Amendment to the
Northeast Water Quality Management Plan

Total Maximum Daily Load
to Address Temperature in the
Pequannock River
Northeast Water Region

Watershed Management Area 3
(Pequannock, Wanaque, Pompton and Ramapo Watersheds)

Proposed:	**June 7, 2004**
Established:	**April 19, 2005**
Approved (by EPA Region 2):	**June 9, 2005**
Adopted:	

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1.0 Executive Summary

In accordance with Section 305(b) of the Federal Clean Water Act (CWA), the State of New Jersey developed the 2002 and proposed 2004 *Integrated List of Waterbodies* (36 N.J.R. 1238(b), March 1, 2004) addressing the overall water quality of the State's waters and identifying impaired waterbodies for which Total Maximum Daily Loads (TMDLs) may be necessary. The proposed 2004 *Integrated List of Waterbodies* identified eleven stream segments in the Pequannock River Watershed as being impaired for temperature, as indicated by elevated temperature levels. Two other segments appear on other Sublists. This report, developed by the New Jersey Department of Environmental Protection (Department), establishes nine TMDLs for temperature in the Pequannock River Watershed and its tributaries located in Morris and Passaic Counties, Watershed Management Area (WMA) 3 for the impaired segments as identified in Table 1. The remaining segments will be deferred to Phase 2 of this TMDL process.

Table 1: Temperature Impaired Stream Segments Located in the Pequannock River Watershed

Site Id #	Station Name/Waterbody	2002	2004	Action
01382410	Macopin River at Echo Lake	Sublist 1	Sublist 5	TMDL
PQ1	Pequannock River above Pacack	Sublist 4	Sublist 4	TMDL
PQ3	Pequannock River below Pacack	Sublist 5	Sublist 5	TMDL
PQ4	Pequannock River above Clinton	Sublist 5	Sublist 5	TMDL
PQ5	Pequannock River below Clinton	Sublist 5	Sublist 5	TMDL
PQ6 01382450	Macopin River at Macopin Reservoir	Sublist 5	Sublist 5	TMDL
PQ7	Pequannock River above Macopin	Sublist 5	Sublist 5	TMDL
PQ8	Pequannock River at Macopin Intake Dam	Sublist 5	Sublist 5	TMDL
PQ10	Pequannock River - Butler	Sublist 5	Sublist 5	Defer
PQ11 01382500	Pequannock River at Riverdale	n/a	Sublist 3	Defer
PQ 14	Outlet Trib of Maple Lake	n/a	Sublist 5	Defer
PQ15	Apshawa Brook	n/a	Sublist 5	Defer
PQ16	Clinton Brook below Clinton Reservoir	n/a	Sublist 5	TMDL

In the 2002 *Integrated List of Waterbodies* (35 N.J.R. 470(a), January 21, 2003), the Department identified seven temperature impairments in the Pequannock River and several of its tributaries. These impairments were carried over to the 2004 *Integrated List of Waterbodies*, which identified four additional segments as impaired for temperature. In the Integrated List of Waterbodies, segments are assigned to one of five categories. Sublists 1 through 4 include waterbodies that are generally unimpaired (Sublist 1 and

2), have limited assessment or data availability (Sublist 3), are impaired due to pollution rather than pollutants or have had a TMDL approved by the United States Environmental Protection Agency (EPA) (Sublist 4). Sublist 5 constitutes the traditional 303(d) list for waters impaired or threatened by one or more pollutants. Table 1 above identifies the stream segments proposed for TMDL preparation at this time or deferred to Phase 2, along with their status on the *Integrated List of Waterbodies* both in 2002 and as proposed on the 2004 list. The segment of the Pequannock River above Pacack (Site ID PQ1) that was and continues to be listed on Sublist 4 was placed on Sublist 4 rather than Sublist 5 because the impairment is attributed primarily to beaver activity and not an anthropogenic source. Nevertheless, the implementation plan in this TMDL document will address the effects of beaver activity and so inclusion of this segment within the set of temperature TMDLs is appropriate. The segment of the Pequannock River at Riverdale (Site ID PQ11 and 01382500), which is on Sublist 3 of the 2004 *Integrated List of Waterbodies*, an indication that there is a need for additional data to assess the status of the segment, is believed to be impaired based on the overall analysis of the watershed conducted during development of the TMDL. This segment, along with segments with Site IDs PQ10, PQ14, and PQ15 will be discussed in the overall assessment of the watershed, but TMDLs will be deferred to Phase 2 to allow collection and assessment of additional data. As a result, this proposed amendment to the Northeast Water Quality Management Plan will establish nine TMDLs that address temperature impairments as identified in Table 1.

A TMDL is developed to identify all the contributors of a pollutant of concern and load reductions necessary to meet the Surface Water Quality Standards (SWQS) relative to that pollutant. The pollutant of concern for these TMDLs is temperature. Phase 1 of the TMDL for each segment is based on a temperature-discharge relationship developed through correlations and regressions of measured data. Loading capacity and load allocations are then assigned based on a series of assumptions that will be checked in Phase 2. The chief cause of temperature impairment is the significant modification of natural flow regime and heating of water that results from current reservoir management practices. Beaver activity, which results in ponding of water, stormwater runoff from paved areas and detention facilities, and increased solar incidence in areas where shading vegetation is lacking in the riparian buffer also contribute to the temperature impairment. From this analysis, it has been determined that attainment of temperature criteria will require a combination of measures that will affect the causes of temperature impairment, including management of water allocation and reservoir operations, as well as addressing the effects of beaver activity, stormwater management practices, and conducting streambank restoration projects, where needed.

This TMDL Report is consistent with EPA's May 20, 2002 guidance document entitled, *Guidelines for Reviewing TMDLs under Existing Regulations Issued in 1992* (Sutfin, 2002) which describes the statutory and regulatory requirements for approvable TMDLs. This TMDL shall be proposed and, upon approval by EPA, adopted by the Department as an amendment to the Northeast Water Quality Management Plan (WQMP) in accordance with N.J.A.C. 7:15-3.4 (g).

2.0 Introduction

This report establishes nine TMDLs that address temperature impairments in the identified waterbodies (Table 1) in the Pequannock River Watershed. New Jersey's 2004 *Integrated List of Waterbodies* identifies eleven stations on Sublist 5 (also known as the 303d list) as being impaired for temperature, two additional stations of concern for temperature impairment are found on Sublist 4 and Sublist 3, respectively. These TMDLs and the associated implementation plan provide the basis for a watershed restoration plan to address temperature impairments caused by various factors, such as reservoir effects, deficient riparian vegetation and beaver activity, in order to attain applicable SWQS for trout production (TP) and trout maintenance (TM) waters, thereby attaining and protecting the designated fisheries use. The stream segment stations known as Macopin River at Echo Lake and Pequannock River at Macopin Intake Dam are both listed for dissolved oxygen, while the latter is also listed for lead. Other pollutants include Fish-Mercury with impairments identified at the Canistear, Oak Ridge, Clinton and Echo Lake Reservoirs. A separate TMDL evaluation will be developed to address the other pollutants of concern. Therefore, these waterbodies will remain on Sublist 5 with respect to these pollutants until such time that a TMDL has been completed and approved by EPA. With respect to the nine temperature impairments addressed in this TMDL document, these waterbodies will be moved to Sublist 4 following approval of these TMDLs by EPA Region 2.

3.0 Background

In accordance with Section 303(d) of the Federal Clean Water Act (CWA) (33 U.S.C. 1315(B)), the State of New Jersey is required biennially to prepare and submit to the USEPA a report that identifies waters that do not meet or are not expected to meet SWQS after implementation of technology-based effluent limitations or other required controls. This report is commonly referred to as the 303(d) List. In accordance with Section 305(b) of the CWA, the State of New Jersey is also required biennially to prepare and submit to the USEPA a report addressing the overall water quality of the State's waters. This report is commonly referred to as the 305(b) Report or the Water Quality Inventory Report.

In November 2001, EPA issued guidance that encouraged states to integrate the 305(b) Report and the 303(d) List into one report. Following USEPA's guidance, the Department chose to develop an Integrated Report for New Jersey and has adopted the *2002 Integrated List of Waterbodies* and the *2004 Integrated List of Waterbodies.* In preparation of the 2002 *Integrated List of Waterbodies*, the Department, for the first time, solicited data and information from the public for use in developing the list. The Department considered quality assurance/quality control, monitoring design, data age, and accuracy of sampling location information, data documentation and use of electronic format for data when deciding to use the submitted data. Data was also solicited for the 2004 *Integrated List of Waterbodies.* The Pequannock River Coalition submitted data that was approved by the Department and used in the development of both the 2002 and the 2004 *Integrated List of Waterbodies.*

The *Integrated List of Waterbodies* assigns waterbodies to one of five sublists. Sublists 1 through 4 include waterbodies that are generally unimpaired (Sublist 1 and 2), have limited assessment or data availability (Sublist 3), are impaired due to pollution rather than pollutants or have had a TMDL approved by EPA (Sublist 4). Sublist 5 constitutes the traditional 303(d) list for waters impaired or threatened by one or more pollutants, for which a TMDL may be required.

A TMDL represents the assimilative or carrying capacity of a waterbody, taking into consideration point and nonpoint sources of pollutants of concern, natural background and surface water withdrawals. A TMDL quantifies the amount of a pollutant a water body can assimilate without violating a state's water quality standards and allocates that load capacity to known point and nonpoint sources in the form of waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and a margin of safety (MOS).

Recent EPA guidance (Sutfin, 2002) describes the statutory and regulatory requirements for approvable TMDLs, as well as additional information generally needed for EPA to determine if a submitted TMDL fulfills the legal requirements for approval under Section 303(d) and EPA regulations. The Department believes that the TMDLs in this report address the following items in the May 20, 2002 guideline document:

1. Identification of waterbody(ies), pollutant of concern, pollutant sources and priority ranking.
2. Description of applicable water quality standards and numeric water quality target(s).
3. Loading capacity – linking water quality and pollutant sources.
4. Load allocations.
5. Wasteload allocations.
6. Margin of safety.
7. Seasonal variation.
8. Reasonable assurances.
9. Monitoring plan to track TMDL effectiveness.
10. Implementation (USEPA is not required to and does not approve TMDL implementation plans).
11. Public Participation.

4.0 Pollutant of Concern and Area of Interest

Pollutant of Concern

The pollutant of concern for these TMDLs is temperature. Temperature levels in segments of the Pequannock River have been found to exceed New Jersey's SWQS at N.J.A.C. 7-9B et seq., as reported in the 2002 and 2004 *Integrated Lists of Waterbodies.* Table 1 shown previously depicts the Pequannock River Watershed listings for temperature impairment. Table 2 and Figure 1 depict the spatial extent of the impairments. All of the listed impairments have a high priority ranking, as described in the *2004 Integrated List of Waterbodies*.

The segment of the Pequannock River above Pacack that was and continues to be listed on Sublist 4 was placed on Sublist 4 rather than Sublist 5 because the impairment is attributed primarily to beaver activity and not an anthropogenic source. Nevertheless, the implementation plan in this TMDL document will address the effects of beaver activity and so inclusion of this segment within the set of temperature TMDLs is

Table 2. Temperature impaired stream segments in the Pequannock River watershed, identified in the 2004 Integrated List of Waterbodies. Italics indicate deferred segment.

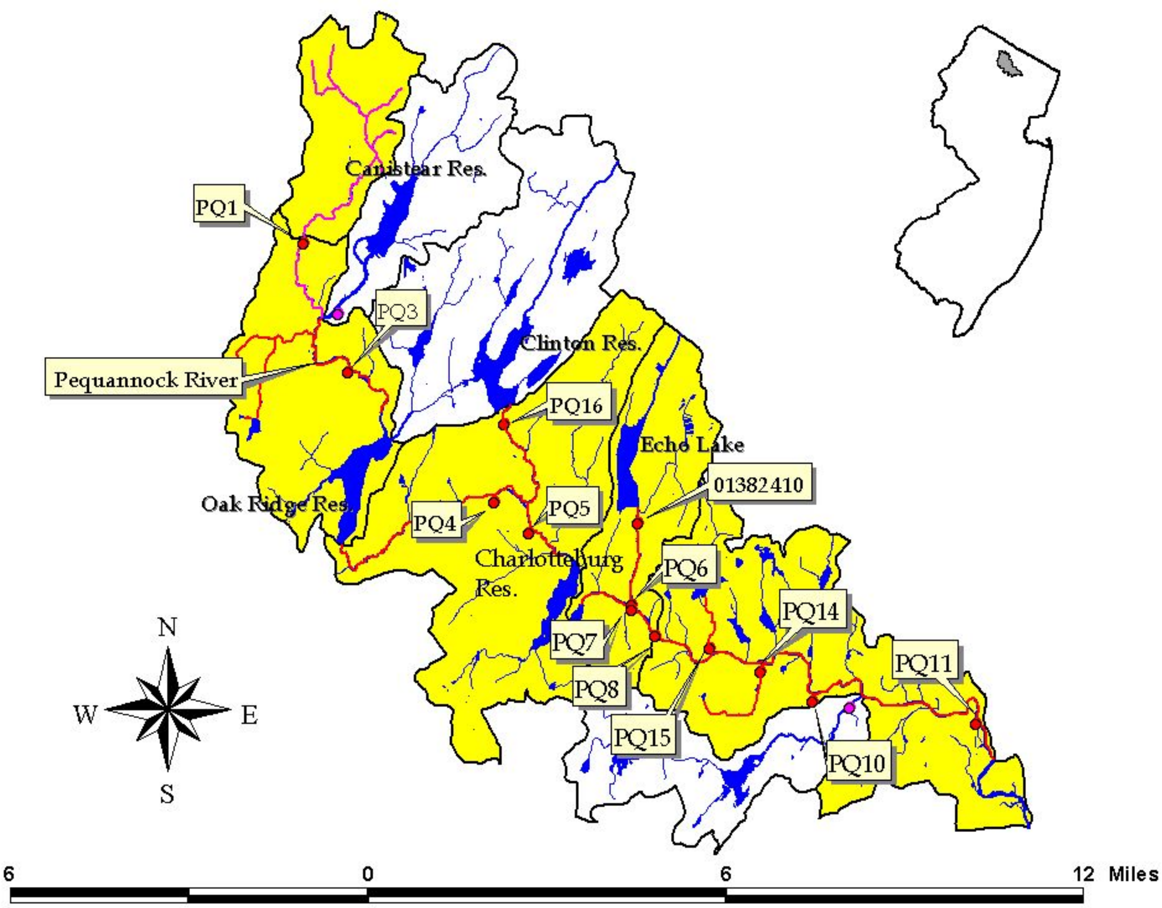
<table>
<tr><th>Site ID</th><th>Sub -list</th><th colspan="2">Site Location and Waterbody/
General Description</th><th>Approx. River Miles</th></tr>
<tr><td>PQ1</td><td>4</td><td colspan="2">Pequannock River above Pacack Brook. Extends upstream to include all headwater tributaries, and downstream to confluence with Pacack Brook.</td><td>8.8</td></tr>
<tr><td>PQ3</td><td>5</td><td colspan="2">Pequannock River below Pacack Brook. Extends upstream to confluence with Pacack Brook, including unnamed tributaries east of Lake Stockholm Road and Holland Mountain Road, and downstream to Oak Ridge Reservoir.</td><td>6.6</td></tr>
<tr><td>PQ4 & PQ5</td><td>5
5</td><td colspan="2">Pequannock River below Clinton and Pequannock River above Clinton. Spatial extents adjoin: mainstem only extending upstream to Oak Ridge Reservoir and downstream to Charlotteburg Reservoir.</td><td>3.9</td></tr>
<tr><td>PQ6 & 01382410</td><td>5
5</td><td colspan="2">Macopin River above Pequannock confluence and Macopin River below Echo Lake. Spatial extents adjoin: extends from confluence with Pequannock River upstream to outfall of Echo Lake.</td><td>1.8</td></tr>
<tr><td>PQ7</td><td>5</td><td>Pequannock River above Macopin.</td><td rowspan="2">Pequannock mainstem from the outfall of Charlotteburg Reservoir downstream to the confluence with Apshawa Brook.</td><td rowspan="2">2.5</td></tr>
<tr><td>PQ8</td><td>5</td><td>Pequannock River below Macopin.</td></tr>
<tr><td>PQ10</td><td>5</td><td>Pequannock River at Butler.</td><td rowspan="2">Pequannock mainstem from outfall of Apshawa Brook downstream to confluence with Pompton River.</td><td rowspan="2">6.4</td></tr>
<tr><td>PQ11</td><td>3</td><td>Pequannock River at Riverdale.</td></tr>
<tr><td>PQ14</td><td>5</td><td colspan="2">Tributary outlet of Maple Lake. Extends from confluence with Pequannock River upstream to unnamed waterbody.</td><td>2.0</td></tr>
<tr><td>PQ15</td><td>5</td><td colspan="2">Apshawa Brook. Extends from confluence with Pequannock River upstream to Butler Reservoir.</td><td>1.2</td></tr>
<tr><td>PQ16</td><td>5</td><td colspan="2">Clinton Brook below Clinton Reservoir. Extends downstream to confluence with Pequannock River.</td><td>1.7</td></tr>
</table>

	Total River miles = ~34.9

appropriate. The segment of the Pequannock River at Riverdale on Sublist 3 of the 2004 *Integrated List of Waterbodies*, an indication that there is a need for additional data to assess the status of the segment, is believed to be impaired based on the overall analysis of the watershed conducted during development of the TMDLs. This segment, along with Segments with IDs PQ10, PQ14, and PQ15 will be discussed as part of the overall watershed assessments, but TMDLs will be deferred to Phase 2 to allow collection and assessment of additional data.

The Pequannock River Watershed contains approximately 153.2 total river miles, of which 34.9 are impaired for temperature. More river miles are covered under these TMDLs than are actually listed as being impaired for temperature due to the fact that the implementation plans, as described in detail later in this document, cover entire watersheds, not just impaired waterbody segments.

Figure 1: Spatial Extent of Impaired Segments



Description of the Pequannock River Watershed

Watershed Management Area 3 (WMA 3) includes watersheds that drain the Highlands portion of New Jersey. WMA 3 lies mostly in Passaic County but also includes parts of Bergen, Morris, and Sussex Counties and is comprised of 21 municipalities that lie entirely or partially within the watershed boundary. There are four watersheds in WMA 3: Pompton, Ramapo, Pequannock and Wanaque River Watersheds. The Pequannock, Wanaque and Ramapo Rivers all flow into the Pompton River. The Pompton River is, in turn, a major tributary to the Upper Passaic River. WMA 3 contains some of the State's major water supply reservoir systems including the Wanaque Reservoir, the largest surface water reservoir in New Jersey.

The Pequannock River Watershed is part of the Highlands physiographic province and is underlain by granite, gneiss and small amounts of marble of Precambrian age. These rocks, the oldest in New Jersey, were formed between 1.3 billion and 750 million years ago by melting and recrystallization of sedimentary rocks that were deeply buried, subjected to high pressure and temperature, and intensely deformed (The Geology of New Jersey, NJGS, 1986).

Spanning the heart of the Highlands Region with the longest stretch of wild trout water remaining in New Jersey is the Pequannock River Watershed. The Pequannock River is 30 miles long. Its headwaters are in Sussex County and it flows east, delineating the Morris/Passaic County line. It continues flowing east and joins the Wanaque River, which flows to the Pompton River in Wayne Township. The great majority of the land within the Pequannock River Watershed is forested and publicly owned. The City of Newark owns over 86 percent of the entire tributary area to the watershed, which is the source of the city's water supply.

City of Newark Water Supply

In the 1800s the City of Newark was a major industrial center of New Jersey. Public officials found the increased population and manufacturing to be a formidable challenge. In particular, public officials had to figure out how to supply the city with fresh drinking water, and at the same time, manage wastewater from residences and industry. While residents of Newark could see and smell the impurities in the water from the Passaic River, then used for both water supply and waste disposal, there was little scientific evidence to demonstrate that the water was a threat to public health. As scientists began examining the water and writing reports testifying to the unsanitary nature of the water supply, Newark's public officials began to recognize that something would have to be done about the water supply for the citizens and industry of the City of Newark.

The East Jersey Water Company, which owned land in West Milford, agreed to supply Newark with a water system, complete for $6,000,000. It was proposed to build a dam in the Pequannock River Watershed, erect reservoirs to store water, build a pipeline to the Belleville Reservoir, and then turn the plant over to the city. The Pequannock supply was placed on line in May, 1892. The initial system included the Oak Ridge, Clinton and Macopin Reservoirs. Water was fed from the Macopin intake through 21 miles of 48-inch pipeline (the Pequannock No. 1 Aqueduct) to the Belleville Reservoir in Newark.

Today, the City of Newark Water Department utilizes five reservoirs with a total capacity of 14.4 billion gallons located in the Pequannock River Watershed and supplies water to over 400,000 residents outside of the watershed. The reservoirs include:

Canistear Reservoir

The Canistear Reservoir is the most upstream reservoir and is located almost entirely in Vernon Township, Sussex County and is formed by a dam on Pacack Brook. This 350-acre reservoir was used for storage and water released for diversion as water supply at Macopin intake dam on the Pequannock River prior to 1961. Currently, water is released for diversion at Charlotteburg Reservoir on the Pequannock River.

Oak Ridge Reservoir

The Oak Ridge Reservoir, which straddles Jefferson Township, Morris County and West Milford Township, Passaic County, is 482 acres. The reservoir was used for storage and water released for diversion at Macopin intake dam on the Pequannock River prior to 1961. Currently it provides water for diversion at Charlotteburg reservoir. Outflow is controlled mostly by operation of gates in pipes through the dam.

Charlotteburg Reservoir

The 149-acre Charlotteburg Reservoir is located between Rockaway Township, Morris County and West Milford Township, Passaic County. The spillway was equipped with an automatic bascule gate 5 feet high, but the gate has since been decommissioned. Water is diverted from the reservoir to serve the City of Newark.

Clinton Reservoir

The 423-acre Clinton Reservoir is located entirely within West Milford, Passaic County. The reservoir was used for storage and water released for diversion at

Macopin intake dam on Pequannock river prior to 1961. Currently it provides water for diversion at Charlotteburg Reservoir. Outflow is controlled mostly by operation of gates in pipes through the dam. Releases from Clinton Reservoir, via Clinton Brook join the mainstem Pequannock River just above Charlotteburg Reservoir.

Echo Lake Reservoir

Echo Lake is also located in West Milford at Echo Lake Dam on Macopin River, 1.6 miles north of Charlotteburg Reservoir. The 300-acre reservoir has a drainage area of 4.35 square miles. Its capacity at the spillway is 1.58 billion gallons, unless flashboards are used, which provide an additional capacity of 180 million gallons. Two streams receive water from Echo Lake. One receives water released from the outlet works on the western end of the dam. That water flows towards a diversions structure, which directs water from Echo Lake into Charlotteburg Reservoir; the water in excess of what is diverted continues in the streambed and joins the Pequannock River above the confluence with the Macopin River. The second is the Macopin River, which receives both overflow from the Echo Lake spillway and water released via a small diameter drain in the Echo Lake Spillway (both at the eastern end of the dam). That water flows down the Macopin River to the Pequannock River; it does not enter Charlotteburg Reservoir and is not available for diversion under the current filtration plant configuration.

Macopin Reservoir

This 32 million gallon reservoir was one of the original reservoirs from the 1800's. It has since been decommissioned.

Sources: Water Resource Data New Jersey Water Year 2001, Volume 1. Surface-Water Data, Water-Data Report NJ-01-1, and the NJDEP, Division of Land Use Management, Water Monitoring & Standards, Bureau of Freshwater Biological Monitoring (BFBM) GIS coverage, Lakes with Name Attributes for the State of New Jersey and the City of Newark written communication.

Land Use

The predominant land use in the Pequannock River Watershed is undeveloped forest, water and wetlands. Urban land use is the main type of altered land use and occurs mostly in the lower portion of the watershed. There is very little agricultural land use. Table 3 depicts the breakdown of land use per watershed at the hydrologic unit code (HUC) 14 level. HUC delineations are part of a national system for identifying watersheds in a nested fashion that was developed by the United States Geological

Survey, United States Soil Conservation Service and the US EPA. The HUC-11 code for the Pequannock is 02030103050 and this delineation can be further subdivided into HUC-14 drainage areas, which are then denoted by the addition of three digits as shown in Table 3 below.

Table 3. Pequannock River Watershed 1995-97 Land Use/Land Cover (by HUC 14) Total Area = ~55,569.3 acre

HUC 14	Site ID	Agriculture	Barren	Forest	Urban	Water	Wetlands
010		0.0	0.0	2,796.7	75.2	64.0	528.0
020		12.4	0.0	3,479.7	69.6	335.0	693.3
030	PQ 1 PQ 3	7.3	0.0	4,851.0	366.5	513.9	970.8
040		8.3	0.0	6,760.5	139.8	719.5	858.0
050	PQ 4 PQ 5 PQ 16	128.3	62.7	8,315.1	1,233.9	365.5	1,654.7
060	01382410 PQ 6 PQ 7 PQ 8	20.3	10.0	3,203.6	760.1	353.9	699.9
Subtotal	**Phase 1**	**176.6**	**72.7**	**29,406.6**	**2,645.1**	**2,351.8**	**5,404.7**
070		*18.3*	*200.4*	*5,655.2*	*3,734.2*	*417.5*	*810.1*
080	*PQ 10* *PQ 11* *PQ 14* *PQ 15*	*0.0*	*0.0*	*2,476.5*	*1,611.7*	*331.2*	*256.7*
Total	*Phase 1 and 2*	*194.9*	*273.1*	*37,538.3*	*7,991.0*	*3,100.5*	*6,471.5*

Figure 1 shown previously highlights the HUC-14 watersheds that are impaired by temperature.

Data Sources

The Department's Geographic Information System (GIS) was used extensively to describe the WMA 3 watershed characteristics. In concert with USEPA's November 2001 listing guidance, the Department is using Reach File 3 (RF3) in the 2002 *Integrated List of Waterbodies* to represent rivers and streams. The following is general information regarding the data used to describe the watershed management area:

- Land use/Land cover information was taken from the 1995/1997 Land Use/Land cover Updated for New Jersey DEP, published 12/01/2000 by Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA), delineated by watershed management area.

- 2004 Assessed Rivers coverage, NJDEP, Watershed Assessment Group, unpublished coverage.

- County Boundaries: Published 11/01/1998 by the NJDEP, Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA), "NJDEP County Boundaries for the State of New Jersey." Online at: http://www.state.nj.us/dep/gis/digidownload/zips/statewide/stco.zip

- Detailed stream coverage (RF3) by County: Published 11/01/1998 by the NJDEP, Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA). "Hydrography of Passaic County, New Jersey (1:24000)." Online at: http://www.state.nj.us/dep/gis/digidownload/zips/strm/

- NJDEP 14 Digit Hydrologic Unit Code delineations (DEPHUC14), published 4/5/2000 by New Jersey Department of Environmental Protection, New Jersey Geological Survey (NJGS) Online at: http://www.state.nj.us/dep/gis/digidownload/zips/statewide/dephuc14.zip

- NJDEP 10-meter Digital Elevation Grid of the Lower Delaware Watershed Management Area (WMA 12), published 12/23/2002 by NJ Department of Environmental Protection (NJDEP), Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA) http://www.state.nj.us/dep/gis/digidownload/zips/wmalattice/wma12lat.zip

- NJPDES Surface Water Discharges in New Jersey, (1:12,000), published 02/02/2002 by Division of Water Quality (DWQ), Bureau of Point Source Permitting - Region 1 (PSPR1).

- Lakes/Reservoir information was taken from the Lakes with Name Attributes for the State of New Jersey GIS coverage (from 95/97 Land Use/Land Cover), published 2/12/2003 by the NJDEP-Bureau of Freshwater Biological Monitoring. Online_Linkage: http://www.state.nj.us/dep/gis/digidownload/zips/statewide/njlakes.zip

- NJDEP Existing Water Quality Stations in New Jersey, published 5/12/2003, NJDEP, Division of Land Use Management (LUM), Water Monitoring and Standards, Bureau of Freshwater Biological Monitoring (BFBM), http://www.state.nj.us/dep/gis/digidownload/zips/statewide/ewqpoi.zip

- NJDEP Ambient Stream Quality Monitoring Sites, published 5/30/2001, NJDEP , Bureau of Freshwater Biological Monitoring (BFBM), http://www.state.nj.us/dep/gis/digidownload/zips/statewide/swpts01.zip

The spatial extent of impaired segments associated with each monitoring site were established using the methodologies described in the November 2003, *Integrated Water Quality Monitoring and Assessment Methods* document, established pursuant to Section 303(d) of the Federal Clean Water Act, which can be accessed through the Department's website at http://www.state.nj.us/dep/wmm/sgwqt/wat/integratedlist/2004methodsdoc.pdf

5.0 Applicable Water Quality Standards

Temperature criteria have been established to protect aquatic life designated uses, and are based upon stream classifications. Under the general technical policies stated in the Surface Water Quality Standards, unless specified otherwise, the design flow for all criteria shall be MA7CD10 flow. According to N.J.A.C. 7:9B-1.5 (c) 2, water quality criteria are expected to be maintained during periods when nontidal or small tidal stream flows are at or greater than the appropriate design flow. The criteria for stream classifications prohibit thermal alterations that would cause temperatures to exceed ambient temperatures by an established limit and, in addition, set a maximum temperature limit. The applicable surface water quality criteria under N.J.A.C. 7:9-1.14 (c) for the Pequannock River include:

FW2-TP No thermal alterations which would cause changes in ambient temperatures except where properly treated wastewater effluents are discharged. Where such discharges occur, temperature shall not deviate more than 0.6°C (1°F) above ambient temperatures (TM criterion of 20°C (68°F) used as a maximum temperature).

FW2-TM No thermal alterations which would cause temperatures to exceed ambient by more than 1.1°C (2°F) at any time or which would cause temperatures in excess of 20°C (68°F).

For the assessments in the Integrated Reports, the numeric limit of 68°F was used to determine impairment since ambient water temperatures for streams have not been calculated. (2002 Integrated Report p. 52)

The impaired segments covered under this TMDL are all classified FW2. Most support trout reproduction and are denoted as FW2-TP, while the remainder support maintenance of trout and are denoted as FW2-TM. The designated uses, both existing and potential, that have been established by the Department for such waters are as stated below:

In all FW2 waters, the designated uses are (N.J.A.C. 7:9B-1.12(c)):

1. Maintenance, migration and propagation of the natural and established aquatic biota;
2. Primary and secondary contact recreation;
3. Industrial and agricultural water supply;
4. Public potable water supply after conventional filtration treatment (a series of processes including filtration, flocculation, coagulation and sedimentation, resulting in substantial particulate removal but no consistent removal of chemical constituents) and disinfection; and
5. Any other reasonable uses.

6.0 Source Assessment

Based on an analysis of land use and stream hydrography, several potential sources of temperature pollution have been identified. Those in the point source category include stormwater, water treatment and wastewater treatment discharges subject to NJPDES regulation. Nonpoint sources include the effects of the reservoir system, beaver activity, and deficiencies in riparian forest buffer.

Point Sources:

Regulated industrial and municipal stormwater discharges, if they accumulate sheet flows from large areas of impervious cover such as asphalt parking lots or discharge from unshaded detention facilities that pond water for a significant period of time, may serve as sources of thermal increases during summer rain events. Water and wastewater treatment discharges can also discharge water that is heated above ambient stream temperatures because of source water temperature or residence time in tanks.

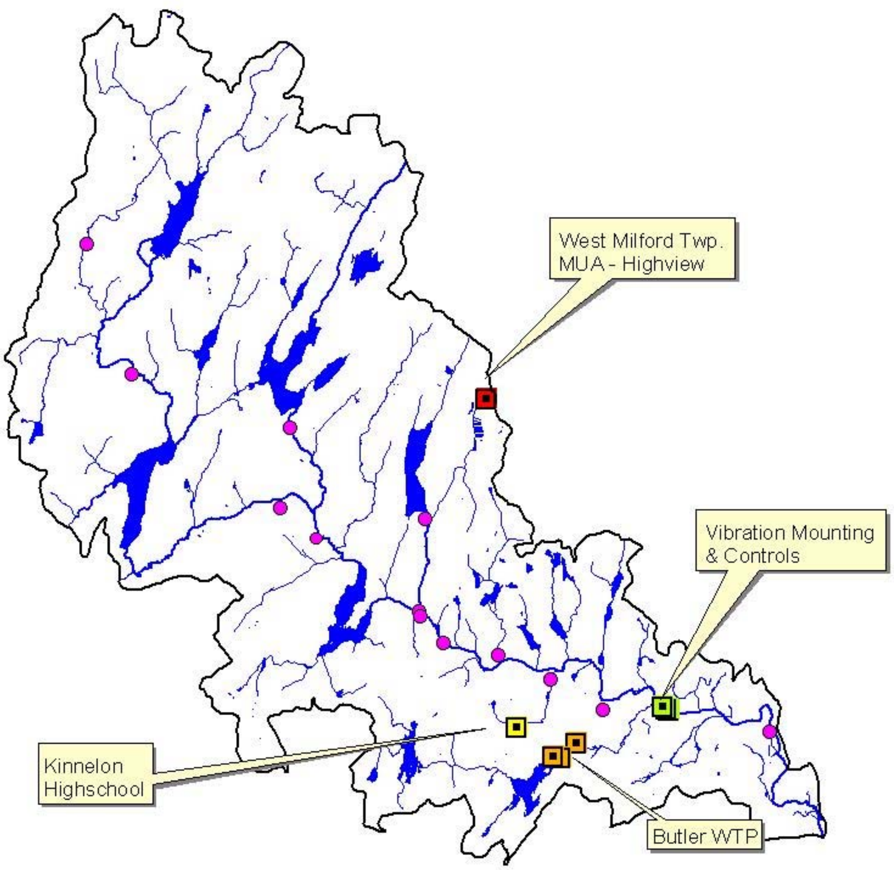
Table 4 identifies the regulated point sources, other than regulated municipal stormwater, in the watershed. Figure 2 depicts the impaired sites relative to the discharges noted in Table 4. There are two permitted industrial and municipal dischargers in the Phase 1 TMDL watershed. The West Milford Twp. MUA-Highview STP discharges to the Macopin River and the Newark-Pequannock WTP discharges to the Pequannock River/Charlotteburg Reservoir. The Newark-Pequannock WTP intermittently discharges only supernatant and emergency overflow from the water treatment facility and is therefore considered a de minimus source. The West Milford Twp. MUA-Highview STP discharges above Echo Lake, located upstream of the spatial extent of the impairment, at an average flow of 0.15 MGD and a maximum observed temperature of 70.5 degrees F (see Appendix E). This discharge is small compared to the in stream flow, and therefore was found to be a de minimus source of heat added to the system, based on best available information.

Table 4. Treatment works that discharge to surface waters in the Pequannock River watershed; bold indicates in Phase 1 TMDL

Facility Name	*Outfall Location*	*NJPDES Number*	*Antidegradation designation of receiving waters*	*Trout designation of receiving waters*	*Comments*
Newark-Pequannock WTP	**Pequannock River/ Charlotteburg Reservoir**	**0063711 (now includes former permit 0069582)**	**C1**	**TP**	**Supernatant and emergency overflows from water treatment facility. Intermittent flows to river and reservoir, de minimus source.**
West Milford Twp. MUA-Highview STP	**Macopin River**	**0027685**	**C2**	**TM**	**Wastewater treatment facility discharging above Echo Lake, outside the spatial extent of the impairment, average flow 0.15 MGD, de minimus relative to receiving impoundment.**
Kinnelon Twp High School STP	Pequannock River via trib. Outlet of Maple Lake	0022284	C1	TP	Discharges above Maple Lake, average discharge is 0.0007 MGD compared to streamflow of 0.95 cfs. Mass balance indicates minimal impact.
Vibration Mounting & Controls (Ind SW)	Pequannock River	0025712	C1	TP	Analysis of effluent relative to stream flow indicates minimal heat addition.
Butler STP	Stonehouse Brook/ (Kikeout Brook)	0025721	C2	NT	Discharges to unimpaired segment. Average flow of 0.01 MGD compared to stream flow is 5.2 cfs. Mass balance indicates minimal impact.
Passaic Crushed Stone Co. (Ind. SW)	Pequannock River	0025500	C1	TP	Will be assessed in Phase 2.
Tilcon River Quarry Llc. (Ind. SW)	Pequannock River	0001601	C1	TP	Will be assessed in Phase 2.
Peerless Concrete Products Inc. (Ind. SW)	Pequannock River	0127221	C1	TP	Will be assessed in Phase 2.

Regulated municipal stormwater systems (MS4s) are assumed to be coincident with urban land use as depicted in GIS coverages. As derived from Table 3, for the Phase 1 area, there are a total 40,057.5 acres of land in the watershed above Macopin, of which 32,301 acres are assumed to contribute to runoff. Areas of water and wetlands are excluded to determine the runoff-contributing area. The urban land use is a relatively small area, 2,645.1 acres (8%), of the runoff-contributing area. The potential for increased temperature from this diffuse source is likely to be minor compared to the potential to increase temperature that can be attributed to overspill of solar heating reservoir surface water, which constitutes over 1,400 acres (4%) of surface area in the watershed and discharges at a few discrete locations. Therefore stormwater from urban areas located in the Phase I TMDL watershed is considered a de minimus source of heat added to the system, based on best available information.

Figure 2. Discharges to Surface water within the Pequannock River HUC 11 watershed. Circles indicate documented sites with temperature impairment.



Nonpoint Sources:

Groundwater inflow into the stream is approximately 53 degrees F, and therefore does not contribute to the temperature impairment. The agricultural area in the watershed is less than 1% and runoff temperature is not expected to be high enough to affect receiving water temperature. Forested areas are expected not to contribute to the temperature impairment. Therefore groundwater and runoff from agricultural and forested land uses are considered de minimus contributors to the temperature impairment.

The Department concludes that the main cause for the temperature violations in the Phase 1 spatial extent is from nonpoint sources, especially the impact of the complex network of five reservoirs, with a combined volume of 14 billion gallons, within this watershed. In order to maintain the maximum amount of water in storage at any time, water is retained in the reservoirs unless released when needed for water supply or when the volume of a reservoir is exceeded and excess water spills over the dam. Reservoir management practices that maximize retention of water in storage result in chronic low flows in the streams and, when reservoirs do exceed capacity in summer months, heated top water from spillways at the reservoirs contributes to temperature impairment. A diversion of Matthews Brook, which formerly connected directly with Macopin River, into Echo Lake increases the relative amount of heated top waters entering the Macopin River over the Echo Lake spillway. The decommissioned Macopin Reservoir, which is currently characterized as a shallow, slow-moving watercourse, allows additional opportunity for artificial heating of waters flowing into the lower Pequannock River.

Chronic low flows can alter the physical, chemical, and biological processes that affect the ecological integrity of the river. For example, low dissolved oxygen is often associated with high water temperature and two stations on the Macopin River are listed for oxygen impairment. Under low flow, the water in the Pequannock River presents a profile that is relatively shallow compared to width, which causes the heating effect of the sun and the air to more rapidly increase water temperature. High water temperature with large diurnal variations can be lethal to aquatic life. This is critical in the Pequannock River, which supports an important cold-water fishery. The impact of the current practice of reservoir operation on water temperature is evident through the observations of temperature violation occurrences. For example, the least number of violations occurred during dry seasons (1999 and 2002) when reservoir discharges are minimal. The increase in number of violations when overspill occurs illustrates the negative effect of this phenomenon.

Nonpoint sources also include natural heating from air and the sun. When this heating is exacerbated compared to normal, it becomes a potentially controllable nonpoint source. For example, the effect of beaver activity, particularly in the smaller first order streams of the Upper Pequannock River and Pacack Brook, results in the creation of wide, shallow ponds that absorb heat more than a free-moving stream would. Beaver activity also results in the loss of tree cover, which would otherwise moderate temperature elevation via shading. Where beaver populations are significant, the effect may need to be addressed. Past flooding by beaver dams has altered extensive land areas from forest to meadows including a half-mile section of Kanouse Brook in West Milford. Spot checks by the Pequannock River Coalition in this portion of Kanouse Brook have revealed temperatures much higher than the receiving segment of the mainstem Pequannock (Pequannock River below Clinton). Similar conditions exist in the Pequannock River headwaters (Pequannock River above Pacack). Another nonpoint source that can be addressed is lack of riparian buffer vegetation, resulting in loss of shading and associated temperature increases, which occurs in some locations as the result of development activities. A Department funded 319(h) Nonpoint Source Project described later on in this document under Long-Term Management Measures examined streambanks throughout WMA 3 and identified candidates for habitat restoration and enhancement.

7.0 Water Quality Data

The Pequannock River Coalition was formed in 1995 in response to environmental threats within the watershed. The Pequannock River Coalition is dedicated to the preservation of the Pequannock River as a natural, recreational, aesthetic and water supply resource. Through a system of electronic devices the Pequannock River Coalition collects, analyzes and disseminates river and tributary water temperature data from monitored sites.

The Pequannock River Coalition monitoring program earned accreditation by the Department and their temperature data was used in the generation of the 2002 *Integrated List of Waterbodies* and again (under their expanded network) for the 2004 *Integrated List of Waterbodies.* Additional data is attached in the appendices at the end of the document.

Figures 3 and 4 illustrate the frequency of temperature violations and flow durations for the period of record, 1998 through 2001. Figure 3 indicates that about 83% of the time, a temperature of 68 degrees Fahrenheit will be equaled or exceeded at Macopin Reservoir. Figure 4 indicates that only 18% of the time a flow of 12 cfs is equaled or exceeded, despite the fact that the excess diversion flow rate in the City of Newark Water Allocation Permit is 12.3 cfs.

Figure 3 Temperature –Duration Curve 1998-2001 June to August

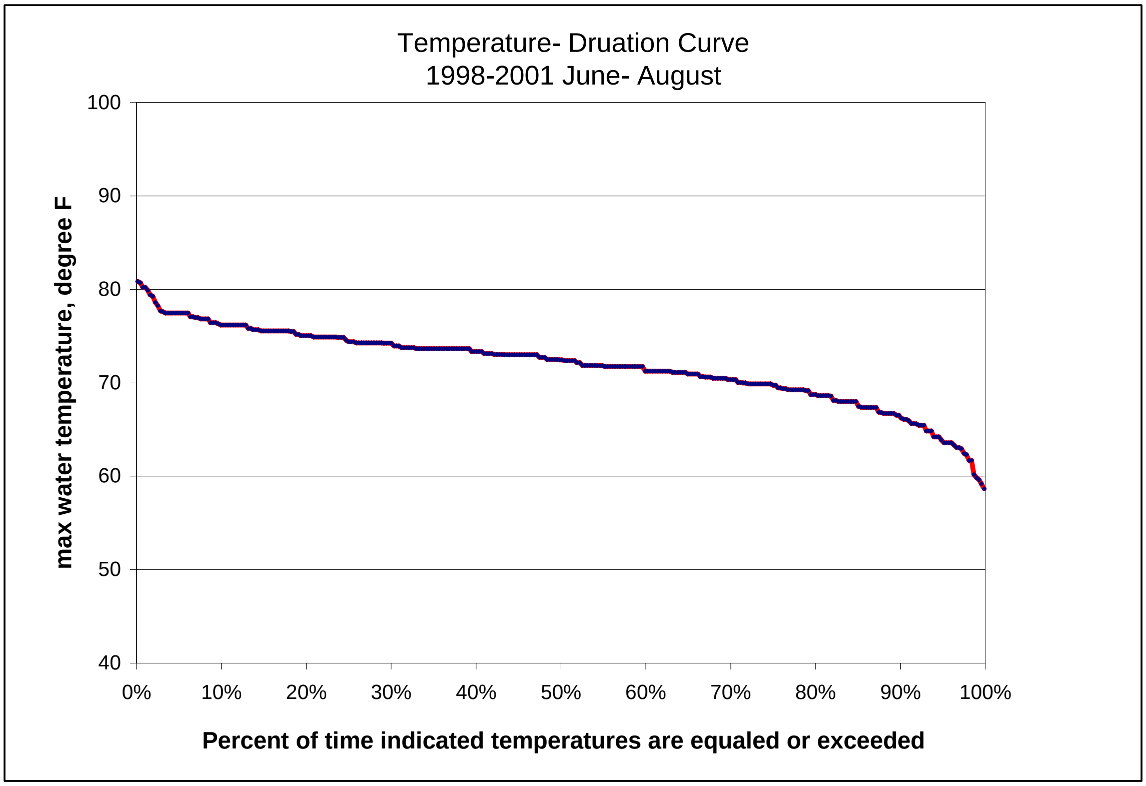
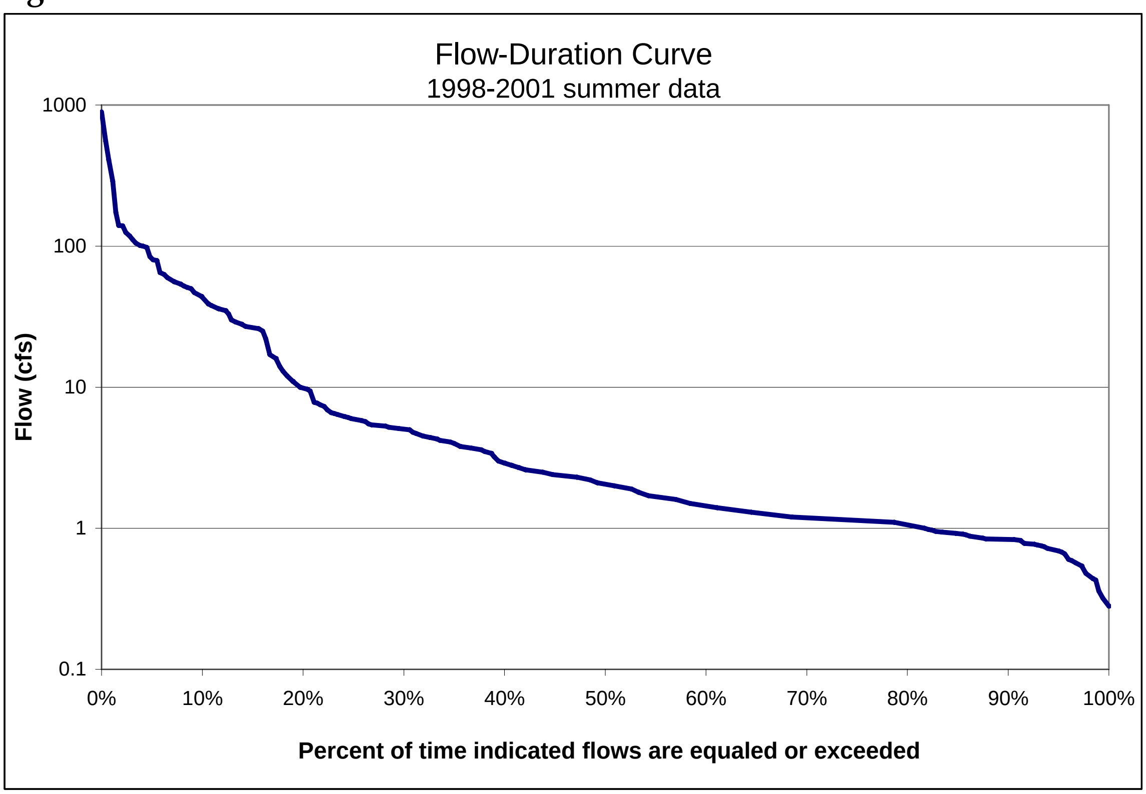


Figure 4 Flow –Duration Curve 1998-2001 Summer Data



Recent Pequannock River Fish Kills

Trout do best at temperatures of 52-68°F and temperatures higher than 78 can be lethal. The first documented and temperature related fish kill occurred on July 9-10, 1995. Water temperatures in excess of 83°F were measured at the Oak Ridge to Charlotteburg section of the Pequannock River. Dozens of dead trout and other fish were collected in this area.

The most recent fish kill occurred on July 3-4, 2002 in the same river section. Water temperatures reached a maximum of 80.8°F on July 3rd and 83.4°F on July 4th. A small number of dead trout and other fish were collected.

8.0 TMDL Calculations

Analytical Approach

There are two types of models used to predict stream temperatures: empirical models and physical models. An empirical model uses statistical techniques to discern patterns or relationships among measured data. Physical models try to model the underlying processes that affect stream temperature, such as solar radiation, conduction, convection, evaporation, advection, stream geometry, dispersion and other factors. Physical or mechanistic models require extensive data input. Examples of such models are Stream Segment Temperature Model (SSTEMP) or Stream Network Temperature Model (SNTEMP). The Department used multiple lines of analysis in these TMDLs. Regression and computational analyses established the significance of key variables with respect to observed temperature violations. SSTEMP was then used to establish the TMDLs in terms of temperature and flow.

Regression and Computational Analysis

The Department investigated the relationship between stream water temperatures, flow rate, and meteorological conditions (maximum air temperature and previous day average temperature) through correlations and regressions of measured data. An empirical regression model was developed based on the relationship between maximum water temperature, maximum air temperature, previous day average temperature and flow, using a total of 107 data points from summer 1999. In this system, water temperature is highly influenced by the operation of the reservoirs; therefore establishing a meaningful correlation between flow and water temperatures for the entire data set would require extensive data from the reservoir outlets. Lacking data sufficient to explain the non-steady state conditions, a data set that exhibited quasi-steady state conditions was used in the regression analysis. Data from summer 1999 (May 17-August 31), a total of 107 samples, served this purpose. An R^2 value of 0.94 was obtained when regressing maximum water temperature as a function of the following predictors: maximum air temperature, previous day average air temperature, and flow. Summer data for 2001 and 2002 also gave strong R^2 values, 0.78 and 0.89 respectively, but 1999 has the best correlation among predictors and maximum water temperature. Use of 1999 data for the regression is appropriate because:

- 1999 data is characterized by low flows and above average air temperature (in 1999 New Jersey had its third warmest summer in 105 years). The most critical flow rates are in the range of zero to 20 cfs (82% of summer flows are below 12 cfs). Including elevated air temperature in the model input expands the model predictability to cover a wide range of meteorological conditions (70 to 100^+ degrees F).
- Flow and temperature data for summer 1999 reached a quasi-steady state condition. Analyzing a steady state condition has several advantages: first, it better demonstrates correlations among parameters if they exist and second, under steady state conditions, a model will be able to predict more clearly the effect of flow on water temperature, isolating this variable, because, during summer 1999, Newark did not release water from the reservoirs, nor did the reservoirs overspill.

The regression approach has several advantages over physical models; for example, regression requires less input data and computation time. To complement this approach, a computational model was also used in the analysis. The input data for this model included all the data from 1998 through 2001. This aspect of the analysis investigated the impact of various minimum flow criteria on the number of days the maximum water temperature exceeded the temperature criteria. The strength of this approach is that computations are based on measured data, and are based on a longer period of record. Such a model was used in the Central Platte River, Nebraska as the basis for setting a minimum passing flow of 900 cfs to achieve compliance with water temperature criteria.

Regression Analysis

For the temperature/flow analyses, diurnal temperature data from Pequannock River Coalition (1998-2002), daily flow data from Macopin station, and air temperature data measured at Charlotteburg Reservoir ID # 281582 (Latitude 41.03 degrees, Longitude -74.42 degrees) by the National Climatic Data Center, NOAA (Refer to Appendix B).

Using a regression model, both linear and nonlinear regressions were explored; both approaches gave almost the same correlation, therefore the linear model was picked for simplicity and ease of application. The linear model has the following form:

$$T = a_0+a_1X_1+a_2 X_2+a_3X_3$$

Where:
T = max water temperature
X1=flow rate (cfs)
X2= max air temperature
X3= previous day average temperature
a0, a1, a2, a3 are constant coefficients

Water temperature data are available for a number of sites on the Pequannock River, and were collected during summer months since 1998. The only flow data available is at Macopin Reservoir, and no data is available on the operation of the reservoirs.
Data from year 1999 was selected to run the regression model for the reasons listed above. The regression model produces the following linear equation:

$$\mathbf{T_w = 25.12 - .223\ Q + .350\ T_a + .239\ T_{av}}$$

Where:
T_w= maximum water temperature
T_a= maximum air temperature
T_{av}= previous day average air temperature
Q = flow rate (cfs)

Solving for flow (Q), gives:

$$\mathbf{Q = 112.632 + 1.570\ T_a + 1.072\ T_{av} - 4.484\ T_w}$$

To provide a conservative foundation, the minimum flow requirement for temperature control should be determined based on critical conditions. For the period of record 1998-2002, the highest air temperature occurred on July 7, 1999.

T_a = 100 degree F (maximum air temperature)
T_{av} = 70 degree F (previous day average air temperature)
T_w = 68 degree F (water temperature standard)
Q = **40 cfs** (the required minimum flow)

The following required minimum flows are calculated based on air temperatures selected to represent an average condition and meeting the water temperature standard of 68 degrees F:
T_a = 83.1 degree F (average maximum air temperature during summer 1999)
T_{av} = 71.3 degree F (average temperature during summer 1999)
T_w = 68 degree F (water temperature standard)
Q = **14.6 cfs** (the required minimum flow)

Table 5 below summarizes the output of these analyses.

Table 5 SUMMARY

Regression Statistics		
Multiple R	0.970	
R Square	**0.941**	
Adjusted R Square	0.939	
Standard Error	1.302	
Observations	107.000	May 17-August 31

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	2793.642249	931.2141	549.3571	3.385E-63
Residual	103	174.5950799	1.695098		
Total	106	2968.237329			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	**25.117**	1.604	15.656	0.000	21.935	28.298
Flow (cfs)	**-0.223**	0.031	-7.071	0.000	-0.285	-0.160
Max air temperature at Charlottesburge	**0.350**	0.017	20.785	0.000	0.316	0.383
Previous day avg air temp	**0.239**	0.021	11.543	0.000	0.198	0.280

Figure 5: Temperature vs. Date

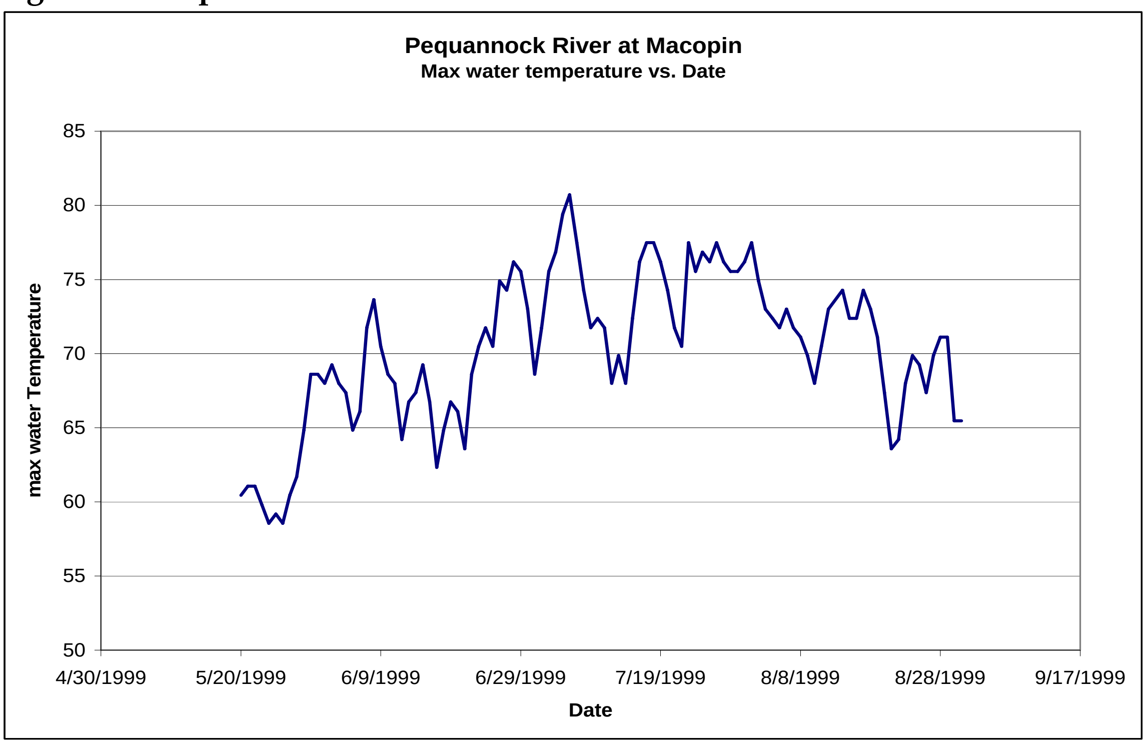
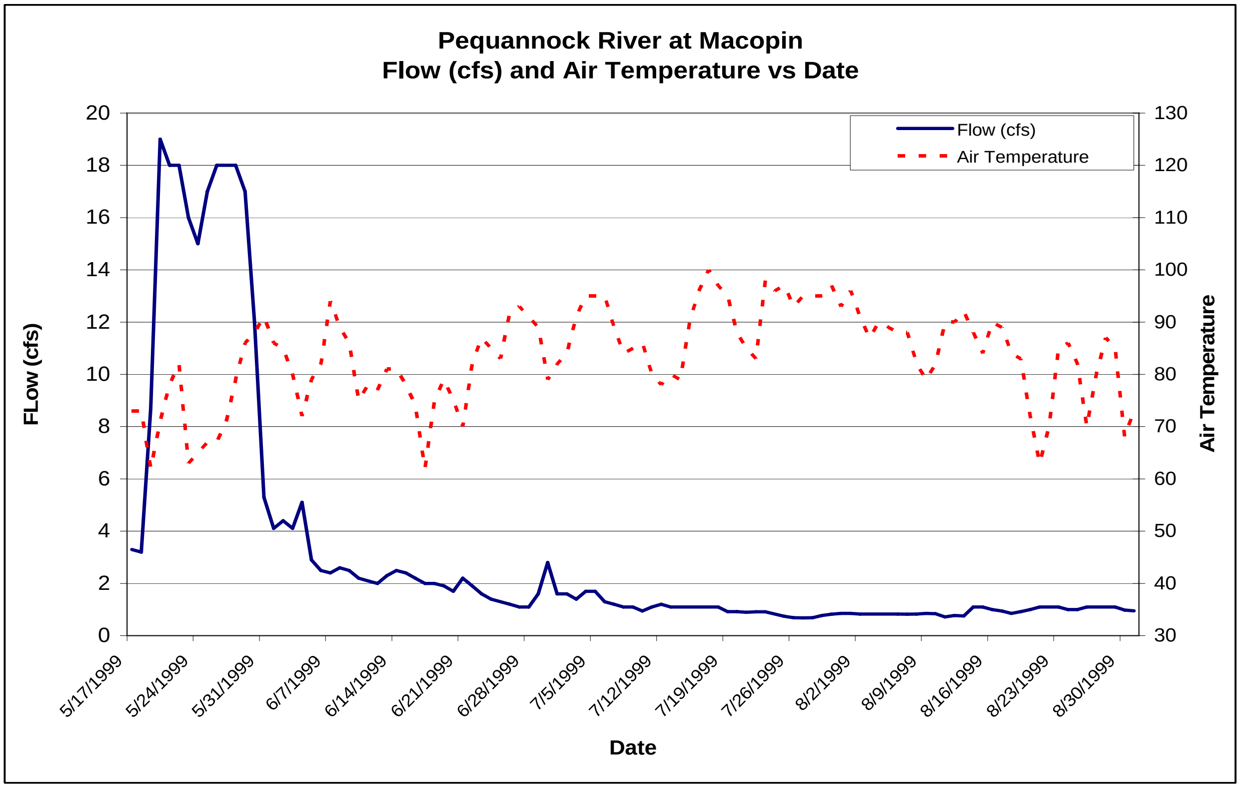


Figure 6: Flow, Air Temperature vs. Date



Figures 5 and 6 show the input data used in the regression with respect to date. Figures 7 through 12 are the outputs of the regression analysis. The line fit plots show that predictability of the model is very strong; this was expected based on the high value of R- square.

Figure 7 Measured Versus Predicted Maximum Water Temperature – Maximum Air Temperature at Charlotteburg Line Fit Plot

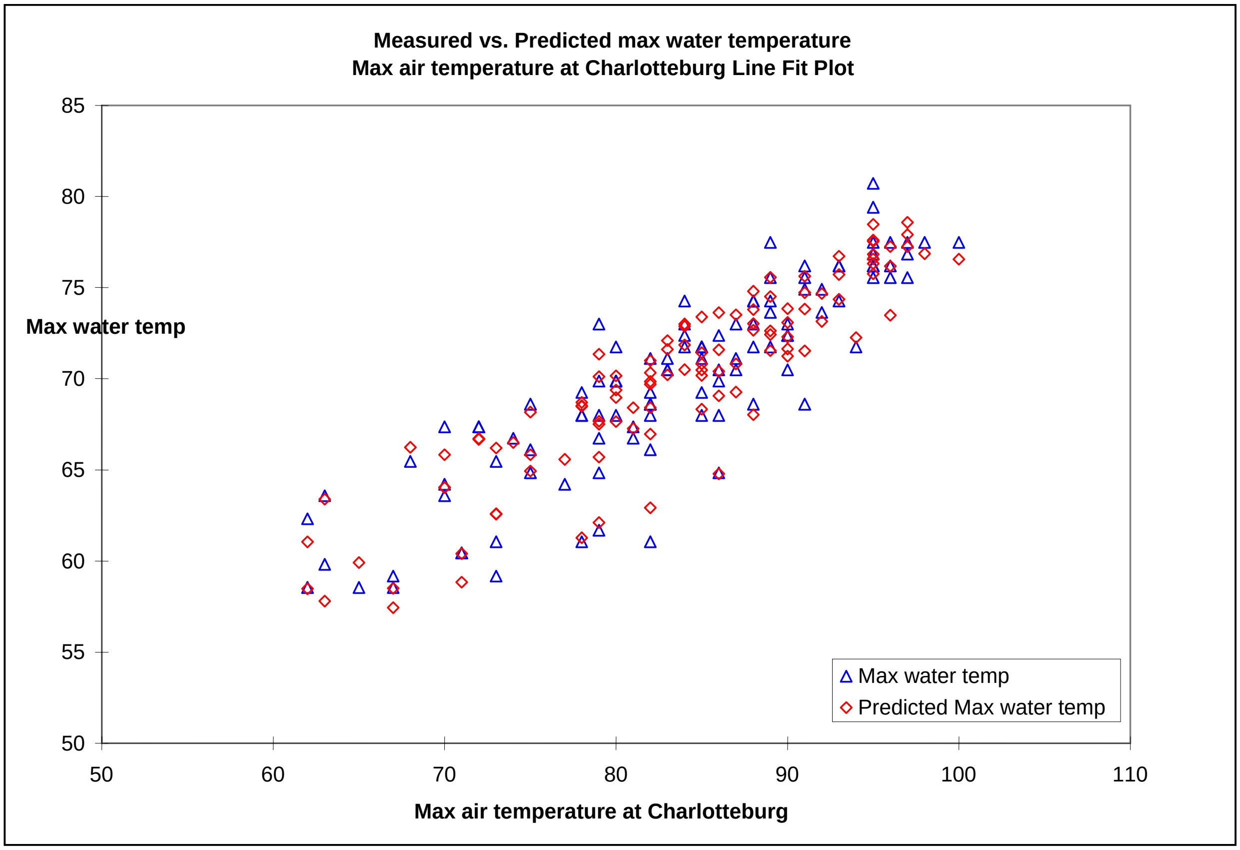


Figure 8 Measured Versus Predicted Maximum Water Temperature – Flow (cfs) Line Fit Plot

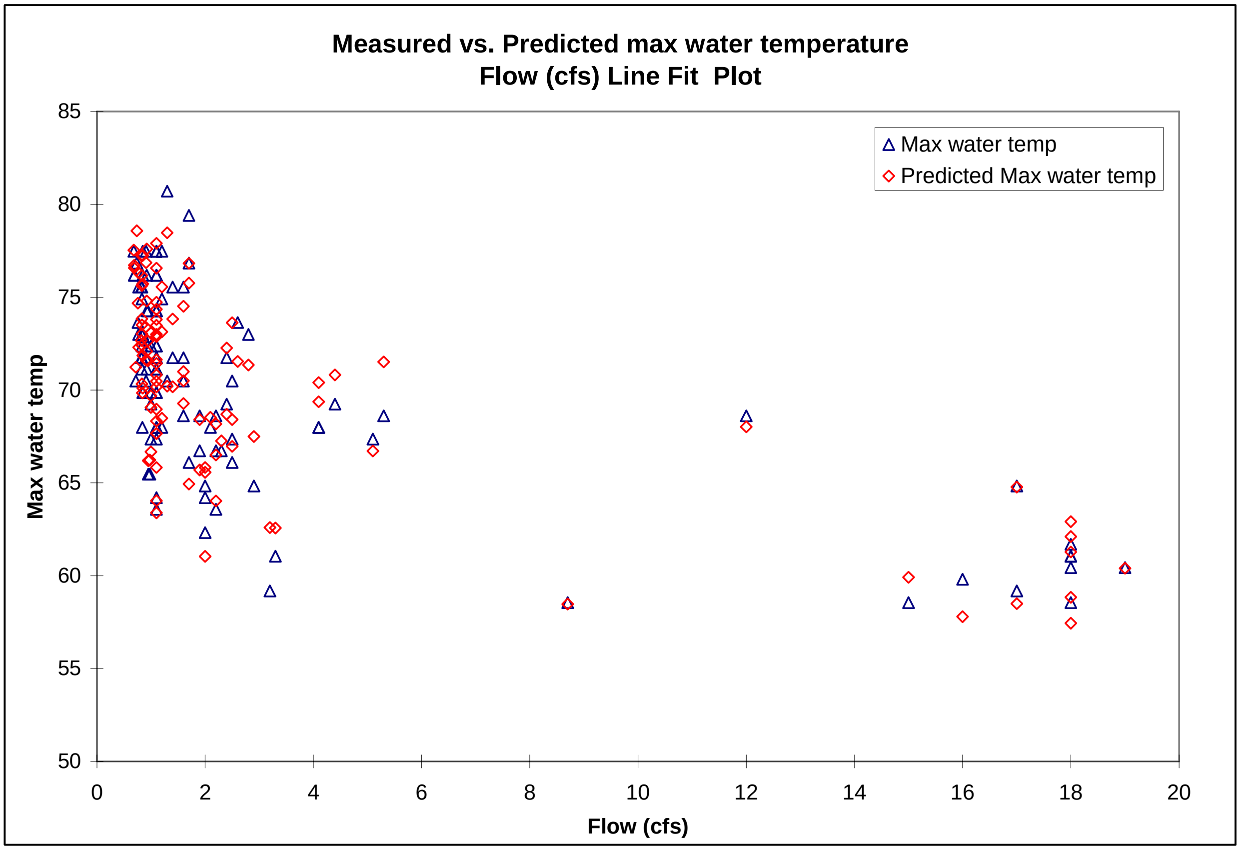


Figure 9 Measured Versus Predicted Maximum Water Temperature – Previous Day Average Air Temperature Line Fit Plot

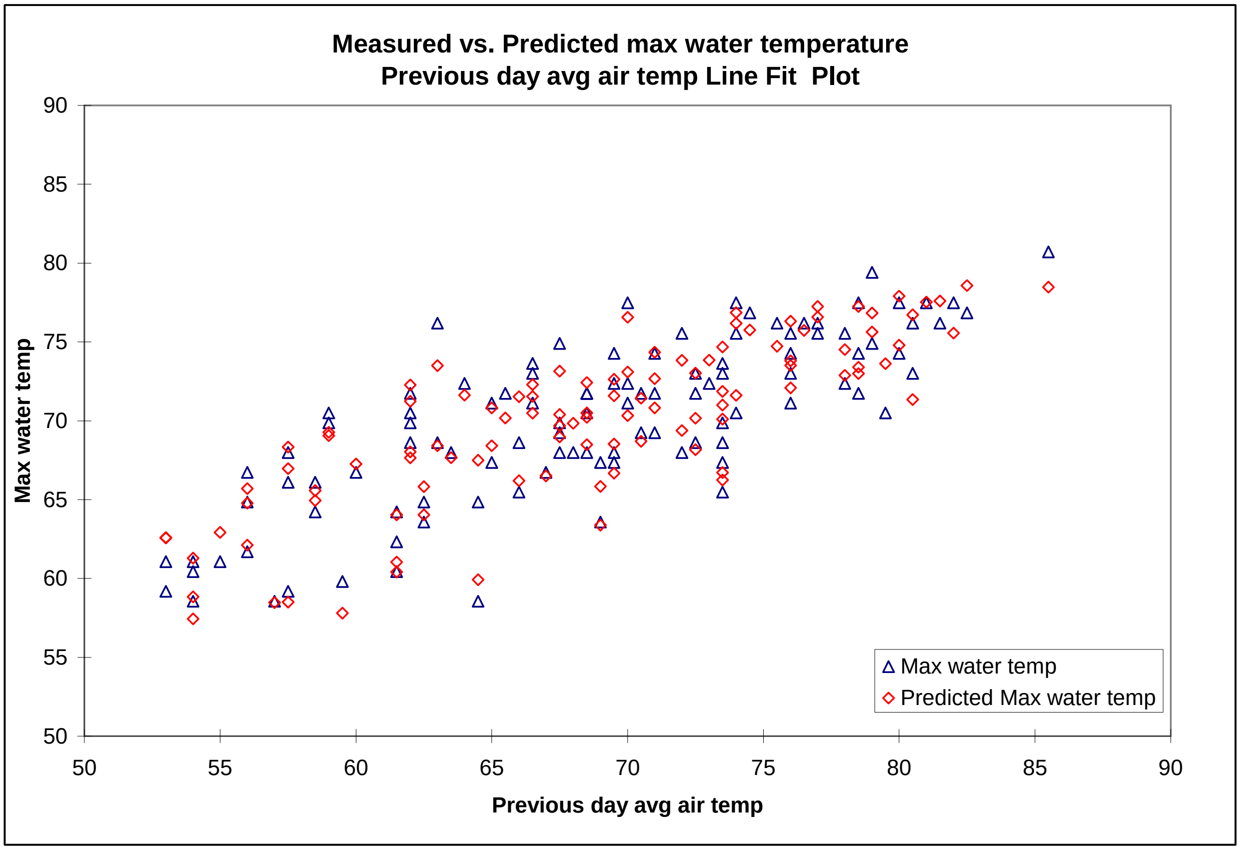


Figure 10 Flow (cfs) Residual Plot

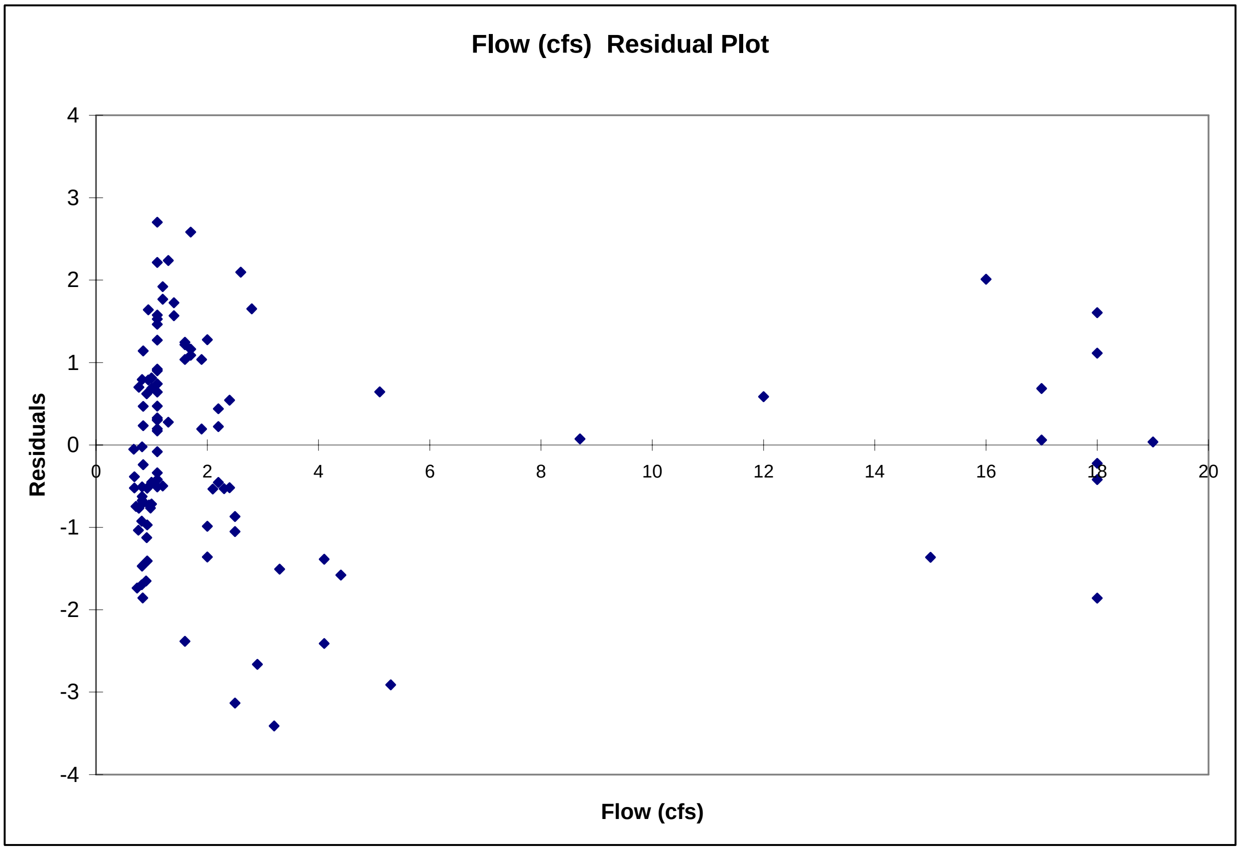


Figure 11 Previous Day Average Air Temperature Residual Plot

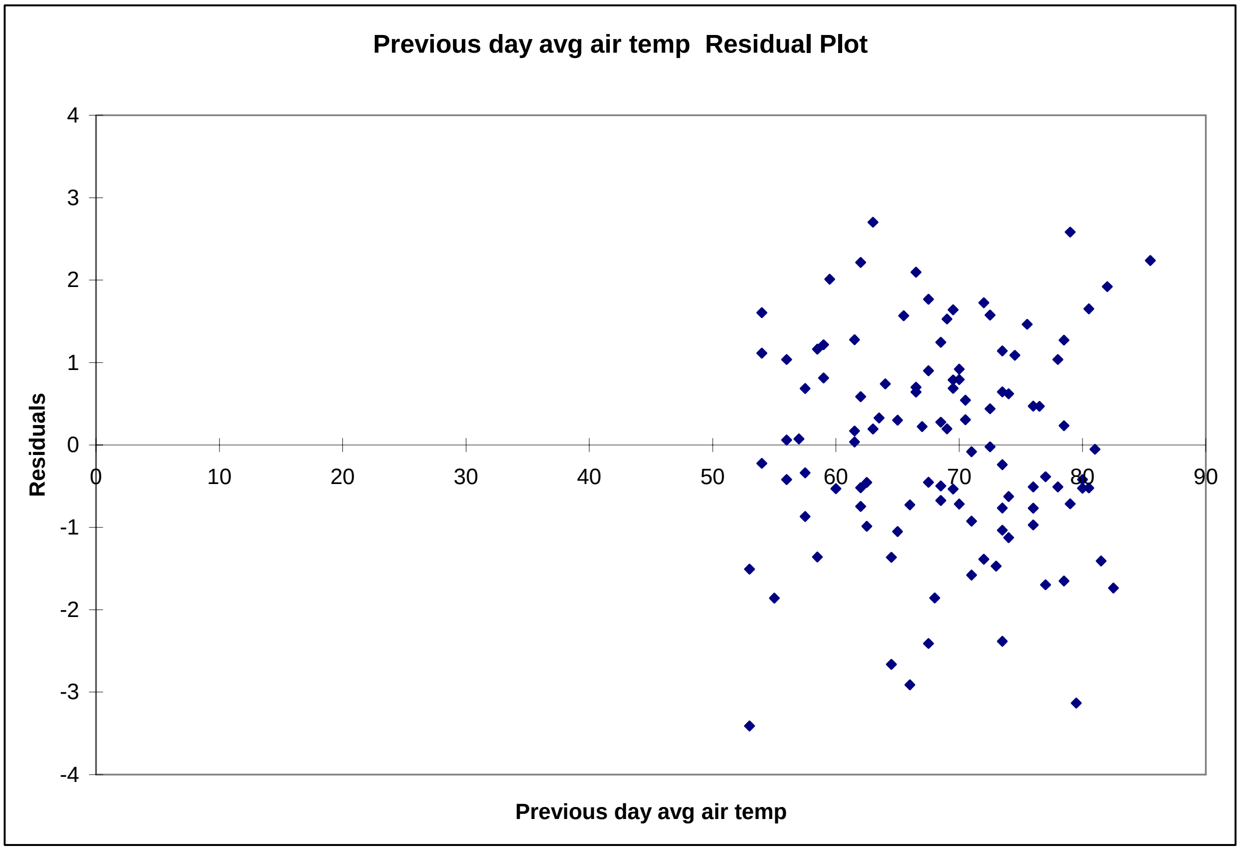
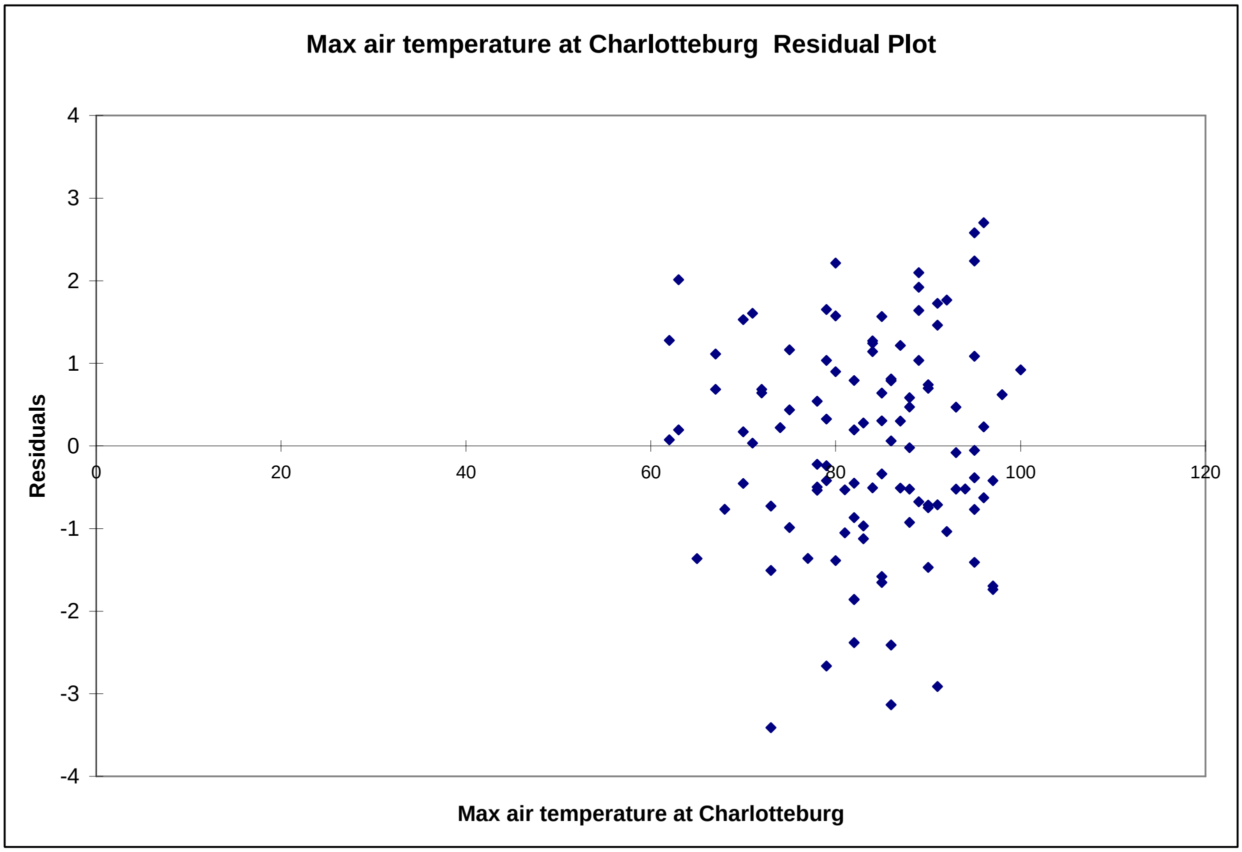


Figure 12 Maximum Air Temperature at Charlotteburg Residual Plot

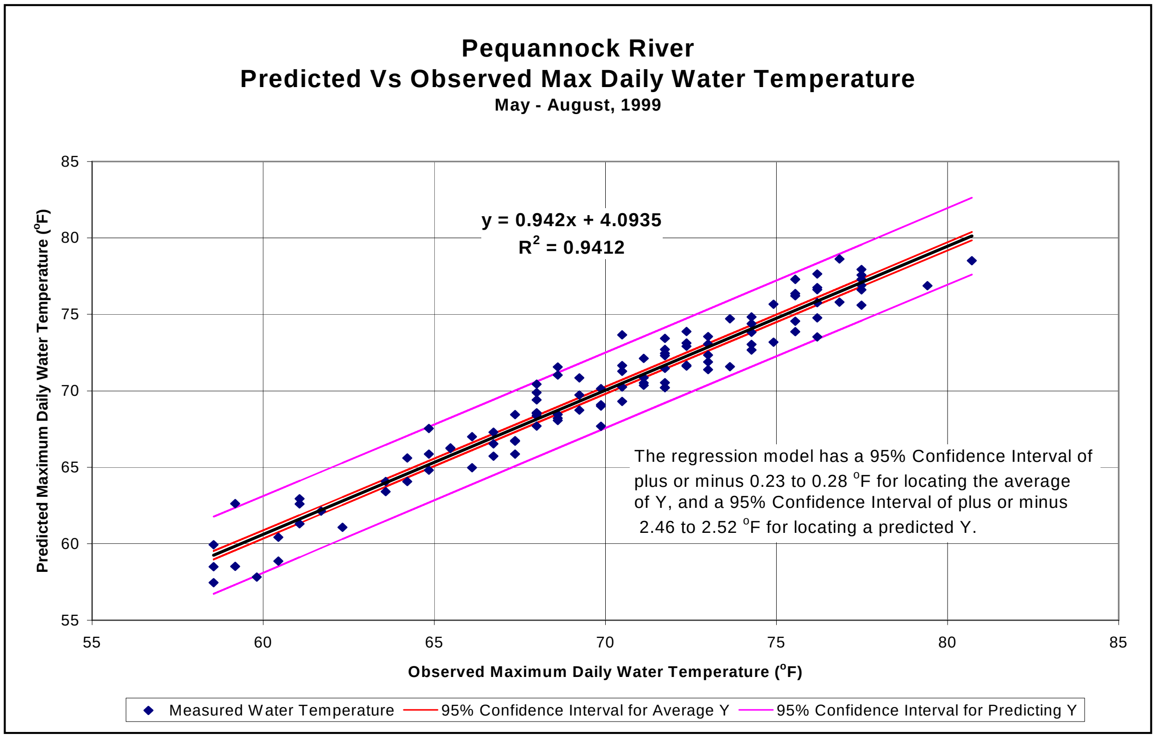


Regression Model Validations

Predicted versus observed maximum daily water temperature regression and multiple-regression residuals:

The predicted maximum daily water temperature from the linear regression equation versus the historical maximum daily water temperatures at Macopin is illustrated in the Figure 13. The coefficient of determination, R^2, is 0.94. A perfect linear relationship between the predicted and observed values would present an R^2 of 1.0 for a positive gradient. Therefore, an R^2 of 0.94 represents a very good prediction capability of the multiple regressions for estimating a maximum daily water temperature. Confidence intervals for the mean of the predicted maximum daily water temperature (Y) and for the prediction of an individual Y were also plotted. The parallel bounds on the regression line represent a 95 percent confidence for locating the average Y between plus or minus 0.28^{o} F and for locating an individual Y between plus or minus 2.52^{o} F. This represents a very good fit of the data about the regression line (minimal residuals).

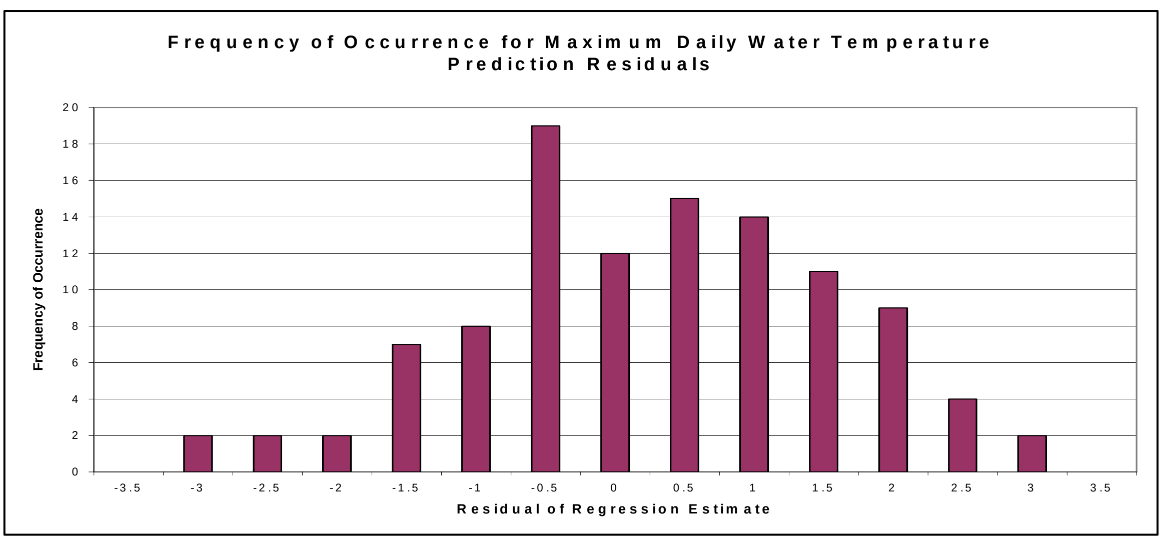
Figure 13 Linear relationship between a predicted and observed maximum daily water temperature at Macopin Reservoir using the multiple-regression model.



Model Diagnostic:

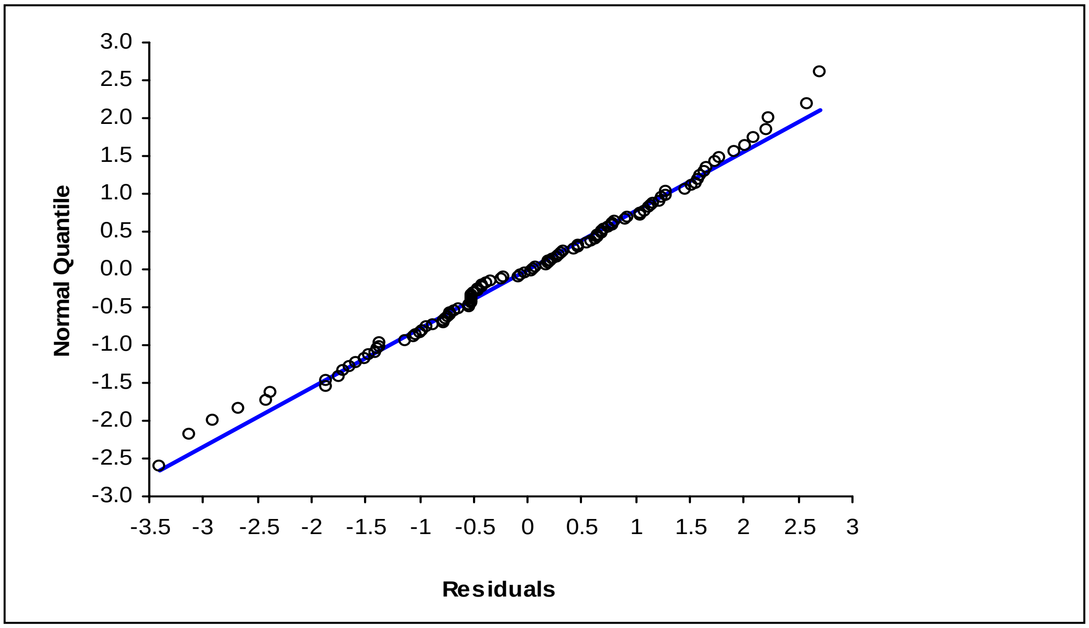
The frequency of occurrence of the residual for maximum daily water temperature in the multiple-regression model is illustrated in Figure 14 below:

Figure 14, Frequency of regression residuals for maximum daily water temperature.



The normal quantiles of a cumulative frequency distribution were plotted against the residuals in Figure 15. The plot shows that the residuals closely follow the straight line, indicating a normal distribution. Normality of the distribution was also tested with a Shapiro-Wilk W, skewness, and kurtosis test. Results of these tests are presented in Table 6. A "p" value that approaches zero for the Shapiro-Wilk W would indicate a greater potential for a non-normal distribution. The p value is half way between zero and one, thus indicating a more normal distribution. Results from the skewness and kurtosis tests indicate a slight left-tail skew and a more peaked distribution (more values grouped around the mean than in the tails) as shown in Figure 14.

Figure 15 Normal Quantiles versus Residuals to test normality. The better the fit to the straight line the more normal the distribution.



Test statistics for characterizing a data distribution. The greater the p value the more likely is the test characteristic.

Table 6

Test Statistic	Coefficient	p
Shapiro-Wilk	0.9891	0.5459
Skewness	-0.2640	0.2500
Kurtosis	-0.1783	0.7989

Computational Analysis

Based on the regression analysis, flow and temperature data show a strong correlation between minimum passing flow and the occurrence of maximum water temperature exceeding the threshold of 68 degrees Fahrenheit. The graph below shows that, as the flow increases, the occurrence of high water temperature tends to decrease, and the decrease is exponential up to a flow of about 10 cfs. This is significant in the selection of the passing flow at the Macopin station in light of historic water allocation permit conditions.

In 1907, the State and General Assembly of the State of New Jersey created the State Water Supply Commission, and established the conditions under which waters of the State may be diverted (Laws, Session of 1907, Chapter 252). Within these conditions was a requirement for fees, payable to the State of New Jersey, for water diversions. The diversion rates were determined based the amount of water which remained in the stream and was allowed to flow downstream from the point of diversion.

As described in this legislation, the minimum flow downstream of the diversion could either be based on actual records (equal to the average daily flow for the driest month), or could be calculated using a standard figure applied to the watershed in question. In order to calculate the anticipated flow downstream of the diversion, a flow rate of 125,000 gallons per day (0.125 MGD) was multiplied by the square mileage of the watershed upstream from that diversion.

Using this method, a flow of 12.3 cfs has been historically used as the minimum flow for the Pequannock River Watershed below the Macopin Reservoir, which is where the City of Newark Reservoir System terminates. The 12.3 cfs was reinstated in the Department's current water allocation permit issued to the City of Newark.

The calculation is as follows:

The Pequannock River Watershed is a total of 63.7 sq miles.

(63.7 sq miles) (.125 MGD) = 7.96 MGD

(7.96 MGD) (1.55)* = 12.3 cfs

* standard conversion factor for converting MGD to cfs.

Setting a minimum passing flow of 12.3 cfs at Macopin, based on watershed area ratios, the following passing flows at the other reservoirs are calculated:

a) Charlotteburg Reservoir outlet: 88% of Macopin flow;

b) Oak Ridge Reservoir outlet: 43% of Macopin flow;

c) Clinton Reservoir outlet: 17% of Macopin flow;

d) Canistear Reservoir outlet: 10% of Macopin flow;

e) Echo Lake outlet: 7% of Macopin flow.

Figure 16

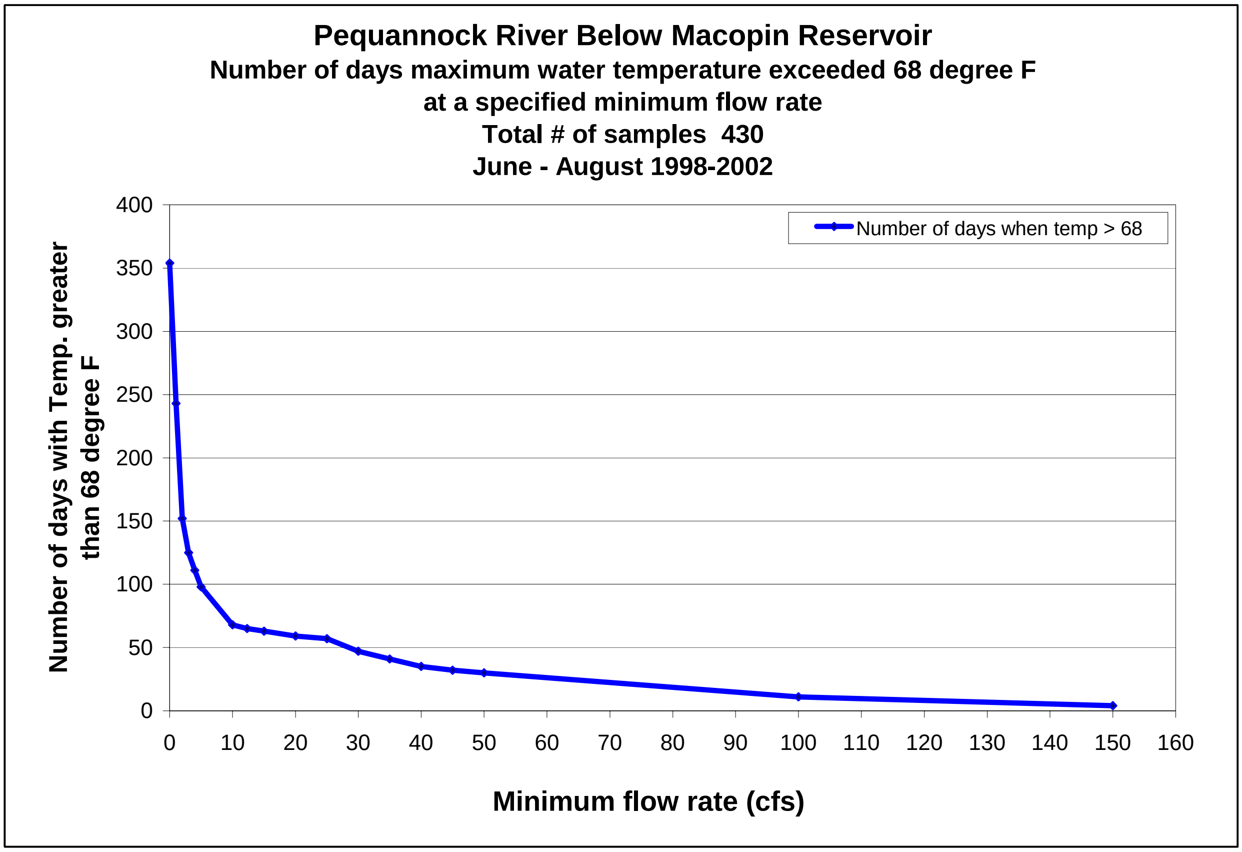


Table 7

Minimum flow rate (cfs)	No min. flow	1	2	3	4	5	10	12.3	15	20	25	30	35	40	45	50	100	150
Number of days when temp > 68	354	243	152	125	111	98	68	65	63	59	57	47	41	35	32	30	11	4
Percent of violations based on the entire record 430 days	82%	57%	35%	29%	26%	23%	16%	15%	15%	14%	13%	11%	10%	8%	7%	7%	3%	1%
Percent reduction from total # of violations	0%	31%	57%	65%	69%	72%	81%	82%	82%	83%	84%	87%	88%	90%	91%	92%	97%	99%

Figure 16 and Table 7 illustrate the number of exceedances of the 68° F criterion at various minimum passing flows, the percent of days in violation of the standard, and the estimated percent reduction based on the total number of violations predicted at the flow. Exceedances above the 68° F criterion decrease at a significant rate between minimum flows of 0.1 and about 10 cfs; at flow rates higher than 10 cfs the decrease approaches a constant rate. When no minimum flow is set, a total number of 354 violations occurred. At a minimum stream flow of 12.3 cfs, the number of violations is reduced to 65, which equals an 82% reduction achieved; with a minimum flow of 20 cfs, an 83% reduction is achieved. Figure 16 shows that a close to constant reduction occurs between the minimum flows of 10 and 25 cfs.

SSTEMP model

Finally, SSTEMP was used to calculate a release temperature based on a constant minimum outflow from the reservoirs that will meet water quality standards at a specific point downstream. By running the SSTEMP model under different hydrological variables, it is possible to estimate the flow at which the temperature criteria will be violated. The basic equations and mechanics governing this model are identical to those in the full version model, Stream Network Temperature Model (SNTEMP), except that SSTEMP model can only simulate temperature in a single segment. A brief description of SSTEMP follows:

> In general terms, SSTEMP calculates the heat gained or lost from a parcel of water as it passes through a stream segment. This is accomplished by simulating the various heat flux processes that determine that temperature change. These physical processes include convection, conduction, evaporation, as well as heat to or from the air (long wave radiation), direct solar radiation (short wave), and radiation back from the water. SSTEMP first calculates the solar radiation and how much is intercepted by (optional) shading. This is followed by calculations of the remaining heat flux components for the stream segment. The details are just that: To calculate solar radiation, SSTEMP computes the radiation at the outer edge of the earth's atmosphere. This radiation is passed through the attenuating effects of the atmosphere and finally reflects off the water's surface depending on the angle of the sun. For shading, SSTEMP computes the day length for the level plain case, i.e., as if there were no local topographic influence. Next, sunrise and sunset times are computed by factoring in local east and Westside topography. Thus, the local topography results in a percentage decrease in the level plain daylight hours. From this local sunrise/sunset, the program computes the percentage of light that is filtered out by the riparian vegetation. This filtering is the result of the size, position and density of the shadow-casting vegetation on both sides of the stream. (Stream Segment

Temperature Model (SSTEMP) Version 2.0 Revised August 2002, by John Bartholow, USGS).

A brief summary of input data required to run this model may include the following:

- Hydrological variables (e.g. flow and temperature data)
- Geometry variables (e.g. Latitude, segment length, elevation, segment width, cross section area, Manning's number, width versus flow data)
- Time of the year
- Meteorological data (e.g. air temperature, ground temperature, relative humidity, wind speed, thermal gradient, possible sun %, dust coefficient
- Shade variable (e.g. Segment Azimuth, topographic altitude, vegetations height, density, and offset)

SSTEMP was used to calculate the TMDLs for the impaired segments that are under the influence of the reservoir system, which include PQ3, PQ4, PQ5, PQ6, 01382410, PQ7, PQ8, and PQ16, using best available information. However, much of the information bears verification. Obtaining additional data to verify or refine the results for these segments and to extend the application to include remaining segments is planned as Phase 2 TMDLs for temperature impairment in the watershed.

Seasonal Variation, Critical Conditions and MOS

A TMDL must account for critical conditions and seasonal variations. To address critical conditions and seasonal variation, the analysis was based on the most critical condition in the period of record and considers data from May to October, the critical season of each year.

A TMDL must also include a margin of safety to deal with uncertainty. The MOS can be implicitly incorporated through the use of conservative assumptions or explicitly specified. When applying the SSTEMP model, described in "Allocation of Load," to determine flow required to achieve the in-stream criterion, an explicit margin of 0.3 ^{o} F was applied to account for model uncertainty, therefore, model temperature output must not exceed 67.7 ^{o} F.

Measures included in the implementation plan provide a degree of conservativism. Because the selection of passing flow has implications for water supply, it is important not to set a passing flow that is higher than needed to address the impairment. Based on the regression analysis, the rate of improvement in compliance with the temperature criterion drops off dramatically after 10 cfs at Macopin. Setting the passing flow at 12.3 cfs at Macopin in the water allocation permit provides a safety factor. The reservoir management plan, discussed previously, is required to be developed through Newark's water allocation permit (Permit No. 5123), which was renewed in 2004. As a condition of the permit, Newark is required to submit an operating plan for Departmental approval describing how a stream temperature of less than 68° F will be maintained from May 1st to October 1st of each year below the outlet of Oak Ridge Reservoir. The plan is to include an alert temperature of 65° F that will trigger action to ensure temperature does not exceed 68° F. The plan is to be expanded to include the other reservoirs by 2007.

<u>Results of SSTEMP segment analysis</u>

The SSTEMP model application assumes meteorological conditions that represent a critical condition, including average maximum high temperature, and sunny conditions; and physical data that was derived from a survey of the riparian conditions in the watershed and GIS coverage. For each segment, SSTEMP was run using existing vegetative cover conditions and then again with improved riparian buffer shading to determine the degree to which this measure could affect the outcome. The SSTEMP outputs and temperature data are included in Appendix C.

Stream reach between Canistear and Oak Ridge Reservoirs (PQ3)
Assuming existing vegetative cover conditions, SSTEMP predicts a temperature of 71.02 degrees F at Oak Ridge Reservoir. In order to achieve the in-stream standard of 68.0 degrees F, the load allocation to Canistear Reservoir discharge, given in terms of minimum passing flow and discharge temperature, the discharge temperature must not exceed 65 degrees F based on a flow of 6.3 cfs and in-stream temperature of 67.7 degrees F (68 degrees F - MOS). Under the revised conditions and improving vegetation cover, the model predicts mean daily temperature of 66.18 degrees F, and a maximum temperature of 67.67 degrees F at segment outflow.

Stream reach between Oak Ridge and Charlotteburg (PQ4 and PQ5)
Assuming existing vegetative cover conditions, SSTEMP predicts a temperature of 72.59 degrees F at Charlotteburg. In order to achieve the in-stream standard of 68.0 degrees F, the load allocation to Oak Ridge Reservoir discharge, given in terms of minimum passing flow and discharge temperature, the discharge temperature must not exceed 63 degrees F based on a flow of 6.3 cfs and in-stream temperature of 67.7 degrees F. Under the revised conditions and improving vegetation cover, the model predicts mean daily temperature of 66.07 degrees F, and a maximum temperature of 67.60 degrees F at the segment outflow.

Stream reach between Echo Lake and Pequannock (PQ6 and 01382410)
Based on existing conditions, SSTEMP predicts a temperature of 73.21 degrees F at the confluence of Macopin and Pequannock Rivers. In order to achieve the in-stream standard of 68.0 degrees F, the load allocation to Echo Lake, given in terms of minimum

passing flow and discharge temperature, the discharge temperature must not exceed 66^{o} F based on a flow of 1.5 cfs and in-stream temperature of 67.7 degrees F (68 degrees F - MOS). Under the revised conditions and improving vegetation cover, the model predicts mean daily temperature of 66.66 degrees F, and a maximum temperature of 67.68 degrees F at the segment outflow.

Stream reach between Clinton Reservoir and Pequannock (PQ16)
Based on existing conditions, SSTEMP predicts a maximum temperature of 72.04 degrees F. In order to achieve the in-stream standard of 68.0 degrees F, the load allocation to Clinton Reservoir, given in terms of minimum passing flow and discharge temperature, must not exceed 65 degrees F based on a flow of 4.0 cfs and in-stream temperature of 67.7 degrees F (68 degrees F - MOS). Under the revised conditions and improving vegetation cover, the model predicts mean daily temperature of 66.66 degrees F, and a maximum temperature of 67.50 degrees F at the segment outflow.

Stream reach between Charlotteburg and Macopin (PQ7, PQ8)
Assuming flow and temperature boundary conditions at the outlet of the reservoir (flow of 10.8 cfs at 67 degrees F) and existing shading variables, the model output suggested that a mean daily temperature 67.53 degrees F, and a maximum temperature of 68.47 degrees F. In order to achieve the in-stream standard of 68.0 degrees F, the load allocation to Charlotteburg Reservoir discharge, given in terms of minimum passing flow and discharge temperature, the discharge temperature must not exceed 67 degrees F based on a flow of 10.8 cfs and in-stream temperature of 67.7 degrees F (68 degrees F - MOS). Under the revised conditions and improving the vegetation cover, the model predicts mean daily temperature of 67.06 degrees F, and a maximum temperature of 67.60 degrees F at segment outflow.

SSTEMP could not be used for segment ID PQ1 because the starting temperature could not be known.

<u>PQ1:</u> Temperature data were evaluated and the highest recorded temperature was almost 77 degrees F. To attain the loading capacity of 68 degrees F, the heating due to beaver effects would have to be reduced by 9 degrees. The implementation plan identifies measures underway or planned that will be taken to address this load reduction. If it is determined through follow-up monitoring that the load reduction is not achieved, then additional measures or site specific criteria will need to be considered.

Allocation of Load

The loading capacity of the waterbodies for these TMDLs is expressed in terms of the maximum temperature, 68 degrees F. The relative contribution of the key sources in causing exceedances of this maximum was estimated. The degree to which low flow was responsible for violations was first estimated. In 1999, 72% of the stream temperature data exceeded the temperature criterion. Summer 1999 represented a particularly dry and unusually warm summer when there were no releases or overspill at the reservoir dams. To assess the significance of runoff effects during this period, rainfall events were considered. In 1999 precipitation was sparse; only 8 out of the 104 days for which there is stream temperature data had rainfall greater than 0.25 inch/day. On only 4 of those days (50%), was the stream temperature criterion exceeded. There were 14 days in which rainfall was greater than 0.1 inch/day, the minimum amount of rainfall likely to create runoff. Of those days, 6 (42%) exceeded the temperature criterion. It is reasonable to assign 72% of the violations to the low flow source of temperature violations. To assess the percent contribution of other sources, non-drought years 1998, 2000 and 2001 were evaluated. In these years, 86% of the data exceeded the stream temperature criterion. In these years, violations would be attributed to all sources: normal heating from air and sun, low flow, beaver effects, stormwater, and overspill of heated top water. The difference, 86% -72% or 14% of the temperature exceedances, is attributed to sources other than low flow.

Figure 17

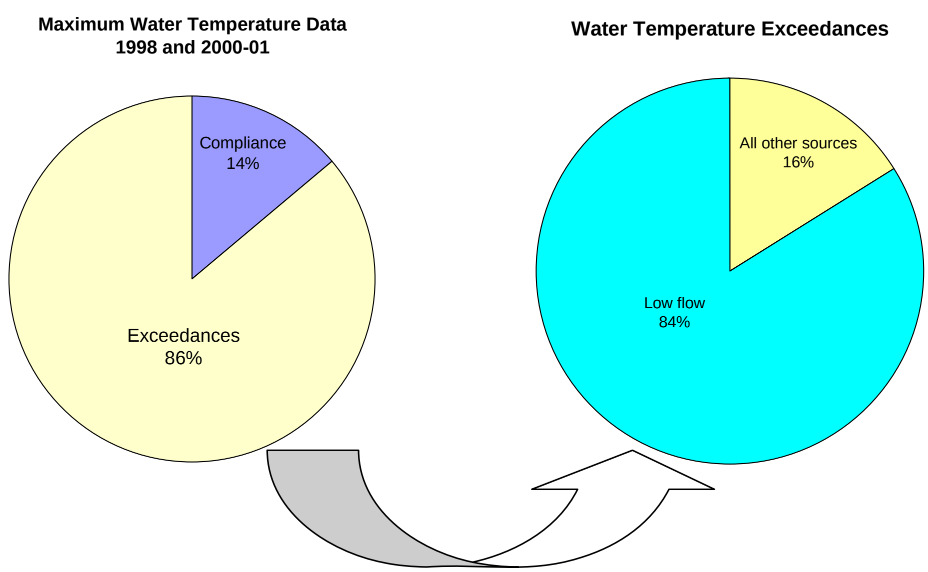


Figure 17 illustrates the percent exceedances observed, and the distribution of the percent exceedances among sources: low flow and all other sources. It is concluded that 84% of the exceedances are caused by low flow, whereas 16% of exceedances are caused by all other sources.

The effect of reservoir overspill is important. Although summer 1999 air temperatures data were the highest within the 1998 through 2002 summer data, it had the least number of water temperature violations. Only 72% of the data exceeded the water temperature criteria of 68 degrees F compared to 85% for 1998, 86% for 2000, 86% for 2001, 82% for 2002, and an average of 86% violations for the entire set 1998-2002 data. The relative contribution of the various remaining heating sources is not known.

Summary of Load Allocation

Wasteload Allocation = 0

- Wastewater and industrial stormwater dischargers are de minimus.
- Urban stormwater (MS4s) is de minimus.

Load Allocation

- Groundwater is de minimus.
- Agricultural and other non-point source runoff are de minimus.
- Reservoir releases:

The load allocation for reservoirs, given as a maximum outflow temperature and minimum release flow, was calculated for each reservoir based on meeting the 67.7 degrees F target (68 degrees F - MOS) at a downstream control point. By achieving the standard at the control point it is assumed that the in-stream standard of 68.0 degrees F will be met for the entire length of the segment. Options for achieving the load will be explored in the implementation plan. The reservoir load allocations are as follows:

Table 8: Reservoir Results

	Flow (cfs)	Temperature (^{o} F)	Downstream Control Point
Canistear Reservoir	6.3	65.0	Entrance to the Oak Ridge Res.
Oak Ridge Reservoir	6.3	63.0	Entrance to the Charlotteburg Reservoir
Echo Lake	1.5	66.0	Confluence of Macopin and Pequannock Rivers
Clinton Reservoir	4.0	65.0	Confluence of Clinton Br. and Pequannock Rivers
Charlotteburg Reservoir	10.8	67.0	Confluence of Pompton and Pequannock Rivers

Margin of Safety = 0.3^{o} F

Point sources were found to be de minimus sources of heat added to the system, based on best available information. Therefore, the Wasteload Allocation component of the TMDL is zero. However, to verify that these sources are de minimus, monitoring of flow and temperature of the effluent and the receiving water from both directly above and below each facility's outfall(s) is needed. Permits will need to be modified to require ambient stream and effluent monitoring to quantify the effect. If a given facility is found to contribute to the temperature impairment of an associated segment, changes in permit conditions will be addressed through an adaptive management process.

In order to achieve the percent reduction in violations assigned to reservoir effects, i.e., base flow modification and overspill, both minimum flow requirements and a Reservoir Management Plan will be needed. The first task is to adhere to the minimum passing flow requirement of 5 cfs at Oak Ridge and 12.3 cfs at Macopin for the summer months. Second, a Reservoir Management Plan will be required for active reservoirs, to set forth the means to achieve the performance standard: water temperature should not exceed 68 degrees F or a temperature deviation of more than 1 degree Fahrenheit from the ambient temperature, absent reservoir effects, downstream from any reservoir outlet. This will require balancing the volume of overspill water with cooler bottom releases as needed. A temperature probe will be installed at an appropriate distance from each reservoir outlet to provide feedback to ensure that the right mixture of top and bottom reservoir waters have been released to comply with the temperature criteria at the monitoring locations. The plan will be piloted at Oak Ridge, then expanded to the other reservoirs by 2007, considering any effect on safe yield. These measures have been included in the Department's recently issued water allocation permit for the City of Newark.

9.0 Implementation Plan

Management Strategies

Management measures are "economically achievable measures for the control of the addition of pollutants from existing and new categories and classes of nonpoint and stormwater sources of pollution, which reflect the greatest degree of pollutant reduction achievable through the application of the best available nonpoint and stormwater source pollution control practices, technologies, processes, citing criteria, operating methods, or other alternatives" (USEPA, 1993). A combination of best management practices and direct remedies of sources will be used to implement these TMDLs. Several overall approaches to addressing nonpoint source impairment from reservoir effects, stormwater and deficient riparian vegetation are discussed below, followed by specific planned and ongoing short-term and long-term management strategies.

Stormwater

On February 2, 2004 the Department promulgated two sets of stormwater rules: The Phase II New Jersey Pollutant Discharge Elimination System (NJPDES) Stormwater Rules, N.J.A.C. 7:14A and the Stormwater Management Rules, N.J.A.C. 7:8

Phase II Stormwater Permit Rules

The Phase II NJPDES Stormwater rules require municipalities, counties, highway systems, and large public complexes to develop stormwater management programs consistent with the NJPDES permit requirements. The stormwater discharged through "municipal separate storm sewer systems" (MS4s) will be regulated under the Department's Phase II NJPDES stormwater rules. Under these rules and associated general permits, the municipalities (and various county, State, and other agencies) in the Pequannock River Watershed will be required to implement various control measures. These control measures include adoption and enforcement of pet waste disposal ordinances, prohibiting the feeding of unconfined wildlife on public property, cleaning catch basins, performing good housekeeping at maintenance yards, and providing related public education and employee training. Follow up monitoring may determine that additional measures are required, which would then be incorporated into Phase II permits. Additional measures that may be considered may include, where feasible, retrofit of stormwater management facilities to include shading of detention facilities, conversion to bioretention facilities, or reconfiguring to allow non-erosive, distributed flow to be discharged through vegetated stream buffers. .

Stormwater Management Rules

The Stormwater Management Rules have been updated for the first time since their original adoption in 1983. These rules establish statewide minimum standards for stormwater management in new development, and the ability to analyze and establish region-specific performance standards targeted to the impairments and other stormwater runoff related issues within a particular drainage basin through regional stormwater management plans. The Stormwater Management rules are currently implemented through the Residential Site Improvement Standards (RSIS) and the Department's Land Use Regulation Program (LURP) in the review of permits such as freshwater wetlands, stream encroachment, CAFRA, and Waterfront Development.

The Stormwater Management Rules focus on the prevention and minimization of stormwater runoff and pollutants in the management of stormwater. The rules require every project to evaluate methods to prevent pollutants from becoming available to stormwater runoff and to design the project to minimize runoff impacts from new development through better site design, also known as low impact development. Some of the issues that are required to be assessed for the site are the maintenance of existing vegetation, minimizing and disconnecting impervious surfaces, and pollution prevention techniques. In addition, performance standards are established to address existing groundwater that contributes to baseflow and aquifers, to prevent increases to flooding and erosion, and to provide water quality treatment through stormwater management measures for TSS and nutrients.

As part of the requirement under the NJPDES Phase II program, municipalities are required to adopt and implement municipal stormwater management plans and stormwater control ordinances consistent with the requirements of the stormwater management rules. As such, in addition to changes in the design of projects regulated through the RSIS and LURP, municipalities will also be updating their regulatory requirements to provide the additional protections in the stormwater management rules within approximately two years of the issuance of the NJPDES General Permit Authorization.

Furthermore, the New Jersey Stormwater Management rules establish a 300-foot special water resource protection area (SWRPA) around Category One (C1) waterbodies and their intermittent and perennial tributaries, within the HUC14 subwatershed. In the SWRPA, new development is typically limited to existing disturbed areas to maintain the integrity of the C1 waterbody. C1 waters receive the highest form of water quality protection in the state, which prohibits any measurable deterioration in the existing water quality.

Table 9 identifies C1 designation for the entire Pequannock River Watershed and was taken from Table 3 in the August 2004 SWQS 7:9B.

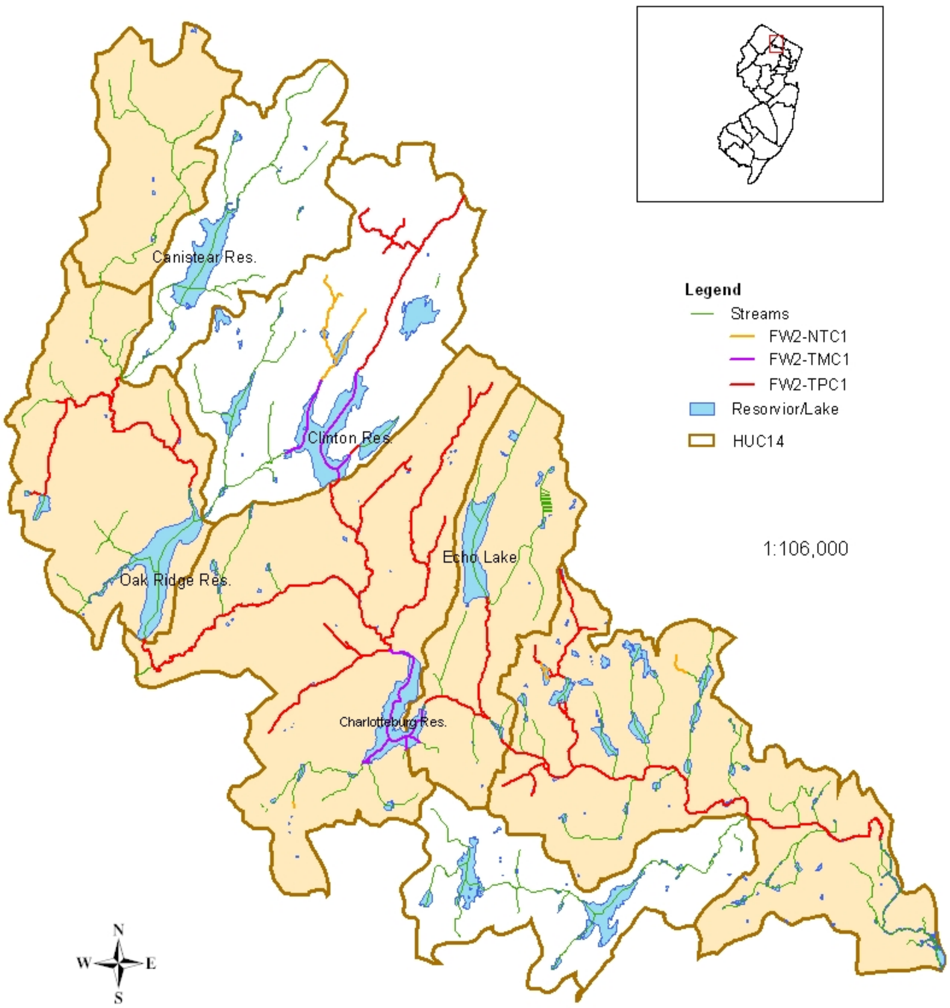
Table 9: C1 designations in Pequannock watershed

Waterbody	Classification
Apshawa Brook (Macopin) – Entire Length	FW2-TP(C1)
Charlotteburg Reservoir (Charlotteburg)	FW2-TM(C1)
Clinton Brook (W. Milford) Clinton Reservoir dam to Pequannock River	FW2-TP(C1)
Clinton Reservoir (W. Milford)	FW2-TM(C1)
Kanouse Brook (New Foundland) – Entire length	FW2-TP(C1)
Macopin River (New Foundland) Echo Lake dam downstream to Pequannock River	FW2-TP(C1)
Mossmans Brook (West Milford) Source to confluence with Clinton Reservoir	FW2-TP(C1)
Pequannock River Mainstem:	
(Hardyston) - River and the easterly tributary from Pacack Brook to, but	FW2-TP(C1)

not including, Oak Ridge Reservoir	
(New Foundland) – Outlet of Oak Ridge Reservoir downstream to, but not including Charlotteburg Reservoir	FW2-TP(C1)
(Charlotteburg) – Outlet of Charlotteburg reservoir to, but not including, Macopin Reservoir or the tributaries described separately below	FW2-TP(C1)
(Kinnelon) - Macopin Reservoir outlet to Hamburg Turnpike bridge in Pompton Lakes Borough	FW2-TP(C1)

Figure 19 depicts C1 designated waterbodies within the impaired segments.

Figure 19



Agricultural Land Use

Although only 2 percent of the watershed is attributed to agricultural land use, best management practices that address agricultural activities through re-establishing vegetated stream buffers may result in temperature reductions. Several programs are available to assist farmers in the development and implementation of conservation management plans and best management practices. The Natural Resource Conservation Service is the primary source of assistance for landowners in the development of resource management pertaining to soil conservation, water quality improvement, wildlife habitat enhancement, and irrigation water management. The USDA Farm Services Agency performs most of the funding assistance. All agricultural technical assistance is coordinated through the locally led Soil Conservation Districts. The funding programs include:

- **The Environmental Quality Incentive Program (EQIP)** is designed to provide technical, financial, and educational assistance to farmers/producers for conservation practices that address natural resource concerns, such as water quality. Practices under this program include integrated crop management, grazing land management, well sealing, erosion control systems, agri-chemical handling facilities, vegetative filter strips/riparian buffers, animal waste management facilities and irrigation systems.

- **The Conservation Reserve Program (CRP)** is designed to provide technical and financial assistance to farmers/producers to address the agricultural impacts on water quality and to maintain and improve wildlife habitat. CRP practices include the establishment of filter strips, riparian buffers and permanent wildlife habitats. This program provides the basis for the Conservation Reserve Enhancement Program (CREP).

- **Conservation Reserve Enhancement Program (CREP)** The New Jersey Departments of Environmental Protection and Agriculture, in partnership with the Farm Service Agency and Natural Resources Conservation Service, signed a $100 million CREP agreement earlier this year. This program matches $23 million of State money with $77 million from the Commodity Credit Corp. within USDA. Through CREP, financial incentives are offered for agricultural landowners to voluntarily implement conservation practices on agricultural lands. NJ CREP will be part of the USDA's Conservation Reserve Program (CRP). There will be a ten-year enrollment period, with CREP leases ranging between 10-15 years. The State intends to augment this program to make these leases permanent easements. The enrollment of farmland into CREP in New Jersey is expected to improve stream health through the installation of water quality conservation practices on New Jersey farmland.

Segment Specific Assessment and Management Measures

<u>Short-Term Management Measures:</u>

Short term management strategies include existing projects dubbed "Action Now" that are on the ground projects funded by the Department to address temperature and other NPS impairments to an impaired waterbody. These projects include streambank restoration and removal of inactive beaver dams. Funding sources include Clean Water Act 319(h) NPS funds and other state sources. Since 1998, 319(h) funds have provided approximately 3 million annually to the Department of which approximately 1 million passed through annually in the form of grants. Priority is given to funding projects that address TMDL implementation, development of Stormwater management plans and projects that address impairment based on Sublist 5 listed waterbodies.

The following short-term measures are either ongoing or are anticipated to be implemented within one year of the establishment of this TMDL. These actions will have an immediate and positive effect on overall temperature reduction and maintenance. The projects are as follows:

- A federally funded, state approved 319(h) grant project, *Pequannock River Thermal Mitigation* is underway in the Pequannock River Basin. This grant includes several components for different areas of the Pequannock River Watershed. In the Upper Pequannock River Watershed one factor that leads to elevated temperatures is impoundment of flows and removal of shading tree canopy by beaver colonies along the Pequannock River and tributaries. As the beaver colonies migrate they leave abandoned dams behind. Also the past flooding of the area has altered extensive land areas creating meadows where forested areas were located.

  A survey of the upper Pequannock River is in the process of being conducted to determine the extent and location of beaver dams, ponds and tree removal and to provide information for future restoration and mitigation projects. The survey will include GIS maps, GPS coordinates, digital photographs and field notes. A component of the upper watershed survey will be the installation of willow and red-osier dogwood cuttings to help re-establish the riparian tree canopy.

  This grant will also fund a temperature and flow study for 11 significant tributaries to the lower Pequannock for the comparison with the mainstem Pequannock to determine the influence of these tributaries on the Pequannock. Some may exert a positive (cooling) influence while others may exert a negative (warming) influence dependant upon the mainstem. GPS mapping of stormwater outfalls will be conducted as stormwater discharges may have elevated temperatures. This mapping will provide background data for possible stormwater mitigation projects.

- A *WMA 3 Restoration Master Plan* was conducted over two years using a visual assessment protocol modified from the USDA methodology. This project was also funded with 319h funding. This project included four sub-watersheds, one of which was the Pequannock. Forty-five sites in the Pequannock Basin were identified for restoration projects. The average score based on the visual assessment for the overall basin was 7.8 SVAP (STREAM VISUAL ASSESSMENT PROTOCOL). Of the 45 sites, 24 scored below the basin average scores. Several of the Pequannock sites were rated as high priority and these sites would be priority sites for future restoration projects. Although the SVAP did not look specifically at temperature impairments, streambank restoration with replacement canopy would have a mitigating effect on temperature exceedances. An addendum of the final report included a Management Strategy Table with a Habitat Enhancement category. For this category several sites on the Pequannock River and Kanouse Brook have been identified as candidates for habitat restoration and enhancement.

- Another 319(h) funded project is the, *Pequannock River Renaturalization of Channelized Flow at Route 23*. This site is downstream of the Oak Ridge Reservoir and just upstream of the confluence with Clinton Brook. At this point the river is 63 feet wide, straight and the bed is lined with concrete. This project was completed due to the expansion of Route 23, and in order to accomplish this expansion it was necessary to move the Pequannock River from its original channel. The wide channel leads to shallow flow and loss of canopy cover, both of which lead to elevated temperatures. At this point in the river the physical constraints are thought to be a significant contributing factor to the temperature impairment. The project will provide construction of a semi-shaded low flow channel within the existing channel using earthen and biological materials. The low flow channel will be constructed to include meanders, point bars and deltas. The newly formed streambanks will be stabilized using fascines, coconut fibers and other appropriate materials. Native trees and shrubs will be planted to help provide canopy.

- The Department has identified the Pequannock River from the outlet of Macopin Reservoir to the Borough of Butler municipal border as the WMA 3 priority stream segment. Funding is provided by the Corporate Business Tax for an in-depth study of the sources of thermal impairment and other nonpoint source impairments. The final deliverable for this project will be an in-depth site specific implementation plan, with associated costs and prioritized projects. This study will be completed by January 2005, and the follow-up associated project will be implementation of the prioritized projects.

<u>Long-term Management Strategies:</u>

Short-term management measures such as the *Pequannock River Thermal Mitigation Project*, the prioritized stream segment implementation plan and the *WMA 3 Restoration Master Plan* will help provide an implementation list for longer term projects to help alleviate nonpoint source thermal degradation, as well as other measures that may be needed to verify and further reduce or eliminate these sources. Both short-term and long-term management strategies that address temperature mitigation related to the identified sources may be eligible for future Department funding.

Beaver Management Strategy

The Department's Division of Fish and Wildlife has been involved in beaver management and control in Newark's Pequannock River Watershed for a number of years. Much of the effort was initiated by complaints from Newark's Superintendent of Water Supply due to his assertion that beaver dams were impeding the flow of water between reservoirs. The Division's involvement has included trapping by division personnel, directing trappers to the watershed area during the trapping season, and issuing depredation permits in emergency situations. In coordination with City of Newark, a comprehensive annual Beaver Management Strategy Plan is needed to reduce overall beaver populations and subsequently the number of beaver dams and ponds within the watershed, particularly along the upper Pequannock River headwaters, Pacack Brook and Clinton Brook. This objective can be approached in the following manner:

a) The Pequannock River Coalition in cooperation with Newark Water Supply will conduct surveys in late October to identify problem areas and beaver wintering colonies.

- Personnel criteria for each entity must be established so that complete areas may be ground-truthed efficiently.
- Comprehensive maps will be necessary to record activity locations.
- Authorization may be necessary on lands not owned by City of Newark or the State.

b) Upon submission of the list of identified problem areas the Division of Fish and Wildlife will direct trappers to these areas.

- Recreational trapping is the Division's first choice for the removal of beavers—trapping season runs January 1—February 9. There is a limit of 10 beavers per trapper

c) The Pequannock River Coalition, with assistance from Newark Water Supply, will breech inactive beaver dams and install beaver baffles or fumes in active dams.

- Personnel criteria for each entity must be coordinated.
- Logistics of dam removals must be determined, i.e., equipment and number of personnel required, how to evaluate costs, etc.
- Landowners are not required to have authorization or permits to remove beaver dams.

Riparian Restoration

Forest canopy and the shading from direct sunlight is a necessary and critical component with regard to limiting temperature increases in a given waterway, particularly smaller first-order and headwater streams. Beaver activity within the Pequannock River Watershed has resulted in multiple areas of treeless meadow where once dense forest had been. In conjunction with the Beaver Management Strategy outlined above, a parallel and companion program of ongoing riparian reforestation such as that outlined below should also be implemented to re-vegetate these sections that have been cleared. Installing protective measures such as shoreline fencing and wire-mesh tree girdles may also be incorporated to prevent future beaver inhabitation.

a) Identify deforested problem areas, eg., during the October surveys for beaver activity.

b) Identify potential funding sources for individual reforestation projects, i.e., 319(h), EPA, HEP, and Watershed Management Group grants, to name several.

c) Identify entities to design and carry out projects, such as Pequannock River Coalition, City of Newark and Trout Unlimited.

d) Install preventative measures as components of related projects or as individual projects.

As part of the WMA 3 Restoration Master Plan the following sites were identified as containing deficient riparian buffers and these sites can provide a starting point for addressing riparian corridor restoration on both the main stem Pequannock and significant tributaries feeding the river:

- Site 142- Pequannock River northwest of Route 23between old Route 23 and Route 23 Railroad
- Site 143- Pequannock River southwest tributary of Pequannock headwater at Rt. 23 bridge crossing
- Site 153- Clinton Brook 0.25 miles above Clinton Reservoir
- Site 155- Kanouse Brook, 0.65 miles north of confluence with Pequannock River
- Site 156- Kanouse Brook, 2.2 miles north of confluence with Pequannock River
- Site 158- Clinton Brook, 1.1 miles south of Clinton Reservoir adjacent to LaRue Road
- Site 168- Stone House Brook at confluence with Pequannock River
- Site 172- Pequannock River, 0.8 miles north of confluence with Wanaque
- Site 174- Matthew Brook
- Site 176- Van Dam Brook, Riverdale Town Park
- Site 177- Pequannock River, 0.15 miles north of confluence of Beaver Brook

This list should not be considered inclusive as it was part of a larger project for which thermal mitigation was not the primary focus; therefore the list should be considered a starting point. The study also looked at ownership of land, and had public lands as a criterion for evaluation. As redevelopment occurs, inclusion of a riparian corridor to provide canopy should be implemented where feasible.

Small Impoundments

Although discharges from large reservoirs are a major contributing factor to the temperature elevation in the Pequannock River, discharges into river tributaries from a number of smaller lakes and ponds can also contribute to thermal elevation in the Pequannock River and its tributaries. This occurs because impoundments slow flows, expose waters to increased sunlight and release heated surface water from impoundments over spillway outlets. The Pequannock River Coalition has determined that this problem is most extensive in the lower Pequannock drainage from Macopin to Riverdale. Of the 14 tributaries in this river segment, 10 (71%) have impoundments. Under one of the previously mentioned 319(h) nonpoint source projects, the Pequannock River Coalition is assessing the precise nature of flows and temperatures in these tributaries. Preliminary sampling has shown that small impoundments do offer a level of temperature stratification within these impoundments that may be utilized to achieve downstream temperature reductions of 3-4 degrees Fahrenheit.

Specific Measures:

- Install a USGS gaging station below Oak Ridge Reservoir
- Identify stormwater outfalls that specifically contribute to elevated water temperatures and determine applicable strategies to address
- Develop a regional stormwater management plan in addition to the required municipal stormwater management plans
- Install multi-depth temperature gages in both Oak Ridge and Charlotteburg Reservoirs.
- Evaluate feasibility of breeching obsolete impoundments and restoring natural stream flow.

There may be instances where the breaching of minor impoundments would be a beneficial activity for the stream ecology. This will be evaluated as part of the Department's ongoing watershed management work with and through stakeholders.

Water Allocation Permit Requirements

A previous Memorandum of Understanding (MOU) between the City of Newark and the Department prevented temperatures from exceeding 75°F and required the maintenance of a minimum passing flow of 5 cfs below the Oak Ridge Reservoir. While this has proven effective in preventing major fish kills in some instances, multiple studies indicate that temperatures above 68-70°F causes stress in native trout species, and may impede reproduction and overall population health. Also during a drought the MOU was not in affect. As stated previously, the SWQS regulates a minimum of 68°F for trout maintenance waterways. In addition, releasing 5 cfs at the 75°F threshold is not always effective due to time-lags between notification and response, i.e., the City of Newark facilities are closed evenings and weekends—a "buffer" of an additional 3°F is therefore warranted. Subsequently, the City of Newark's water allocation was renewed in 2004 to include a specific condition to replace the MOU with a new action temperature threshold of 65°F to both conform to the SWQS as well as provide a sufficient buffer to protect against criterion exceedances. Newark must develop an operating plan describing how it is planned to maintain a stream temperature less than 68°F from May 1st to October 1st at the outlet of Oak Ridge initially and at each of the reservoirs by 2007 as a permit requirement. The plan must be submitted to the Department for approval prior to implementation. In addition, the minimum passing flow of 12.3 cfs below Macopin has been reinstated in the present water allocation permit. The safe yield of the system must also be updated and verified based on the drought of 2002. Based on the rough SSTEMP analysis, it appears that a target temperature of several degrees lower, varying by location, may be needed in order to attain the SWQS. Coordination with City of Newark is necessary to create and adopt a comprehensive "release regime" that will achieve multiple objectives.

Ecological Flow Goals

Over the past couple of years, the Department and the USGS have met to conduct a research project aimed at examining flow characteristics and basis for developing ecological flow goals for New Jersey streams. One main goal of the study is to develop methodologies appropriate to New Jersey to calculate stream flows needed to protect aquatic communities such as: fish, aquatic invertebrates, endangered and threatened species. A preliminary report is expected in 2005. Results of this study will help to inform any needed modifications to these TMDLs, for example, in terms of higher passing flows.

10.0 Follow - up Monitoring

The Department's primary surface water quality monitoring program is the Bureau of Water Monitoring with the Division of Science and Research. In association with the Water Resources Division of the United States Geological Survey, the Department has cooperatively operated the Ambient Stream Monitoring Network (ASMN) in New

Jersey since the 1970s. The ASMN currently includes 3 stations that are routinely monitored on a quarterly basis. Three impairments are part of this network. As stated previously, beginning with the 2002 Integrated List the Department began to accept data from other entities. This comprises the impairments from which the TMDLs are based.

The Pequannock River Coalition presently monitors 16 sites within the Pequannock River Watershed, on the mainstem and tributary locations, for both temperature and flow rates. Readings are recorded from June through October from continuous recorders set every ½ - 1 hour for 24-48 readings per day. This organization currently has 2 grant applications pending to further enhance this network with 11-16 more sites, including 3 STP outfalls, 2 stormwater outfalls, and data points on multiple tributaries just short of their confluences with the Pequannock River mainstem to determine which are contributing flows that are warmer, cooler, or neutral in temperature. The Department will also continue to monitor temperature through its Ambient Surface Water Monitoring Program.

In order to establish a baseline of current fish health and to gauge changes over time in the fish to measure the effect the management measures are having on mitigating elevated water temperature, the Department's Bureau of Fresh Water Fisheries will conduct a 5 year project to perform fish IBI. Therefore the use of trout species that are sensitive to temperature as an indicator species, would serve as an additional "tool" to measure water quality improvement over time. This project will entail electrofishing, that will be used to establish reliable population estimates, length-weight relationships, and age and growth of the trout and other fish found in the Pequannock River. Two to three sites in a specified stretch of the Pequannock River will be monitored. It is anticipated that the results from this study will verify that the implementation of both long term and short term management measures are reducing temperature impairment.

11.0 Reasonable Assurance

Commitment to carry out the activities described in the implementation plan to reduce temperatures provides reasonable assurance that the New Jersey's Surface Water Quality Standards will be attained for temperature. The follow up monitoring program will identify if the strategies implemented are completely, or only partially successful. It will then be determined if additional measures can be implemented to fully attain the SWQS or if it is necessary to consider site specific criteria for some segments.

12.0 Public Participation

In accordance with the Water Quality Management Planning Rules N.J.A.C. 7:15–7 et seq., each TMDL shall be proposed by the Department as an amendment to the appropriate areawide water quality management plan(s) in accordance with N.J.A.C. 7:15-3.4(g).

As part of the public participation process for the development and implementation of the TMDLs for temperature in the Northeast Water Region, the Department worked collaboratively with stakeholders in WMA 3 as part of the Department's ongoing watershed management efforts. The Department's watershed management process includes a comprehensive stakeholder process that includes members from major stakeholder groups (agricultural, business and industry, academia, county and municipal officials, commerce and industry, purveyors and dischargers, and environmental groups), organized into Public advisory Committees (PACs) and Technical Advisory Committees (TACs). The PACs serve in an advisory capacity to the department, examining and commenting on a myriad of issues in the watersheds. The TACs are focused on scientific, ecological, and engineering issues relevant to the issues of the watershed, including water quality impairments and management responses to them.

The Department shared the Department's TMDL process through various presentations and discussions with the WMA 3 TAC members. The draft TMDL document and methodology where presented at meetings held on April 30, 2004 and May 21, 2004. In addition to the presentations, the TAC and Pequannock River Coalition have been instrumental in providing comments and suggestions to the Department during this process.

Additional input was received through Rutgers New Jersey EcoComplex (NJEC). The Department contracted with the NJEC in August 2001. The NJEC consists of a nine member review panel of New Jersey university professors whose role is to provide comments on the Department's technical approaches for the development of TMDLs and other management strategies. An overview of the Pequannock River temperature impairments was presented to the panel on December 12, 2003. Several approaches were subsequently discussed with NJEC before the present methodology was found to be acceptable to address the impairments.

Amendment Process

Notice proposing these TMDLs was published June 7, 2004 in the New Jersey Register and in a newspaper of general circulation in the affected area in order to provide the public an opportunity to review the TMDLs and submit comments. In addition, a public hearing was held on July 9, 2004 at the Kinnelon Public Library. Notice of the proposal and hearing was provided to affected municipalities.

All comments received during the public notice period and at any public hearings will become part of the record for these TMDLs and has been considered in the establishment of these TMDLs for submittal to EPA Region 2 and a Response to Comments was prepared as an addendum to this document. Once approved by EPA, these TMDLs will be adopted as amendments to the Northeast WQMP.

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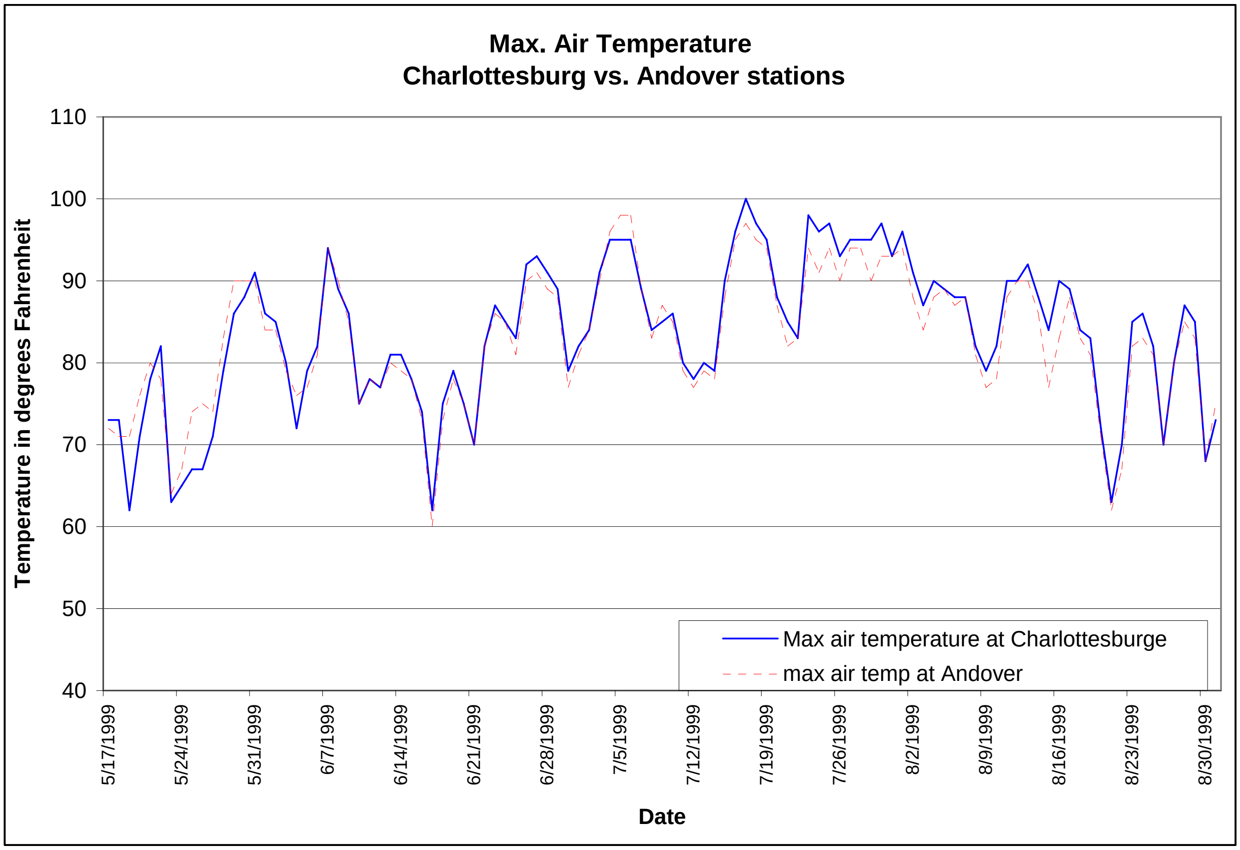
Appendix B Data for Regression/Computational Analysis

Date	Average water temp	Max water temp	Flow (cfs)	Max air temperature at Charlotteburg	Previous day avg air temp	Max air temp at Andover
5/17/1999	56.79	61.06	3.3	73	53	72
5/18/1999	57.20	59.18	3.2	73	53	71
5/19/1999	57.84	58.55	8.7	62	57	71
5/20/1999	58.22	60.44	19	71	61.5	76
5/21/1999	58.64	61.06	18	78	54	80
5/22/1999	59.35	61.06	18	82	55	78
5/23/1999	59.63	59.81	16	63	59.5	64
5/24/1999	58.12	58.55	15	65	64.5	67
5/25/1999	57.27	59.18	17	67	57.5	74
5/26/1999	57.63	58.55	18	67	54	75
5/27/1999	58.27	60.44	18	71	54	74
5/28/1999	59.70	61.69	18	79	56	83
5/29/1999	61.88	64.84	17	86	56	90
5/30/1999	63.31	68.61	12	88	62	90
5/31/1999	63.40	68.61	5.3	91	66	90
6/1/1999	64.6	68.0	4.1	86	67.5	84
6/2/1999	65.9	69.2	4.4	85	71	84
6/3/1999	65.7	68.0	4.1	80	72	79
6/4/1999	63.9	67.4	5.1	72	73.5	76
6/5/1999	61.7	64.8	2.9	79	64.5	77
6/6/1999	62.5	66.1	2.5	82	57.5	81
6/7/1999	67.2	71.7	2.4	94	62	94
6/8/1999	69.7	73.6	2.6	89	66.5	90
6/9/1999	67.7	70.5	2.5	86	79.5	85
6/10/1999	65.0	68.6	2.2	75	72.5	75
6/11/1999	63.4	68.0	2.1	78	69.5	78
6/12/1999	61.5	64.2	2	77	58.5	77
6/13/1999	64.3	66.7	2.3	81	60	80
6/14/1999	65.1	67.4	2.5	81	65	79
6/15/1999	65.7	69.2	2.4	78	70.5	78
6/16/1999	63.2	66.7	2.2	74	67	73
6/17/1999	60.9	62.3	2	62	61.5	60
6/18/1999	60.9	64.8	2	75	62.5	73
6/19/1999	61.7	66.7	1.9	79	56	78
6/20/1999	62.2	66.1	1.7	75	58.5	75
6/21/1999	61.5	63.6	2.2	70	62.5	70
6/22/1999	63.4	68.6	1.9	82	63	82
6/23/1999	65.7	70.5	1.6	87	59	86
6/24/1999	66.6	71.7	1.4	85	65.5	85

6/25/1999	65.8	70.5	1.3	83	68.5	81
6/26/1999	69.1	74.9	1.2	92	67.5	90
6/27/1999	69.9	74.3	1.1	93	71	91
6/28/1999	72.0	76.2	1.1	91	75.5	89
6/29/1999	72.4	75.6	1.6	89	78	88
6/30/1999	69.3	73.0	2.8	79	80.5	77
7/1/1999	67.3	68.6	1.6	82	73.5	81
7/2/1999	69.5	71.7	1.6	84	68.5	84
7/3/1999	71.6	75.6	1.4	91	72	90
7/4/1999	72.8	76.8	1.7	95	74.5	96
7/5/1999	75.2	79.4	1.7	95	79	98
7/6/1999	75.9	80.7	1.3	95	85.5	98
7/7/1999	74.0	77.5	1.2	89	82	89
7/8/1999	69.9	74.3	1.1	84	78.5	83
7/9/1999	68.0	71.7	1.1	85	70.5	87
7/10/1999	68.9	72.4	0.94	86	69.5	85
7/11/1999	66.8	71.7	1.1	80	72.5	79
7/12/1999	64.5	68.0	1.2	78	68.5	77
7/13/1999	65.8	69.9	1.1	80	62	79
7/14/1999	64.4	68.0	1.1	79	63.5	78
7/15/1999	66.4	72.4	1.1	90	64	88
7/16/1999	70.2	76.2	1.1	96	63	95
7/17/1999	72.5	77.5	1.1	100	70	97
7/18/1999	73.1	77.5	1.1	97	80	95
7/19/1999	72.6	76.2	0.92	95	81.5	94
7/20/1999	71.7	74.3	0.92	88	80	87
7/21/1999	69.5	71.7	0.9	85	78.5	82
7/22/1999	68.8	70.5	0.91	83	74	83
7/23/1999	72.1	77.5	0.91	98	74	94
7/24/1999	72.2	75.6	0.83	96	74	91
7/25/1999	72.8	76.8	0.74	97	82.5	94
7/26/1999	72.3	76.2	0.69	93	80.5	90
7/27/1999	72.1	77.5	0.68	95	81	94
7/28/1999	71.9	76.2	0.69	95	77	94
7/29/1999	71.3	75.6	0.77	95	76	90
7/30/1999	71.6	75.6	0.82	97	77	93
7/31/1999	72.1	76.2	0.85	93	76.5	93
8/1/1999	73.5	77.5	0.85	96	78.5	94
8/2/1999	71.1	74.9	0.83	91	79	88
8/3/1999	69.3	73.0	0.83	87	76	84
8/4/1999	68.3	72.4	0.83	90	73	88
8/5/1999	68.7	71.7	0.83	89	68.5	89
8/6/1999	69.0	73.0	0.83	88	72.5	87
8/7/1999	68.7	71.7	0.82	88	71	88
8/8/1999	68.3	71.1	0.83	82	70	81
8/9/1999	67.1	69.9	0.85	79	73.5	77
8/10/1999	63.9	68.0	0.84	82	68	78
8/11/1999	66.2	70.5	0.72	90	62	88
8/12/1999	69.8	73.0	0.77	90	66.5	90
8/13/1999	70.8	73.6	0.76	92	73.5	90

8/14/1999	72.0	74.3	1.1	88	76	86
8/15/1999	69.9	72.4	1.1	84	78	77
8/16/1999	69.4	72.4	1	90	70	83
8/17/1999	70.0	74.3	0.94	89	69.5	88
8/18/1999	70.6	73.0	0.85	84	73.5	83
8/19/1999	68.3	71.1	0.92	83	76	81
8/20/1999	65.4	67.4	1	72	69.5	71
8/21/1999	62.6	63.6	1.1	63	69	62
8/22/1999	62.6	64.2	1.1	70	61.5	67
8/23/1999	64.1	68.0	1.1	85	57.5	82
8/24/1999	66.1	69.9	1	86	59	83
8/25/1999	66.5	69.2	1	82	67.5	81
8/26/1999	66.8	67.4	1.1	70	69	70
8/27/1999	67.3	69.9	1.1	80	67.5	80
8/28/1999	68.5	71.1	1.1	87	65	85
8/29/1999	68.7	71.1	1.1	85	66.5	83
8/30/1999	63.2	65.5	0.98	68	73.5	68
8/31/1999	62.9	65.5	0.95	73	66	75

The graph below illustrate the difference in air temperature between Charlotteburg and Andover stations:



Pequannock River Coalition data Macopin Station

Site No.	# days >68°F in 2000	# days >75°F in 2000	# days >68°F in 2001	# days >75°F in 2001
PQ1	20	0	97	26
PQ2	n/a	n/a	99	49
PQ3	48	1	n/a	n/a
PQ4	31	2	n/a	n/a
PQ5	88	7	13	1
PQ7	n/a	n/a	49	0
PQ6	n/a	n/a	44	0
PQ8	55	13	84	18
PQ10	27	2	92	9
PQ11	97	9	97	15
PQ15	n/a	n/a	6	0
PQ12	n/a	n/a	49	0

Source: Pequannock River Coalition

Appendix C: SSTEMP Runs

The most complete information for running SSTEMP is available for the reach between Charlotteburg and Macopin. The use of SSTEMP is illustrated for this reach, from the outflow of Charlotteburg Reservoir to the USGS flow monitoring station just downstream of the Macopin Reservoir. Assuming flow and temperature boundary conditions at the outlet of the reservoir (flow of 10.8 cfs at 67^{o} F) and existing shading variables, the model output suggested that a mean daily temperature 67.53^{o} F, and a maximum temperature of 68.47^{o} F. In order to achieve the in-stream standard of 68.0^{o} F, the load allocation to Charlotteburg Reservoir discharge, given in terms of minimum passing flow and discharge temperature at the reservoir outlet and improving vegetation cover, discharge temperature must not exceed 67 ^{o} F based on a flow of 10.8 cfs and in-stream temperature of 67.7 ^{o}F (68 ^{o}F- MOS). Under the revised conditions, the model predicts mean daily temperature of 67.06^{o} F, and a maximum temperature of 67.60^{o} F at Macopin Intake. The model simulates steady-state conditions for the thermal capacity of the stream flow for a single day. The following inputs were used in the model run.

Hydrology

Segment Inflow (cubic feet per second, cfs): inflow to the model from the Charlotteburg Reservoir, = 10.8 cfs.

Inflow Temperature (^{o}F): temperature of inflow to the model from the Charlotteburg Reservoir, = 67 ^{o}F.

Segment Outflow (cfs): the modeled flow of the Pequannock River at the USGS gage (01382500) downstream of the Macopin Reservoir, = 12.3 cfs.
Accretion Temperature (^{o}F): Temperature of ground water inflow, distributed uniformly along the channel length, = 53.0 ^{o}F.

Geometry

Latitude (decimal degrees): refers to the position of the stream segment on the earth's surface, = 40.1^{o}.

Dam at head of segment (Yes, checked; No, unchecked): if checked, maintains a constant upstream boundary condition for the discharge water temperature, otherwise if unchecked, allows the water to heat upstream of the upper boundary of the modeled reach a distance equal to a half-day travel time, = Yes.

Segment Length (mile): is the length of the modeled segment of the Pequannock River (outflow of Charlotteburg Reservoir to the USGS gaging station just downstream of the Macopin Reservoir), = 1.6 miles.

Upstream Elevation (feet above mean sea level): the elevation of the channel at the upstream boundary of the modeled reach, = 700 feet.

Downstream Elevation (feet above mean sea level): the elevation of the channel at the downstream boundary of the modeled reach, = 620 feet.

Width's A Term (seconds per square feet, s/ft^2): is derived by calculating the wetted width-discharge relationship, $W = A * Q^B$; where Q is a known discharge, W is a measured wetted-width (flow width), and B is a power coefficient. Based on a discharge of 10.8 cfs, a wetted-width of 15 feet and a default of 0.2 for B, A is approximately 10 s/ft^2.

B Term (unitless): is the power coefficient for $W = A * Q^B$ (see "Width's A Term" above). The recommended model default of 0.2 was used.

Manning's n (unitless): is an empirical measure of the channel "roughness," = approximately 0.05 for the characteristics of the modeled reach substrate.

Meteorology

Air Temperature (^{o}F): represents the maximum daily average air temperature for the period of simulation from May through September, = 82 ^{o}F which is the maximum daily average for the period of record 1998 through 2002. Air temperature data is provided below.

Maximum Air Temperature (^{o}F): estimated by the model (if unchecked) based on a set of coefficients within the model, or maximum air temperature may be entered manually (if checked). The value estimated by the model = 86 ^{o}F.

Relative Humidity (%): is the mean daily value for the area at the modeled stream reach. An estimate of 65 % was used in the simulation, this value is more representative with a 90% possible sun.

Wind Speed (miles per hour, mi/hr): relates to the wind speed directly above the water's surface. An average of 3 mi/hr (4.4 feet per second) was used in the model.

Ground Temperature (^{o}F): is the average temperature of the ground surface, estimated at 62 ^{o}F for this simulation.

Thermal Gradient (joules per square meter per second per ^oC, $j/m^2/s/^oC$): measures the thermal input or output from the streambed to the water. The model default of 1.65 was used in the simulation.

Possible Sun (%): relates to the inverse measure of cloud cover. An average of 90 % was used in the simulation to represent a mostly clear sky.

Dust Coefficient (unitless): represents the amount of dust in the air. The value used in the simulation was in the lower range of recommended values (from 3 to 13), = 5.0.

Ground Reflectivity (%): is a measure of the amount of short-wave radiation reflected from the earth back into the atmosphere. The value recommended in the model documentation was 29 % for vegetation in late summer. This value was chosen based on GIS aerial photos showing moderate to dense vegetation coverage within 50 feet of the modeled stream channel.

Solar Radiation (Langleys per day, Langleys/d): calculated internally by the model, using the input date, dust coefficient, and ground reflectivity of the simulation, = 620 Langleys/d for mid July.

Shade

Total Shade (%): refers to how much of the segment is shaded by vegetation, cliffs, and other channel and topographic features. The number represents the percent of incoming solar radiation that does not reach the water and can be either entered, or calculated internally by the program. Based on the inputs in the "Optional Shading Variables" section, the calculated value = 74.2 %.

Optional Shading Variables

Segment Azmith (degrees): refers to the general orientation of the stream segment with respect to due North. The general orientation of Pequannock River at the modeled stream segment, using a topographic map, is approximately -70^o.

Topographic Altitude (degrees): is the average incline to the horizon from the middle of the stream, looking perpendicular to the flow path. An 85^o altitude was approximated for both sides of the channel.

Vegetation Height (feet): is the average height of the shade producing vegetation along the stream from the water's surface. An average height of 35 feet was estimated for the model.

Vegetation Crown (feet): is the average maximum crown diameter of the shade producing vegetation along the stream. An average diameter of 35 feet was estimated for the model.

Vegetation Offset (feet): refers to the average offset of the trunks of the shade producing vegetation from the water edge. Offset was approximated from GIS aerial photographs as 5 feet.

Vegetation Density (%): the average screening factor (0 to 100%) of the shade producing vegetation along the stream. It is composed of two parts: the continuity of the vegetative coverage along the stream (quantity), and the percent of light filtered by the vegetation leaves and trunks (quality). Using aerial photos in GIS, the percent coverage along the channel bank was approximated at 90 % with a light removal efficiency of approximately 75%.

Time of Year

Month/day (mm/dd): Date used by model for simulation of solar radiation, = 07/15. Note, when using middle of the month date the output of the model represents the average for that month.

Temperature data for Charlotteburg-Macopin reach

Date	Average water temp	Max water temp	Flow (cfs)	Max air temperature at Charlotteburg	Previous day avg air temp	Average air temp
6/1/1998	70.2	71.74	40	69	70	70
6/2/1998	68.8	69.87	55	75	70	54.5
6/3/1998	68.4	69.24	34	65	54.5	60.5
6/4/1998	64.8	66.73	28	66	60.5	52
6/5/1998	60.2	62.95	7.2	67	52	54.5
6/6/1998	60.1	64.21	5.6	68	54.5	56.5
6/7/1998	57.9	59.81	4.3	66	56.5	53.5
6/8/1998	57.3	59.18	4.2	65	53.5	54.5
6/9/1998	59.2	63.58	3.7	75	54.5	53.5
6/10/1998	62.0	66.73	3.1	74	53.5	60
6/11/1998	61.9	63.58	2.9	70	60	63
6/12/1998	60.9	61.69	7.8	64	63	62.5
6/13/1998	60.5	61.69	19	66	62.5	61
6/14/1998	62.6	65.47	506	69	61	62.5
6/15/1998	64.7	64.84	894	69	62.5	60.5
6/16/1998	66.2	69.24	553	82	60.5	63
6/17/1998	67.5	69.87	408	81	63	69
6/18/1998	68.9	71.12	288	81	69	70
6/19/1998	71.8	74.27	174	86	70	68.5
6/20/1998	73.7	74.91	125	89	68.5	72.5

6/21/1998	75.5	77.48	100	85	72.5	71.5
6/22/1998	74.7	76.84	63	75	71.5	73.5
6/23/1998	72.2	73	44	74	73.5	68.5
6/24/1998	72.1	73	38	87	68.5	68.5
6/25/1998	74.3	75.55	36	90	68.5	74
6/26/1998	76.0	77.48	35	90	74	77.5
6/27/1998	75.0	76.19	33	82	77.5	80
6/28/1998	71.9	73.64	26	80	80	67.5
6/29/1998	67.1	68.61	11	78	67.5	69
6/30/1998	67.5	69.87	16	82	69	70
7/1/1998	67.4	68.61	28	75	70	70.5
7/2/1998	68.0	71.74	22	82	70.5	65.5
7/3/1998	68.8	73.64	7.7	85	65.5	68.5
7/4/1998	68.5	71.74	6	84	68.5	69.5
7/5/1998	69.5	73	6.4	81	69.5	69
7/6/1998	68.1	71.74	4.4	81	69	66.5
7/7/1998	67.2	69.24	3.5	78	66.5	67.5
7/8/1998	65.3	67.36	3.4	66	67.5	68.5
7/9/1998	66.2	69.87	3.8	82	68.5	61
7/10/1998	68.6	71.74	4	80	61	69
7/11/1998	67.1	69.87	4.3	79	69	67.5
7/12/1998	67.5	71.74	2.7	84	67.5	65
7/13/1998	68.9	73.64	2.1	85	65	67
7/14/1998	70.8	74.91	1.9	86	67	70
7/15/1998	71.4	74.27	1.9	85	70	74
7/16/1998	72.2	75.55	1.9	88	74	75.5
7/17/1998	71.9	75.55	2.9	87	75.5	75
7/18/1998	71.6	75.55	11	85	75	74.5
7/19/1998	70.3	73.64	3.8	86	74.5	69.5
7/20/1998	71.1	73.64	2.7	86	69.5	75
7/21/1998	71.8	76.19	2.5	89	75	72.5
7/22/1998	73.8	77.48	2.6	90	72.5	76
7/23/1998	73.5	75.55	2.3	87	76	77.5
7/24/1998	72.8	76.84	2.3	82	77.5	75.5
7/25/1998	70.0	73	2	79	75.5	66.5
7/26/1998	69.6	74.27	1.5	82	66.5	66
7/27/1998	69.6	73.64	1.5	85	66	67
7/28/1998	71.1	75.55	1.3	87	67	71
7/29/1998	72.7	77.48	1.4	90	71	75
7/30/1998	72.0	76.19	1.5	85	75	74.5
7/31/1998	70.3	73.64	1.6	62	74.5	72
5/17/1999	56.79	61.06	3.3	73	53	53
5/18/1999	57.20	59.18	3.2	73	53	57
5/19/1999	57.84	58.55	8.7	62	57	61.5
5/20/1999	58.22	60.44	19	71	61.5	54
5/21/1999	58.64	61.06	18	78	54	55
5/22/1999	59.35	61.06	18	82	55	59.5
5/23/1999	59.63	59.81	16	63	59.5	64.5
5/24/1999	58.12	58.55	15	65	64.5	57.5
5/25/1999	57.27	59.18	17	67	57.5	54

5/26/1999	57.63	58.55	18	67	54	54
5/27/1999	58.27	60.44	18	71	54	56
5/28/1999	59.70	61.69	18	79	56	56
5/29/1999	61.88	64.84	17	86	56	62
5/30/1999	63.31	68.61	12	88	62	66
5/31/1999	63.40	68.61	5.3	91	66	67.5
6/1/1999	64.6	68.0	4.1	86	67.5	71
6/2/1999	65.9	69.2	4.4	85	71	72
6/3/1999	65.7	68.0	4.1	80	72	73.5
6/4/1999	63.9	67.4	5.1	72	73.5	64.5
6/5/1999	61.7	64.8	2.9	79	64.5	57.5
6/6/1999	62.5	66.1	2.5	82	57.5	62
6/7/1999	67.2	71.7	2.4	94	62	66.5
6/8/1999	69.7	73.6	2.6	89	66.5	79.5
6/9/1999	67.7	70.5	2.5	86	79.5	72.5
6/10/1999	65.0	68.6	2.2	75	72.5	69.5
6/11/1999	63.4	68.0	2.1	78	69.5	58.5
6/12/1999	61.5	64.2	2	77	58.5	60
6/13/1999	64.3	66.7	2.3	81	60	65
6/14/1999	65.1	67.4	2.5	81	65	70.5
6/15/1999	65.7	69.2	2.4	78	70.5	67
6/16/1999	63.2	66.7	2.2	74	67	61.5
6/17/1999	60.9	62.3	2	62	61.5	62.5
6/18/1999	60.9	64.8	2	75	62.5	56
6/19/1999	61.7	66.7	1.9	79	56	58.5
6/20/1999	62.2	66.1	1.7	75	58.5	62.5
6/21/1999	61.5	63.6	2.2	70	62.5	63
6/22/1999	63.4	68.6	1.9	82	63	59
6/23/1999	65.7	70.5	1.6	87	59	65.5
6/24/1999	66.6	71.7	1.4	85	65.5	68.5
6/25/1999	65.8	70.5	1.3	83	68.5	67.5
6/26/1999	69.1	74.9	1.2	92	67.5	71
6/27/1999	69.9	74.3	1.1	93	71	75.5
6/28/1999	72.0	76.2	1.1	91	75.5	78
6/29/1999	72.4	75.6	1.6	89	78	80.5
6/30/1999	69.3	73.0	2.8	79	80.5	73.5
7/1/1999	67.3	68.6	1.6	82	73.5	68.5
7/2/1999	69.5	71.7	1.6	84	68.5	72
7/3/1999	71.6	75.6	1.4	91	72	74.5
7/4/1999	72.8	76.8	1.7	95	74.5	79
7/5/1999	75.2	79.4	1.7	95	79	85.5
7/6/1999	75.9	80.7	1.3	95	85.5	82
7/7/1999	74.0	77.5	1.2	89	82	78.5
7/8/1999	69.9	74.3	1.1	84	78.5	70.5
7/9/1999	68.0	71.7	1.1	85	70.5	69.5
7/10/1999	68.9	72.4	0.94	86	69.5	72.5
7/11/1999	66.8	71.7	1.1	80	72.5	68.5
7/12/1999	64.5	68.0	1.2	78	68.5	62
7/13/1999	65.8	69.9	1.1	80	62	63.5
7/14/1999	64.4	68.0	1.1	79	63.5	64

7/15/1999	66.4	72.4	1.1	90	64	63
7/16/1999	70.2	76.2	1.1	96	63	70
7/17/1999	72.5	77.5	1.1	100	70	80
7/18/1999	73.1	77.5	1.1	97	80	81.5
7/19/1999	72.6	76.2	0.92	95	81.5	80
7/20/1999	71.7	74.3	0.92	88	80	78.5
7/21/1999	69.5	71.7	0.9	85	78.5	74
7/22/1999	68.8	70.5	0.91	83	74	74
7/23/1999	72.1	77.5	0.91	98	74	74
7/24/1999	72.2	75.6	0.83	96	74	82.5
7/25/1999	72.8	76.8	0.74	97	82.5	80.5
7/26/1999	72.3	76.2	0.69	93	80.5	81
7/27/1999	72.1	77.5	0.68	95	81	77
7/28/1999	71.9	76.2	0.69	95	77	76
7/29/1999	71.3	75.6	0.77	95	76	77
7/30/1999	71.6	75.6	0.82	97	77	76.5
7/31/1999	72.1	76.2	0.85	93	76.5	78.5
8/1/1999	73.5	77.5	0.85	96	78.5	79
8/2/1999	71.1	74.9	0.83	91	79	76
8/3/1999	69.3	73.0	0.83	87	76	73
8/4/1999	68.3	72.4	0.83	90	73	68.5
8/5/1999	68.7	71.7	0.83	89	68.5	72.5
8/6/1999	69.0	73.0	0.83	88	72.5	71
8/7/1999	68.7	71.7	0.82	88	71	70
8/8/1999	68.3	71.1	0.83	82	70	73.5
8/9/1999	67.1	69.9	0.85	79	73.5	68
8/10/1999	63.9	68.0	0.84	82	68	62
8/11/1999	66.2	70.5	0.72	90	62	66.5
8/12/1999	69.8	73.0	0.77	90	66.5	73.5
8/13/1999	70.8	73.6	0.76	92	73.5	76
8/14/1999	72.0	74.3	1.1	88	76	78
8/15/1999	69.9	72.4	1.1	84	78	70
8/16/1999	69.4	72.4	1	90	70	69.5
8/17/1999	70.0	74.3	0.94	89	69.5	73.5
8/18/1999	70.6	73.0	0.85	84	73.5	76
8/19/1999	68.3	71.1	0.92	83	76	69.5
8/20/1999	65.4	67.4	1	72	69.5	69
8/21/1999	62.6	63.6	1.1	63	69	61.5
8/22/1999	62.6	64.2	1.1	70	61.5	57.5
8/23/1999	64.1	68.0	1.1	85	57.5	59
8/24/1999	66.1	69.9	1	86	59	67.5
8/25/1999	66.5	69.2	1	82	67.5	69
8/26/1999	66.8	67.4	1.1	70	69	67.5
8/27/1999	67.3	69.9	1.1	80	67.5	65
8/28/1999	68.5	71.1	1.1	87	65	66.5
8/29/1999	68.7	71.1	1.1	85	66.5	73.5
8/30/1999	63.2	65.5	0.98	68	73.5	66
8/31/1999	62.9	65.5	0.95	74	66	58
6/1/2000	65.21	68.73	35	85	58	57
6/2/2000	68.83	72.49	31	88	57	68.5

6/3/2000	66.53	69.36	29	73	68.5	69.5
6/4/2000	63.70	68.11	17	75	69.5	56
6/5/2000	60.13	62.44	8.2	65	56	60
6/6/2000	56.93	58.66	32	52	60	56
6/7/2000	61.34	63.07	125	74	56	47
6/8/2000	63.84	66.22	107	78	47	58
6/9/2000	65.59	68.11	73	86	58	64.5
6/10/2000	68.34	71.24	56	92	64.5	70.5
6/11/2000	71.19	74.39	44	91	70.5	74
6/12/2000	69.83	71.24	79	72	74	77.5
6/13/2000	66.73	67.48	98	58	77.5	60
6/14/2000	64.92	65.59	81	60	60	51.5
6/15/2000	65.10	66.85	69	73	51.5	53
6/16/2000	67.95	70.61	61	85	53	62
6/17/2000	70.49	73.12	54	87	62	76
6/18/2000	68.39	69.36	52	68	76	70.5
6/19/2000	67.95	68.73	54	72	70.5	61.5
6/20/2000	68.87	71.24	47	83	61.5	59.5
6/21/2000	70.72	72.49	39	80	59.5	66.5
6/22/2000	71.49	73.76	56	83	66.5	70.5
6/23/2000	71.41	73.12	50	80	70.5	68
6/24/2000	72.23	75.03	39	87	68	65
6/25/2000	74.13	77.6	30	90	65	72.5
6/26/2000	75.09	78.25	26	89	72.5	76.5
6/27/2000	74.70	76.96	27	85	76.5	76
6/28/2000	74.11	76.96	35	82	76	70.5
6/29/2000	73.27	75.67	26	79	70.5	68.5
6/30/2000	71.95	75.03	25	79	68.5	65.5
7/1/2000	71.56	75.67	16	82	65.5	63.5
7/2/2000	71.26	75.67	7.8	85	63.5	65.5
7/3/2000	70.23	73.76	5.1	85	65.5	68.5
7/4/2000	71.23	75.03	5.4	84	68.5	72.5
7/5/2000	71.63	76.31	5	83	72.5	69.5
7/6/2000	67.83	72.49	3.6	76	69.5	64
7/7/2000	66.58	70.61	3.2	76	64	61
7/8/2000	65.64	71.24	3.7	77	61	62
7/9/2000	66.88	71.86	3.7	82	62	61.5
7/10/2000	70.91	75.03	2.3	86	61.5	65
7/11/2000	69.83	74.39	2.8	82	65	70
7/12/2000	67.76	72.49	4.5	82	70	65.5
7/13/2000	68.28	73.12	4.2	83	65.5	65
7/14/2000	68.78	71.86	3.7	79	65	67.5
7/15/2000	68.62	71.24	60	67	67.5	68.5
7/16/2000	71.07	73.76	140	81	68.5	62.5
7/17/2000	71.58	74.39	139	83	62.5	67.5
7/18/2000	73.20	75.03	105	85	67.5	69
7/19/2000	70.86	73.12	80	67	69	67.5
7/20/2000	70.22	71.86	65	78	67.5	59.5
7/21/2000	70.86	73.76	56	83	59.5	62
7/22/2000	72.13	73.76	51	79	62	67

7/23/2000	71.28	73.76	44	81	67	63.5
7/24/2000	70.62	71.86	36	77	63.5	64.5
7/25/2000	69.71	71.86	29	77	64.5	66
7/26/2000	67.31	68.73	28	67	66	66
7/27/2000	68.73	69.99	118	69	66	61.5
7/28/2000	70.39	72.49	111	82	61.5	63.5
7/29/2000	71.02	71.86	79	78	63.5	70
7/30/2000	69.63	71.24	101	72	70	67
7/31/2000	69.53	70.61	98	75	67	66
8/1/2000	68.78	69.99	84	68	66	67
6/1/2001	57.09	60.19	8.2	70	67	51.5
6/2/2001	57.11	59.62	34	74	51.5	53.5
6/3/2001	60.56	63.05	27	72	53.5	57
6/4/2001	61.01	63.34	32	72	57	58
6/5/2001	62.69	65.95	46	74	58	60
6/6/2001	63.69	65.65	38	75	60	62.5
6/7/2001	63.89	66.82	24	77	62.5	61
6/8/2001	63.97	66.53	15	73	61	61.5
6/9/2001	63.91	66.53	13	87	61.5	60
6/10/2001	63.28	65.65	9.1	78	60	66.5
6/11/2001	62.10	63.91	6.6	79	66.5	63.5
6/12/2001	65.30	69.75	5.9	85	63.5	67.5
6/13/2001	68.87	73.34	5.3	84	67.5	70.5
6/14/2001	68.07	70.34	5.1	83	70.5	72
6/15/2001	69.15	73.34	5.8	88	72	72
6/16/2001	69.74	71.24	5	83	72	76.5
6/17/2001	68.02	69.75	10	79	76.5	74
6/18/2001	68.30	71.24	12	83	74	69
6/19/2001	70.28	73.64	9.4	87	69	69
6/20/2001	71.56	75.81	6.2	89	69	75.5
6/21/2001	68.69	71.24	5.5	72	75.5	75
6/22/2001	68.67	71.84	5.8	81	75	67
6/23/2001	69.00	71.24	17	79	67	73
6/24/2001	67.18	68.57	26	76	73	68.5
6/25/2001	67.83	70.94	14	82	68.5	65.5
6/26/2001	70.25	73.64	13	87	65.5	69
6/27/2001	72.12	75.18	9.7	88	69	73
6/28/2001	73.08	76.43	7.5	89	73	75
6/29/2001	73.52	76.43	6.5	85	75	76
6/30/2001	74.23	77.68	4.7	91	76	75.5
7/1/2001	72.73	75.81	4.3	84	75.5	79.5
7/2/2001	66.54	70.34	7.3	72	79.5	66.5
7/3/2001	65.66	69.45	5	77	66.5	57
7/4/2001	67.57	70.94	3.6	81	57	63
7/5/2001	69.85	73.34	4.1	82	63	67
7/6/2001	66.79	69.16	6.6	71	67	66
7/7/2001	66.22	70.64	4.5	82	66	59
7/8/2001	66.07	67.99	5.7	70	59	62
7/9/2001	68.57	73.34	6.9	88	62	65
7/10/2001	70.47	73.95	5.3	87	65	74.5

7/11/2001	69.50	72.14	5.3	78	74.5	73
7/12/2001	67.41	70.04	5.2	76	73	66.5
7/13/2001	65.38	67.41	3.6	74	66.5	62
7/14/2001	65.52	69.45	2.4	72	62	62
7/15/2001	66.63	71.24	2.5	81	62	57
7/16/2001	68.38	73.64	1.8	85	57	67
7/17/2001	69.20	72.74	1.3	84	67	71.5
7/18/2001	69.88	73.04	1.3	81	71.5	74
7/19/2001	69.20	73.95	1.2	80	74	68.5
7/20/2001	68.51	74.26	1.1	81	68.5	66
7/21/2001	68.87	74.87	1	84	66	67
7/22/2001	69.63	75.50	0.92	85	67	70
7/23/2001	70.83	77.06	0.83	89	70	70
7/24/2001	73.90	79.89	0.78	91	70	77
7/25/2001	75.46	80.84	0.75	94	77	81
7/26/2001	70.79	73.64	1.1	72	81	81
7/27/2001	67.78	72.44	1.2	76	81	60
7/28/2001	66.64	70.94	0.88	79	60	62.5
7/29/2001	66.85	70.34	0.69	76	62.5	67.5
7/30/2001	66.72	70.34	0.66	79	67.5	64.5
7/31/2001	67.21	73.04	0.59	84	64.5	65.5
8/1/2001	69.06	74.87	0.54	89	65.5	70
8/2/2001	70.91	76.43	0.48	89	70	75
8/3/2001	70.68	74.26	0.43	86	75	75.5
8/4/2001	70.52	72.74	2	84	75.5	77
8/5/2001	70.99	74.87	5.3	90	77	72
8/6/2001	73.42	77.06	1.3	93	72	76.5
8/7/2001	74.26	79.26	0.54	95	76.5	80.5
8/8/2001	75.04	80.20	0.44	96	80.5	81
8/9/2001	75.05	80.20	0.6	98	81	80
8/10/2001	75.46	78.62	1	92	80	81.5
8/11/2001	72.40	74.56	1	73	81.5	79
8/12/2001	70.25	70.94	0.77	75	79	69
8/13/2001	72.41	75.50	1.4	85	69	71
8/14/2001	71.57	75.18	1.3	86	71	73
8/15/2001	71.03	73.95	2.2	84	73	71.5
8/16/2001	70.62	74.26	1.3	84	71.5	70.5
8/17/2001	71.14	74.26	1.1	80	70.5	73
8/18/2001	70.23	73.64	1.1	83	73	68.5
8/19/2001	70.19	73.04	1.1	83	68.5	70.5
8/20/2001	70.96	73.64	1.1	86	70.5	73.5
8/21/2001	70.00	73.34	1	87	73.5	71.5
8/22/2001	69.41	73.04	0.97	85	71.5	76
8/23/2001	67.56	70.04	1.1	81	76	69.5
8/24/2001	68.79	72.14	1.4	84	69.5	68.5
8/25/2001	67.24	70.94	1	83	68.5	67.5
8/26/2001	66.75	70.64	0.57	82	67.5	67
8/27/2001	68.63	71.84	0.44	83	67	67.5
8/28/2001	69.03	72.74	0.36	82	67.5	71.5
8/29/2001	68.11	71.84	0.32	83	71.5	70.5

8/30/2001	65.73	69.16	0.28	79	70.5	67
8/31/2001	69.04	72.44	0.28	84	67	66
6/1/2002	65.22	69.36	3.5	85	66	67.5
6/2/2002	64.38	68.11	3	75	67.5	67
6/3/2002	61.63	65.59	2.4	72	67	59.5
6/4/2002	61.50	63.70	2	75	59.5	59
6/5/2002	63.83	68.11	1.9	88	59	64.5
6/6/2002	65.62	67.48	5	74	64.5	74
6/7/2002	61.94	63.70	17	72	74	64
6/8/2002	61.13	64.33	8.5	74	64	59
6/9/2002	62.16	66.22	4.5	85	59	59
6/10/2002	64.83	68.73	3.8	84	59	69
6/11/2002	66.43	70.61	3.2	89	69	69
6/12/2002	67.19	68.11	2.8	82	69	74
6/13/2002	63.78	66.85	2.8	65	74	66.5
6/14/2002	60.77	62.44	3.9	58	66.5	58
6/15/2002	59.01	59.93	6.5	62	58	54.5
6/16/2002	60.48	63.70	4.9	75	54.5	56.5
6/17/2002	61.95	64.96	3.9	77	56.5	61.5
6/18/2002	62.68	66.22	3.2	78	61.5	61
6/19/2002	63.96	67.48	2.8	80	61	65
6/20/2002	65.09	69.36	2.4	83	65	65.5
6/21/2002	65.64	69.99	2.2	84	65.5	66.5
6/22/2002	67.34	71.86	2	88	66.5	69.5
6/23/2002	68.91	72.49	1.8	87	69.5	70.5
6/24/2002	70.04	73.76	1.7	88	70.5	75
6/25/2002	70.27	73.76	1.6	86	75	76
6/26/2002	69.99	73.76	1.5	92	76	76.5
6/27/2002	70.20	74.39	1.9	88	76.5	78
6/28/2002	70.48	73.12	2.3	83	78	75.5
6/29/2002	69.59	73.12	1.7	86	75.5	70
6/30/2002	69.20	73.12	1.4	86	70	71
7/1/2002	69.78	72.49	1.2	87	71	74.5
7/2/2002	71.78	76.96	1.1	94	74.5	75.5
7/3/2002	74.01	78.89	1	94	75.5	81.5
7/4/2002	74.33	79.53	0.93	95	81.5	81
7/5/2002	71.72	76.31	0.84	79	81	80
7/6/2002	67.32	70.61	0.8	77	80	68
7/7/2002	67.08	73.12	0.75	84	68	66.5
7/8/2002	68.10	74.39	0.7	88	66.5	69
7/9/2002	69.83	74.39	0.78	91	69	73
7/10/2002	71.22	75.67	1.2	81	73	76.5
7/11/2002	67.29	71.86	1.3	77	76.5	64
7/12/2002	67.13	71.86	1.7	82	64	61
7/13/2002	67.37	71.24	0.98	82	61	65
7/14/2002	65.75	68.11	0.53	79	65	71
7/15/2002	68.36	73.12	0.73	90	71	70.5
7/16/2002	70.75	75.67	0.79	86	70.5	74.5
7/17/2002	68.81	75.67	0.53	93	74.5	69
7/18/2002	71.53	76.31	0.52	93	69	77.5

7/19/2002	70.94	76.96	0.54	93	77.5	77.5
7/20/2002	70.99	76.31	0.54	86	77.5	77
7/21/2002	70.20	74.39	0.42	84	77	73.5
7/22/2002	71.47	78.25	0.33	91	73.5	72
7/23/2002	73.28	78.25	0.73	95	72	78.5
7/24/2002	71.87	74.39	1	80	78.5	76.5
7/25/2002	69.05	73.76	0.45	79	76.5	68
7/26/2002	64.91	66.85	0.33	71	68	65
7/27/2002	65.75	68.73	0.33	78	65	63.5
7/28/2002	67.82	70.61	0.33	84	63.5	68
7/29/2002	72.60	78.89	0.34	94	68	72.5
7/30/2002	73.55	79.53	0.33	92	72.5	84.5
7/31/2002	73.29	80.18	0.43	95	84.5	79
8/1/2002	72.52	78.25	0.35	96	79	78.5
8/2/2002	74.03	80.83	0.79	98	78.5	79
8/3/2002	75.17	78.25	1.5	91	79	80
8/4/2002	74.65	79.53	0.4	93	80	77
8/5/2002	72.81	75.67	0.34	88	77	79
8/6/2002	71.09	75.03	0.4	77	79	75
8/7/2002	66.97	72.49	0.33	80	75	63.5
8/8/2002	66.79	72.49	0.3	82	63.5	64.5
8/9/2002	67.18	75.03	0.29	84	64.5	65
8/10/2002	68.68	76.96	0.29	89	65	67
8/11/2002	70.61	78.89	0.29	94	67	69.5
8/12/2002	72.32	78.89	0.29	97	69.5	76.5
8/13/2002	73.71	80.18	0.29	98	76.5	79.5
8/14/2002	74.38	79.53	0.29	99	79.5	83.5
8/15/2002	74.71	80.18	0.29	94	83.5	83.5
8/16/2002	74.61	77.60	0.29	96	83.5	81
8/17/2002	75.32	81.47	0.29	94	81	82.5
8/18/2002	76.36	81.47	0.28	95	82.5	79.5
8/19/2002	76.33	81.47	0.25	93	79.5	78.5
8/20/2002	73.88	77.60	0.29	78	78.5	78
8/21/2002	72.59	80.18	0.29	86	78	67
8/22/2002	70.67	75.03	0.29	85	67	70
8/23/2002	70.92	71.86	0.33	78	70	71.5
8/24/2002	67.43	69.36	0.35	66	71.5	68.5
8/25/2002	69.42	75.67	0.44	84	68.5	61.5
8/26/2002	68.54	73.12	0.39	82	61.5	68
8/27/2002	68.47	72.49	0.55	86	68	67.5
8/28/2002	66.88	68.73	0.36	75	67.5	71
8/29/2002	63.49	64.96	6	60	71	64
8/30/2002	64.38	66.22	1.6	73	64	56.5
8/31/2002	64.59	66.85	0.55	75	56.5	62

References

Watershed Management Area 3 Watershed Restoration Master Plan, Omni Environmental, summer 2002.

- flow width data and channel substrate type used for the “Width’s A Term” and the Manning’s n value.

USGS flow-monitoring gage (01382500), Pequannock River at Macopin Intake Dam, just downstream of Macopin Reservoir on the Pequannock River.

- Flows, water temperature, and flow width data used to develop the regression and stochastic models

NJDEP, Aerial photographs for GIS, 2002.

- Vegetative offset, coverage, and density; and channel characteristics data for estimating vegetative shading and the “Width’s A Term.”

Bartholow, J. M., 2002, SSTEMP for Windows: The Stream Segment Temperature Model (Version 2.0), US Geological Survey computer model and documentation. Available on the Internet at http://www.fort.usgs.gov/.

Figure 1:
Stream Reach Between Charlotteburg and Macopin (PQ7 & PQ8) Model output based on existing vegetative conditions:

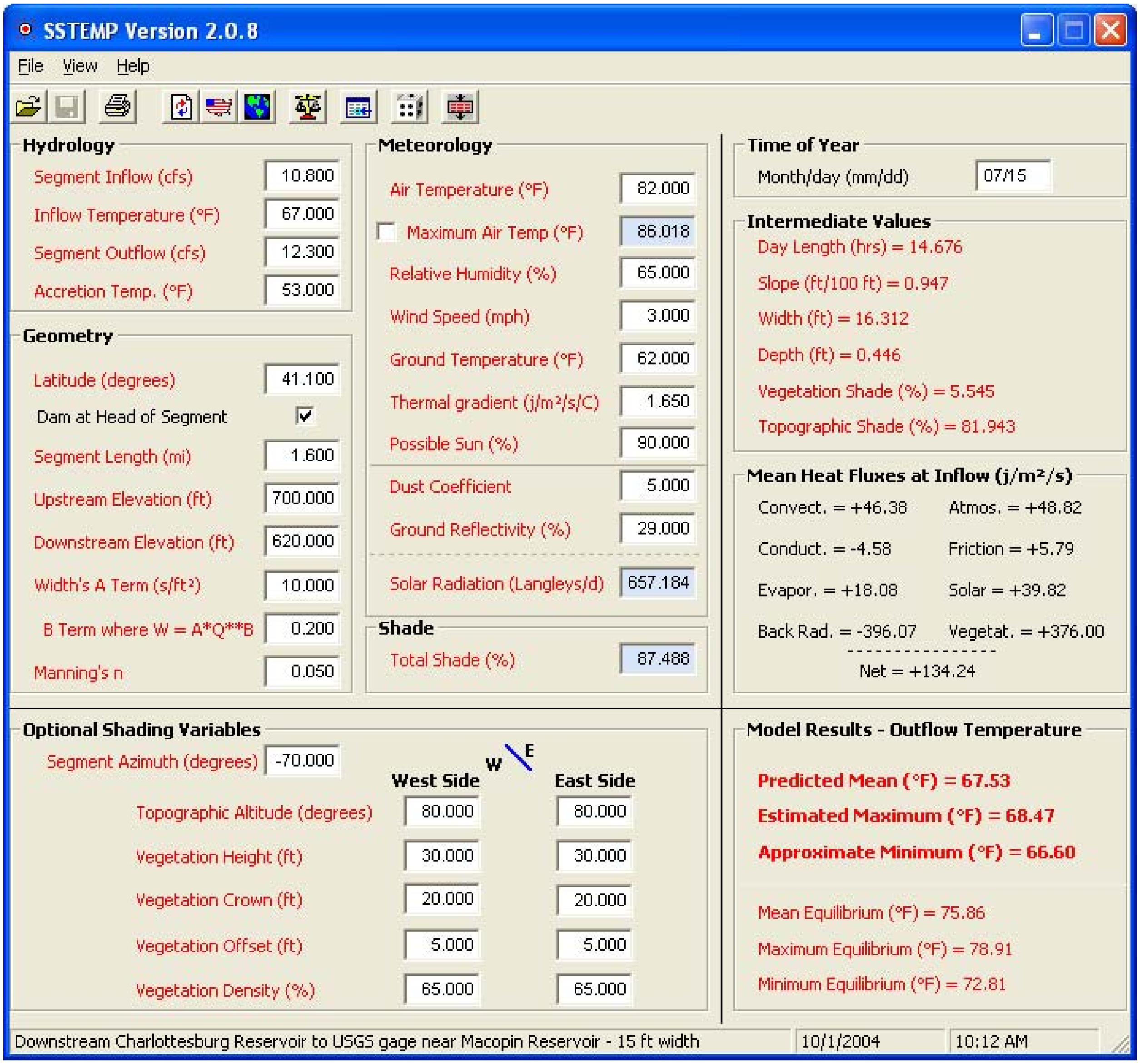
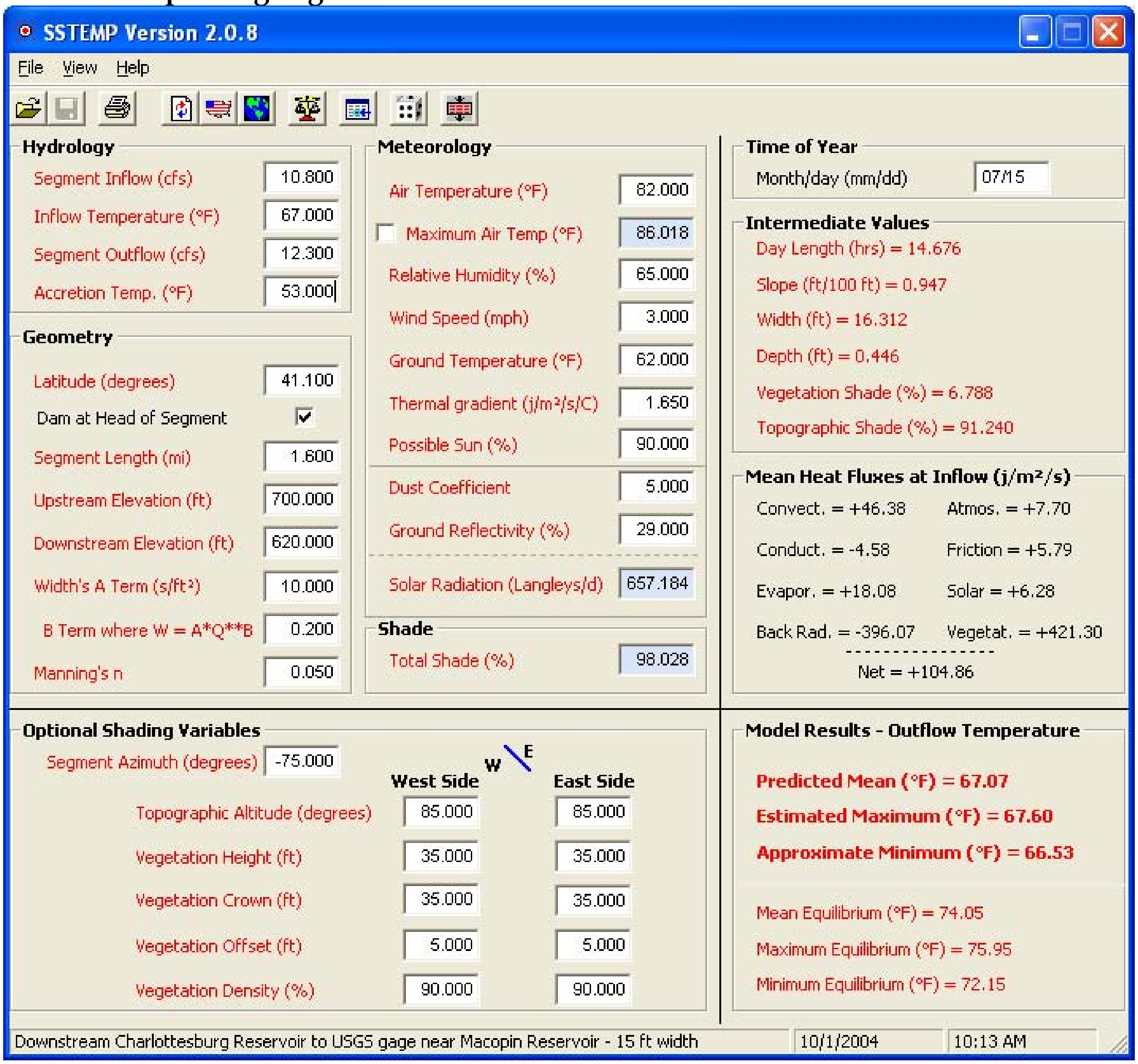
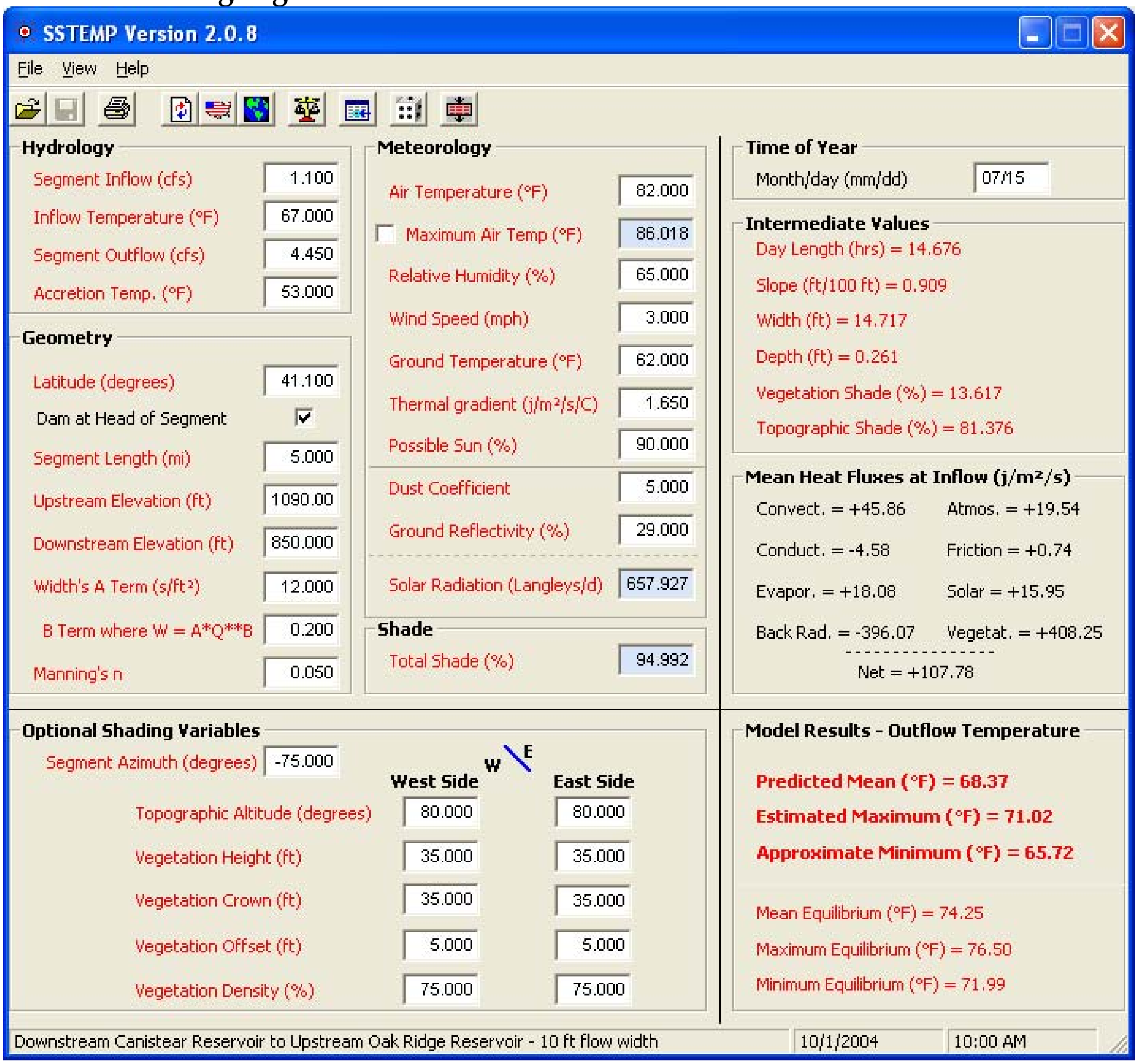


Figure 2: Stream Reach Charlotteburg and Macopin (PQ 7 & PQ8) Model output based on improving vegetation cover

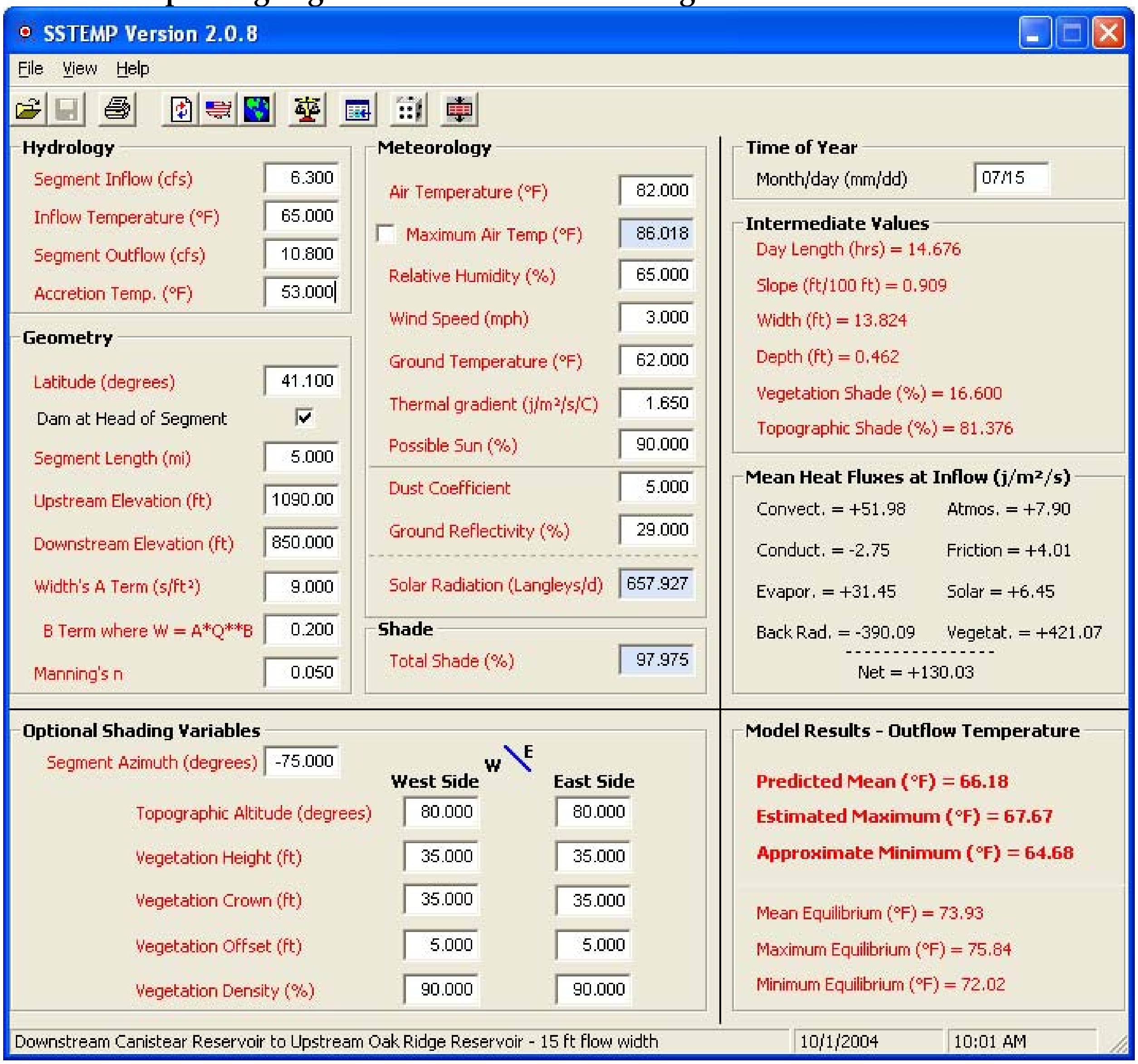


Runs for other segments were adjusted for drainage area, travel time and width. The runs for existing vegetation and enhanced vegetation and flow for the other segments are as follows:

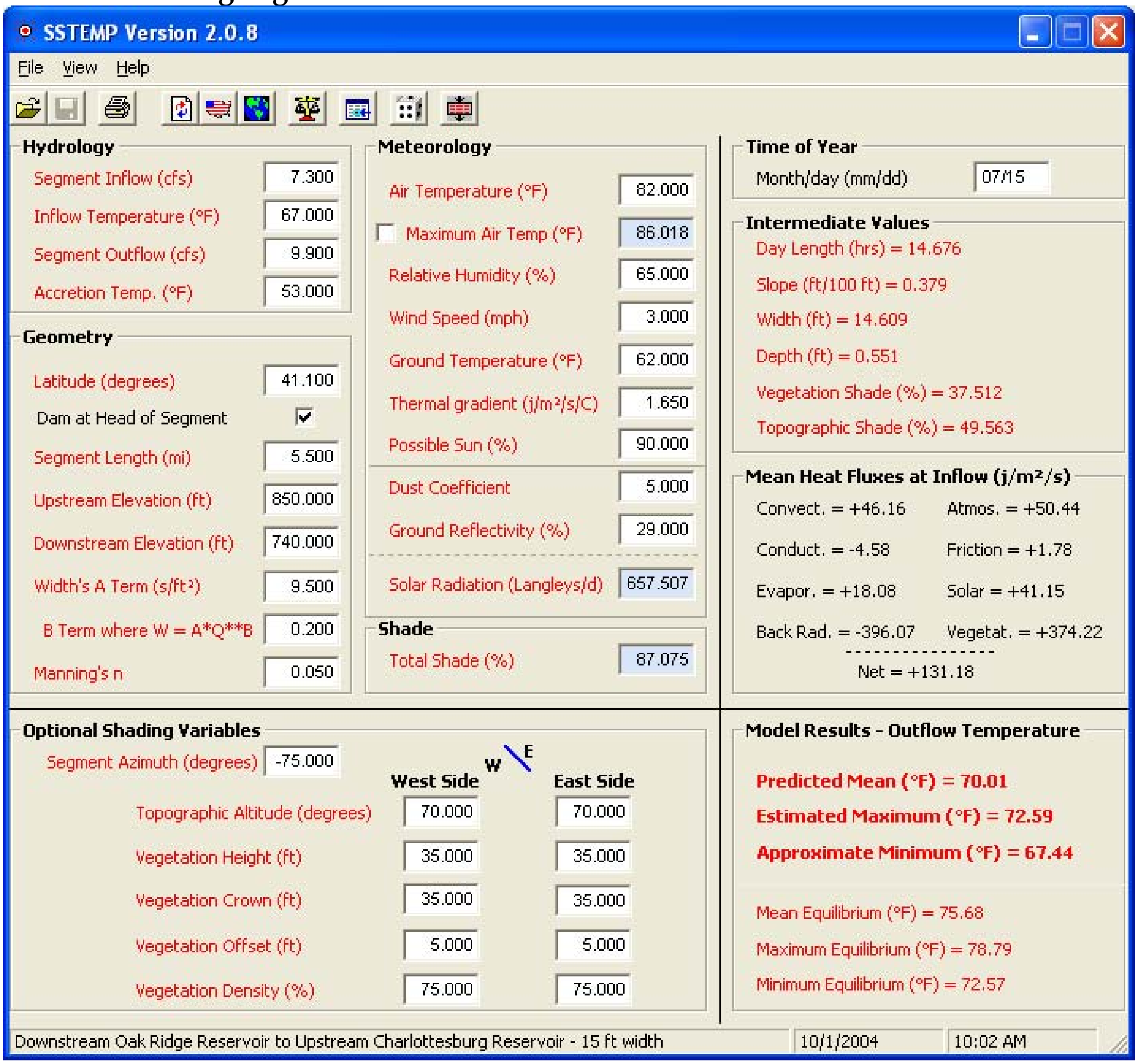
Stream Reach Between Canistear and Oak Ridge Reservoirs (PQ3) Model output based on existing vegetative conditions:



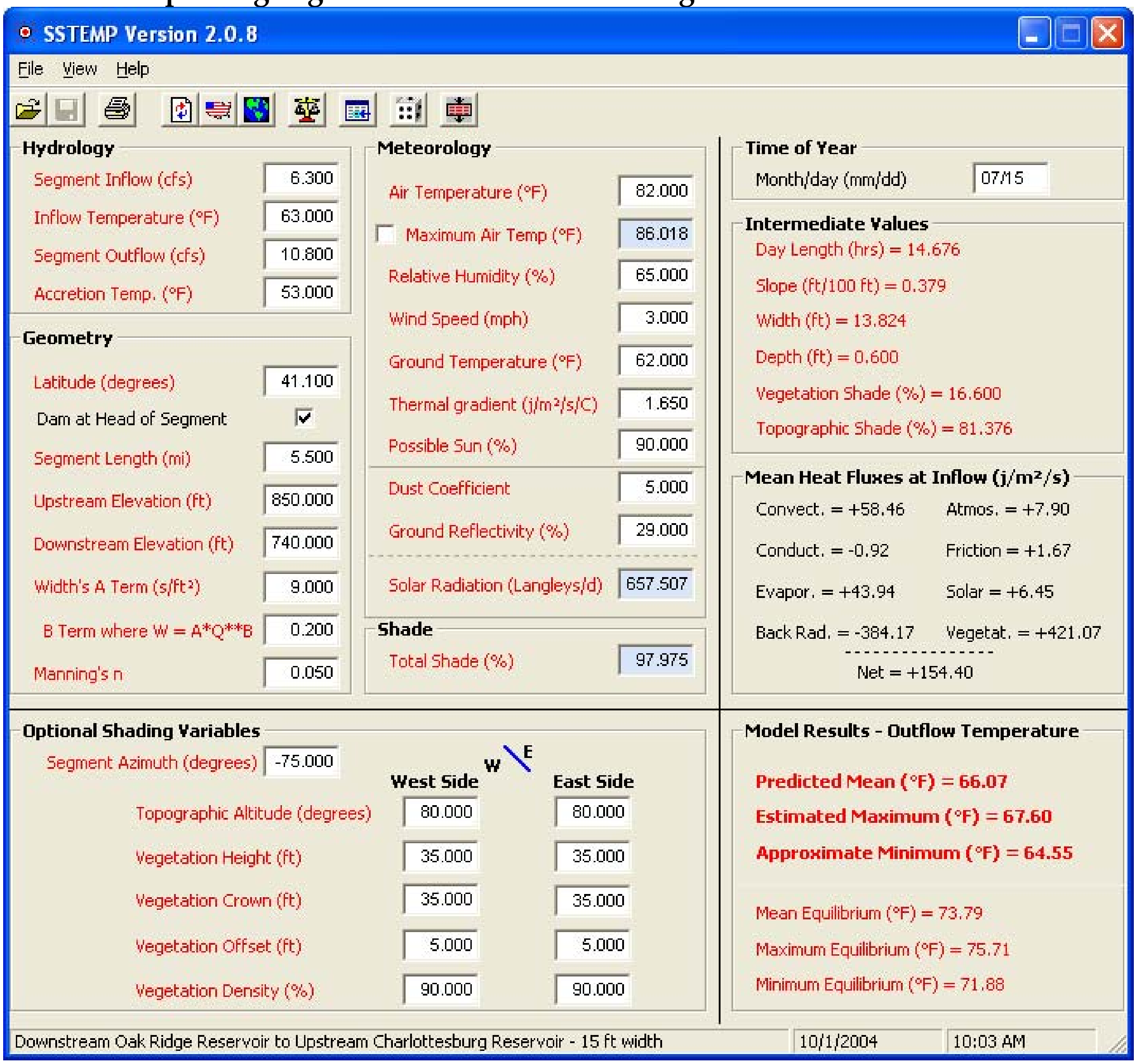
Stream Reach Between Canistear and Oak Ridge Reservoirs (PQ3) Model output based on improving vegetation cover and increasing flow rate:



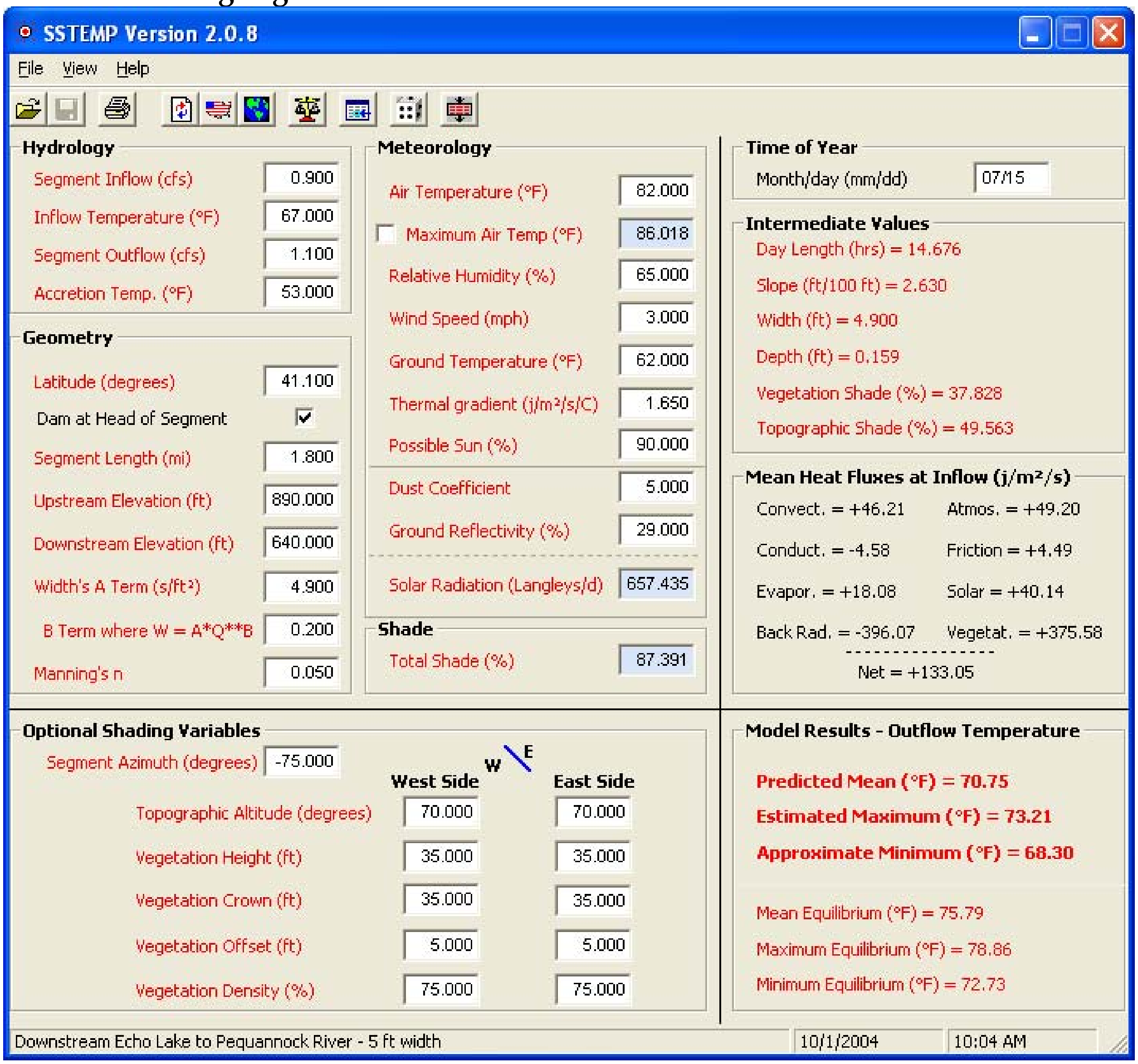
Stream Reach Between Oak Ridge and Charlotteburg (PQ4 & PQ5) Model output based on existing vegetative conditions:



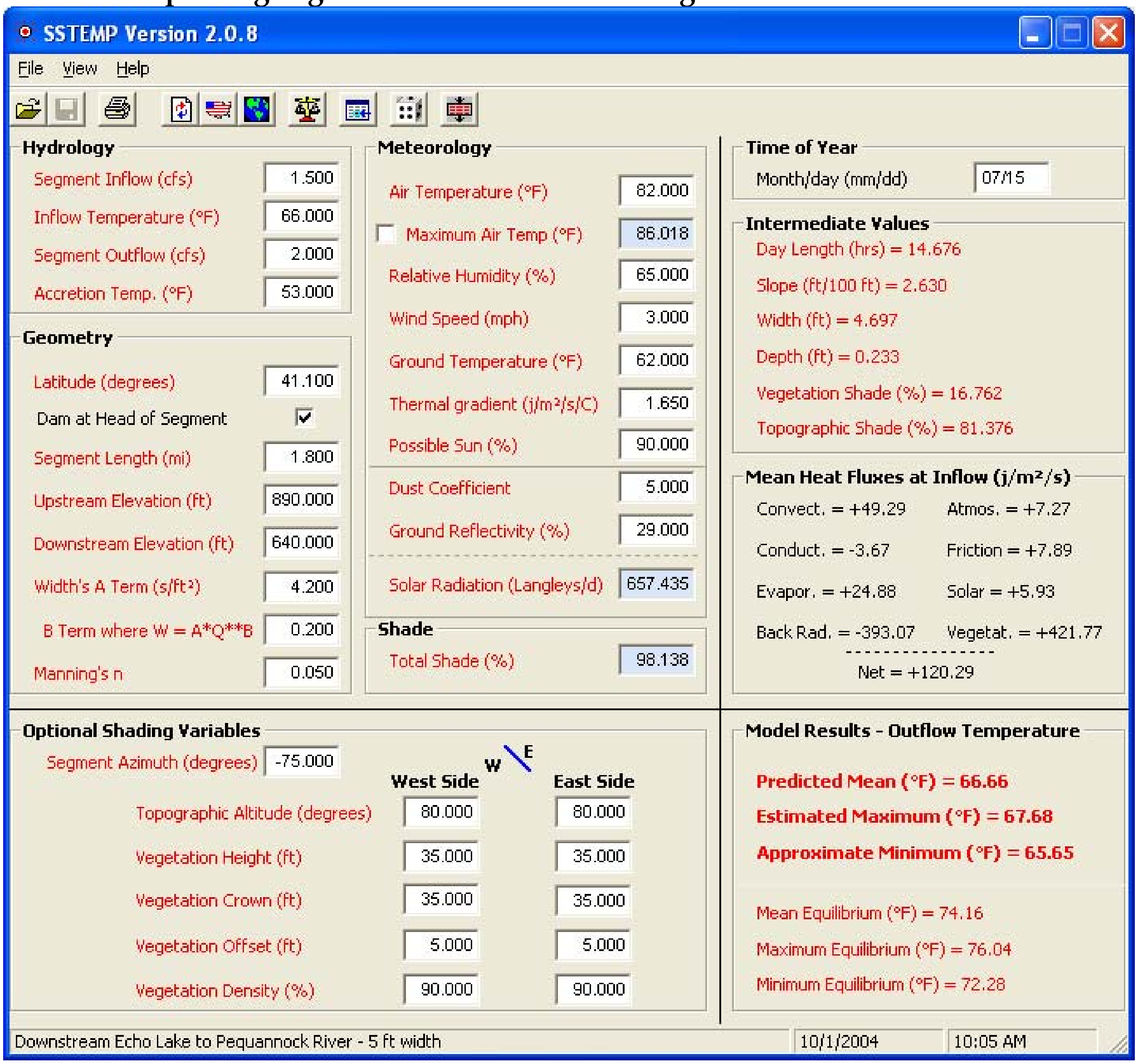
Stream Reach Between Oak Ridge and Charlotteburg (PQ4 & PQ5) Model output based on improving vegetation cover and increasing flow rate:



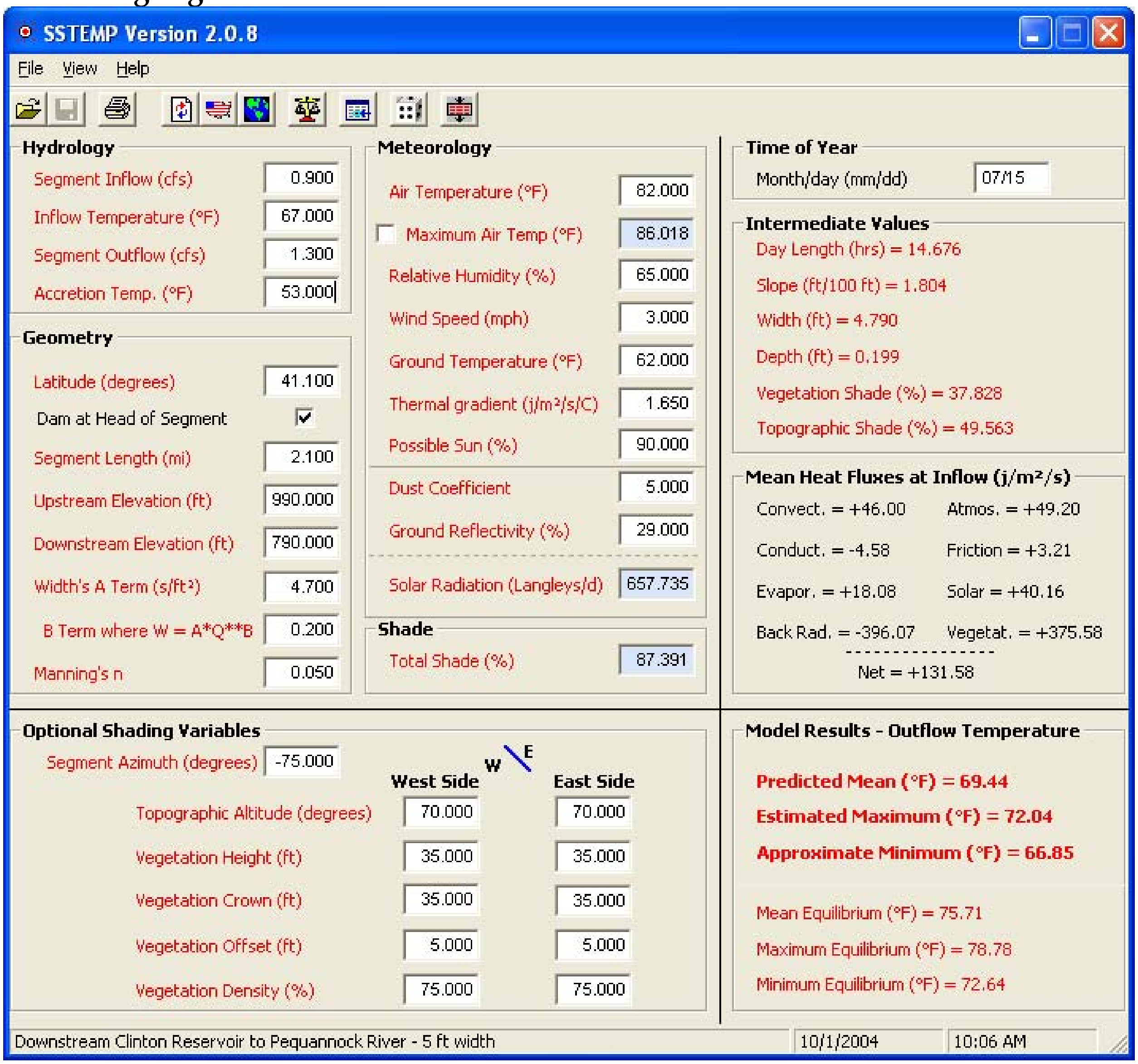
Stream Reach Between Echo Lake and Pequannock (PQ6 & 01382410) Model output based on existing vegetative conditions:



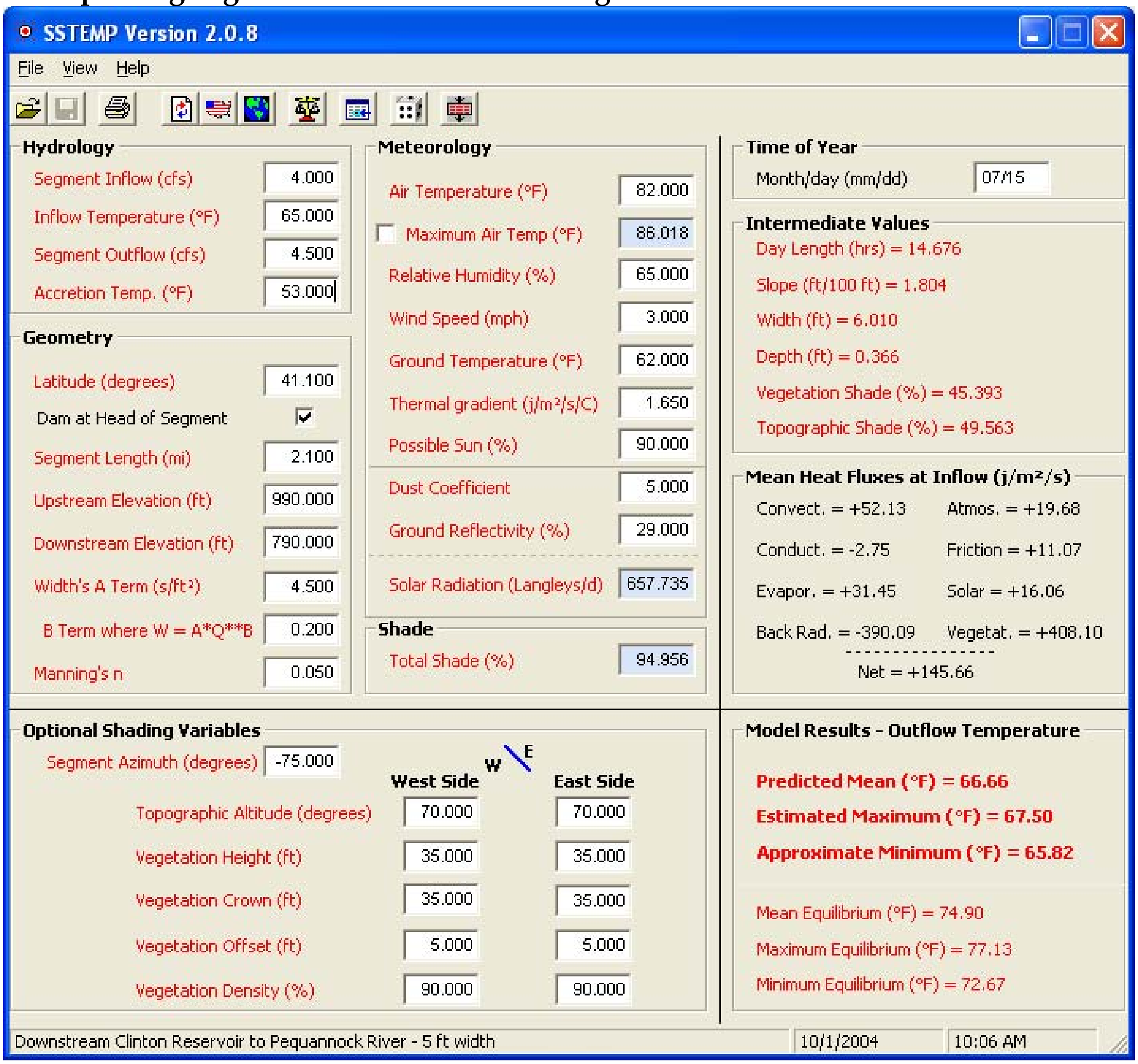
Stream Reach Between Echo Lake and Pequannock (PQ6 & 01382410) Model output based on improving vegetation cover and increasing flow rate:



Stream Reach Between Clinton Reservoir and Pequannock (PQ16) Model output based on existing vegetative conditions:



Stream Reach Between Clinton Reservoir and Pequannock (PQ16) Model output based on improving vegetation cover and increasing flow rate:



Appendix D Temperature data for PQ1, PQ14 andPQ15

Temperature Data for PQ1 reach—Pequannock River above Pacack Brook

Date	Max Of Temp F°	Min Of Temp F°	Avg Of Temp F°
05/28/04	65.97	63.93	65.10
05/29/04	64.80	59.64	62.30
05/30/04	63.64	56.27	60.00
05/31/04	61.64	57.38	58.73
06/01/04	62.21	56.27	58.75
06/02/04	64.51	58.22	61.28
06/03/04	65.38	59.36	62.26
06/04/04	64.80	59.07	62.17
06/05/04	63.36	58.50	60.28
06/06/04	58.50	57.10	57.65
06/07/04	64.80	57.10	60.48
06/08/04	69.47	62.78	65.68
06/09/04	72.77	66.26	69.31
06/10/04	71.27	67.14	69.41
06/11/04	66.84	63.93	65.29
06/12/04	66.84	59.93	63.35
06/13/04	64.22	59.64	62.24
06/14/04	64.80	61.93	62.97
06/15/04	71.27	63.93	67.02
06/16/04	73.37	67.72	70.41
06/17/04	71.87	69.18	70.36
06/18/04	73.07	67.72	70.34
06/19/04	72.17	68.88	71.00
06/20/04	68.59	63.93	66.40
06/21/04	68.30	60.50	64.63
06/22/04	66.26	64.22	64.99
06/23/04	70.07	63.64	66.44
06/24/04	70.67	63.07	67.06
06/25/04	68.88	64.80	67.10
06/26/04	68.59	64.51	66.34
06/27/04	67.72	62.21	65.11
06/28/04	65.67	62.21	64.27
06/29/04	68.30	62.21	65.02
06/30/04	68.30	62.78	65.63
07/01/04	70.07	63.07	66.48
07/02/04	71.87	65.67	68.80
07/03/04	71.27	64.22	68.04
07/04/04	70.67	64.51	67.76
07/05/04	72.77	68.01	70.22
07/06/04	71.87	67.43	69.66
07/07/04	71.27	64.51	68.34
07/08/04	72.77	68.88	70.64

07/09/04	70.07	65.09	67.49
07/10/04	68.88	62.50	65.77
07/11/04	69.77	63.36	66.87
07/12/04	67.72	64.51	66.69
07/13/04	65.97	63.64	64.38
07/14/04	66.26	63.36	64.65
07/15/04	67.72	64.51	66.06
07/16/04	68.01	64.22	66.10
07/17/04	71.57	65.67	68.51
07/18/04	69.77	66.26	67.32
07/19/04	67.43	64.80	65.91
07/20/04	71.57	64.22	67.59
07/21/04	73.37	65.67	69.34
07/22/04	72.77	67.72	70.37
07/23/04	71.87	68.88	70.25
07/24/04	70.97	66.55	68.38
07/25/04	69.77	66.26	67.83
07/26/04	70.97	65.38	68.29
07/27/04	69.47	65.97	67.40
07/28/04	67.72	63.64	65.56
07/29/04	71.87	65.09	67.95
07/30/04	70.97	66.26	68.71
07/31/04	73.37	68.59	70.91
08/01/04	73.98	70.07	71.99
08/02/04	74.59	69.77	72.07
08/03/04	76.15	70.37	73.16
08/04/04	74.90	70.97	73.08
08/05/04	73.07	68.88	70.60
08/06/04	68.59	64.22	65.95
08/07/04	64.51	61.93	63.23
08/08/04	66.26	60.21	63.19
08/09/04	67.43	61.35	64.60
08/10/04	68.59	62.50	65.76
08/11/04	68.88	66.84	68.00
08/12/04	69.77	67.43	68.48
08/13/04	70.37	67.43	68.97
08/14/04	69.47	66.26	67.81
08/15/04	68.88	66.84	67.64
08/16/04	68.59	66.84	67.66
08/17/04	68.59	63.93	66.50
08/18/04	69.47	65.67	67.54
08/19/04	70.37	66.84	68.62
08/20/04	72.77	67.72	70.28
08/21/04	71.57	67.14	68.50
08/22/04	67.72	63.36	65.80
08/23/04	68.88	61.93	65.29
08/24/04	69.77	65.38	67.45
08/25/04	69.18	65.97	67.27

08/26/04	66.55	63.07	64.80
08/27/04	68.30	64.51	66.11
08/28/04	72.47	65.97	68.74
08/29/04	73.67	68.59	70.69
08/30/04	72.47	69.47	70.90
08/31/04	72.77	69.47	70.88
09/01/04	70.07	65.38	67.94
09/02/04	68.30	63.93	66.15
09/03/04	67.14	62.50	65.34
09/04/04	68.30	63.07	65.87
09/05/04	67.14	63.64	65.02
09/06/04	65.38	61.64	63.60
09/07/04	65.97	63.36	64.68
09/08/04	64.80	63.64	64.29
09/09/04	68.59	64.51	66.33
09/10/04	69.47	64.80	66.99
09/11/04	66.55	62.21	64.29
09/12/04	66.55	59.93	62.99
09/13/04	66.55	61.07	63.90
09/14/04	65.97	63.36	64.22
09/15/04	64.22	61.35	62.91
09/16/04	64.22	63.36	63.75

Temperature Data for PQ14 reach—Outlet Trib of Maple Lake

Date	Max Of Temp F°	Min Of Temp F°	Avg Of Temp F°
05/26/04	63.52	62.11	62.59
05/27/04	67.59	59.87	63.09
05/28/04	64.63	62.11	63.29
05/29/04	62.36	58.15	59.58
05/30/04	61.29	57.03	58.97
05/31/04	60.82	58.54	59.21
06/01/04	61.63	58.07	59.29
06/02/04	63.43	58.89	61.02
06/03/04	63.26	60.48	61.85
06/04/04	62.66	59.87	61.31
06/05/04	61.76	59.27	60.22
06/06/04	59.23	57.98	58.34
06/07/04	63.43	57.81	59.97
06/08/04	65.66	62.19	63.74
06/09/04	68.36	64.59	66.24
06/10/04	68.14	65.06	66.77
06/11/04	64.93	62.49	63.57
06/12/04	62.96	60.73	61.87
06/13/04	62.36	60.56	61.62
06/14/04	63.73	61.51	62.29
06/15/04	66.47	63.73	64.75

06/16/04	67.07	65.87	66.48
06/17/04	72.05	66.22	67.99
06/18/04	72.01	68.61	69.76
06/19/04	69.60	64.46	67.42
06/20/04	64.38	61.98	62.68
06/21/04	63.05	60.26	61.75
06/22/04	65.40	62.62	63.74
06/23/04	65.10	63.52	64.32
06/24/04	64.76	62.71	63.90
06/25/04	70.46	63.39	65.41
06/26/04	69.90	64.59	67.06
06/27/04	64.38	62.28	63.13
06/28/04	63.13	61.55	62.48
06/29/04	65.27	62.96	64.50
06/30/04	65.02	62.62	63.76
07/01/04	65.49	63.60	64.65
07/02/04	65.96	64.59	65.37
07/03/04	65.49	63.78	64.62
07/04/04	64.85	62.45	63.85
07/05/04	68.10	64.42	66.52
07/06/04	67.93	64.93	65.93
07/07/04	66.17	63.78	65.01
07/08/04	67.07	65.74	66.39
07/09/04	66.39	63.43	64.76
07/10/04	64.67	62.79	63.74
07/11/04	65.45	63.69	64.71
07/12/04	69.13	64.89	65.99
07/13/04	68.06	63.95	64.64
07/14/04	64.50	63.05	63.65
07/15/04	64.93	63.52	64.27
07/16/04	64.59	63.30	63.96
07/17/04	65.92	64.03	64.91
07/18/04	68.14	64.72	65.82
07/19/04	67.16	65.27	66.21
07/20/04	67.67	64.50	65.95
07/21/04	67.03	65.02	66.13
07/22/04	67.37	65.74	66.60
07/23/04	72.09	66.94	68.41
07/24/04	69.47	67.16	68.20
07/25/04	68.23	65.62	66.64
07/26/04	67.20	65.06	66.18
07/27/04	67.67	65.53	66.12
07/28/04	66.52	64.59	65.47
07/29/04	68.83	64.38	66.41
07/30/04	69.26	65.87	67.22
07/31/04	70.72	67.59	68.99
08/01/04	70.89	69.34	70.12
08/02/04	70.20	68.44	69.31

08/03/04	70.54	68.61	69.53
08/04/04	69.99	68.53	69.18
08/05/04	69.34	66.30	67.45
08/06/04	66.09	63.05	64.01
08/07/04	63.05	61.76	62.14
08/08/04	62.92	60.69	61.78
08/09/04	63.69	61.76	62.73
08/10/04	64.50	62.53	63.47
08/11/04	66.77	64.38	65.18
08/12/04	68.66	65.45	67.08
08/13/04	67.46	66.39	66.91
08/14/04	66.60	64.97	65.50
08/15/04	67.33	65.49	66.91
08/16/04	67.46	65.92	66.82
08/17/04	66.04	63.60	64.91
08/18/04	65.45	64.33	64.82
08/19/04	66.34	65.02	65.55
08/20/04	67.76	65.66	66.63
08/21/04	71.10	67.16	68.97
08/22/04	67.54	63.95	65.64
08/23/04	66.47	62.92	64.72
08/24/04	66.26	64.50	65.34
08/25/04	65.23	64.08	64.61
08/26/04	63.95	62.23	63.21
08/27/04	65.23	63.56	64.24
08/28/04	66.94	64.89	65.76
08/29/04	67.41	66.52	67.03
08/30/04	67.80	66.90	67.32
08/31/04	68.06	66.56	67.71
09/01/04	66.43	64.33	64.94
09/02/04	64.29	63.01	63.57
09/03/04	63.90	62.28	63.22
09/04/04	64.38	62.88	63.67
09/05/04	63.90	62.32	63.23
09/06/04	62.28	61.33	61.72

Temperature Data for PQ15 reach—Apshawa Brook

Date	Max Of Temp F°	Min Of Temp F°	Avg Of Temp F°
05/26/04	61.72	60.82	61.20
05/27/04	68.31	60.43	64.79
05/28/04	67.41	65.40	66.76
05/29/04	65.27	60.35	62.45
05/30/04	61.55	57.94	59.94
05/31/04	60.35	58.93	59.40
06/01/04	61.85	59.14	60.28
06/02/04	63.43	60.22	61.85

06/03/04	63.56	61.63	62.58
06/04/04	62.53	59.83	61.48
06/05/04	61.29	59.27	60.07
06/06/04	59.23	58.50	58.92
06/07/04	62.96	58.76	60.78
06/08/04	65.74	61.98	63.94
06/09/04	68.14	63.95	66.26
06/10/04	67.89	64.63	66.55
06/11/04	64.50	61.20	62.86
06/12/04	61.89	58.84	60.62
06/13/04	61.20	58.37	60.17
06/14/04	63.30	60.56	61.71
06/15/04	66.56	63.30	65.04
06/16/04	67.93	65.87	66.89
06/17/04	69.30	66.04	67.16
06/18/04	68.96	66.34	67.75
06/19/04	68.66	64.67	67.40
06/20/04	64.50	61.25	62.49
06/21/04	62.75	58.71	61.06
06/22/04	63.56	61.81	62.60
06/23/04	65.40	63.13	64.22
06/24/04	65.53	62.11	64.11
06/25/04	66.90	63.30	64.96
06/26/04	66.13	63.52	65.21
06/27/04	63.52	60.86	62.48
06/28/04	62.92	60.69	62.06
06/29/04	64.08	61.81	62.98
06/30/04	65.23	61.51	63.34
07/01/04	66.13	62.71	64.58
07/02/04	67.84	64.80	66.41
07/03/04	66.64	63.86	65.58
07/04/04	66.64	63.65	65.33
07/05/04	69.13	66.04	67.51
07/06/04	68.79	66.60	67.70
07/07/04	68.19	64.80	66.79
07/08/04	70.07	67.41	68.58
07/09/04	68.19	65.40	66.72
07/10/04	67.11	63.90	65.73
07/11/04	68.14	65.23	66.83
07/12/04	67.59	65.74	67.05
07/13/04	65.70	64.97	65.18
07/14/04	65.87	64.80	65.31
07/15/04	66.81	65.15	65.99
07/16/04	66.39	64.63	65.70
07/17/04	68.36	65.66	67.09
07/18/04	67.80	66.00	66.72
07/19/04	67.03	65.53	66.22
07/20/04	68.31	65.53	67.08

07/21/04	68.74	65.70	67.48
07/22/04	69.90	66.94	68.65
07/23/04	72.44	68.44	69.55
07/24/04	68.44	66.90	67.58
07/25/04	67.07	65.79	66.46
07/26/04	67.46	65.40	66.58
07/27/04	67.07	66.26	66.53
07/28/04	69.60	66.09	67.58
07/29/04	70.33	67.71	69.09
07/30/04	71.10	67.80	69.25
07/31/04	72.27	69.94	71.04
08/01/04	72.39	71.45	71.95
08/02/04	72.09	70.42	71.43
08/03/04	72.48	70.50	71.58
08/04/04	71.96	70.12	71.14
08/05/04	71.32	67.67	69.06
08/06/04	67.46	63.69	65.20
08/07/04	63.60	62.23	62.93
08/08/04	64.25	61.08	62.83
08/09/04	65.92	62.88	64.52
08/10/04	67.46	63.90	65.81
08/11/04	68.61	67.29	67.85
08/12/04	68.79	67.16	67.93
08/13/04	69.30	68.23	68.76
08/14/04	68.53	67.24	67.91
08/15/04	68.10	67.59	67.88
08/16/04	70.03	67.50	68.62
08/17/04	69.26	66.77	68.17
08/18/04	69.21	67.24	68.19
08/19/04	70.37	68.27	69.26
08/20/04	71.53	68.70	70.19
08/21/04	71.10	69.64	70.29
08/22/04	69.51	66.90	68.22
08/23/04	69.43	65.62	67.62
08/24/04	68.87	67.76	68.49
08/25/04	68.14	66.52	67.53
08/26/04	66.64	64.03	65.54
08/27/04	68.36	66.00	67.11
08/28/04	70.54	67.80	69.22
08/29/04	71.28	69.64	70.53
08/30/04	71.40	69.69	70.59
08/31/04	71.28	68.83	70.49
09/01/04	68.66	65.83	67.18
09/02/04	66.34	64.12	65.55
09/03/04	66.43	63.48	65.26
09/04/04	67.29	64.42	66.06
09/05/04	66.69	64.55	65.67
09/06/04	64.89	63.22	64.24

09/07/04	65.02	64.59	64.72

Appendix E Discharge Monitoring Data

Discharge Monitoring Reports with regard to effluent temperature along the Pequannock River and associated tributaries. Bolded values indicate those above the Surface Water Quality Standard value of 68° F.

Facility Name	Monthly Average Temperature based on permitted monitoring period		Temperature °C	Temperature Converted °F
	Monthly	Quarterly		
West Milford Twp. MUA-Highview	2000: July		19.4	66.9
	Aug.		19.5	67.1
	Sept.		18.2	64.8
	Oct.		15.0	59.0
	2001: May		14.4	57.9
	June		17.4	63.3
	July		18.9	66.0
	Aug.		**20.4**	**68.7**
	Sept.		18.5	65.3
	Oct.		15.3	59.5
	2002: May		13.9	57.0
	June		18.5	65.3
	July		**21.1**	**70.0**
	Aug.		**21.4**	**70.5**
	Sept.		19.4	66.9
	Oct.		16.3	61.3
	2003: May		14.8	58.6
	June		17.0	62.6
	July		**20.3**	**68.5**
	Aug.		**21.0**	**69.8**
	Sept.		19.1	66.4
	Oct.		14.8	58.6
Kinnelon Twp High School	2000: July		**20.4**	**68.7**
	Aug.		**20.3**	**68.5**
	Sept.		18.8	65.8
	Oct.		15.0	59.0
	2001: May		15.9	60.6
	June		**20.0**	**68.0**
	July		**21.1**	**70.0**
	Aug.		**22.8**	**73.0**
	Sept.		**20.1**	**68.2**
	Oct.		15.3	59.5
	2002: May		14.6	58.3
	June		19.8	67.6
	July		**23.4**	**74.1**
	Aug.		**22.3**	**72.1**
	Sept.		19.8	67.6
	Oct.		15.9	60.6

	2003: May June July Aug. Sept. Oct.		13.9 **20.0** **22.4** **22.3** 19.6 14.7	57.0 **68.0** **72.3** **72.1** 67.3 58.5
Vibration Mounting & Controls (2 outfalls/2 temp. readings)		2000: May Aug.	**21.3**/19.0 **21.3/21.6**	**70.3**/66.2 **70.3/70.9**
		2001: May Aug.	18.8/18.4 19.6/17.4	65.8/65.1 67.3/63.3
		2002: May Aug.	**22.7/20.8** **23.6**/18.8	**72.9/69.4** **74.5**/65.8
		2003: May Aug.	**20.2**/18.5 **21.4**/15.2	**68.4**/65.3 **70.5**/59.4