9 RECHARGE

Recharge is degree to which precipitation infiltrates into the ground to become groundwater. Infiltration depends on geologic and soil condition, as well as land use. The more impervious surface there is in an area, the less infiltration, and thus recharge of groundwater is possible.

The NJ Geologic Survey (NJGS) has developed a method to calculate recharge rates and volumes in New Jersey. This method uses soils, land use categories, a climate factor and a recharge factor to come up with a recharge rate. This rate can be multiplied by the land area to calculate recharge volume. However, the method is useful for recharge volumes primarily for smaller sites.

In order to investigate the impact of development on recharge, an analysis was conducted using the NJGS Method. Figure 18 presents the overall recharge rates for the Wreck Pond Watershed using the existing land use, soils from the Monmouth County GIS, and the NJGS model. For simplicity, it was assumed that the location was Wall Township, since this encompasses most of the watershed.

Wreck Pond Brook is within Watershed Management Area 12. For this area, the NJGS has developed Recharge Rank Categories as follow:

A	>16 Inches per year
B	12-16 in per year
C	9-11 in per yr
D	1-8 in per yr
E	0 in per yr

Under the existing condition, recharge occurs can be calculated for about 6,325 acres of the about 8,172 acres. The analysis of ranks is as follows in Table 26 and illustrated on Figure 18. The remaining area is either water, has hydric soils (L), or has soil types for which recharge can't be calculated.

Table 26: Existing Land Use Recharge Rankings

Recharge Rank	Acreage	Percent of Watershed
A	1146.8	18%
B	3077.3	48%
C	1313.0	21%
D	584.6	9%
E	196.9	3%

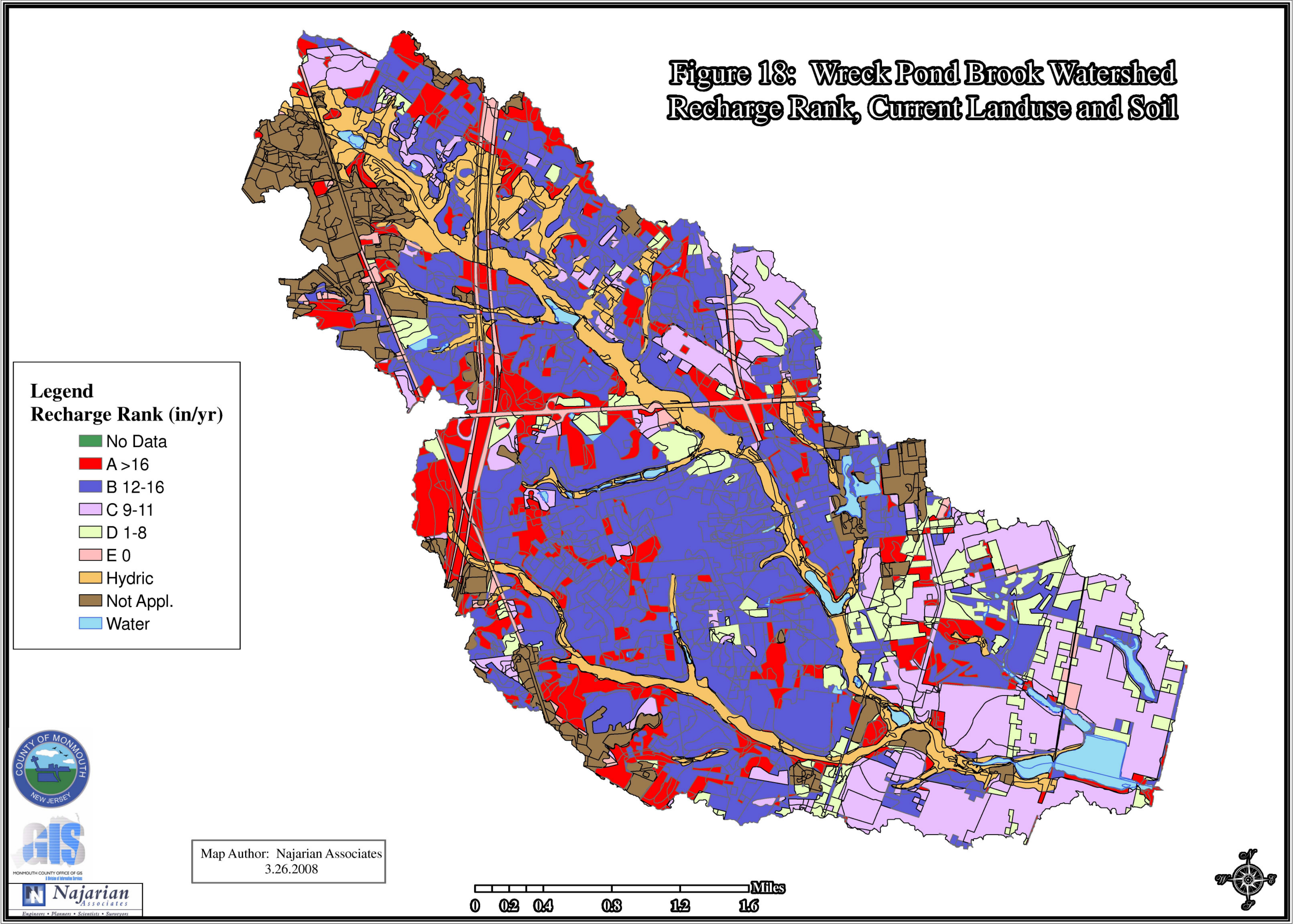


Figure 18: Wreck Pond Brook Watershed
Recharge Rank, Current Landuse and Soil
Legend
Recharge Rank (in/yr)
No Data
A >16
B 12-16
C 9-11
D 1-8
E 0
Hydric
Not Appl.
Water
Map Author: Najarian Associates
3.26.2008
Miles
0
0.2
0.4
0.8
1.2
1.6
COUNTY OF MONMOUTH
NEW JERSEY
GIS
Najarian Associates

9.1 Groundwater and Baseflow

Baseflow in streams is created by groundwater discharge. The discharge of groundwater varies depending on the elevation of the water-table. The local water table elevation varies with precipitation and with season. Typically, in New Jersey, the seasonal high water table occurs in the spring.

Baseflow in the main tributaries in the watershed were determined from flows during the SWMM and HEC modeling. Base flows ranges calculated were:

Wreck Pond Brook	2.5-7.5 cfs
Hannabrand Brook	2.0-4.0 cfs
Black Creek	2.0-3.5 cfs

Groundwater discharge to baseflow can also depend on any groundwater pumping from the local aquifers. Sections 7 and 8, above, discuss the hydrologic modeling done for this project and provides more detail on streamflow variation over time.

10 WATER QUALITY ASSESSMENT

Water quality data were collected under several study elements for this watershed management plan. Sections 5 and 6, above, summarize water quality data collected by RCE and MU in their studies. The following sections summarize the water quality sampling conducted by Monmouth County for this Plan and that done for the Spring Lake Borough Wreck Pond Environmental Study.

10.1 County Water Quality Sampling

Monmouth County collected water quality data at eight stations within the watershed for more than one year. Stations are shown on Figure 10 and listed in Table 12. Water quality data were collected for pH, temperature, TSS and two bacteria types: fecal coliform and enterococci. The data were collected weekly, generally on a Monday although sampling occasionally occurred on other weekdays. Figures 19 and 20 summarize this data.

Table 27 summarizes the data within Wreck Pond Brook from upstream to downstream for the conventional parameters while Table 28 summarizes the bacterial data. pH data shows a definite gradient moving downstream, with the lowest mean at W6 and the highest mean at W3. The maximum pH level, however, was recorded at W9.

Review of the bacterial constituents also shows the largest geometric mean at Station W9. The maximum bacterial count is difficult to determine, as some of the data were reported as “Too Numerous to Count”. W9 is the outlet from Hurley’s Pond. Thus, the data here may be affected by Pond conditions.

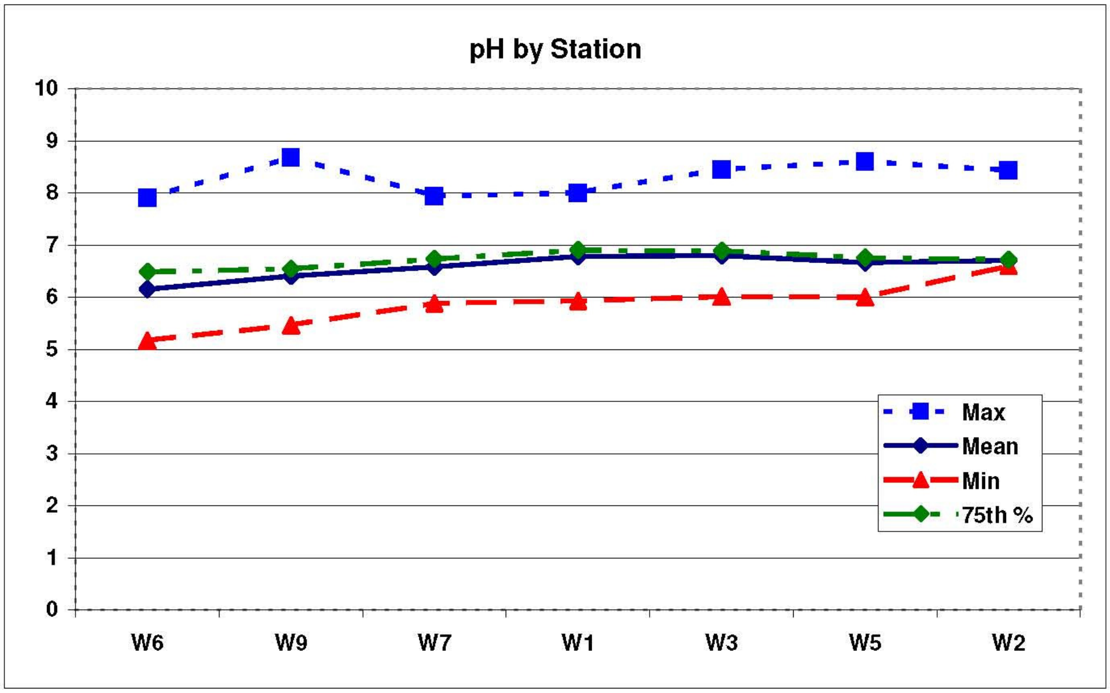
Table 29 summarizes the data for Hannabrand Brook for conventional parameters, while Table 30 summarizes the bacteria data

Bacteria levels in the two streams are similar. Neither station in Hannabrand Brook has levels as high as noted at Station W9. Elevated bacteria levels occur at both stations at certain times. The levels of fecal coliform at W2 were above the standard of 200 count/100 ml at least 24% of the time.

pH in Hannabrand Brook is similar to that found in the mid- to lower reaches of Wreck Pond Brook. The low pH levels found at W6 and W9, the upstream stations in Wreck Pond Brook, are not found. Temperature levels are similar to those in the middle sections of Wreck Pond Brook. For TSS, the mean values for Hannabrand Brook are the same as Wreck Pond Brook stations W7 and W1. The maximum TSS values in Wreck Pond Brook are substantially higher than at W7 and slightly higher than at W1. However, the peaks are not as high as at W9.

Tables 31 and 32 summarize the data for the Black Creek Station.

Figure 19: Monmouth County Weekly Sampling Summary of Results



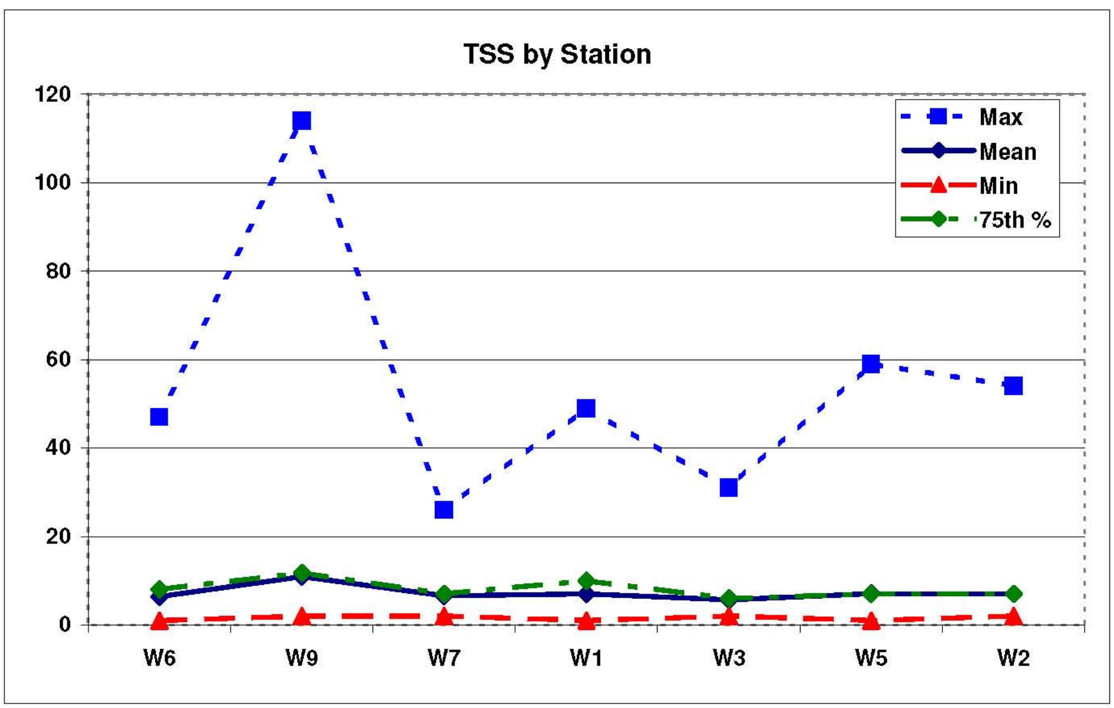
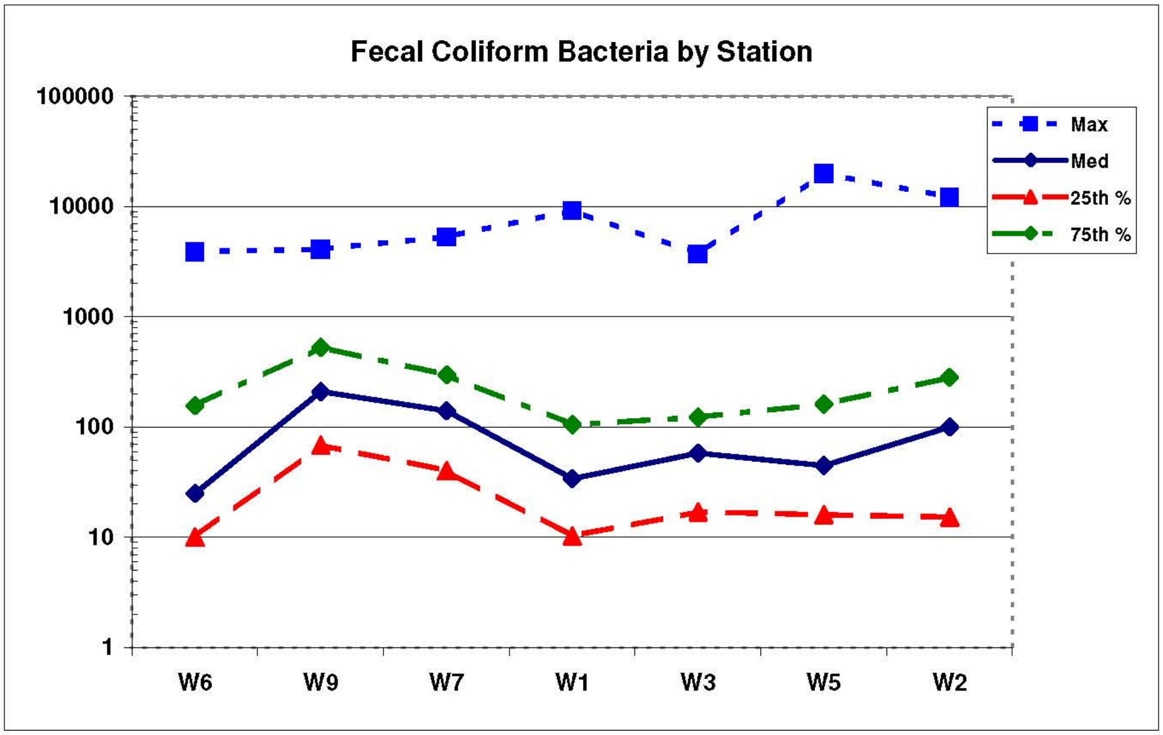


Figure 20: Monmouth County Weekly Sampling: Summary of Bacteria Results



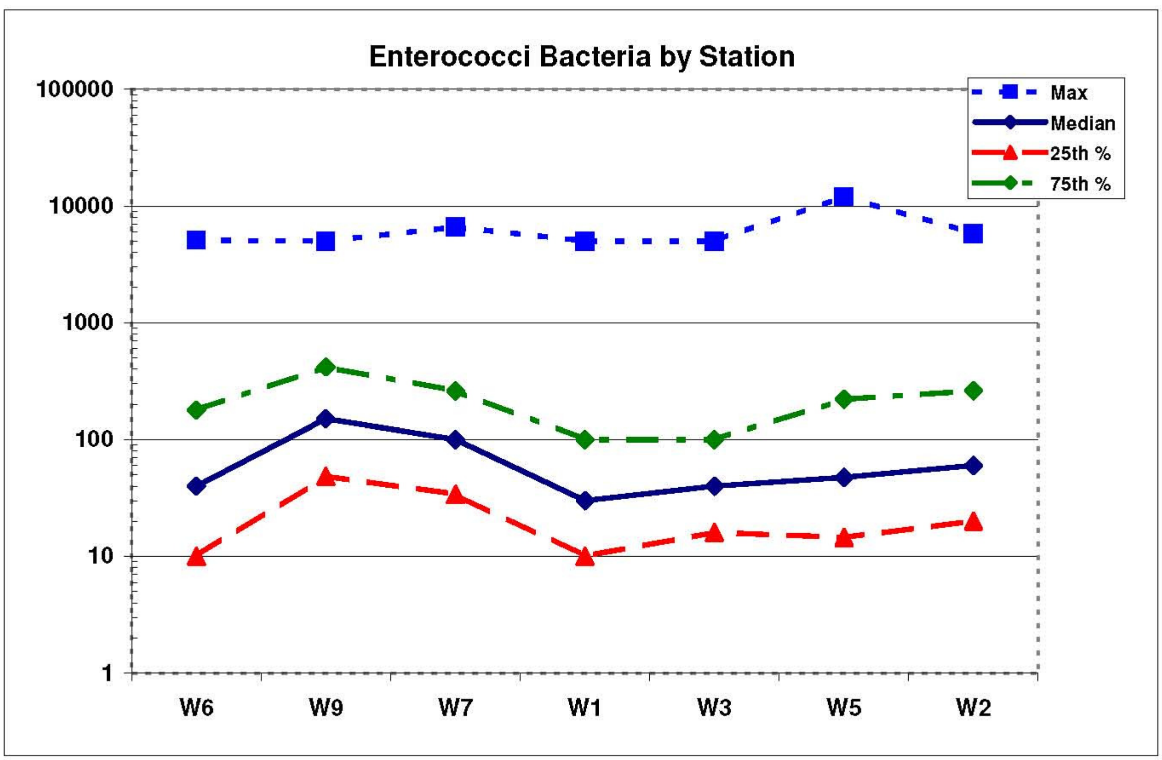


Table 27: County Water Quality Data Wreck Pond Brook - Conventional Parameters								
	N	Mean	Median	Max	Min	25th	75^{th}	StdDev
pH								
W6	64	6.15	6.07	7.90	5.17	5.79	6.49	0.53
W9	64	6.40	6.30	8.68	5.46	6.07	6.54	0.55
W7	63	6.58	6.50	7.94	5.88	6.32	6.73	0.41
W1	64	6.78	6.73	8.00	5.93	6.63	6.90	0.40
W3	63	6.80	6.74	8.45	6.01	6.63	6.89	0.35
Temperature								
W6	62	15.0	14.8	25.8	3.3	11.8	19.1	5.2
W9	62	15.8	16.0	26.6	3.4	11.7	20.6	6.0
W7	62	16.0	15.9	26.0	3.5	11.7	20.5	5.8
W1	62	16.8	16.7	29.0	3.0	12.3	21.7	6.1
W3	62	16.4	16.2	31.2	3.0	11.2	21.1	6.7
TSS								
W6	58	6	4	47	1	3	8	7
W9	58	11	7	114	2	5	12	16
W7	58	7	4	26	2	3	7	6
W1	69	7	4	49	1	2	10	8
W3	58	6	3	31	2	3	6	5

Table 28: County Water Quality Data Wreck Pond Brook - Bacteria							
	N	GeoMean	Median	Max	Min	25th	75th
Fecal Coliform							
W6	70	40	25	3900	4	10	156
W9	70	174	209	TNTC	4	69	528
W7	70	96	140	5300	4	40	298
W1	70	41	34	9200	4	10	105
W3	70	49	58	3700	4	17	123
Enterococci Bacteria							
W6	70	45	40	5100	4	10	178
W9	70	149	150	TNTC	4	49	416
W7	70	97	100	6600	5	34	260
W1	70	36	30	TNTC	4	10	100
W3	70	46	40	TNTC	4	16	100

Table 29: County Water Quality Data Hannabrand Brook - Conventional Parameters								
	N	**Mean**	**Median**	**Max**	**Min**	**25th**	**75th**	**StdDev**
pH								
W5	63	6.66	6.55	8.60	6.00	6.47	6.76	0.40
W2	63	6.70	6.60	8.43	5.82	6.52	6.72	0.39
Temperature								
W5	62	15.9	16.2	27.0	3.9	11.5	19.8	5.7
W2	62	16.2	16.1	28.8	3.1	11.6	21.2	5.9
TSS								
W5	69	7	3	59	1	2	7	10
W2	69	7	4	54	2	3	7	8

Table 30: County Water Quality Data Hannabrand Brook - Bacteria							
	N	**GeoMean**	**Median**	**Max**	**Min**	**25th**	**75th**
Fecal Coliform							
W5	70	56	45	20000	4	16	160
W2	70	75	100	12100	4	15	283
Enterococci							
W5	70	59	48	12000	4	15	220
W2	70	75	70	5800	4	20	290

Table 31: County Water Quality Data Black Creek - Conventional Parameters								
	N	**Mean**	**Median**	**Max**	**Min**	**25th**	**75th**	**StdDev**
pH								
W8	63	6.73	6.69	8.45	5.89	6.55	6.83	0.38
Temperature								
W8	62	16.99	16.70	28.80	3.20	12.30	22.38	6.29
TSS								
W8	69	9.74	4.00	197.00	2.00	3.00	8.00	23.80

Table 32: County Water Quality Data Black Creek - Bacteria							
	N	GeoMean	Median	Max	Min	25th	75th
Fecal Coliform							
W8	70	61	90	5200	4	13	230
Enterococci							
W8	70	54	60	7300	4	13	159

Bacteria levels in the Black Creek station were similar to the other streams. There were no samples reported as too numerous to count.

10.2 Borough of Spring Lake Wreck Pond Environmental Study

The Borough of Spring Lake, under a USEPA grant, recently completed an Environmental Study of Wreck Pond conducted by NA. Several water quality monitoring programs were conduced for the Borough study. These included:

Ambient Pond and Tributary Sampling: These programs were designed to monitor the current ambient conditions within Wreck Pond and it direct tributaries. Three stations were monitored within the Pond and three within the tributaries for a period of one year with monthly samples for September, October, March and April and twice monthly samples during May through August.

Pollutant Budget Monitoring: This monitoring element was designed to monitor water quality during storm events to conduct pollutant load analyses and as input to the SWMM model discussed in Section 8. The program consisted of monitoring at three locations during two storm events.

Storm Outfall Monitoring: This element was designed to evaluate the contribution of direct stormwater discharges to the Pond. Monitoring was conducted at twelve outfall locations during one storm event.

Sediment Sampling: Sediment cores were taken from Wreck Pond and the Spring Lake. This sampling was designed to investigate bacterial levels in the Pond as well as other potential pollutants in the sediments in the Pond.

The following sections summarizes the monitoring programs and results. Additional information, including QA/QC reports, monitoring methods, and further data can be found in the Borough of Spring Lake's Wreck Pond Environmental Study. Figure 21 shows the sampling locations for the monitoring elements in this Study. Appendix F provides additional information.

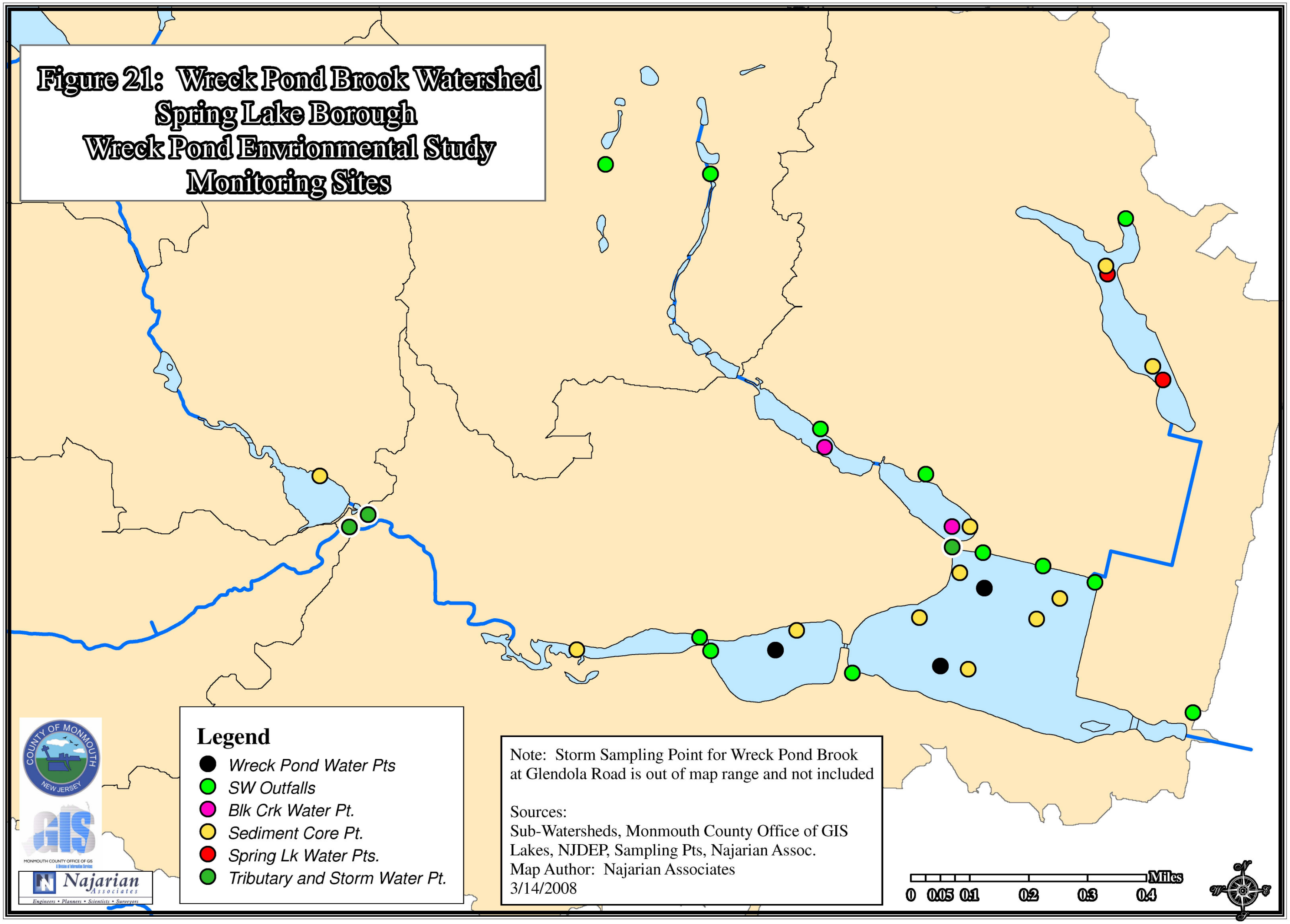


Figure 21: Wreck Pond Brook Watershed
Spring Lake Borough
Wreck Pond Envrionmental Study
Monitoring Sites
Legend
Wreck Pond Water Pts
SW Outfalls
Blk Crk Water Pt.
Sediment Core Pt.
Spring Lk Water Pts.
Tributary and Storm Water Pt.
Note: Storm Sampling Point for Wreck Pond Brook
at Glendola Road is out of map range and not included
Sources:
Sub-Watersheds, Monmouth County Office of GIS
Lakes, NJDEP, Sampling Pts, Najarian Assoc.
Map Author: Najarian Associates
3/14/2008
0 0.05 0.1 0.2 0.3 0.4
Miles
Najarian Associates

10.2.1 Pond Sampling

Three locations were sampled in the Pond as shown on Figure 21. The following field parameters were measured using a Horiba U-10 water quality meter and additional measuring instruments:

- pH
- Conductivity
- Temperature
- DO
- Turbidity
- Salinity
- Water depth (survey rod in Pond, staff gauge in streams)
- Secchi depth (only in Pond, using a secchi disk)

Grab samples were collected and sent to QC Laboratories for analysis. Samples were analyzed for the following parameters:

Nitrate	Manganese
Nitrite	Hardness
TKN	Alkalinity
Ammonia	Chloride
Total Phosphorous	Turbidity
Ortho-Phosphate	TSS
CBOD	TDS
Iron	Chlorophyll-a

In addition to chemical parameters, several bacteria groups were monitored, to evaluate the nature of bacteria in Wreck Pond. These are Fecal Coliform, Total Coliform, Fecal Streptococcus, Enterococci bacteria and Clostridium Perfringens. Algal counts were conducted and algae were identified at the genera level.

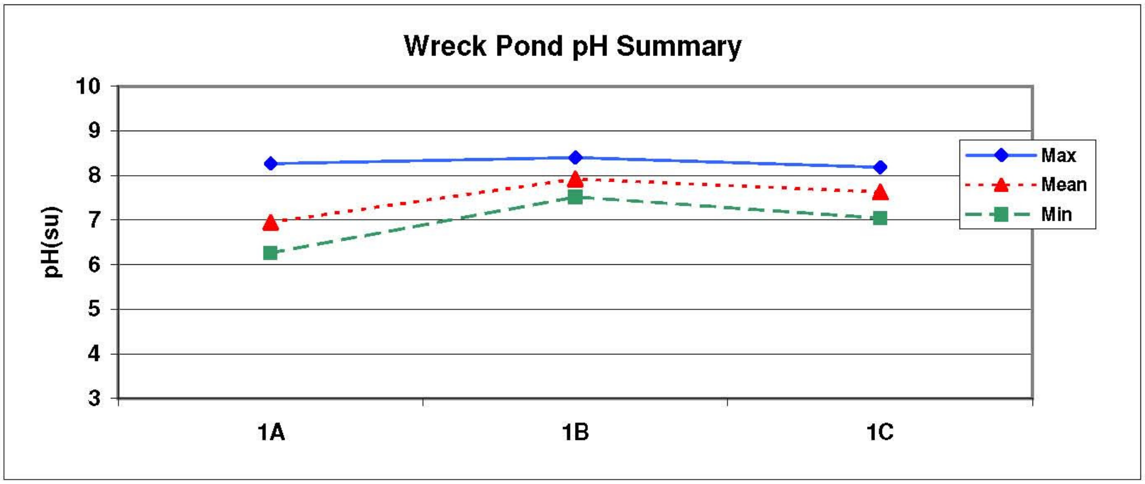
Tables 33 through 35 summarize the Pond water quality data. Figure 22 summarizes some of the Pond Monitoring data.

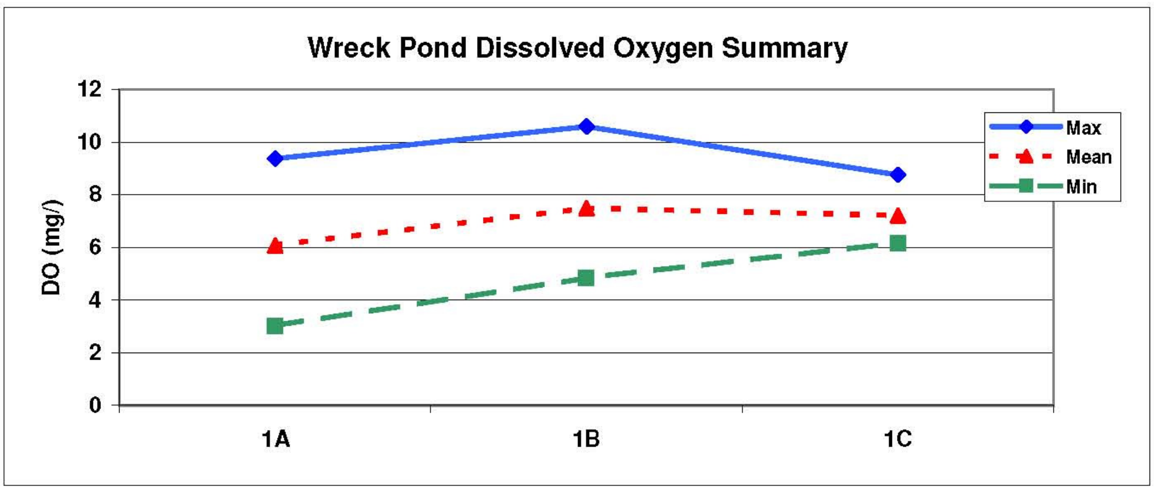
The overall quality of Wreck Pond is discussed in two separate sections: west and east of the Route 71 Bridge, as there were differences noted in the water quality conditions of the Pond in these areas.

Western Pond: The western portion of the Pond is characterized by Station WP1 and does not receive much tidal mixing, based on the limited salinity variation. This section of the Pond had earlier peaks in algal mass. DO was at a minimum in this area, dropping to just over 3 mg/l. Nitrate levels are higher in this portion of the Pond than at the other two stations. The average and minimum pH was lower in this part of the Pond. The turbidity average also was higher.

DO at Station WP1 shows a typical DO sag curve, with the minimum value in mid-summer. The minimum concentration of just over 3 mg/l is below the NJDEP standard

Figure 22: Spring Lake Wreck Pond Environmental Study
Wreck Pond Water Quality Results





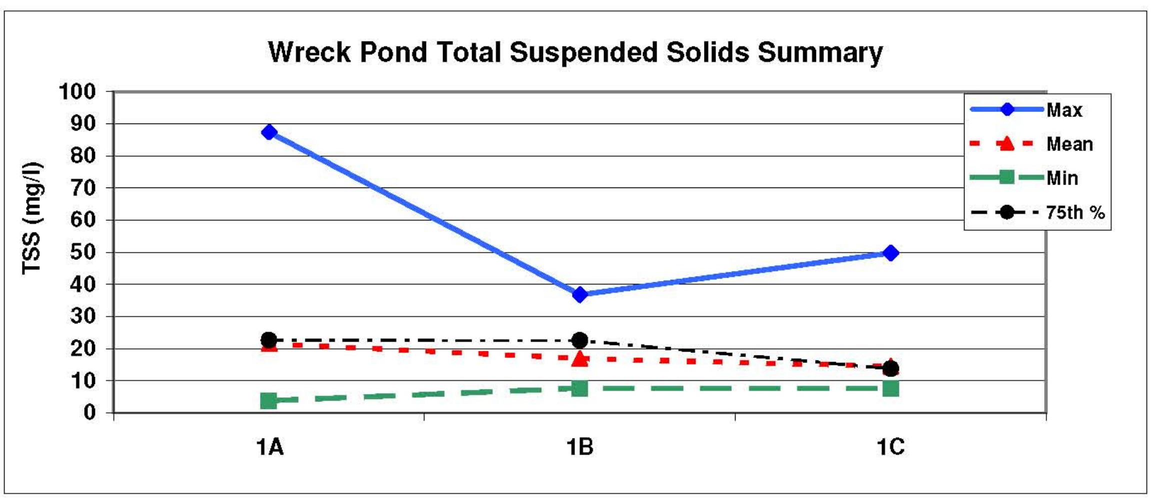
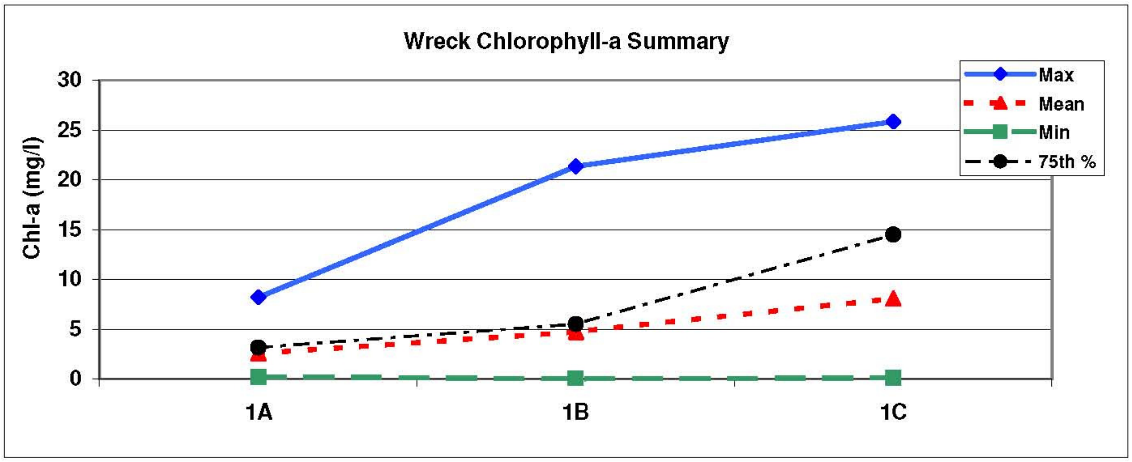
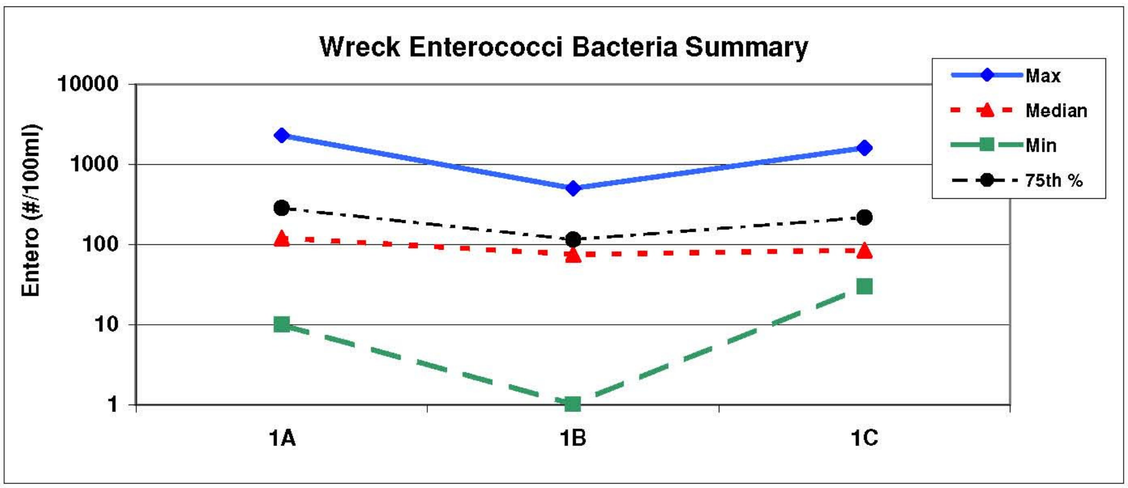


Figure 22: Spring Lake Wreck Pond Environmental Study
Wreck Pond Water Quality Results





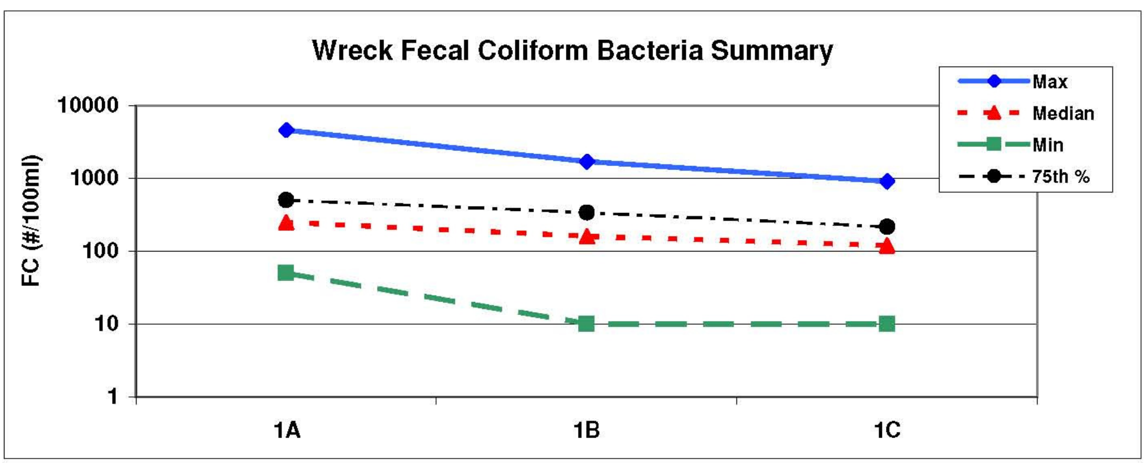


Table 33: Pond Sampling Results – WP1

Parameter	n	Units	Mean	Median	Max	Min	25th Percent	75th Percent	Std. Dev
pH	12	su	6.95	6.87	8.26	6.26	6.54	7.26	0.54
Temperature	12	^{o}C	20.2	22.2	27.1	5.2	15.3	25.4	6.8
Dissolved Oxygen (DO)	12	mg/l	6.07	6.66	9.37	3.02	4.69	7.18	1.87
Spec Cond	12	mg/l	5.8	1.1	33.5	0.2	0.3	6.1	10.0
Turbidity (field)	11	ntu	21	18	70	5	9	24	19
WD Top Sed	12	ft	1.27	1.35	1.70	0.90	1.09	1.40	0.25
WD Bot Sed	8	ft	2.05	2.10	2.60	1.50	1.90	2.23	0.36
Salinity	12	%	0.33	0.07	2.13	0.00	0.01	0.26	0.63
Calcium Hardness	12	mg/l	63	35	280	18	21	51	78
Magnesium Hardn.	12	mg/l	191	72	940	12	14	155	299
Total Hardness	12	mg/l	252	105	1200	29	37	213	370
Calcium	12	mg/l	25.3	13.9	114.0	7.2	8.3	20.3	31.5
Iron	12	mg/l	1.124	1.095	1.930	0.641	0.782	1.253	0.423
Magnesium (Mg)	12	mg/l	47	17	229	3	3	39	73
Manganese (Mn)	12	mg/l	0.0668	0.0619	0.1130	0.0388	0.0494	0.0857	0.0235
Chloride	12	mg/l	1224	374	10600	42	52	596	2976
Alkalinity	12	mg/l	19.8	17.9	54.8	8.3	12.4	22.4	12.5
Tot Diss Solid (TDS)	12	mg/l	1639	458	12100	106	168	1235	3372
Tot Susp Solid (TSS)	12	mg/l	21.5	11.0	87.3	3.7	7.2	22.6	24.5
Turbidity (lab)	12	ntu	6	4	16	2	4	6	4
TKN	12	mg/l	0.628	0.695	1.290	0.300	0.300	0.820	0.324
Ammonia (NH_3-N)	12	mg/l	0.126	0.095	0.340	0.050	0.058	0.136	0.096
Nitrate (NO_3-N)	12	mg/l	0.44	0.50	0.84	0.10	0.34	0.58	0.23
OrthoPhosphate- PO_4-P	4	mg/l	0.015	0.014	0.020	0.011	0.012	0.017	0.004
Total Phosphorus	12	mg/l	0.092	0.055	0.550	0.020	0.036	0.069	0.146
Chlorophyll-a	12	mg/m^3	2.555	1.765	8.179	0.214	0.595	3.148	2.490
Carbon BOD	2[a]	mg/l	--	--	4.1	2.1	--	--	--
Clostridium Perfringens	6	/ml	--	35	120	10	15	47.5	--
Total Coliform	12	c/100ml	--	1150	4600	150	500	2250	--
Enterococci	12	c/100ml	--	120	2300	10	55	285	--
Fecal Coliform	12	c/100ml	--	250	4600	50	120	500	--
Fecal Streptococcus	12	mpn/100ml	--	950	6000	200	420	4900	--

[a]Other samples non-detect; all samples analyzed for parameter

Table 34: Pond Sampling Results – WP2									
Parameter	**n**	**Units**	**Mean**	**Median**	**Max**	**Min**	**25th Percent**	**75th Percent**	**Std. Dev**
pH	12	su	7.92	7.81	8.40	7.52	7.72	8.20	0.32
Temperature	12	^oC	20.8	23.3	27.8	6.0	16.4	24.8	6.4
Dissolved Oxygen (DO)	12	mg/l	7.49	7.32	10.58	4.84	6.08	8.86	1.87
Spec Cond	12	mg/l	30.3	30.8	44.1	7.5	25.9	39.8	10.7
Turbidity (field)	11	ntu	14	10	61	3	7	15	16
WD Top Sed	12	ft	1.32	1.33	1.90	0.78	1.14	1.47	0.34
WD Bot Sed	8	ft	2.01	1.96	2.30	1.80	1.88	2.14	0.19
Salinity	12	%	1.86	1.98	2.79	0.40	1.42	2.60	0.74
Calcium Hardness	12	mg/l	416	440	750	130	305	490	183
Magnesium Hardn.	12	mg/l	2038	2100	3300	580	1475	2625	922
Total Hardness	12	mg/l	2446	2550	4000	710	1750	3125	1095
Calcium	12	mg/l	166.2	175.0	299.0	51.6	123.4	196.5	73.3
Iron	12	mg/l	0.492	0.423	0.766	0.257	0.327	0.678	0.185
Magnesium (Mg)	12	mg/l	493	509	793	141	358	635	222
Manganese (Mn)	11	mg/l	0.0398	0.0395	0.0785	0.0218	0.0286	0.0457	0.0155
Chloride	12	mg/l	9651	9230	18200	2350	7620	11250	4713
Alkalinity	12	mg/l	68.5	74.4	90.5	35.7	57.5	78.8	16.5
Tot Diss Solid (TDS)	12	mg/l	15143	16350	24300	5350	8838	19075	6370
Tot Susp Solid (TSS)	12	mg/l	16.9	11.3	36.7	7.7	8.8	22.5	10.7
Turbidity (lab)	12	ntu	3	3	6	2	3	4	1
TKN	12	mg/l	0.584	0.380	1.350	0.300	0.300	0.745	0.379
Ammonia (NH_3-N)	12	mg/l	0.106	0.060	0.370	0.050	0.050	0.106	0.100
Nitrate (NO_3-N)	12	mg/l	0.24	0.11	0.63	0.10	0.10	0.31	0.20
OrthoPhosphate- PO_4-P	3[a]	mg/l	0.030	0.014	0.061	0.014	0.014	0.038	0.027
Total PHosphorus	12	mg/l	0.043	0.045	0.079	0.010	0.027	0.058	0.022
Chlorophyll-a	12	mg/m^3	8.014	3.889	27.670	0.000	0.381	14.453	9.663
Carbon BOD	2[a]	mg/l	--	--	4	3.1	--	--	--
Clostridium Perfringens	3[a]	/ml	--	10	300	10	--	--	--
Total Coliform	11	c/100ml	--	300	4600	30	80	780	--
Enterococci	12	c/100ml	--	75	500	1	18	115	--
Fecal Coliform	12	c/100ml	--	160	1700	10	50	338	--
Fecal Streptococcus	11	mpn/100ml	--	230	1100	60	150	455	--

[a]Other samples non-detect; all samples analyzed for parameter

Table 35: Pond Sampling Results – WP3									
Parameter	n	Units	Mean	Median	Max	Min	25th Percent	75th Percent	Std. Dev
pH	12	su	7.63	7.64	8.18	7.04	7.44	7.79	0.31
Temperature	12	^oC	20.3	21.9	27.8	5.7	16.0	24.3	6.6
Dissolved Oxygen (DO)	12	mg/l	7.21	7.08	8.75	5.91	6.45	7.85	0.98
Spec Cond	12	mg/l	27.4	27.6	40.2	11.5	22.5	34.3	9.2
Turbidity (field)	11	ntu	10	6	22	4	5.5	14	6
WD Top Sed	12	ft	1.31	1.32	1.75	0.69	1.08	1.60	0.34
WD Bot Sed	8	ft	1.69	1.75	1.96	1.24	1.56	1.91	0.26
Salinity	12	%	1.65	1.56	2.56	0.51	1.33	2.25	0.66
Calcium Hardness	12	mg/l	394	395	810	120	268	483	204
Magnesium Hardn.	12	mg/l	1931	1900	3500	540	1250	2425	996
Total Hardness	12	mg/l	2318	2300	4200	660	1520	2875	1192
Calcium	12	mg/l	157.4	158.5	323.0	47.5	108.0	192.8	81.1
Iron	12	mg/l	0.548	0.528	1.020	0.277	0.325	0.696	0.249
Magnesium (Mg)	12	mg/l	468	461	844	131	310	585	241
Manganese (Mn)	11	mg/l	0.0431	0.0379	0.0829	0.0241	0.0315	0.0485	0.0180
Chloride	12	mg/l	9341	9670	15900	2580	7217.5	11350	4062.
Alkalinity	12	mg/l	62.9	61.7	97.4	34.9	55.8	72.2	16.9
Tot Diss Solid (TDS)	12	mg/l	13916	13300	24400	5300	10453	18875	5890
Tot Susp Solid (TSS)	12	mg/l	14.5	11.4	49.7	7.7	8.9	13.7	11.5
Turbidity (lab)	12	ntu	3	3	6	2	2	4	1
TKN	12	mg/l	0.45	0.32	0.94	0.3	0.3	0.545	0.217
Ammonia (NH_3-N)	12	mg/l	0.144	0.071	0.540	0.050	0.050	0.148	0.152
Nitrate (NO_3-N)	12	mg/l	0.17	0.11	0.45	0.10	0.10	0.18	0.11
OrthoPhosphate- PO_4-P	2	mg/l	0.012	0.012	0.012	0.011	0.011	0.012	0.001
Total PHosphorus	12	mg/l	0.047	0.039	0.110	0.010	0.026	0.057	0.031
Chlorophyll-a	12	mg/m^3	8.067	3.716	25.820	0.100	0.421	14.478	9.256
Carbon BOD	3[a]	mg/l	3.4	--	5.1	2.3	--	--	--
Clostridium Perfringens	4[a]	/ml	--	15	20	10	--	--	--
Total Coliform	12	c/100ml	--	450	3500	70	107.5	900	--
Enterococci	12	c/100ml	--	85	1600	30	65	217.5	--
Fecal Coliform	12	c/100ml	--	120	900	10	57.5	215	--
Fecal Streptococcus	12	Mpn/100ml	--	370	3700	30	200	1350	--
[a]Other samples non-detect; all samples analyzed for parameter									

of 4 mg/l and indicates possibly stressed conditions. However, by the next monitoring event two weeks later the DO had recovered and was above 4 mg/l. DO in the western section remained lower than in the Central section of the Pond throughout the summer.

Eastern (Main) Pond: Stations WP2 and WP3 characterize the main section of the Pond between Route 71 and the Railroad Bridge. This portion of the Pond is shallow and the bottom is very mucky. Movement of the boat during sampling disturbed the sediments. This portion of the Pond is influenced by tidal action.

The central part of the pond has higher DO, with the minimum at 4.8 mg/l. During the hottest part of the summer, the DO concentrations at Stations WP2 and WP3 were above the oxygen saturation level for the water temperature. Supersaturated DO can indicate that oxygen is being added to a water body through photosynthetic organisms. However, that is typically accompanied by excessive respiration at night which may drop the DO level significantly, causing DO levels below standard. As discussed further below, the period of DO super-saturation are accompanied by elevated, but not maximum, chlorophyll-a data (which indicates algal growth). DO in the central part of the Pond also is influenced by tidal action, which adds mixing to the system and increases DO.

Bacteria levels increased throughout the summer. During much of the summer, bacteria levels were above the NJDEP standard. Maximum Enterococci bacteria counts were at 1,600 #/100ml and 2,300 #/100ml at Stations WP3 and WP1, respectively at the end of August. Fecal coliform concentrations peaked at 4,600 #/100ml at WP1 and 1,700 #/100ml at WP2 in mid- to late-August.

Total phosphorus was above the NJDEP standard of 0.05 mg/l for the summer months. While common in New Jersey lakes and ponds, this indicates there is sufficient phosphorus enrichment to produce algal growth. Ortho-phosphate is generally low and is higher at Station WP1 than the other two stations.

Algal growth peaked first at Station WP1; with green algae predominate in June. In July, the green algae peaked at Station WP2, with increasing blue-green algae. Peak algal growth peaked later at Station WP3. The main section of the Pond had higher algae counts than in the western section.

The algae were dominated by green algae at the beginning of the season. The percentage of cyanobacteria, so-called blue-green algae, increased over the summer. The blue-green algae fraction increased to about 40-43% in the late summer. At Station WP3, less fluctuation was noted. At both mid-pond stations, diatom counts peaked in mid-July at 30-32%, dropping to 14-15% in the late summer.

Summer data were reviewed to determine the overall characterization of the Pond water quality. Summer chlorophyll-a averaged 11.9 ug/l, with a peak value of 27.7 ug/l. The EPA nutrient guidance document for lakes provides levels of water quality parameters that characterize trophic states in lakes. The trophic levels have overlapping ranges for these parameters, as the value of one parameter may vary in a lake considered eutrophic. The guidance document uses nutrient, chlorophyll-a, secchi depth, oxygen in the hypoliminion, and fish parameters data to classify lakes. In this case, nutrient and chlorophyll-a data are available. However, Wreck Pond is very shallow so that secchi depth is meaningless and there is no hypoliminion.

The concentrations of the available parameters fall within the eutrophic range. The peak chlorophyll–a 27.7 ug/l is below the average peak for eutrophic lakes (43) but above the average peak for mesotrophic lakes (16). Phosphorus mean is 0.045 mg/l for all of the data and 0.054 mg/l for the summer data. These values are within the eutrophic range, and also in the upper range of the mesotrophic. The average Total N is 0.72 mg/l with 0.71 mg/l in the summer. The maximum value is 1.590 mg/l. The mean N is below the mesotrophic total N mean of 0.79 mg/l, but with the exception of the minimum value, the range of Total N concentrations (0.358-1.590) fall within the eutrophic range of 0.139-1.600 mg/l.

The algal community composition is a component of eutrophication level. In the main portion of Wreck Pond, up to 43% of the algae at Station WP2 and 38% at WP3 are blue-green algae. Thus, a substantial proportion of the algae in the Pond are blue-green, often indicative of more eutrophic conditions. .

Thus, Wreck Pond is a mesotrophic/eutrophic water with nitrogen, phosphorus and chlorophyll-a values within the eutrophic range. Further nutrient enrichment will continue the eutrophication process.

Bacteria levels were somewhat higher in the western Pond, particularly for fecal coliform and fecal streptococcus. However, enterococci counts were similar in both sections. This may be due to the higher die-off of the bacteria species in saline waters or other factors.

10.2.2 Tributary Results

Three tributary stations were monitored. There are shown on Figure 21 and are:

WB1: Wreck Pond Brook at Old Mill Road, downstream side of culvert
HB: Hannabrand Brook at Old Mill Road, upstream side of culvert
BC: Black Creek at Ocean Road Weir, at intersection of Ocean and Shore Roads

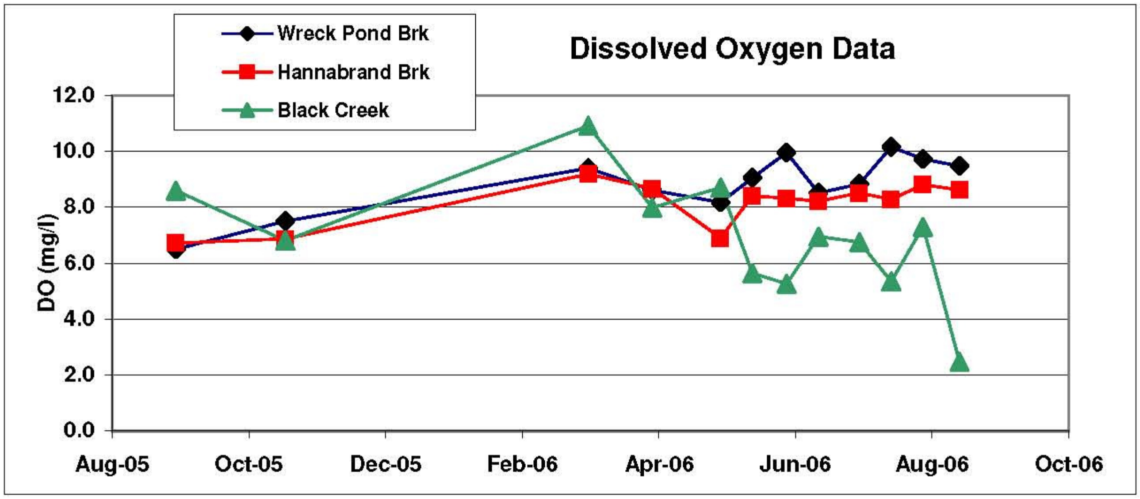
Stations WB1 and HB are located in the vicinity of County gaging stations W3 and W2, respectively. The BC station is farther downstream than County gage W8.

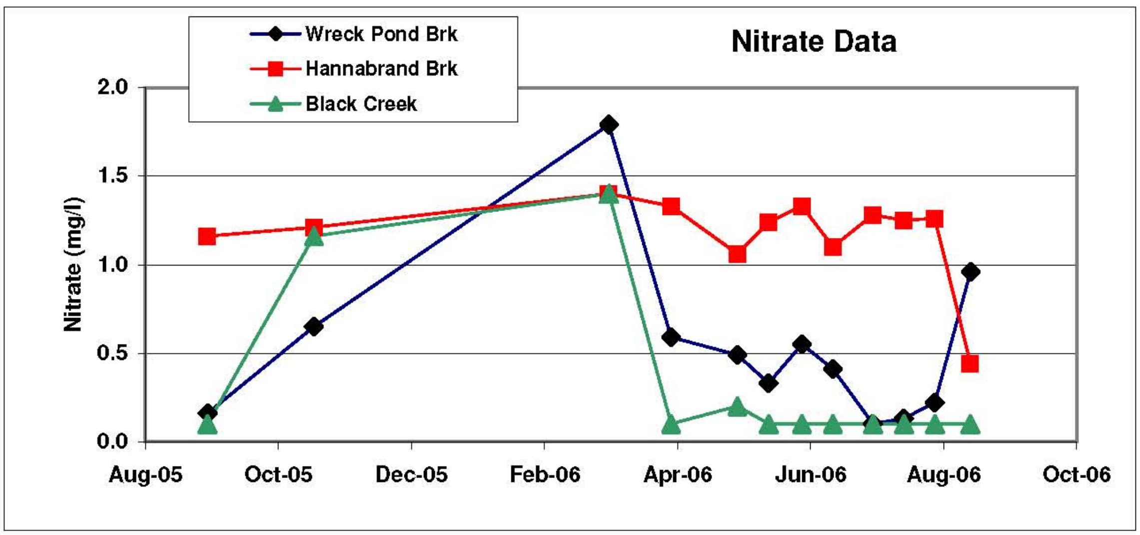
Table 36 through 38 summarize the tributary monitoring results. Figure 23 illustrates results for some parameters and additional information is provided in Appendix F.

Average Total Phosphorus was below standard at all three stations, although the concentrations were highest in Black Creek and exceeded the state standard of 0.1 mg/l from mid-July through the end of the summer. The peak phosphorus concentration in Black Creek was 0.273 mg/l on the last sampling day on August 30. As noted above, DO at this station was low at this time. Some of the phosphorus may be released from

Wreck Pond Brook Wateshed Study

Figure 23: Spring Lake Wreck Pond Environmental Study
Tributary Analyses





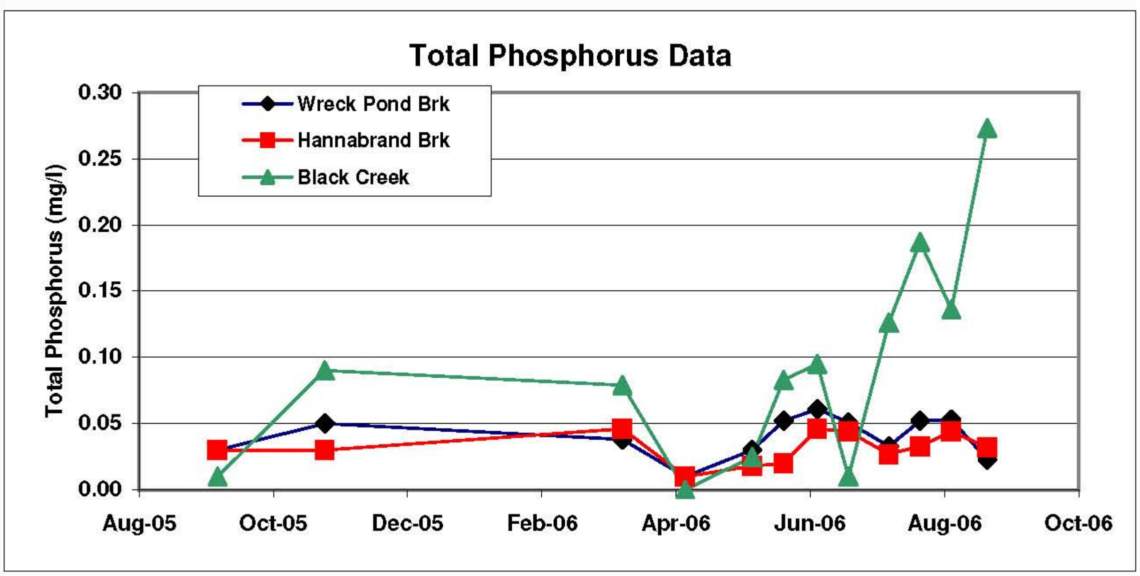
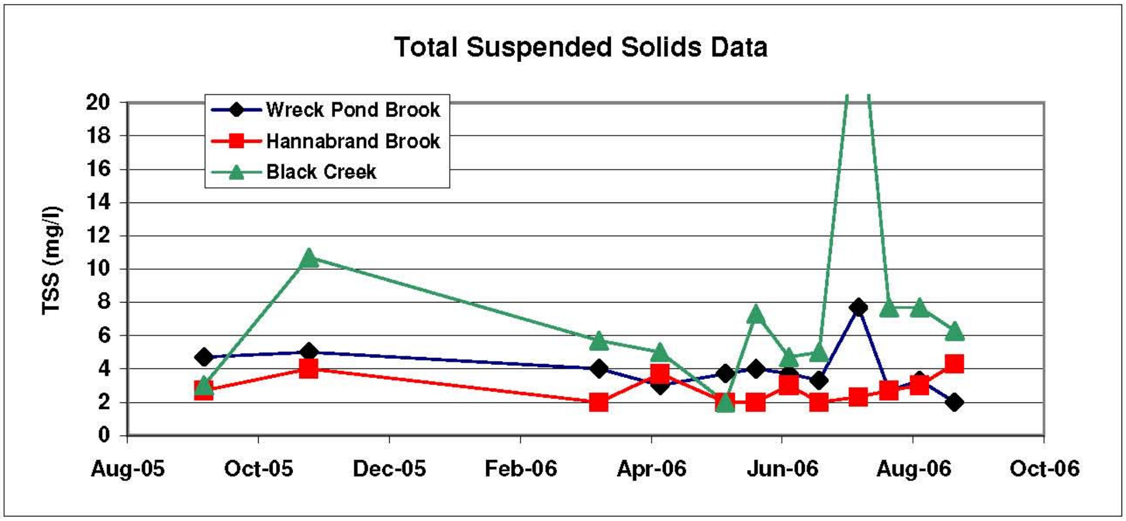
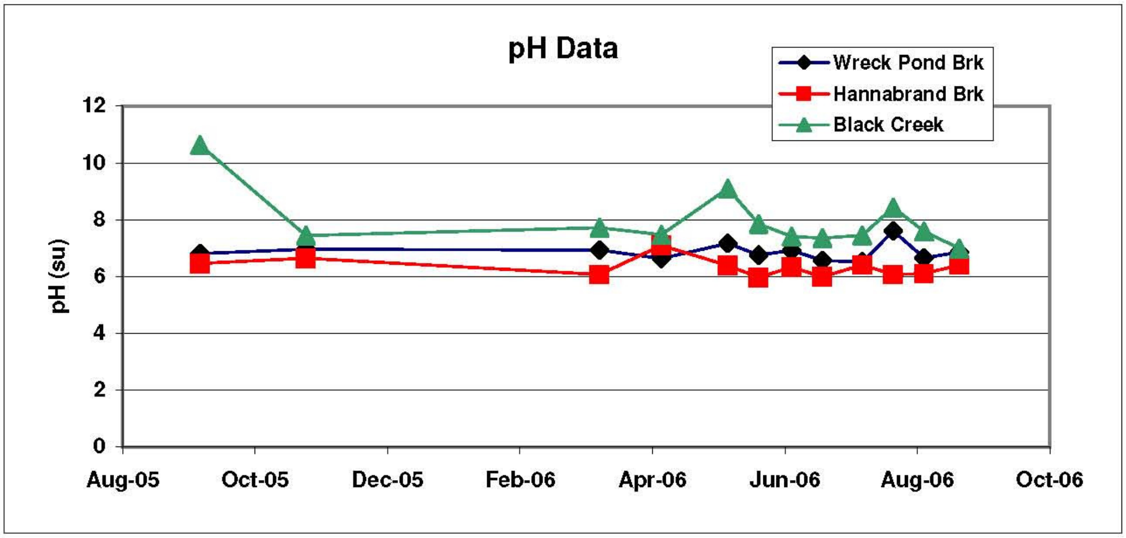


Figure 23: Spring Lake Wreck Pond Environmental Study
Tributary Analyses





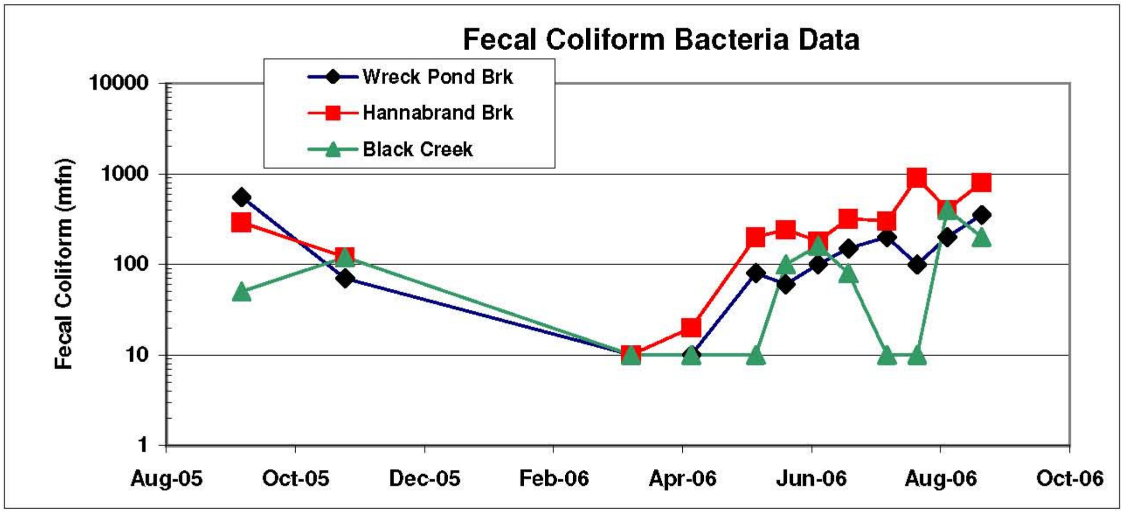


Table 36: Summary of Monitoring Data - Wreck Pond Brook									
	Units	**n**	**Mean**	**Med**	**Std Dev**	**Max**	**Min**	**75th Perc**	**25th Perc**
pH	su	12	6.86	6.83	0.30	7.60	6.51	6.94	6.65
Temperature	^{o}C	12	21.9	23.5	6.5	30.3	7.4	25.4	18.7
Dissolved Oxygen	mg/l	12	8.82	8.94	1.06	10.15	6.50	9.53	8.43
Specific Conductance	mg/l	12	0.22	0.22	0.02	0.26	0.19	0.23	0.21
Field Turbidity	ntu	12	7.50	6.50	4.19	18.00	4.00	9.00	4.00
Water Level	ft	12	0.86	0.87	0.11	1.00	0.68	0.96	0.76
Calcium Hardness	mg/l	12	20	20	3	24	14	21	19
Magnesium Hardness	mg/l	12	11	12	2	13	8	12	11
Total Hardness	mg/l	12	31	32	4	37	22	33	30
Calcium	mg/l	12	7.84	7.95	1.01	9.57	5.59	8.36	7.44
Iron	mg/l	12	1.137	1.160	0.297	1.570	0.713	1.348	0.923
Magnesium	mg/l	12	2.80	2.88	0.35	3.17	2.01	3.04	2.72
Manganese	mg/l	12	0.046	0.043	0.013	0.067	0.030	0.056	0.037
Chloride	mg/l	12	45.2	43.2	5.5	58.7	38.1	46.4	42.8
Alkalinity	mg/l	12	10.36	10.30	2.57	14.80	4.60	11.50	9.73
Total Dissolved Solids	mg/l	12	148	146	16	180	131	153	136
Total Suspended Solids	mg/l	12	3.9	3.7	1.4	7.7	2.0	4.2	3.2
Turbidity (lab)	ntu	12	3.249	3.125	1.522	7.140	0.324	3.348	2.830
TKN	mg/l	12	0.597	0.600	0.212	0.970	0.300	0.720	0.488
Ammonia (NH3-N)	mg/l	12	0.082	0.070	0.043	0.190	0.050	0.088	0.050
Nitrate (NO3-N)	mg/l	12	0.532	0.450	0.470	1.790	0.100	0.605	0.205
Total Phosphorus	mg/l	12	0.040	0.044	0.015	0.061	0.010	0.052	0.030
Total Coliform	#/100 ml	12		645		3600	30	1075	375
Enterococci	#/100 ml	12		40		700	10	60	10
Fecal Coliform	#/100 ml	12		100		550	10	200	68
Fecal Streptococcus	#/100 ml	12		415		4400	30	1450	200

Table 37: Summary of Monitoring Data – Hannabrand Brook									
	Units	n	Mean	Med	Std Dev	Max	Min	75th Perc	25th Perc
pH	su	12	6.32	6.35	0.32	7.09	5.96	6.42	6.07
Temperature	°C	12	17.4	18.4	4.3	22.5	7.6	20.2	14.8
Dissolved Oxygen	mg/l	12	8.12	8.36	0.83	9.18	6.72	8.63	7.88
Specific Conductance	mg/l	12	0.20	0.20	0.01	0.23	0.18	0.20	0.19
Field Turbidity	ntu	12	14.92	5.50	19.65	68.00	4.00	14.50	4.00
Water Level	ft	12	1.17	1.16	0.07	1.31	1.10	1.20	1.12
Calcium Hardness	mg/l	12	21	21	2	25	18	21	20
Magnesium Hardness	mg/l	12	14	15	1	16	12	15	14
Total Hardness	mg/l	12	35	36	3	41	30	36	34
Calcium	mg/l	12	8.35	8.21	0.67	9.92	7.25	8.61	8.06
Iron	mg/l	12	0.701	0.682	0.140	0.941	0.404	0.799	0.634
Magnesium	mg/l	12	3.52	3.58	0.30	3.87	2.94	3.74	3.42
Manganese	mg/l	12	0.043	0.041	0.008	0.059	0.032	0.044	0.037
Chloride	mg/l	12	35.2	33.9	4.3	45.9	30.1	36.2	32.7
Alkalinity	mg/l	10	10.71	10.70	1.16	12.40	8.84	11.20	10.13
Total Dissolved Solids	mg/l	12	1658	130	5304	18500	89	136	125
Total Suspended Solids	mg/l	12	2.8	2.7	0.8	4.3	2.0	3.2	2.0
Turbidity (lab)	mg/l	12	1.766	1.770	0.634	2.850	0.258	1.995	1.613
TKN	mg/l	12	0.503	0.500	0.168	0.860	0.300	0.583	0.398
Ammonia (NH3-N)	mg/l	12	0.112	0.100	0.050	0.250	0.056	0.120	0.090
Nitrate (NO3-N)	mg/l	12	1.172	1.245	0.250	1.400	0.440	1.293	1.145
Total Phosphorus	mg/l	12	0.032	0.031	0.012	0.046	0.010	0.044	0.025
Total Coliform	#/100 ml	12		1200		7000	90	2550	700
Enterococci	#/100 ml	12		265		600	10	405	105
Fecal Coliform	#/100 ml	12		265		900	10	340	165
Fecal Streptococcus	#/100 ml	12		750		5400	20	3525	313

Table 38: Summary of Monitoring Data – Black Creek									
	Unit	n	Mean	Med	Std Dev	Max	Min	75th Perc	25th Perc
pH	su	12	7.95	7.53	1.01	10.63	6.99	8.00	7.43
Temperature	^{o}C	12	22.1	23.9	6.6	30.1	7.3	26.0	19.0
DO	mg/l	12	6.89	6.88	2.13	10.91	2.47	8.13	5.57
Specific Conduc	mg/l	12	0.30	0.28	0.08	0.47	0.21	0.35	0.25
Field Turbidity	ntu	12	9.00	7.00	5.98	24.00	4.00	11.00	5.00
Water Level	ft	12	2.37	2.38	0.16	2.55	2.00	2.50	2.29
Calcium Hardness	mg/l	12	44	45	9	59	29	49	39
Magnesium Hardness	mg/l	12	20	20	5	30	13	22	18
Total Hardness	mg/l	12	64	65	14	90	42	69	56
Calcium	mg/l	12	17.63	17.90	3.76	23.80	11.80	19.63	15.50
Iron	mg/l	12	1.464	1.440	0.728	2.820	0.564	2.025	0.854
Magnesium	mg/l	12	4.75	4.73	1.18	7.39	3.07	5.17	4.20
Manganese	mg/l	12	0.058	0.054	0.041	0.177	0.013	0.062	0.039
Chloride	mg/l	12	49.1	44.5	16.4	82.9	28.9	58.4	38.7
Alkalinity	mg/l	12	49.34	48.85	8.97	67.20	31.50	51.73	44.45
Total Dissolved Solids	mg/l	12	193	203	47	274	134	215	148
Total Suspended Solids	mg/l	12	7.7	6.0	6.4	26.7	2.0	7.7	4.9
Turbidity (lab)	ntu	12	3.727	4.050	1.650	5.730	0.245	4.993	2.770
TKN	mg/l	12	1.065	0.775	0.781	2.720	0.300	1.275	0.595
Ammonia (NH3-N)	mg/l	12	0.235	0.080	0.296	1.000	0.050	0.323	0.054
Nitrate (NO3-N)	mg/l	12	0.305	0.100	0.459	1.400	0.100	0.125	0.100
Total Phosphorus	mg/l	12	0.094	0.087	0.080	0.273	0.010	0.129	0.021
Total Coliform	#/100 ml	12		300		2600	10	525	40
Enterococci	#/100 ml	12		35		120	10	83	10
Fecal Coliform	#/100 ml	12		65		400	10	130	10
Fecal Streptococcus	#/100 ml	12		155		2200	10	333	100
Clostridium Perf	#/100 ml	12		10		300	7	23	10

the sediments within Black Creek under the low oxygen conditions found there in late summer. Interestingly, total phosphate in the sediment core from Black Creek (see Section 2.2.3) were lower than in the cores from Wreck Pond. Also, the die-off of algae seen in the impounded section of the Creek likely added phosphorus to the system. Concentrations at the other two stations did not violate the standard.

Nitrate showed a spring peak at all three stations, with Wreck Pond Brook having the highest value of 1.79 mg/l. After the March peak, nitrate levels dropped at Stations WPB and BC to around 0.5 mg/l and to the detection limit of 0.1 mg/l, respectively. However, the nitrate concentration at Station HB remained relatively higher at about 1.1 to 1.3 mg/l. Nitrate values at this station were lower for sampling events following rainfall (5/17, 6/29 and 8/30). This was not noted in the other streams. This suggests there is higher nitrate in the base flow of Hannabrand Brook, likely from groundwater flow.

As in Wreck Pond, the bacteria concentrations in the tributary streams increased throughout the summer. The maximum fecal coliform counts per 100 ml were 550, 900 and 400 while the maximum enterococci counts (#/100ml) were 700, 600, and 120 in Wreck Pond Brook, Hannabrand Brook and Black Creek, respectively. Fecal streptococcus counts per 100 ml were 4,400, 5,400 and 2,200 at those locations.

10.2.3 Sediment Sampling

Sediment cores were taken from seven locations within Wreck Pond and four other watershed locations, including Old Mill Pond, Black Creek, and Spring Lake.

The sediment cores showed a thick layer of mucky material on the bottom of Wreck Pond and other ponds. Figures in Appendix F provide sediment grain size analysis for the cores.

Sediments were tested for several types of bacteria: Clostridium Perfringens, Total Coliform, Enterococci, Fecal Coliform and Fecal Streptococcus. It should be noted that unlike in water samples, the detection limit for bacteria in sediment is 100 #/dry grm. The tested parameters were:

Sample Depth
Grain Size
TOC
% Moisture
PP + 40
Herbicides
Fecal Coliform
Total Coliform
Fecal Streptococcus
Enterococci
Clostridium Perfringens

Nitrate
Nitrite
TKN
Ammonia
Total Phosphorous
Ortho-Phosphate
SOD

Figure 24 summarizes the bacteria results, while other data figures are located in Appendix F. Elevated phosphorus levels were found in certain cores within Wreck Pond.

Bacteria levels exhibit naturally high variability. Thus, the sediment results simply provide data at one point in time but were not extensive enough to fully describe the bacterial concentration in the Pond sediments. As discussed in Section 5 the bacteria species that are commonly measured in water quality studies are considered indicator organisms. That is, while these bacteria are present in the human intestinal tract, they are also present in the intestinal tract of animals as well as in soils. Thus, elevated levels of indicator bacteria do not necessarily mean the water is contaminated with human waste.

The highest levels of bacteria were found in the top layer of sediment, for the most part. Figure 24 shows the concentration of various types of indicator bacteria in the top layer from each core. As shown, the highest counts were of fecal streptococcus.

Further analysis of the fecal streptococcus bacteria show that the highest concentration was >600,000 #/gm found in the bottom layer in the core from Old Mill Pond (Core 3A). In Wreck Pond proper, the highest concentration was 450,000 #/gm found in the top layer in both Core 3C and Core 3G. The levels of FS are much lower in the mid-core and bottom-core samples than in the top-core samples.

10.2.4 Storm Sampling

Water quality monitoring was conducted during two storm events in the watershed. The monitoring program was designed to compare pollutant loadings and to provide calibration data for the watershed model.

The sampling involved collecting surface water samples during two storm events, at three (3) sampling stations as summarized below:

WPB - OM: Wreck Pond Brook at Old Mill Road, downstream side of culvert (same location as in tributary sampling discussed above) – in vicinity of County Station W3

HB: Hannabrand Brook at Old Mill Road, upstream side of culvert (same location as in tributary sampling) – in vicinity of County Station W2

WPB-GR: Wreck Pond Brook at Glendola Road, downstream side of culvert in Wall Township- in vicinity of County Station W7

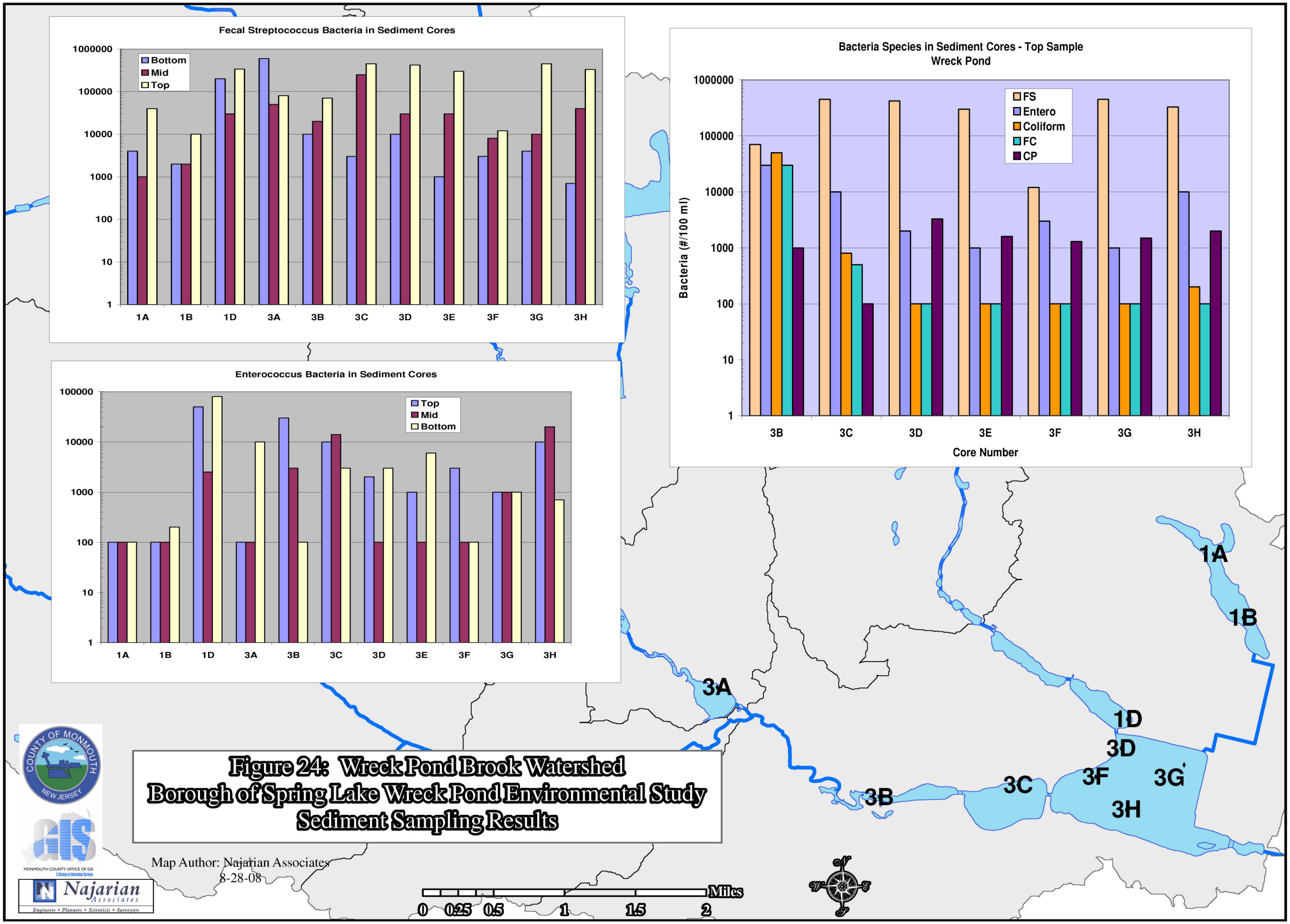


Figure 24: Wreck Pond Brook Watershed
Borough of Spring Lake Wreck Pond Environmental Study
Sediment Sampling Results

WPB-OM and HB were selected to measure contributions from the major tributaries, Wreck Pond Brook and Hannabrand Brook, and to be located near County gage stations. The third sampling point, WPB-GR, is further upstream on Wreck Pond and provided information regarding pollutant loadings contributed from upstream parts of the watershed, which have a lower percentage of residential land uses. In addition, this station would be used to look at flow and pollutant load continuity within Wreck Pond Brook.

Storm sampling was initiated during two storm events. However, during the first storm, September 2006, precipitation did not occur as projected. Thus, sampling occurred primarily during the early part of the storm and the true rising limb and peak were not sampled. Detailed analysis was not conducted for this storm.

The storm of October 17-18 2006 was determined to be a good storm for sampling and samples were collected over the entire storm hydrograph. The total rainfall was 1.08 inches starting at about noon on October 17 and extending until about 1 am on the 18^{th}. The peak intensity was 0.16 in/hour which occur in about the middle of the storm, at about 7 pm.

The parameters selected were those expected to impact overall quality of Wreck Pond. These parameters included:

- pH
- Conductivity
- Temperature
- DO
- Turbidity
- Salinity
- Gauge height
- Nitrate
- Nitrite
- TKN
- Ammonia
- Total Phosphorous
- Ortho-Phosphate
- CBOD
- TSS
- Fecal Coliform
- Total Coliform

Further details regarding the precipitation and monitoring methods are provided in the Wreck Pond Environmental Study and data are show in Appendix E as part of the SWMM modeling effort.

The results indicate that TSS and total phosphorus concentrations were significantly higher at Hannabrand Brook than at WPB at Old Mill. The concentrations of those parameters declined on Wreck Pond Brook from Glendola Road to Old Mill Road.

The water quality data were combined with flow data from the SWMM watershed model (see Section 8) to calculate storm loadings. In addition in order to compare the loadings from the two watersheds unit loading rates (loading per acre) and Event Mean Concentration (total load divided by flow volume) were calculated for each watershed. Table 39 summarizes these results.

The load of a parameter carried by a stream would increase in a downstream direction, unless material is deposited somewhere along the way. By comparing loads on WPB at Glendola Road and Old Mill Road, the flow and loading dynamics can be examined.

As noted above, the TSS concentrations for the WPB-OM station showed little response to the storm event. This is reflected in the loading analysis. The largest TSS load is from the WPB-GR Station with the smallest load at WPB-OM. In fact, the WPB loses over 2,000 pounds of TSS between these two stations. The EMC and loads for HB are similar to those for WPB-GR.

A similar, but less pronounced pattern is noted for total phosphorus. Here, the lower Wreck Pond Brook watershed loses about half the load that is present at the WPB-GR station. For nitrate and phosphate, no such pattern is apparent and the lower watershed generates a similar amount of this parameter as the upper watershed and the HB watershed.

Ammonia and phosphate unit loading rates are very similar for all three stations. Nitrate is the almost the same for both WPB stations, but is higher at HB. This may be due in part to the higher concentration in the baseflow of HB which was noted in the pre-storm sample.

Bacteria loads are more complex as bacteria dynamics include transport and die-off. In addition, bacteria counts are notably variable. The results suggest that HB is contributing the higher load per unit acre.

The analysis demonstrates that there is some process in the lower watershed that is reducing the load of certain constituents on Wreck Pond Brook between Glendola Road and Old Mill. The Glendola Road station is about 6,500 feet downstream of the closest pond, whereas the Old Mill station is just below Old Mill Pond. In addition, Osborne's Pond, is located in the reach of WPB between these two stations. It appears that these two ponds are allowing settling of suspended solids and certain associated pollutants.

Table 39: Pollution Budget Sampling Loading Analysis				
		Hannabrand Brk (HB)	**Wreck Pond Brk at Old Mill (WPB)**	**WPB at Glendola Rd (GR)**
	Watershed Size (acres)	**1976.5**	**4643.3**	**3109.4**
TSS	EMC (mg/l)	16.4	2.3	13.2
	Load (lbs)	1771	689	2945
	Load per acre	0.896	0.148	0.947
Ammonia NH3	EMC (mg/l)	0.070	0.058	0.060
	Load (lb)	7.6	17.2	13.4
	Load per acre	0.004	0.004	0.004
Nitrate NO3- N	EMC (mg/l)	0.804	0.511	0.463
	Load (lb)	87.03	150.8	103.4
	Load per acre	0.044	0.032	0.033
Phosphate TPO4 -P	EMC (mg/l)	0.019	0.012	0.015
	Load (lb)	2.1	3.4	3.2
	Load per acre	0.001	0.001	0.001
Total Phosphorus	EMC (mg/l)	0.060	0.019	0.057
	Load (lb)	5.5	6.5	12.8
	Load per acre	0.003	0.001	0.004
Total Coliform	EMC (#/100 ml)	88916	11637	18159
	Load (billions #)	20929	15593	18389
	Load per acre	11	3	6
Fecal Coliform	EMC (#/100 ml)	5399	889	1580
	Load (billions #)	1618	1191	1600
	Load per acre	0.819	0.256	0.515

10.2.5 Storm Outfall Sampling

The final monitoring program undertaken for the Wreck Pond Environmental Study was sampling directly within stormwater outfall pipes discharging to the Pond or other waterbodies. Details regarding the process of selecting the outfalls for sampling is provided in the Wreck Pond Environmental Study. Table 40 summarizes the outfalls sampled. Figure 21 includes outfall sampling locations.

TABLE 40: Stormwater Outfall Details

Outfall Pipe #	Location/ Municipality	Pipe Size/ Type	Baseflow (inches)	DA (acres)	Notes
6b	Rt. 71, southeast of WPB Culvert, Sea Girt	21" RCP	None	51.8	
7a	End of 6th Ave., Sea Girt	24" RCP	None	18.5	
15a	Municipal Parking Lot at Ocean Ave., Spring Lake	24" RCP	None	22.5	Standing water, sand at pipe invert
18a	3rd Ave. and Passaic Ave., Spring Lake	24" RCP	1.32	75.0	
20a	End of 6th Ave., Spring Lake Heights	12"x30" RCP	1.2	72.0	
21a	5th Ave. and Salem Ave., Spring Lake	30" RCP	5.04	47.5	
22a	Ocean Rd. and Fourth Ave., Spring Lake	30" RCP	0.48	30.5	
23a	Ocean Rd. and Third Ave., Spring Lake	27" RCP	0.48	17.1	
24a	Ocean Rd. and Second Ave., Spring Lake	30" RCP	0.48	35.7	Large root 4' up from invert, damming water
33a	Rt. 71, West side of WPB Culvert, Spring Lake Heights	18" CMP	None	13.7	
GC-1	Warren Ave. East of GC Entrance, Spring Lake Heights	54" RCP	4.8	229.9	
GC-2	Warren Ave. West of GC Entrance, Spring Lake Heights	48" RCP	0.24	50.0	

The following parameters that were monitored:

- Flow depth
- Total Nitrate/Nitrite
- TKN
- Ammonia
- Total Phosphorous
- TSS
- Fecal Coliform

Sampling was conducted for two different storm events (September and December of 2006), with six outfalls sampled during each storm.

During the storm events, the depth of flow at each outfall pipe was measured at regular time increments. Depths were converted to flow using the Manning's equation. These equations use pipe information such as slope, diameter and pipe material to convert water depth to flow volume. The flow and measured constituent concentration were used to calculate mass loadings of each pollutant at each outfall for each event. These loading values are the first flush mass loading of pollutants, and are illustrated for each storm in Tables 41-42 below: In this table the data are provided to two significant figures for loads to allow relative comparison of the loadings.

Base flow, that is flow prior to the storm event, was noted in certain pipes. During the October storm, Pipe 20a had the largest base flow. Bacteria concentrations in the base flow in this pipe were an order of magnitude higher than any other pipe in this round of sampling. Bacteria concentrations were also elevated in the post-storm baseflow in Pipe 21a for the December storm. For nitrate, the baseflow concentrations were higher in both storms. TP showed a "first flush" effect at most of the pipes for Storm 1, while TSS peaked in the second round for the most part although Pipe 6a had very high TSS concentrations in the third round. Bacteria concentrations were higher in the second storm event sampling.

10.2.6 Discussion of Storm Pipe Sampling Results

The results showed the transport of flow and water quality parameters through the pipes. Reviewing the data, certain flow or pollutant anomalies were found which are discussed briefly below.

- Outfall 15a: After the sampling began, the pipe filled very quickly to about half full. It was determined that a large quantity of sand was in the lower portion of the pipe, reducing its capacity. It is very likely that the flows at this station are biased high.

Table 41: October 27, 2006 (Storm 1) First Flush Pollutant Loads								
Outfall	**Area**	**Total Flow Volume**	**TSS**	**TKN**	**NH_3**	**NO_2/ NO_3**	**TP**	**Fecal Coliform**
	(Ac)	(L)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(billions of col)
15a*	22.4	672,765	15.3	0.61	0.39	0.51	0.14	1.82
24a[T]	35.7	66,858	1.41	0.04	0.04	0.08	0.04	0.78
23a	17.1	64,032	1.80	0.02	0.05	0.05	0.05	0.70
22a	30.5	92,747	3.06	0.09	0.10	0.09	0.10	1.97
7a	18.5	40,440	1.39	0.03	0.02	0.04	0.02	0.61
20a	72.0	278,962	7.44	0.16	0.14	0.23	0.11	34.97

*Loading larger then expected due to unexplained high field flows
[T]The Spring Lake outfall primary sub-catchment

Table 42: December 1, 2006 (Storm 2) First Flush Pollutant Loads								
Outfall	**Area**	**Total Flow Volume**	**TSS**	**TKN**	**NH_3**	**NO_2/ NO_3**	**TP**	**Fecal Coliform**
	(Ac)	(L)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(billions of col)
18a	75.0	191,339	23.37	0.37	0.11	0.42	0.10	88.82
GC-1	255.3	546,165	44.88	1.08	0.25	1.60	0.22	161.16
GC-2**	50.0	11,170	0.71	0.01	0.00	0.03	0.00	0.03
21a*	47.5	719,086	143.53	1.78	0.67	0.63	0.52	125.81
33a	13.7	25,115	2.06	0.12	0.02	0.02	0.01	8.32
6b	51.8	112,764	21.00	0.16	0.08	0.08	0.07	54.07

*Loading larger then expected due to unexplained high field flows
**Loading smaller then expected due to limited field flows and upstream pond storage

- Outfall 24a: The Spring Lake outfall pipe transports flows from Spring Lake as well as direct stormwater from the sub-watershed area. The flow analysis determined that during the monitoring period the first flush only included flow from the local sub-watershed, with only limited flows, if any, from increased flows out of the Spring Lake itself.

- Outfall 21a: Higher than expected flows were measured during the storm sampling at this pipe. Although not initially mapped as part of the sub-watershed to this pipe, it is possible that a large portion of the Spring Lake Borough DPW yard contributes flows to this outfall. Even with revision of the pipe sub-watershed to include this area, the flows from this sub-watershed were much larger than anticipated based on the flow per unit area for other sub-watersheds. Water quality loadings were higher than anticipated as well, based on the combination of abnormal flows and high pollutant concentrations found during sample collection. The sediment trap in the DPW yard is tied into this system, which could account for the TSS and bacteria sources, but not the large volumes of flow. This outfall should be investigated to determine flow sources as well as pollutant sources, since this is one of the primary sub-watersheds flowing to Black Creek. At this point however, the flows are so far out of range that the water quality loadings are considered inaccurate.

- Outfall GC-2: During the storm sampling, flows at this outfall were much lower than anticipated. It was discovered that the outfall is connected to an upstream pond with a control structure that detained stormwater flows. Thus, this outfall did not provide adequate flow and loadings could not be calculated.

10.3 Monmouth County Health Department

Wreck Pond is located at the mouth of the watershed. As noted previously, it is subject to tidal exchange with the Atlantic Ocean via an outfall structure. Discharge from the Pond to the Ocean has been the cause of numerous closings of ocean bathing beaches near the outfall due to high bacterial levels in the waters. One goal of the Regional Stormwater Plan is to reduce or eliminate such beach closings.

Bacteria data are collected by the Monmouth County Health Department (MCHD). Bacteria data are not collected after every storm event. Most beach closings are required due to the provisional rainfall ban, not actual monitoring data. The NJDEP extended the length of the Wreck Pond outfall to move the discharge away from the bathing zone and thus reduce the occasions when the outfall would cause bacteria levels to rise above the bathing beach standard. The actual impact of the extension of the outfall on recreational water quality in the bathing beach area has not been determined. MCHD and NJDEP are planning further monitoring in the bathing beaches near the Pond outfall.

The Monmouth County Health Department conducts monitoring of bacteria levels at beaches during the CCMP program, including Monday morning sampling. This monitoring is not designed to sample following rainfall, so there is limited data during periods of rainfall.

Review of data for the last few years does not consistently show a direct correlation between rainfall during the previous 24 hours and bacteria levels at bathing beaches near the outfall. For example, York Ave. beach in Spring Lake shows exceedances of the bacteria standard when the previous rainfall was zero as well as no exceedances when rainfall is 0.83 inches. In fact, for the sampling that occurred following the second-highest rainfall (0.83 inches, 9/5/06) only the Terrace showed any detected bacteria and, at 20 cfu, was below the standard.

Interestingly, the highest values at all of the beaches occurred when there was no antecedent rainfall for the previous week at the Wall Township station. For the July 17, 2006 sampling, elevated enterococci bacteria levels were noted at the York and Brown Avenue beaches, just north of Wreck Pond as well as the Terrace and Beacon Boulevard locations south of the Pond. The highest reading was at Beacon Blvd. at 12,400 cfu. Further south in Sea Girt the Philadelphia Ave. beach testing showed no detection and the Newark Ave was 20 cfu. Beaches to the North of York Ave also were not impacted.

MCHD discusses this event in their paper titled “Changes in Water Quality near the Extended Wreck Pond Outfall”. MCHD notes that this was an “unusual event”. The report speculates that the rapid warming of water temperatures between July 10 and 17 may have created a “downwelling” condition, in which surface water is pushed downward in the Ocean. This can interact with a secondary ocean current that flows to the South, driven by the Hudson-Raritan plume. This plume is a lighter, warmer plume of water that comes into the Ocean above Sandy Hook and flows south, and has been associated with events that have polluted the shores of Monmouth County. The MCHD notes that the relocated outfall extends 300 feet and may be into or near this southerly current driven by the Hudson-Raritan Plume. Thus, this event may not be related to water quality within Wreck Pond. By the next day all readings were at or below the detection limit of 10 cfu. Further research is required to test this theory.

The other time an exceedance occurred in the absence of rainfall was in September at the York Avenue beach. The MCHD report notes that there was very rough surf at this time that may have contributed to this transitory exceedance.

MCHD notes that overall exceedances were reduced in 2006 after extension of the outfall pipe, as compared to 2004. MCHD compared these two years as rainfall was similar. The report notes that detections and exceedances increased at bathing beaches south of the extended outfall. However, it must be noted that these results are based on the Monday morning sampling only, and thus the specific data for the two years likely represents different antecedent rainfall events.

10.4 NJDEP

The NJDEP conducted studies of Wreck Pond prior to extending the outfall and doing some initial dredging. During the summers of 2007 and 2008, NJDEP conducted monitoring under storm conditions in Wreck Pond and at stormwater outfalls. Additional monitoring is expected in the summer of 2008. Preliminary results suggest that certain stormwater outfall structures may be impacting beach bacteria levels.

10.5 Overall Evaluation of Pollutant Sources

The Wreck Pond Brook watershed has been the subject of two modeling studies and several water quality monitoring programs including the County weekly sampling and the sampling done for the Borough of Spring Lake's Wreck Pond Environmental Study. In addition, Monmouth University and Rutgers Cooperative Extension collected water quality data as part of their studies. Further, MCHD continues to conduct summer bacteria monitoring at the beaches and NJDEP is conducting bacteria studies. The results of these studies were used to evaluate possible pollutant sources.

The watershed contains a number of sources that may contribute to the loading of bacteria, nutrients and other pollutants. However, some sources are not known to be present, including:

- **Point Sources other than Stormwater:** There are no known point source discharges in the watershed.

- **Septic Systems:** There are no known septic systems within the watershed, the area is entirely sewered. It is possible that unknown historic septic systems are present.

The primary source of nonpoint sources of stormwater pollution are the land surfaces within the watershed. The various land uses generate water pollutants. Another potential non-point source is failing sewer infrastructure.

10.5.1 Assessment of Non-Point Sources

The watershed contains mixed land uses. The water quality modeling study results, described in Section 8, indicate that the Wreck Pond Brook produces most of the actual pollutant loads. As the land uses are mixed, it is not possible to use the model results to directly determine the contribution of each land use.

The modeling results, the results of the agricultural and recreational land surveys and literature information are used to assess the contribution of various land uses.

10.5.2 Land Uses

Agricultural Lands: The Rutgers survey of agricultural land, discussed in Section 5, determined that agricultural lands are not having a "significant" impact on the "overall health of the Wreck Pond Brook watershed". This finding is based on water quality data collected indicating that standards are rarely exceeded during routine sampling for pH, nutrients and other parameters using a meter. While agricultural lands are not causing contravention of water quality standards, runoff from these lands is likely adding to the overall load of bacteria, nutrients and sediment in Wreck Pond.

The Rutgers survey found that farmers reported fertilizer use within the range that would be taken up by the crops and thus excessive nutrient loading from this source was not expected. However, manure management was of concern at a few farms. These farms generally had few farm animals and thus are not likely a major source of bacteria.

Agricultural practices can impact sediment, nutrient and bacteria loading.

Park and Recreational Land: The Rutgers survey of park and recreational land also found these lands did not appear to be having a major impact on water quality.

Urban/Suburban Land: Residential land uses are dominant in the lower watershed. Construction activity is a source of sediment. Landscaping also can be a source of sediment and nutrients. Human use and pets are a source of bacteria.

10.5.3 Streams

A stream assessment and survey was conducted by the Freehold Soils Conservation District, as discussed in Section 4. The results reveal that certain stream segments are contributing sediment and possibly associated pollutants.

10.5.4 Pond Processes

The ponds in the upper watershed appear to act as retention structures that slow the flow of water and allow settling of sediment and associated pollutants. Under certain conditions, the sediments in these ponds may become re-suspended in high flows and be transported downstream.

The sediments and organic matter in the bottom of the upstream ponds and of Wreck Pond were found to contain bacteria and nutrients. Under certain environmental conditions, these pollutants may be released from the sediments back into the water column. The studies conducted thus far have not quantified these processes.

10.5.5 Water Fowl and Wildlife

Wreck Pond, Black Creek and the watershed ponds are home to a variety of water fowl including mute swans, geese and ducks. These water fowl produce fecal matter that adds bacteria directly to the ponds and is deposited along the shorelines. Other wildlife including deer may produce fecal matter that is carried to the waterways. Deer and other wildlife also use the stream corridors and the watershed in general. They impact stream and area vegetation by over-grazing sometimes stripping areas of plants. This can affect erosion. Wildlife may also be a source of bacteria.

10.5.6 Natural Conditions

The low pH in the western portions of the streams may well be due to the naturally acidic soils found in the Pineland type woodlands and soils.

10.5.7 Pollutant Source Summary

For the Wreck Pond watershed, the mixed land uses are a major source of all pollutants of interest. The results of the watershed modeling, agricultural survey, stream assessments, and bacteria source tracking did not identify one source of highest importance. For each pollutant group, identified sources are noted below.

Nutrients: Developed land uses, agricultural lands, fertilizer application

Bacteria: Developed land use, manure management in farmlands, water fowl, possible leaking infrastructure, wildlife, pets, release from Pond sediments

Sediment: Developed lands, agricultural land, un-vegetated uplands, construction sites, stream erosion, re-suspension of pond sediments

The analyses in this study did not find a particular source that was the most important component of sources for each pollutant. Thus, the sources are not ranked

Book 2 of the RSWMP provides further data and analysis of pollutant sources and the overall management plan for the watershed.