

# **Water Quality in the Upper Passaic River**

Final Report, April 2014

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From 2011 to 2013, GSWA's Stream Team, under its Adopt-a-Stream program<sup>1</sup>, conducted quarterly water-quality monitoring at several sites on the Upper Passaic River and its tributaries. This report documents the results obtained during this program.

## **1. Prior Monitoring of the Upper Passaic**

During 1999 through 2008, the Ten Towns Great Swamp Watershed Management Committee (TTC) conducted water-quality monitoring of the five major streams in the Great Swamp watershed. GSWA Stream Team staff and volunteers participated in some phases of that work, which focused on key nitrogen and phosphorus nutrients and total suspended solids. Some additional parameters, including total dissolved solids (TDS), were included in the last two years of the program. Reports prepared by TTC's consultants were issued<sup>2</sup> in 2002, 2007, and 2009. Overall, these studies indicated that the major streams in the less-developed western part of the watershed, Upper Passaic River and Primrose Brook, were significantly less impaired chemically than Great Brook, Loantaka Brook, and Black Brook in the east. Annual macroinvertebrate monitoring by Leland W. Pollock<sup>3</sup> has also shown a similar difference in biological quality between the western and eastern streams.

## **2. GSWA's 2011 to 2013 Program**

To develop a more extensive characterization of the stream's water quality, six sites distributed along the Passaic and its tributaries were initially selected for monitoring. Four of these sites

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<sup>1</sup> GSWA's Adopt-a-Stream program is aimed at studying one stream at a time within the Great Swamp watershed over a three year period to collect baseline data on water quality.

<sup>2</sup> TTC (F. X. Browne) 2002, [http://www.tentowns.org/10t/docs\\_etc/wqrep602.pdf](http://www.tentowns.org/10t/docs_etc/wqrep602.pdf)  
TTC (Princeton Hydro) 2007, [http://www.tentowns.org/10t/docs\\_etc/wqrep307.pdf](http://www.tentowns.org/10t/docs_etc/wqrep307.pdf)  
TTC (Princeton Hydro) 2009, The Loantaka Brook Watershed Report, pp 79 – 147,  
<http://greatswamp.org/PDFs/Princeton%20Hydro%20Report%202009-07.pdf>

<sup>3</sup> See for example, Leland W. Pollock, "The Macroinvertebrate Communities of the Great Swamp Watershed", May 2013, <http://greatswamp.org/PDFs/GS12results.pdf>

are located on the main stem of the stream, and two sites are on the tributaries Indian Grave Brook and Penn's Brook, both in Somerset County. During the second half of the program, from August 2012 through December 2013, an additional site at the watershed outlet was included in the monitoring. These sites and their geographical coordinates are shown in Figure 1 (page 3). The sampling and analytical procedures were modeled on those followed in our 2005–2010 studies<sup>4</sup> of Loantaka Brook and Great Brook, and the program was carried out under a Quality Assurance Project Plan.

Quarterly samples were submitted for analysis to Environmental Compliance Monitoring, Inc., a NJDEP-certified laboratory in Hillsborough, NJ. The concentrations of total dissolved solids (TDS), sodium, chloride, soluble reactive phosphate, total phosphorus, nitrate, nitrite, total Kjeldahl nitrogen and total suspended solids (TSS) were determined. Total ammonia content was also evaluated in two sampling rounds at some of the sites

Supplementing the lab analyses, additional in-stream measurements were made using a portable multi-parameter water quality meter. During 2011 and 2012 a Horiba meter was leased for each sampling event and used for taking on-site measurements of water temperature, pH, dissolved oxygen (DO), turbidity, and conductivity. In 2013, a YSI Pro Plus meter, supplemented by an Oakton T-100 Turbidity meter, were used for this purpose, but operational difficulties with the YSI meter prevented its use in two of the four sampling rounds.

On each monitoring date, measurements of stream flow volumes were made at several of the sites using the Volunteer Stream Monitoring Partnership protocol. Sampling was usually performed under baseflow conditions, meaning that less than 0.5 inches of precipitation had occurred during the 48 hours prior to each collection. However, on two occasions this criterion was exceeded, resulting in higher than normal flows, especially at the downstream sites, and stormflow conditions were therefore applicable in those cases.

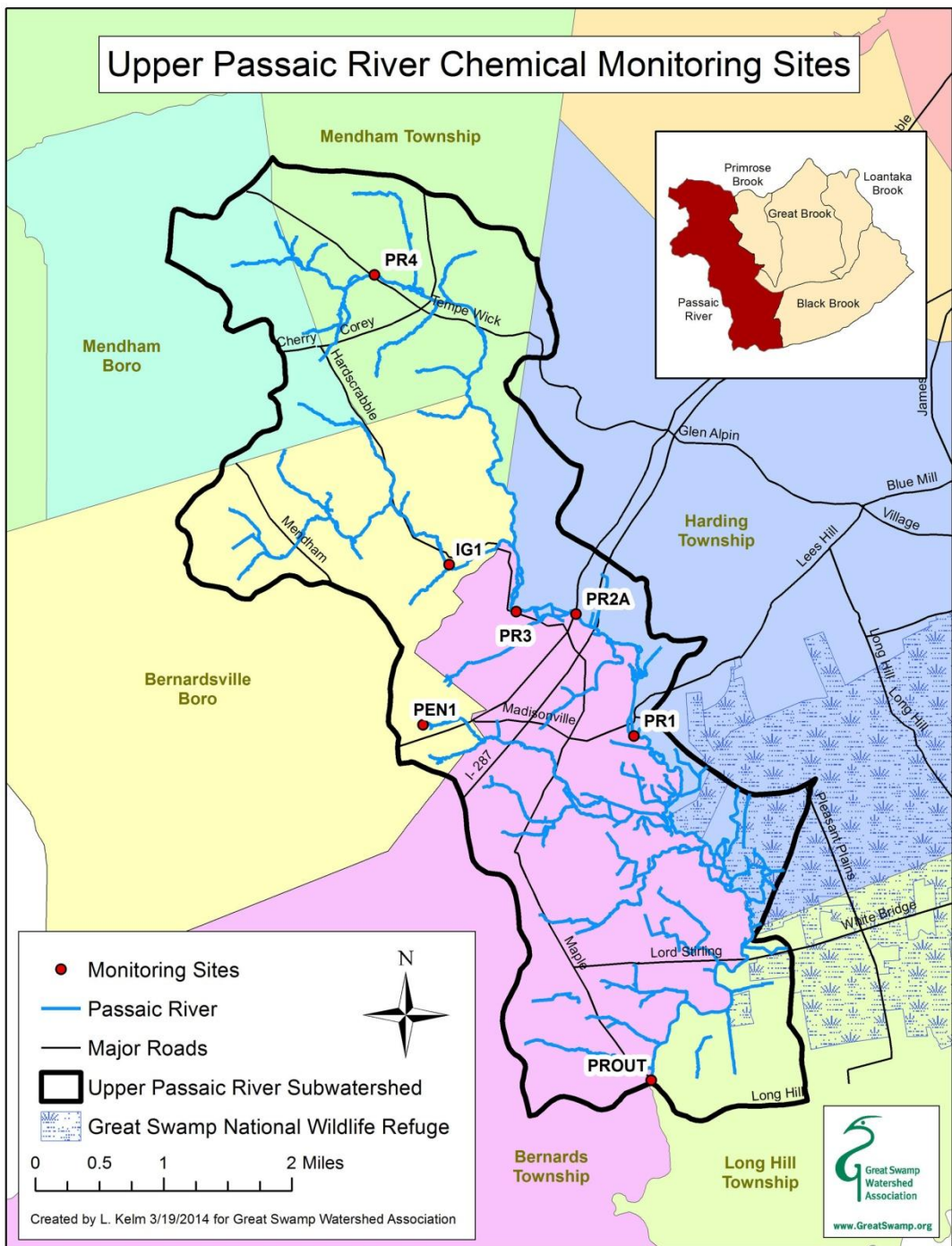
In August 2012 an Interim Report<sup>5</sup> was issued summarizing the results of the first 18 months of the program.

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<sup>4</sup> GSWA 2008, <http://www.greatswamp.org/GSWA-ST-NJDEP-LB-Report2008.pdf>

GSWA 2011, [http://www.greatswamp.org/PDFs/GSWA%20ST%20GreatBrook2010\\_FINAL.pdf](http://www.greatswamp.org/PDFs/GSWA%20ST%20GreatBrook2010_FINAL.pdf)

<sup>5</sup> GSWA 2012 <http://www.greatswamp.org/PDFs/PR%20Interim%20Report%202012-10-14.pdf>



Site	Location	Latitude	Longitude
PR4	Off Tempe Wick Rd. above Ledells Pond	40° 46' 18.9" N	74° 34' 11.0" W
IG1	Indian Grave Brook below Chestnut Ave. bridge	40° 44' 20.5" N	74° 33' 30.7" W
PR3	Off Hardscrabble Rd. opposite Butternut Lane	40° 44' 01.6" N	74° 32' 57.1" W
PR2A	Above I-287 bridge near Olde Mill Inn	40° 43' 56.7" N	74° 32' 20.1" W
PR1	Off Madisonville Rd. below Osborn Pond	40° 43' 14.7" N	74° 31' 55.2" W
PEN1	Penn's Brook near Bernards High School	40° 43' 14.7" N	74° 33' 39.6" W
PRout	Off Basking Ridge Rd., Millington	40° 40' 52.4" N	74° 31' 42.6" W

Figure 1. Locations of Upper Passaic Sampling Sites

### 3. Monitoring Results

The results of the twelve quarterly monitoring rounds are summarized in the appended Tables A1 through A3 (laboratory data) and B1 through B3 (on-site measurements). These tables also include applicable values of certain quality standards. The NJ standards developed by NJDEP relevant to monitored parameters are provided for both “trout production” and “non-trout” waters, since the Upper Passaic subwatershed contains stream segments of both these designations. The sites monitored in this program that fall under the “trout production” designation are PR2A, PR3, PR4, and IG1. In addition, more stringent criteria proposed as goals for standards specific to the Upper Passaic<sup>6</sup> by the Ten Towns Great Swamp Watershed Management Committee (TTC) in 2002 are shown in Tables A1 to A3. Some specific results and inferences which may be drawn from them are as follows.

#### 3.1 Total Nitrogen-N

Total nitrogen (TN) was determined by summing the lab-measured “as N” concentrations of nitrates, nitrites, and total Kjeldahl nitrogen (i.e. organic-N plus ammonia-N). Figure 2 summarizes the total nitrogen values at the various sites, plotted as a function of the sampling date. At the six sites other than PEN1, most TN concentrations are seen to be less than 2 mg/l and to have rather similar values on a given sampling date. The seasonal variation showing a tendency for low TN levels to occur in summer is a behavior often seen in our streams, and is sometimes attributed to the warm-weather action of denitrification agents such as bacteria. (Denitrification converts reactive nitrogen into nitrogen gas.)

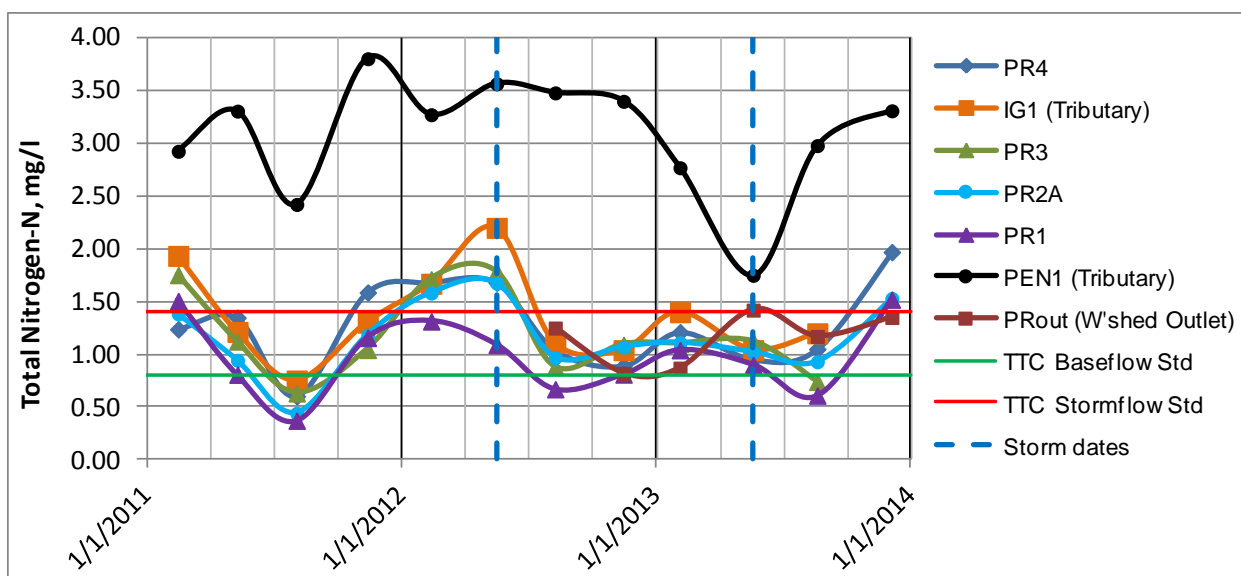


Figure 2. Total Nitrogen, Upper Passaic, 2011 – 2013

However, at PEN1 nitrogen values at all times were significantly higher than at the other sites. This site on Penn’s Brook is located in largely-urbanized downtown Bernardsville in a wooded area behind a shopping center and a short distance from the high-school playing fields. Under normal baseflow conditions it is a feeble trickle of a stream, providing little dilution of any nutrients or contaminants which might drain into it.

<sup>6</sup> TTC (F. X. Browne) 2002, [http://www.tentowns.org/10t/docs\\_etc/wqstd602.pdf](http://www.tentowns.org/10t/docs_etc/wqstd602.pdf)

The two stormflow dates are indicated on the graph by the dashed blue lines. On the first of these, 5/17/2012, about 1.4” of rain had fallen in the 48 hours prior to the sampling, resulting in higher levels of total Kjeldahl nitrogen (TKN) than usual being found at most sites. TKN components are known to form on ground surfaces or in shallow soils in wooded watersheds and tend to be flushed into streams during and after storms. On the second storm date, 5/20/2013, the prior rain amounted to only 0.6”, barely meeting the criterion for stormflow and little effect on TKN or TN was seen except possibly at PRout. where nitrogen levels are likely to reflect the impact of other watershed streams, all of which join the Passaic River upstream of this site.

Figure 2 also includes indications of the TTC baseflow and stormflow standard goals for TN. These were always exceeded at the PEN1 site, and the baseflow targets were usually not met at the other sites, except during some of the summer lows. New Jersey has no total-nitrogen standard, but has a nitrate standard of 10 mg/l maximum based on a human health criterion. Clearly all the Figure 2 data easily satisfy that standard.

### 3.2 Total Phosphorus-P

Results for total phosphorus are shown in Figure 3, which also indicates the applicable NJ and TTC standards. Phosphorus levels at all sites except PRout were consistently low with respect to the 0.1 mg/l NJ standard and the TTC stormflow standard (also 0.1 mg/l). Since the entire watershed contributes water to the flow at PRout, the TP levels can be expected

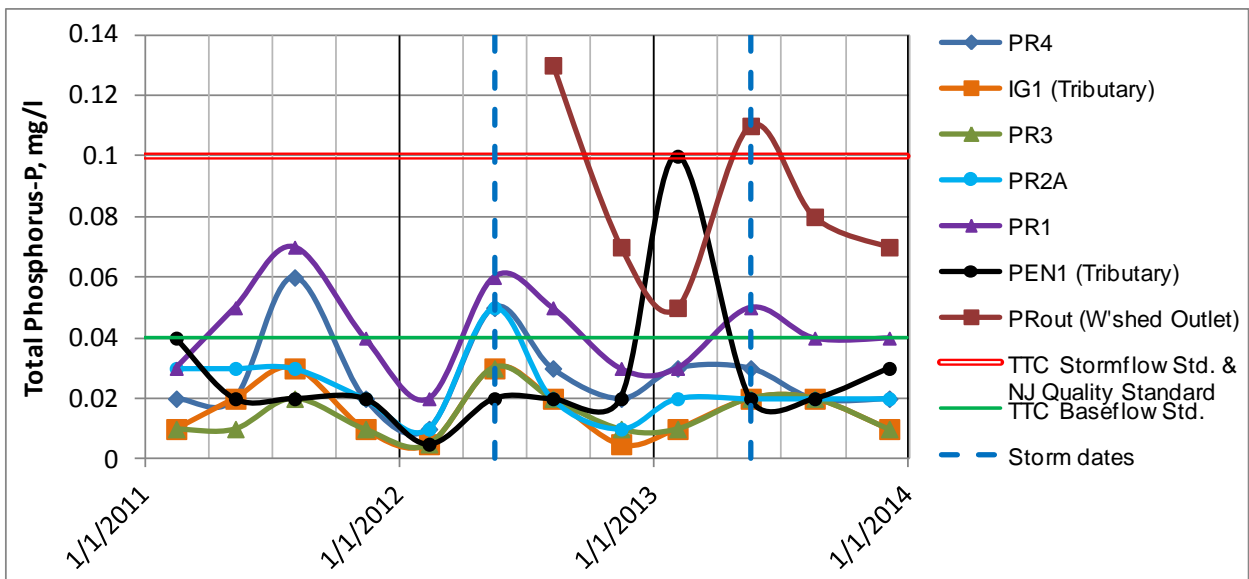


Figure 3. Total Phosphorus, Upper Passaic, 2011 – 2013

to reflect the influence of tributaries, especially Loantaka Brook which is known<sup>7</sup> to contain higher phosphorus concentrations than the other streams, as well as possible effects of phosphorus released seasonally in the wetlands within and near to the Great Swamp National Wildlife Refuge. In general, seasonal variation is seen at most sites, with the lower

<sup>7</sup> See footnote references 2 and 4 (pages 1 and 2)



values being more apparent during winter, in contrast to the nitrogen experience. During the 3-year monitoring period, the stringent TTC baseflow standard of 0.04 mg/l for TP was always met at IG1 and PR3, two of the highest-quality sites in the Great Swamp watershed.

The large surge in TP at PEN1 in February 2013 probably resulted from winter construction work aimed at improving the drainage into Penn’s Brook. This caused considerable soil disturbance just upstream from the sampling location (loosely-packed soil is more easily penetrated by rain water or snowmelt, leading to greater flushing of contaminants retained in the soil). The work, which included installation of a buried pipe to carry the drainage from a nearby shopping center, was completed soon after the February sampling round, and subsequent monitoring shows TP to have returned to its former level.

### 3.3 Total Dissolved Solids

Tables A1 through A3 contain the lab results for the concentrations of TDS and two of its principal components, sodium and chloride. These parameters frequently reflect the aftermath of road-salt dispersion on local roads and parking lots, with winter surges being followed by prolonged declines as salt retained in local soils slowly leaches into a stream. Figure 4 shows that at the beginning of the 3-year monitoring period, TDS concentrations were relatively high during the February 2011 deicing season. Subsequently, at most sites, somewhat lower TDS values were measured, with minor fluctuations during the following two winters of relatively light snowfall.

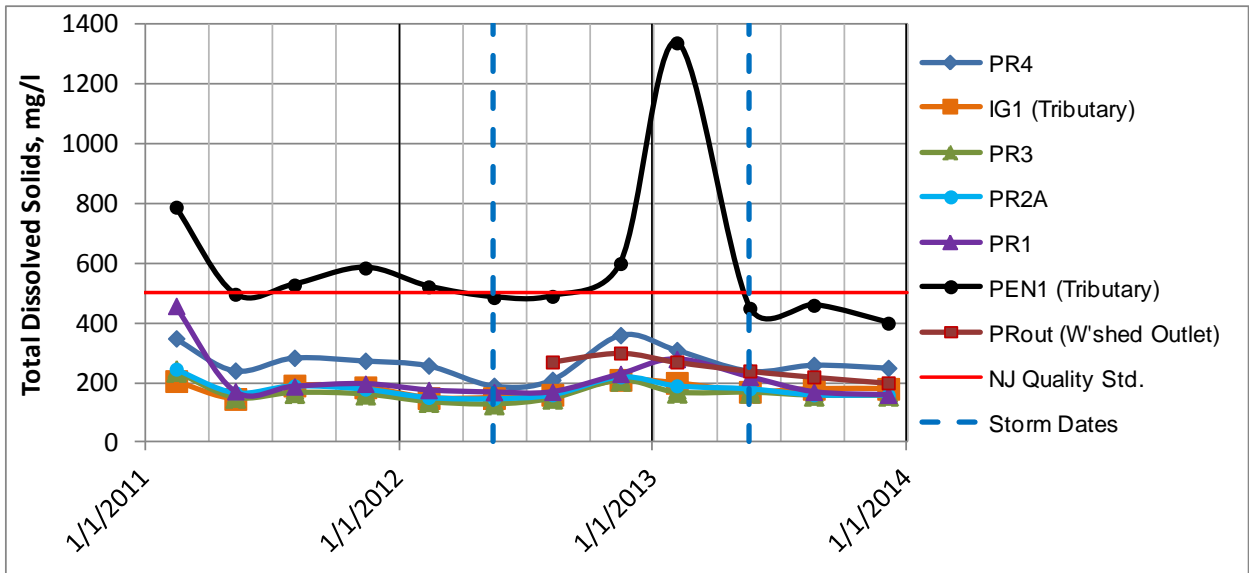


Figure 4. Total Dissolved Solids, Upper Passaic, 2011 – 2013

TDS at PEN1 was significantly higher than at the other sites, as expected from the stream’s proximity to roads and parking lots and its low volume of natural receiving water. A similar surge occurred in February 2013 to that described above for total phosphorus, again probably associated with the soil disturbance resulting from the drainage upgrade. The NJ TDS standard was exceeded at PEN1 in about half the sampling rounds. There is no TTC standard for TDS, sodium or chloride.

The sodium and chloride patterns generally reflected the TDS behavior, with high values each February, especially at the low-flow sites PR4 and PEN1 which are very vulnerable to road-salt contamination. There were three exceedances of the NJ chloride chronic toxicity standard at PEN1, one in each February sampling. As indicated in the final column of the A1 through A3 tables, the combined sodium and chloride percentage of TDS also reached its highest values in these same PEN1 February samples, as would be expected from the impact of road salt.

Inspection of the TDS levels measured at the main stem sites in upstream-to-downstream order shows relatively high values at the upstream PR4 site where the low-volume Passaic is vulnerable to runoff from Mendham roads. The stream then passes for several miles through extensive tracts of undeveloped land where the cleaner water draining into it provides dilution and leads to much lower TDS numbers. For this reason the Upper Passaic in the vicinity of the next site, PR3, probably is one of the least-contaminated reaches in the watershed's five major streams. Subsequently, after flowing past busy highways and developed parts of Basking Ridge, there is a slight rise in TDS as the higher-volume stream receives more contaminated runoff. The Indian Grave Brook tributary measured at the IG1 site also contains a low level of TDS content, closely comparable to that seen at PR3. It is noteworthy that the PR3 and IG1 locations, in addition to being among the least-impaired chemically, are consistently two of the highest rated by Leland W. Pollock<sup>8</sup> in his annual surveys of macroinvertebrate habitat and diversity in the Great Swamp watershed.

### 3.4 Water Temperature

Water temperatures were normally measured at each sampled site using a dedicated temperature gauge or a NJDEP-calibrated thermometer. On occasions when neither of these instruments was available or operable, the temperatures recorded by the multi-parameter meter were used.

A water temperature of 24.1 °C was measured at PR4 on 8/4/2011, followed by similar high temperatures on 8/9/2012 at all four sites upstream of Osborne Pond. As previously mentioned, this uppermost portion of the Passaic River is classified by NJDEP as a "trout-production" stream segment, and these temperatures exceeded the applicable NJ daily-maximum standard of 22 °C for such segments. The remainder of the non-tidal portion of the Passaic River carries the "non-trout" designation, for which the daily-maximum temperature standard is 31 °C. No exceedances of this standard have been seen at PR1, PEN1 or PRout, which are located in the "non-trout" segment.

A single temperature measurement at any given site in August does not capture the daily temperature excursions which might result in other exceedances of the daily-maximum standard on warm summer days. There is also a rolling seven-day average of daily maxima specified in the temperature standards for the various stream classifications. Continuous temperature recording in sensitive stream segments is therefore needed to fully assess conformance with these standards.

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<sup>8</sup> See footnote 3, page 1.

### 3.5 Other Parameters

The history of high nitrate levels seen at PEN1 suggested that ammonia content should be checked in samples taken at that site. Higher-than-normal levels of both nitrate and ammonia might indicate an unintentional discharge from a septic system or failing sanitary sewer line. Measurements of total-ammonia made at 3 sites are included in the Figure 5 table below. The highest total-ammonia-N level of 0.17 mg/l at PEN1 was comparable with those at the high end of the range of measurements made by Princeton Hydro at all the traditional TTC sites in 2006 – 2008. However, it represents only a small portion of either total-nitrogen or TKN values measured at PEN1 on the same date.

Sampling Date	Sampling Site	Water Temp. °C	pH	Calculated NH <sub>3</sub> -N Toxicity Criteria		Measured (NH <sub>3</sub> + NH <sub>4</sub> <sup>+</sup> )-N Concentration mg/l	Calculated Un-ionized NH <sub>3</sub> -N Concentration mg/l
				Acute mg/l	Chronic mg/l		
				5/20/2013	PR3	15.5	7.8
5/20/2013	PEN1	15.8	7.8	0.156	0.042	0.11	0.00198
12/5/2013	PR3	7.0	7.57	0.066	0.017	0.05	0.00027
12/5/2013	PEN1	10.0	7.26	0.077	0.020	0.17	0.00057
12/5/2013	PRout	5.0	6.85	0.039	0.010	0.05	0.00004

Figure 5. Total-ammonia-N results and calculated un-ionized-ammonia-N values

Figure 5 also includes an assessment of un-ionized ammonia with respect to NJ toxicity criteria. In solution, un-ionized NH<sub>3</sub> exists in equilibrium with the ammonium ion NH<sub>4</sub><sup>+</sup>, with the fraction of total ammonia in the NH<sub>3</sub> form being principally dependent on pH and water temperature. In addition, the toxicity of a given concentration of NH<sub>3</sub> is itself sensitive to pH and temperature. NJDEP includes a set of formulae among its Surface Water Quality Standards, from which Chronic and Acute toxicity criteria specific to several NJ fish and invertebrate species can be determined. The Figure 5 table shows that the calculated un-ionized NH<sub>3</sub>-N levels fall well below the toxicity criteria at the sampled sites by a large margin. Future assessments of un-ionized ammonia concentrations should include samples taken in warm summer months when the NH<sub>3</sub> - NH<sub>4</sub><sup>+</sup> equilibrium shifts towards higher un-ionized-NH<sub>3</sub> values.

No exceedance of either the NJ standards or the TTC stormflow standards for total suspended solids was seen at any of the sites, but there were a number of failures to meet the much more stringent TTC baseflow standard. The high TSS value of 36 mg/l at PEN1 on 2/4/2013 was almost certainly caused by the soil disturbance mentioned in Section 3 regarding the surges in TP and TDS at that site on the same date.

On three occasions (2 at PEN1 and 1 at IG1), pH failed to meet the NJ standard; all measurements of dissolved oxygen and turbidity satisfied the standards.



## 4.0 Long Term Perspective

At most of the sampling sites covered by this report very little prior data is available for comparison purposes. Exceptions are PR1 and PRout, which were monitored for most of the same chemical parameters by the Ten Towns Committee over the period 1999 – 2008, as detailed in the footnote 2 references (page 1). In addition, the US Geological Survey performed extensive chemical and physical monitoring<sup>9</sup> in earlier decades at PRout, especially from the 1970's through 1990's. These bodies of data are helpful in determining if any long-term trend, or lack of trend, can be confirmed for certain parameters. Some trends were discussed in GSWA's 2013 "State of the Streams" report<sup>10</sup> and are updated here. The graphs in the following subsections display uncensored data acquired under both baseflow and stormflow conditions, with no adjustment for influences on solute concentrations by variables such as flow volumes or sampling season.

### 4.1 Total Nitrogen

Total-nitrogen-N values from 1973 – 2013 at PRout are shown in Figure 6. The data mostly range from around 0.5 to 1.5 milligrams/liter over 4 decades, and it seems appropriate to regard the TN data as essentially unchanged during this period.

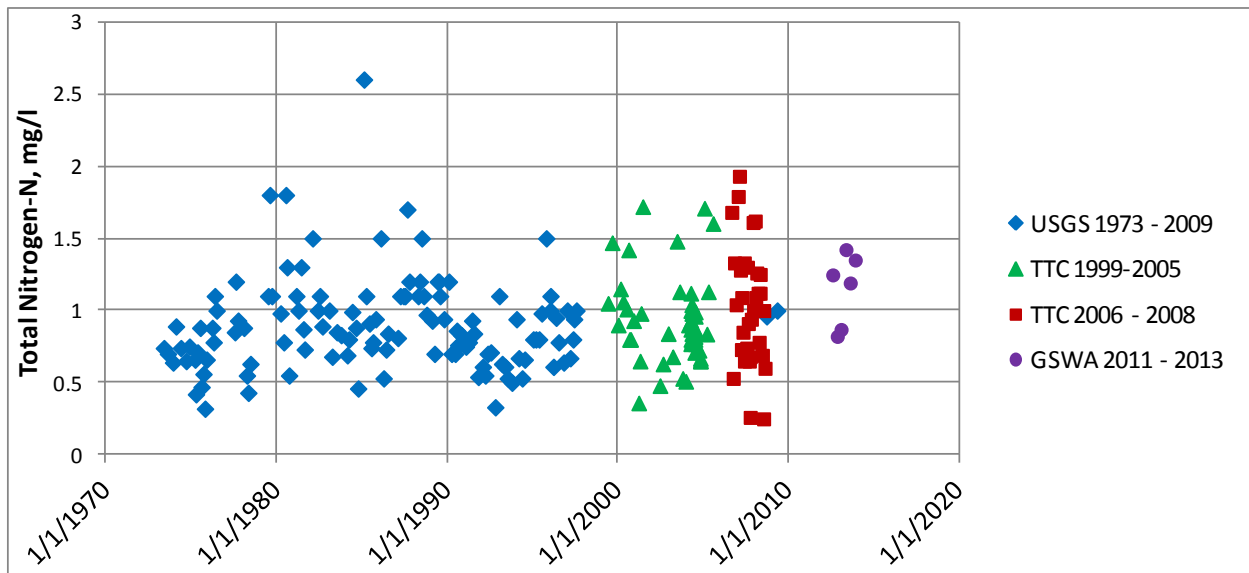


Figure 6. Total-nitrogen-N concentrations at PRout, 1973 - 2013

### 4.2 Total Phosphorus

The long-term total-phosphorus-P data, plotted in Figure 7, showing fewer high-value outliers in the last 20 years than earlier, appear to be suggestive of a downward trend with an increasing fraction of analyzed samples meeting the NJ TP quality standard over time.

<sup>9</sup> USGS 01379000 Passaic River near Millington NJ, [http://nwis.waterdata.usgs.gov/usa/nwis/qwdata/?site\\_no=01379000](http://nwis.waterdata.usgs.gov/usa/nwis/qwdata/?site_no=01379000)

<sup>10</sup> Laura Kelm, "The State of the Streams in the Great Swamp Watershed", April 2013, <http://www.greatswamp.org/PDFs/State%20of%20the%20Streams%20Report%20-%20FINAL%20for%20website.pdf>

However, because of the large degree of scatter in the data the best linear trend line shown in Figure 7 is a weak fit ( $R^2=0.09$ ). In 2010, the results were published of a collaborative USGS-NJDEP study<sup>11</sup> of water quality data from about 70 NJ sites; the study was designed to identify increasing or decreasing trends in certain parameters. These sites (which did not

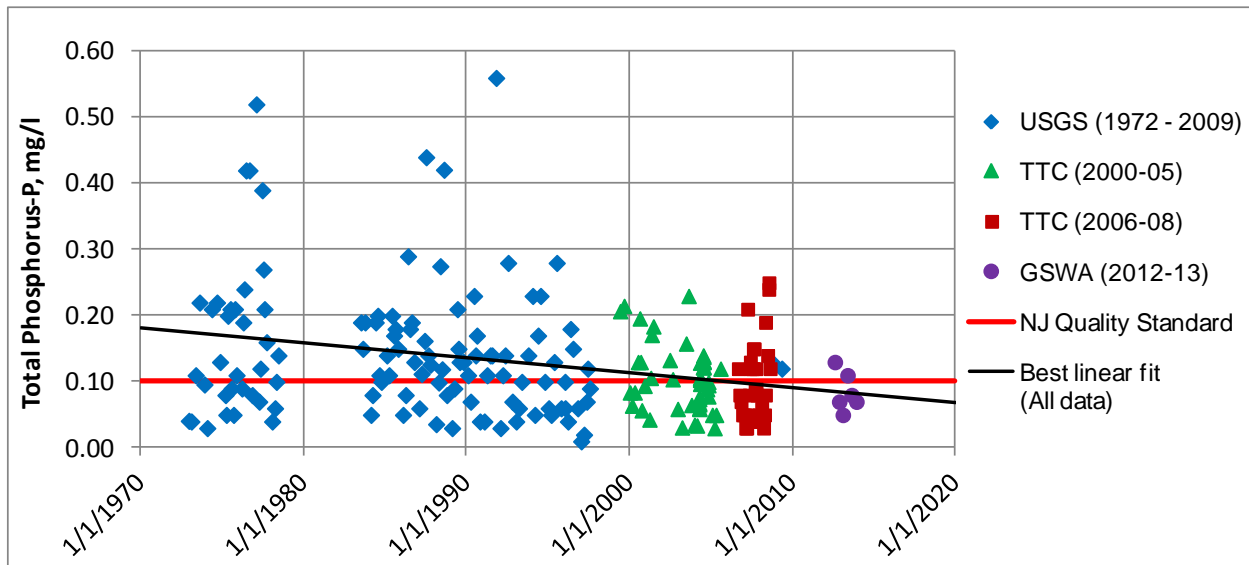


Figure 7. Total-phosphorus-P concentrations at PRout, 1972 - 2013

include PRout) had been monitored from 1998-2007. In the case of total phosphorus, the study showed decreasing trends in concentration over the 10-year period at about 17% of the sites, compared with increases at about 7%. To better establish the existence or non-existence of the implied downward trend indicated in Figure 7, it is important that quarterly evaluation of total-phosphorus levels at PRout be continued well into the future.

### 4.3 Total Dissolved Solids

In the case of TDS the main body of USGS data extends from 1962 to 1997, but a handful of data points were recorded in 1923-1924. The TTC monitored TDS from 2006 to 2008. The accumulated data are shown in Figure 8. The plot indicates a clearly defined increase in TDS concentration over the 90-year period. The best polynomial fit shown has a level of significance,  $R^2$ , of 0.47, and a current rate of increase of about 3 mg/l per year. This rising trend is undoubtedly associated with the growth in road-salt use over these decades. A degree of corroboration of the increasing TDS trend is provided by the USGS-NJDEP study mentioned above in Section 4.2; in that study an increasing trend in TDS was seen at 34% of the 70 NJ sites over the 1998-2007 period, and a decreasing trend occurred at no sites.

It is interesting to note that in 1923-24 the reported sodium and chloride concentrations at PRout averaged approximately 7 and 5 milligrams/liter respectively. Such low concentrations of these parameters, as well as the associated low TDS value of about 80 mg/l, are today only measured in very pristine streams, such as, in the Great Swamp watershed, the upper reaches of Primrose Brook in Morristown NHP.

<sup>11</sup> R. Edward Hickman and Bonnie J. Gray, "Trends in the Water Quality of New Jersey Streams, Water Years 1998-2007", USGS 2010, <http://pubs.usgs.gov/sir/2010/5088/pdf/sir2010-5088.pdf>

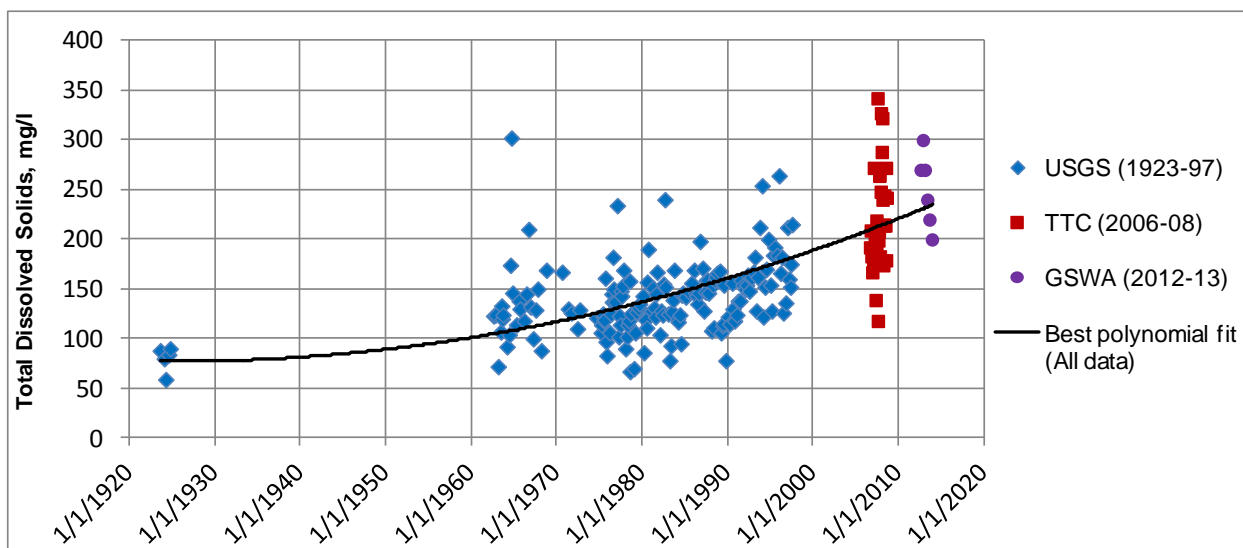


Figure 8. Total dissolved solids at PRout, 1923-2013

## 5.0 Closing comments

The multi-site body of data covered in this report provides overall support for earlier findings that the Upper Passaic is one of the Great Swamp watershed's chemically least-impaired streams. The principal points emerging from the 3-year study include:

- The Penn's Brook tributary in downtown Bernardsville was found to be the most severely impaired chemically of the monitored stream segments, but fortunately the flow volume is extremely low except during storms.
- The main stem of the Upper Passaic is especially uncontaminated in the long reach through the relatively undeveloped land upstream of US 202. The Indian Grave Brook tributary which joins the river in this same reach contains similar low pollutant levels.
- At the watershed outlet in Millington, the Passaic water quality reflects contributions of nutrients and contaminants from the entire watershed, resulting most notably in higher phosphorus concentrations than found in the Passaic waters further upstream.
- Exceedances of New Jersey Surface Water Quality Standards were identified in three main categories:
  1. High levels of Total Dissolved Solids are commonly seen in all our watershed streams as a result of road-salt runoff. In the Upper Passaic study, exceedances of NJ standards were limited to the very vulnerable Penn's Brook, especially in winter but sometimes at other times of year. At the same site there were also exceedances of the NJ chloride chronic toxicity standard each February.
  2. Although total-phosphorus concentrations were remarkably low at most of the monitoring sites throughout the 3-year study, two exceedances of the NJ standard were recorded at the PRout site. To acquire more information on water quality at PRout, especially with respect to phosphorus, sampling at this site will be included in the 3-year monitoring of Primrose and Black Brooks which is planned for 2014-2017.
  3. Several summer high water-temperature exceedances were measured at sites in the river segment designated as trout-production waters in the upper reaches of the Passaic subwatershed. To ensure capture of such exceedances in future stream

- monitoring, GSWA intends to conduct continuous water-temperature monitoring through the use of data sondes.
- Nutrient and TDS concentrations at the Great Swamp watershed outlet, measured over several decades by USGS, the Ten Towns Great Swamp Watershed Management Committee and GSWA, have been examined in an attempt to identify possible long-term trends in these parameters. Current conclusions are that no systematic trend in total nitrogen is evident, but total-phosphorus data suggest a possible decline in concentration over time; however, continued phosphorus monitoring is necessary for confirmation of such a trend. In the case of total dissolved solids, the data clearly indicate a rising trend over many decades, resulting from the growth in use of road salt and other deicing materials.

### **Acknowledgements**

This study was initiated by Kelley Curran, GSWA's former Director of Water Quality Programs. The work completed under the Adopt-a-Stream program in 2011 was made possible through a grant from The Watershed Institute. Grants from The Hyde and Watson Foundation and The Norcross Wildlife Foundation allowed for the purchase of the water quality meters used in the third year of this program. Thanks are due to the following Stream Team volunteers and GSWA staff members for their enthusiastic participation in this work: Joe Balwierczak, Tonya Biondi, Wesley Boyce, Jack Donahue, Mike Duffy, George Finlay, Mary Fisher, Gene Fox, Chuck Gullage, Charlotte Henderson, Sophia Hull, Tatiana Ivanova, Alexandra Lucas, Emily Meringolo, Bill Marshall, Kelly Martin, Anthony Morello, Daniel Panetta, Carlos Pomares, Sally Rubin, Ben Wolkowitz., and Karen Witt.

Questions or comments relating to this report may be directed to Laura Kelm, Director of Water Quality Programs for the Great Swamp Watershed Association at [lkelm@greatswamp.org](mailto:lkelm@greatswamp.org) or 973-538-3500, extension 16.

A1. Lab Results: N- and P- Nutrients, TSS, TDS, Na & Cl, Upper Passaic River, 2011

Sampling Site	Sampling Date	Flow Volume cf/s	Water Temp. °C	Results of Lab Analysis, Concentrations in milligrams/liter										Total Na <sup>+</sup> + Cl <sup>-</sup> Percent of TDS
				Total Kjeldahl Nitrogen-N	Nitrate-N	Nitrite-N	Total Nitrogen-N	Soluble Reactive Phosphate-P	Total Phosphorus-P	Total Suspended Solids	Total Dissolved Solids	Major TDS Components		
												Sodium	Chloride	
PR4 Tempe Wick Rd.	02/15/11	6.0	2.0	0.23	1.0	0.008	1.24	0.008	0.02	3	349	73.2	141	61.4%
	05/11/11	4.2	17.2	0.37	0.97	0.008	1.35	0.005	0.02	6	241	22.3	60.7	34.4%
	08/04/11	3.0	24.1	0.19	0.41	0.003	0.60	0.002	0.06	8	284	20.2	69	31.3%
	11/14/11		10.4	0.28	1.30	0.007	1.59	0.005	0.02	4	274	20.3	65	31.1%
IG1 Indian Grave Brook (trib.) Chestnut Ave.	02/15/11	3.6	3.8	0.13	1.8	0.004	1.93	0.006	0.01	ND <2	206	36.1	70	51.6%
	05/11/11	5.5	13.7	0.24	0.97	0.00	1.21	0.006	0.02	6	146	16.2	38	36.8%
	08/04/11	2.8	21.8	0.12	0.63	0.002	0.75	0.018	0.03	ND <3	191	15.9	47	33.0%
	11/14/11	6.0	11.8	0.2	1.1	0.001	1.30	ND <0.002	0.01	3	185	15.9	41	30.8%
PR3 nr Butternut Road	02/15/11	15.9	2.4	0.25	1.50	0.003	1.75	0.008	0.01	ND <2	240	40.0	81	50.3%
	05/11/11		15.8	0.41	0.71	0.003	1.12	0.006	0.01	ND <2	153	15.3	37	33.9%
	08/04/11		21.7	0.12	0.49	0.021	0.63	0.011	0.02	ND <3	169	14.3	41	32.6%
	11/14/11	13.5	10.2	0.23	0.81	0.003	1.04	0.003	0.01	3	164	15.0	41	34.1%
PR2A nr Olde Mill Inn	02/15/11		2.0	0.08	1.3	0.004	1.38	0.006	0.03	ND <2	246	42.7	87	52.5%
	05/11/11	21.0	15.8	0.26	0.68	0.004	0.94	0.008	0.03	ND <2	167	16.3	38	32.8%
	08/04/11		21.7	0.12	0.32	0.002	0.44	0.010	0.03	ND <3	190	14.6	41	29.2%
	11/14/11		9.8	0.23	1.0	0.002	1.18	0.014	0.02	ND <3	179	15.7	41	31.7%
PR1 Madisonville Rd.	02/15/11		1.6	0.40	1.1	0.006	1.51	0.005	0.03	4	458	117	202	69.7%
	05/11/11		16.0	0.41	0.39	0.008	0.81	0.006	0.05	9	172	20.3	44	37.2%
	08/04/11	30.9	23.8	0.24	0.13	0.002	0.37	0.020	0.07	ND <3	188	17.7	49	35.3%
	11/14/11	29.0	8.7	0.34	0.81	0.007	1.16	0.017	0.04	11	197	20.5	49	35.3%
PEN1 Penn's Brk (trib.) nr Bernards High School	02/15/11		3.5	0.22	2.7	0.006	2.93	0.009	0.04	15	789	217	370	74.4%
	05/11/11		16.7	0.32	2.98	0.007	3.31	0.010	0.02	ND <2	497	82.1	156	47.9%
	08/04/11		20.6	0.12	2.3	0.002	2.42	0.006	0.02	ND <3	528	80.9	188	50.9%
	11/14/11		13.1	0.20	3.6	0.004	3.80	0.002	0.02	5	585	78.6	198	47.3%
PRout Millington (USGS day's mean flows)	02/15/11	108												
	05/11/11	55												
	08/04/11	14												
	11/14/11	64												
NJ Quality Standards (mg/l except for Temp.)	TP waters	22 °C			10.0				0.1	25	500	230 (chronic toxicity)		
	NT waters	31 °C			10.0				0.1	40	500	230 (chronic toxicity)		
Ten Towns Upper Passaic Stds. (mg/l)	Base			0.4	0.4		0.8	0.02	0.04	4.0				
	Storm			1.0	0.4		1.4	0.02	0.1	25				

**Red** entries indicate failure to meet the applicable NJ Surface Water Quality Standard  
**Green** entries indicate failure to meet the applicable Ten Towns Upper Passaic River Quality Standard.

A2. Lab Results: N- and P- Nutrients, TSS, TDS, Na & Cl, Upper Passaic River, 2012

Sampling Site	Sampling Date	Flow Volume cf/s	Water Temp. °C	Results of Lab Analysis, Concentrations in milligrams/liter										Total Na <sup>+</sup> + Cl <sup>-</sup> Percent of TDS
				Total Kjeldahl Nitrogen-N	Nitrate-N	Nitrite-N	Total Nitrogen-N	Soluble Reactive Phosphate-P	Total Phosphorus-P	Total Suspended Solids	Total Dissolved Solids	Major TDS Components		
												Sodium	Chloride	
PR4 Tempe Wick Rd.	02/13/12		3.9	0.28	1.4	0.003	1.68	0.006	0.01	ND <3	258	29.6	90	46.4%
	05/17/12		20.0	0.84	0.83	0.010	1.68	0.009	0.05	5	190	12.9	32	23.6%
	08/09/12		26.0	0.58	0.45	0.008	1.04	0.013	0.03	2	210	17.2	54	33.8%
	11/15/12		6.6	0.10	0.78	0.005	0.89	0.006	0.02	ND <2	360	53.2	110	45.3%
IG1 Indian Grave Brook (trib.) Chestnut Ave.	02/13/12	5.6	4.9	0.17	1.5	ND <0.001	1.67	0.003	ND <0.01	ND <3	149	14.2	43	38.4%
	05/17/12	4.4	16.8	1.20	1.00	0.00	2.20	0.009	0.03	4	149	12.6	27	26.6%
	08/09/12	1.6	23.4	0.30	0.81	ND <0.002	1.11	0.014	0.02	2	160	15.3	41	35.1%
	11/15/12	2.5	7.8	0.10	0.94	ND <0.002	1.04	0.006	ND <0.01	ND <2	210	26.4	60	41.1%
PR3 nr Butternut Road	02/13/12	31.7	4.3	0.21	1.50	0.002	1.71	0.003	ND <0.01	ND <3	139	14.1	41	39.6%
	05/17/12		16.9	0.93	0.85	0.004	1.78	0.009	0.03	4	131	10.8	25	27.3%
	08/09/12	6.6	22.9	0.30	0.58	ND <0.002	0.88	0.014	0.02	ND <2	150	14.0	37	34.0%
	11/15/12		7.0	0.10	0.98	0.005	1.09	0.005	0.01	ND <2	210	26.5	60	41.2%
PR2A nr Olde Mill Inn	02/13/12		3.9	0.28	1.3	0.002	1.58	0.005	0.01	ND <3	151	15.0	45	39.7%
	05/17/12	25.8	16.9	0.84	0.83	0.005	1.68	0.007	0.05	7	147	12.4	26	26.1%
	08/09/12		24.2	0.51	0.46	ND <0.002	0.97	0.007	0.02	3	160	15.0	40	34.3%
	11/15/12	8.9	7.1	0.10	1.0	0.003	1.07	0.005	0.01	ND <2	220	25.6	60	38.9%
PR1 Madisonville Rd.	02/13/12	18.7	4.3	0.21	1.1	0.003	1.31	0.006	0.02	ND <3	176	20.4	56	43.4%
	05/17/12		18.1	0.23	0.85	0.010	1.09	0.015	0.06	10	169	19.1	38	33.8%
	08/09/12	8.0	25.4	0.54	0.13	ND <0.002	0.67	0.017	0.05	ND <2	170	18.9	45	37.7%
	11/15/12	14.2	6.2	0.10	0.70	0.005	0.81	0.008	0.03	ND <2	230	32.3	70	44.5%
PEN1 Penn's Brk (trib.) nr Bernards High School	02/13/12		7.2	0.17	3.1	0.003	3.27	0.002	ND <0.01	ND <3	522	94.7	260	68.0%
	05/17/12		14.2	0.76	2.80	0.006	3.57	0.006	0.02	ND <3	486	65.7	146	43.6%
	08/09/12		21.7	0.58	2.9	0.004	3.48	0.008	0.02	ND <2	490	84.3	203	58.6%
	11/15/12		8.0	0.10	3.3	0.003	3.40	0.004	0.02	2	600	107	230	56.2%
PRout Millington (USGS day's mean flows)	02/13/12	52												
	05/17/12	160												
	08/09/12	12	24.7	0.65	0.59	0.007	1.25	0.054	0.13	27	270	40.5	76.4	43.3%
	11/15/12	35	6.0	0.37	0.44	0.011	0.82	0.027	0.07	4	300	47.1	90.0	45.7%
NJ Quality Standards (mg/l except for Temp.)	TP waters	22 °C			10.0				0.1	25	500	230 (chronic toxicity)		
	NT waters	31 °C			10.0				0.1	40	500	230 (chronic toxicity)		
Ten Towns Upper Passaic Stds. (mg/l)	Base			0.4	0.4		0.8	0.02	0.04	4.0				
	Storm			1.0	0.4		1.4	0.02	0.1	25				

Red entries indicate failure to meet the applicable NJ Surface Water Quality Standard

Green entries indicate failure to meet the applicable Ten Towns Upper Passaic River Quality Standard.

Indicates storm flow conditions since >0.5" of rain fell during the 48 hours preceding the sampling

A3. Lab Results: N- and P- Nutrients, TSS, TDS, Na & Cl, Upper Passaic River, 2013

Sampling Site	Sampling Date	Flow Volume cf/s	Water Temp. °C	Results of Lab Analysis, Concentrations in milligrams/liter										Total Na <sup>+</sup> + Cl <sup>-</sup> Percent of TDS
				Total Kjeldahl Nitrogen-N	Nitrate-N	Nitrite-N	Total Nitrogen-N	Soluble Reactive Phosphate-P	Total Phosphorus-P	Total Suspended Solids	Total Dissolved Solids	Major TDS Components		
												Sodium	Chloride	
PR4 Tempe Wick Rd.	02/04/13		2.0	ND < 0.10	1.2	0.006	1.21	0.006	0.03	9	310	52.6	110	52.5%
	05/20/13		18.7	0.32	0.62	0.009	0.95	0.013	0.03	3	240	20.0	53	30.4%
	08/20/13		20.5	0.23	0.81	0.008	1.05	0.007	0.02	2	260	21.2	40	23.5%
	12/05/13		6.0	0.86	1.1	0.009	1.97	0.009	0.02	2	250	18.7	61	31.9%
IG1 Indian Grave Brook (trib.) Chestnut Ave.	02/04/13		3.0	ND < 0.10	1.4	0.002	1.40	0.005	0.01	5	200	30.1	60	45.1%
	05/20/13	4.6	15.7	0.12	0.92	ND <0.002	1.04	0.016	0.02	ND <2	170	20.1	43	37.1%
	08/20/13	3.2	20.0	0.30	0.90	ND <0.002	1.20	0.026	0.02	ND <2	180	16.3	44	33.5%
	12/05/13	3.9	8.0		1.3	ND <0.002		0.007	0.01	2	180	16.4	43	33.0%
PR3 nr Butternut Road	02/04/13		1.0	0.13	0.97	0.002	1.10	0.005	0.01	4	170	25.4	50	44.4%
	05/20/13		15.5	0.32	0.80	0.004	1.12	0.016	0.02	ND <2	170	17.4	41	34.4%
	08/20/13		19.0	0.19	0.55	ND <0.002	0.74	0.018	0.02	2	160	14.9	39	33.7%
	12/05/13		7.0		1.3	ND <0.002		0.005	0.01	2	160	14.4	38	32.8%
PR2A nr Olde Mill Inn	02/04/13	16.1	2.5	0.18	0.93	0.003	1.11	0.005	0.02	4	190	28.4	60	46.5%
	05/20/13	20.2	14.7	0.24	0.77	0.007	1.02	0.016	0.02	ND <2	180	19.0	45	35.6%
	08/20/13	10.1	20.0	0.37	0.56	0.003	0.93	0.027	0.02	2	160	15.9	41	35.6%
	12/05/13	11.9	6.0	0.43	1.1	0.002	1.53	0.005	0.02	ND <2	160	15.0	38	33.1%
PR1 Madisonville Rd.	02/04/13	20.5	1.0	0.15	0.9	0.006	1.04	0.010	0.03	5	280	56.9	110	59.6%
	05/20/13	27.7	15.4	0.32	0.57	0.010	0.90	0.018	0.05	5	220	32.0	64	43.6%
	08/20/13	13.4	20.5	0.30	0.31	0.004	0.61	0.029	0.04	4	170	18.2	45	37.2%
	12/05/13	10.2	6.0	0.58	0.93	0.005	1.52	0.008	0.04	6	160	17.3	42	37.1%
PEN1 Penn's Brk (trib.) nr Bernards High School	02/04/13		3.0	0.15	2.6	0.019	2.77	0.006	0.10	36	1340	378	700	80.4%
	05/20/13		15.8	0.24	1.50	0.014	1.75	0.014	0.02	ND <2	450	102	170	60.4%
	08/20/13		19.0	0.37	2.6	0.005	2.98	0.020	0.02	ND <2	460	79.1	160	52.0%
	12/05/13		10.0	0.97	2.3	0.040	3.31	0.014	0.03	6	400	80.7	173	63.4%
PRout Millington (USGS day's mean flows)	02/04/13	137	0.0	0.29	0.57	0.009	0.87	0.010	0.05	8	270	55.8	103	58.8%
	05/20/13	79	15.0	0.97	0.41	0.042	1.42	0.046	0.11	15	240	37.3	70	44.7%
	08/20/13	26	20.5	0.88	0.30	0.011	1.19	0.048	0.08	11	220	31.6	60	41.6%
	12/05/13	53	5.0	0.86	0.48	0.010	1.35	0.022	0.07	8	200	30.4	55	42.7%
NJ Quality Standards (mg/l except for Temp.)	TP waters	22 °C			10.0				0.1	25	500	230 (chronic toxicity)		
	NT waters	31 °C			10.0				0.1	40	500	230 (chronic toxicity)		
Ten Towns Upper Passaic Stds. (mg/l)	Base			0.4	0.4		0.8	0.02	0.04	4.0				
	Storm			1.0	0.4		1.4	0.02	0.1	25				

Red entries indicate failure to meet the applicable NJ Surface Water Quality Standard

Green entries indicate failure to meet the applicable Ten Towns Upper Passaic River Quality Standard.

Indicates storm flow conditions since >0.5" of rain fell during the 48 hours preceding the sampling



Table B1. On-site Measurements: Flow and Meter Measurements,  
Passaic River Upper Headwaters, 2011

Sampling Site	Sampling Date	Flow Volume	Water Temperature	Conductivity	pH	Dissolved Oxygen		Turbidity
						DO meas.	Approx. % of Saturation	
		cf/s	°C	µS/cm	mg/l	NTU		
PR4 Tempe Wick Rd.	02/15/11	6.0	2.0	598	6.86	12.39	90.5%	7
	05/11/11	4.2	17.2	355	7.70	11.23	117.0%	0
	08/04/11	3.0	24.1	415		9.3	110.7%	3.8
	11/14/11		10.4	453	6.61	10.9	93.8%	0.5
IG1 Indian Grave Brook (trib.) Chestnut Ave.	02/15/11	3.6	3.8	354	6.84	12.21	93.6%	0
	05/11/11	5.5	13.7	224	6.64	11.02	107.0%	0
	08/04/11	2.8	21.8	281		8.21	93.3%	0.4
	11/14/11	6.0	11.8	292	6.23	11.5	104.7%	0.0
PR3 nr Butternut Road	02/15/11	15.9	2.4	414	6.93	11.65	86.0%	0
	05/11/11		15.8	218	6.65	10.88	109.9%	0
	08/04/11		21.7	258		11.40	129.5%	0.2
	11/14/11	13.5	10.2	277	7.52	13.65	116.7%	0.8
PR2A nr Olde Mill Inn	02/15/11		2.0	437	6.82	10.50	76.7%	4
	05/11/11	21.0	15.8	229	7.26	11.36	114.7%	0
	08/04/11		21.7	265		9.24	105.0%	0.8
	11/14/11		9.8	292	7.09	12.88	109.2%	1.1
PR1 Madisonville Rd.	02/15/11		1.6	852	6.73	10.60	76.6%	11
	05/11/11		16.0	249	7.53	12.42	126.7%	1
	08/04/11	30.9	23.8	294		6.60	77.6%	0.9
	11/14/11	29.0	8.7	324	6.56	10.01	83.4%	5.8
PEN1 Penn's Brk (trib.) nr Bernards High School	02/15/11		3.5	1540	6.30	12.50	95.1%	29
	05/11/11		16.7	726	6.90	10.02	103.3%	0
	08/04/11		20.6	758		6.85	77.0%	6.6
	11/14/11		13.1	901	6.24	5.51	51.2%	1.9
PRout Millington (USGS day's mean flows)	02/15/11	108						
	05/11/11	55						
	08/04/11	14						
	11/14/11	64						
NJ Quality Standards	TP waters		22 °C		6.5 to 8.5	7.0 mg/l min.		50 NTU
	NT waters		31 °C		6.5 to 8.5	4.0 mg/l min.		50 NTU

Red entries indicate failure to meet the applicable NJ Surface Water Quality Standard.

**Table B2. On-site Measurements: Flow and Meter Measurements,  
Passaic River Upper Headwaters, 2012**

Sampling Site	Sampling Date	Flow Volume	Water Temperature	Conductivity	pH	Dissolved Oxygen		Turbidity
						DO meas.	Approx. %	
PR4 Tempe Wick Rd.	02/13/12		3.9	435	7.23	13.71	100.7%	
	05/17/12		20.0	217	7.33	8.77	92.8%	5.9
	08/09/12		26.0	367	7.49	7.57	90.1%	0.0
	11/15/12		6.6	608	7.38	17.25	140.4%	1.7
IG1 Indian Grave Brook (trib.) Chestnut Ave.	02/13/12	5.6	4.9	232	7.37	13.48	104.7%	
	05/17/12	4.4	16.8	157	7.33	10.62	106.2%	0.8
	08/09/12	1.6	23.4	275	7.33	11.43	130.0%	0.0
	11/15/12	2.5	7.8	342	7.43	15.70	131.3%	0.5
PR3 nr Butternut Road	02/13/12	31.7	4.3	232	7.39	14.09	107.7%	
	05/17/12		16.9	140	7.43	11.15	111.5%	0.3
	08/09/12	6.6	22.9	259	7.42	9.58	107.5%	0.0
	11/15/12		7.0	355	7.80	16.50	135.9%	0.5
PR2A nr Olde Mill Inn	02/13/12		3.9	244	6.82	14.11	106.8%	
	05/17/12	25.8	16.9	164	7.56	9.89	98.9%	1.4
	08/09/12		24.2	276	7.32	8.55	98.4%	0.4
	11/15/12	8.9	7.1	333	7.67	16.24	134.1%	6.7
PR1 Madisonville Rd.	02/13/12	18.7	4.3	304	6.89	13.40	98.2%	
	05/17/12	30.3	18.1	221	7.53	9.90	101.0%	1.6
	08/09/12	8.0	25.4	303	6.93	10.20	120.0%	0.3
	11/15/12	14.2	6.2	398	7.29	15.01	121.4%	1.9
PEN1 Penn's Brk (trib.) nr Bernards High School	02/13/12		7.2	872	6.61	12.47	102.7%	
	05/17/12		14.2	678	6.99	8.66	83.3%	0.0
	08/09/12		21.7	881	6.90	11.20	123.1%	1.3
	11/15/12		8.0	794	7.19	15.03	126.5%	10.0
PRout Millington (USGS day's mean flows)	02/13/12	52						
	05/17/12	160						
	08/09/12	12	24.7	487	6.63	5.57	64.7%	6.0
	11/15/12	35	6.0	468	7.15	17.80	145.5%	4.0
NJ Quality Standards		TP waters	22 °C		6.5 to 8.5	7.0 mg/l min.		50 NTU
		NT waters	31 °C		6.5 to 8.5	4.0 mg/l min.		50 NTU

**Red** entries indicate failure to meet the applicable NJ Surface Water Quality Standard.

 Indicates storm flow conditions

Table B3. On-site Measurements: Flow and Meter Measurements,  
Passaic River Upper Headwaters, 2013

Sampling Site	Sampling Date	Flow Volume	Water Temperature	Conductivity	pH	Dissolved Oxygen		Turbidity
						DO meas.	Approx. % of Saturation	
		cf/s	°C	µS/cm	mg/l	NTU		
PR4 Tempe Wick Rd.	02/04/13		2.0	519.9	7.31	12.84	93.3%	
	05/20/13		18.7		7.5			3.85
	08/20/13		20.5		8.0			7.66
	12/05/13		6.0	402.3	7.26	10.82	86.9%	3.52
IG1 Indian Grave Brook (trib.) Chestnut Ave.	02/04/13		3.0	329.0	7.43	12.30	89.8%	
	05/20/13	4.6	15.7		7.6			5.40
	08/20/13	3.2	20.0		7.7			1.08
	12/05/13	3.9	8.0	300.2	7.37	11.28	93.8%	0.27
PR3 nr Butternut Road	02/04/13		1.0	293.5	7.48	14.30	102.4%	
	05/20/13		15.5		7.8			2.02
	08/20/13		19.0		8.1			0.74
	12/05/13		7.0	292.4	7.57	12.11	99.5%	0.77
PR2A nr Olde Mill Inn	02/04/13	16.1	2.5	316.1	7.24	14.45	103.2%	
	05/20/13	20.2	14.7		7.8			3.48
	08/20/13	10.1	20.0		7.9			2.28
	12/05/13	11.9	6.0	309.6	7.38	12.55	100.3%	1.43
PR1 Madisonville Rd.	02/04/13	20.5	1.0	466.8	7.39	13.63	96.3%	
	05/20/13	27.7	15.4		7.6			6.73
	08/20/13	13.4	20.5		7.7			3.28
	12/05/13	10.2	6.0	294.5	7.25	11.05	86.0%	5.73
PEN1 Penn's Brk (trib.) nr Bernards High School	02/04/13		3.0	2346	7.13	11.40	84.6%	
	05/20/13		15.8		7.8			1.21
	08/20/13		19.0		7.7			0.39
	12/05/13		10.0	685.9	7.26	6.75	59.8%	1.23
PRout Millington (USGS day's mean flows)	02/04/13	137	0.0	437.2	6.89	11.10	76.7%	
	05/20/13	79	15.0		7.2			12.80
	08/20/13	26	20.5		7.4			10.25
	12/05/13	53	5.0	350.0	6.85	10.75	84.0%	8.29
NJ Quality Standards	TP waters		22 °C		6.5 to 8.5	7.0 mg/l min.		50 NTU
	NT waters		31 °C		6.5 to 8.5	4.0 mg/l min.		50 NTU

Red entries indicate failure to meet the applicable NJ Surface Water Quality Standard.

Indicates storm flow conditions