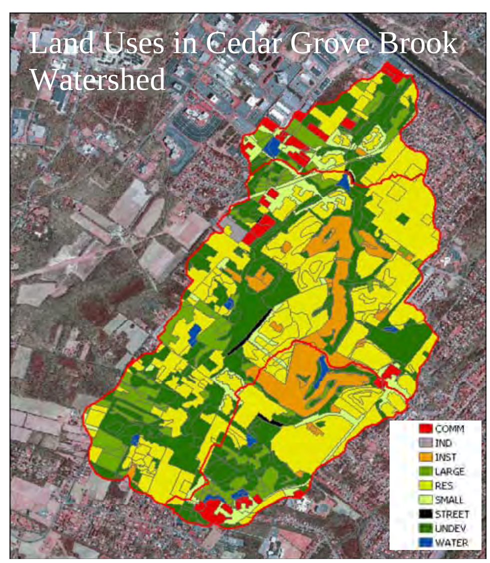
However, the water quality data collected previously (TRC Omni, 2006) suggest that actual loads from Cedar Grove Brook are much lower than its potential impact based on the ranking of infalls. In addition to the impoundment at the outlet of Cedar Grove Brook (Lower Pond), there are two other impoundments (Golf Course Pond and Ukrainian Village Pond) that also act as pollutant sinks and mitigate the potential impact of Cedar Grove Brook. In order to be able to quantify the existing impact of the Golf Course Pond (Quail Brook Golf Course Pond)

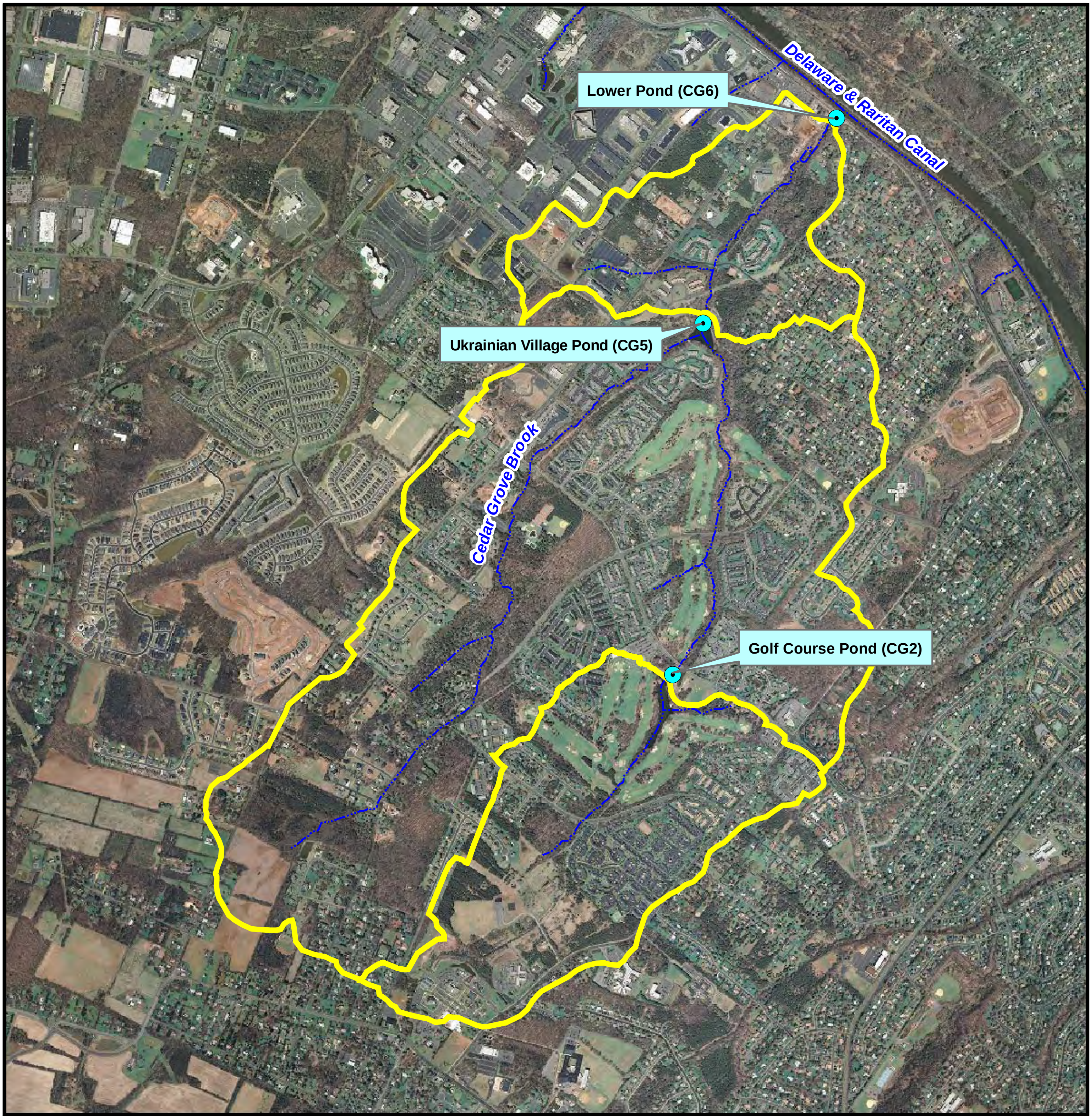
[1] All WinSLAMM modeling work was performed by Joseph J. Skupien, P.E., P.P., of SWM Consulting under subcontract to Omni.

and Ukranian Village Pond, a refined WinSLAMM (Version 9.3.0) simulation of the Cedar Grove Brook watershed was developed. Cedar Grove Brook was divided into three subwatersheds based on the drainage areas to the Golf Course Pond (395 acres), the Ukrainian Village Pond (1,545 acres), and the Lower Pond (1,784). The subwatershed delineations are shown in Figure 1; the 2005 sampling stations (TRC Omni, 2006) at the outlet of each pond are shown in parentheses after each pond label. The refined WinSLAMM simulation incorporated improved source terms from the stormwater sampling performed for the Canal Restoration Project in small subwatersheds that drain specific land use areas. Simulations were developed for the July 2005 and October 2005 storms (1.4 and 3.8 inches, respectively) that were sampled previously (TRC Omni, 2006). Predicted and observed loads were compared in order to understand the accuracy and limitations of both the model and the observed estimates. The refined WinSLAMM model was used then to assess the benefits of potential BMPs in terms of reduced sediment loads.



WinSLAMM simulations predict total volumes and pollutant loads to a single outlet over a storm based on individual watershed characteristics, most importantly soil type and land use (see figures to the right). A low particle size distribution was assumed for all subwatersheds; since heavier particles settle faster, assuming a low particle size provides a conservative simulation of sediment removal rates. Predicted and observed comparisons were performed for both total runoff volumes and sediment removal rates at each of the three ponds during both 2005 storms. The predicted runoff volumes and removal rates were based on the output of the WinSLAMM simulations; the observed runoff volumes and removal rates represent best estimates based on continuous depth and discrete water quality measurements.





Subwatershed Outlet
Subwatershed Boundary

FIGURE 1
Cedar Grove Brook
Subwatershed Delineations

Cedar Grove Brook Watershed
Restoration Planning Project

March 31, 2009

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Aerial Photography - NJDEP 2007

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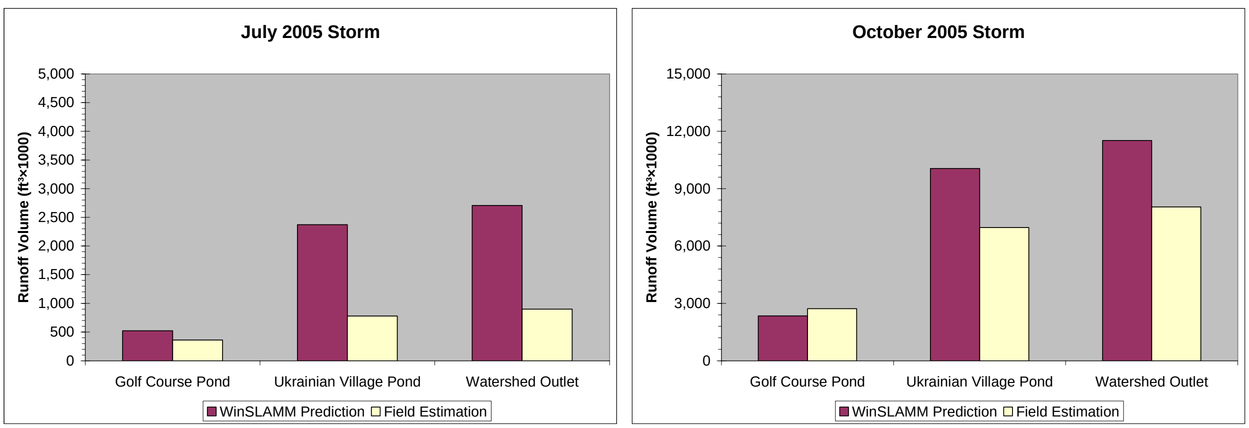
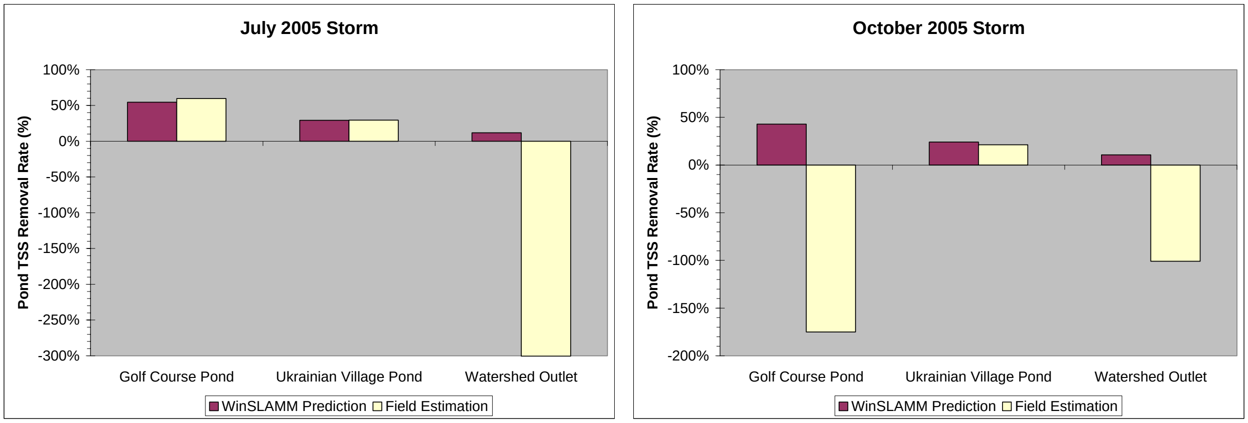
Estimates of the observed runoff volumes during the 2005 storms were calculated based on continuous measurements of depth over the weirs at the Golf Course Pond (CG2) and the Ukrainian Village Pond (CG5) using pressure transducers. Meaningful flow calculations could not be performed at the watershed outlet (Lower Pond, CG6) because the depth of water in the canal was over the height of the weir, producing backwater effects. There are no significant tributaries between the Ukrainian Village Pond and the watershed outlet; the volume at CG5 (Ukrainian Village Pond) was multiplied by 1.15 to account for the increased drainage area. A comparison between the runoff volume predicted by WinSLAMM for each storm and the estimated runoff volume based on field data is provided in Figure 2 below. The trends and magnitudes compare reasonably well, although the field estimation of volume was significantly lower than the model predictions during the July storm. Differences can be explained by model uncertainty (runoff models often overestimate volume), field estimation uncertainty, and differences between simulated and actual local rainfall.

FIGURE 2: Runoff Volume Comparison



Estimates of the observed sediment removal rates during the 2005 storms were based on discrete water quality measurements at the inlet and outlet of each pond. The measured Total Suspended Sediment (TSS) concentrations at the inlet(s) and outlet were flow-weighted based on the estimated flow at the time of sampling in order to calculate Event Mean Concentrations (EMCs) for each storm. Since the total flow in and out of each pond is the same over the course of each storm, the difference between the EMC at the outlet and the EMC at the inlet represents the pond removal rate. A comparison between the TSS removal rates predicted by WinSLAMM for each storm and the estimated removal rates based on field data is provided in Figure 3 below. The removal rates compare extremely well, except that the Golf Course Pond and Lower Pond act as sources rather than sinks under certain conditions, apparently due to resuspension of bottom sediments. This is to be expected during the very large October 2005 storm event (3.8 inches); it indicates that sediment accumulates in the pond during the course of smaller, more typical events, but that large events can resuspend that sediment and cause an increase in TSS concentration. For instance, the EMC entering the Golf Course Pond at CG1 during the October 2005 storm was 4.7 mg/l of TSS; the EMC leaving the Golf Course Pond at CG2 during the same storm was 12.9 mg/l of TSS. The fact that the Lower Pond also increased TSS concentration during the much smaller July 2005 storm reflects the accumulated sediment behind the weir, leaving less than one foot of water beneath the crest of the existing weir.

FIGURE 3: Pond TSS Removal* Rate Comparison



*Negative "removal" rates indicate that the pond is adding TSS (due to resuspension) during a storm rather than removing it.

These comparisons demonstrate the utility as well as the limitations of the WinSLAMM modeling tools for the Cedar Grove Brook watershed. Relative to all the other canal contributions in the region, the Cedar Grove Brook represents a significant potential source of sediment and other pollutants. The three existing pond structures together are providing significant sediment removal, but also can act as sediment sources due to the resuspension of accumulated sediment under certain storm conditions.

III. IMPACT OF CEDAR GROVE BROOK ON THE D&R CANAL

The Canal Restoration Project is focused on TSS loads, the underlying presumption being that TSS is related to turbidity and total organic carbon (TOC), both of which have been identified as water quality issues of concern for water supply uses in the canal. Specifically, pulses of high turbidity and total organic carbon at the water supply intakes have been noted during storm events. Additional monitoring was performed in 2008 in order to understand the impact of Cedar Grove Brook on turbidity in the canal and to understand the relationships among turbidity, TSS, and TOC under high and low flow conditions.

Continuous recording devices were equipped with turbidity sensors[2] and installed in the following five locations as shown in Figure 4:

- D&R Canal near Ten Mile Lock;
- Cedar Grove Brook at Easton Avenue near confluence with canal;
- D&R Canal just upstream of Cedar Grove Brook confluence;
- D&R Canal just downstream of Cedar Grove Brook confluence; and
- D&R Canal near Route 18 spillway.

Turbidity was monitored continuously during a variety of flow conditions for a three-week period from October 28 to November 18, 2008. Continuous monitoring data from Cedar Grove Brook and from the canal upstream and downstream of Cedar Grove Brook were used to assess the impact of Cedar Grove Brook on turbidity in the canal during a variety of flow conditions. Furthermore, data from the most upstream and downstream locations in the canal (Ten Mile Lock and Route 18 Spillway at Landing Lane, respectively) were used to confirm the observations made previously by USGS (USGS, 2001) that identified Cedar Grove Brook as a likely source of turbidity to the canal. These data at the upstream and downstream boundaries of the segment of interest in the canal also provide a context in which to evaluate the impact of Cedar Grove Brook on the canal.

[2] YSI Model 6920V2 continuous recording device with YSI 6136 Turbidity Sensors

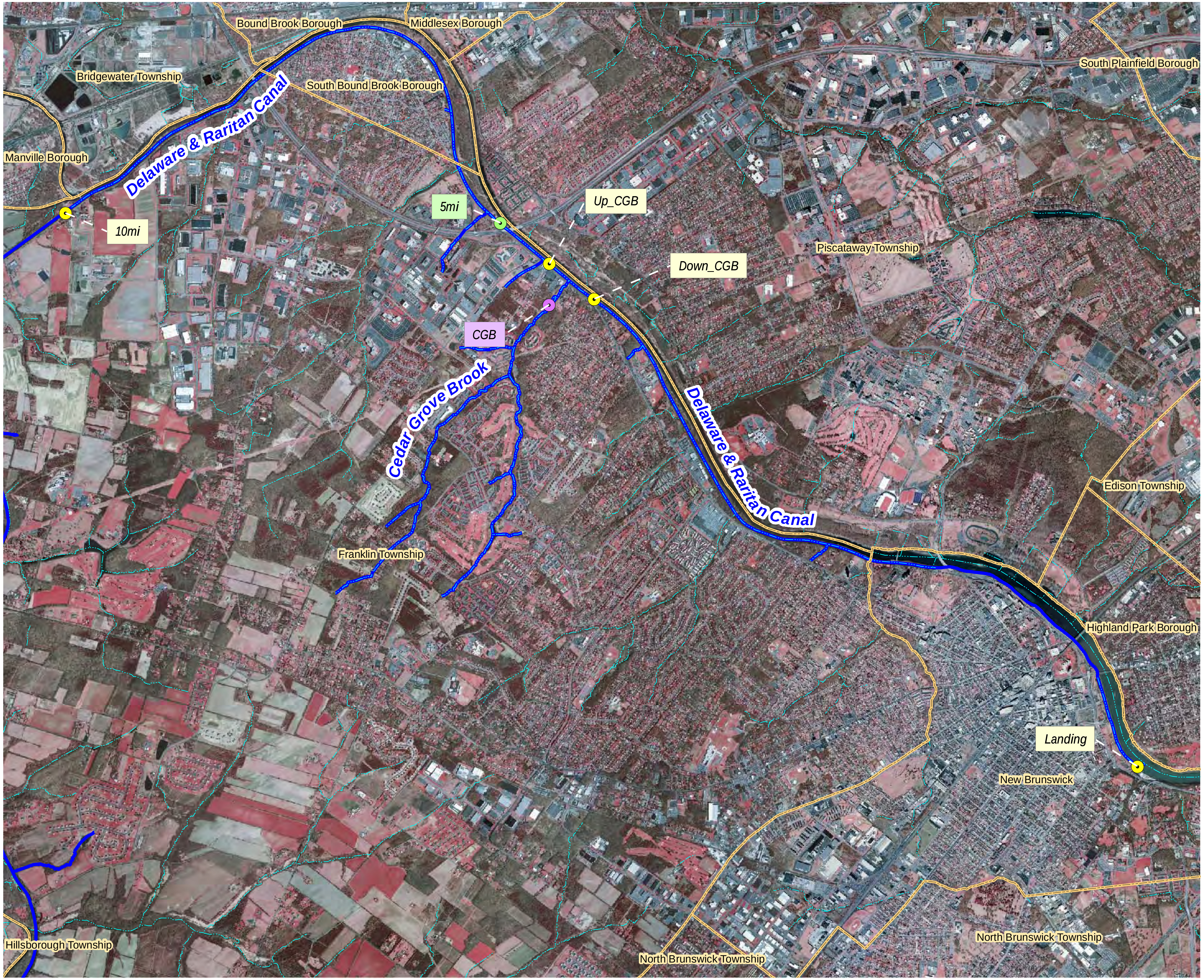


FIGURE 4
2008 Monitoring Locations

Cedar Grove Brook Watershed Restoration Planning Project

Sampling Location

- Grab
- Continuous
- Grab/Continuous
- Stream
- Municipal Boundary

10mi = Ten Mile Lock
5mi = Five Mile Lock
CGB = Cedar Grove Brook near outlet
Up_CGB = Canal upstream of CGB
Down_CGB = Canal downstream of CGB
Landing = Rt. 18 Spillway at Landing Lane

0 3,000 6,000
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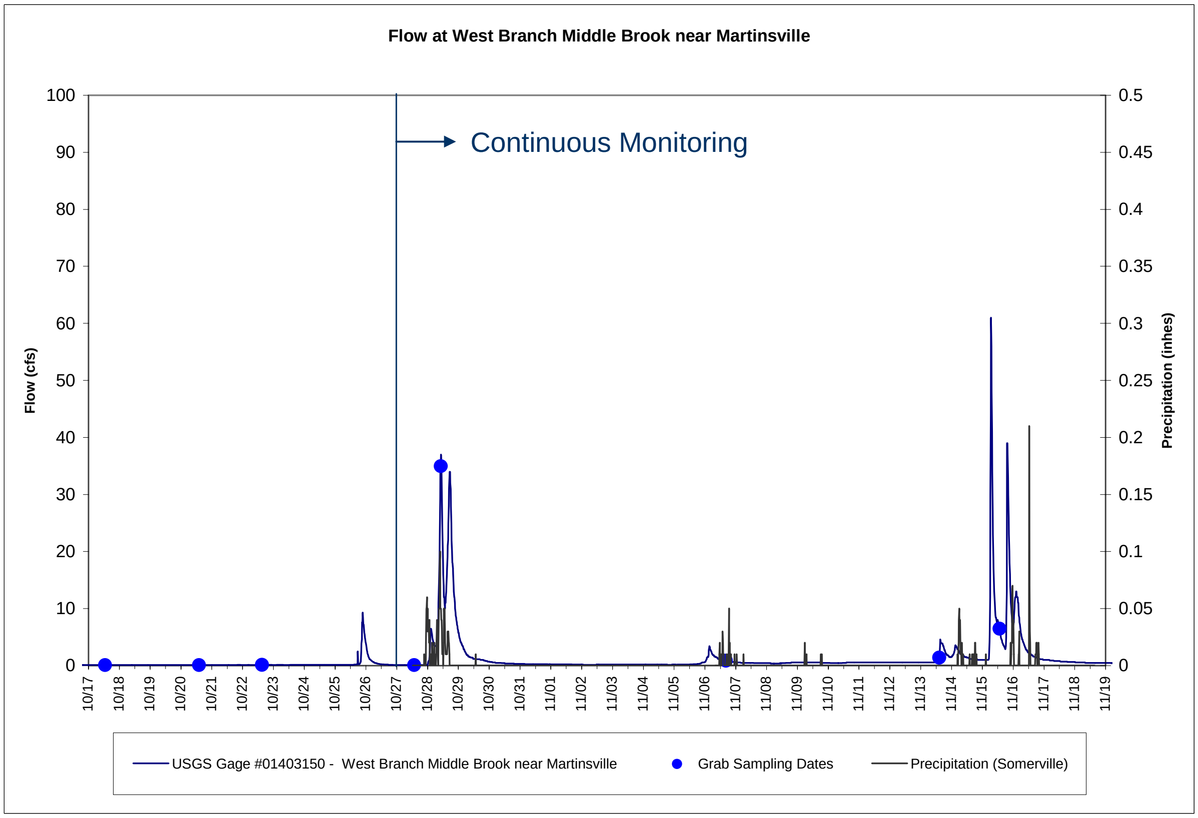
In addition to the continuous turbidity monitoring described previously, water quality samples were collected from Cedar Grove Brook at Easton Avenue (upstream of weir near canal confluence) and the D&R Canal at Five Mile Lock, which is near the Route 287 bridge upstream of Cedar Grove Brook. Samples were collected under both low and high flow conditions, and analyzed[3] for turbidity, TSS, and TOC. The grab sampling data were used to explore the relationships among TSS, turbidity, and TOC in Cedar Grove Brook and the canal under various conditions. Eight grab sampling events were performed: four low-flow events, three high-flow events, and one medium flow event (2 days after a rain event). Each event consisted of a single sample collected at both locations. The grab sampling in the canal and in Cedar Grove Brook were used to assess the degree to which turbidity and TOC are in fact related to TSS in this system. Figure 5 shows the flow and precipitation conditions prevalent during the monitoring period.

Flow is characterized in Figure 5 using a nearby USGS stream gage (#01403150, West Branch Middle Brook near Martinsville). A small local stream was selected rather than the canal gage at Port Mercer because the canal gage is farther away and flow in the canal is not as responsive to precipitation as a small stream, which would better characterize the response of canal inlets and tributaries. Precipitation is shown in 15-minute increments based on data from the USGS heated rain gage in Somerville (#403410074364001). The cumulative rainfall amounts for each storm event that occurred during the 2008 continuous monitoring period were as follows: 1.8 inches on 10/28, 0.31 inches on 11/5-11/6, and 1.27 inches on 11/13-11/15.

[3] Laboratory analysis performed at New Jersey Analytical Laboratories, NJDEP laboratory certification #1105. TOC Method SM 20-5310B; TSS Method SM 2540D; turbidity Method EPA 180.1.

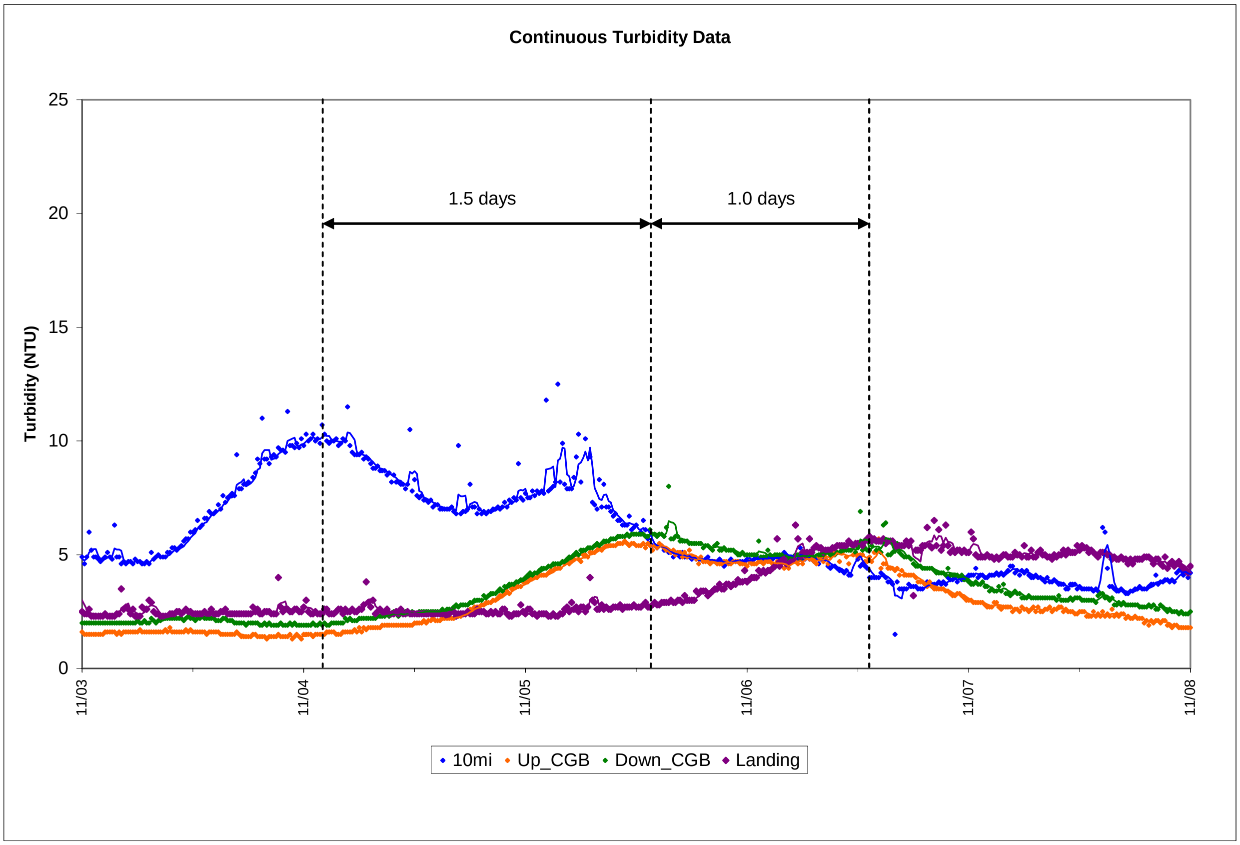
FIGURE 5: Flow and Precipitation Conditions During Monitoring Period



A. Turbidity Monitoring Results

Evaluating turbidity monitoring data from the four D&R Canal locations (10mi, Up_CGB, Down_CGB, and Landing) yielded some interesting results. Figure 6 zooms in on a low-flow period from November 3 to 8 and shows that at least some of the turbidity variation observed at the locations upstream and downstream of Cedar Grove Brook, as well as Landing Lane, can be explained simply by downstream propagation of the turbidity signature at the upstream study boundary at Ten Mile Lock. In fact, the turbidity peak at Ten Mile Lock was observed (albeit attenuated) approximately 1.5 days later at the meters upstream and downstream of Cedar Grove Brook, and then again approximately 1 day after that at the downstream study boundary at Landing Lane (near Route 18 spillway). The total travel time of 2.5 days compares favorably with the expected travel time of 2 days 8 hours between Ten Mile Lock and the Route 18 Spillway as reported in the USGS study (USGS, 2001).

FIGURE 6: Travel Time of Turbidity in the D&R Canal



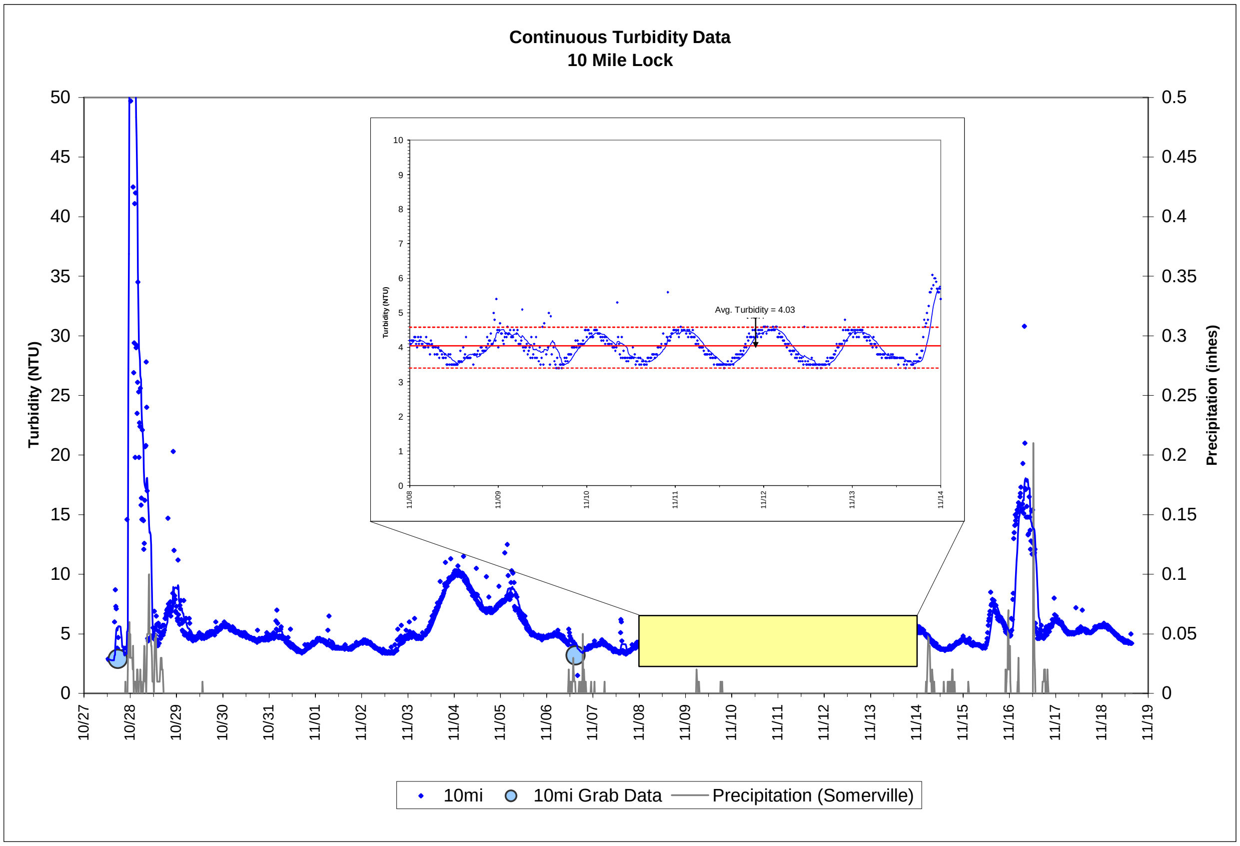
The continuous turbidity monitoring yielded one unexpected and interest result: during low-flow periods, the D&R Canal at Ten Mile Lock exhibits clear diurnal turbidity variation (Figure 7) that appears to be natural in origin. The magnitude of the variation – about 1 Nephanolometric Turbidity Unit (NTU) – is not significant from a water quality perspective; however, it is consistent and definitely diurnal in nature, with peaks occurring at night (2:00–3:00AM) and troughs occurring in the mid-afternoon. Furthermore, as discussed previously and shown in Figure 6, the diurnal turbidity pattern exhibited at Ten Mile Lock is propagated downstream as well.

Traditionally, studies relating to diurnal variation in surface waters have focused on dissolved oxygen and pH. However, researchers are increasingly interested in diurnal variation of other surface water constituents, as evidenced by a recent symposium[4] sponsored by New Jersey Water Resources Research Institute entitled: "Diurnal (Diel) Cycling of

[4] NJWRRI symposium: "Diurnal (Diel) Cycling of Chemical Constituents in Surface Water and Related Media – Scientific and Regulatory Considerations." Held December 12, 2008 at NJDEP in Trenton. http://www.njwrri.rutgers.edu/diurnal_cycling.html.

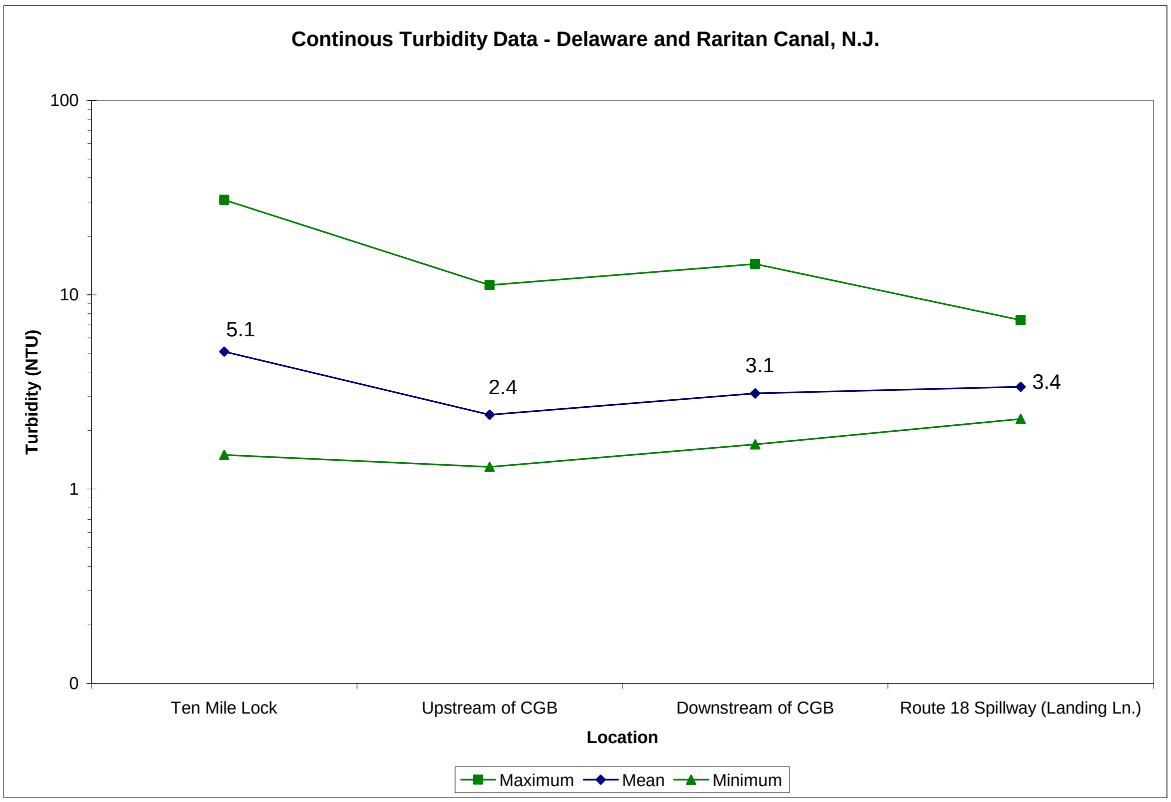
Chemical Constituents in Surface Water and Related Media – Scientific and Regulatory Considerations." Researchers noted significant diurnal variations in arsenic and other metals, nutrients, hardness, organic carbon, and solids concentrations in surface waters, in addition to constituents that are more often associated with diurnal variations (e.g., temperature, pH, and dissolved oxygen). The results of the continuous turbidity monitoring suggest that turbidity varies diurnally under some circumstances as well. Possible causes of diurnal variation include changes in flow, biological factors such as photosynthesis and macroinvertabrate activity, and temperature-related physical factors such as viscosity and sorption rates. The meter at Ten Mile Lock was deployed downstream of the lock itself, closer to the footbridge, and well past the area of turbulence associated with the lock. The smooth and consistent pattern point to a natural diurnal phenomenon.

FIGURE 7: Diurnal Turbidity Variation Observed in D&R Canal at Ten Mile Lock



The maximum, mean, and minimum turbidity values from the continuous turbidity data collected at the four D&R Canal locations are shown in Figure 8. This format is similar to that provided in the USGS study (USGS, 2001, Figure 21) and can be compared directly. The USGS study was performed over a longer period of time (16 months), but did not include any turbidity measurements between Ten Mile Lock and the Route 18 Spillway. Results of the 2008 continuous turbidity monitoring are comparable to the previous monitoring performed by USGS for the same segment of the D&R Canal. In terms of overall magnitude, the USGS average turbidity was approximately 9 NTU at Ten Mile Lock and the Route 18 Spillway locations, while the observed means during the 3-week survey in 2008 were 5.1 and 3.4 NTU at Ten Mile Lock and the Route 18 Spillway, respectively. The lower magnitude of the average can be attributed to the shorter time frame that included fewer major storms with high turbidity peaks. In fact, the highest maximum turbidity observed during the three-week survey in 2008 was 31 NTU at Ten Mile Lock, whereas the USGS long-term monitoring reported a maximum turbidity over 200 NTU at the same location. It is not surprising that the maximum recorded turbidity over a 16-month period would be substantially larger than that observed over a 3-month period.

FIGURE 8: Turbidity Changes in D&R Canal from Ten Mile Lock to Route 18 Spillway



More importantly, the overall trends between Ten Mile Lock and the Route 18 Spillway were similar in both studies. The maximum recorded turbidity was significantly higher at Ten Mile Lock than at the Route 18 Spillway during both studies. Furthermore, the minimum recorded turbidity was very similar at both Ten Mile Lock and Route 18 Spillway locations during both studies. While the average turbidity during the 3-week survey in 2008 decreased by 1.7 NTU between the Ten Mile Lock and Route 18 Spillway locations (compared to only 0.1 NTU during the long term study by USGS), the observed average decrease was still much less than the 4 NTU that might be expected based on turbidity settling in other segments of the canal (USGS, 2001). The turbidity trends at the Ten Mile Lock and Route 18 Spillway locations are similar between the two studies, such that the monitoring results upstream and downstream of Cedar Grove Brook can be meaningfully interpreted. It is evident from Figure 8 that Cedar Grove Brook does increase turbidity in the D&R Canal – maximum, average, and minimum turbidity all increase between the canal monitoring locations upstream and downstream of the Cedar Grove Brook discharge point into the canal. However, the magnitude of the increase in maximum, minimum, and average turbidity does not appear to be significant from a water quality perspective; for example, the maximum turbidity increased from 11 to 14 NTU due to the impact of Cedar Grove Brook. It is also worth noting that turbidity continues to increase between Cedar Grove Brook and the Route 18 Spillway, indicating that there may be another important discharge to the canal in that segment.

In order to better assess the impact of Cedar Grove Brook on turbidity in the D&R Canal, it is helpful to zoom in on high and low flow periods. Figure 9 shows turbidity in the canal upstream and downstream of Cedar Grove Brook, as well as in Cedar Grove Brook itself, during and after a storm event. Precipitation is also shown (in 15-minute intervals) along with grab turbidity sampling results that confirm the validity of the continuous turbidity results. During the storm event, turbidity in Cedar Grove Brook peaked at over 40 NTU, whereas the turbidity in the canal remained below 10 NTU. The maximum increase in turbidity in the canal downstream of Cedar Grove Brook was 6.3 NTU; furthermore, the impact of Cedar Grove Brook on the canal was transient, with turbidity returning to pre-storm levels in about 1 day. However, while the magnitude of the turbidity change due to Cedar Grove Brook was not that significant, it is worth noting that the turbidity in the Canal more than tripled the turbidity peak during the storm due to the impact of Cedar Grove Brook. The long-term turbidity monitoring conducted previously by USGS (USGS, 2001) recorded turbidity events much higher than was observed during the 3-week period monitored in 2008. Given the relative increase in turbidity observed in the canal immediately downstream of Cedar Grove Brook compared to immediately upstream during the 2008 monitoring, it is reasonable to conclude that Cedar Grove Brook likely increases the maximum turbidity peaks in the canal significantly during large storm events.

FIGURE 9: Turbidity Impact During High and Low Flow Periods

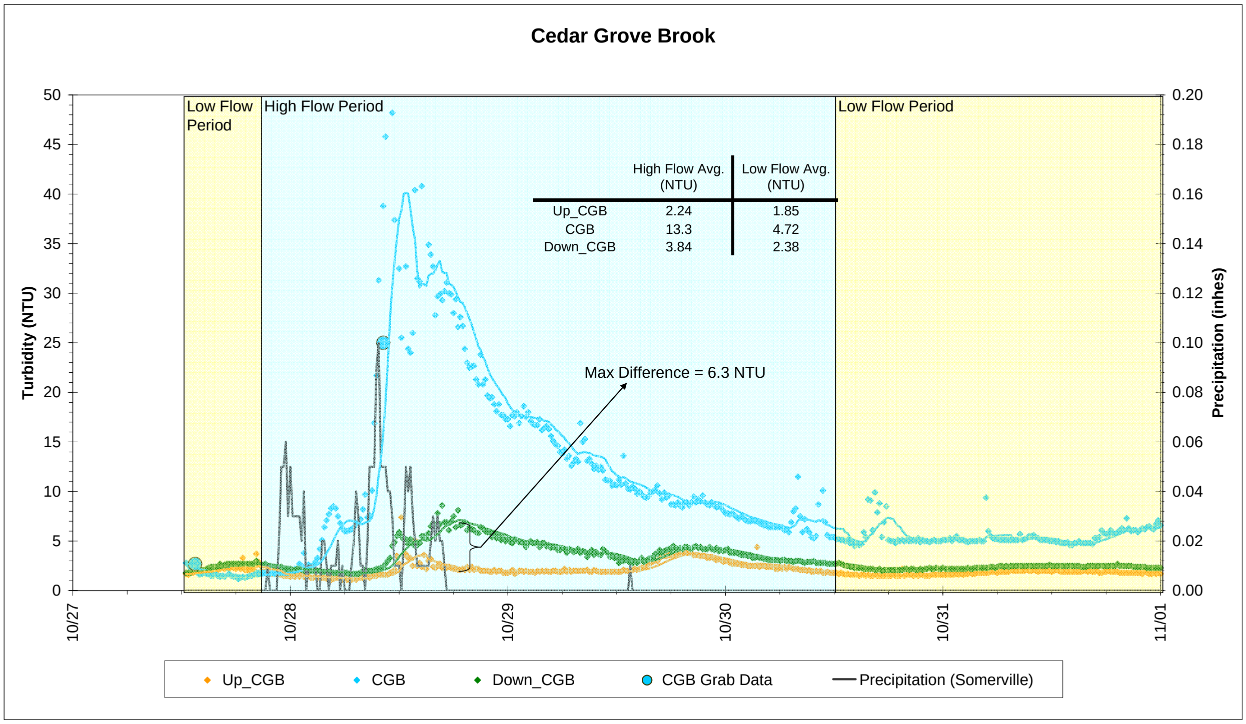


Figure 9 also shows that the impact of Cedar Grove Brook on turbidity in the D&R Canal during low-flow periods is negligible. The difference in turbidity in the canal immediately upstream and downstream of Cedar Grove Brook was less than 1 NTU during the low-flow period shown in Figure 9. It is clear from these data that the impact of Cedar Grove Brook on turbidity in the D&R Canal is limited to the turbidity peaks that occur during relatively infrequent storm events. During low-flow and more typical flow conditions, the impact of Cedar Grove Brook on turbidity in the canal is relatively minor and not significant from a water quality perspective.

In summary, the continuous turbidity monitoring performed in 2008 yielded useful information regarding turbidity in the D&R Canal from Ten Mile Lock to the Route 18 Spillway and the impact of Cedar Grove Brook on this segment of the canal. The first assessment based on the data is that turbidity in the D&R Canal from Ten Mile Lock to the Route 18 Spillway is generally fairly low in comparison to the turbidity criteria for freshwater in the Surface Water Quality Standards (N.J.A.C. 7:9B), namely a maximum 3-day average of 15 NTU and a maximum of 50 NTU at any time. Even during storm events, turbidity at the four canal locations did not exceed these criteria during the 2008 monitoring period. The long-term monitoring performed in 1999-2000 (USGS, 2001) found a slightly higher average turbidity, likely driven by the substantially higher maximum peaks observed. It is unlikely that turbidity conditions have improved significantly between 2000 and 2008. It is more likely that the higher turbidity peaks occur during larger, less frequent storms, and perhaps also seasonally during summer phytoplankton growth periods in the canal.

Cedar Grove Brook does appear to add turbidity to the D&R Canal under typical and low-flow conditions, and this does in fact reduce the amount of turbidity attenuation (due to settling primarily) that might otherwise be expected to occur in this segment of the canal, as suggested by long-term study (USGS, 2001). However, the average turbidity in the Canal at Ten Mile Lock is relatively low: approximately 5 NTU during the three-week survey in 2008 and approximately 9 NTU during the long-term monitoring performed in 1999-2000. The fact that, due to the impact of Cedar Grove Brook discharge, turbidity in the D&R Canal during typical and low-flow conditions does not decrease as much between Ten Mile Lock and the Route 18 Spillway may not be significant from a water quality perspective.

The continuous turbidity monitoring results suggest that Cedar Grove Brook can significantly increase the turbidity peaks in the D&R Canal that occur during storm events. Since the long-term monitoring indicates that such turbidity peaks can be very high, the impact of Cedar Grove Brook on turbidity peaks in the canal appears to be important from a water quality perspective, given the proximity to the water supply intake. The fact that the 1.8 inch rainfall event that fell mostly on October 28, 2008 did not result in excessive turbidity in the canal indicates that it is larger less frequent storm events that must be driving the maximum turbidity events reported in the long-term study (USGS, 2001). To put this rainfall event in perspective, the idealized 2-year storm event for Somerset County is 3.3 inches over a 24-hour period. Furthermore, the idealized "water quality storm" is 1.25 inches of rain in a 2-hour period. While the October 28th storm totaled 1.8 inches of rain, no more than 0.5 inches fell in any 2-hour period.

B. Grab Sampling Results

As described previously, pairs of grab water quality samples from the D&R Canal (at Five Mile Lock) and Cedar Grove Brook (just upstream of the outlet to the canal) were collected under a variety of flow conditions and analyzed for TOC, TSS, and turbidity. Results are provided in Table 1 below.

TABLE 1: Water Quality Sampling Data

Location	Flow Conditions	Date	Time	TOC mg/l	TSS mg/l	Turbidity NTU
D&R Canal at Five Mile Lock (5mi)	Low	10/17/2008	14:45	2.8	<2.5	2.1
		10/20/2008	15:00	3	<2.5	1.6
		10/22/2008	15:15	2.2	<2.5	2.8
		10/27/2008	14:30	6.5	<2.5	3.3
	Medium	11/6/2008	18:37	5.8	<2.5	4.2
	High	10/28/2008	12:00	2.9	3	3.1
		11/13/2008	14:30	5.6	3.5	5.8
		11/15/2008	13:40	4.9	3	3.1
Cedar Grove Brook (CGB)	Low	10/17/2008	12:50	3.9	9.5	2.2
		10/20/2008	14:00	3.1	<2.5	0.7
		10/22/2008	15:00	3	<2.5	0.9
		10/27/2008	12:00	8.7	<2.5	2.7
	Medium	11/6/2008	16:17	3.6	5	1.7
	High	10/28/2008	10:15	4.7	30	25
		11/13/2008	14:20	3.8	<2.5	2.8
		11/15/2008	13:20	5.2	5	9.7

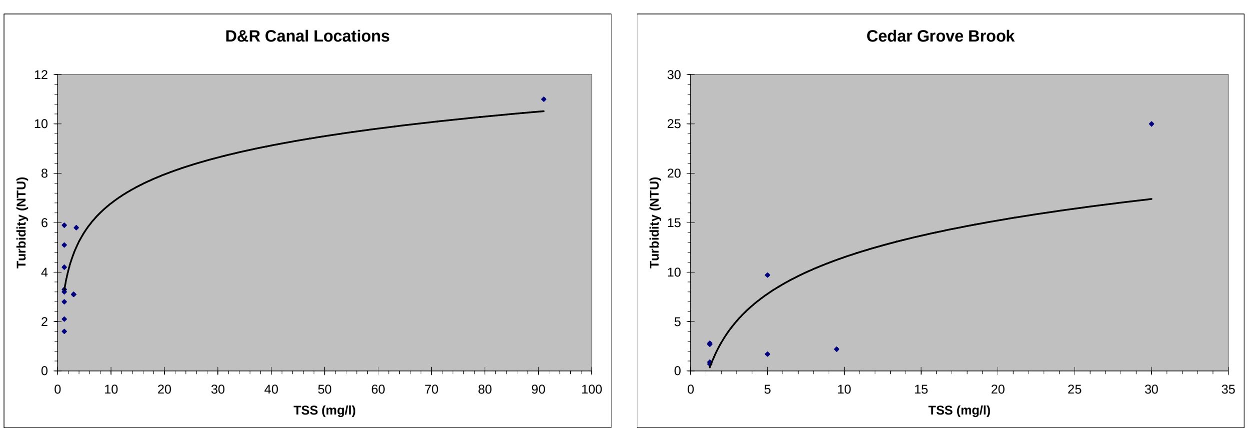
The characterization of flow condition is qualitative. The sampling event on November 6th was intended to be a high-flow event, but the actual rainfall was less than expected and ended more than 24 hours before the sampling was performed. For this reason, the flow condition was characterized as "Medium" for that event. Eight pairs of water quality data were obtained under a variety of flow conditions that were available during the sampling period in 2008. In addition, TSS was inadvertently analyzed along with confirmatory grab turbidity samples collected on November 6th at the four continuous turbidity monitoring locations in the canal (Table 2).

TABLE 2: Additional TSS and Turbidity Samples at Canal Locations

Location	Date	Time	TSS mg/l	Turbidity NTU
D&R Canal at Ten Mile Lock (10mi)	11/06/2008	15:55	<2.5	3.2
D&R Canal upstream Cedar Grove Brook (Up_CGB)		17:06	<2.5	5.9
D&R Canal downstream Cedar Grove Brook (Down_CGB)		18:00	<2.5	5.1
D&R Canal near Route 18 Spillway (Landing)		18:15	91	11

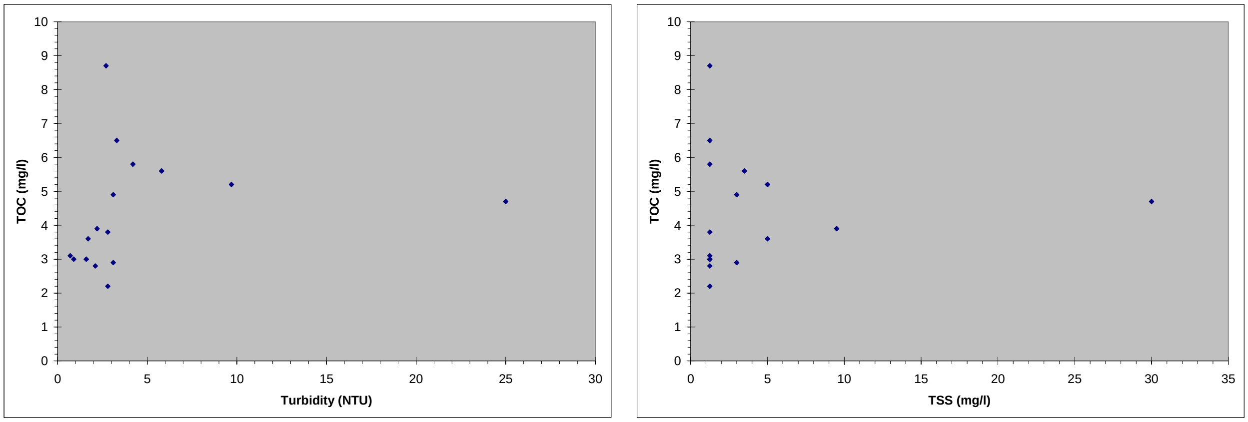
Relationships among TOC, TSS, and turbidity were explored both in the canal and in Cedar Grove Brook. Because the sample results did not include many high values, especially for TSS and turbidity, statistical relationships were not developed. Instead, parameter values were plotted against each other and simple logarithmic regressions were fitted. Given the limited data range, the strength of the regression is not as important as the qualitative trend. For instance, Figure 10 shows turbidity versus TSS for D&R Canal locations and Cedar Grove Brook. In both cases the highest turbidity value occurred in the sample with the highest TSS concentration, which is unlikely to be a coincidence.

FIGURE 10: Turbidity vs. TSS in the D&R Canal and Cedar Grove Brook



On the other hand, TOC did not show any correlation with either turbidity or TSS, as shown in Figure 11. However, given the small number of high values, it is possible that a weak relationship exists that was not observed in this dataset.

FIGURE 11: TOC vs. Turbidity and TOC vs. TSS



Because of the co-occurrence of high values of turbidity and TSS, it is likely that measures to reduce TSS loads to the canal, which is the parameter of interest for the Canal Restoration Project, will also reduce turbidity. In this sense, TSS is a useful surrogate for elevated turbidity. The same cannot be said for TOC. Nothing in the data obtained for this study suggests that efforts to reduce TSS loads to the canal will also reduce TOC.

IV. BMP PRIORITIZATION AND CONCEPTUAL DESIGNS

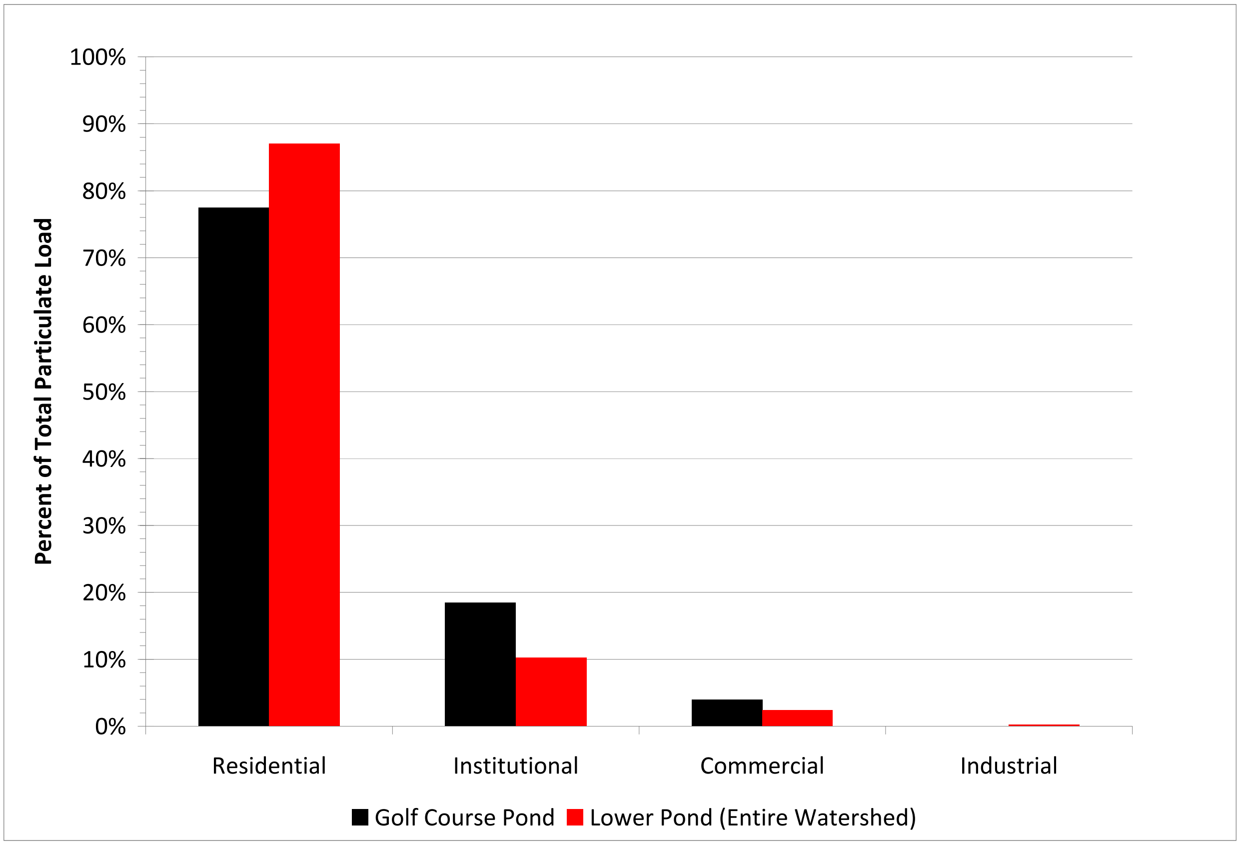
As discussed previously, the Cedar Grove Brook represents a significant potential source of sediment and other pollutants to the D&R Canal relative to other inputs to the canal between Ten Mile Lock and the Route 18 Spillway. Continuous turbidity monitoring demonstrated that Cedar Grove Brook does add turbidity to the D&R Canal under typical and low-flow conditions, reducing the amount of turbidity attenuation (due to settling primarily) that might otherwise be expected to occur in this segment of the canal. More importantly from a water quality perspective, Cedar Grove Brook significantly increases the turbidity peaks in the D&R Canal that occur during storm events. Since such turbidity peaks can be very high, the impact of Cedar Grove Brook on turbidity peaks in the canal appears to be important from a water quality perspective, especially given the proximity to the water supply intake. Water quality sampling in both Cedar Grove Brook and the D&R Canal demonstrate that high values of turbidity occur together with high values of TSS; it is therefore likely that measures to reduce TSS loads to the canal, which is the parameter of interest for the Canal Restoration Project, will also reduce turbidity. TSS is often used as a surrogate for stormwater pollutants in general, and the water quality data support this approach with regard to addressing elevated turbidity in the canal system.

For the reasons stated above, the Cedar Grove Brook watershed was evaluated for potential stormwater BMP improvements. A windshield survey of the Cedar Grove Brook watershed was performed by Brian Friedlich, a Project Engineer with Omni, and Joe Skupien, Principal of SWM Consulting, on January 8, 2009. A long-term WinSLAMM simulation was developed based on rainfall data from Newark airport from 1953 to 1999 in order to evaluate potential BMPs to reduce the particulate load exported from Cedar Grove Brook to the D&R Canal.

A. Evaluation of Source Areas

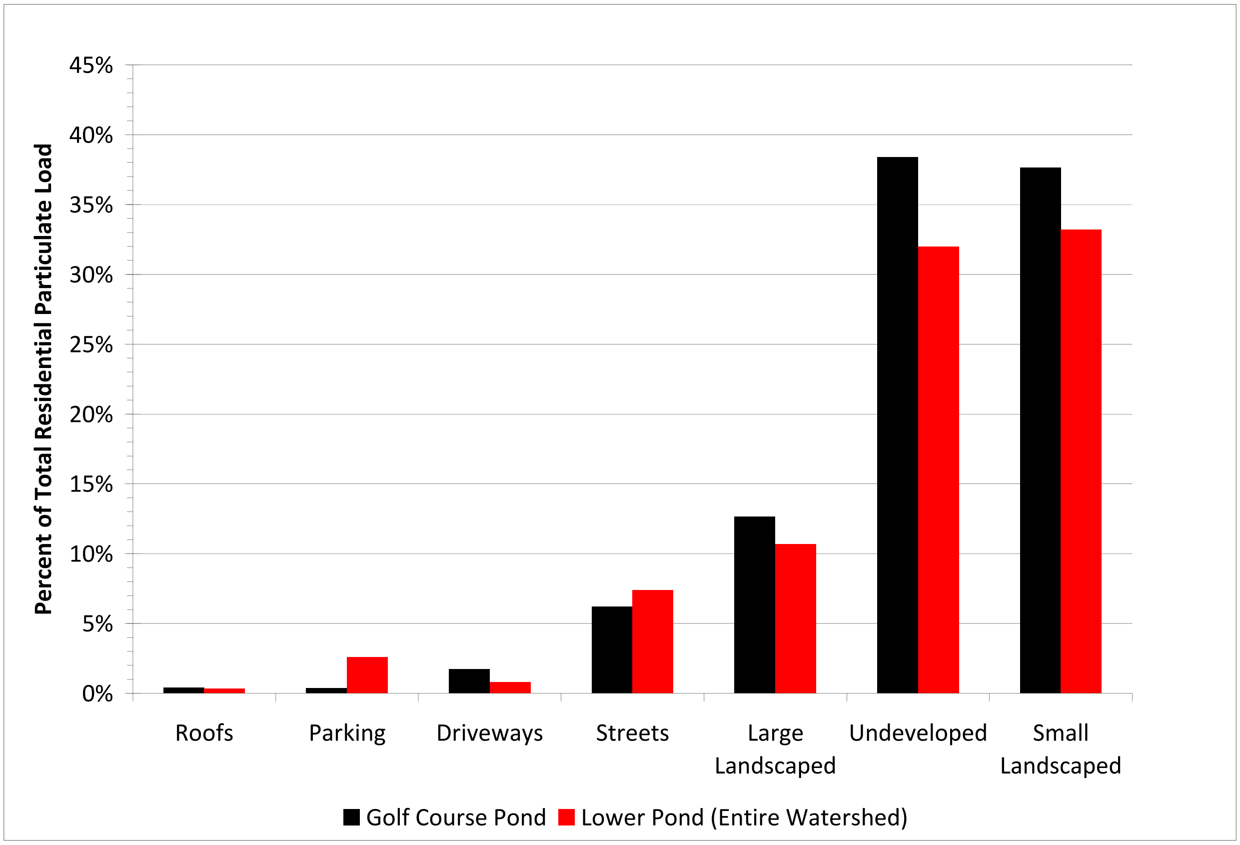
Before contemplating non-structural BMPs, it is helpful to first evaluate the contributing source areas to assess which are the most important. Figure 12 provides an estimate of the relative contribution of sediment load to Cedar Grove Book from various land use areas in the watershed, based on WinSLAMM modeling. The relative contribution from any source area is a function of: 1) the percent of the watershed comprised of the source area; and 2) the potency (pounds per acre) of the source area in terms of sediment load contribution. Residential land use areas can be expected to contribute the most sediment load to Cedar Grove Brook, largely because residential land uses comprise approximately 76% of the Golf Course Pond drainage area and 88% of the entire Cedar Grove Brook watershed. The Quail Brook Golf Course itself is included in the "Institutional" land use category.

FIGURE 12: Particulate Load by Land Use



Given the importance of residential land uses, individual residential source areas were broken down further and evaluated separately. Results are provided in Figure 13. Undeveloped residential areas include mostly wooded areas on residential properties. Landscaped areas are mostly residential lawns and other landscaped areas. Landscaped areas (small and large) and undeveloped residential areas contribute an estimated 89% and 76% of sediment load from residential areas in the Golf Course Pond watershed and Lower Pond (entire Cedar Grove Brook) watershed, respectively. The importance of these types of residential sources is not due to elevated potency (pounds per acre) of sediment load contribution, but rather it is driven by land cover: these source areas comprise approximately 80% of the residential land use area in the watershed.

FIGURE 13: Particulate Load by Residential Source Area



According to the WinSLAMM model analysis, most of the sediment load in the Cedar Grove Brook watershed originates from private residential areas; of the sediment load from residential areas, most of this originates from pervious (wooded or landscaped) source areas. This limits the effectiveness of many structural and non-structural BMPs that might otherwise be contemplated. For instance, street-sweeping of commercial areas, in fact any efforts limited only to commercial areas, will yield at most a very small benefit simply because so little sediment load originates from commercial areas in the Cedar Grove Brook watershed. Even within residential areas, traditional emphasis on impervious source areas (roofs, parking areas, driveways, etc.) will not address the source areas that contribute most of the sediment load.

There are two non-structural BMP opportunities that would appear to yield benefits in terms of reducing sediment load contributions to Cedar Grove Brook, and therefore to the D&R Canal. The first is to improve fill management practices at the Quail Brook Golf Course. It is important to understand that nothing in this study suggests that the golf course is a major source of sediment to Cedar Grove Brook or that the golf course is doing a poor job managing its fill. However, sediment loads from Institutional land use areas (including the golf course) were estimated to be second only to Residential land use areas, and the Quail Brook Golf Course comprises the riparian zone of much of Cedar Grove Brook upstream of Ukrainian Village Pond. Furthermore, the pictures in Figure 14 do suggest that there is room for improvement in terms of fill management at the golf course.

FIGURE 14: Sediment Management at Quail Brook Golf Course

The second non-structural BMP that would potentially yield a positive result in terms of improved water quality is public education aimed at local residents. By far, most of the sediment load to Cedar Grove Brook appears to originate from pervious areas on residential properties. Efforts to reduce stormwater runoff from landscaped areas, such as the installation of rain gardens, would directly address the major source of sediment in the watershed. Public education should emphasize to residents that pollutants wash off their properties into Cedar Grove Brook, where they end up discharging into the D&R Canal upstream of a drinking water intake. This includes wooded areas, since residents often use their wooded areas to dump lawn clippings and sometimes other refuse. Finally, public education should emphasize the importance of maintaining a healthy lawn. While many public education efforts emphasize reducing nutrient over-fertilization, it is even more important to ensure lawns are full enough to stabilize the soils in order to minimize soil erosion.

B. Structural BMPs

As discussed in the previous section, most of the sediment load to Cedar Grove Brook originates from pervious residential land areas, which are the least susceptible to BMP improvements. In addition, the three existing pond structures in Cedar Grove Brook (Golf Course Pond, Ukrainian Village Pond, and Lower Pond) are providing significant sediment removal such that Cedar Grove Brook is currently discharging far less sediment to the D&R Canal than it otherwise would be. However, these same pond structures can also act as sediment sources due to the resuspension of accumulated sediment under certain storm conditions. Given the above considerations, the highest prioritization should be given toward improving the pond structures that already exist in order to optimize their water quality benefits. Each pond feature was evaluated for BMP opportunities, and the outlet structure of each pond was evaluated using long-term WinSLAMM simulations to explore possible modifications to enhance sediment removal. It is important to understand that these are conceptual BMPs only; actual BMPs would require detailed engineering designs.

1. Golf Course Pond

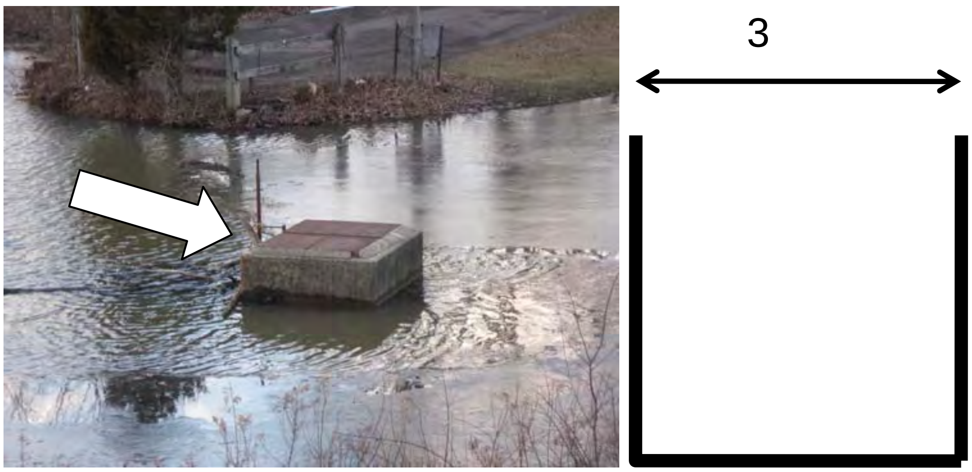
The most upstream of the pond features in Cedar Grove Brook is the Golf Course Pond (Figure 15).

FIGURE 15: Golf Course Pond

Two potential BMP improvements were identified to increase the sediment removal rate and thereby reduce the sediment load to the downstream portion of Cedar Grove Brook: 1) modification to the outlet structure; and 2) flowpath routing baffles.

The existing outlet structure is a 3-foot long weir in the upstream side of an outlet box (Figure 16). The long-term WinSLAMM simulation suggests an overall sediment removal rate of approximately 50%; in other words, approximately half of the sediment entering the Golf Course Pond is discharged to Cedar Grove Brook. In addition, because the weir faces "upstream," much of the pond volume appears to be short-circuited, which reduces the expected sediment removal rate.

FIGURE 16: Existing Outlet Structure for Golf Course Pond



Two relatively simple changes to the outlet structure of the Golf Course Pond are proposed. The first is to face the opening "downstream," thereby increasing residence time in the pond, and thereby allow more time for settling to occur. More importantly, adding a smaller outlet weir at the base of the existing 3 foot weir (Figure 17) will increase the residence time as well and increase the overall sediment removal rate of the pond feature. Various weir heights and widths were explored, and their associated long-term sediment removal rates were estimated using WinSLAMM (Figure 18). It turns out that sediment removal is more sensitive to weir width than weir height. Smaller weir widths would result in higher sediment removal rates. Widths smaller than 3 inches were not explored, since such a small weir would clog too easily. In terms of the height of the proposed smaller weir, a 12 inch high weir would be marginally better than a 6 inch weir.

Adding a smaller weir between 3 and 6 inches wide and 6 to 12 inches high would substantially improve the sediment removal performance of the Golf Course Pond.

FIGURE 17: Proposed Modification to Outlet Structure for Golf Course Pond

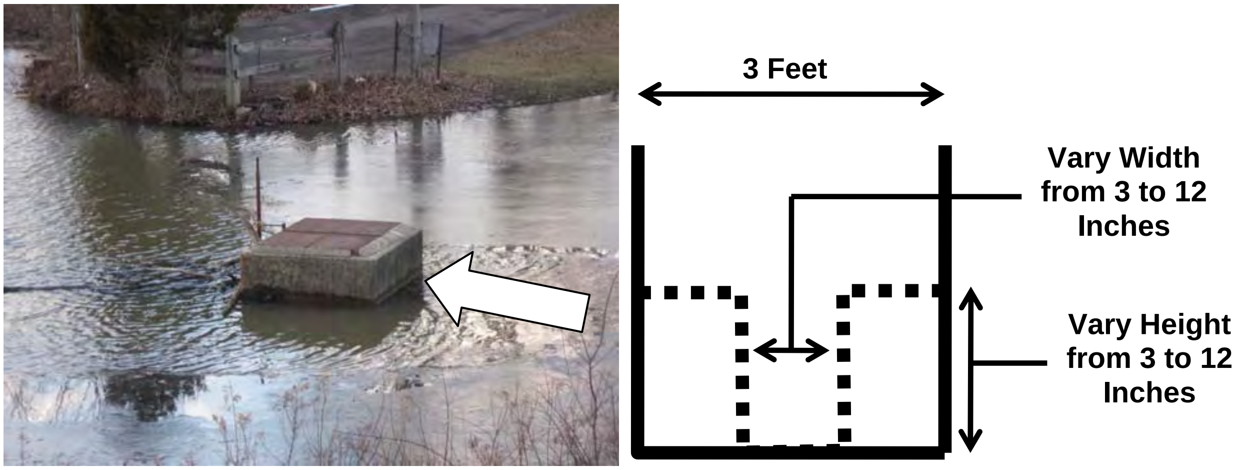
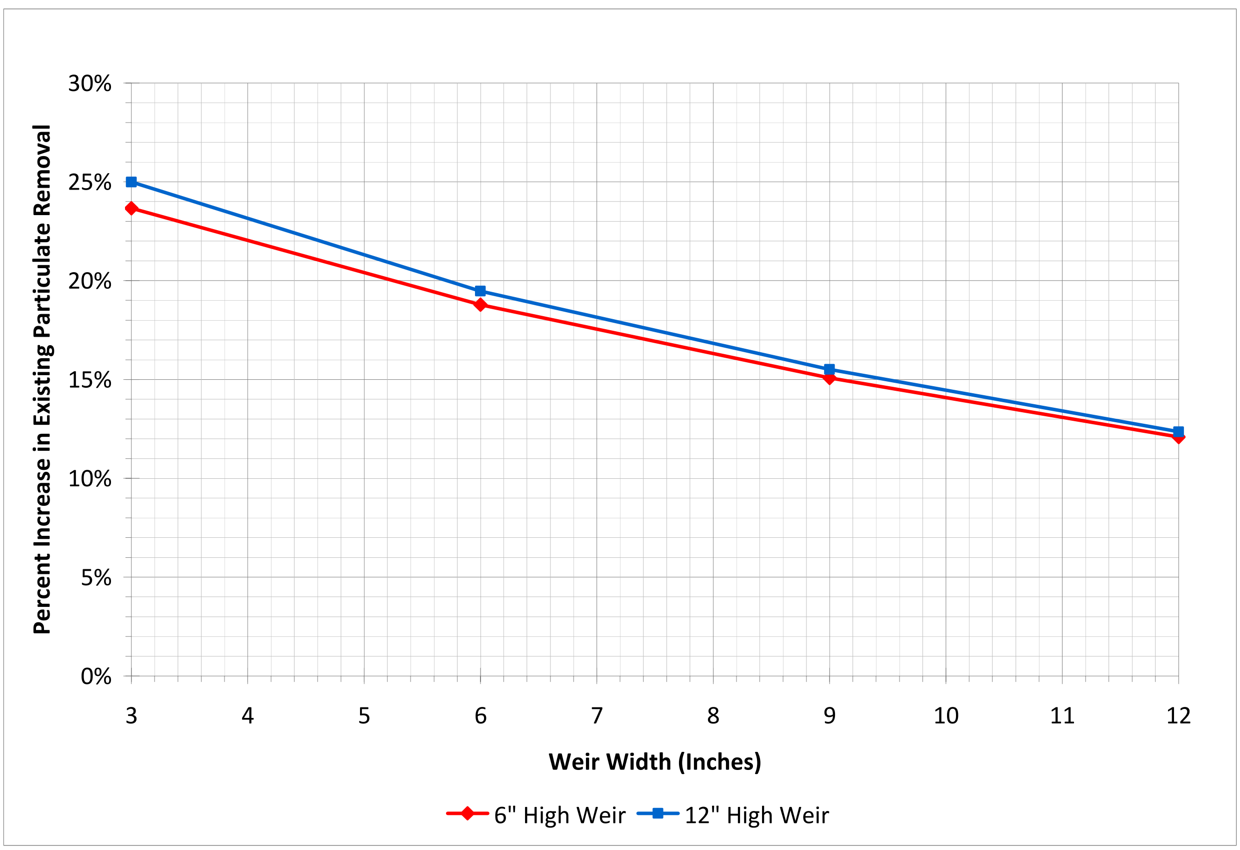
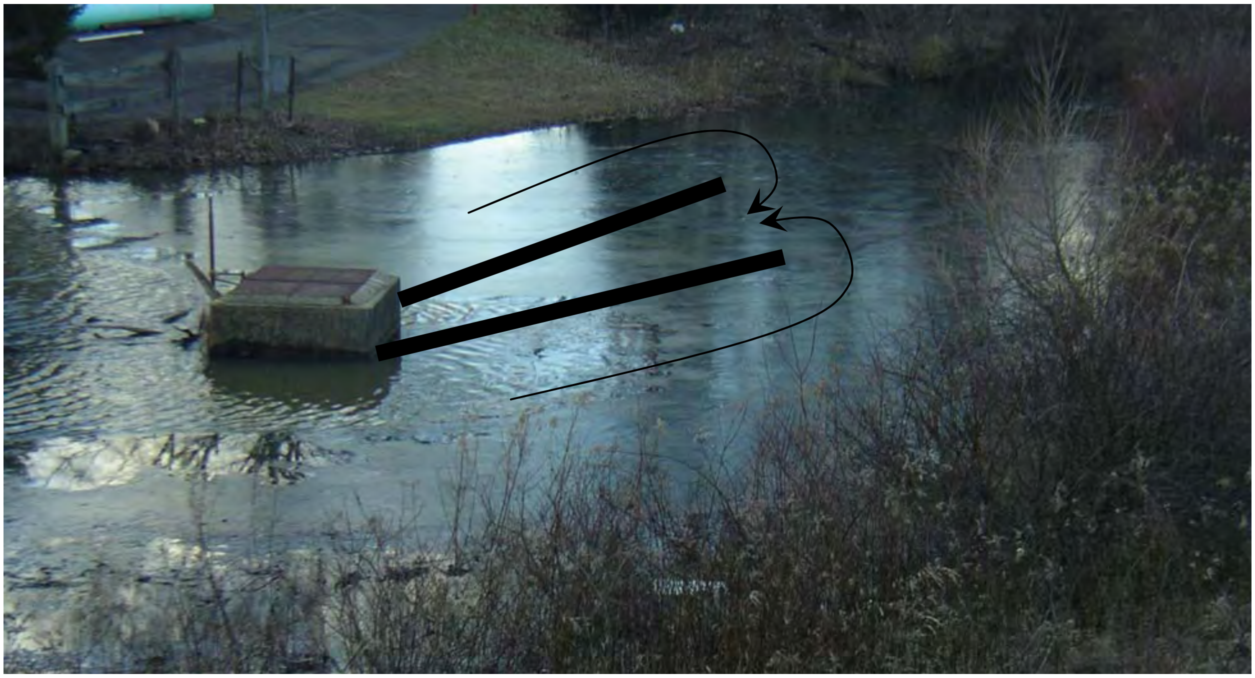


FIGURE 18: Percent Change in Existing Golf Course Pond Particulate Removal



The second conceptual BMP for the Golf Course Pond is to add flowpath baffles (Figure 19). As mentioned previously, the Golf Course Pond is somewhat linear, and the outlet is a straight flowpath from the inlet. As a result, the bulk of the pond volume is often short-circuited. The WinSLAMM modeling of course does not account for this phenomenon, and its importance is difficult to quantify. Orienting the weir opening downstream will certainly help somewhat, but adding flowpath baffles would force flow under most circumstances into more of the pond volume. This would increase residence time and therefore increase settling. Flowpath baffles are essentially concrete walls that extend downstream from the weir inlet in order to force water to circulate through more of the pond volume.

FIGURE 19: Proposed Flowpath Baffles for Golf Course Pond



Finally, a bathymetry survey is recommended to investigate dredging. Recall from Figure 3 that the stormwater monitoring showed higher TSS concentrations leaving the Golf Course Pond than entering the pond during the large storm event in October 2005. This suggests that during larger storm events, accumulated sediment in the Golf Course Pond is being re-suspended and may be acting as a sediment source rather than a sink. The first step to evaluate the extent of accumulated sediment is to perform a bathymetric survey of the depth of unconsolidated sediment throughout the pond. The results of the survey can be used to investigate whether dredging is needed. It should be noted that stream impoundments such as the Golf Course Pond tend to fill-in over time and will eventually need to be dredged in order to maintain their hydrologic and water quality benefits.

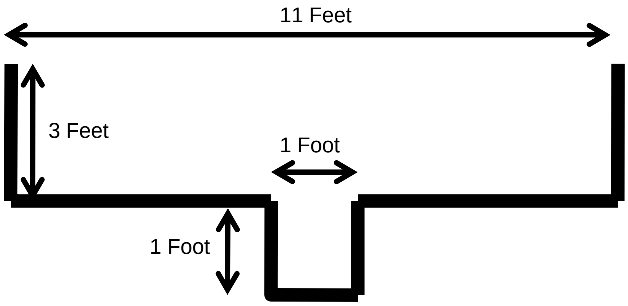
2. Ukrainian Village Pond

Ukrainian Village Pond (Figure 20) is downstream of the Golf Course Pond close to the center of the Cedar Grove Brook watershed. Ukrainian Village Pond is an impoundment with two tributary inlets that discharges to Cedar Grove Brook. A relatively simple modification to the outlet structure is proposed to increase the sediment removal rate and thereby reduce the sediment load to the downstream portion of Cedar Grove Brook.

FIGURE 20: Ukrainian Village Pond

The existing outlet structure for the Ukrainian Village Pond is a 1-foot square weir within a larger 11-foot weir (Figure 21), which is actually within a very large weir as shown in the picture. According to the long-term WinSLAMM simulations performed for the Ukrainian Village Pond, the overall sediment removal rate is approximately 33%.

FIGURE 21: Existing Outlet Structure for Ukrainian Village Pond



The existing 1-foot weir provides a negligible benefit in terms of sediment removal efficiency. However, simply increasing the height of the existing weir, as shown in Figure 22, from 1 foot to 3 or 4 feet would improve the sediment removal by approximately 15% (Figure 23).

FIGURE 22: Proposed Modification to Outlet Structure for Ukrainian Village Pond

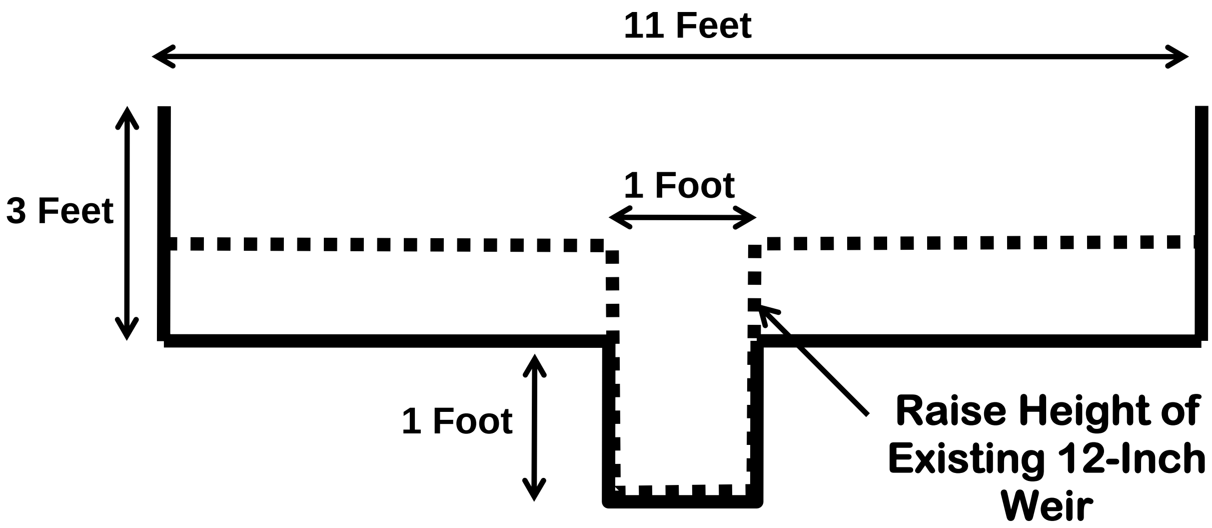
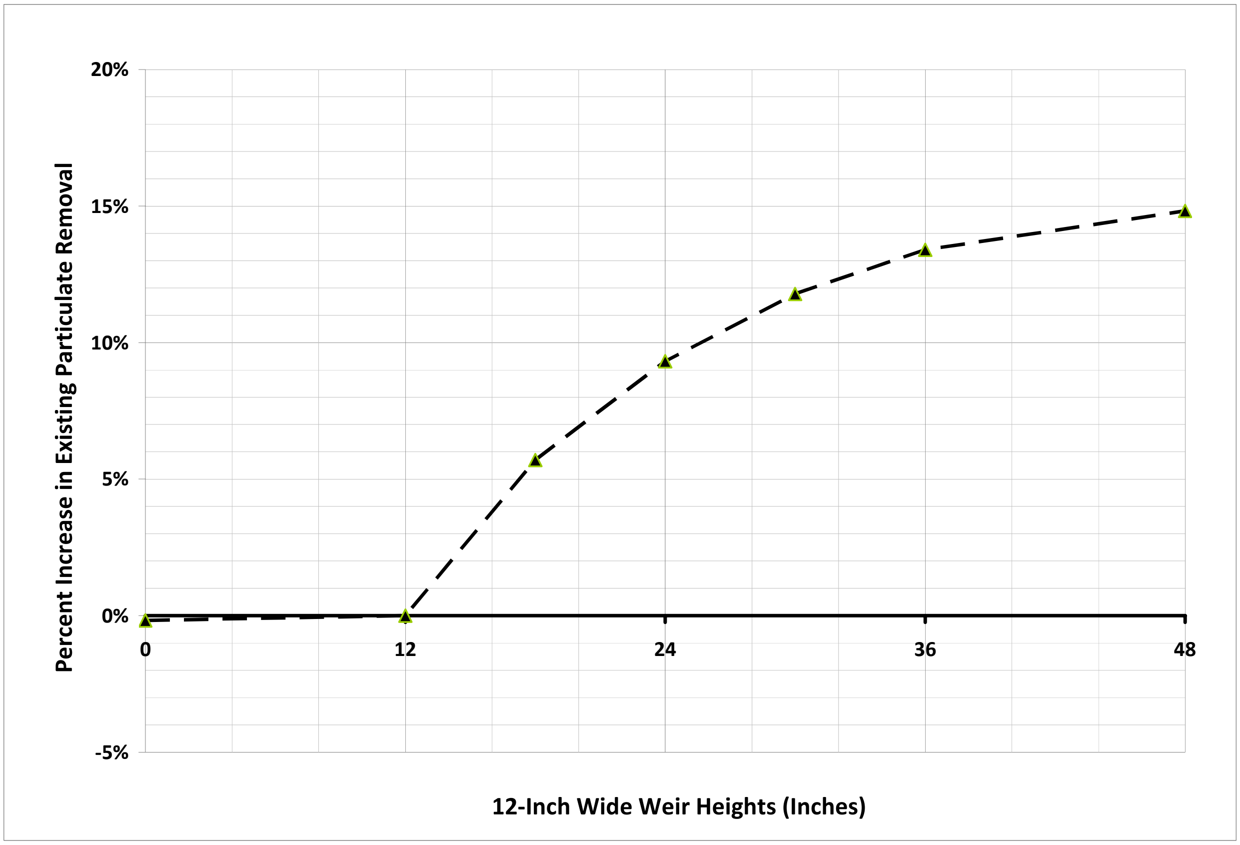


FIGURE 23: Percent Change in Existing Ukrainian Village Pond Particulate Removal



A bathymetry survey is also recommended to investigate dredging. The stormwater monitoring performed in 2005 did not show the Ukrainian Village Pond acting as a sediment source during either of the storm events monitored. However, it is still likely that, during at least some large storm events, accumulated sediment in the Ukrainian Village Pond is being re-suspended and causing the pond to act as a sediment source rather than a sink. Since a bathymetric survey is recommended for the Golf Course Pond, it makes sense to survey the Ukrainian Village Pond on the same day. The results of the survey can be used to investigate whether dredging is needed. As noted previously, stream impoundments tend to fill-in over time and will eventually need to be dredged in order to maintain their hydrologic and water quality benefits.

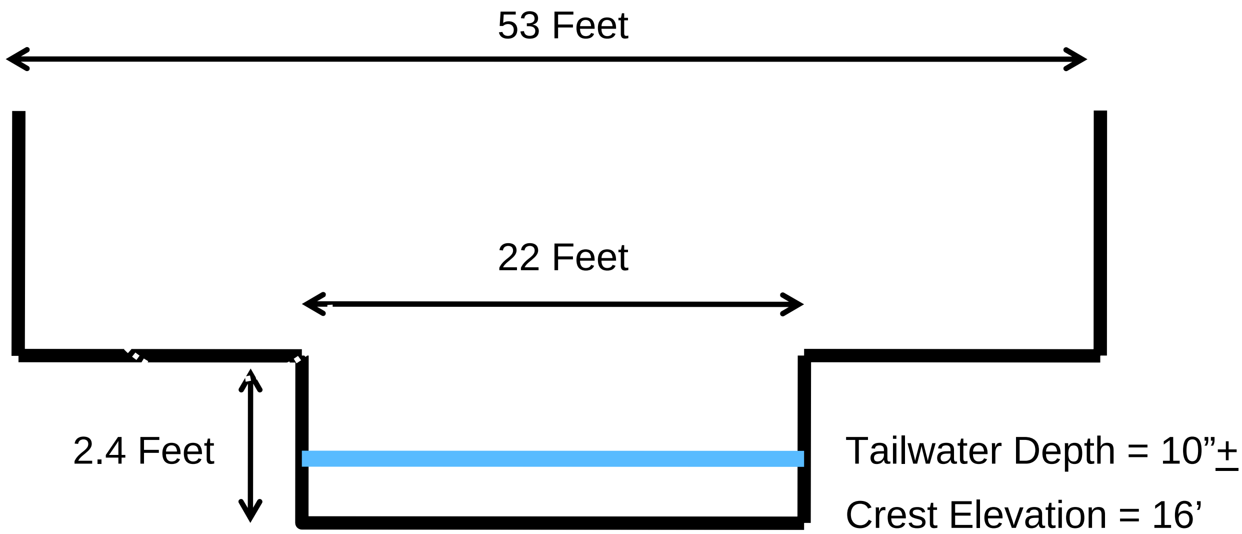
3. Lower Pond

The outlet of Cedar Grove Brook (called "Lower Pond" for the purposes if this study) is impounded slightly by a dam structure just upstream of the Easton Avenue bridge with a weir that is generally submerged at the crest (Figure 24). Despite the dam structure, the outlet of Cedar Grove would not likely be identified by the casual observer as a pond under current conditions; one can see the bottom less than one foot below the weir crest. Nevertheless, the designation "Lower Pond" was adopted to reflect what this feature would become after the recommended restoration is complete. The reason is that the conceptual improvement identified for the outlet of Cedar Grove Brook to reduce the sediment load to the D&R Canal is a significant modification to the outlet structure. This modification would increase the height of the weir crest, resulting in a permanent pool of water 5 to 7 feet deep, thereby making it a more easily recognized pond feature.

FIGURE 24: Cedar Grove Brook Watershed Outlet (Lower Pond)

A diagram of the existing outlet structure is shown in Figure 25. The current structure is not very useful from the standpoint of sediment removal. In fact, long-term WinSLAMM simulations indicate that the existing structure might be expected to remove approximately 3% of the sediment that reaches the outlet of Cedar Grove Brook. However, the WinSLAMM simulation does not account for the fact that the weir crest is generally submerged by canal tailwater, nor does it account for the resuspension of accumulated sediment. It is very likely that the out of Cedar Grove Brook provides a net source of sediments to the D&R Canal. The outlet structure could be improved substantially be increasing the elevation of the crest and decreasing the width of the smallest weir.

FIGURE 25: Existing Outlet Structure for Lower Pond



In terms of increasing the crest elevation, the flood plain at the Cedar Grove Brook watershed outlet is long and deep (Figure 26), providing plenty of room to significantly increase the crest elevation above the existing level. A new five foot wide weir is proposed (Figure 27) at a significantly higher crest elevation.

FIGURE 26: Lower Pond Flood Plain

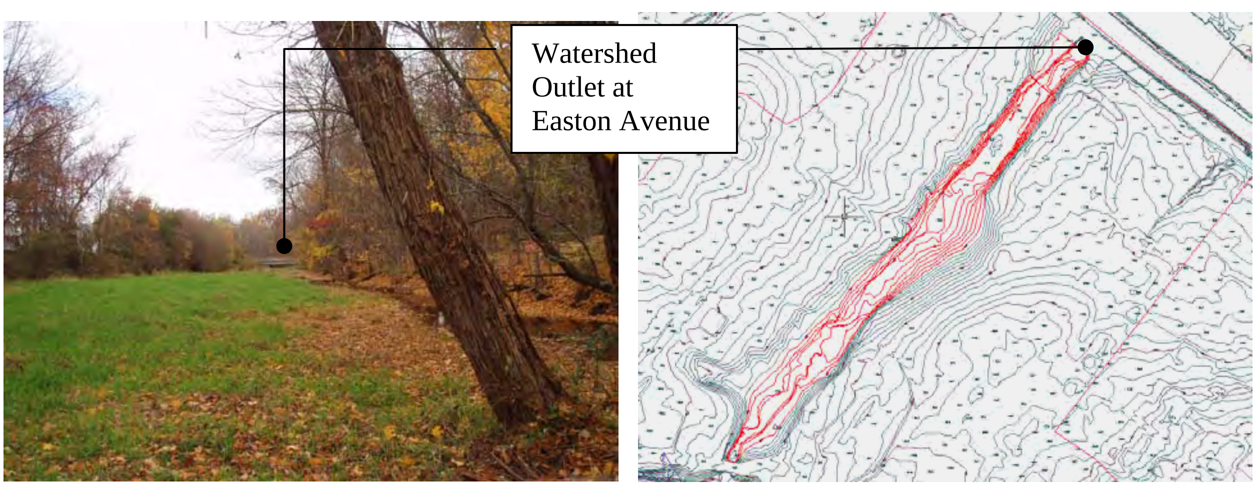
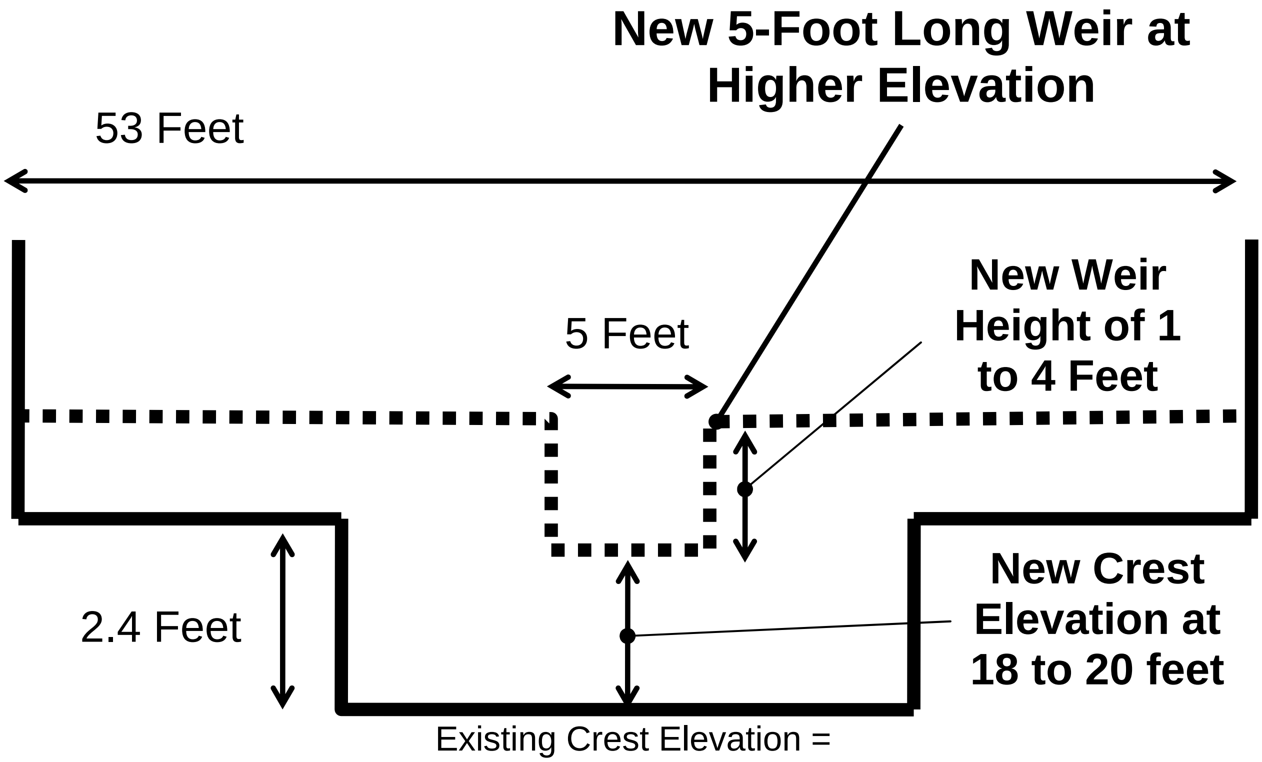
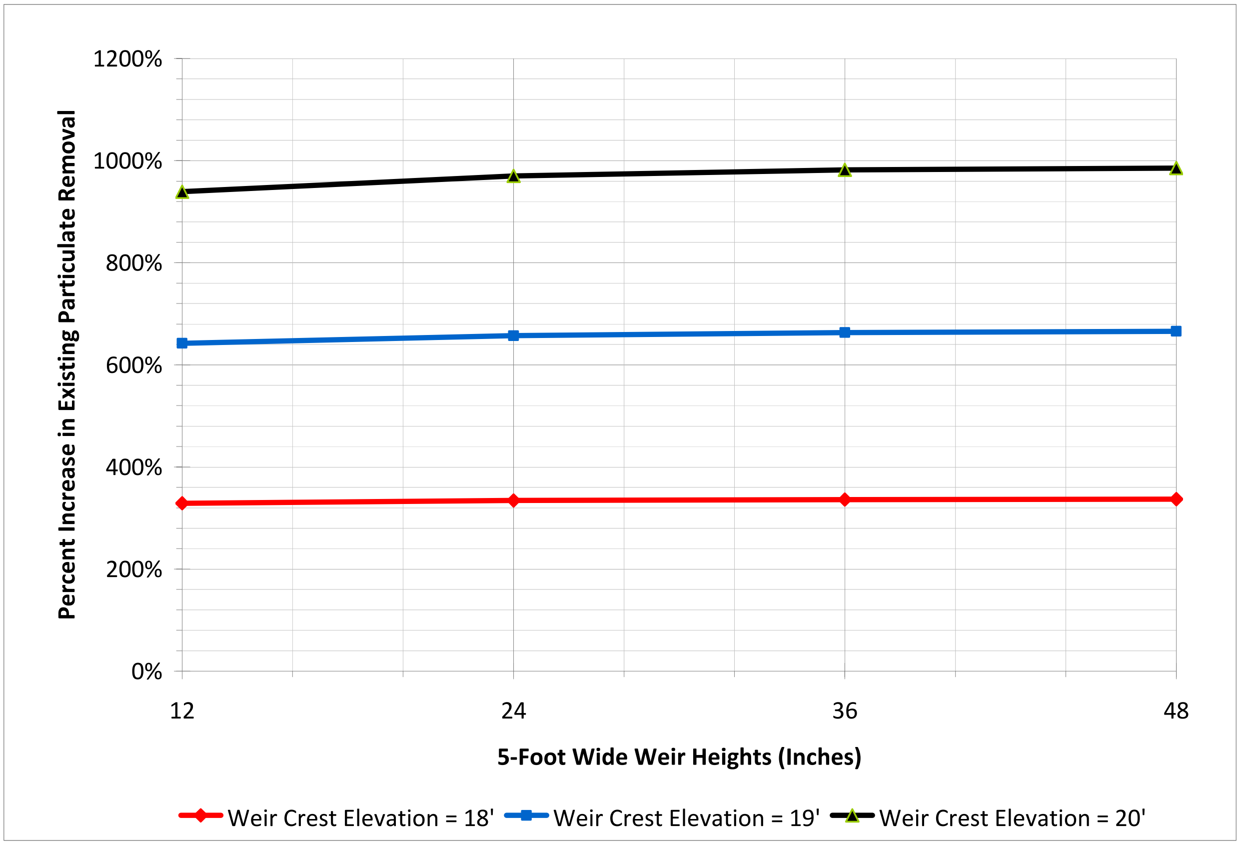


FIGURE 27: Proposed Modification to Outlet Structure for Lower Pond



Crest elevations of 2, 3, and 4 feet above the current elevation were explored using WinSLAMM, as well as weir heights of 1, 2, 3, and 4 feet. As shown in Figure 28, the sediment removal rate is relatively insensitive to weir height. A 5 foot weir at a significantly higher crest elevation will significantly improve the sediment removal rate of the outlet structure. Furthermore, the extent of the benefit is strongly influenced by the height of the weir crest. Increasing the crest elevation by four feet would provide the most benefit of the elevation options explored, increasing the overall sediment removal rate ten-fold to approximately 30%. Note that this does not even account for the fact that the weir crest would no longer be submerged by canal tailwater, or the additional benefit of reduced sediment resuspension.

FIGURE 28: Percent Change in Existing Lower Pond Particulate Removal



C. <u>Conceptual BMP Prioritization Matrix</u>

Table 3 provides a matrix that summarizes the conceptual BMPs explored in this chapter and assesses them qualitatively based on best professional judgment from one to three according to the following criteria: Cost (1 = expensive, 3 = inexpensive); Ease of Permitting (1 = difficult, 3 = none required); Potential Benefit (1 = modest benefit, 3 = substantial benefit). The qualitative assessment criteria were then multiplied together in order to score the conceptual BMPs; higher prioritization scores indicate higher priority BMPs. The conceptual BMPs are listed in Table 3 in recommended order of priority.

TABLE 3: Conceptual BMP Prioritization Matrix

Conceptual BMPs Ranked from High to Low Priority	Cost	Ease of Permitting	Potential Benefit	Prioritization Score
Lower Pond (Watershed Outlet): Modification to Outlet Structure	2	2	3	12
Non-Structural BMP: Public Education for Residents Regarding Stormwater Management	3	3	1	9
Non-Structural BMP: Improved Sediment Management at Quail Brook Golf Course	3	3	1	9
Golf Course Pond: Modification to Outlet Structure	2	2	2	8
Ukrainian Village Pond: Modification to Outlet Structure	2	2	2	8
Golf Course Pond: Adding Flowpath Baffles	2	2	1	4

Recommended bathymetry surveys of the Golf Course Pond and Ukrainian Village Pond were not included in the prioritization matrix. The bathymetry surveys are relatively inexpensive; however, they will not in themselves produce a water quality benefit. Instead they are intended to characterize the unconsolidated sediment volume in order to assess the costs and benefits of potential dredging. Dredging is very expensive and can be difficult to permit, but would likely produce major water quality benefits by greatly reducing sediment loads delivered during major storm events.

V. CONCLUSIONS

This report was prepared to present the data collected during Task 2 of the project, evaluate the results, and summarize conceptual BMP recommendations for the Cedar Grove Brook watershed. Relative to all the other canal contributions in the region, the Cedar Grove Brook represents a significant potential source of sediment and other pollutants. While the three existing pond structures together in Cedar Grove Brook are providing significant sediment removal, they also can act as sediment sources due to the resuspension of accumulated sediment under certain storm conditions.

Turbidity in the D&R Canal from Ten Mile Lock to the Route 18 Spillway is generally fairly low in comparison to the turbidity criteria for freshwater. However, high turbidity peaks occur during storm events. Cedar Grove Brook does appear to add turbidity to the D&R Canal under typical and low-flow conditions, and this does in fact reduce the amount of turbidity attenuation (due to settling primarily) that might otherwise be expected to occur in this segment of the canal. More importantly from a water quality perspective, discharge from Cedar Grove Brook can significantly increase the turbidity peaks in the D&R Canal that occur during storm events. Because of the co-occurrence of high values of turbidity and TSS, it is likely that measures to reduce TSS loads to the canal will also reduce turbidity. In this sense, TSS appears to be a useful surrogate for elevated turbidity in this watershed.

Most of the sediment load in the Cedar Grove Brook watershed originates from private residential areas; of the sediment load from residential areas, most of this originates from pervious (wooded or landscaped) source areas. This limits the effectiveness of many structural and non-structural BMPs that might otherwise be contemplated in the watershed. Non-structural BMPs that would potentially yield a positive result in terms of improved water quality include public education aimed at local residents and improved fill management at the golf course. By far, most of the sediment load to Cedar Grove Brook appears to originate from pervious areas on residential properties. Efforts to reduce stormwater runoff from landscaped areas, such as the installation of rain gardens, would directly address the major source of sediment in the watershed.

Relatively simple improvements to the outlet structures of all three of the pond features in Cedar Grove Brook are recommended. The most important of these is the higher weir crest proposed for the dam structure at the outlet of the watershed. The proposed outlet modification would make use of the available flood plain to create a permanent pool approximately 7 feet deep, resulting in a true pond feature with greatly enhanced pollutant removal properties. None of the proposed outlet structure modifications are expensive from a design and construction perspective; permitting will be challenging but not likely to be prohibitive since the proposed BMPs are modifications to existing structures.

VI. REFERENCES

TRC Omni. July 7, 2006. Cedar Grove Brook Water Quality Characterization and Assessment. Prepared for New Jersey Water Supply Authority.

United States Geological Survey. 2001. Water Quality of the Delaware and Raritan Canal, New Jersey, 1998-99. Water Resources Investigations Report 01-4072. Prepared in cooperation with the New Jersey Water Supply Authority.

QUALITY ASSURANCE PROJECT PLAN (QAPP)

NEW JERSEY WATER SUPPLY AUTHORITY
CEDAR GROVE BROOK WATERSHED
STORMWATER MANAGEMENT PLAN (SMP)
319 (H) RP04-011 FIELD SERVICES

Applicant: Amy Shallcross, Senior Watershed Protection Specialist
New Jersey Water Supply Authority

Amy L. Shallcross 5-12-06
Signature Date

Project Officer: James F. Cosgrove, Jr., P.E., President
TRC Omni Environmental Corporation

James Cosgrove 5/5/06
Signature Date

QA Officer: Greg Soska, Senior Scientist
TRC Omni Environmental Corporation

Greg Soska 5-5-06
Signature Date

NJDEP: Robert Mancini
Bureau of Watershed Planning

Robert Mancini 5/24/06
Signature Date

NJDEP: Beth Torpey, NJDEP
Division of Watershed Management

Beth Torpey 5/24/06
Signature Date

NJDEP: Marc Ferko, Senior Chemist
Office of Quality Assurance

Marc Ferko
Signature Date

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QUALITY ASSURANCE PROJECT PLAN FOR CEDAR GROVE BROOK WATERSHED STORMWATER MANAGEMENT PLAN (SMP) 319 (H) RP-04-011 FIELD SERVICES

Prepared For:
NEW JERSEY WATER SUPPLY AUTHORITY

Submitted to:
NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION DIVISION OF WATERSHED MANAGEMENT

Revised: March 30, 2006

QUALITY ASSURANCE PROJECT PLAN (QAPP)

NEW JERSEY WATER SUPPLY AUTHORITY CEDAR GROVE BROOK WATERSHED STORMWATER MANAGEMENT PLAN (SMP) 319 (H) RP04-011 FIELD SERVICES

Applicant:	Amy Shallcross, Senior Watershed Protection Specialist New Jersey Water Supply Authority
	Signature Date
Project Officer:	James F. Cosgrove, Jr., P.E., President TRC Omni Environmental Corporation
	Signature Date
QA Officer:	Greg Soska, Senior Scientist TRC Omni Environmental Corporation
	Signature Date
NJDEP:	Robert Mancini Bureau of Watershed Planning
	Signature Date
NJDEP:	Beth Torpey, NJDEP Division of Watershed Management
	Signature Date
NJDEP:	Marc Ferko, Senior Chemist Office of Quality Assurance
	Signature Date

1.	Project Name:	New Jersey Water Supply Authority: Cedar Grove Brook Watershed SMP Field Services
2.	Applicant Name:	New Jersey Water Supply Authority P.O. Box 5196 Clinton, NJ 08809
3.	NJDEP 319 (h) Grants:	Cedar Grove Brook Stormwater Management Plan; Franklin Township, Somerset County, New Jersey
4.	Sampling Dates:	May 2005 through October 2005
5.	Project Officer:	James F. Cosgrove, Jr., P.E. President TRC Omni Environmental Corporation 321 Wall Street Princeton, NJ 08540-1515 (609) 924-8821 (Ext. 11)
6.	QA Officer:	Michael Wright Senior Associate TRC Omni Environmental Corporation 321 Wall Street Princeton, NJ 08540-1515 (609) 924-8821 (Ext. 12)

7. Project Description:

The NJWSA is developing Stormwater Best Management Practice (BMP) strategies for the Cedar Grove Brook (also known as Al's Brook) watershed. This 2,300 acre watershed in Franklin Township, New Jersey conveys drainage to the Delaware and Raritan Canal, a major water purveyor supply conduit operated by the NJWSA in the Raritan River Basin. Increased levels of total suspended solids (TSS) and turbidity have been reported by the purveyors during and immediately after precipitation events. Recent studies and observations have confirmed that Cedar Grove Brook is a contributor of suspended sediments. Upon recognizing the need to quantify and control sediment loading, NJWSA and Franklin Township obtained a 319(h) nonpoint source grant to develop a regional stormwater management plan for the Cedar Grove Brook watershed.

The initial tasks required by NJWSA to develop this plan include field services and water quality sampling to determine watershed runoff rates and volumes and associated sediment loads. The field data will be used to assist NJWSA in the development of a watershed computer model that will be used to predict turbidity and TSS loadings and target areas within the watershed for remedial action. Technical assistance will then be provided to the NJWSA to identify and develop remedial measures that will be used by the NJWSA and Franklin Township to help reduce these TSS loadings and turbidity levels and achieve water quality goals both within the Canal and the Cedar Grove Brook Watershed.

The Delaware and Raritan Canal is classified as Fresh Water 2, Non-Trout (FW2-NT). A recent study by the USGS using data from 1998 and 1999 (USGS, 2001) reported that turbidity in the canal does not decrease in the reach between Ten Mile Lock and the Route 18 spillway, as would be expected given the 2.3 day travel time involved. Since water velocity in the canal is very low, there should be minimal resuspension of settled sediments. The conclusion of the USGS study was that those solids that settle out are replaced by turbidity from influent streams and stormwater discharges into the Canal in this reach. Subsequent field observations downstream of the Canal's confluence with Cedar Grove Brook note the formation of a sand bar, indicating that Cedar Grove Brook contributes sediment-laden stormwater to the Canal. The water supply intakes for New Brunswick and North Brunswick and the Middlesex Water Company are immediately downstream of the project area and are directly affected by pollutant loads to this reach of the Canal. Since 1997, these water purveyors have reported increased turbidity and total suspended solids concentrations in the raw water during and immediately after precipitation events, requiring increased chemical use for removal and increasing sludge generation from residuals.

Of the more than 50 "infalls" to the Canal identified by the NJWSA for the ongoing Canal Nonpoint Source Management Project, none are known point sources of treated or untreated effluent to the Canal. The problem is thus apparently caused entirely by nonpoint source pollution. Based upon these facts, it is apparent that the problem is one of turbidity and TSS loads delivered by the tributaries downstream from Ten Mile Lock including Cedar Grove Brook. While most of the water suppliers' problem is the turbid fraction of TSS, sediment deposition in the canal due to the coarser fraction of TSS settling out is a separate, albeit related, problem.

Sampling for this project will obtain data necessary to evaluate targeted pollutants with respect to flow conditions, seasonal variations and pertinent weather conditions. This sampling plan was designed to assess water quality impacts due to erosion and storm water runoff, which could then be examined to determine the effectiveness of BMP installations. In order to incorporate these assessments into an integrated plan, the field services will be conducted as described below.

A. Monitoring Network Design and Rationale

Spatial Extent of Study:

The sample stations and boundaries for the study area are shown in Figure 1.

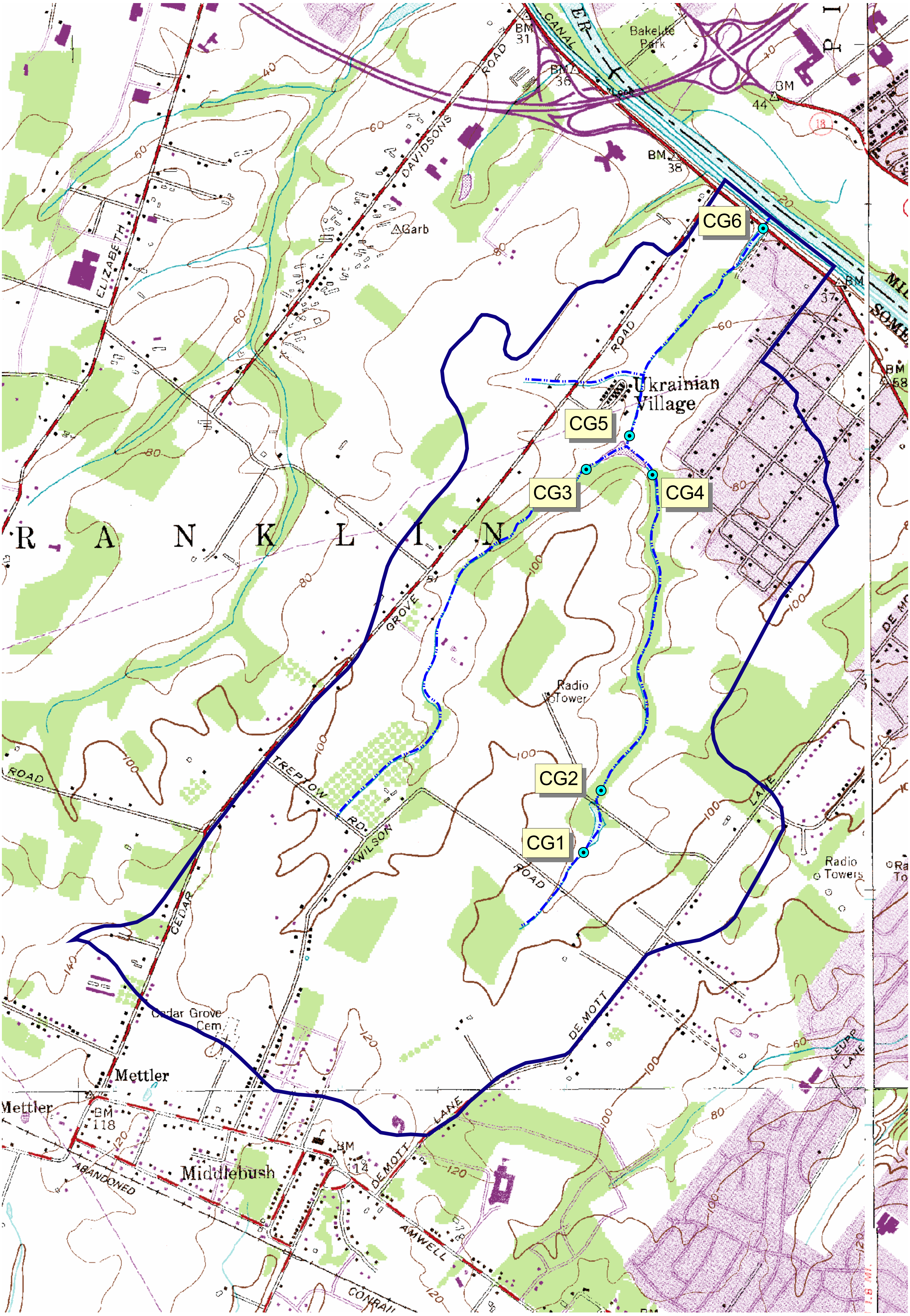
Sampling Locations:

The sampling station locations as shown on Figure 1 and listed in Appendix A will be monitored during this study. The stations are comprised of the following networks (station types):

- Six (6) baseline storm water locations;
- Six (6) low flow locations;
- Approximately ten (10) intensive storm water locations.

Stream sampling stations were selected so that the sources of nonpoint pollutants could be identified. Tributary stations were selected in order to characterize substantial inputs into the Cedar Grove Brook study area. The following list describes the selected sampling stations:

CG1: Cedar Grove Brook, Upstream from Quail Brook Pond
CG2: Cedar Grove Brook, Effluent from Quail Brook Pond
CG3: Cedar Grove Brook, West Branch upstream from Ukrainian Village Pond
CG4: Cedar Grove Brook, East Branch upstream from Ukrainian Village Pond
CG5: Cedar Grove Brook, Effluent from Ukrainian Village Pond
CG6: Cedar Grove Brook, at weir south of Easton Avenue



Cedar Grove Brook Watershed

FIGURE 1 - Proposed Sampling Stations

N W E S

0.25 0 0.25 Miles

Prepared by: TRC Omni Environmental Corporation

Temporal Aspects:

Baseline Storm Water Events (All Stations)

Sampling will be performed at the six (6) stations of interest. These stations were selected during the initial site visit with the goal of identifying pollutant loading throughout the watershed. Two baseline storm water events will be performed during the summer period from May through August. Over the course of each storm event, a total of three grab samples will be collected for a total of 6 samples per station **(Baseline stormwater sampling will consist of 2 events with three samples collected from each of six stations during each event, for a total of 36 samples)**. The first sample will be collected at the beginning of the storm (when approximately 0.1 inch of precipitation has been observed) and the remaining two samples will be collected during the storm to characterize the water quality over the hydrograph. The second grab sample will be collected when approximately 0.3 inches of precipitation has been observed and the third sample will be collected as close as possible to the end of precipitation. Storm water events will be performed during storms predicted to deliver at least 0.5 inches of rain that are preceded by at least 72 hours with no more than 0.1 inches of rain. These two sampling events will be used to determine the water quality impacts of stormwater runoff throughout the watershed. The results of these two events will be used to determine the locations to be sampled in the final intensive stormwater sampling event.

During the first Baseline Storm Water Event, a Sedimentation Characterization will be completed by conducting settleability studies. Flow weighted composites will be prepared at each station and each composite will be shaken vigorously and transferred to Imhoff cones for settleability testing. Sedimentation will be observed and measured during the study. In addition, aliquots of supernatant will be removed from the cones at regular intervals and submitted to a NJDEP certified laboratory for testing of TSS and Turbidity.

Low-Flow Event (All Stations)

One low-flow event will be performed. Sampling will be performed at the same six (6) stations identified in the baseline storm water events. Low-flow events will be performed when measured flow at USGS station 01403150 is below the stream flows that are exceeded 70% of the time (d70). In addition, this event will be performed only when preceded by at least 72 hours with no more than 0.1 inches of rain. The majority of the water in the stream during low flow events should consist of base flow, and water quality impacts from storm water runoff should be negligible.

Intensive Storm Water Event (Stations to be Determined)

One Intensive Storm Water event will be performed. Sampling will be performed at approximately ten (10) stations of interest. These stations will be selected based on data obtained during the baseline storm events, with the goal of identifying and isolating specific pollutant sources. Sampling stations will include locations detailed in the Work Plan and may also incorporate additional locations identified during the Baseline Storm Water Events. The intensive storm water event consists of three samples per station. The first sample will be collected at the beginning of the storm (when approximately 0.1 inch of precipitation has been observed) and the remaining two samples will be collected during the storm to characterize the water quality over the hydrograph. Storm water events will be performed during storms predicted to deliver at least 0.5 inches of rain that are preceded by at least 72 hours with no more than 0.1 inches of rain.

Spatial Aspects:

Samples will be collected in accordance with the approved QAPP, when possible, moving from downstream to upstream locations to avoid the potential from cross-contamination of samples. Because the upstream locations are affected by precipitation prior to the downstream locations this is not always possible however all reasonable procedures to avoid cross contamination will be utilized during the sampling events. At least three subsurface grab samples will be collected mid-depth at equidistant points across the sampling location. These grab samples will be composited in a larger volume container, from which the desired volume will be transferred to the sample bottles. A dedicated large volume container will be assigned to each sample location. Prior to each sampling event, the large volume containers will be decontaminated using the following procedure: (1) distilled/deionized water rinse, (2) non-phosphate detergent wash, (3) distilled/deionized water rinse, (4) air dry and (5) distilled/deionized water rinse. Sampling will be conducted in accordance with methods specified in the NJDEP Field Sampling Procedures Manual (1992).

Rationale for Sampling Locations:

In order to obtain sufficient data required to complete this evaluation sample stations were selected at various locations on the Cedar Grove Brook within the spatial extent of the study. These stations were selected in order to characterize substantial inputs into the study area. Locations CG1, CG3 and CG4 will characterize influent loading to impoundment areas in the watershed. Locations CG2, and CG5 will characterize loading from impoundment areas in the watershed. Location CG6 will characterize loading from Cedar Grove Brook to the canal.

B. Monitoring Parameters

Watershed Conditions

Precipitation*

Flow**

* Precipitation will be retrieved from the rain gage established by the TRC Omni, at Station CG7.

** **Manual measurement of stream flow during a storm event is inherently inaccurate. Therefore, in an effort to collect as much data as possible to produce a superior work product, real time stream flow measurements are proposed for the three critical locations identified in the watershed. This data will be submitted along with the water quality data. Flow data will be calculated from pressure transducers installed at locations CG2, CG5 and CG6.** In addition low flow conditions will be determined from USGS station 01403150 (West Middle Brook near Martinsville). This location was chosen as a surrogate for the study watershed due to the lack of a USGS gage on Cedar Grove Brook.

Laboratory

Total Suspended Solids

Turbidity

TRC Omni Environmental Corporation, NJDEP certified laboratory #11697, will perform sample collection and measurements for all of the sampling events. Monitoring for all parameters will be performed according to the Sampling Design Matrix Tables in Appendix A. New Jersey Analytical Laboratory (NJAL), NJDEP certified laboratory #11005, will measure all laboratory parameters in accordance with the procedures specified in Appendices B1 and B2, and may assist in the sample collection program. Stream sampling stations will be marked in the field with a steel post and clearly marked flagging prior to initial sample collection. In addition, a digital photograph of each location will be taken and included as part of the final report. All personnel responsible for sample collection will visit each site as part of their training in sample collection.

In support of the flow monitoring portion of the program, measurements of velocity and depth will be obtained at three selected monitoring locations (CB2, CB5 and CB6) under various flow conditions. Prior to the initial storm water monitoring event, data loggers equipped with pressure transducers will be installed at each of these sample station to determine stream flow depth. Depth readings will be obtained and recorded during each subsequent sample event in order that a corresponding flow rating curve can be determined. The data loggers that will be installed to continuously record water depth will be synchronized with the measured depths, at each of the stations, during the storm water sampling events. These data will be correlated with corresponding precipitation data and will be used in conjunction with the stream bathometric data to determine hydraulic conditions as influenced by storm water runoff into Cedar Grove Brook.

C. Parameter Table

Measurements of the sampled parameters will be performed in accordance with Table 1B (40 CFR Part 136) of Appendix B1. Also, preservation techniques and holding times will be in accordance with Table II (40 CFR Part 136) of Appendix B2. Any deviations from the test procedures and/or preservation methods and holding times will be noted in the final report from the laboratory.

8. Schedule:

The original Quality Assurance Project Plan was submitted to NJDEP on May 16, 2005. Sampling began in July 2005. Sampling is expected to be completed by June 1, 2006, contingent on weather conditions and regulatory approvals. Sampling occurred prior to final approval of the QAPP in furtherance of the project (at NJWSA's risk). These samples were collected and analyzed in accordance with the draft QAPP. The results of sampling to date, with recommendations for sampling locations for the Intensive Storm Water event are included as an addendum to this revised QAPP. If the methods used to collect and analyze these samples change from the draft to the final QAPP, or if NJDEP requires modification to the selected sampling locations identified in the addendum to this document, then these samples will not be used and new samples will be collected in accordance with the final approved QAPP.

9. Project Organizations and Responsibility:

Overall Coordination:	(Project Officer)	James F. Cosgrove, Jr., P.E.
Overall QA:	(QA Officer)	Michael Wright
Performance/Systems Auditing:	(NJDEP)	Marc Ferko
Sampling QC:	(QA Officer)	Greg Soska
Sampling Operations:	(NJDEP Representative)	Marc Ferko
Laboratory QC:	(Manager)	Allen Thomas, NJAL
Laboratory QC:	(QC Officer)	George Latham, NJAL

10. Organizational Chart:

Overall Coordination Project Officer: James Cosgrove	
Overall QA QA Officer: Michael Wright	
Performance/Systems Auditing: Marc Ferko	
Sampling QA Officer: Greg Soska	
Laboratory QC (NJAL) Manager: Allen Thomas	Laboratory QC (NJAL) QC Officer: George Latham
Sampling QC/ Sampling Operations: TRC Omni Field Supervisor: Greg Soska NJDEP Representative: Marc Ferko	

11. Sampling Procedures:

All sampling procedures will be in conformance with the NJDEP Field Sampling Procedures Manual (1992), USGS NAWQA field sampling protocols, any applicable USEPA guidance, or with prior written approval from NJDEP.

Sampling will be conducted in accordance with the methods identified under Section 7 of this quality assurance project plan.

Temperature and pH references were inadvertently included in previous drafts and are no longer considered applicable to this project.

12. Chain of Custody Procedures:

Chain of custody procedures will be followed for all samples collected for this study. A sample of a Chain of Custody Form is provided in Appendix D.

A sample is in someone's "custody" if:

- It is in one's actual physical possession.

- It is in one's view, after being in one's physical possession.
- It is in one's physical possession and then locked up so that no one can tamper with it.
- It is kept in a secured area, restricted to authorized personnel only.

13. Calibration Procedures and Preventive Maintenance:

Calibration and preventive maintenance of field equipment (i.e., pH and temperature meters) will be in accordance with the manufacturer's instructions and the Field Sampling Procedures Manual. In addition, calibration and preventive maintenance of laboratory equipment will be in accordance with N.J.A.C. 7:18-1.1 et seq. and 40 CFR Part 136.

14. Documentation, Data Reduction, and Reporting:

Laboratories will supply all quality assurance and quality control (QA/QC) data with the summary of results. All data will be kept on file by the applicant for a minimum of five years, and all data will be included in the quarterly reports to the NJDEP.

15. Quality Assurance and Quality Control:

N.J.A.C. 7:18-1.1 et seq. and 40 CFR Part 136 will be followed for all QA/QC practices, including detection limits, quantitation limits, precision, and accuracy. A table of parameter detection limits, quantitation limits, accuracy, and precision applicable to this study is provided in Appendix C.

16. Performance and Systems Audits:

All NJDEP certified laboratories participate in the Office of Quality Assurance (OQA) Performance Testing Program (PTP), in accordance with NJAC 7:18-2.13, for each category of certification. Laboratories are required to pass the PTP studies in order to maintain certification. The NJDEP Office of Quality Assurance conducts performance audits of each certified laboratory.

The NJDEP Office of Quality Assurance periodically conducts on-site Technical Systems Audits of each certified laboratory. The findings of these audits, together with the PTP results, are used to update each laboratory's certification status.

The NJDEP Office of Quality Assurance periodically conducts a field audit of project sampling operations. The Office of Quality Assurance will be contacted early in the study to schedule a field audit.

17. Data Validation:

Data validation will be performed by TRC Omni, RVRSA and NJAL, and shall include the following:

Method Blank: The method blank cannot show the presence of the parameter of interest above the reported detection limit. Analysis of the batch should not continue until the source of the problem has been corrected.

Laboratory Fortified Blank (LFB): Where appropriate, the LFB must fall within the QC control limits. If the LFB is outside the limits, the following corrective actions should be taken:

- Check data and recovery calculations
- Check reference QC standard
- Reanalyze sample batch

QC Matrix Spike: The matrix spike should fall within the QC control limits established for each methodology. The corrective actions should be as follows:

- Check data and recovery calculations.
- Check whether LFB and reference standard are acceptable.
- If only the matrix spike is not within control limits, check other analytes present for possible sample matrix interference as detailed in the specific method. If the sample matrix is identified as the problem, this may be footnoted. If the matrix spike is consistently outside for a particular parameter, another methodology may have to be considered for sample analysis.
- Check reference QC standard, if one was performed in that batch.
- If the matrix spike is not within control limits, check for presence of that analyte at a high value, which may be greater than the spike amount, causing invalid spike recovery.

Precision evaluated by:

Precision of method is evaluated by control charts, continuously maintained and updated at quarterly intervals. Matrix Spike Duplicates (MSD) must have a relative percent difference (RPD) equal to or lower than the calculated maximum RPD. If reproducibility cannot be achieved and sample matrix interferences are not apparent, batch reanalysis should occur. Calculations, dilutions, etc., should be checked prior to reanalysis.

Accuracy evaluated by:

- Initial and continuing calibrations must be within acceptance criteria.
- LFB acceptance by control limits shall be continuously maintained and updated. LFB result must fall within control limits.
- Recovery control charts must be continuously maintained and updated. All parameters will have upper and lower warning limits (UWL/LWL) set at two standard deviation (SD) units, and upper and lower control limits (UCL/LCL) set at three SD units. Matrix spikes must fall within control limits unless sample value (raw) is four or more times concentration of spike level.

Accuracy and Precision values have been calculated in accordance with the EPA Handbook for Analytical Control in Water and Wastewater Laboratories, June 1972, Sections 6 and 7.

18. Corrective Action:

All NJDEP certified laboratories must have a written corrective action procedure that is adhered to in the event that calibration standards, performance evaluation results, blanks, duplicates, spikes, etc., are out of the acceptable range or control limits. If the acceptable results cannot be obtained for the above-mentioned QA/QC samples during any given day, sample analysis must be repeated for that day with the acceptable QA/QC results. TRC Omni and NJDEP will be notified if there are any deviations from the approved sampling plan.

19. Reports:

A report will be prepared that will present an analysis of the data along with a summary of the conclusions. The report will include all flow and precipitation measurements, and laboratory data in summary tables as well as in an electronic database. **The data and reports will be submitted to NJDEP in hard copy and in the electronic format (spreadsheet). This will include stream flow at each location, at the time each sample is collected, at the locations where flow is measured.** Data will be assessed and used to evaluate TSS and turbidity loading issues and sources in the study area. The report will identify BMP measures to control pollutant loading, and recommend monitoring and evaluation techniques for determining the effectiveness of the management measures.

APPENDIX A

Sampling Design Matrix Tables

Sampling Event	Baseline Stormwater Events	Sedimentation Characterization	Low-Flow Baseline	Intensive Stormwater Events
Sampling Regime	2 events	1 event*	1 event	1 event
Total Number of Samples per Station per Event	3 grab samples	1 composite sample	1 sample	3 grab samples
Sampling Conditions Goal (weather-permitting)	≥ 72 hrs. with ≤ 0.1 in. rain; During storm > 0.5 in. rain	≥ 72 hrs. with ≤ 0.1 in. rain; During storm > 0.5 in. rain	stream flow ≤ d70	≥ 72 hrs. with ≤ 0.1 in. rain; During storm > 0.5 in. rain
CG1	√	√	√	**TBD**
CG2	√	√	√	**TBD**
CG3	√	√	√	**TBD**
CG4	√	√	√	**TBD**
CG5	√	√	√	**TBD**
CG6	√	√	√	**TBD**
Alternate Locations	**No**	**No**	**No**	**TBD**
Laboratory Analysis	**TSS and Turbidity**	**Settleability**	**TSS and Turbidity**	**TSS and Turbidity**

NOTES:

d70 - That stream flow which is exceeded 70% of the time.

* **-** Performed concurrent with the initial Baseline Stormwater Event

APPENDIX B1

List of Approved Test Procedures

40 CFR Part 136
October 23, 2002

47. Palladium—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration, or	253.1	3111 B [18th, 19th]			p. S27[10]
AA furnace	253.2				p. S28[10]
DCP					Note 34.
48. Phenols, mg/L:					
Manual distillation[26]	420.1				Note 27.
Followed by:.					
Colorimetric (4AAP) manual, or.	420.1				Note 27.
Automated[19]	420.2.				
49. Phosphorus (elemental), mg/L:					
Gas-liquid chromatography					Note 28.
50. Phosphorus—Total, mg/L:					
Persulfate digestion followed by	365.2	4500–P B, 5 [18th, 19th, 20th].			973.55[3]
Manual or	365.2 or 365.3	4500–P E [18th, 19th, 20th]	D515–88(A)		
Automated ascorbic acid reduction.	365.1	4500–P F [18th, 19th, 20th]		I–4600–85	973.56[3]
Semi-automated block digestor	365.4		D515–88(B)	I–4610–91[48].	
51. Platinum—Total,[4] mg/L: Digestion[4] followed by:					
AA direct aspiration	255.1	3111 B [18th, 19th].			
AA furnace	255.2.				
DCP					Note 34
52. Potassium—Total,[4] mg/L: Digestion[4] followed by:					
AA direct aspiration	258.1	3111 B [18th, 19th]		I–3630–85	973.53[3]
ICP/AES	200.7[5]	3120 B [18th, 19th, 20th].			
Flame photometric, or		3500–K B [20th] and 3500–K D [18th, 19th].			
Colorimetric					317 B[17]
53. Residue—Total, mg/L:					
Gravimetric, 103–105°	160.3	2540 B [18th, 19th, 20th]		I–3750–85.	
54. Residue—filterable, mg/L:					
Gravimetric, 180°	160.1	2540 C [18th, 19th, 20th]		I–1750–85.	
55. Residue—nonfilterable (TSS), mg/L:					
Gravimetric, 103–105° post washing of residue.	160.2	2540 D [18th, 19th, 20th]		I–3765–85.	
56. Residue—settleable, mg/L:					
Volumetric, (Imhoff cone), or gravimetric.	160.5	2540 F [18th, 19th, 20th].			
57. Residue—Volatile, mg/L:					
Gravimetric, 550°	160.4			I–3753–85.	
58. Rhodium-Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration, or	265.1	3111 B [18th, 19th].			
AA furnace	265.2.				

TABLE IB—LIST OF APPROVED INORGANIC TEST PROCEDURES—Continued

Parameter, units and method	Reference (method number or page)				
	EPA [1, 35]	*Standard Methods* [Edition(s)]	ASTM	USGS [2]	Other
59. Ruthenium—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration, or	267.1	3111 B [18th, 19th].			
AA furnace	267.2.				
60. Selenium—Total,[4] mg/L; Digestion[4] followed by:					
AA furnace	270.2	3113 B [18th, 19th]	D3859–98(B)	I–4668–98[49].	
ICP/AES,[36] or	200.7[5]	3120 B [18th, 19th, 20th].			
AA gaseous hydride		3114 B [18th, 19th]	D3859–98(A)	I–3667–85.	
61. Silica[37]—Dissolved, mg/L; 0.45 micron filtration followed by:					
Colorimetric, Manual or	370.1	4500–SiO_2 C [20th] and 4500–Si D [18th, 19th].	D859–94	I–1700–85.	
Automated (Molybdosilicate), or				I–2700–85.	
ICP	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50].	
62. Silver—Total,[4] mg/L: Digestion[4 29] followed by:					
AA direct aspiration	272.1	3111 B or C [18th, 19th]		I–3720–85	974.27,[3] p. 37[9]
AA furnace	272.2	3113 B [18th, 19th]		I–4724–89[51]	
ICP/AES	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50]	
DCP					Note 34.
63. Sodium—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration	273.1	3111 B [18th, 19th]		I–3735–85	973.54[3]
ICP/AES	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50]	
DCP, or					Note 34.
Flame photometric		3500 Na B [20th] and 3500 Na D [18th, 19th].			
64. Specific conductance, micromhos/cm at 25 °C:					
Wheatstone bridge	120.1	2510 B [18th, 19th, 20th]	D1125–95(A)	I–2781–85	973.40[3]
65. Sulfate (as SO_4), mg/L:					
Automated colorimetric (barium chloranilate).	375.1.				
Gravimetric	375.3	4500–SO_4^{-2}C or D [18th, 19th, 20th].			925.54[3]
Turbidimetric	375.4		D516–90		426C[30]
66. Sulfide (as S), mg/L:					
Titrimetric (iodine), or	376.1	4500–S^{-2}F [19th, 20th] or 4500–S^{-2}E [18th].		I–3840–85.	
Colorimetric (methylene blue)	376.2	4500–S^{-2}D [18th, 19th, 20th].			
67. Sulfite (as SO_3), mg/L:					

Titrimetric (iodine-iodate)	377.1	4500–SO_3^{-2}B [18th, 19th, 20th].			
68. Surfactants, mg/L:					
Colorimetric (methylene blue)	425.1	5540 C [18th, 19th, 20th]	D2330–88.		
69. Temperature, °C:					
Thermometric	170.1	2550 B [18th, 19th, 20th]			Note 32.
70. Thallium—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration	279.1	3111 B [18th, 19th].			
AA furnace	279.2.				
ICP/AES	200.7[5]	3120 B [18th, 19th, 20th].			
71. Tin—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration	282.1	3111 B [18th, 19th]		I–3850–78[8].	
AA furnace, or	282.2	3113 B [18th, 19th].			
ICP/AES	200.7[5].				
72. Titanium—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration	283.1	3111 D [18th, 19th].			
AA furnace	283.2.				
DCP					Note 34.
73. Turbidity, NTU:					
Nephelometric	180.1	2130 B [18th, 19th, 20th]	D1889–94(A)	I–3860–85.	
74. Vanadium—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration	286.1	3111 D [18th, 19th].			
AA furnace	286.2		D3373–93.		
ICP/AES	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50].	
DCP, or			D4190–94		Note 34.
Colorimetric (Gallic Acid)		3500–V B [20th] and 3500–V D [18th, 19th].			
75. Zinc—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration[36]	289.1	3111 B or C [18th, 19th]	D1691–95(A or B)	I–3900–85	974.27,[3] p. 37[9]
AA furnace	289.2.				
ICP/AES[36]	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50].	
DCP,[36] or			D4190–94		Note 34.
Colorimetric (Dithizone) or		3500–Zn E [18th, 19th].			
(Zincon)		3500–Zn B [20th] and 3500–Zn F [18th, 19th].			Note 33.

Table 1B Notes:

[1] "Methods for Chemical Analysis of Water and Wastes," Environmental Protection Agency, Environmental Monitoring Systems Laboratory—Cincinnati (EMSL–CI), EPA–600/4–79–020, Revised March 1983 and 1979 where applicable.

[2] Fishman, M.J., *et al.* "Methods for Analysis of Inorganic Substances in Water and Fluvial Sediments, "U.S. Department of the Interior, Techniques of Water-Resource Investigations of the U.S. Geological Survey, Denver, CO, Revised 1989, unless otherwise stated.

[3] "Official Methods of Analysis of the Association of Official Analytical Chemists," methods manual, 15th ed. (1990).

APPENDIX B2

Required Containers, Preservation Techniques, and Holding Times

40 CFR Part 136
July 1, 2003

Systems Laboratory, the Regional Administrator may grant a variance applicable to the specific charge to the applicant. A decision to approve or deny a variance will be made within 90 days of receipt of the application by the Regional Administrator.

TABLE II—REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES

Parameter No./name	Container [1]	Preservation [2,3]	Maximum holding time [4]
Table IA—Bacteria Tests:			
1–4 Coliform, fecal and total	P,G	Cool, 4C, 0.008% $Na_2S_2O_3$ [5]	6 hours.
5 Fecal streptococci	P,G	Cool, 4C, 0.008% $Na_2S_2O_3$ [5]	6 hours.
Table IA—Aquatic Toxicity Tests:			
6–10 Toxicity, acute and chronic	P,G	Cool, 4 °C [16]	36 hours.
Table IB—Inorganic Tests:			
1. Acidity	P, G	Cool, 4°C	14 days.
2. Alkalinity	P, G	......do	Do.
4. Ammonia	P, G	Cool, 4°C, H_2SO_4 to pH<2	28 days.
9. Biochemical oxygen demand	P, G	Cool, 4°C	48 hours.
10. Boron	P, PFTE, or Quartz.	HNO_3 TO pH<2	6 months.
11. Bromide	P, G	None required	28 days.
14. Biochemical oxygen demand, carbonaceous	P, G	Cool, 4°C	48 hours.
15. Chemical oxygen demand	P, G	Cool, 4°C, H_2SO_4 to pH<2	28 days.
16. Chloride	P, G	None required	Do.
17. Chlorine, total residual	P, G	......do	Analyze immediately.
21. Color	P, G	Cool, 4°C	48 hours.
23–24. Cyanide, total and amenable to chlorination.	P, G	Cool, 4°C, NaOH to pH>12, 0.6g ascorbic acid [5].	14 days.[6]
25. Fluoride	P	None required	28 days.
27. Hardness	P, G	HNO_3 to pH<2, H_2SO_4 to pH<2	6 months.
28. Hydrogen ion (pH)	P, G	None required	Analyze immediately.
31, 43. Kjeldahl and organic nitrogen	P, G	Cool, 4°C, H_2SO_4 to pH<2	28 days.
Metals:[7]			
18. Chromium VI [7]	P, G	Cool, 4 °C	24 hours.
35. Mercury [17]	P, G	HNO_3 to pH<2	28 days.
3, 5–8, 12,13, 19, 20, 22, 26, 29, 30, 32–34, 36, 37, 45, 47, 51, 52, 58–60, 62, 63, 70–72, 74, 75. Metals except boron, chromium VI and mercury [7].	P, G	do	6 months.
38. Nitrate	P, G	Cool, 4°C	48 hours.
39. Nitrate-nitrite	P, G	Cool, 4°C, H_2SO_4 to pH<2	28 days.
40. Nitrite	P, G	Cool, 4°C	48 hours.
41. Oil and grease	G	Cool to 4°C, HCl or H_2SO_4 to pH<2.	28 days.
42. Organic Carbon	P, G	Cool to 4 °C HC1 or H_2SO4 or H_3PO4, to pH<2.	28 days.
44. Orthophosphate	P, G	Filter immediately, Cool, 4°C	48 hours.
46. Oxygen, Dissolved Probe	G Bottle and top.	None required	Analyze immediately.
47. Winkler	......do	Fix on site and store in dark	8 hours.
48. Phenols	G only	Cool, 4°C, H_2SO_4 to pH<2	28 days.
49. Phosphorus (elemental)	G	Cool, 4°C	48 hours.
50. Phosphorus, total	P, G	Cool, 4°C, H_2SO_4 to pH<2	28 days.
53. Residue, total	P, G	Cool, 4°C	7 days.
54. Residue, Filterable	P, G	......do	7 days.
55. Residue, Nonfilterable (TSS)	P, G	......do	7 days.
56. Residue, Settleable	P, G	......do	48 hours.
57. Residue, volatile	P, G	......do	7 days.
61. Silica	P, PFTE, or Quartz.	Cool, 4 °C	28 days.
64. Specific conductance	P, G	......do	Do.
65. Sulfate	P, G	......do	Do.
66. Sulfide	P, G	Cool, 4°C add zinc acetate plus sodium hydroxide to pH>9.	7 days.
67. Sulfite	P, G	None required	Analyze immediately.
68. Surfactants	P ,G	Cool, 4°C	48 hours.
69. Temperature	P, G	None required	Analyze.
73. Turbidity	P, G	Cool, 4°C	48 hours.
Table IC—Organic Tests [8]			
13, 18–20, 22, 24–28, 34–37, 39–43, 45–47, 56, 76, 104, 105, 108–111, 113. Purgeable Halocarbons.	G, Teflon-lined septum.	Cool, 4 °C, 0.008% $Na_2S_2O_3$ [5].	14 days.

TABLE II—REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES—Continued

Parameter No./name	Container [1]	Preservation [2, 3]	Maximum holding time [4]
6, 57, 106. Purgeable aromatic hydrocarbons	......do	Cool, 4 °C, 0.008% $Na_2S_2O_3$,[5] HCl to pH2[9].	Do.
3, 4. Acrolein and acrylonitrile	......do	Cool, 4 °C, 0.008% $Na_2S_2O_3$,[5] adjust pH to 4–5[10].	Do.
23, 30, 44, 49, 53, 77, 80, 81, 98, 100, 112. Phenols [11].	G, Teflon-lined cap..	Cool, 4 °C, 0.008% $Na_2S_2O_3$ [5]	7 days until extraction; 40 days after extraction.
7, 38. Benzidines [11]	......do	......do	7 days until extraction.[13]
14, 17, 48, 50–52. Phthalate esters [11]	......do	Cool, 4 °C	7 days until extraction; 40 days after extraction.
82–84. Nitrosamines [11 14]	......do	Cool, 4 °C, 0.008% $Na_2S_2O_3$,[5] store in dark.	Do.
88–94. PCBs [11]	.....do	Cool, 4 °C	Do.
54, 55, 75, 79. Nitroaromatics and isophorone [11] ..	......do	Cool, 4 °C, 0.008% $Na_2S_2O_3$,[5] store in dark.	Do.
1, 2, 5, 8–12, 32, 33, 58, 59, 74, 78, 99, 101. Polynuclear aromatic hydrocarbons [11].	......do	......do	Do.
15, 16, 21, 31, 87. Haloethers [11]	......do	Cool, 4 °C, 0.008% $Na_2S_2O_3$ [5]	Do.
29, 35–37, 63–65, 73, 107. Chlorinated hydrocarbons [11].	......do	Cool, 4 °C	Do.
60–62, 66–72, 85, 86, 95–97, 102, 103. CDDs/CDFs [11].			
aqueous: field and lab preservation.	G	Cool, 0–4 °C, pH<9, 0.008% $Na_2S_2O_3$ [5].	1 year.
Solids, mixed phase, and tissue: field preservation..	......do	Cool, <4 °C	7 days.
Solids, mixed phase, and tissue: lab preservation	......do	Freeze, < − 10 °C	1 year.
Table ID—Pesticides Tests:			
1–70. Pesticides [11]	......do	Cool, 4°C, pH 5–9 [15]	Do.
Table IE—Radiological Tests:			
1–5. Alpha, beta and radium	P, G	HNO_3 to pH<2	6 months.

Table II Notes

[1] Polyethylene (P) or glass (G). For microbiology, plastic sample containers must be made of sterilizable materials (polypropylene or other autoclavable plastic).

[2] Sample preservation should be performed immediately upon sample collection. For composite chemical samples each aliquot should be preserved at the time of collection. When use of an automated sampler makes it impossible to preserve each aliquot, then chemical samples may be preserved by maintaining at 4°C until compositing and sample splitting is completed.

[3] When any sample is to be shipped by common carrier or sent through the United States Mails, it must comply with the Department of Transportation Hazardous Materials Regulations (49 CFR part 172). The person offering such material for transportation is responsible for ensuring such compliance. For the preservation requirements of Table II, the Office of Hazardous Materials, Materials Transportation Bureau, Department of Transportation has determined that the Hazardous Materials Regulations do not apply to the following materials: Hydrochloric acid (HCl) in water solutions at concentrations of 0.04% by weight or less (pH about 1.96 or greater); Nitric acid (HNO_3) in water solutions at concentrations of 0.15% by weight or less (pH about 1.62 or greater); Sulfuric acid (H_2SO_4) in water solutions at concentrations of 0.35% by weight or less (pH about 1.15 or greater); and Sodium hydroxide (NaOH) in water solutions at concentrations of 0.080% by weight or less (pH about 12.30 or less).

[4] Samples should be analyzed as soon as possible after collection. The times listed are the maximum times that samples may be held before analysis and still be considered valid. Samples may be held for longer periods only if the permittee, or monitoring laboratory, has data on file to show that for the specific types of samples under study, the analytes are stable for the longer time, and has received a variance from the Regional Administrator under § 136.3(e). Some samples may not be stable for the maximum time period given in the table. A permittee, or monitoring laboratory, is obligated to hold the sample for a shorter time if knowledge exists to show that this is necessary to maintain sample stability. See § 136.3(e) for details. The term ''analyze immediately'' usually means within 15 minutes or less of sample collection.

[5] Should only be used in the presence of residual chlorine.

[6] Maximum holding time is 24 hours when sulfide is present. Optionally all samples may be tested with lead acetate paper before pH adjustments in order to determine if sulfide is present. If sulfide is present, it can be removed by the addition of cadmium nitrate powder until a negative spot test is obtained. The sample is filtered and then NaOH is added to pH 12.

[7] Samples should be filtered immediately on-site before adding preservative for dissolved metals.

[8] Guidance applies to samples to be analyzed by GC, LC, or GC/MS for specific compounds.

[9] Sample receiving no pH adjustment must be analyzed within seven days of sampling.

[10] The pH adjustment is not required if acrolein will not be measured. Samples for acrolein receiving no pH adjustment must be analyzed within 3 days of sampling.

[11] When the extractable analytes of concern fall within a single chemical category, the specified preservative and maximum holding times should be observed for optimum safeguard of sample integrity. When the analytes of concern fall within two or more chemical categories, the sample may be preserved by cooling to 4°C, reducing residual chlorine with 0.008% sodium thiosulfate, storing in the dark, and adjusting the pH to 6–9; samples preserved in this manner may be held for seven days before extraction and for forty days after extraction. Exceptions to this optional preservation and holding time procedure are noted in footnote 5 (re the requirement for thiosulfate reduction of residual chlorine), and footnotes 12, 13 (re the analysis of benzidine).

[12] If 1,2-diphenylhydrazine is likely to be present, adjust the pH of the sample to 4.0±0.2 to prevent rearrangement to benzidine.

[13] Extracts may be stored up to 7 days before analysis if storage is conducted under an inert (oxidant-free) atmosphere.

[14] For the analysis of diphenylnitrosamine, add 0.008% $Na_2S_2O_3$ and adjust pH to 7–10 with NaOH within 24 hours of sampling.

[15] The pH adjustment may be performed upon receipt at the laboratory and may be omitted if the samples are extracted within 72 hours of collection. For the analysis of aldrin, add 0.008% $Na_2S_2O_3$.

[16] Sufficient ice should be placed with the samples in the shipping container to ensure that ice is still present when the samples arrive at the laboratory. However, even if ice is present when the samples arrive, it is necessary to immediately measure the temperature of the samples and confirm that the 4C temperature maximum has not been exceeded. In the isolated cases where it can be documented that this holding temperature can not be met, the permittee can be given the option of on-site testing or can request a variance. The request for a variance should include supportive data which show that the toxicity of the effluent samples is not reduced because of the increased holding temperature.

[17] Samples collected for the determination of trace level mercury (100 ng/L) using EPA Method 1631 must be collected in tightly-capped fluoropolymer or glass bottles and preserved with BrCl or HCl solution within 48 hours of sample collection. The time to preservation may be extended to 28 days if a sample is oxidized in the sample bottle. Samples collected for dissolved trace level mercury should be filtered in the laboratory. However, if circumstances prevent overnight shipment, samples should be filtered in a designated clean area in the field in accordance with procedures given in Method 1669. Samples that have been collected for determination of total or dissolved trace level mercury must be analyzed within 90 days of sample collection.

[38 FR 28758, Oct. 16, 1973, as amended at 41 FR 52781, Dec. 1, 1976; 49 FR 43251, 43258, 43259, Oct. 26, 1984; 50 FR 691, 692, 695, Jan. 4, 1985; 51 FR 23693, June 30, 1986; 52 FR 33543, Sept. 3, 1987; 55 FR 24534, June 15, 1990; 55 FR 33440, Aug. 15, 1990; 56 FR 50759, Oct. 8, 1991; 57 FR 41833, Sept. 11, 1992; 58 FR 4505, Jan. 31, 1994; 60 FR 17160, Apr. 4, 1995; 60 FR 39588, 39590, Aug. 2, 1995; 60 FR 44672, Aug. 28, 1995; 60 FR 53542, 53543, Oct. 16, 1995; 62 FR 48403, 48404, Sept. 15, 1997; 63 FR 50423, Sept. 21, 1998; 64 FR 4978, Feb. 2, 1999; 64 FR 10392, Mar. 4, 1999; 64 FR 26327, May 14, 1999; 64 FR 30433, 30434, June 8, 1999; 64 FR 73423, Dec. 30, 1999; 66 FR 32776, June 18, 2001; 67 FR 65226, Oct. 23, 2002; 67 FR 65886, Oct. 29, 2002; 67 FR 69971, Nov. 19, 2002]

§ 136.4 Application for alternate test procedures.

(a) Any person may apply to the Regional Administrator in the Region where the discharge occurs for approval of an alternative test procedure.

(b) When the discharge for which an alternative test procedure is proposed occurs within a State having a permit program approved pursuant to section 402 of the Act, the applicant shall submit his application to the Regional Administrator through the Director of the State agency having responsibility for issuance of NPDES permits within such State.

(c) Unless and until printed application forms are made available, an application for an alternate test procedure may be made by letter in triplicate. Any application for an alternate test procedure under this paragraph (c) shall:

(1) Provide the name and address of the responsible person or firm making the discharge (if not the applicant) and the applicable ID number of the existing or pending permit, issuing agency, and type of permit for which the alternate test procedure is requested, and the discharge serial number.

(2) Identify the pollutant or parameter for which approval of an alternate testing procedure is being requested.

(3) Provide justification for using testing procedures other than those specified in Table I.

(4) Provide a detailed description of the proposed alternate test procedure, together with references to published studies of the applicability of the alternate test procedure to the effluents in question.

(d) An application for approval of an alternate test procedure for nationwide use may be made by letter in triplicate to the Director, Analytical Methods Staff, Office of Science and Technology (4303), Office of Water, U.S. Environmental Protection Agency, 1200 Pennsylvania Ave., NW., Washington, DC 20460. Any application for an alternate test procedure under this paragraph (d) shall:

(1) Provide the name and address of the responsible person or firm making the application.

(2) Identify the pollutant(s) or parameter(s) for which nationwide approval of an alternate testing procedure is being requested.

(3) Provide a detailed description of the proposed alternate procedure, together with references to published or other studies confirming the general applicability of the alternate test procedure to the pollutant(s) or parameter(s) in waste water discharges from representative and specified industrial or other categories.

(4) Provide comparability data for the performance of the proposed alternate test procedure compared to the performance of the approved test procedures.

[38 FR 28760, Oct. 16, 1973, as amended at 41 FR 52785, Dec. 1, 1976; 62 FR 30763, June 5, 1997]

APPENDIX C

Parameter Detection Limits, Quantitation Limits, Accuracy, and Precision

Parameter Detection Limits, Quantitation Limits, and Precision
(Laboratory Measurements)

Parameter:	Total Suspended Solids (mg/L)	Turbidity (NTU)
EPA Method Number:	160.2	180.1
Method Detection Limit	0.5	.019
Project Detection Limit	1	0.1
Quantitation Limit	1	0.1
Precision (mean % RPD)	10.32	3.7
Precision Protocol (maximum allowable RPD)	30.1	7.4

RPD - Relative % Difference
Laboratory: NJAL (NJDEP #11005)

APPENDIX D

Chain of Custody Form

Chain of Custody Form

NEW JERSEY ANALYTICAL LABORATORY									
Client: TRC Omni		Phone: (609) 924-8821			Sampling Method:		Project No. 6089		Page of
Project: Cedar Grove Brook Watershed		Sample Technician (Print/Sign):							Report and Invoice to: Michael Wright
Laboratory ID No.	Sample ID/Location	DATE	TIME	Sample Matrix	ANALYSIS				
				Aqueous	pH = (S.U.); Temperature = ^{0}C				
		DATE	TIME	Sample Matrix	Number Bottles	Volume Bottles	Preservative	ANALYSIS	Comments:
Relinquished by: (signature)				Date:		Time:	Received by: (signature)	Date:	Time:
Relinquished by: (signature)				Date:		Time:	Received by: (signature)	Date:	Time:
New Jersey Analytical Laboratory 1590 Reed Road Suite 102A Phone: 609-737-3477 Pennington, New Jersey 08534 Fax: 609-737-3052				Method of Shipment		All bottles received for Laboratory (NJAL) by: (Signature)			

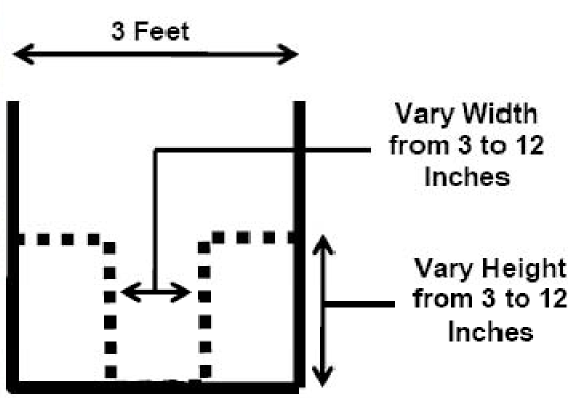
Quail Brook Golf Course Pond Project #1

Location: Quail Brook Golf Course Franklin Township, Somerset County	**Parcel Description:** Bl 424.04 Lot 63.02
Project Type: Structural. Modification of outlet structure – relocate opening and resize outlet weir.	**Owner:** County of Somerset, Administration Building, Somerville, NJ 08876

Issues and Concerns: The stormwater monitoring showed higher TSS concentrations leaving the Golf Course Pond than entering the pond during the large storm event in October 2005. This suggests that during larger storm events, accumulated sediment in the Golf Course Pond is being re-suspended and may be acting as a sediment source rather than a sink.

Existing Condition: The Golf Course Pond is somewhat linear, and the outlet is a straight flowpath from the inlet. As a result, the bulk of the pond volume is often short-circuited. The WinSLAMM modeling of course does not account for this phenomenon, and its importance is difficult to quantify.

Proposed Solutions: Relocate the outlet opening “downstream,” thereby increasing residence time in the pond, and allowing more time for settling to occur. More importantly, adding a smaller outlet weir at the base of the existing 3-foot weir will increase the residence time as well and increase the overall sediment removal rate of the pond feature. Adding a smaller weir between 3 and 6 inches wide and 6 to 12 inches high would substantially improve the sediment removal performance of the Golf Course Pond.



Anticipated Benefits: Increase sediment removal from 154,998 lbs/yr to 193,735 lbs/yr and reduce turbidity.				
Major Implementation Issues: Funding. Maintenance				
Possible Funding Sources: 319 (h) and/or Somerset County Parks Commission				
Partners/Stakeholders: Somerset County Park Commission, Somerset/Union Soil Conservation District				
Task	**Description**	**Sources of Funds**	**Responsibility**	**Estimated Cost**
Design	Construction ready plans and permits	319 (h) and/or Somerset County Parks Commission	Somerset County Parks Commission	$12,500
Acquisition	N/A	N/A	N/A	N/A
Construction	Mobilization, construction, contingencies, final as-built plans, inspections.	319 (h) and/or Somerset County Parks Commission	Somerset County Parks Commission	$50,000
			Total Installation Cost:	$62,500
Maintenance	Inspection/repair of physical improvements and removal of sediment as needed	Somerset County Parks Commission	Somerset County Parks Commission	Unknown

Quail Brook Golf Course Pond Project #2

Location: Quail Brook Golf Course, Franklin Township, Somerset County	**Parcel Description**: Bl 424.04 Lot 63.02
Project Type: Structural. Adding flowpath baffles	**Owner:** County of Somerset, Administration Building, Somerville, NJ 08876

Issues and Concerns: The stormwater monitoring showed higher TSS concentrations leaving the Golf Course Pond than entering the pond during the large storm event in October 2005. This suggests that during larger storm events, accumulated sediment in the Golf Course Pond is being re-suspended and may be acting as a sediment source rather than a sink.

Existing Condition: The Golf Course Pond is somewhat linear, and the outlet is a straight flowpath from the inlet. As a result, the bulk of the pond volume is often short-circuited. The WinSLAMM modeling of course does not account for this phenomenon, and its importance is difficult to quantify.

Proposed Solutions: Adding flowpath baffles would force flow under most circumstances into more of the pond volume. This would increase residence time and therefore increase settling. Flowpath baffles are essentially concrete walls that extend downstream from the weir inlet in order to force water to circulate through more of the pond volume.

Anticipated Benefits:
Reduced turbidity.

Major Implementation Issues:
Funding. Maintenance

Possible Funding Sources:
319 (h) and/or Somerset County Parks Commission

Partners/Stakeholders:
Somerset County Park Commission, Somerset/Union Soil Conservation District

Task	Description	Sources of Funds	Responsibility	Estimated Cost
Design	Construction ready plans and permits	Construction ready plans and permits	319 (h) and/or Somerset County Parks Commission	$10,000
Acquisition	N/A	N/A		
Construction	Mobilization, construction,	Mobilization,	319 (h) and/or	$40,000

	contingencies, final as-built plans, inspections.	construction, contingencies, final as-built plans, inspections.	Somerset County Parks Commission	
			Total Installation Cost:	$50,000
Maintenance	Inspection/repair of physical improvements and removal of sediment as needed	Inspection/repair of physical improvements and removal of sediment as needed	Somerset County Parks Commission	Unknown

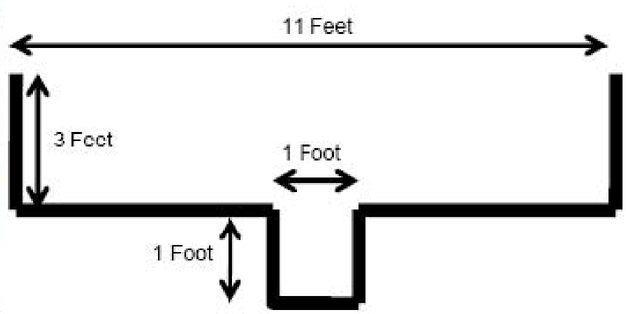
Ukrainian Village Pond

Location: Ukrainian Village, Franklin Township, Somerset County	**Parcel Description:** Bl 424.02 Lot 11.96
Project Type: Structural. Modification of outlet structure	**Owner:** Lakewood Townhouse Assoc., c/o 4-08 Towne Center Drive, N. Brunswick, NJ 08902

Issues and Concerns: Continuous turbidity monitoring demonstrated that Cedar Grove Brook adds turbidity to the D&R Canal under typical and low-flow conditions, reducing the amount of turbidity attenuation (due to settling primarily) that might otherwise be expected to occur in this segment of the Canal. Sediment is resuspended during certain high flow storm events.

Existing Condition: The existing outlet structure for the Ukrainian Village Pond is a 1-foot square weir within a larger 11-foot weir, which is actually within a very large weir. According to the long-term WinSLAMM simulations performed for the Ukrainian Village Pond, the overall sediment removal rate is approximately 33%.

Proposed Solutions: The existing 1-foot weir provides a negligible benefit in terms of sediment removal efficiency; however, simply increasing the height of the existing weir from 1 foot to 3 or 4 feet would improve the sediment removal by approximately 15%.



Anticipated Benefits:
Increase sediment removal from 398,427lbs/yr to 458,368 lbs/yr and reduce turbidity.

Major Implementation Issues:

The structure is located on private property.				
Possible Funding Sources: 319 (h) and/or private funds				
Partners/Stakeholders: Ukrainian Village Home Owner Association, Somerset/Union Soil Conservation District				
Task	**Description**	**Sources of Funds**	**Responsibility**	**Estimated Cost**
Design	Construction ready plans and permits	319 (h) and/or private funds	Ukrainian Village	$25,000
Acquisition	N/A			
Construction	Mobilization, construction, contingencies, final as-built plans, inspections.	319 (h) and/or private funds	Ukrainian Village	$100,000
			Total Installation Cost:	$125,000
Maintenance	Inspection/repair of physical improvements and removal of sediment as needed	319 (h) and/or private funds	Ukrainian Village	Unknown

<table>
<tr><td colspan="2">Lower Pond (Watershed Outlet)</td></tr>
<tr><td>Location:
50’ upstream from the Easton Ave. bridge,
Franklin Township, Somerset County</td><td>Parcel Description:
Bl 424.02 Lot 24</td></tr>
<tr><td>Project Type:
Structural. Modification of outlet structure</td><td>Owner:
Rukh Easton Avenue Properties, LLC,
c/o Rupen Patel, Managing Member, 28 Ambrose Valley Lane, Piscataway, NJ 08854
Access and maintenance easement previously secured by NJDOT and recorded in Somerset County Book 1345 Page 79</td></tr>
<tr><td colspan="2">Issues and Concerns: Continuous turbidity monitoring demonstrated that Cedar Grove Brook adds turbidity to the D&R Canal under typical and low-flow conditions, reducing the amount of turbidity attenuation (due to settling primarily) that might otherwise be expected to occur in this segment of the Canal. Sediment is resuspended during certain high flow storm events.</td></tr>
<tr><td colspan="2">Existing Condition: The current structure is not very useful from the standpoint of sediment removal. In fact, long-term WinSLAMM simulations indicate that the existing structure might be expected to remove approximately 3% of the sediment that reaches the outlet of Cedar Grove Brook, however, the WinSLAMM simulation does not account for the fact that the weir crest is generally submerged by Canal tailwater, nor does it account for the resuspension of accumulated sediment. It is very likely that the outlet of Cedar Grove Brook provides a net source of sediments to the D&R Canal. The outlet structure could be improved substantially be increasing the elevation of the crest and decreasing the width of the smallest weir.</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Proposed Solutions: A 5 foot weir at a significantly higher crest elevation will significantly improve the sediment removal rate of the outlet structure. Increasing the crest elevation by four feet would provide the most benefit of the elevation options explored, increasing the overall sediment removal rate ten-fold to approximately 30%. Note that this does not account for the fact that the weir crest would no longer be submerged by Canal tailwater, or the additional benefit of reduced sediment resuspension.</td></tr>
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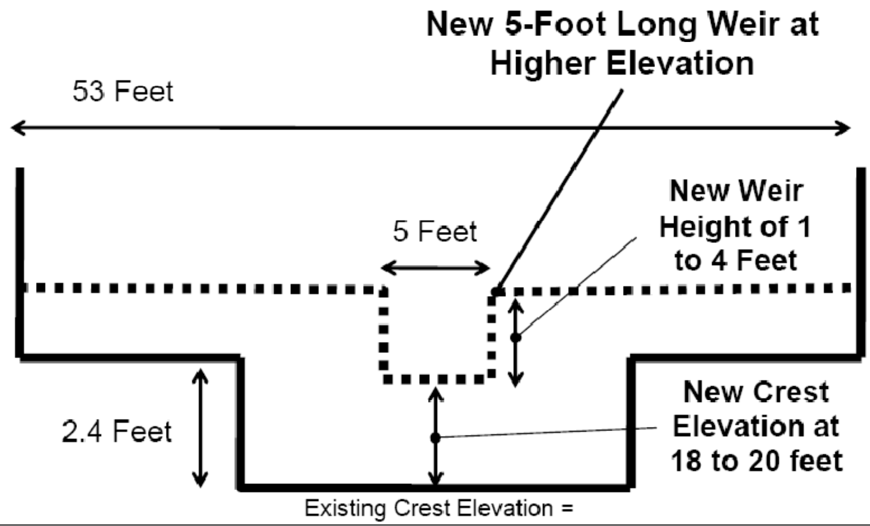


Anticipated Benefits:
Increase sediment removal from 37,331 lbs/yr to 439,368 lbs/yr and reduced turbidity.

Major Implementation Issues:
The structure is located on private property, however, there is a maintenance easement in favor of the New Jersey Department of Transportation on record.

Possible Funding Sources:
319 (h) or Private

Partners/Stakeholders:
Property Owner, Somerset/Union Soil Conservation District

Task	Description	Sources of Funds	Responsibility	Estimated Cost
Design	Construction ready plans and permits	319 (h), NJDOT or private	Private or NJDOT	$100,000
Acquisition	N/A			
Construction	Mobilization, construction, contingencies, final as-built plans, inspections.	319 (h), NJDOT or private	Private or NJDOT	$400,000
			Total Installation Cost:	$500,000
Maintenance	Inspection/repair of physical improvements and removal of sediment as needed	NJDOT or private	Private or NJDOT	unknown

Riparian Restoration			
Location: Varies, see map.		**Parcel Description:** Varies	
Project Type: Structural. Riparian restoration		**Owner:** Varies	
Road Crossing ID *SVAP #*	*Nearest Road*	*Approximate Area*	*Estimated Cost*
Cedar Grove Brook 2 NA 	Martino Way	800 sf	$500
Cedar Grove Brook 4 CGB-7 	Wilson Road	7,000 sf	$750
Cedar Grove Brook 5 CGB-9 	Martino Way	12,000 sf	$1,000
Cedar Grove Brook 6 CGB-6	New Brunswick Road	6,400 sf	$600

			
Cedar Grove Brook 10 NA	New Brunswick Road	16,000 sf	$1,500
Cedar Grove Brook 12 CGB-1 	Cedar Grove Lane	10,000 sf	$1,000
Cedar Grove Brook 18 NA 	Denbigh	500 sf	$500
Cedar Grove Brook 19 NA	Middlebush Park Road	32,000 sf	$2,600

Issues and Concerns:
Degraded riparian areas lead to stream bank erosion.

Existing Condition:
Lawn area is maintained to the stream bank, or vegetation should be improved.

Proposed Solutions:
Work with property owners to reestablish a vegetated buffer zone.

Anticipated Benefits:
Stream bank stabilization, nutrient and sediment removal and reduced stream temperature.

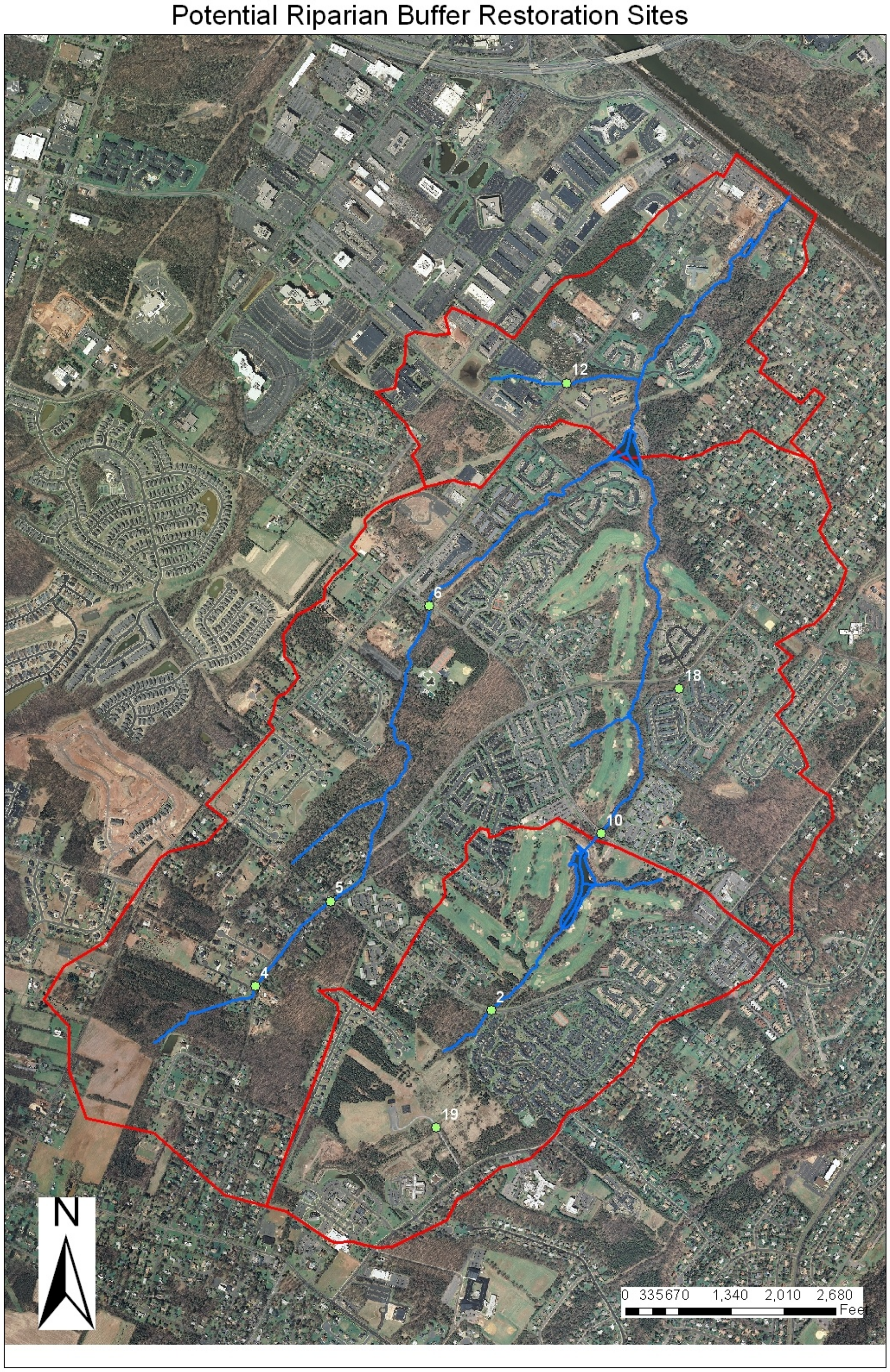
Major Implementation Issues:
Some areas are on private property. Maintenance after planting

Possible Funding Sources:
Section 319(h), NRCS, e.g. Conservation Reserve Enhancement Program, Conservation Reserve Program, Wildlife Habitat Incentives Program

Partners/Stakeholders:
Property owners, Franklin Township, and NJWSA

Task	Description	Sources of Funds	Responsibility	Estimated Cost
Design	Implementation ready plans and permits	Section 319(h), Private , Franklin Twp. Stormwater mitigation fund, NRCS, USFWS, In-kind from Franklin Township and NJWSA	Property owner	$1,000 -$2,000 per site, depending on size of site and permitting needs
Acquisition	N/A	N/A	N/A	N/A
Construction	Mobilization, construction, contingencies, final as-built plans, inspections.	Section 319(h), Private , Franklin Twp. Stormwater mitigation fund, NRCS, USFWS, In-kind from Franklin Township and NJWSA	Property owners, HOA, Franklin Township, NJWSA	See above
			Total Installation Cost:	See above
Maintenance	Watering, weeding, removal of invasive	Private	Property owner	Routine maintenance

	species			



Potential Riparian Restoration Sites

Stormwater Pond Retrofits			
Location: Watershed-wide			**Parcel Description:** Residential and Commercial
Project Type: Stormwater basin retrofits			**Owner:** Varies
	Basin Identifier	**Street Location/ Block/Lot**	**Recommendations**
2	Candlewood Hotel Co./ First Industrial L.P. 	Block 468.09/Lot 47	Remove low flow channels Improve vegetation
4	Stonehenge Estates 	19 Wexford Way/ Block 424.12/Lot 4.13	Remove low flow channels Improve vegetation
5	Franklin Twp. 1/Renoir Way 	186 Cedar Grove Lane/ Block 424.12/Lot 2.32	Remove low flow channels Improve vegetation
6	Hunter's Crossing 	Block 423.01 Lot 40.07	Remove low flow channels Improve vegetation
7	Franklin Twp. 3/Gauguin Way	Block 417.01 Lot 22.01	Improve vegetation
8	Franklin Twp. 2	Block 417.01 Lot 5.04	Remove low flow channels Improve vegetation

			Good location for demonstration project
9	Somerset AL Holdings #1 	473 De Mott Lane/ Block 417.01/Lot 4.02	Remove low flow channels Improve vegetation Improve maintenance
10	Somerset AL Holdings #2 	473 De Mott Lane/ Block 417.01/Lot 4.02	Improve vegetation
12	Community Baptist Church 	211 De Mott Lane/ Block 424.08/Lot 58.01	Remove low flow channels Improve vegetation
13	Franklin Township #4/147 	Block 424.08/Lot 368	Remove low flow channels Improve vegetation Improve maintenance
14	Paddock Estates	Block 423.01/Lot 17.10	Remove low flow channels Improve vegetation Improve maintenance

			
15	Jain Center 	111 Cedar Grove Lane/Block 468.07/Lot 45	Remove low flow channels Improve vegetation

Issues and Concerns: Many basins were not designed for water quality treatment.

Existing Condition: Many basins have low flow channels and are regularly mowed. Modifying basins to provide better water quality treatment will reduce the load of sediments and other pollutants.

Proposed Solutions: Varies by basin, may include removal of low-flow channels, improvement of vegetation, modification of outlet structures.

Anticipated Benefits:
Reduced pollutant loads, better infiltration of runoff.

Major Implementation Issues:
Maintenance

Possible Funding Sources:
Section 319(h), Franklin Township stormwater mitigation funds

Partners/Stakeholders:
Franklin Township, Rutgers Cooperative Extension, HOAs, NJWSA

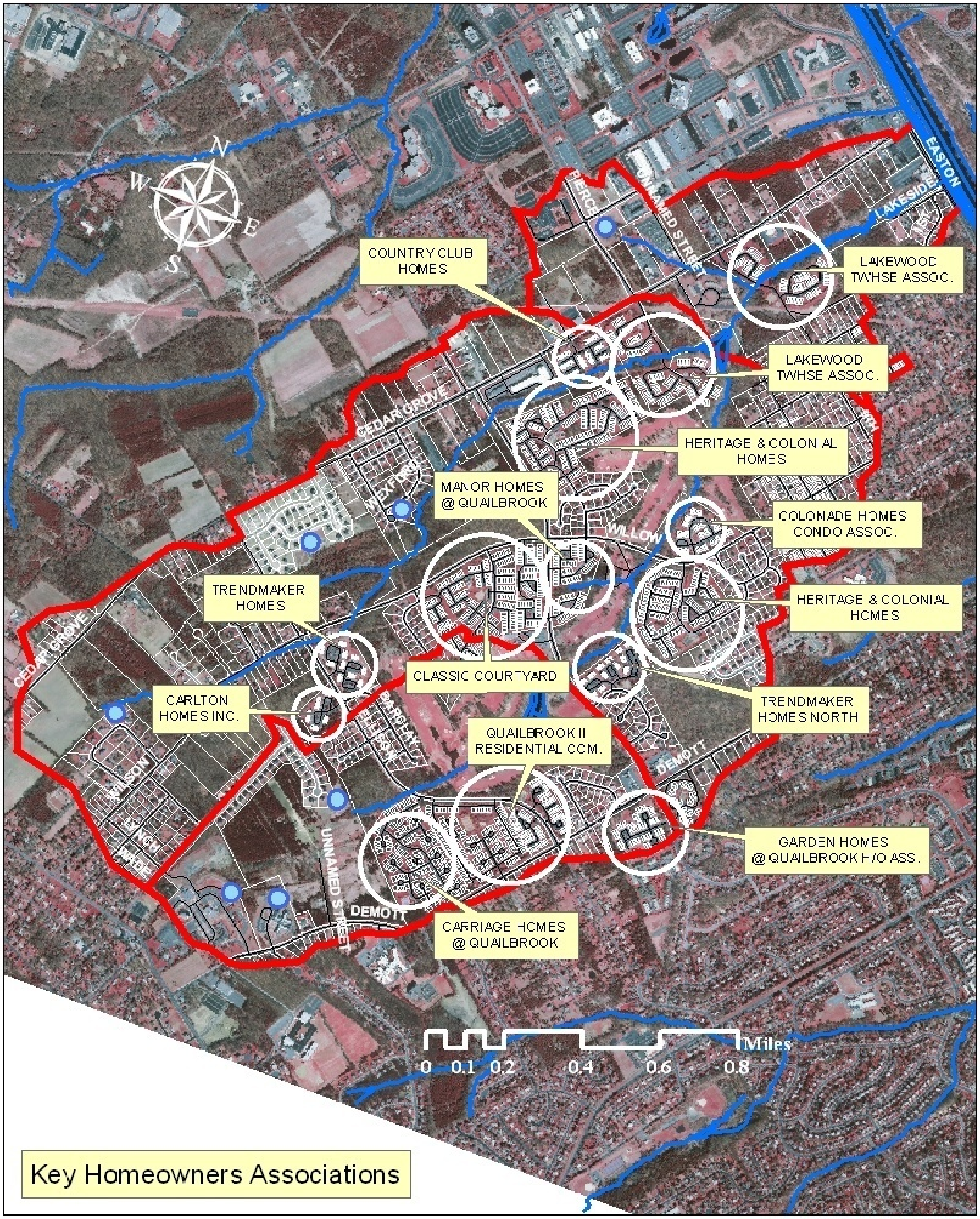
Task	Description	Sources of Funds	Responsibility	Estimated Cost
Design	Conceptual plans and alternatives Construction ready plans and specifications	Section 319(h), Franklin Township stormwater mitigation fund, Private	Pond owner	varies
Retrofit	Modification of basin	Section 319(h), Franklin Township stormwater mitigation fund, Private		varies
Maintenance		Owner	Owner	varies
			Total Cost:	unknown

Key Detention Basins in the Cedar Grove Brook Watershed

River-Friendly Communities	
Location: Varies	**Parcel Description**: Varies
Project Type: Non-structural. Outreach and Education	**Owner:** Varies
Issues and Concerns: Landscaped areas (small and large) and undeveloped residential areas contribute significant sediment load from residential areas in the watershed.	
Existing Condition: Common areas appear to be maintained by commercial landscapers in typical fashion.	
Proposed Solutions: Reduce lawn areas, alter lawn maintenance regime	
Anticipated Benefits: Reduced stormwater volume. Reduced nutrient and sediment loads.	
Major Implementation Issues: New program. Private contractors for lawn maintenance.	
Possible Funding Sources: 319, Franklin Township, NJWSA	
Partners/Stakeholders: HOAs, Franklin Township, NJWSA	

Task	Description	Sources of Funds	Responsibility	Estimated Cost
Develop Program	Develop program materials and guidance	319 and in kind from Franklin Township and NJWSA	NJWSA	$3,000
Implement program	Interact with HOA Develop actions for each HOA Provide technical support for HOA to complete actions	319 and in kind from Franklin Township and NJWSA	NJWSA	$5,000 per HOA
			Total Cost:	Dependent on number of participants

Key Homeowner Groups in the Cedar Grove Brook Watershed



(NJWSA / 1-28-09 / O'Neil)

Rain Gardens

Location:
Watershed-wide

Parcel Description:
Residential and commercial properties

Remediation Type:
Stormwater disconnection and infiltration

Owner:
Varies

Issues and Concerns:
Roofs and lawns in residential areas are potential sources of nutrients and sediments. Pollutants that accumulate can be carried to streams in runoff.

Existing Condition Based on Field Evaluation:
In many cases, residences throughout the watershed have their gutter downspouts directly connected to their driveway which then lead to the stormwater conveyance system and ultimately, the Cedar Grove Brook. Impervious surfaces increase runoff volume in the stream leading to bank erosion.

Proposed Solutions:
A rain garden could be strategically designed and placed to capture, treat and infiltrate stormwater runoff from residential areas. A rain garden is a landscaped, shallow depression that allows for rain and runoff to be collected and then either infiltrates into the soil or evapotranspirates to the atmosphere.

Anticipated Benefits:
Rain gardens can, when implemented on a large scale, reduce the cumulative effects of runoff in a watershed. Sediment, runoff, and pollutants can settle out and be taken up by the plants. This will prevent these loads from reaching the Cedar Grove Brook. Additionally, rain gardens can help reduce the amount of runoff that reaches the stream.

Major Implementation Issues:
Potential physical problems include the lack of space to install a rain garden or soil that does not drain very well and soil amendments are needed. Finding willing landowners and adequate funding are other implementation issues.

Possible Funding Sources:
A rain garden program funded by 319(h) grant money, A rain garden rebate program, Out-of-pocket by landowner

Partners/Stakeholders:
NJWSA, Franklin Township, Homeowners Associations

Task	Description	Sources of Funds	Responsibility	Estimated Cost
Design	Complete topographic survey and soils test. Prepare final design	319(h)	Homeowner	$1,000
Acquisition	Purchase Plant Material and Soil Amendments	319(h)	Homeowner	$1,00

Construction	Install rain garden	Homeowner	Homeowner	$500
Maintenance	Clean out debris, weeds, and accumulated sediment. Reapply mulch and replace any failed plants.	Homeowner	homeowner	$200/year
			Total Cost:	$2,750 per raingarden

Rain Barrels

Location: Watershed-wide	**Parcel Description:** Residential and commercial
Remediation Type: Stormwater disconnection	**Owner:** Varies

Issues and Concerns:
Impervious surfaces like roofs and driveways as well as compacted lawns can contribute nutrients, sediments and stormwater volume in a watershed. Rain barrels can help reduce area of impervious surfaces that are directly connected to stormwater infrastructure.

Existing Condition:
In many cases, residences throughout the watershed have their gutter downspouts directly connected to their driveway which then lead to the stormwater conveyance system and ultimately, the Cedar Grove Brook. Impervious surfaces increase runoff volume in the stream leading to bank erosion. Rain barrels are not widely used as a means to disconnect impervious surfaces.

Proposed Solutions:
Rain barrels could be installed throughout the watershed to increase the disconnection of impervious surfaces to the stormwater system. A rain barrel is typically a 55-gallon barrel and is placed under a gutter's downspout next to a house, small sheds or other outdoor structures to collect rain water from the roof.

Anticipated Benefits:
Disconnecting impervious surfaces can reduce the loading of sediment and pollutants as well and runoff volume in a watershed. Harvesting rain water provides an alternative to utilizing the drinking water supply for gardening and other uses, and the overflow from a rain barrel can be directed to a pervious area (an area where rain water can infiltrate into the ground) such as a lawn or garden and help replenish ground water supplies.

Major Implementation Issues:
Lack of stormwater pollution awareness hinders the implementation of small scale BMPs. Lack of funding for implementation. Educating the public of these issues and providing technical support will help increase usage of rain barrels. Some maintenance required to ensure safety and reduce the chance for mosquito breeding habitat.

Possible Funding Sources:
Rain barrel rebate program, out-of-pocket homeowner cost

Partners/Stakeholders:
Franklin Township, NJWSA, Homeowners Associations

Task	**Description**	**Sources of Funds**	**Responsibility**	**Estimated Cost**
Install a rain	Either purchase a pre-	319(h) grant	NJWSA, local	$50-$150

barrel	made barrel or modify a 55-gallon drum and install on downspout		conservation groups	per barrel
Conduct rain barrel workshops	Invite community members from a target watershed to learn about stormwater pollution and build a rain barrel	Registration fees, Conservation group grant money	NJWSA, local conservation groups	$1700-$3500 per workshop
Provide rebate for rain barrels	Administer a small scale cost share with homeowners to reduce the cost of purchasing a rain barrel	319(h) grant	Franklin Township	$16,000 for 300 barrels
			Total Cost:	NA