PLUMSTED TOWNSHIP
Ocean County, New Jersey

Interim Report

Anti-Degradation Study for the Plumsted Township Wastewater Treatment Plant with Discharge to the Crosswicks Creek

Prepared for Plumsted Township in Conjunction with Van Cleef Engineering Associates

March 2013
Project No: VCEA – 165103-005

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SECTION 1

INTRODUCTION

The following report presents the raw data, model inputs and modeling work completed in fulfillment of requirements of the approved Antidegradation Study Quality Assurance Sampling Plan (QASP) for the Plumsted Township with discharge to the Crosswicks Creek, Plumsted Township, Ocean County, New Jersey. The Anti Degradation QASP was approved by the Department on July 18, 2011. The purpose of the sampling plan is to characterize ambient water quality of the Crosswicks Creek at the proposed discharge location of a new sanitary wastewater treatment facility. In addition, the plan includes the monitoring to satisfy the data needs associated with modeling the future dissolved oxygen (DO) impacts of the proposed discharge. A site has been identified as a potential location for the wastewater treatment facility. This site is located on County Route 537 where it crosses over the Crosswicks Creek. Although this site is located approximately 1.25 miles from the New Egypt Town Center, its location appears well suited for wastewater treatment and disposal due to its proximity to the county road for access and the Crosswicks Creek for discharge. The site is located in an area zoned for commercial/industrial uses with only two (2) residential properties located within 1/4 mile of the proposed wastewater treatment facility.

The Crosswicks Creek is classified by the NJDEP as a Fresh Water Category 2 – Non Trout stream (FW2-NT) for its entire length. As such its designated uses are:

1. Maintenance, migration and propagation of the natural and established biota;
2. Primary contact recreation;
3. Industrial and agricultural water supply;
4. Public water supply after conventional filtration treatment; and
5. Any other reasonable uses.

The data collected during this study is being used in addressing the anti-degradation provisions at N.J.A.C. 7:9B-1.5(d) associated with the proposed discharge. Utilization of this data will include

1. Characterization of existing water quality levels in the Crosswicks Creek;
2. Characterization of the likely future water quality levels in Crosswicks Creek after initiation of the proposed effluent discharge, and

3. Assistance to the Department in establishing effluent limitations for the proposed discharge that comply with the provisions of N.J.A.C. 7:14A and N.J.A.C. 7:9B.

SECTION 2

SAMPLING

The sampling plan consisted of collecting 20 ambient samples to characterize water quality and 2 intensive field events for used in calibration and verification of the water quality model. Sampling was conducted in the summers of 2011 and 2012. The initial time frame to complete the sampling was July 15 through October 30, 2011. However due to high rain events that occurred in the late summer and early fall of 2011, only seven of the planned 20 ambient sampling events took place in 2011. With the approval of the NJDEP the remainder of the ambient sample events and the intensive events took place in May through August 2012. As required in the QASP, all sampling took place during low flow conditions. Low flow is defined as when the flow is below the stream flow that is exceeded 70% of the time, (d70) and a minimum of 2 days after a rainfall event of 0.5 inches or greater within a 24 hour period.

All sampling analyses as described in Section 8 of the QASP were completed following all sample procedures as defined in Section 11 of the QASP.

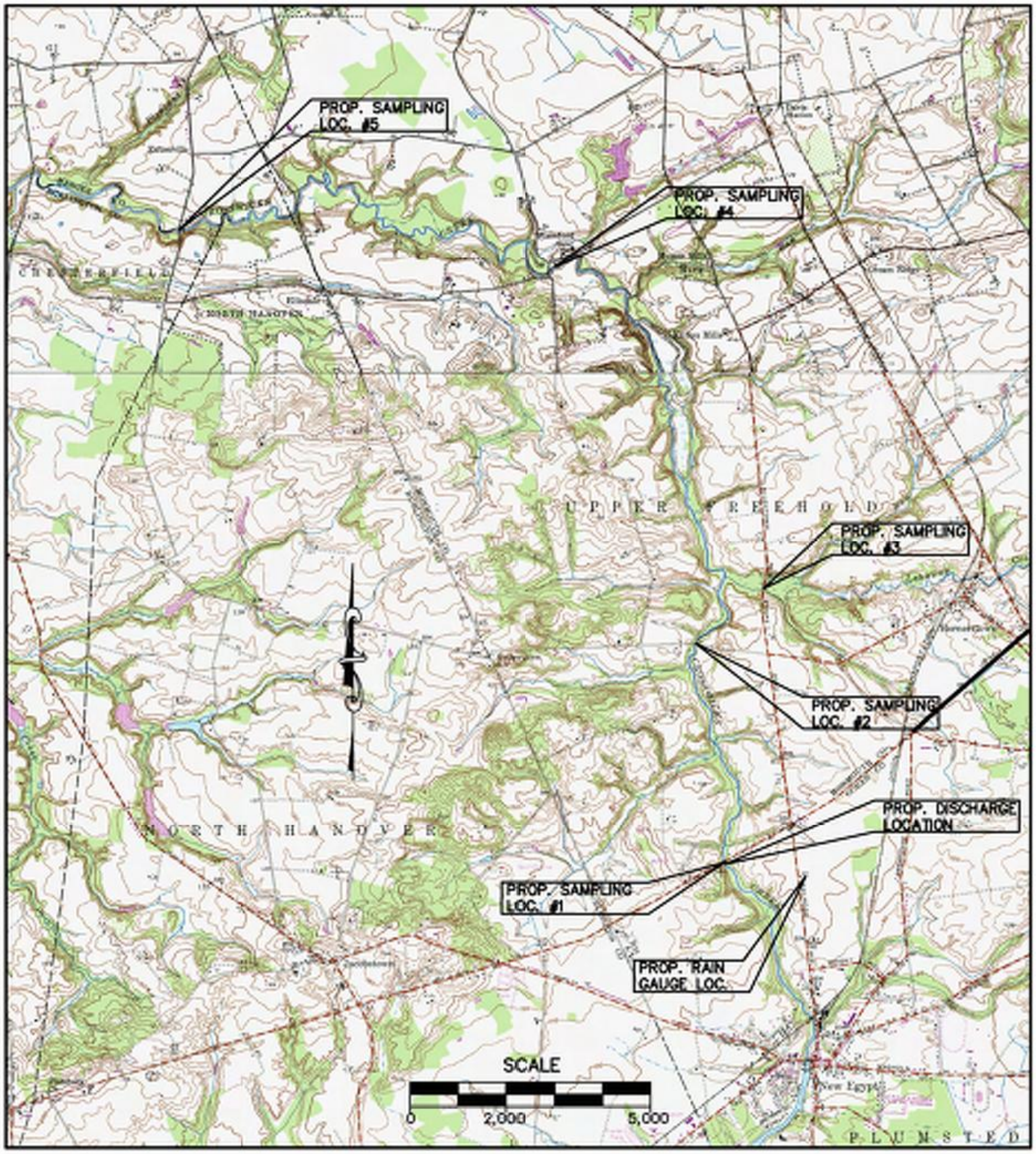
2.1 SAMPLING AND FLOW MEASUREMENT LOCATIONS

Five (5) sampling locations for this study are shown on the USGS Map in Figure 1. The locations were inspected by NJDEP representatives during a study area site visit conducted on May 26, 2011. Sample Location #1 is the location for water quality characterization. Sampling Locations #1 through #5 are the locations for data collection including ambient water quality and flow to support the Crosswicks Creek Dissolved Oxygen Model calibration and validation.

To identify locations #1, #2, #3 & #4, marker stakes were placed on both sides of the stream above the water line. Location #5, being the USGS gauging station location, is identified by the weir across the stream. All sampling and measurement of flow was performed between the location markers or immediately upstream of the weir in the case of Location #5.

The locations are as follows:

Sample Location #1: This location is also the anticipated discharge location for the proposed wastewater treatment facility. The location is approximately 100 feet upstream of the Rt. 537 Bridge. Coordinates and elevation of the location are 40º05’02.80”N - 74º32’26.70'W and approximately 58’ above mean sea level.



LOCATION MAP - STREAM STUDY SAMPLING PLAN
U.S.G.S. ALLENTOWN & NEW EGYPT QUADRANGLES

Location #1 - Crosswicks Creek/Rt. 537 Bridge
Location #2 - Crosswicks Creek/Arneytown-Hornerstown Rd. Bridge
Location #3 - Lahaway Creek/Holmes Mill Road Bridge
Location #4 - Crosswicks Creek at Walnford Park Gristmill
Location #5 - Crosswicks Creek at Extonville Road (USGS Gauge)

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Van Cleef
ENGINEERING ASSOCIATES

Figure 1. Study Area and Sample Locations

Sample Location #2: This location is on the Crosswicks Creek approximately 1.36 miles downstream from the proposed discharge location (Location #1). The location is approximately 200 feet downstream from the Arneytown-Hornerstown Bridge over the Crosswicks Creek. Coordinates and elevation of the location are 40º06'10.05"N - 74º32'37.55'W and approximately 50' above mean sea level. For ease of sampling, flow measurements were taken approximately 50' upstream of the Arneytown-Hornerstown Bridge.

Sample Location #3: This location is on the Lahaway Creek which is a significant tributary to the Crosswicks Creek. The sampling location is immediately downstream from the Holmes Mill Road (a.k.a. Allentown – New Egypt Road) bridge over the Lahaway Creek. Coordinates and elevation of the location are 40º06'25.40"N - 74º32'11.50'W and approximately 50' above mean sea level.

Sample Location #4: This location is on the Crosswicks Creek approximately 4.6 miles downstream from the proposed discharge location. The sampling location is immediately downstream from the Walnford Road Bridge over the Crosswicks Creek. Coordinates and elevation of the location are 40º08'00"N - 74º33'36.70'W and approximately 49' above mean sea level.

Sample Location #5: This location is on the Crosswicks Creek approximately 8.0 miles downstream from the proposed discharge location. This location is also the site of Gauging Station #01464500, Crosswicks Creek at Extonville, which is maintained by the USGS. Samples will be obtained immediately upstream of the weir structure associated with the gauging station. Coordinates and elevation of the location are 40º08'14"N - 74º36'00'W and approximately 28' above mean sea level.

2.2 RAW DATA

Raw chemistry and volatile organic results for the 20 ambient samples are presented in Tables 1 and 2. Ambient in-situ results are presented in Table 3. Results for the 2 intensive surveys are presented in Tables 4 and 5. Each of the tables also tabulates the method detection limit (MDL) and project quantitation limit (PQL) listed in the QASP. All raw data along with the laboratory method detection limits (MDL) and the reporting limits (RL) are given in Appendix A. Appendix B includes measurements of geometry and velocity to compute flows during the intensive surveys as well as flow at the Extonville gage. Flows at the Extonville gage were used to determine that the 70% flow criteria were met during sampling. Appendix C contains the laboratory reports for the ambient and intensive surveys.

The intensive survey results have been used to develop the water quality model for the Crosswicks Creek. The ambient samples have been used in the antidegradation and wasteload allocation analyses. Development of the model and the antidegradation and wasteload allocation analyses are presented in the following report sections.

Table 1. Raw Ambient Chemistry Data

Plumsted Township - Crosswicks Creek: Water Quality Sampling

Sample Location #1 - Upstream of Rt. 537 Bridge - Ambient Water Quality

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		From Sampling Plan	
PARAMETER NAME	**7/18/11**	**7/21/11**	**7/26/11**	**7/28/11**	**8/2/11**	**8/9/11**	**8/11/11**	**5/21/12**	**5/31/12**	**6/4/12**	**6/6/12**	**6/11/12**	**6/18/12**	**6/28/12**	**7/2/12**	**7/9/12**	**7/16/12**	**7/23/12**	**8/9/12**	**8/13/12**	**UNITS**	**MDL**	**PQL**
CALCIUM HARDNESS	55,400	55,200	54,900	55,200	45,700	48,700	49,200	48,200	41,900	54,200	47,900	54,700	52,200	36,000	48,200	63,200	65,400	63,700	34,700	51,700	ug/l	5000	5000
MAGNESIUM HARDNESS	14,700	14,900	13,800	14,100	12,300	13,000	13,400	11,900	10,600	13,800	12,000	13,800	12,800	10,100	11,700	15,200	16,200	15,600	10,000	12,800	ug/l	none	none
TOTAL HARDNESS	70.2	70.1	68.7	69.3	58	61.7	62.6	60.3	52.5	68	60	68.5	65	46	59.9	78.4	81.6	79.3	44.8	64.5	mg/l	none	none
CALCIUM	22.2	22.1	22	22.1	18.3	19.5	19.7	19.4	16.8	21.7	19.2	21.9	20.9	14.4	19.3	25.3	26.2	25.5	13.9	20.7	mg/l	none	none
MAGNESIUM	3.58	3.62	3.35	3.42	2.99	3.15	3.26	2.89	2.57	3.35	2.92	3.35	3.1	2.45	2.85	3.7	3.93	3.79	2.44	3.1	mg/l	none	none
SILVER	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0170 B	ND	ND	-	ND	ND	ND	ND	ug/l	0.652	2
ARSENIC	ND	0.948 B	ND	0.841 B	ND	0.923 B	ND	1.1 B	ND	ND	ND	.922B	0.860 B	.912B	.828B	ND	1.2B	ND	1.5B	1.2B	ug/l	0.549	2
BARIUM	45.6	43.7	48.4	46.3	38.4	39.3	40.2	39.3	37.4	41	37.5	41.1	41.2	37.3	39.7	42.4	55.9	42.6	34.5	37.7	ug/l	0.126	2
CADMIUM	ND	ND	ND	ND	ND	ND	ND	0.063	0.06 B	ND	ND	ND	ND	ND	ND	ND	0.067	ND	ND	ND	ug/l	0.0649	2
CHROMIUM, Total	1.60 B	0.687 B	3.4	0.776 B	0.628 B	0.946 B	1.8 B	1.8 B	2.2	ND	2.2	1.2B	1.70 B	2.4	1.4B	1.7B	3.7	1.9B	1.7B	ND	ug/l	0.491	2
COPPER	0.729 B	ND	ND	0.841 B	1.30 B	0.229 B	0.441 B	2.5	4.5	2.5	2.7	1.6B	1.90 B	3.6	2.1	1.1B	2.3	0.725B	5.9	1.5B	ug/l	0.221	2
NICKEL	0.790 B	1.30 B	1.4 B	1.90 B	1.40 B	1.40 B	1.5 B	2.7	1.2 B	2.0 B	2.2	2.3	2.2	2.4	2	2.8	3.2	1.6B	2.2	1.7B	ug/l	0.139	2
LEAD	1.60 B	0.546 B	0.879 B	.727B	0.939 B	1.10 B	1.0 B	3.2	5.2	3.6	4	2.5	2.4	4.3	2.6	1.0B	3.9	1.1B	4.1	1.7B	ug/l	0.07	2
SELENIUM	0.0021	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ug/l	0.752	2
THALLIUM	0.369 B	0.505 B	0.911 B	0.752 B	ND	0.676 B	ND	0.253 B	ND	ND	ND	ND	0.396 B	ND	ND	ND	.346B	ND	.828B	ND	ug/l	0.239	2
ZINC	8.8	11.6	8.6	11.9	10.3	49.5	10.8	21.7	23.6	18.3	19.7	16.6	17.2	18.8	19.2	16.4	23.7	13.3	22.5	117.1	ug/l	1.48	5
MERCURY	ND	ND	ND	ND	ND	ND	ND	ND	0.093 B	ND	ND	ND	ND	ND	ND	ND	.184B	.026B	.017B	ND	ug/l	0.047	0.2
CHROMIUM TRIVALENT	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.4	ND	ND	ND	ND	ND	ug/l	N/A	
SULFATE	23.8	24.4	24.9	25.5	20.1	20.3	19.8	20.9	16.6	20.3	18.5	24	20.3	19.8	22	23.2	25.1	23.8	17.1	20.4	mg/l	1.7	5
NITRITE (AS N)	ND	ND	ND	ND	ND	ND	ND	0.0368	0.0446	0.0468	ND	ND	ND	0.0413	ND	ND	ND	ND	ND	ND	mg/l	0.0049	0.025
ALKALINITY	47.2	49.8	46.5	47.4	39.9	43.6	44.5	40.1	35.8	45.1	41.6	44.9	42.6	26.1	40.1	49.4	57.4	50.7	28.4	44	mg/l	2	2
TURBIDITY	7.0	4.4	4.6	5.4	5.4	6.6	7.2	13.0	0.2	11.0	14.0	10.0	9.2	9.8	9.3	5.9	10.0	8.2	10.0	6.9	ntu	0.1	0.1
CHROMIUM HEXAVALENT	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ug/l	5	10
TOTAL DISSOLVED SOLIDS	157	140	171	129	131	114	100	131	134	160	140	160	134	131	160	171	271	140	120	151	mg/l	20	20
TOTAL SUSPENDED SOLIDS	2.4	4.4	4.0	2.8	3.3	2.5	3.2	10.0	14.0	4.0	8.0	8.0	43.0	9.0	3.0	ND	34.0	3.0	6.0	4	mg/l	2	2
PHOSPHORUS TOTAL	0.109	0.114	0.097	0.097	0.103	0.1	0.119	0.096	0.144	0.105	0.136	0.071	0.099	0.142	0.118	0.085	0.204	0.101	0.145	0.089	mg/l	0.006	0.009
NITRATE AS N LOW LEVEL	0.31	0.18	0.32	0.27	0.34	0.28	0.32	0.353	0.315	0.413	0.44	0.42	0.32	0.38	0.38	0.28	0.13	ND	0.23	0.39	mg/l	0.0257	0.1
CBOD-5	ND	1.45	1.44	ND	1.58	1.3	ND	ND	ND	ND	ND	ND	ND	ND	1.2	ND	2.6	ND	ND	ND	mg/l	1	1
AMMONIA (AS N)	0.108	0.114	0.304	0.348	0.192	0.14	0.08	0.19	0.58	0.33	0.15	0.24	0.14	0.21	0.19	0.21	0.12	0.12	0.14	ND	mg/l	0.01	0.1
CYANIDE, TOTAL	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	2.8	10
Oil & Grease	2.74	2.32	2.74	2.16	4.21	ND	ND	ND	ND	ND	ND	1.3	ND	1.1	ND	ND	ND	ND	ND	1.54	mg/l	1.02	1.4
CHLORINE RESIDUAL	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	<0.02	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	mg/l	0.02	0.02
E. COLI-MF (1603)	64	220	78	57	110	300	59	8	65	80	52	31	>800	270	75	23	>800	62	210	48	col/100ml	1	1
FECAL COLIFORM-MF	59	90	46	60	100	340	21	36	50	220	58	20	>600	200	40	23	>600	150	320	80	col/100ml	1	1
Flow at Extonville Rd (USGS)	29	30	27	24	30	40	41	49	52	51	48	37	35	56	38	34	40	31	49	41	cfs		

ND = Not Detected. A result of "ND" indicates the concentration of the analyte tested was either not detected or below the RLs

B = Indicates that a value is greater than the MDL but lower than the laboratory quantitation limit.

Reporting units

ug/l	= micrograms per liter (parts per billion)
mg/l	= milligrams per liter (parts per million)
ntu	= nephlometric units
col/100ml	= colonies per 100 ml
cfs	= cubic feet per second

Table 2. Raw Ambient Volatile Organics Data

Plumsted Township - Crosswicks Creek: Water Quality Sampling

Sample Location #1 - Upstream of Rt. 537 Bridge - Ambient Water Quality

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		As Required From Sampling Plan	
PARAMETER NAME	7/18/11	7/21/11	7/26/11	7/28/11	8/2/11	8/9/11	8/11/11	5/21/12	5/31/12	6/4/12	6/6/12	6/11/12	6/18/12	6/28/12	7/2/12	7/9/12	7/16/12	7/23/12	8/9/12	8/13/12			
			Volatile Organics																			MDL	PQL
BIS(2-ETHYLHEXYL)PHTHALATE	ND	ND	1.23 J	0.710 J	ND	4.87 J	ND	ND	ND	ND	ND	ND	ND	ND	0.78J	ND	-	-	-	ND	ug/l	0.7	1
CHLOROMETHANE	0.270 J	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	none	none
VINYL CHLORIDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	0.22	1
BROMOMETHANE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	0.38	1
CHLOROETHANE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	0.19	1
TRICHLOROFLUOROMETHANE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	0.2	1
1,1-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	0.19	1
ACROLEIN	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	1.81	2
ACRYLONITRILE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	0.51	2
METHYLENE CHLORIDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	0.15	1
TRANS-1,2-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	0.19	1
1,1-DICHLOROETHANE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	0.1	1
CARBON TETRACHLORIDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	0.19	1
CHLOROFORM	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	0.12	1
1,1,1-TRICHLOROETHANE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	0.19	1
BENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	0.11	1
1,2-DICHLOROETHANE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	0.14	1
TRICHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	0.12	1
1,2-DICHLOROPROPANE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	0.21	1
BROMODICHLOROMETHANE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	0.13	1
TOLUENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	0.15	1
TRANS-1,3-DICHLOROPROPENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	0.12	1
CIS-1,3-DICHLOROPROPENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	0.1	1
1,1,2-TRICHLOROETHANE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	0.12	1
2-CHLOROETHYL VINYL ETHER	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	0.15	1
DIBROMOCHLOROMETHANE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	0.13	1
TETRACHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	0.19	1
CHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	0.13	1
ETHYL BENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	0.11	1
BROMOFORM	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	0.12	1
1,1,2,2-TETRACHLOROETHANE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	0.16	1
1,3-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	none	none
1,4-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	none	none
1,2-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	ug/l	none	none

* = The "RLs" represents a reporting/quantitation limit. When an "*" is present in the column identified as the "RLs". It is being reported as a Method Detection Limit (MDL).

J = Indicates that the value is greater than the MDL but lower that the lowest standard. It is used to indicate that a compound is tentatively identified in a library search.

ND = Not Detected. A result of "ND" indicates the concentration of the analyte tested was either not detected of below the RLs

Old Name	Current UPAC Name
1,1-DICHLOROETHENE =	1,1-DICHLOROETHYLENE
TRANS-1,2-DICHLOROETHENE =	TRANS-1,2-DICHLOROETHYLENE
TRICHLOROETHENE =	TRICHLORETHYLENE

Table 3. Raw Ambient In-Situ Data

Plumsted Township - Crosswicks Creek: Water Quality Sampling

Sample Location #1 - Upstream of Rt. 537 Bridge - Ambient Water Quality

In-Situ Tests

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		From Sampling Plan	
PARAMETER NAME	**7/18/11**	**7/21/11**	**7/26/11**	**7/28/11**	**8/2/11**	**8/9/11**	**8/11/11**	**5/21/12**	**5/31/12**	**6/4/12**	**6/6/12**	**6/11/12**	**6/18/12**	**6/28/12**	**7/2/12**	**7/9/12**	**7/16/12**	**7/23/12**	**8/9/12**	**8/13/12**	**Units**	**MDL**	**PQL**
CONDUCTIVITY	217	233	233	228	187	200	202	210	180	250	261	178	199	116	347	200	225	207	162	183	umhos	10	10
DISSOLVED OXYGEN	5.59	5.75	4.69	4.69	4.51	5.05	5.58	5.91	3.19	5.08	5.32	3.37	4.9	4.22	4.67	4.18	3.52	3.39	5.2	3.73	mg/l	0.25	0.25
TEMPERATURE	26.9	29.4	26.5	25.1	25.7	25.6	24.2	19.25	25.6	21.07	25.35	26.75	19.98	24.6	26.16	26.62	25.4	24.2	24.56	24.3	Deg. C	0	0
PH	6.51	6.78	6.62	6.5	6.52	6.42	6.78	8.29	6.56	7.48	7.60	7.52	6.63	6.39	5.1	6.98	6.34	7.02	6.15	6.93	Std. units	0.5	0.5
CONDUCTIVITY	218	234	233	228	187	201	202														umhos	10	10
DISSOLVED OXYGEN	5.55	5.78	4.71	4.71	4.52	5.08	5.55														mg/l	0.25	0.25
TEMPERATURE	26.9	29.4	26.4	25.1	25.7	25.7	24.2														Deg. C	0	0
PH	6.44	6.74	6.72	6.59	6.63	6.59	6.73														Std. units	0.5	0.5
CONDUCTIVITY	218	234	233	228	187	201	202														umhos	10	10
DISSOLVED OXYGEN	5.56	5.77	4.66	4.7	4.52	5.04	5.54														mg/l	0.25	0.25
TEMPERATURE	26.9	29.5	26.4	25.1	25.7	25.7	24.2														Deg. C	0	0
PH	6.55	6.87	6.73	6.65	6.64	6.62	6.76														Std. units	0.5	0.5

<-Performed by QC Labs. (tests at 1/4 - 1/2 & 3/4 marks on stream width)-> | <----------- Performed by Accutest Labs. Single test of composite sample collected at 1/4, 1/2 & 3/4 marks on stream width) ----------->

Table 4. Raw Plumsted Township - Crosswicks Creek: Dissolved Oxygen Model Sampling-Intensive Survey #1

		1st Intensive Sampling							
	Station #1	**Station #2**	**Station #3**	**Station #4**	**Station #5**			**From Sampling Plan**	
DATE: 6/19/12	8:00 am	8:30 am	9:05 am	9:35 am	10:05 am	units		**PQL**	**MDL**
DISSOLVED OXYGEN	5.07	5.50	7.14	5.78	5.51	mg/l		0.25	0.25
CONDUCTIVITY	317	315	222	302	290	umhos		10	10
TEMPERATURE	21.33	20.79	20.04	20.09	19.71	Deg. C		0.0	0.0
Ph	6.68	6.93	7.04	7.16	7.15	Std. units		0.5	0.5
Chlorophyll A	ND	3.34	1.34	3.67	2.34	mg/m^3		0.5	0.5
Calcium hardness	53.7	55.7	33.0	51.9	79.9	mg/l		5.0	5.0
Magnesium hardness	13.0	13.1	9.22	12.1	12.5	mg/l		5.0	5.0
Total hardness	66.7	68.8	42.2	64.1	62.5	mg/l		5.0	5.0
Calcium	21.5	22.3	13.2	20.8	20	mg/l		-	-
Magnesium	3.15	3.19	2.24	2.95	3.04	mg/l		-	-
Alaklinity	42.7	39.1	22.4	48.3	41.4	mg/l		2	2
Ortho Phosphate	0.056	0.07	0.04	0.065	0.072	mg/l		0.006	0.009
Nitrite	ND	ND	ND	ND	ND	mg/l		0.0049	0.025
Turbidity	8.8	8.5	12.0	10.0	9.4	ntu		0.1	0.1
TDS	143	140	111	137	134	mg/l		2	2
Phosphorus	0.087	0.101	0.079	0.136	0.108	mg/l		0.006	0.009
Nitrate	0.23	0.29	0.22	0.31	0.3	mg/l		0.0257	0.1
TSS	3.00	2.00	4.00	4.00	2.00	mg/l		2	2
TSVSS	ND	ND	ND	ND	ND	mg/l		10	10
TKN	0.57	0.39	1.1	0.77	ND	mg/l		0.12	0.3
BOD-20	1.2	ND	ND	ND	ND	mg/l		1	1
BOD-5	1.2	1.2	ND	1.1	ND	mg/l		1	1
Ammonia	0.16	ND	ND	ND	ND	mg/l		0.01	0.1
Flow at 8 - 10 am *	16.5	17.7	12.8	32.3	34	c.f.s.			
DATE: 6/20/12	4:20 pm	4:50 pm	5:20 pm	5:45 pm	6:05 pm	units		**PQL**	**MDL**
DISSOLVED OXYGEN	4.64	5.37	6.45	4.43	5.49	mg/l		0.25	0.25
CONDUCTIVITY	344	347	239	315	312	umhos		10	10
TEMPERATURE	26.49	26.4	25.61	25.59	24.58	Deg. C		0.0	0.0
Ph	6.52	6.95	7.06	7.1	7.15	Std. units		0.5	0.5
Chlorophyll A	4.4	11	6.3	10	7.2	mg/m^3		0.5	0.5
Calcium hardness	54.4	57.2	29	52.4	49.4	mg/l		5.0	5.0
Magnesium hardness	13.6	13.3	8.28	11.9	11.9	mg/l		5.0	5.0
Total hardness	68	70.4	37.2	64.3	61.4	mg/l		5.0	5.0
Calcium	21.8	22.9	11.6	21	19.8	mg/l		-	-
Magnesium	3.3	3.22	2.01	2.88	2.9	mg/l		-	-
Alaklinity	43.1	45.2	22.2	42.4	45.4	mg/l		2	2
Ortho Phosphate	0.054	0.065	0.044	0.065	0.076	mg/l		0.006	0.009
Nitrite	ND	ND	ND	ND	ND	mg/l		0.0049	0.025
Turbidity	6.1	5.8	9.8	8	8.3	ntu		0.1	0.1
TDS	140	129	100	149	134	mg/l		2	2
Phosphorus	0.073	0.077	0.062	0.079	0.079	mg/l		0.006	0.009
Nitrate	0.24	0.27	0.26	0.31	0.3	mg/l		0.0257	0.1
TSS	47	4	6	4	3	mg/l		2	2
TSVSS	33	4	3	2	3	mg/l		10	10
TKN	1.09	1.12	0.93	1.28	0.36	mg/l		0.12	0.3
BOD-20	2.1	ND	ND	2.4	ND	mg/l		1	1
BOD-5	ND	ND	ND	ND	ND	mg/l		1	1
Ammonia	0.18	0.13	ND	0.12	0.31	mg/l		0.01	0.1
Flow at 1 - 3 pm *	16.8	26.5	15.8	34.6	37	c.f.s.			
Plumsted Township - Crosswicks Creek: Dissolved Oxygen Model Sampling									

Table 4. Raw Plumsted Township - Crosswicks Creek: Dissolved Oxygen Model Sampling-Intensive Survey #1 (Continued)

	1st Intensive Sampling								
	Station #1	Station #2	Station #3	Station #4	Station #5				
DATE: 6/21/12	6:08 am	6:30 am	6:45 am	7:10 am	7:30 am	units		PQL	MDL
DISSOLVED OXYGEN	4.56	4.82	6.31	4.08	5.8	mg/l		0.25	0.25
CONDUCTIVITY	359	354	253	306	312	umhos		10	10
TEMPERATURE	26.36	25.25	24.62	25.08	24.08	Deg. C		0	0
Ph	6.90	7.02	6.81	7.07	7.02	Std. units		0.5	0.5
DATE: 6/21/12	8:10 am	8:25 am	8:10 am	9:00 am	9:25 am	units		PQL	MDL
DISSOLVED OXYGEN	4.72	5.04	5.33	4.82	5.90	mg/l		0.25	0.25
CONDUCTIVITY	359	362	243	312	311	umhos		10	10
TEMPERATURE	26.03	25.51	24.65	25.09	24.27	Deg. C		0	0
Ph	6.84	7.02	6.83	7.03	7.01	Std. units		0.5	0.5
DATE: 6/21/12	10:00 am	10:20 am	10:40 am	10:55 am	11:20 am	units		PQL	MDL
DISSOLVED OXYGEN	4.61	4.78	5.18	4.19	5.84	mg/l		0.25	0.25
CONDUCTIVITY	363	366	234	313	311	umhos		10	10
TEMPERATURE	26.22	25.91	25.14	25.16	24.86	Deg. C		0	0
Ph	6.83	7.05	6.82	7.07	7.03	Std. units		0.5	0.5
DATE: 6/21/12	11:50 am	12:20 pm	12:45 pm	1:05 pm	1:20 PM	units		PQL	MDL
DISSOLVED OXYGEN	3.87	4.72	6.05	4.37	5.26	mg/l		0.25	0.25
CONDUCTIVITY	365	369	230	324	312	umhos		10	10
TEMPERATURE	26.87	26.65	26.05	26.42	25.83	Deg. C		0	0
Ph	6.86	7.04	6.88	7.08	7.02	Std. units		0.5	0.5
Chlorophyll A	5	8.5	6.4	10	21	mg/m^3			
Calcium hardness	58.9	60.7	30.2	52.2	51.7	mg/l			
Magnesium hardness	14	14.2	8.69	11.8	12.4	mg/l			
Total hardness	72.9	74.9	38.9	64	64.1	mg/l			
Calcium	23.6	24.3	12.1	20.9	20.7	mg/l			
Magnesium	3.39	3.45	2.11	2.87	3.01	mg/l			
Alaklinity	46	49.7	21.3	41.9	41.7	mg/l			
Ortho Phosphate	0.049	0.062	0.046	0.054	0.073	mg/l			
Nitrite	ND	ND	ND	0.35	ND	mg/l			
Turbidity	5.3	5.3	11	9.5	7.7	ntu			
TDS	154	143	100	134	123	mg/l			
Phosphorus	0.156	0.079	0.062	0.097	0.091	mg/l			
Nitrate	0.24	0.29	0.27	0.35	0.33	mg/l			
TSS	3	3	5	5	3	mg/l			
TSVSS	2	3	2	2	2	mg/l			
TKN	0.71	0.76	0.74	1	0.7	mg/l			
BOD-20	ND	ND	ND	4.2	ND	mg/l			
BOD-5	ND	ND	ND	2.4	ND	mg/l			
Ammonia	0.29	0.21	0.14	0.14	0.12	mg/l			
Flow at 8 - 10 am *	13.4	24.5	15.3	38.7	38	c.f.s.			
DATE: 6/21/12	2:15 pm	2:35 pm	2:55 pm	3:25 pm	3:40 pm	units		PQL	MDL
DISSOLVED OXYGEN	4.05	4.87	5.73	4.23	5.27	mg/l		0.25	0.25
CONDUCTIVITY	367	374	234	323	310	umhos		10	10
TEMPERATURE	28.64	27.89	27.51	27.48	26.81	Deg. C		0	0
Ph	6.89	7.09	6.96	7.27	7.06	Std. units		0.5	0.5
DATE: 6/21/12	5:05 pm	6:20 pm	6:40 pm	5:50 pm	5:30 pm	units		PQL	MDL
DISSOLVED OXYGEN	3.88	4.83	4.11	4.83	4.90	mg/l		0.25	0.25
CONDUCTIVITY	365	375	239	325	310	umhos		10	10
TEMPERATURE	28.6	28.91	28.16	29.02	27.00	Deg. C		0	0
Ph	6.88	7.12	6.98	7.28	7.00	Std. units		0.5	0.5

Station #1: Route 537 Bridge
Station #2: Crosswicks Creek at Arneytown-Hornerstown Bridge
Station #3: Lahaway Creek at Holmes Mill Road
Station #4: Crosswicks Creek at Walnford Road Bridge
Station #5: Crosswicks Creek at Extonville Road
* Flow at Stations #1 - #4 measured by VCEA
Flow at Station #5 based on USGS on-line data

Table 5. Raw Plumsted Township - Crosswicks Creek: Dissolved Oxygen Model Sampling-Intensive Survey #2									
	2nd Intensive Sampling								
	Station #1	Station #2	Station #3	Station #4	Station #5			From Sampling Plan	
DATE: 7/11/12	3:45 PM	4:15 PM	4:35 PM	5:00 PM	5:35 PM	units		PQL	MDL
DISSOLVED OXYGEN	3.42	5.67	6.41	4.89	6.17	mg/l		0.25	0.25
CONDUCTIVITY	207	210	114	177	169	umhos		10	10
TEMPERATURE	28.4	27.02	26.52	26.24	25.98	Deg. C		0.0	0.0
Ph	6.79	7.17	7.14	6.97	7.19	Std. units		0.5	0.5
Chlorophyll A	0.89	3.2	5.8	0.44	3.3	mg/m^3		0.5	0.5
Calcium hardness	63.4	64.9	32.5	53.4	51.2	mg/l		5.0	5.0
Magnesium hardness	15.1	14.7	9.22	12.8	13.2	mg/l		5.0	5.0
Total hardness	78.5	79.7	41.7	66.2	64.4	mg/l		5.0	5.0
Calcium	25.4	26	13	21.4	20.5	mg/l		-	-
Magnesium	3.67	3.58	2.24	3.11	3.21	mg/l		-	-
Alaklinity	50	54.2	23.8	42.7	52.8	mg/l		2	2
Ortho Phosphate	0.07	0.086	0.049	0.073	0.078	mg/l		0.006	0.009
Nitrite	ND	ND	ND	ND	ND	mg/l		0.0049	0.025
Turbidity	7.2	6.8	8.3	7.1	6.6	ntu		0.1	0.1
TDS	171	191	134	166	154	mg/l		2	2
Phosphorus	0.11	0.13	0.089	0.124	0.13	mg/l		0.006	0.009
Nitrate	0.32	0.36	0.3	0.36	0.3	mg/l		0.0257	0.1
TSS	6	3	6	4	3	mg/l		2	2
TSVSS	4	3	3	3	3	mg/l		10	10
TKN	1.58	1.42	1.29	1.25	1.18	mg/l		0.12	0.3
BOD-20	3.6	2.1	2.4	3.6	2.1	mg/l		1	1
BOD-5	2.7	1.5	1.8	2	1.1	mg/l		1	1
Ammonia	0.13	0.11	ND	0.11	ND	mg/l		0.01	0.1
Flow at 8 - 10 am *	10.1	12.6	13.2	26.6	29	c.f.s.			
DATE: 7/12/12	11:45 am	12:20 PM	12:55 PM	1:15 PM	1:30 PM	units		PQL	MDL
DISSOLVED OXYGEN	3.93	4.94	5.71	4.71	5.85	mg/l		0.25	0.25
CONDUCTIVITY	204	204	118	170	163	umhos		10	10
TEMPERATURE	26.19	25.36	24.98	25.55	25.05	Deg. C		0.0	0.0
Ph	6.97	7.34	7.33	7.45	7.4	Std. units		0.5	0.5
Chlorophyll A	ND	2.7	ND	3.2	1.1	mg/m^3		0.5	0.5
Calcium hardness	65.9	66.7	38.5	57.2	54.4	mg/l		5.0	5.0
Magnesium hardness	15.7	15.4	9.59	13.4	13.7	mg/l		5.0	5.0
Total hardness	81.7	82.1	48	70.6	68.1	mg/l		5.0	5.0
Calcium	26.4	26.7	15.4	22.9	21.8	mg/l		-	-
Magnesium	3.82	3.74	2.33	3.25	3.33	mg/l		-	-
Alaklinity	50.8	54.4	24.6	44.2	43.1	mg/l		2	2
Ortho Phosphate	0.065	0.083	0.049	0.06	0.081	mg/l		0.006	0.009
Nitrite	ND	ND	ND	ND	ND	mg/l		0.0049	0.025
Turbidity	6.7	6.7	9.1	8.4	7.3	ntu		0.1	0.1
TDS	171	169	114	154	146	mg/l		2	2
Phosphorus	0.11	0.12	0.083	0.14	0.118	mg/l		0.006	0.009
Nitrate	0.29	0.36	0.34	0.35	0.33	mg/l		0.0257	0.1
TSS	2	3	5	7	4	mg/l		2	2
TSVSS	3	4	4	5	4	mg/l		10	10
TKN	1.79	1.64	1.29	1.93	1.25	mg/l		0.12	0.3
BOD-20	3.2	2.1	3.9	5.8	1.7	mg/l		1	1
BOD-5	1.3	1.1	1.1	4	1.4	mg/l		1	1
Ammonia	0.11	ND	ND	ND	ND	mg/l		0.01	0.1
Flow at 3 - 4 pm *	8.7	12.9	12.4	24.8	26	c.f.s.			
Plumsted Township - Crosswicks Creek: Dissolved Oxygen Model Sampling									

Table 5. Raw Plumsted Township - Crosswicks Creek: Dissolved Oxygen Model Sampling-Intensive Survey #2 (Continued)

		2nd Intensive Sampling							
	Station #1	**Station #2**	**Station #3**	**Station #4**	**Station #5**				
DATE: 7/13/12	6:45 AM	7:20 AM	7:45 AM	8:15 AM	8:40 AM	units		**PQL**	**MDL**
DISSOLVED OXYGEN	3.91	4.59	5.68	4.06	4.3	mg/l		0.25	0.25
CONDUCTIVITY	208	209	125	170	169	umhos		10	10
TEMPERATURE	25.62	24.31	23.81	23.72	23.79	Deg. C		0.0	0.0
Ph	6.47	7.27	7.28	7.44	7.34	Std. units		0.5	0.5
Chlorophyll A	2.2	3.2	4.9	3.1	ND	mg/m^3		0.5	0.5
Calcium hardness	59.9	62.4	40.7	51.7	51.7	mg/l		5.0	5.0
Magnesium hardness	14.5	14.2	8.98	12.3	12.6	mg/l		5.0	5.0
Total hardness	74.4	76.6	49.7	64	64.2	mg/l		5.0	5.0
Calcium	24	25	16.3	20.7	20.7	mg/l		-	-
Magnesium	3.51	3.45	2.18	2.99	3.05	mg/l		-	-
Alaklinity	50.5	56	29.5	43.7	44.1	mg/l		2	2
Ortho Phosphate	0.064	0.083	0.054	0.099	0.083	mg/l		0.006	0.009
Nitrite	ND	ND	ND	ND	ND	mg/l		0.0049	0.025
Turbidity	7.3	7.1	11	9.6	8.3	ntu		0.1	0.1
TDS	166	169	131	157	146	mg/l		2	2
Phosphorus	0.114	0.134	0.112	0.171	0.136	mg/l		0.006	0.009
Nitrate	0.27	0.34	0.41	0.37	0.34	mg/l		0.0257	0.1
TSS	4	5	9	9	4	mg/l		2	2
TSVSS	ND	2	2	4	2	mg/l		10	10
TKN	ND	1.78	0.95	1.28	0.81	mg/l		0.12	0.3
BOD-20	2.6	2.2	2.4	5.1	2.7	mg/l		1	1
BOD-5	ND	ND	ND	2.6	ND	mg/l		1	1
Ammonia	0.24	0.11	0.11	ND	ND	mg/l		0.01	0.1
Flow at 3 - 4 pm *	7.4	11.7	10.8	23.6	26	c.f.s.			
DATE: 7/13/12	9:15 AM	9:35 AM	9:55 PM	10:15 AM	10:35 AM	units		**PQL**	**MDL**
DISSOLVED OXYGEN	3.59	3.76	5.2	4.01	4.71	mg/l		0.25	0.25
CONDUCTIVITY	210	210	123	171	169	umhos		10	10
TEMPERATURE	25.39	24.62	24.08	24.13	23.92	Deg. C		0	0
Ph	7.25	7.52	7.45	7.5	7.41	Std. units		0.5	0.5
DATE: 7/13/12	11:00 AM	11:15 AM	11:30 AM	11:50 AM	12:15 PM	units		**PQL**	**MDL**
DISSOLVED OXYGEN	3.34	3.62	5.62	3.81	3.93	mg/l		0.25	0.25
CONDUCTIVITY	211	205	118	177	168	umhos		10	10
TEMPERATURE	25.39	24.82	24.31	24.47	24.28	Deg. C		0	0
Ph	7.26	7.51	7.46	7.58	7.53	Std. units		0.5	0.5
DATE: 7/13/12	12:40 PM	12:40 PM	1:30 PM	1:55 PM	2:20 PM	units		**PQL**	**MDL**
DISSOLVED OXYGEN	3.66	3.76	5.2	4.03	3.41	mg/l		0.25	0.25
CONDUCTIVITY	212	209	119	178	169	umhos		10	10
TEMPERATURE	26.32	25.44	24.84	24.85	24.69	Deg. C		0	0
Ph	7.21	7.21	7.37	7.59	7.54	Std. units		0.5	0.5
DATE: 7/13/12	2:55 PM	3:10 PM	3:30 PM	3:45 PM	4:05 PM	units		**PQL**	**MDL**
DISSOLVED OXYGEN	3.86	3.46	5.56	4.02	3.16	mg/l		0.25	0.25
CONDUCTIVITY	214	21	119	174	169	umhos		10	10
TEMPERATURE	26.76	25.97	25.42	25.1	25.08	Deg. C		0	0
Ph	7.24	7.58	7.5	7.61	7.59	Std. units		0.5	0.5
DATE: 7/13/12	4:35 PM	4:56 PM	5:10 PM	5:30 PM	5:55 PM	units		**PQL**	**MDL**
DISSOLVED OXYGEN	3.87	3.34	5.54	4.15	3.33	mg/l		0.25	0.25
CONDUCTIVITY	215	212	120	181	169	umhos		10	10
TEMPERATURE	26.98	26.48	25.93	25.63	25.38	Deg. C		0	0
Ph	7.25	7.69	7.39	7.57	7.55	Std. units		0.5	0.5
	Station #1: Route 537 Bridge								
	Station #2: Crosswicks Creek at Arneytown-Hornerstown Bridge								
	Station #3: Lahaway Creek at Holmes Mill Road								
	Station #4: Crosswicks Creek at Walnford Road Bridge								
	Station #5: Crosswicks Creek at Extonville Road								
	* Flow at Stations #1 - #4 measured by VCEA								
	Flow at Station #5 based on USGS on-line data								

SECTION 3

WATER QUALITY MODELING

3.1 WATER QUALITY MODEL-QUAL2K

Under the approved Work Plan, the water quality model selected for the evaluation of the future dissolved oxygen impacts of the proposed discharge on Crosswicks Creek was QUAL2E, a one-dimensional, steady-state stream model. QUAL2E has been used extensively as a water quality evaluation tool by the NJDEP and permittees. QUAL2E was selected as the appropriate model framework during the May 26, 2011 site visit by NJDEP personnel including Tom Jenq, the Department's modeling expert. The decision was based on the observed conditions in the stream including the relatively simple geometry with little observed biological activity (little floating algae, rooted aquatics or periphyton). The field parameters of dissolved oxygen, temperature and conductivity measured during the site visit indicated minimal spatial variation along the study area length from the Rt. 537 Crossing downstream to Extonville which gives further support to the choice of QUAL2E.

As QUAL2E is no longer supported by EPA, its successor model QUAL2K, supported by EPA has been used for this evaluation. QUAL2K (or Q2K) is a river and stream water quality model that is intended to represent a modernized version of the QUAL2E (or Q2E) model (Brown and Barnwell 1987). Q2K is similar to Q2E in the following respects:

- One dimensional. The channel is well-mixed vertically and laterally;
- Branching. The system can consist of a mainstem river with branched tributaries;
- Steady state hydraulics. Non-uniform, steady flow is simulated;
- Diel heat budget. The heat budget and temperature are simulated as a function of meteorology on a diel time scale;
- Diel water-quality kinetics. All water quality variables are simulated on a diel time scale; and
- Heat and mass inputs. Point and non-point loads and withdrawals are simulated.

The QUAL2K framework includes the following new elements:

- Software Environment and Interface. Q2K is implemented within the Microsoft Windows environment. Numerical computations are programmed in Fortran 90. Excel is used as the graphical user interface. All interface operations are programmed in the Microsoft Office macro language: Visual Basic for Applications (VBA).

- Model segmentation. Q2E segments the system into river reaches comprised of equally spaced elements. Q2K also divides the system into reaches and elements. However, in contrast to Q2E, the element size for Q2K can vary from reach to reach. In addition, multiple loadings and withdrawals can be input to any element.
- Carbonaceous BOD speciation. Q2K uses two forms of carbonaceous BOD to represent organic carbon. These forms are a slowly oxidizing form (slow CBOD) and a rapidly oxidizing form (fast CBOD).
- Anoxia. Q2K accommodates anoxia by reducing oxidation reactions to zero at low oxygen levels. In addition, denitrification is modeled as a first-order reaction that becomes pronounced at low oxygen concentrations.
- Sediment-water interactions. Sediment-water fluxes of dissolved oxygen and nutrients can be simulated internally rather than being prescribed. That is, oxygen (SOD) and nutrient fluxes are simulated as a function of settling particulate organic matter, reactions within the sediments, and the concentrations of soluble forms in the overlying waters.
- Bottom algae. The model explicitly simulates attached bottom algae. These algae have variable stoichiometry.
- Light extinction. Light extinction is calculated as a function of algae, detritus and inorganic solids.
- pH. Both alkalinity and total inorganic carbon are simulated. The river's pH is then computed based on these two quantities.
- Pathogens. A generic pathogen is simulated. Pathogen removal is determined as a function of temperature, light, and settling.
- Reach specific kinetic parameters. Q2K allows you to specify many of the kinetic parameters on a reach-specific basis.
- Weirs and waterfalls. The hydraulics of weirs as well as the effect of weirs and waterfalls on gas transfer are explicitly included.

3.1.1 QUAL2K Model Framework

The QUAL2K model consists of various constituents as listed in 6.

Table 6. Model State Variables

Variable	Symbol	Units*
Conductivity	s	μmhos
Inorganic suspended solids	m_i	mgD/L
Dissolved oxygen	o	mgO_2/L
Slowly reacting CBOD	c_s	mgO_2/L
Fast reacting CBOD	c_f	mgO_2/L
Organic nitrogen	n_o	μgN/L
Ammonia nitrogen	n_a	μgN/L
Nitrate nitrogen	n_n	μgN/L
Organic phosphorus	p_o	μgP/L
Inorganic phosphorus	p_i	μgP/L
Phytoplankton	a_p	μgA/L
Phytoplankton nitrogen	IN_p	μgN/L
Phytoplankton phosphorus	IP_p	μgP/L
Detritus	m_o	mgD/L
Pathogen	X	cfu/100 mL
Alkalinity	Alk	$mgCaCO_3/L$
Total inorganic carbon	c_T	mole/L
Bottom algae biomass	a_b	mgA/m^2
Bottom algae nitrogen	IN_b	mgN/m^2
Bottom algae phosphorus	IP_b	mgP/m^2
Constituent i		
Constituent ii		
Constituent iii		

* mg/L ≡ g/m^3; In addition, the terms D, C, N, P, and A refer to dry weight, carbon, nitrogen, phosphorus, and chlorophyll *a*, respectively. The term cfu stands for colony forming unit which is a measure of viable bacterial numbers.

For all but the bottom algae variables, a general mass balance for a constituent in an element is written as:

$$\frac{dc_i}{dt} = \frac{Q_{i-1}}{V_i} c_{i-1} - \frac{Q_i}{V_i} c_i - \frac{Q_{out,i}}{V_i} c_i + \frac{E'_{i-1}}{V_i}\left(c_{i-1} - c_i\right) + \frac{E'_i}{V_i}\left(c_{i+1} - c_i\right) + \frac{W_i}{V_i} + S_i \tag{1}$$

where W_i = the external loading of the constituent to element i [g/d or mg/d], and S_i = sources and sinks of the constituent due to reactions and mass transfer mechanisms [g/m^3/d or mg/m^3/d].

The sources and sinks for the state variables are depicted in Figure 2. Further development of the mathematical representations of these processes can be found in the QUAL2K documentation (Chapra, 2008).

The model requires that the stoichiometry of organic matter (i.e., phytoplankton and detritus) be specified by the user. Stoichiometry as suggested by Redfield et al. 1963, Chapra 1997 was applied in the model.

$$100\ \text{gD} : 40\ \text{gC} : 7200\ \text{mgN} : 1000\ \text{mgP} : 1000\ \text{mgA} \tag{2}$$

where gX = mass of element X [g] and mgY = mass of element Y [mg]. The terms D, C, N, P, and A refer to dry weight detritus, carbon, nitrogen, phosphorus, and chlorophyll *a*, respectively.

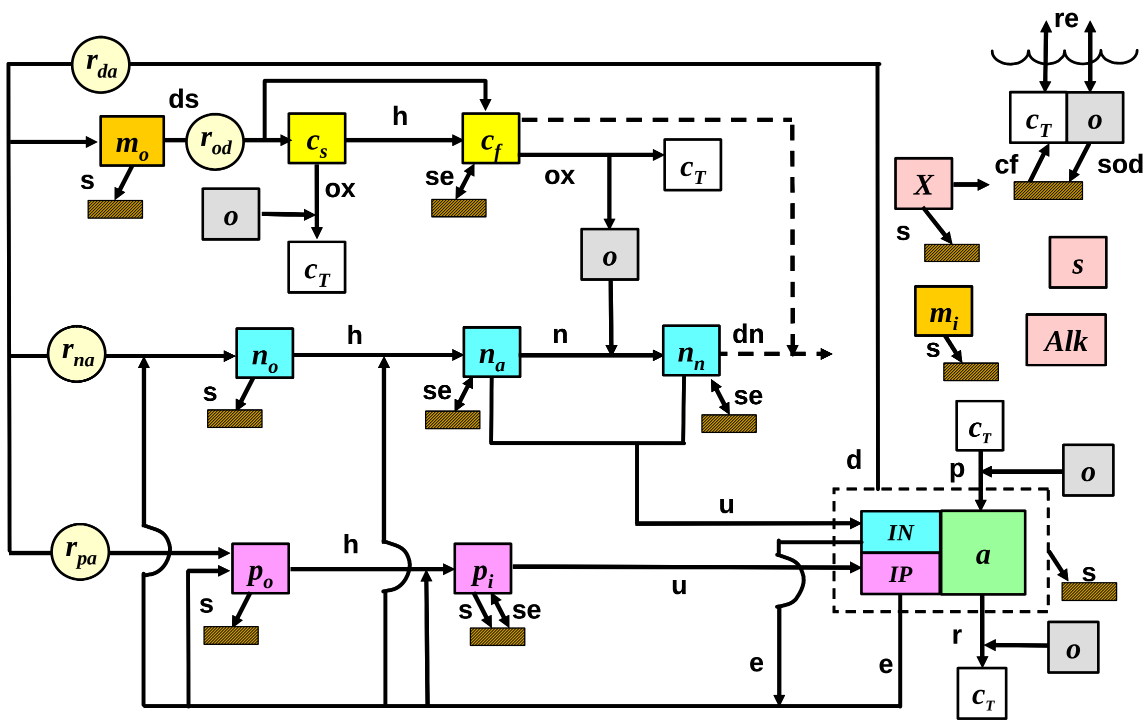

Figure 2. Model kinetics and mass transfer processes. The state variables are defined in Table 6. Kinetic processes are dissolution (ds), hydrolysis (h), oxidation (ox), nitrification (n), denitrification (dn), photosynthesis (p), respiration (r), excretion (e), death (d), respiration/excretion (rx). Mass transfer processes are reaeration (re), settling (s), sediment oxygen demand (SOD), sediment exchange (se), and sediment inorganic carbon flux (cf).

Constituents run for the Crosswicks Creek application include conductivity, inorganic suspended solids, dissolved oxygen, CBOD, nitrogen and phosphorus species, detritus, total inorganic carbon, and pH. Given the lack of observed biological activity (little floating algae, rooted aquatics or periphyton) on the May 26, 2011 site visit, bottom algae was not modeled, nor was bottom algae data collected. In Q2K CBOD can be run using 2 components (slow reacting CBOD and fast reacting CBOD). In order to differentiate between the PWWTP and other sources of BOD all sources other than from the PWWTP were input and run as fast reacting CBOD. The PWWTP will be run as the CBOD slow constituent during the projection run. Separate oxidation rates for each of CBOD classes will be applied. Also, in order for these parameters to act independently, the slow reacting CBOD hydrolysis rate to fast reacting CBOD is set to zero. Detrital dissolution that contributes to the CBOD pool is cycled to the fast reacting CBOD.

It should be noted that reported CBOD for the intensive surveys was measured on an unfiltered sample with nitrification inhibition. Therefore the sample includes demand from carbon sources including algal carbon. Algal carbon, as a result of dye off and dissolution of detritus, is cycled into the model CBOD. Therefore all CBOD data was corrected for demand from algal carbon prior to being used as model input. Also note that in comparisons of model CBOD to the data, computed DO demand due to algal carbon is added to the model calculated CBOD. Since 20 day CBODs were measured, the model and data input are input at ultimate CBOD.

3.2 MODEL SEGMENTATION

The Crosswicks Creek Model has been segmented into 5 reaches beginning 300 ft upstream of the proposed Plumsted WWTP discharge and extending approximately 8 miles downstream to the USGS gage 01464500 at Extonville. It is anticipated that the Plumsted WWTP discharge would be located on the right bank near the Rt 537 Bridge. Figure 1 shows the Crosswicks Creek study area. As discussed previously, data collected during 2 intensive surveys at 4 sample locations on the creek and 1 sample location on the Lahaway Creek tributary to the Crosswicks Creek have been used for model calibration and verification. Data collected at these locations provide the hydraulic and water quality information needed to establish the model segmentation. Each model reach is further segmented into elements of 0.5 km each. In the Q2K model reaches are defined by hydraulic conditions. The hydraulic conditions for the reaches have been established based on the geometry and flow data collected during the 2 intensive studies. Division of the reaches into elements allows calculations to be performed within an element rather than averaged over the entire reach. For the purposes of this model, this will allow refined computations for identifying the point of critical DO, or DO sag. Figure 3 depicts the model segmentation.

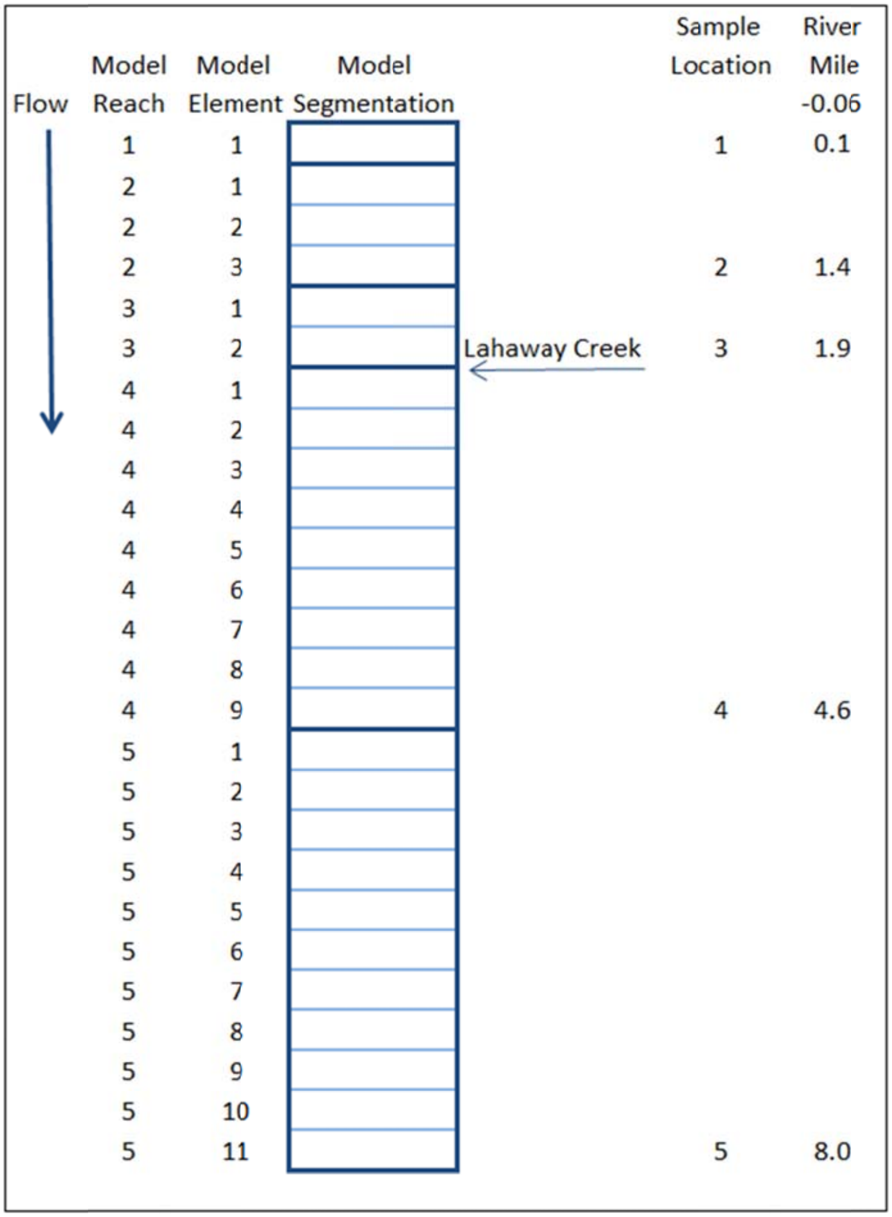

Figure 3. Crosswicks Creel QUAL2K Model Segmentation

3.3 MODEL GEOMETRY

Key elements to define in any model are the study area geometry and travel time. Several measurements of creek cross sections were completed that provide depth, width, and velocity data to characterize creek geometry and flow. Detailed creek cross-section measurements are completed by measuring water depth and velocity across the creek at widths of 2-3 foot increments. These detailed geometry and velocity measurements were made by Van Cleef Engineers during the 2 intensive surveys. The velocity and geometry data used to define model geometry and to calculate flow are included in Appendix B. The measured geometry and velocity at the creek sampling stations were taken on the same days that water quality samples were collected. Velocity and geometry measurements were not taken at the Extonville gage. Rather USGS flow, width, area, and velocity data collected upstream of the weir were used to define model geometry and velocity at Station 5. Within the model, the physical parameters of velocity and depth for each segment are calculated as a function of flow. The following equations are utilized in the model to determine stream velocity and depth:

$$U = aQ^b \qquad H = cQ^d \tag{3}$$

where:

Q = segment flow (cfs);
U = segment velocity (ft/sec); and
H = segment depth (ft).

The exponents and coefficients have been defined from the field geometry data. The exponents and coefficients have been set as constants within each reach assuming relatively uniform conditions based on observations during the May 26, 2011 site visit. Figure 4 shows the relationships of flow to velocity and depth for the sample locations along Crosswicks Creek. Table 7 presents the exponents and coefficients derived from the field data. Derivation of these physical parameters are provided in the spreadsheet FlowMetric.xls.

Table 7. Velocity and Depth Exponents and Coefficents

	Velocity		Depth	
Station	Coefficient	Exponent	Coefficient	Exponent
1	0.0972	0.7999	0.6251	0.0955
2	0.3419	0.2567	0.4895	0.6180
4	0.0566	0.7363	1.1864	0.1957
5	0.1538	0.3855	0.4183	0.4435

Model inputs defining reach elevation, length, latitude and longitude and velocity and depth exponents and coefficients are listed in Table 8.

Table 8. Model Reach Information

Reach	Downstream		Location		No.	Elevation		Rating Curves			
Length	Latitude	Longitude	Upstream	Downstream	Elements	Upstream	Downstream	Velocity		Depth	
(mi)			(mi)	(mi)		(ft)	(ft)	Coefficient	Exponent	Coefficient	Exponent
0.06	40.0842	74.5408	-0.06	0.00	1	58.2	58.0	0.0972	0.800	0.6251	0.096
1.36	40.1028	74.5438	0.00	1.36	3	58.0	50.0	0.3419	0.257	0.4895	0.618
0.52	40.1080	74.5417	1.36	1.88	2	50.0	50.0	0.3419	0.257	0.4895	0.618
2.72	40.1333	74.5600	1.88	4.60	9	50.0	49.0	0.0566	0.736	1.1864	0.196
3.40	40.1372	74.6000	4.60	8.00	11	49.0	28.0	0.1538	0.386	0.4183	0.444

Flow balances between Stations 1 and 2 and Stations 4 and 5 shown in Table 9 indicate that there are potentially other sources of inflow to Crosswicks Creek. Additional flows represented as differences in Table 9 were added to the model calibration and verification simulations. Figures 5 and 6 show the geometry data and model profiles for each of the locations and for each of the sample dates. These figures demonstrate that the model is capable of representing the creek geometry as represented by the field data.

Table 9. Flow Balances

		Flow (cfs)									
Period	Date	Sta 1	Sta 2	Sta 1 Average	Sta 2 Average	Difference	Sta 4	Sta 5	Sta 4 Average	Sta 5 Average	Difference
Calibration	6/19/2012	16.8	17.7	15.6	22.9	7.3	32.3	34	35.2	36.3	1.1
	6/20/2012	16.5	26.5				34.6	37			
	6/21/2012	13.4	24.5				38.7	38			
Verification	7/11/2012	10.1	12.6	8.7	12.4	3.7	26.6	29	25.0	27.0	2.0
	7/12/2012	8.7	12.9				24.8	26			
	7/13/2012	7.4	11.7				23.6	26			

3.4 MODEL INPUTS

3.4.1 Upstream Boundary

Data collected at Station 1 serves as the upstream boundary. Average concentrations over the three intensive survey dates, for each the calibration and verification periods, were used as input to the respective calibration or verification model. Table 10 lists the model inputs for the upstream boundary.

Table 10. Model Boundary and Point and Non Point Source Input Concentrations

Source	Location River Mile	Inflow m3/s	Inflow cfs	Temperature °C	Specific Conductance umhos	Inorganic Suspended Solids mg/L	Dissolved Oxygen mg/L	Fast CBOD mgO2/L	Organic N ugN/L	Ammonia N ugN/L	Nitrate + Nitrite N ugN/L
CALIBRATION											
Upstream Boundary	-0.06	0.441	15.6	26.0	355	5.0	4.43	0.9	557	210	249
Potential PS	0.02	0.210	7.4	25.2	237	2.0	4.43	4.0	810	80	263
Lahaway Creek	1.88	0.414	14.6	25.2	237	2.0	5.79	0.1	810	80	263
Potential NPS	4.4-4.6	0.030	1.1	25.2	237	2.0	5.79	4.0	5000	80	263
VERIFICATION											
Upstream Boundary	-0.06	0.247	8.7	25.4	210	0.7	3.70	3.0	1600	160	306
Potential PS	0.02	0.104	3.7	25.0	119	3.7	3.70	4.0	1080	70	362
Lahaway Creek	1.88	0.337	11.9	25.0	119	3.7	5.62	2.5	1080	70	362
Potential NPS	4.4-4.6	0.050	1.8	25.0	119	3.7	5.62	4.0	5000	70	362

Source	Location River Mile	Inflow m3/s	Inflow cfs	Organic P ugP/L	Inorganic P ugP/L	Phytoplankton ugA/L	Internal Nitrogen ugN/L	Internal Phosphorus ugP/L	Detritus mgD/L	Alkalinity mgCaCO3/L	pH s.u.
CALIBRATION											
Upstream Boundary	-0.06	0.441	15.6	49	53	4.7	33.8	4.7	3.0	43.9	6.80
Potential PS	0.02	0.210	7.4	20	43	10.0	72.0	10.0	3.3	21.0	6.84
Lahaway Creek	1.88	0.414	14.6	20	43	4.7	33.8	4.7	3.3	21.0	6.84
Potential NPS	4.4-4.6	0.030	1.1	500	43	4.7	33.8	4.7	3.3	21.0	6.84
VERIFICATION											
Upstream Boundary	-0.06	0.247	8.7	44	66	1.1	8.0	1.1	4.0	50.4	7.06
Potential PS	0.02	0.104	3.7	40	51	10.0	72.0	10.0	3.0	26.0	7.37
Lahaway Creek	1.88	0.337	11.9	40	51	3.7	26.3	3.7	3.0	26.0	7.37
Potential NPS	4.4-4.6	0.050	1.8	500	51	3.7	26.3	3.7	3.0	26.0	7.37

3.4.2 Point and Non Point Sources

Besides the Lahaway Creek, no additional significant point sources were identified for the study area during the site visit in 2011. Data collected in Lahaway Creek at Station 3 is input to the model as a point source load to Crosswicks Creek. Average concentrations over the three intensive survey dates for each the calibration and verification periods were used as input to the respective calibration or verification model. Table 10 lists the model inputs.

During model calibration and verification development, one potential point source discharge and one potential non point source discharge to Crosswicks Creek were identified and have been applied in the model. The potential point source input was identified at approximately the location where the PWWTP would discharge to the creek. A discharge pipe is visible on the left bank near Station 1. It is not clear whether this is a stormwater discharge or dry weather discharge. Also, while not deemed significant during the field visit, a small stream discharging to the creek was seen between Stations 1 and 2. Flow for the point source discharge was estimated from a flow balance between sample locations 1 and 2. The flow for the non point source discharge was estimated from a flow balance between sample locations 4 and 5. Table 10 lists the location and input concentrations for these potential sources.

Point source and non-point source inflows are added to Reach 2 and Reach 4 to calculated flows for the calibration and verification simulations. Conductivity equal to that measured for the Lahaway Creek for each of the calibration and verification periods was applied and suggests a surface water discharge rather than a ground water discharge where conductivity would be higher. Since there is no data to represent potential sources, the average concentrations used for the Lahaway Creek were used for each of the remaining potential source concentrations with adjustments to DO, CBOD and organic nutrients as follows. Instead of applying the Lahaway Creek DO to the point source inflow, the upstream boundary DO was used. A CBOD of 4.0 mg/L for both point source and non-point source inflows was used. The data shows an increase in organic nitrogen and phosphorus in the area of the potential non-point source. Therefore calibrated concentrations of 50 mg/L organic nitrogen and 0.5 mg/L organic phosphorus were applied to the potential non-point source inflow. It is not clear what the source of these organic nutrients would be.

3.4.3 Meterological Data

Meterological data was obtained for both the calibration and verification periods from the NOAA National Climatic Data Center website and used to develop model inputs for wind speed, air temperature, dew point temperature, and cloud cover. Data from the

McGuire Air Force Base was downloaded for the three days of each of the 2012 intensive surveys (June 19, 20, 21 and July 11, 12, 13). Average hourly wind speed, air temperature, dew point temperature, and cloud cover was calculated over the respective 3 day periods and used for model input for the calibration or verification runs. Meterological data are contained in Appendix D.

Solar radiation of 732 lg/day for the June – July periods (US EPA, 1985) was applied in the model and divided by the photoperiod for the sample periods. Shading along the Crosswicks Creek was assigned at 20% for reaches 1 to 3 and 40% for reaches 4 and 5 based on tree cover at the site. The model also calculated light and heat exchange. Default model inputs were used for the light and heat model inputs.

3.4.4 Dissolved Oxygen

Levels of dissolved oxygen are affected by the nitrification of ammonia, oxidation of organic carbon, algal oxygen production and respiration, sediment oxygen demand (SOD) and atmospheric reaeration. The following describes the rates used for these mechanisms in the model.

Sediment Oxygen Demand

Water column particulate organic matter that has settled to the sediment will eventually decay and oxidize in the sediment. This process, known as diagenesis, exerts an oxygen demand on the overlying water column. The oxygen that is depleted in the overlying water column as diagenesis takes place is called sediment oxygen demand (SOD). The SOD impacts the DO balance in the water column and can be either calculated in the model or prescribed by the user. In order to measure the Crosswicks Creek SOD, a field program where sediment was collect and SOD measurements were made was conducted. Duplicate sediment cores were taken on August 9, 2011 according to the NJDEP approved Antidegradation Work Plan. The cores were measured for SOD at the HDR|HydroQual Laboratory on August 10, 2011. As per the Work Plan, cores were taken at the mainstem Crosswicks Creek (Sta 1, Sta 2, Sta 4, and Sta 5). Results are summarized in Table 11. An SOD technical memo including calculations was prepared and is included in Appendix E. Since SOD measurements were taken at point locations and the model applies them for the entire reach, average SODs between stations were applied in the model. For example the average of the SODs for Stations 4 and 5 was applied for reach 5.

Table 11. Sediment Oxygen Demand (SOD), g/m²/day at 20°C

	Core A	Core B
Station 1	1.4	1.51
Station 2	2.07	1.8
Station 4	2.23	2.37
Station 5	1.23	1.13

Atmospheric Reaeration

Atmospheric reaeration is one of the two major sources supplying dissolved oxygen in many water bodies; the other source is phytoplankton oxygen production. In the Q2K model the atmospheric reaeration coefficient, K_a, can be accounted for by various formulas or it can be prescribed by the user. The internal Churchill equation was selected as it is applicable for streams similar to the Crosswicks Creek (Thomann & Mueller, 1987) and provides a reasonable fit to the data. The equation applied in the model follows:

$$K_a = 11.6U/H^{3/2} \tag{4}$$

Where U = velocity, in fps and H = depth, in ft. Although the model can account for wind effects on reaeration, this effect is typically more significant for lakes, reservoirs, or large open bays. Given the tree cover and width of the creek, wind effects were not included in the model.

Inorganic Solids, CBOD, and Nutrient Rates

Several rates to describe nutrient, carbon and algal cycling are required. Through hydrolysis, organic nitrogen and phosphorus are transformed to inorganic nutrients; ammonia and ortho-phosphorus, respectively. Through nitrification, ammonia can be transformed to nitrate and then nitrate. Nitrate can be lost through denitrification. Inorganic suspended solids, organic nitrogen and phosphorus, and inorganic phosphorus can be lost through settling. The Q2K model accepts system wide rates or reach specific rates. Depending on the parameter, either system wide or reach specific rates have been used and are listed in Table 12. These rates are based on experience as well as model calibration and verification.

Table 13 lists applied rates for phytoplankton growth, respiration, excretion, and death. Phytoplankton die off cycles to detritus. Detritus represents the particulate organic matter resulting from plant death. Detritus can settle or be returned to the carbon pool through dissolution. It has been assumed here that all of the detritus dissolution is returned to the carbon pool as part of the fast CBOD. The processes of CBOD oxidation, nitrification and plant respiration exert an oxygen demand. The process of photosynthesis for plant growth along with reaeration provides an oxygen source.

Table 12. Inorganic Solids, CBOD, and Nutrient Rates

		ISS	Fast CBOD	Organic N		Ammonium	Nitrate		Organic P		Inorganic P
Reach	Mile Pt	Settling Velocity	Oxidation Rate	Hydrolysis Rate	Settling Velocity	Nitrification Rate	Denit Rate	Sed Denit transfer coeff	Hydrolysis Rate	Settling Velocity	Settling Velocity
		m/d	/d	/d	m/d	/d	m/d	m/d	/d	m/d	m/d
1	-0.06 to 0.0	0.50	1.00	0.08	0.01	0.08	0.01	0.00	0.50	0.01	0.00
2	0.0 - 1.36	0.50	8.00	0.08	0.01	2.00	0.01	0.00	0.50	0.01	0.00
3	1.36-1.88	0.50	2.00	0.08	0.01	0.08	0.01	0.00	0.50	0.01	0.00
4	1.88-4.6	0.50	0.15	0.08	0.01	0.04	0.01	0.00	0.50	0.01	0.00
5	4.6-8.0	0.50	3.00	0.40	0.25	2.80	4.00	0.10	1.00	0.01	0.00

ISS=Inorganic Suspended Solids

Table 13. Phytoplankton and Detritus Rates

		Phytoplankton					Detritus		
Reach	Mile Pt	Max Growth Rate	Respiration Rate	Excretion Rate	Death Rate	Settling Velocity	Dissolution Rate	Settling Velocity	Fraction fast CBOD
		/d	/d	/d	/d	m/d	/d	m/d	
1	-0.06 to 0.0	2.30	0.20	0.05	0.20	0.20	0.50	0.05	1.00
2	0.0 - 1.36	2.30	0.20	0.05	0.20	0.20	0.50	0.05	1.00
3	1.36-1.88	2.30	0.20	0.05	0.20	0.20	0.50	0.05	1.00
4	1.88-4.6	2.30	0.10	0.05	0.20	0.20	0.50	0.05	1.00
5	4.6-8.0	2.30	0.10	0.05	0.20	0.20	0.50	0.05	1.00

All rates are input to the model at 20C. Reaction rates are corrected to ambient temperature internally and applied in the model at the ambient calculated water temperature.

3.5 MODEL CALIBRATION AND VERIFICATION

Model geometry and flow are compared to the data in Figures 5 and 6 for the calibration and verification simulations. In these and the following figures, the model is represented by solid line and the data is represented by the symbols. Application of the measured data and potential sources results in good model representation of the system. Travel time calculated by the model is 1.4 days for the calibration and 1.8 days for the verification simulations.

Temperature and conductivity calibration and verification runs are compared to the data in Figures 7 and 8. The black line represents average daily temperature and the blue lines represent daily maximums and minimums. The daily temperature variation reflects the air temperature variation. Model and data conductivity are in good agreement.

Nutrient model results are compared to the intensive survey data in Figures 9 and 10 for the calibration and in Figures 11 and 12 for the verification data. The data suggests an increase in organic N and P around Station 4 and then a decrease in concentration. Otherwise the nutrient data is fairly consistent for the length of the study area. Reaction rates in Reach 5, presented in Table 12 above, reflect potentially more labile material that may be entering the water column.

The bottom panels of Figures 10 and 12 show chlorophyll-a data and model results for the calibration and verification simulations. Chlorophyll-a concentrations are generally between 3 ug/L and 10 ug/L during the calibration period. Chlorophyll-a levels are less than 4.0 ug/L during the verification period. One outlier value of 22 ug/L at Station 5 was measured during the calibration period, therefore model calibration and verification focused on the remainder of the data. ISS and detritus calibration and verification model results are compared to data in Figures 13 and 14. ISS concentrations are determined from source loads and settling. As reflected in the figures, model and data are in good agreement.

Figures 15 and 16 depict model results and data for CBOD and DO. Model results along with the data suggest that a potential point source in Reach 2 might contribute a BOD load. Model results and data suggest that the potential source in the vicinity of Station 4 might contribute a BOD load and a more significant nutrient load. BOD concentrations of 4.0 mg/L were assigned for both inflows. Organic nitrogen and phosphorus was assigned at 50 mg/L and 0.5 mg/L, respectively. Both data organic nitrogen and phosphorus data are increased at this location and decrease in DO in the area of the stream between the junction of the Lahaway Creek and the Walnford Park area. This would be consistent with a potential non point source of nutrients and CBOD from agricultural sources, septics, or nearby golf course runoff.

3.6 MODEL PROJECTION

3.6.1 Proposed Conditions

The following describes conditions for the projected water quality simulation. All boundary, point and nonpoint concentrations measured during model calibration would be used for projections. All rates used for the calibration and verification models would be applied for the projection simulation. As is set forth in State regulations, model simulations are to be run under worse case conditions, meaning a low flow condition. The 7Q10 low flow is the required flow need for the projection. A 7Q10 flow of 6 cfs as provided by the USGS was used. Flows for Lahaway Creek and the potential point and non point sources would be scaled by the ratio of the 7Q10 flow to the upstream flow during the calibration, or

0.385 (6cfs/15.6cfs). The projected PWWTP discharge of 0.6 MGD (0.924 cfs) discharge and discharge concentrations as listed in Table 14 would be applied. The maximum temperature of 25C from the Skillman WWTP data had been applied. The remaining discharge concentrations represent the high quality that the proposed treatment plant is expected to meet.

3.6.2 Preliminary Projections

A preliminary projection run with these conditions has been done with results for CBOD and DO shown in Figure 17. The results indicate that DO would violate the standards of never less than 4.0 mg/L and daily average not less than 5.0 mg/L. DO concentrations taken during the summers of 2011 and 2012 also had values that exceeded these criteria.

A model simulation under the summer low flow condition but without the proposed treatment plant indicates that the violations that would occur are the result of the nature of the water body rather than the discharge. In fact the proposed discharge of 0.6 MGD would improve the DO levels slightly, by 0.12 mg/L at the point of greatest deficit at river mile 4.45.

Table 14. Expected Plumsted Township Discharge Concentrations and Flow

Constituent	Concentration
Flow	0.6 MGD
Temperature	25 C
pH	7.5
DO	8 mg/L
BOD	0.70 mg/L
Ammonia	0.33 mg/L
Nitrate	0.94 mg/L
Phosphorus	0.10 mg/L

SECTION 4

ANTIDEGRADATION ANALYSIS

New direct discharges into NJ state waters are required to meet specific surface water quality standards (SWQS) as defined in NJ AC 7:9B. New discharges are also required to undergo an evaluation to ensure that the State's waters will not be degraded due to the discharge. Plumsted Township has performed these analyses using stream sampling conducted in July and August, of both 2011 and 2012. This section briefly describes the antidegradation and wasteload calculations done as part of an evaluation of the creek's ability to meet surface water quality standards given typical discharges for parameters of potential concern.

Antidegradation Calculations

The analysis focuses on discharge parameters that typically are of concern for municipal wastewater treatment facilities. These parameters include temperature, pH, TSS, TDS, ammonia, nitrate, phosphorus, copper, lead, nickel, silver, zinc, chlorine produced oxidants (CPO), bis(2-ethylhexyl) phthalate, and methylene chloride. Instream measurements of priority pollutants were all less than the detection limits except for one chloromethane value. Therefore the focus of the following analysis will be on the aforementioned parameters of concern. An antidegradation analysis includes first testing the likelihood that a parameter will not increase the instream concentration by more than 5% of the ambient concentrations and will also not decrease the stream assimilative capacity by more than 5%. Should any parameter fail these tests then a socio-economic analysis is required. The following describes flows, instream data, and effluent data used in the calculations and antidegradation test results.

Critical Flows

The critical low-flows used in these calculations depend on whether the assessment is being completed for parameters that have acute and/or chronic SWQS, human health based criteria. The 1Q10 low-flow (minimum 1-day average flow that has a recurrence interval of once in 10 years) is used for parameters with acute SWQS and the 7Q10 (minimum 7-day average flow that has a recurrence interval of once in 10 years) is used for chronic SWQS with the exception of ammonia. The chronic ammonia criterion is based on the 30Q10 (minimum 30-day average flow that has a recurrence interval of once in 10 years). For some parameters where the SWQS is based on human health, the flow that is exceeded 75 percent of the time is used. Lastly, some parameters that do not have acute, chronic, or human health based criteria (e.g., TSS, pH, Temperature, TDS), the antidegradation evaluations should be based on the 7Q10 value. The 1Q10, 7Q10, 30Q10, and 75th

percentile flows for Crosswicks Creek at gage #01464420 (Rt 537 near New Egypt Bridge) were provided by the USGS West Trenton, NJ office. USGS provided critical flows for the periods 1941-2010 and 1990-2010 are presented in Table 15. The low flow values for the 1990-2010 period are consistently lower than the corresponding values for 1940-2010. Though reasons for the difference in flows is not understood at this time and the 1990-2010 period represents a relatively shorter 20 years, this period of record was used in the following analyses. At the planned wastewater flow of 0.6 MGD (0.924 cfs), available effluent dilution for the 1990-2010 period is 5.4:1 at the 1Q10 river flow, 6.5:1 at the 7Q10 river flow, 8.7:1 at the 30Q10 flow and 32.5:1 at the 75th percentile flow in Crosswicks Creek.

Table 15. USGS Critical Stream Flows at Rt 537 near the New Egypt Bridge (#01464420)[(1)]

	Stream Flows (cfs)	
Critical Flow Statistic	**1941-2010**	**1990-2010**
1Q10 (Annual)	9	5
7Q10 (Annual)	11	6
30Q10 (annual)	14	8
75th percentile	33	30

(1) Provided by USGS New Jersey Water Science Center, West Trenton, NJ

Applicable Data

In order to perform the first set of antidegradation tests, instream data and estimates for discharge concentrations are needed. The 2011 and 2012 sampling provides the instream data and Skillman Village Discharge Monitoring (DMR) data serves as an estimate of discharge concentrations except for bis (2-ethylhexyl phthalate) and methylene chloride. Effluent concentrations from the Allentown WWTP have been used for these 2 parameters. Both the Skillman Village WWTP and the Allentown WWTP utilize Nutrient Biological Removal which is the system that is anticipated for the PTWTP. The Skillman and Allentown systems are comprised of a similar composition of residential and business uses, as well as ground water source for the water supply, thus an expected similar influent that the PTWTP would be treating. This is noteworthy for those constituents that are not specifically treated in the treatment process, such as metals and volatile organic compounds. Although not specifically treated, some are removed as sludge or volatized in the aeration process, they remained simply passing through the facility.

Completely mixed mass balance calculations were completed to determine a likely instream mixed concentration. Then these mixed concentrations are compared to background or instream collected data to evaluate the antidegradation criteria. Table 16 presents results of these tests using the appropriate critical flows, the 95% percentile values about the mean of the instream and Skillman or Allentown DMR data, and the proposed PTWTP discharge flow of 0.6 MGD. Calculations have been made for acute, chronic, and/or human health based criteria as required by State rules (NJ AC 7:9B). Supporting information for flows, temperature, hardness, and pH for the instream and effluent concentrations are given at the top of the table. Also shown in Table 16 are the instream and effluent 95% values about the mean, surface water criteria and the antidegradation test result. A Yes in the two far right columns indicates that the parameter has failed the antidegradation tests.

Parameters that fail the antidegradation analysis based on data are pH, total dissolved solids (TDS), copper, and bis (2-ethylhexyl) phthalate (also known as DEHP, a byproduct of plastics). Parameters that fail but due to an artifact of detection limits are silver, and methylene chloride. Although DEHP fails, this result is arguable because false positives are common. CPO in treatment plant effluent is the result of chlorination and given that the anticipated disinfection will be achieved using UV technology, chlorination is not anticipated and CPOs are not a concern for the PTWTP.

The PTWTP will likely employ Biological Nutrient Removal (BNR) with chemical treatment for removal of phosphorus. Treatment will also likely include nitrification and denitrification. The antidegradation analysis was completed with target concentrations of 0.33 mg/L for ammonia, 0.94 mg/L for nitrate, and 0.10 mg/L for phosphorus, since it is anticipated that an effluent concentration for these parameters is achievable.

Therefore, for this antidegradation analysis pH, TDS, and copper are of potential concern. Further discussion with NJDEP will be needed regarding these parameters to determine if the next step in the antidegradation analysis, a socio-economic evaluation, is required. Although there may be challenges with the antidegradation evaluation presented, a lowering of water quality may be allowed if such a lowering is deemed necessary to accommodate important economic or social development in the area in which the waters are located. Further discussion with NJDEP are needed as to what potential discharge concentrations might be should the water quality be lowered as a result of the full antidegradation analysis.

Table 16. Water Quality Criteria Antidegradation Analysis

Flow from USGS in Crosswicks Creek, at Rt 537 Bridge near New Egypt, 1990 - 2010

Stream Information-Summer 2011 & 2012 Data		Stream Flows (cfs)		Effluent Information		Source
Lower 95% Total Hardness (as CaCo3)	51.8	1Q10 (Annual)	5	Hardness-as CaCo3	72	Englishtown aquifer
95% Temperature	26.2	7Q10 (Annual)	6	Temperature (Maximum)	25.0	Skillman June 1-Sept 30, 2009-2012
95% pH	7.34	30Q10 (annual)	8	95% Temperature	23.5	Skillman-June 1 to Sept 30, 2009-2012
		75th percentile	30	maximum pH	8.5	Skillman-reported max
Mass Balance Hardness				minimum pH	7.4	Skillman-reported min
1Q10 (Annual)	55.0					
7Q10 (Annual)	54.5			Discharge Flow (MGD)	0.6	

	Ambient Concentration (95%)	Effluent Concentration (95%) (2)	Mass Balance Concentration	Surface Water Criteria	Increase Ambient by > 5%	Decrease Assimilitive Capacity by >5%
Temperature - summer - C (1)	26.2	23.5	25.8	28	No	No
pH	7.3	7.5	7.4	4.5 - 7.5	No	Yes
TSS - mg/L	13.5	3.34	12.2	40	No	No
TDS - mg/L (3)	163	401	195.3	500	Yes	Yes

ACUTE	Ambient Concentration (95%)	Effluent Concentration (95%)	Mass Balance Concentration	Surface Water Criteria	Increase Ambient by > 5%	Decrease Assimilitive Capacity by >5%
Ammonia - mg/L	0.25	0.33	0.3	13.9	No	No
Nitrate - mg/L		See Human Health				
Total Phosphorus - mg/L	0.13	0.10	0.12	0.1	No	No
Copper - ug/L	2.54	9.99	3.71	8.0	Yes	Yes
Lead - ug/L (4,5)	3.0	1.47	2.75	52.6	No	No
Nickel - ug/L (5)	2.19	1.4	2.07	282.9	No	No
Silver - ug/L (6)	0.009	1.16	0.19	1.4	Yes	Yes
Zinc - ug/L	34.1	19.9	31.88	72.2	No	No
Chlorine Produced Oxidants - ug/L (7)	10	0	8.4	19	No	No
Bis(2-Ethylhexyl Phthalate) - ug/L		See Human Health				
Methylene Chloride - ug/L		See Human Health				

CHRONIC	Ambient Concentration (95%)	Effluent Concentration (95%)	Mass Balance Concentration	Surface Water Criteria	Increase Ambient by > 5%	Decrease Assimilitive Capacity by >5%
Ammonia - mg/L	0.25	0.33	0.3	4	No	No
Nitrate - mg/L		See Human Health				
Total Phosphorus - mg/L	0.13	0.10	0.1	0.10	No	No
Copper - ug/L	2.54	9.99	3.5	5.56	Yes	Yes
Lead - ug/L (4,5)	3.0	1.47	2.8	7.47	No	No
Nickel - ug/L (5)	2.19	1.4	2.1	31.23	No	No
Silver - ug/L (6)		No Chronic Criteria				
Zinc - ug/L	34.1	19.9	32.2	71.68	No	No
Chlorine Produced Oxidants - ug/L (7)	10	0	8.7	11.00	No	No
Bis(2-Ethylhexyl Phthalate) - ug/L		See Human Health				
Methylene Chloride - ug/L		See Human Health				

HUMAN HEALTH	Ambient Concentration (95%)	Effluent Concentration (95%)	Mass Balance Concentration	Surface Water Criteria	Increase Ambient by > 5%	Decrease Assimilitive Capacity by >5%
Nitrate - mg/L (8)	0.35	0.94	0.37	10	No	No
Lead - ug/L (8)	3.0	2.50	3.0	5.0	No	No
Bis(2-Ethylhexyl Phthalate) - ug/L (9,10)	1.51	6.62	1.7	1.2	Yes	Yes
Methylene Chloride - ug/L (10,11)	0.075	0.72	0.1	2.5	Yes	No

(1) Temperature shall not exceed a maximum of 31C or a 7 day rolling average of daily max not to exced 28C, unless due to natural conditions. The WLA was calculated using the 95% percentile about the mean of the field temperautre.

(2) Concentrations represent the 95 percentile about the mean of the data except for pH and nitrate. There is no nitrate data available for Skillman Village effluent. Nitrate and pH concentrations reflective of anticipated treatment level of < 1.22 mg/L and 7.5 maximum, respectively have been used. Ammonia concentrations are set to 0.33 mg/L and 0.94 mg/L to pass the antidegradation analysis and it is expected that these levels will be met with the anticipated treatment. Also CPO = 0 is anticipated for the UV treatment systen

(3) Estimated effluent TDS is based on additional TDS that can be expected from chemical treatment for TP removal with a target of 0.024 mg/L TP = spreadsheet "TDS estimate" of 258.8 plus instream background. No other background TDS is readily available. TP of 0.024 mg/L is the maximum Skillman effluent data.

(4) Lead acute and chronic SWQC are listed in NJ rules in the dissolved form while field measures were of total recoverable. Therefore a translator of 0.723 as listed in NJ AC 7:14 Subchapter 13.6c was used to calculate the total recoverable SWQC. The lead human health SWQC is listed at total recoverable and therefore did not have the translator appliec

(5) In review of the previous years WCR for Skillman village, it is noted that from 2007 through 2012 effluent nickel was tested 7 times with an average concentration of 2.8 ug/l (peak 4.5 ug/l). There was no significant change in effluent concentrations following upgrade of the facility to the MBR system. Additionally, a check of the 2011 water report from NJ American Water (who provide water to the area served by the Skillman STP) revealed nickel at a concentration of 7.0 ug/l in the public water supply. This represents a removal of approximately 60%. The water supply reports for New Egypt (NJ American Water) show nickel levels of 0.8 ug/l in 2011 and 1.4 ug/l in 2010. Even without utilizing a removal factor in the STP, this level of nickel is lower than the ambient stream water quality. Therefore the antidegradation calculation for nickel using nickel at 1.4 ug/L

(6) Silver instream sample measurements were reported as not detect (except one value). However all effluent data is also below the detection limit so using half the detection lim for effluent indicates violation of the antidegredation tests when this is an artifact of detection limits.

(7) Residual chlorine can result from the chlorination-dechlorination process and can be toxic to fish. The field measured residual chlorine is less than detection . The effluent discharge was set at 0 assuming no CPO in effluent using UV treatment.

(8) Human health noncarcinogen-uses monthly maximum effluent concentrations for WLA.

(9) Effluent bis (2 ethyl hexyl phthalate) is known for being difficult to measure because it is used to make plastics and false possitives are a problem. The Allentown data was use since no DEHP data was available for Skillman. Allentown data has one high value of 23 ug/L, two other detected values of 3 and 4 ug/L, and the remaining 8 values are less tha the detection limit.

(10) Human health carcinogen-uses longterm average which is the average of the available effluent data for WLA.

(11) Instream data are below the detection limit of 1 ug/L so use half the detection limit.The Allentown data was used since no methylene chloride data was available for Skillman. Effluent data are also below detection. Therefore violations are an artifact of detection limits.

Waste Load Allocations

Completely mixed mass-balance calculations were completed for the discharge to determine whether the expected effluent concentrations would meet the State SWQS and also to determine what maximum effluent concentrations might be discharged. These calculations are similar to the antidegradation mass balance calculations except that instead of using the 95% effluent concentrations about the mean, maximums are used. Using the same critical flows, instream data, effluent data, and proposed peak effluent flow of 0.6 MGD, as in the antidegradation calculations, comparisons of potential effluent concentrations to expected waste load allocations (WLA) can be made. The WLA is the potentially allowable discharge maximum concentration to meet the State SWQS. Surface water quality criteria are set forth in NJ AC 7:9.1.14. Depending on the parameter, these criteria are stated or based on calculations.

Table 17 shows the instream and effluent concentrations, the calculated mass balance concentration, the State SWQS, and finally, the WLA. Total phosphorus and DEHP mass balance concentrations exceed the SWQS. DEHP exceeds the SWQS upstream of the discharge and would also exceed the SWQS below the discharge. However, this is a contentious parameter because it is ubiquitous in the environment and false positives are not uncommon. Discussions with NJDEP will be needed concerning this parameter. As mentioned above, the PTWTP will likely employ BNR with chemical treatment for removal of phosphorus. Treatment will also likely include nitrification and denitrification. This WLA includes ammonia, nitrate, and total phosphorus concentrations reflective of this treatment. The ambient total phosphorus concentration of 0.15 mg/L is in excess of the SWQS which states that concentrations of total P, in non tidal streams with FW2 classifications such as Crosswicks Creek, can not exceed 0.1 mg/L, except in cases where the Department determines that concentrations do not render the waters unsuitable. The anticipated total phosphorus effluent can be expected to be low as demonstrated by the Skillman effluent data (range of 0.06 mg/L to 0.22 mg/L). Further discussions with the Department are needed with respect to phosphorus discharge concentrations.

Table 17. Water Quality Criteria Waste Load Allocation Analysis

Flow from USGS in Crosswicks Creek, at Rt 537 Bridge near New Egypt, 1990 - 2010

Stream Information-Summer 2011 & 2012 Data		**Stream Flows (cfs)**		**Effluent Information**		
Lower 95% Total Hardness (as CaCo3)	51.8	1Q10 (Annual)	5	Hardness-as CaCo3	72	Englishtown aquifer
95% Temperature	26.2	7Q10 (Annual)	6	Temperature (Maximun	25.0	Skillman-June 1 to Sept 30, 2009-2012
95% pH	7.34	30Q10 (annual)	8	95% Temperature	23.5	Skillman-June 1 to Sept 30, 2009-2012
		75th percentile	30	maximum pH	8.5	Skillman-reported max
Mass Balance Hardness				minimum pH	7.4	Skillman-reported min
1Q10 (Annual)	55.0					
7Q10 (Annual)	54.5			Discharge Flow (MGD)	0.6	

	Ambient Concentration (95%)	Effluent Concentration [2]	Mass Balance Concentration	Surface Water Criteria	WLA
Temperature - summer - C [1]	26.2	25.0	26.0	28	39.7
pH	7.34	7.5	7.4	4.5 - 7.5	8.5
TSS - mg/L	13.5	6	12.5	40	211.0
TDS - mg/L[3]	163	401	194.9	500	2678.4

ACUTE	Ambient Concentration (95%)	Effluent Concentration	Mass Balance Concentration	Surface Water Criteria	WLA
Ammonia - mg/L	0.25	0.33	0.3	13.8	86.5
Nitrate - mg/L		See Human Health			
Total Phosphorus - mg/L	0.13	0.1	0.12	0.1	0.10
Copper - ug/L	2.54	12.4	4.08	8.0	37.2
Lead - ug/L [4,5]	3.0	2.5	2.91	52.6	319.6
Nickel - ug/L [5]	2.19	1.4	2.07	282.9	1794.9
Silver - ug/L [6]	0.009	2.0	0.321	1.4	8.6
Zinc - ug/L	34.1	35.3	34.29	72.2	277.3
Chlorine Produced Oxidants - ug/L [7]	10	0	8.4	19	67.5
Bis(2-Ethylhexyl Phthalate) - ug/L		See Human Health			
Methylene Chloride - ug/L		See Human Health			

CHRONIC	Ambient Concentration (95%)	Effluent Concentration	Mass Balance Concentration	Surface Water Criteria	WLA
Ammonia - mg/L	0.25	0.33	0.3	4	33.4
Nitrate - mg/L		See Human Health			
Total Phosphorus - mg/L	0.13	0.10	0.12	0.10	0.10
Copper - ug/L	2.54	12.4	3.9	5.56	25.1
Lead - ug/L [4,5]	3.0	2.5	2.9	7.47	36.4
Nickel - ug/L [5]	2.19	1.4	2.1	31.2	218.9
Silver - ug/L [6]		No Chronic Criteria			
Zinc - ug/L	34.1	35.3	34.3	71.68	314.5
Chlorine Produced Oxidants - ug/L [7]	10	0	8.7	11.00	17.5
Bis(2-Ethylhexyl Phthalate) - ug/L		See Human Health			
Methylene Chloride - ug/L		See Human Health			

HUMAN HEALTH	Ambient Concentration (95%)	Effluent Concentration	Mass Balance Concentration	Surface Water Criteria	WLA
Nitrate - mg/L [8]	0.35	0.94	0.37	10	93.15
Lead - ug/L [8]	3.0	2.50	3.0	5.0	18.0
Bis(2-Ethylhexyl Phthalate) - ug/L [9,10]	1.51	3.35	1.6	1.2	-1.49
Methylene Chloride - ug/L [10,11]	0.075	0.59	0.09	2.5	23.40

(1) Temperature shall not exceed a maximum of 31C or a 7 day rolling average of daily max not to exced 28C, unless due to natural conditions. The WLA was calculated using the 95% percentile about the mean of field temperautre.

(2) Concentrations represent data maximums for acute and chronic, or as indicated in notes 8 and 10 below for human health criteria, except for pH, nitrate, ammonia and phosphorus. There is no nitrate data available for Skillman Village effluent. Nitrate and pH concentrations reflective of anticipated treatment level of < 1.22 mg/L and 7.5 maximum, respectively have been used. Ammonia concentrations are set to 0.33 mg/L and 0.94 mg/L to pass the antidegradation analysis and it is expected that these levels will be met with the anticipated treatment. Also CPO = 0 is anticipated for the UV treatment system.

(3) Estimated effluent TDS is based on additional TDs that can be expected from chemical treatment for TP removal with a target of 0.08 mg/L TP - spreadsheet "TDS estimate" of 243.3 plus instream background. No other background TDS is readily available.

(4) Lead acute and chronic SWQC are listed in NJ rules in the dissolved form while field measures were of total recoverable. Therefore a translator of 0.723 as listed in NJ AC 7:14 Subchapter 13.6c was used to calculate a the total recoverable SWQC. The lead human health SWQC is listed at total recoverable and therefore did not have the translator applied.

(5) In review of the previous years WCR for Skillman village, it is noted that from 2007 through 2012 effluent nickel was tested 7 times with an average concentration of 2.8 ug/l (peak 4.5 ug/l). There was no significant change in effluent concentrations following upgrade of the facility to the MBR system. Additionally, a check of the 2011 water report from NJ American Water (who provide water to the area served by the Skillman STP) revealed nickel at a concentration of 7.0 ug/l in the public water supply. This represents a removal of approximately 60%. The water supply reports for New Egypt (NJ American Water) show nickel levels of 0.8 ug/l in 2011 and 1.4 ug/l in 2010. Even without utilizing a removal factor in the STP, this level of nickel is lower than the ambient stream water quality. Therefore the antidegradation calculation for nickel using nickel at 1.4 ug/L

(6) Silver instream sample measurements were reported as not detect (except one value). However all effluent data is also below the detection limit so using half the detection limit for effluent indicates violation of the antidegredation tests when this is an artifact of detection limits.

(7) Residual chlorine can result from the chlorination-dechlorination process and can be toxic to fish. The field measured residual chlorine is less than detection . The effluent discharge was set at 0 assuming no CPO in effluent using UV treatment.

(8) Human health noncarcinogen-uses monthly maximum effluent concentrations for WLA.

(9) Effluent bis (2 ethyl hexyl phthalate) is known for being difficult to measure because it is used to make plastics and false possitives are a problem. The Allentown data was used since no DEHP data was available for Skillman. Allentown data used herein has one high value of 23 ug/L, two other detected values of 3 and 4 ug/L, and the remaining 8 values are less than the detection limit.

(10) Human health carcinogen-uses longterm average which is the average of the available effluent data for WLA.

(11) Instream data are below the detection limit of 1 ug/L so use half the detection limit.The Allentown data was used since no methylene chloride data was available for Skillman. Effluent data are also below detection. Therefore violations are an artifact of detection limits.

Summary

In summary, these calculations include the required sample parameters and twenty events as prescribed in the sampling plan collected in the summers of 2011 and 2012. There are a limited number of parameters that exceed the antidegradation requirements. These include pH, TDS and copper. Given the nature and limited number of parameters that exceed the antidegradation analysis, it is hoped that discussions with DEP would help to determine the allowance of the discharge thus negating the need for a full antidegradation analysis including a social-economic evaluation. Comparisons of expected effluent concentrations to the waste load allocations for the proposed effluent wastewater treatment of biological nutrient removal potentially through a membrane filtration type treatment system including chemical addition indicate that nutrient discharges can be addressed. Chlorine produced oxidants will be irrelevant since UV disinfection will be used. Therefore how to handle DEHP warrants further discussions with NJDEP and NJ American Water as the water supplier to the area.