APPENDICES

Appendix A

Cornell Cooperative Extension Watershed Plan

Lake Montauk Watershed Plan
Cornell Cooperative Extension-Marine

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Lake Montauk Watershed Plan.

A cooperative effort between the Town of East Hampton's Division of Natural Resources and Cornell Cooperative Extension of Suffolk County's Marine Program looked at stream inputs to Lake Montauk during the summer of 2008. The purpose was to observe which streams may be contributing the most runoff to the lake during a stormwater event. Sites were visited during both dry and wet conditions, and assessed based on historical and empirical data. A total of 15 streams, or stations, were then picked for further evaluation for the purpose of this study.

Sites were distributed so as to cover the most of the lake. Stations for the study included sites on the eastern, southern and western portions of the lake.

For the purpose of this study, each station had several components.

First, each station was monitored for flow four times a year for two years. Second, each station was tested for fecal coliform using membrane filtration for a total of 8 samples (4 times during a wet event, and 4 times for a dry event).

And lastly, each station had one sample from the fecal coliform study to be also used for a bacterial source tracking study. Cornell Cooperative Extension has developed an E. coli based fecal coliform DNA library. Water samples collected and chosen for the DNA study would be compared to the animal source library in an effort to determine the source of the bacteria within the stormwater flow.

Additionally, as part of the watershed study, Cornell Cooperative Extension was contracted to conduct the following projects in and around the lake:

1. Map and conduct survey of eelgrass beds within the lake.
2. TR-20 modeling of the lake to determine stormwater loadings into the lake.
3. Sediment and infauna analysis.
4. Research alternatives to on site sanitary systems.

Preliminary Report on the Eelgrass Monitoring Effort in Lake Montauk

The following information represents an informal synthesis of the observations and data collected on 23 September, 2008. The data was analyzed using SigmaStat and the graphs were generated in SigmaPlot. Data regarding sediment grain size and organic content is currently being analyzed and will be submitted at a later date.

Eelgrass Monitoring Stations

The eelgrass monitoring stations were chosen at random at the two eelgrass sites, but they were always positioned in eelgrass. The stations were marked with a non-DGPS with an accuracy of ± 9 foot circular error. The GPS coordinates of the nine (9) stations within Lake Montauk are:

Station		
LM1	N 41.06857	W 71.92794
LM2	N 41.06878	W 71.92715
LM3	N 41.06943	W 71.92664
LM4	N 41.07009	W 71.92645
CG1	N 41.07436	W 71.93350
CG2	N 41.07435	W 71.93311
CG3	N 41.07405	W 71.93272
CG4	N 41.07384	W 71.93238
CG5	N 41.07373	W 71.93199

Quadrat Sampling of Eelgrass Shoot Density and Percent Macroalgae Cover

Eelgrass shoot density and percent macroalgae cover were sample at random within a ten (10) meter radius of each station center point (as marked with GPS and indicated with temporary marker buoy). A total of ten, $0.10m^2$ PVC quadrats were sampled within the 10m radius of the center point. Quadrats were haphazardly tossed by divers within the designated areas then sampled for percent macroalgae cover and a raw eelgrass shoot density. Macroalgae was identified to at least the genus level (and to species when possible) *in-situ*.

Descriptive Statistics: Wednesday, September 24, 2008, 13:35:26

Data source: Lake Montauk-2008 Eelgrass Monitoring-Lake Montauk Site-Eelgrass Shoot Density

Column	Size	Missing	Mean	Std Dev	Std. Error	C.I. of Mean
LM1-ShtDen	10	0	154.00	94.89	30.01	67.88
LM2-ShtDen	9	0	56.67	54.08	18.03	41.57
LM3-ShtDen	11	0	111.82	85.30	25.72	57.31
LM4-ShtDen	10	0	23.00	30.93	9.78	22.13
LM-Comb. ShtDen	40	0	79.08	87.33	13.81	27.93

Column	Range	Max	Min	Median	25%	75%
LM1-ShtDen	290.00	310.00	20.00	130.00	80.00	190.00
LM2-ShtDen	180.00	190.00	10.00	40.00	27.50	65.00
LM3-ShtDen	270.00	280.00	10.00	90.00	60.00	170.00
LM4-ShtDen	100.00	100.00	0.00	15.00	0.00	30.00
LM-Comb. ShtDen	310.00	310.00	0.00	45.00	10.00	125.00

Descriptive Statistics: Wednesday, September 24, 2008, 13:35:51

Data source: Lake Montauk-2008 Eelgrass Monitoring-Lake Montauk Site-%Macroalgae

Column	Size	Missing	Mean	Std Dev	Std. Error	C.I. of Mean
LM1-%Algae	10	0	1.80	2.25	0.71	1.61
LM2-%Algae	9	0	18.11	16.53	5.51	12.71
LM3-%Algae	11	0	69.55	38.17	11.51	25.65
LM4-%Algae	10	0	42.50	28.89	9.14	20.67
LM-Comb. %Algae	40	0	34.27	36.37	5.75	11.63

Column	Range	Max	Min	Median	25%	75%
LM1-%Algae	5.00	5.00	0.00	1.00	0.00	5.00
LM2-%Algae	50.00	50.00	0.00	10.00	7.50	27.00
LM3-%Algae	100.00	100.00	0.00	95.00	32.50	100.00
LM4-%Algae	80.00	90.00	10.00	35.00	20.00	75.00
LM-Comb. %Algae	100.00	100.00	0.00	25.00	3.00	62.50

Descriptive Statistics: Wednesday, September 24, 2008, 13:36:13

Data source: Lake Montauk-2008 Eelgrass Monitoring-Coast Guard Site-Eelgrass Shoot Density

Column	Size	Missing	Mean	Std Dev	Std. Error	C.I. of Mean
CG1-ShtDen	10	0	138.00	109.73	34.70	78.49
CG2-ShtDen	10	0	145.00	126.16	39.90	90.25
CG3-ShtDen	10	0	61.00	27.26	8.62	19.50
CG4-ShtDen	10	0	82.00	50.95	16.11	36.44
CG5-ShtDen	11	0	147.27	92.53	27.90	62.16
CG-Comb. ShtDen	51	0	115.29	93.07	13.03	26.18

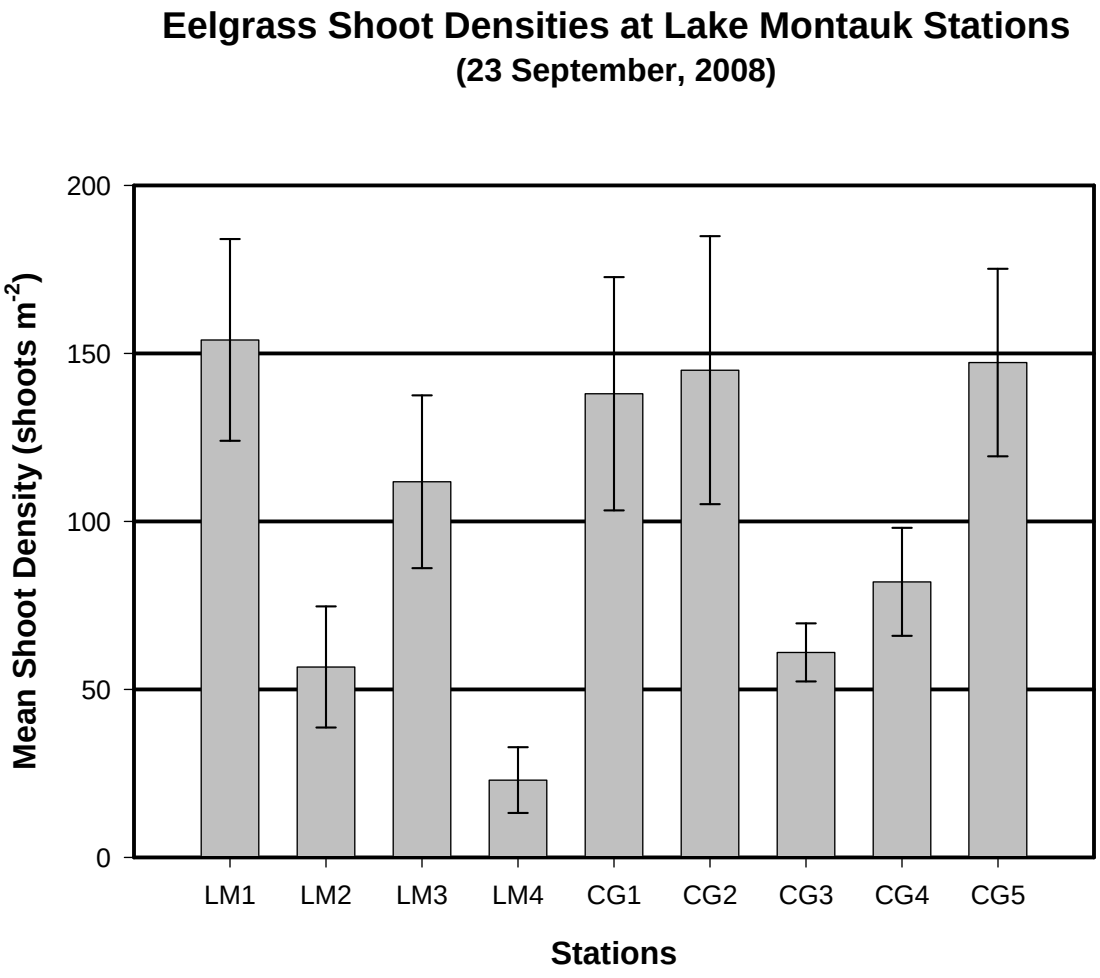
Column	Range	Max	Min	Median	25%	75%
CG1-ShtDen	410.00	420.00	10.00	115.00	80.00	150.00
CG2-ShtDen	380.00	380.00	0.00	135.00	50.00	240.00
CG3-ShtDen	100.00	130.00	30.00	55.00	50.00	70.00
CG4-ShtDen	140.00	160.00	20.00	70.00	40.00	120.00
CG5-ShtDen	250.00	270.00	20.00	170.00	60.00	225.00
CG-Comb. ShtDen	420.00	420.00	0.00	90.00	50.00	167.50

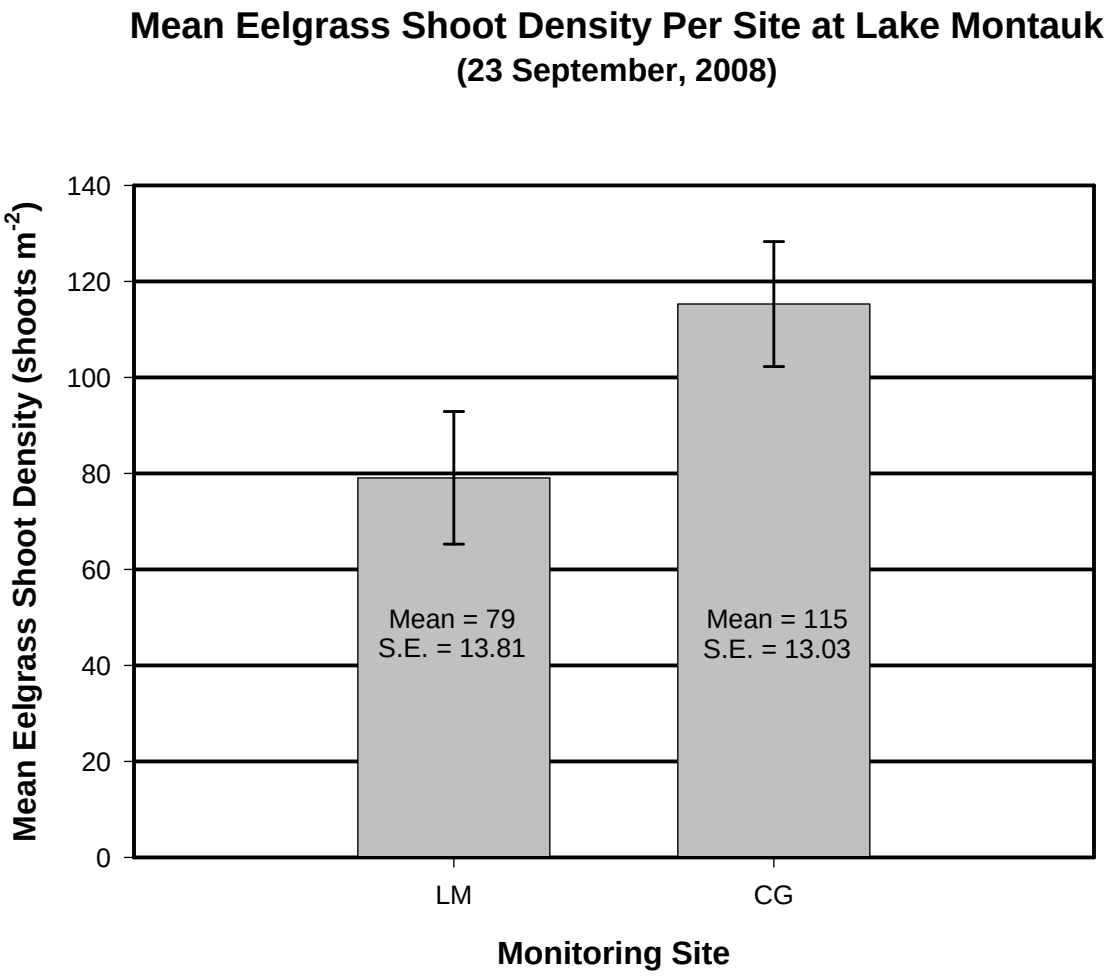
Descriptive Statistics: Wednesday, September 24, 2008, 13:36:47

Data source: Lake Montauk-2008 Eelgrass Monitoring-Coast Guard Site-%Macroalgae

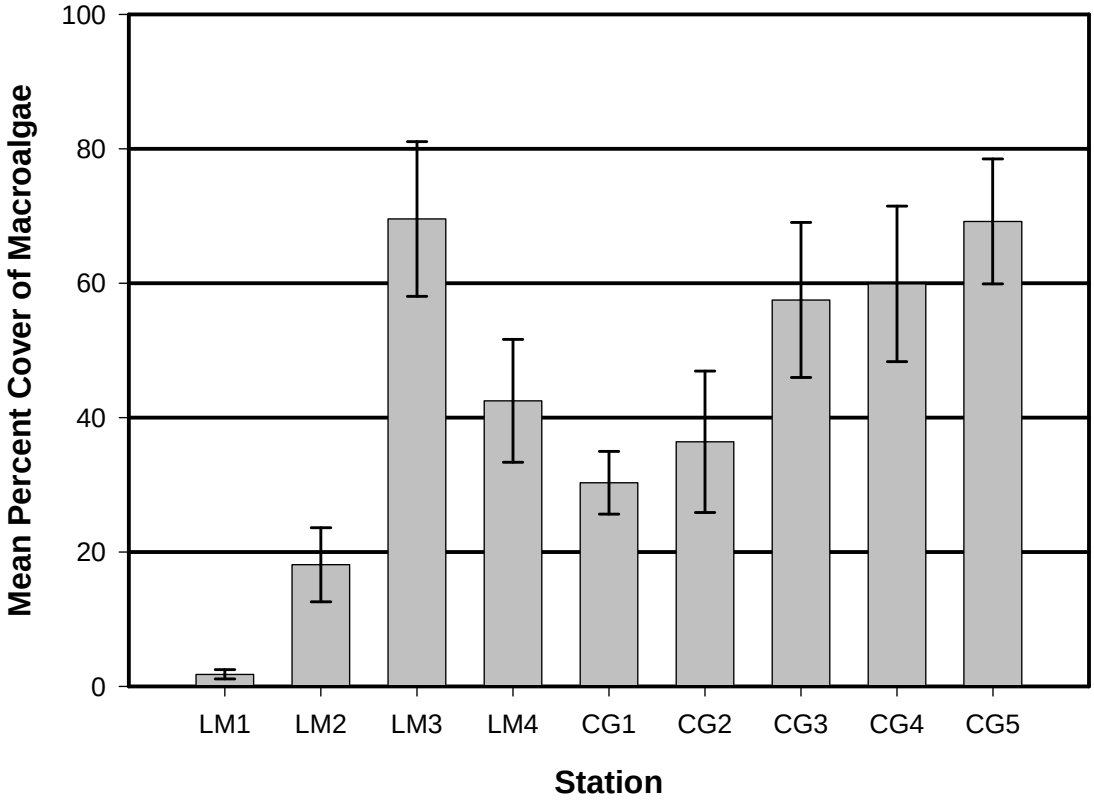
Column	Size	Missing	Mean	Std Dev	Std. Error	C.I. of Mean
CG1-%Algae	10	0	30.30	14.75	4.66	10.55
CG2-%Algae	10	0	36.40	33.32	10.54	23.83
CG3-%Algae	10	0	57.50	36.54	11.55	26.14
CG4-%Algae	10	0	59.90	36.62	11.58	26.20
CG5-%Algae	11	0	69.18	30.88	9.31	20.74
CG-Comb. %Algae	51	0	51.02	33.72	4.72	9.48

Column	Range	Max	Min	Median	25%	75%
CG1-%Algae	40.00	50.00	10.00	29.00	20.00	40.00
CG2-%Algae	99.00	100.00	1.00	26.50	10.00	50.00
CG3-%Algae	100.00	100.00	0.00	45.00	33.00	99.00
CG4-%Algae	99.00	99.00	0.00	65.00	30.00	95.00
CG5-%Algae	80.00	100.00	20.00	75.00	50.00	100.00
CG-Comb. %Algae	100.00	100.00	0.00	50.00	21.25	87.50

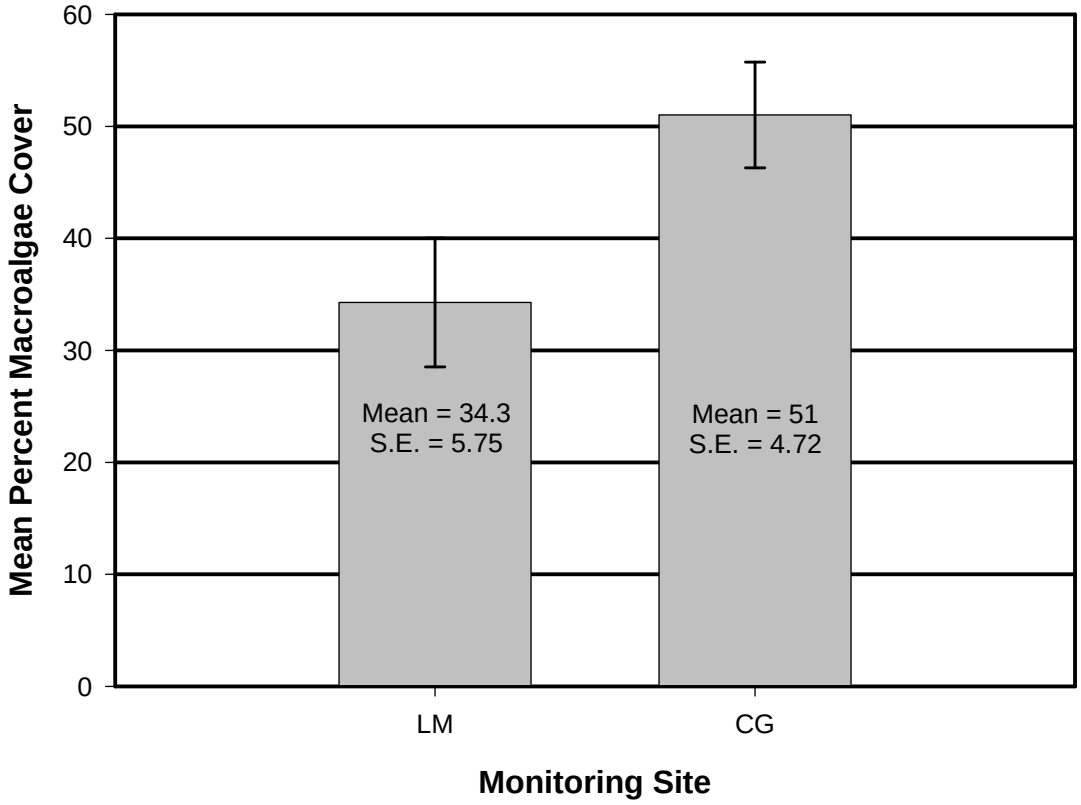

Eelgrass Shoot Densities at Lake Montauk Stations
(23 September, 2008)
Mean Shoot Density (shoots m-2)
200
150
100
50
0
LM1
LM2
LM3
LM4
CG1
CG2
CG3
CG4
CG5
Stations


Mean Eelgrass Shoot Density Per Site at Lake Montauk
(23 September, 2008)
Mean Eelgrass Shoot Density (shoots m-2)
140
120
100
80
60
40
20
0
Mean = 79
S.E. = 13.81
Mean = 115
S.E. = 13.03
LM
CG
Monitoring Site

Mean Percent Macroalgae Cover at Lake Montauk Stations
(23 September, 2008)



Mean Percent Macroalgae Cover Per Monitoring Site at Lake Montauk
(23 September, 2008)



Macroalgae Species List

Species	Site Observed	Notes
Codium fragile	Both	Non-indigenous, invasive
Ulva intestinalis	Both	Epiphytic and non-epiphytic
Ulva flexuosa	LM	
Ulva lactuca	Both	
Laminaria saccharina	Both	Drift material
Sargassum filipendula	CG	
Agardhiella subulata	Both	Drift and attached
Champia parvula	Both	Epiphytic and non-epiphytic
Chondrus crispus	LM	Drift material
Dasya baillouviana	Both	Drift material
Grateloupia turuturu	Both	Non-indigenous, invasive; Drift material
Grinnellia americana	Both	
Polysiphonia species	Both	Epiphytic
Spermothamnion repens	Both	Epiphytic and Drift material

Tr-20 Subwatershed

The TR-20 model is the most widely used application for simulating rainfall events and calculating runoff during storms. Direct runoff is computed based on a number of variables including land use, topography, and soil types. TR-20 is a valuable tool used in analyzing current watershed conditions as well as assessing the impact of proposed changes within the watershed. The model is typically run at the watershed level, as was done in the current study for Lake Montauk.

TR-20 can simulate multiple storm events within one model run. This study looked at the impacts of 1, 2, 10, and 100 year rainfall events. In order to assess the differences between seasons, the model was run in average, dry and wet antecedent soil conditions (e.g. spring runoff would be expected to be higher since the soil is likely already wet prior to a given rain event). Historically TR-20 calculations were done by hand which was extremely time consuming. To simplify the calculations, the Natural Resources Conservation Service (NRCS) developed a windows-compatible computer program called WinTR-20. This free software package was utilized for all runoff calculations.

It should be noted that a limitation of the current study is that stormwater conveyance systems were not factored into the model. Since stormwater retention structures were excluded from the study, it's likely that calculations over-estimate the amount of runoff that a particular storm generates. While including stormwater structures would enhance the accuracy of the model, it was beyond the scope of the study.

Methods

While it is easiest to perform the TR-20 analysis on the entire Lake Montauk watershed, it was deemed to be more valuable to first divide the area up into discrete subwatersheds. This allows for the comparison between areas surrounding Lake Montauk, and allows us to determine which areas contribute the greatest amount of runoff. In order to remove the variability associated with delineating subwatersheds by hand, various extensions in ArcGIS were utilized to delineate the subwatersheds in a more repeatable manner.

In order to delineate subwatersheds, an accurate topographic map is required. In 2006 an aerial LiDAR survey was conducted and resulted in the production detailed digital topographic maps. While it is beyond the scope of this document to detail the multiple steps required to create subwatersheds in ArcGIS the results can be seen in the following figures. The initial ArcGIS delineating steps produced a map of catchment areas (see Figure 1), which can be characterized as distinct areas where runoff is being conveyed to the same location. In order to determine which catchment areas lead to Lake Montauk, ArcGIS created a map of flow or drainage lines as can be seen in Figure 2. The drainage lines allow for the easy identification of catchment areas which contribute to Lake Montauk. For the purpose of this study, a subwatershed was considered to be a collection of catchment areas which share a common drainage into Lake Montauk. In some cases, some small subwatersheds were joined together to simplify the analysis. So while there is a degree of subjectivity in defining subwatersheds, the catchment areas which contribute to Lake Montauk were quantitatively calculated. Figure 3 represents the delineated subwatersheds of the Lake Montauk watershed. There are a total of 14 subwatersheds ranging in size from 41.6 acres to 518.4 acres. The total watershed was calculated to be 2,728.32 acres.

Figure 1 – Lake Montauk and surrounding catchment areas.

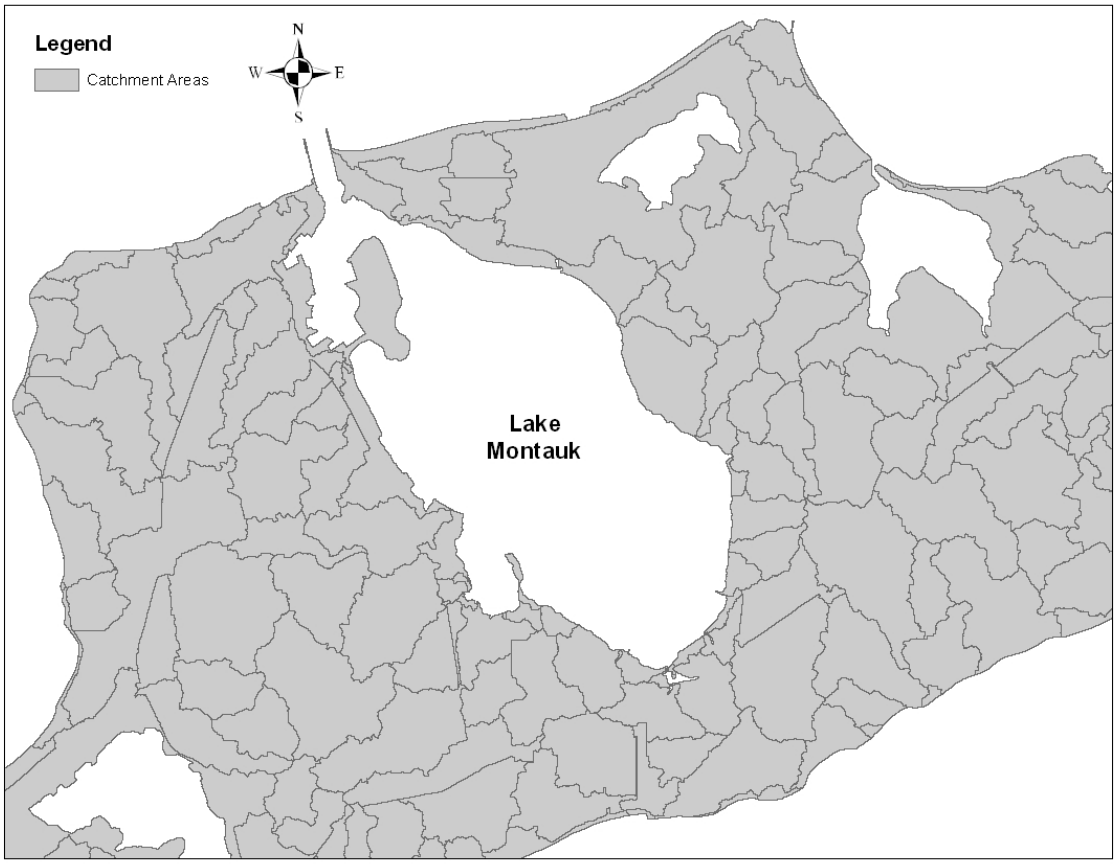


Figure 2 – Drainage lines of Lake Montauk and surrounding area catchments.

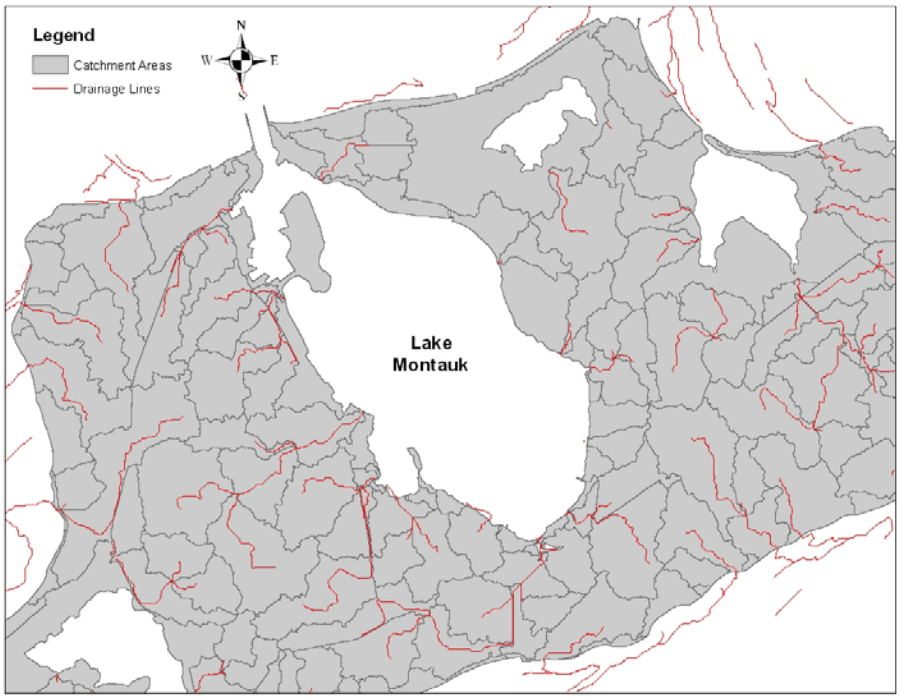
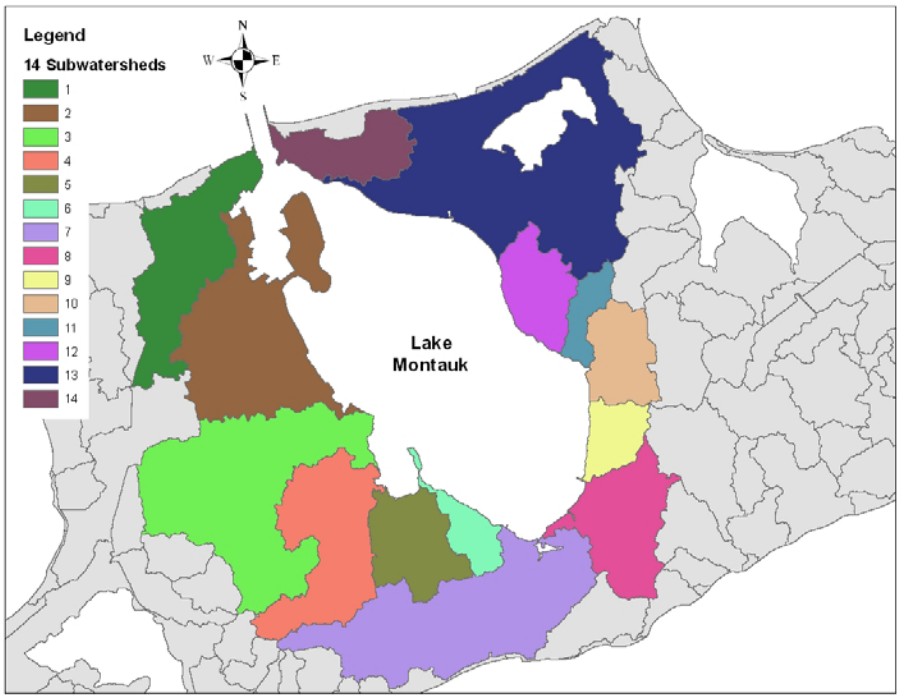


Figure 3 – 14 Subwatersheds of Lake Montauk



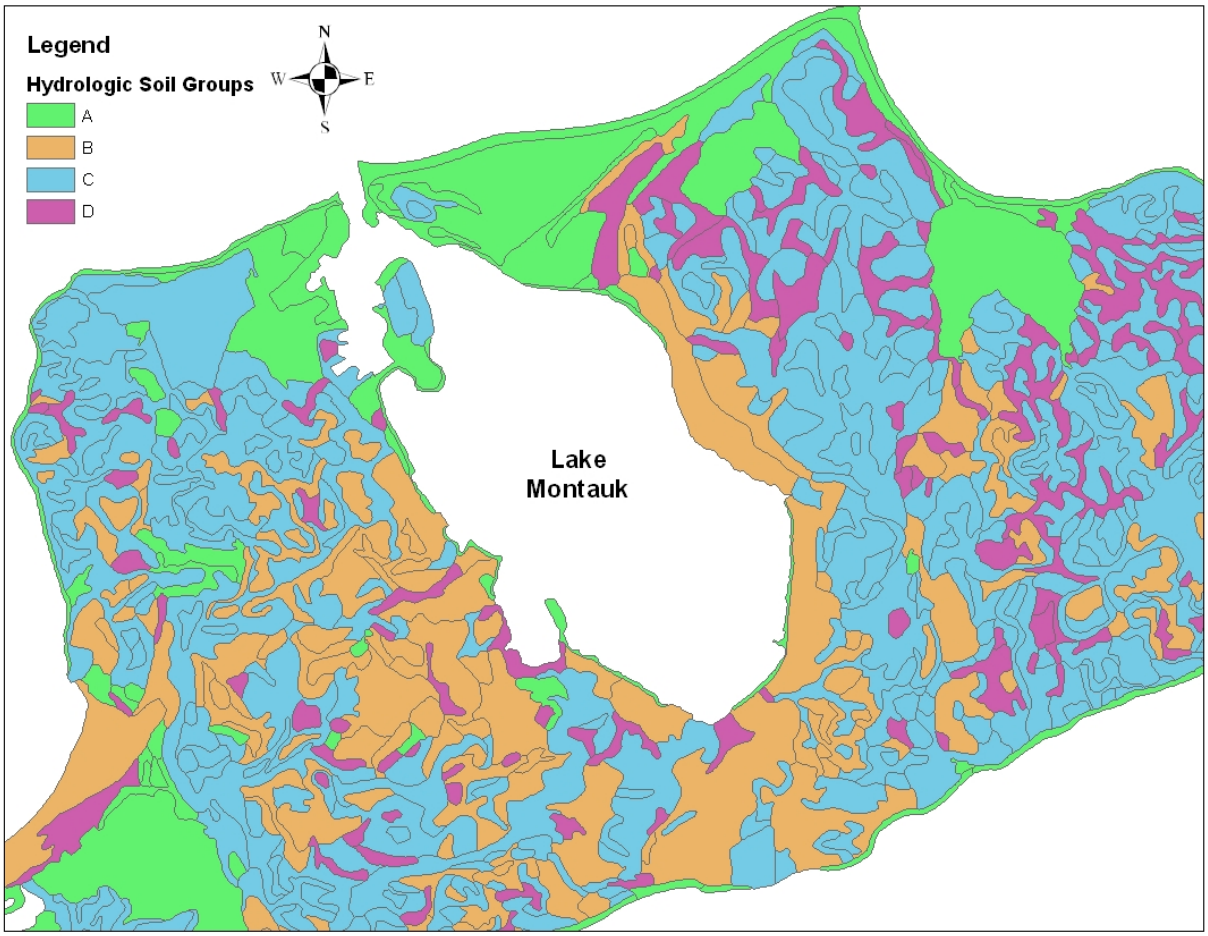
TR-20 Model Input Data

Hydrologic Soil Groups

The first variable that significantly impacts runoff potential is the soil type. Soils are classified by the Natural Resource Conservation Service into four hydrologic soil groups based on the

runoff potential. The 4 groups are A, B, C and D. Group A soils are predominantly sand or sandy loam and have the lowest runoff potential while group D soils are clay based and have the greatest runoff potential. Figure 4 represents the soil types surrounding Lake Montauk. The ArcGIS layer was produced by and obtained from the United States Department of Agriculture (USDA).

Figure 4 – Hydrologic soil types from the USDA.



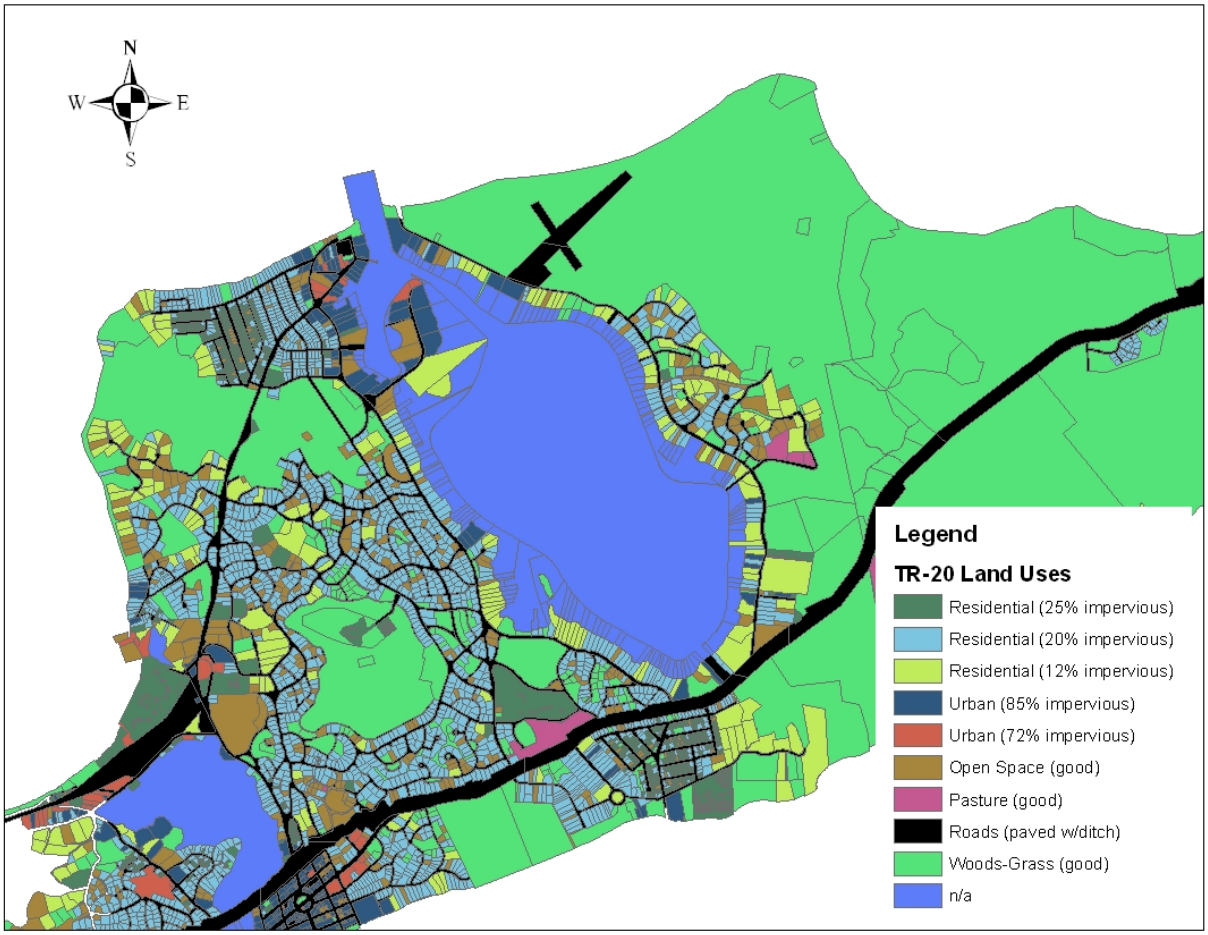
Land Use

A second input which greatly impacts runoff potential is the existing land use. Impervious surfaces like roadways allow very little water to infiltrate into the ground, and the amount of time it takes for water to run off into surface waters is significantly decreased. The Town of East Hampton provided CCE with updated land use maps which were subsequently modified to make them compatible with TR-20. This entailed filling in missing data (e.g. some Town roads) and reclassifying official East Hampton land use designations with the appropriate TR-20 land use condition (see Table 1). Figure 5 demonstrates the land uses present in the Lake Montauk watershed.

Table 1 – East Hampton land use designations and equivalent TR-20 conditions.

East Hampton Designation	**East Hampton Description**	**TR-20 Condition**
1	Low Density Residential	Residential (12% impervious)
2	Med Density Residential	Residential (20% impervious)
3	High Density Residential	Residential (25% impervious)
4	Commercial	Urban (85% impervious)
5	Industrial	Urban (72% impervious)
6	Institutional	Urban (72% impervious)
7	Recreational Open Space	Woods-Grass (good)
8	Agriculture	Pasture (good)
9	Vacant	Open Space (good)
10	Transportation	Roads (Paved w/ditch)
11	Utilities	Residential (25% impervious)
12	Waste Handling Mngmt.	Open Space (fair)
13	Surface Water	n/a
14	Cemetary	Open Space (good)

Figure 5 – Lake Montauk TR-20 land use conditions.



Topography

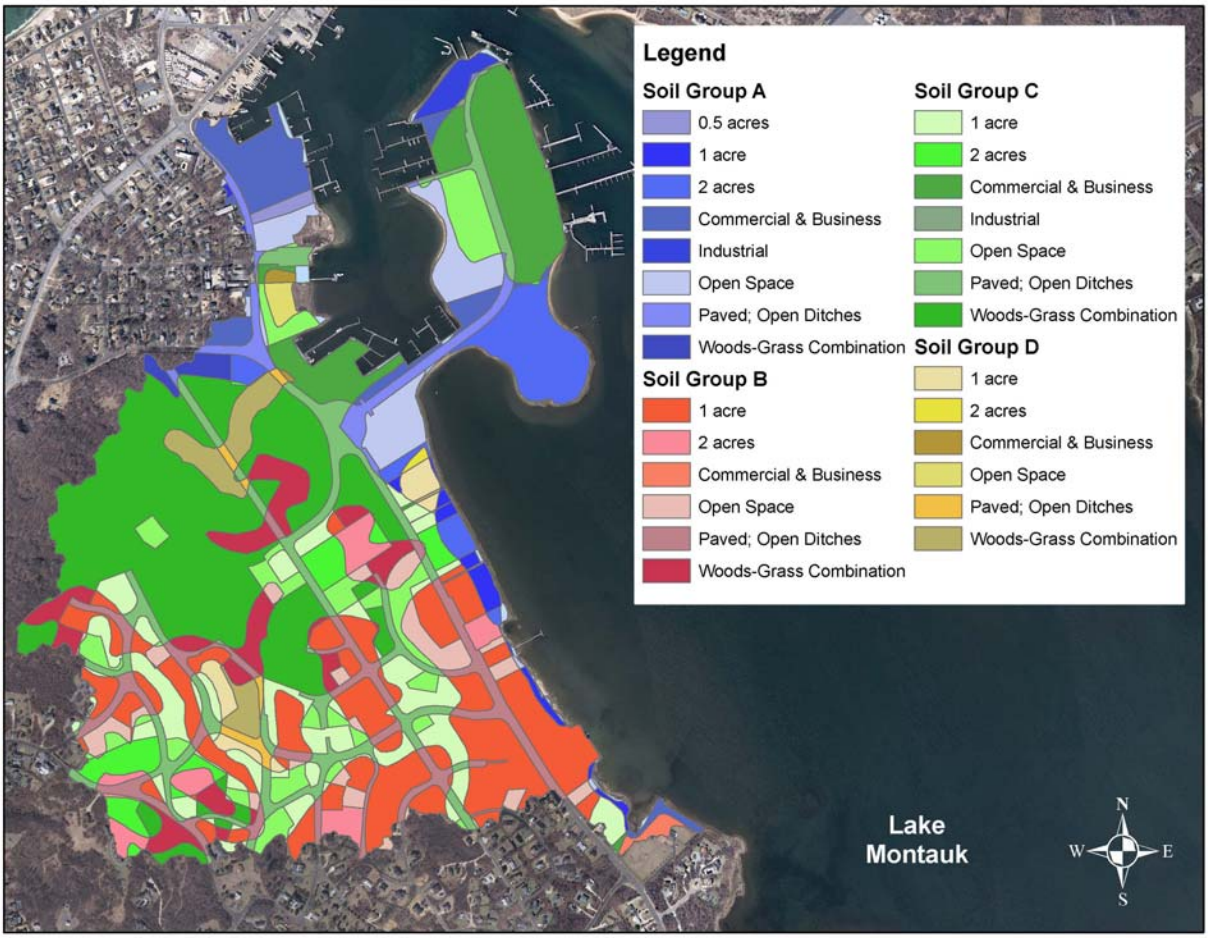
The final variable which is critical for calculating runoff loading is topography. In addition to using topography to delineate the watersheds, the TR-20 computations require that the average slopes of the drainage lines be determined. Since the LiDAR data is the most accurate topographic data available, it was also used for calculating the average slopes.

Results

Subwatershed, hydrological soil group, land use and topography information was entered into WinTR-20 to calculate stormwater runoff. Effectively, a separate analysis was conducted for each subwatershed. The TR-20 analysis functions by assigning a "curve number" to all areas within a subwatershed. The value of the curve number is dependent upon the land use and the hydrologic soil group. The higher the curve number, the more infiltration occurs at that particular area. To start, the subwatershed is broken down into the different land uses. So for subwatershed 2 for example, the subwatershed is first broken down into 8 different land use areas. But these land uses occur over different hydrological soil groups and the goal is to

identify areas with unique combinations of land uses and hydrological soil groups. So the next step is to further break down the land use GIS layer.

Figure 6 – Subwatershed 2 hydrologic soil groups and land use.



This is accomplished by cutting the land use layer with the hydrologic soil group layer. In this case, we end up with 27 unique combinations of land use and hydrological soil groups, as can be seen in Figure 6. The area is determined for each unique combination and the WinTR-20 software generates the curve number. The averaging of all curve numbers weighted by percent area allows WinTR-20 to calculate runoff. The above process was repeated for each subwatershed.

In order to assess the differences between seasons, the model was run in average, dry and wet antecedent soil conditions (e.g. spring runoff would be expected to be higher since the soil is likely already wet prior to a given rain event). Therefore, there will be three complete sets of results. The first assumes normal or average soil conditions, the second assumes dry soil conditions antecedent to various rainfall events, and the third set of results assumes wet soil conditions. Runoff is expected to be significantly higher under antecedent wet soil conditions since there will be a reduced capacity for infiltration, especially in hydrological soil types which are more clay based.

The TR-20 model was run for 1, 2, 10 and 100 year rainfall events. As indicated in the New York State Stormwater Management Design Manual, these correspond to 2.5, 3.5, 5.0 and 7.5 inches of rain within a 24 hour period respectively. The above rainfall events were categorized as Type III rainfalls, which are typical for the East Coast. Type III rainfalls assume a normal type distribution of rain over the 24 hours. The rain starts at Hour 0, increases in strength and peaks at Hour 12, and gradually abates until Hour 24 where it ceases. The results of this study were split up into the following data representations:

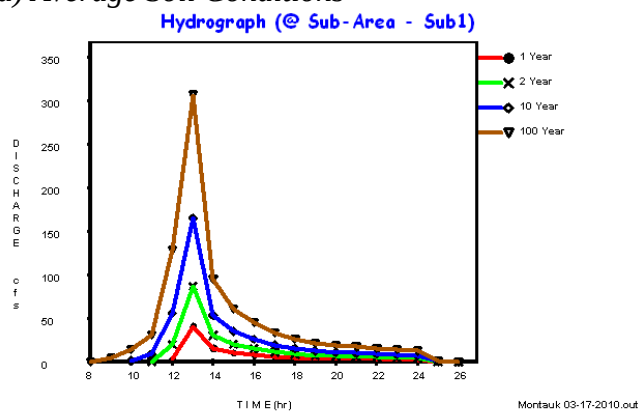
a) Hydrographs – a hydrograph is a graph showing changes in subwatershed discharge over time. The crest of a hydrograph therefore represents the greatest flow rate. Each hydrograph showed curves for each of the rainfall events. For each subwatershed 3 hydrographs were generated: one for average, dry and wet antecedent soil conditions.

b) Runoff Tables – the area under curve of a hydrograph represents the total discharge for the subwatershed in a given rain event. These values were calculated so the impacts of rain event (inches of rain), antecedent soil wetness, and subwatershed could be compared.

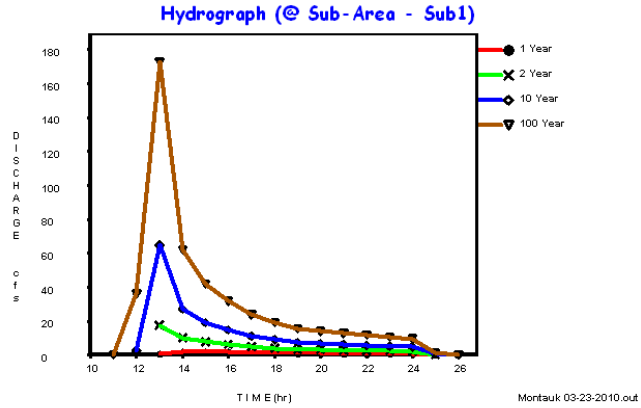
<u>Hydrographs</u>

Figure 7 – Subwatershed 1 Hydrographs

a) Average Soil Conditions



b) Dry Soil Conditions



c) Wet Soil Conditions

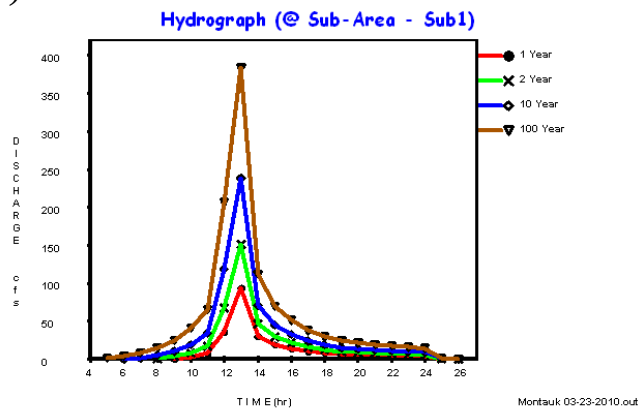
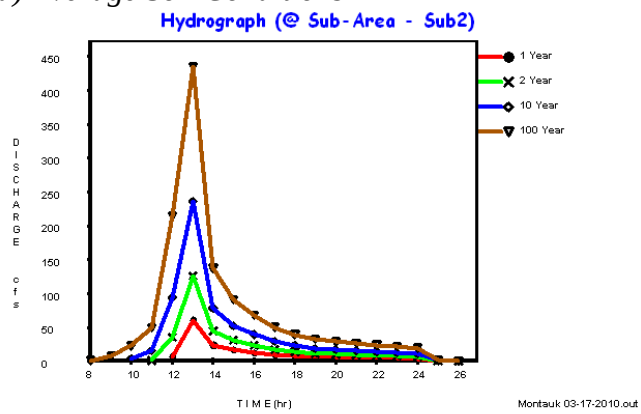
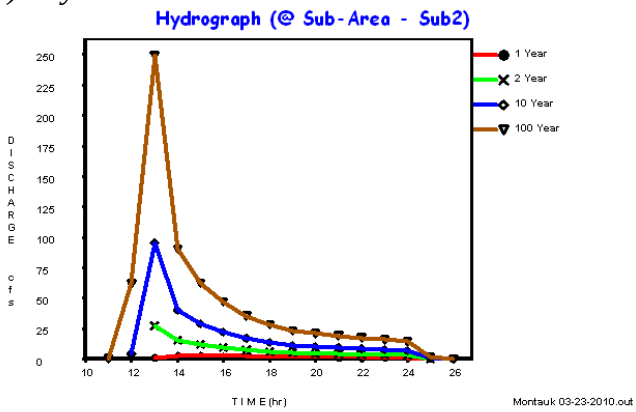


Figure 8 – Subwatershed 2 Hydrographs

a) Average Soil Conditions



b) Dry Soil Conditions



c) Wet Soil Conditions

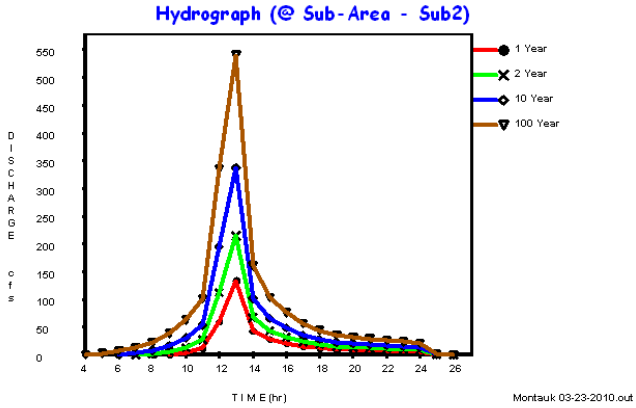
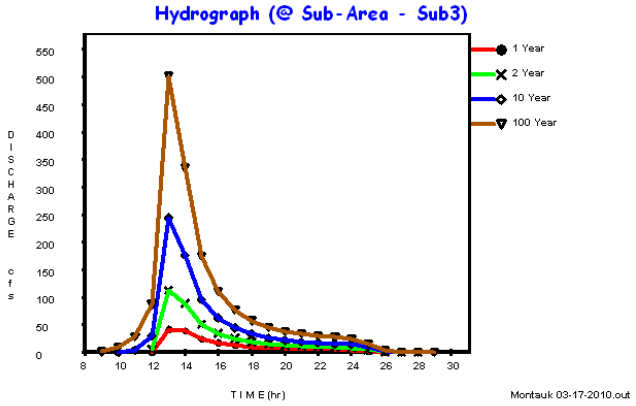
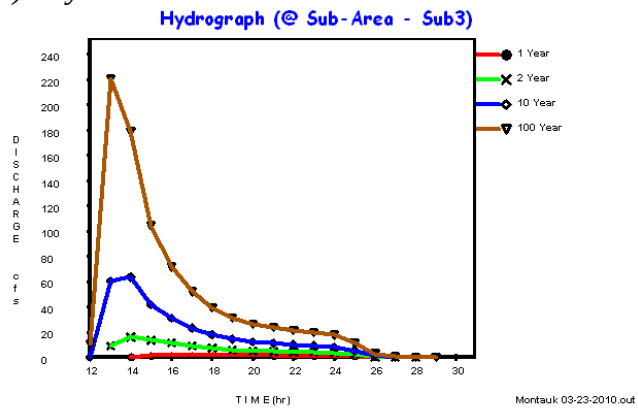


Figure 9 – Subwatershed 3 Hydrographs

a) Average Soil Conditions



b) Dry Soil Conditions



c) Wet Soil Conditions

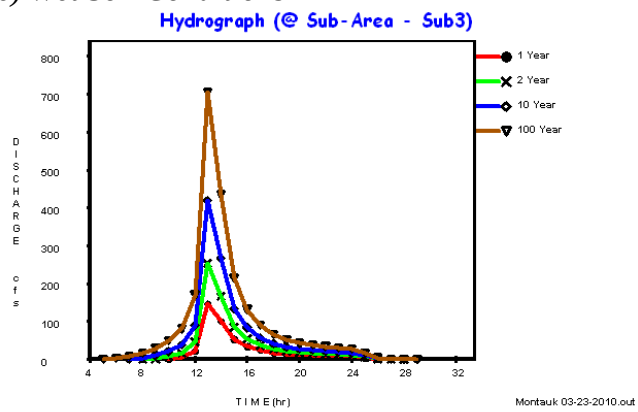
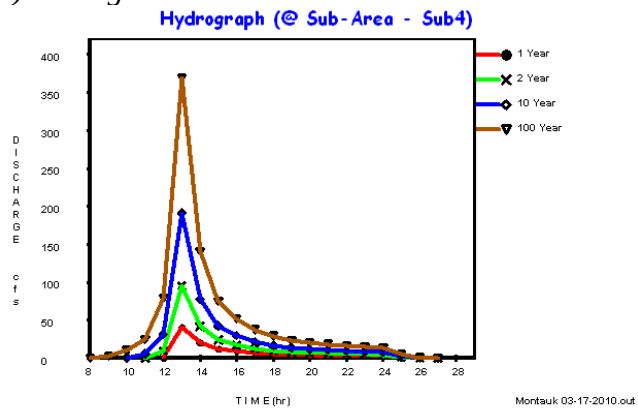
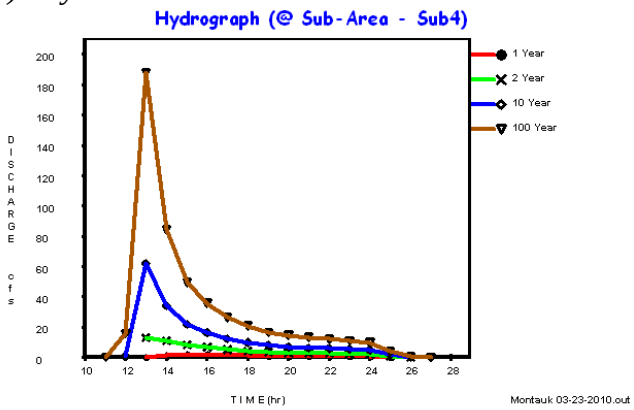


Figure 10 – Subwatershed 4 Hydrographs

a) Average Soil Conditions



b) Dry Soil Conditions



c) Wet Soil Conditions

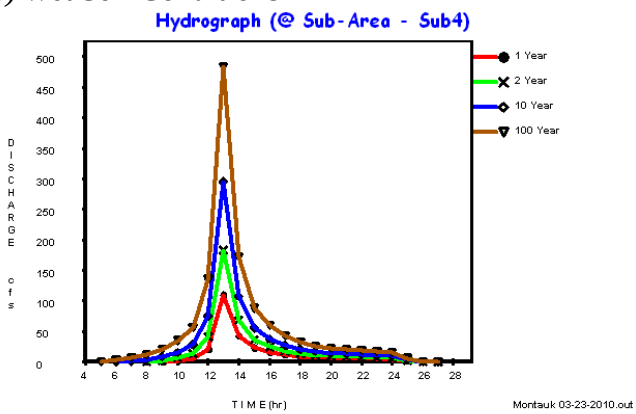
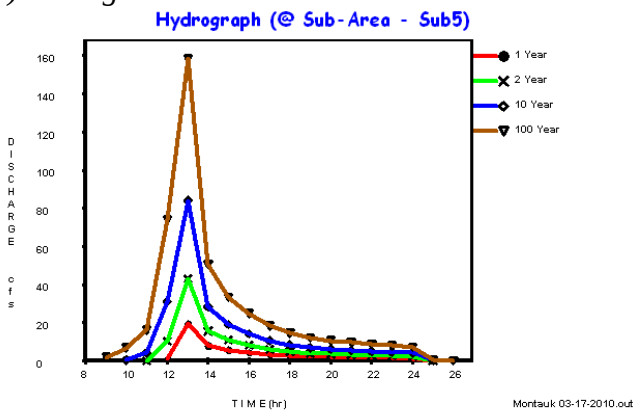
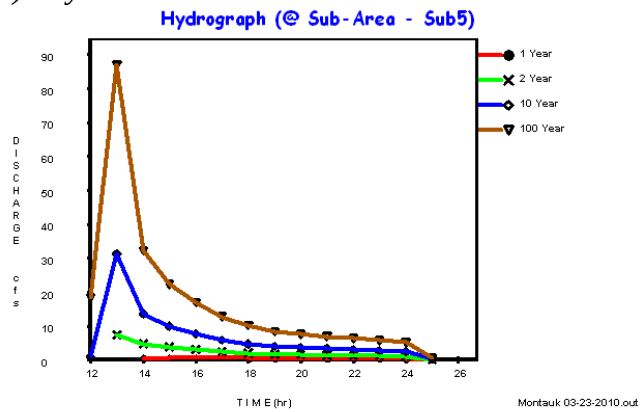


Figure 11 – Subwatershed 5 Hydrographs

a) Average Soil Conditions



b) Dry Soil Conditions



c) Wet Soil Conditions

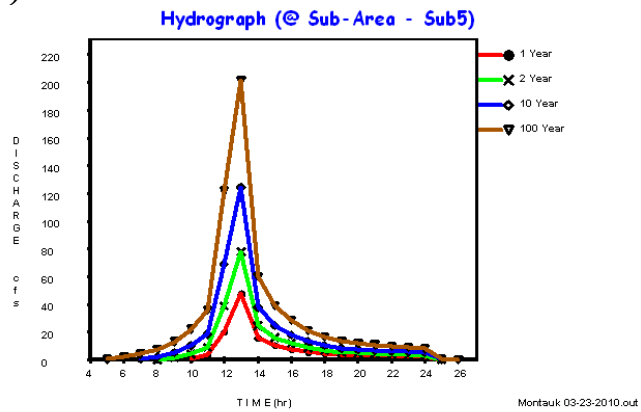
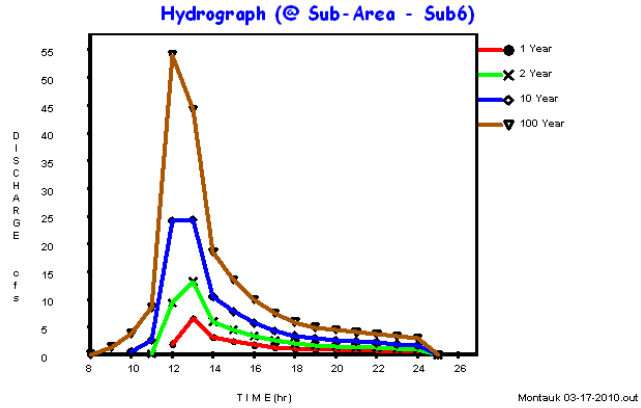
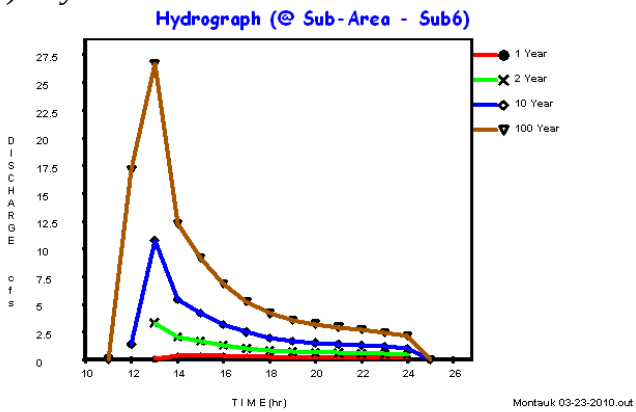


Figure 12 – Subwatershed 6 Hydrographs

a) Average Soil Conditions



b) Dry Soil Conditions



c) Wet Soil Conditions

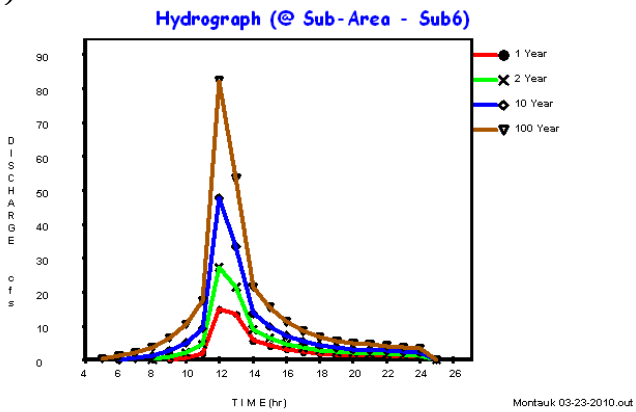
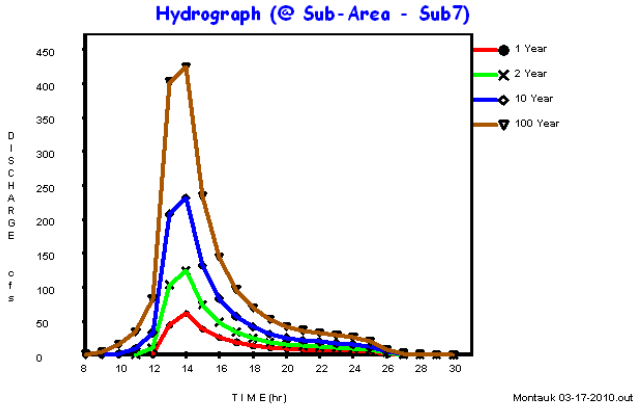
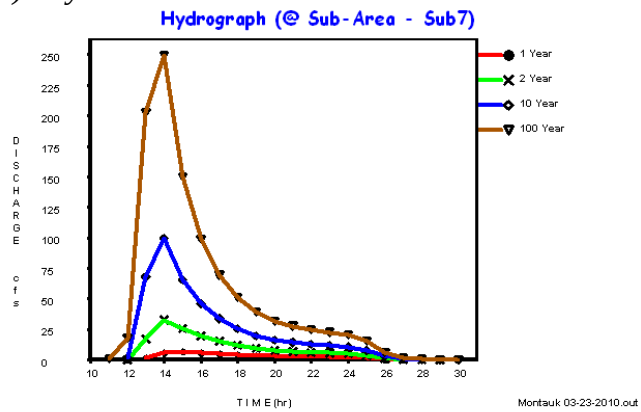


Figure 13 – Subwatershed 7 Hydrographs

a) Average Soil Conditions



b) Dry Soil Conditions



c) Wet Soil Conditions

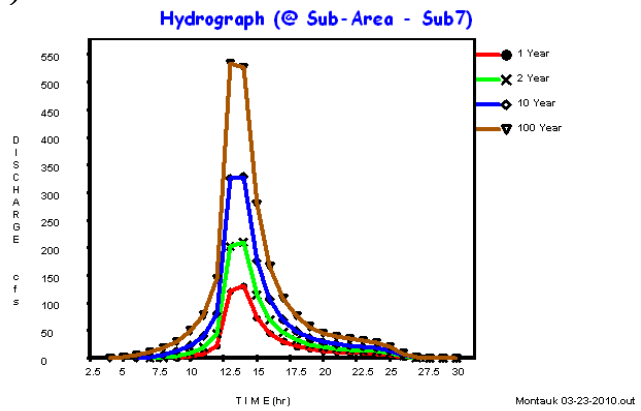
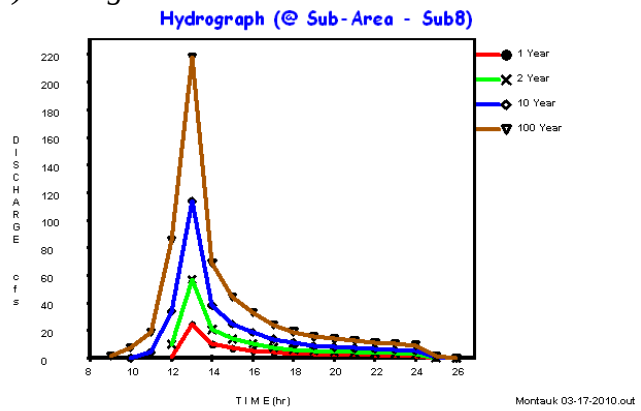
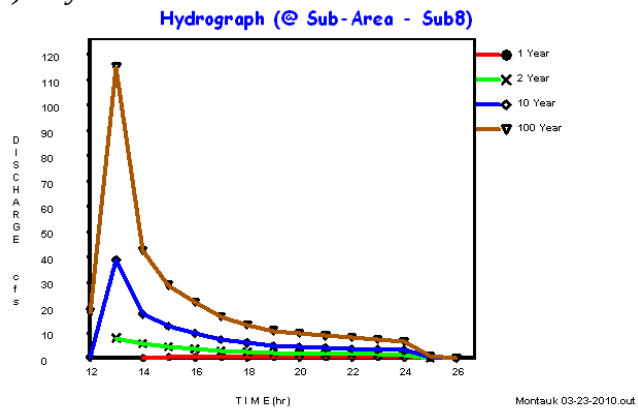


Figure 14 – Subwatershed 8 Hydrographs

a) Average Soil Conditions



b) Dry Soil Conditions



c) Wet Soil Conditions

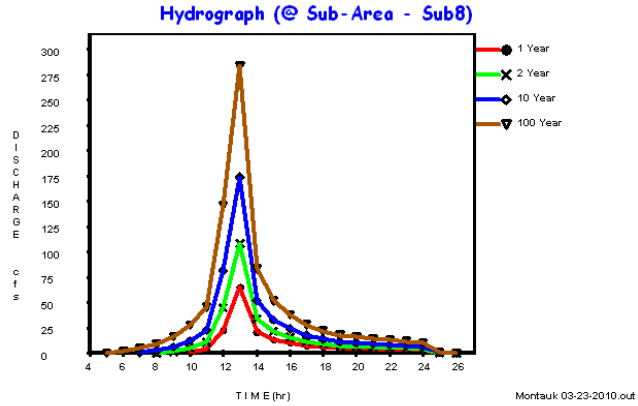
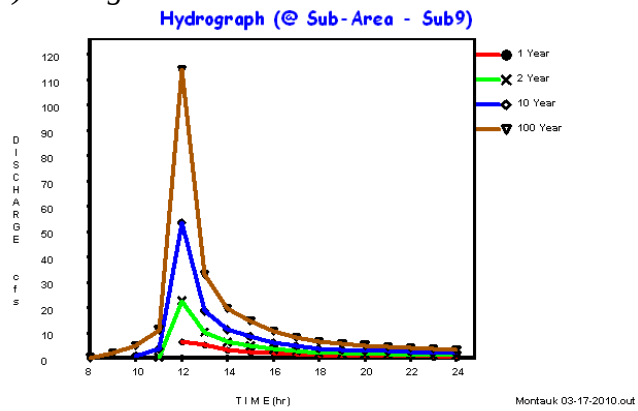
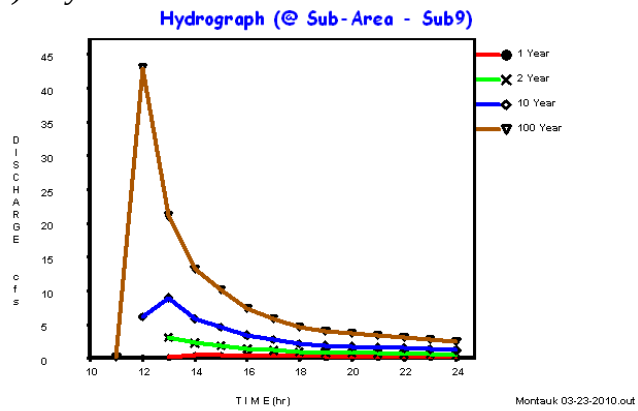


Figure 15 – Subwatershed 9 Hydrographs

a) Average Soil Conditions



b) Dry Soil Conditions



c) Wet Soil Conditions

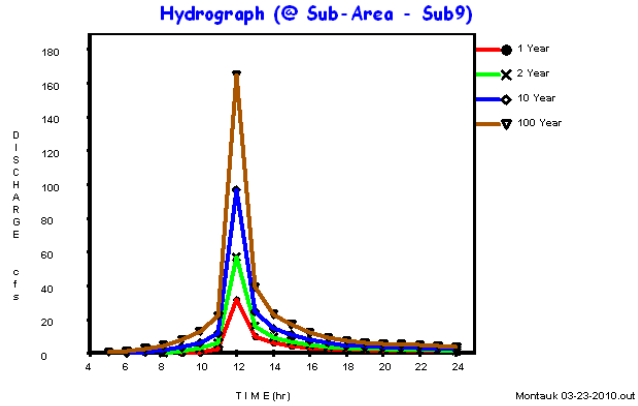
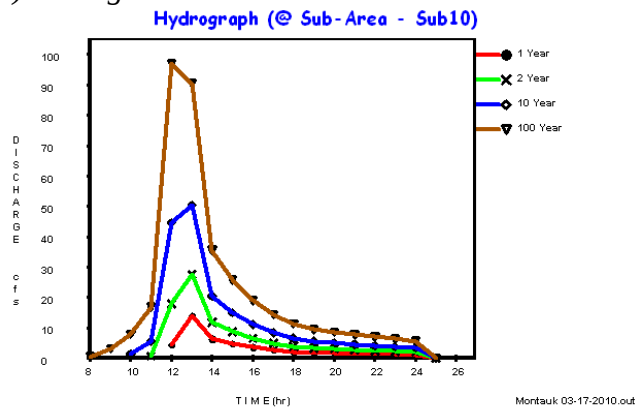
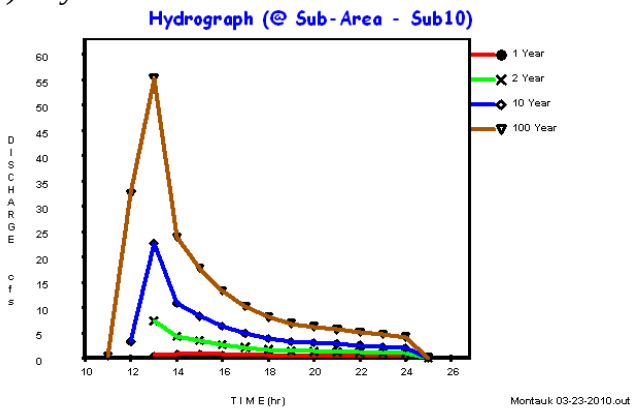


Figure 16 – Subwatershed 10 Hydrographs

a) Average Soil Conditions



b) Dry Soil Conditions



c) Wet Soil Conditions

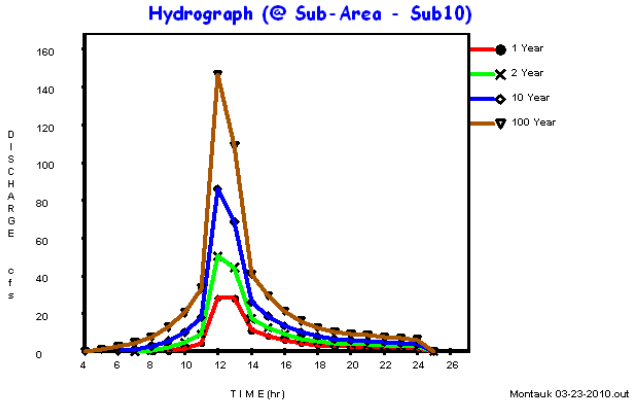
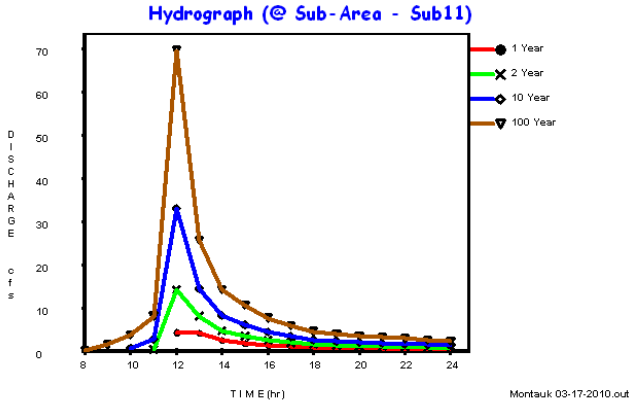
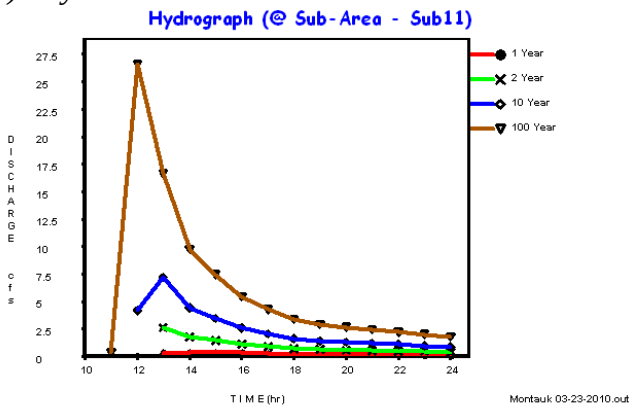


Figure 17 – Subwatershed 11 Hydrographs

a) Average Soil Conditions



b) Dry Soil Conditions



c) Wet Soil Conditions

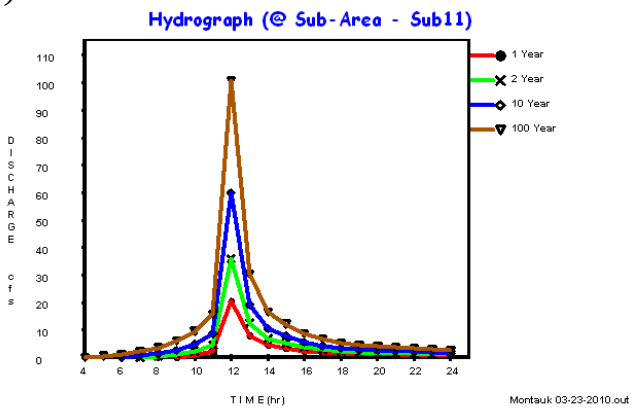
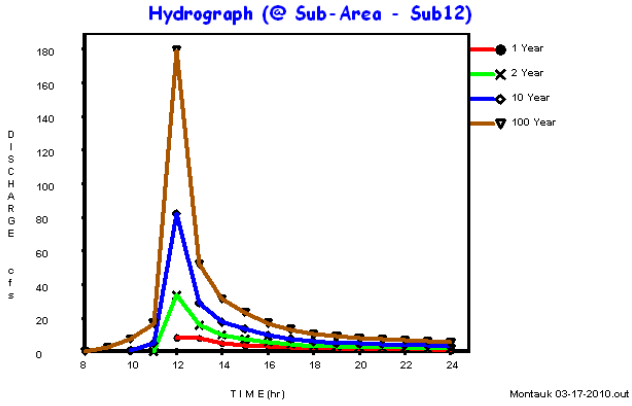
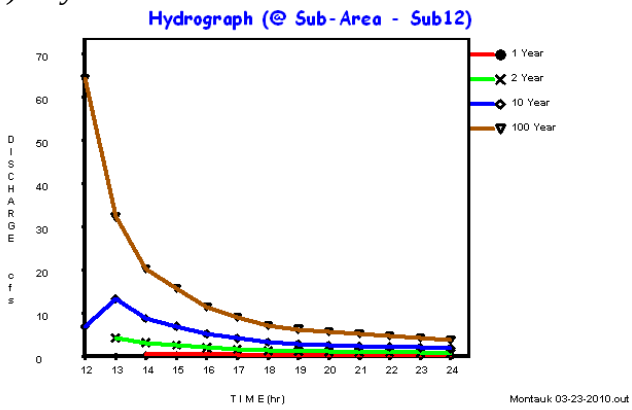


Figure 18 – Subwatershed 12 Hydrographs

a) Average Soil Conditions



b) Dry Soil Conditions



c) Wet Soil Conditions

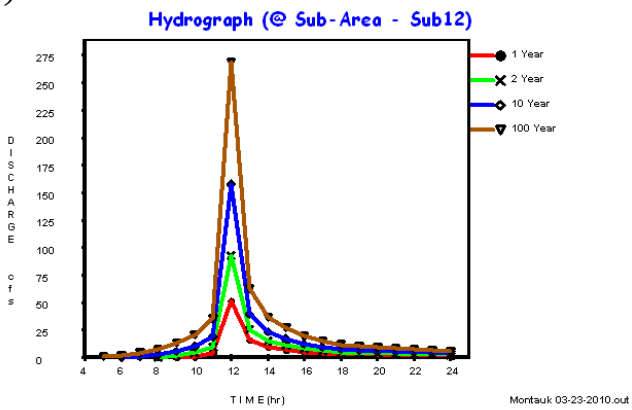
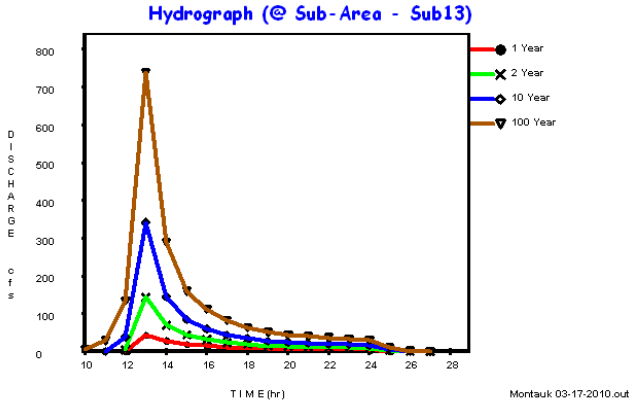
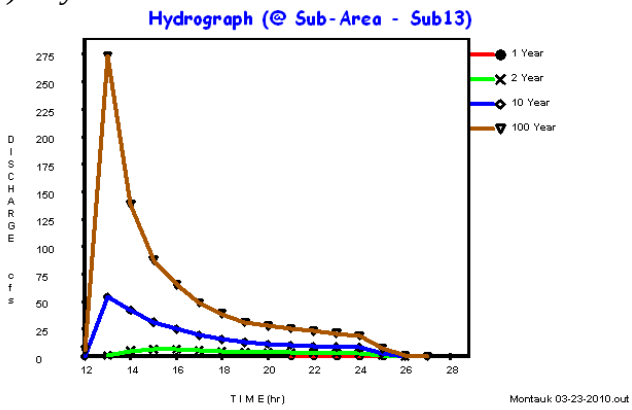


Figure 19 – Subwatershed 13 Hydrographs

a) Average Soil Conditions



b) Dry Soil Conditions



c) Wet Soil Conditions

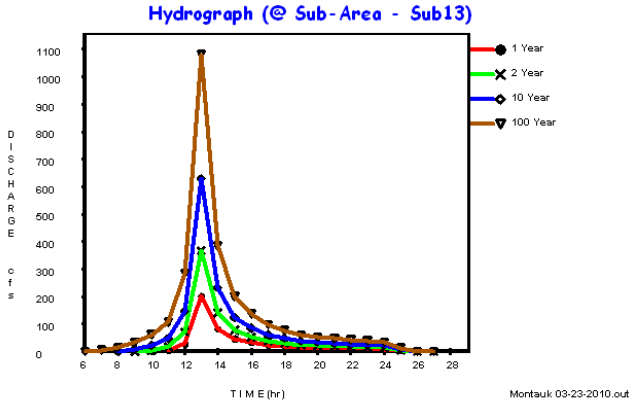
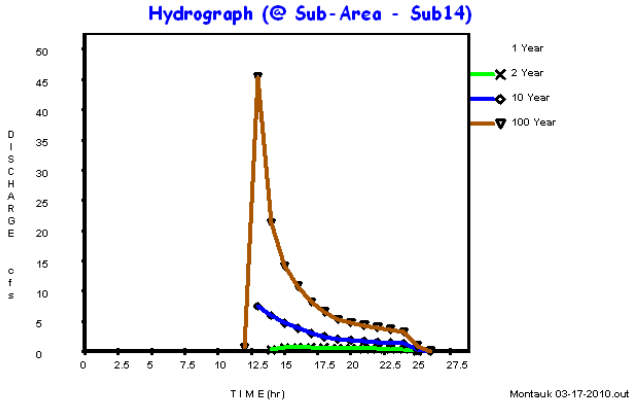
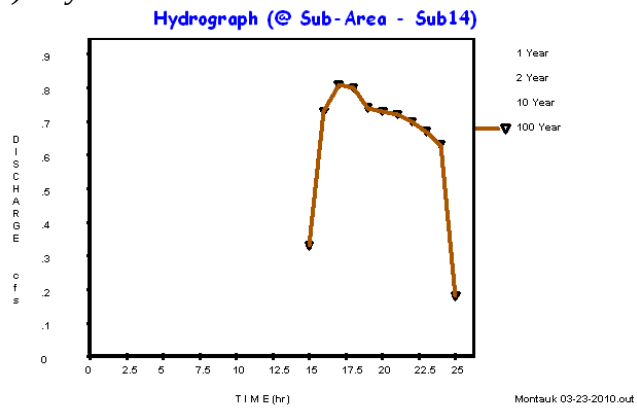


Figure 20 – Subwatershed 14 Hydrographs

a) Average Soil Conditions



b) Dry Soil Conditions



c) Wet Soil Conditions

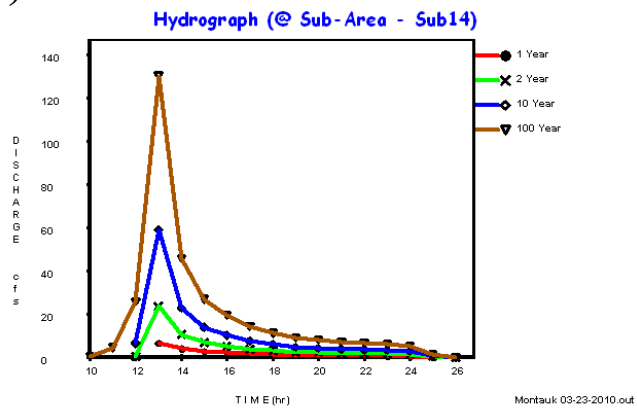
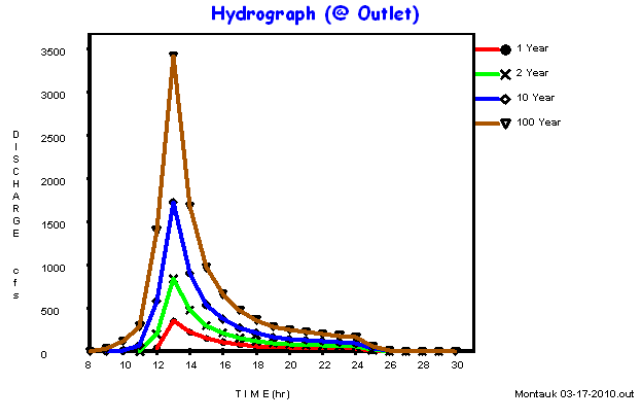
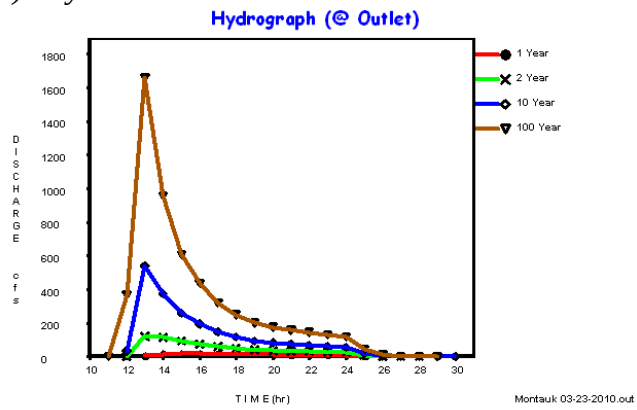


Figure 21 – All Subwatersheds Combined Hydrographs

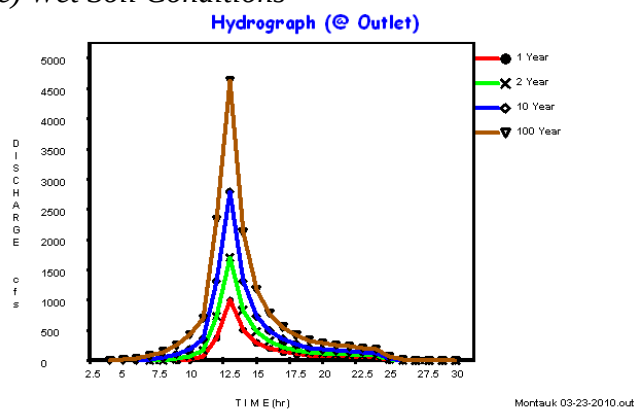
a) Average Soil Conditions



b) Dry Soil Conditions



c) Wet Soil Conditions



Runoff Tables

Table 2 – Runoff Volumes for Average Soil Conditions.

a) 1 Year Rain Event (2.5 inches)

Sub-Watershed	Area (square miles)	Runoff (inches)	Greatest Flow Rate (ft3/sec.)	Runoff (cubic feet)	Runoff (gallons)
1	0.330	0.575	54.750	440,827	3,297,616
2	0.494	0.584	87.410	670,234	5,013,698
3	0.596	0.496	50.080	686,775	5,137,434
4	0.336	0.557	41.440	434,792	3,252,466
5	0.187	0.508	27.380	220,695	1,650,911
6	0.080	0.544	15.760	101,106	756,323
7	0.575	0.702	64.250	937,760	7,014,930
8	0.247	0.473	31.190	271,422	2,030,376
9	0.093	0.536	23.110	115,807	866,296
10	0.148	0.589	31.730	202,518	1,514,940
11	0.065	0.586	16.910	88,491	661,956
12	0.149	0.492	33.160	170,309	1,274,001

13	0.810	0.321	45.590	604,055	4,518,647
14	0.154	0.000	0.000	0	0
All Subs	**4.263**	**0.499**	**381.800**	**4,941,997**	**36,968,705**

b) 2 Year Rain Event (3.5 inches)

Sub-Watershed	Area (square miles)	Runoff (inches)	Greatest Flow Rate (ft3/sec.)	Runoff (cubic feet)	Runoff (gallons)
1	0.330	1.190	125.460	912,321	6,824,632
2	0.494	1.204	198.080	1,381,784	10,336,459
3	0.596	1.072	123.020	1,484,320	11,103,487
4	0.336	1.164	96.560	908,613	6,796,896
5	0.187	1.090	66.590	473,538	3,542,309
6	0.080	1.145	36.970	212,805	1,591,893
7	0.575	1.376	135.060	1,838,116	13,750,061
8	0.247	1.036	78.890	594,488	4,447,081
9	0.093	1.132	54.900	244,577	1,829,565
10	0.148	1.212	71.610	416,726	3,117,329
11	0.065	1.207	38.420	182,267	1,363,449
12	0.149	1.065	82.790	368,657	2,757,746
13	0.810	0.791	143.860	1,488,497	11,134,734
14	0.154	0.060	0.740	21,466	160,580
All Subs	**4.263**	**1.063**	**940.730**	**10,527,741**	**78,752,972**

Table 2 – Runoff Volumes for Average Soil Conditions (continued).

c) 10 Year Rain Event (5 inches)

Sub-Watershed	Area (square miles)	Runoff (inches)	Greatest Flow Rate (ft3/sec.)	Runoff (cubic feet)	Runoff (gallons)
1	0.330	2.295	251.430	1,759,476	13,161,791
2	0.494	2.315	395.100	2,656,835	19,874,504
3	0.596	2.128	260.170	2,946,487	22,041,251
4	0.336	2.258	196.630	1,762,584	13,185,044
5	0.187	2.155	138.480	936,215	7,003,373
6	0.080	2.231	75.270	414,645	3,101,758
7	0.575	2.550	257.680	3,406,392	25,481,582
8	0.247	2.076	167.480	1,191,272	8,911,333
9	0.093	2.214	112.140	478,352	3,578,318
10	0.148	2.326	142.250	799,757	5,982,597
11	0.065	2.318	76.610	350,037	2,618,455
12	0.149	2.119	173.280	733,506	5,487,008
13	0.810	1.713	348.970	3,223,510	24,113,527

14	0.154	0.378	7.850	135,238	1,011,651
All Subs	**4.263**	**2.100**	**1,990.950**	**20,797,983**	**155,579,720**

d) 100 Year Rain Event (7.5 inches)

Sub-Watershed	Area (square miles)	Runoff (inches)	Greatest Flow Rate (ft3/sec.)	Runoff (cubic feet)	Runoff (gallons)
1	0.330	4.389	486.070	3,364,853	25,170,850
2	0.494	4.416	760.060	5,068,070	37,911,797
3	0.596	4.164	521.330	5,765,588	43,129,591
4	0.336	4.340	383.400	3,387,783	25,342,378
5	0.187	4.200	274.280	1,824,641	13,649,265
6	0.080	4.304	146.640	799,924	5,983,849
7	0.575	4.724	482.760	6,310,508	47,205,879
8	0.247	4.093	336.830	2,348,688	17,569,405
9	0.093	4.280	219.000	924,727	6,917,435
10	0.148	4.430	273.110	1,523,183	11,394,199
11	0.065	4.420	147.310	667,455	4,992,913
12	0.149	4.151	343.890	1,436,897	10,748,735
13	0.810	3.581	763.370	6,738,697	50,408,955
14	0.154	1.351	46.460	483,351	3,615,717
All Subs	**4.263**	**4.103**	**4,022.980**	**40,635,298**	**303,973,138**

Table 3 – Runoff Volumes for Dry Soil Conditions.

a) 1 Year Rain Event (2.5 inches)

Sub-Watershed	Area (square miles)	Runoff (inches)	Greatest Flow Rate (ft3/sec.)	Runoff (cubic feet)	Runoff (gallons)
1	0.330	0.070	1.980	53,666	401,449
2	0.494	0.074	3.130	84,927	635,297
3	0.596	0.045	2.070	62,308	466,098
4	0.336	0.064	1.810	49,958	373,712
5	0.187	0.048	0.760	20,853	155,992
6	0.080	0.060	0.410	11,151	83,418
7	0.575	0.137	6.820	183,010	1,369,010
8	0.247	0.038	0.760	21,806	163,117
9	0.093	0.057	0.450	12,315	92,125
10	0.148	0.076	0.970	26,131	195,476
11	0.065	0.074	0.420	11,175	83,592
12	0.149	0.044	0.540	15,231	113,935
13	0.810	0.001	0.230	1,882	14,077

14	0.154	0.000	0.000	0	0
All Subs	**4.263**	**0.056**	**19.500**	**554,613**	**4,148,793**

b) 2 Year Rain Event (3.5 inches)

Sub-Watershed	Area (square miles)	Runoff (inches)	Greatest Flow Rate (ft3/sec.)	Runoff (cubic feet)	Runoff (gallons)
1	0.330	0.318	18.490	243,797	1,823,725
2	0.494	0.326	29.960	374,137	2,798,742
3	0.596	0.256	16.310	354,465	2,651,579
4	0.336	0.304	14.150	237,301	1,775,134
5	0.187	0.265	7.830	115,126	861,204
6	0.080	0.294	4.860	54,642	408,748
7	0.575	0.459	32.840	613,151	4,586,685
8	0.247	0.237	8.070	135,998	1,017,334
9	0.093	0.287	6.650	62,009	463,856
10	0.148	0.330	10.860	113,465	848,778
11	0.065	0.327	5.570	49,380	369,385
12	0.149	0.252	8.470	87,232	652,537
13	0.810	0.099	6.750	186,297	1,393,601
14	0.154	0.000	0.000	0	0
All Subs	**4.263**	**0.265**	**121.420**	**2,624,507**	**19,632,679**

Table 3 – Runoff Volumes for Dry Soil Conditions (continued).

c) 10 Year Rain Event (5 inches)

Sub-Watershed	Area (square miles)	Runoff (inches)	Greatest Flow Rate (ft3/sec.)	Runoff (cubic feet)	Runoff (gallons)
1	0.330	0.930	81.830	712,990	5,333,536
2	0.494	0.945	130.370	1,084,539	8,112,919
3	0.596	0.811	76.040	1,122,933	8,400,120
4	0.336	0.904	62.000	705,658	5,278,689
5	0.187	0.830	40.910	360,584	2,697,355
6	0.080	0.885	23.520	164,483	1,230,415
7	0.575	1.180	103.120	1,576,291	11,791,477
8	0.247	0.775	46.590	444,719	3,326,726
9	0.093	0.872	34.110	188,402	1,409,347
10	0.148	0.952	47.300	327,330	2,448,595
11	0.065	0.947	25.080	143,005	1,069,749
12	0.149	0.805	48.780	278,656	2,084,493
13	0.810	0.480	57.670	903,260	6,756,855

14	0.154	0.000	0.000	0	0
All Subs	**4.263**	**0.809**	**562.220**	**8,012,175**	**59,935,235**

d) 100 Year Rain Event (7.5 inches)

Sub-Watershed	Area (square miles)	Runoff (inches)	Greatest Flow Rate (ft3/sec.)	Runoff (cubic feet)	Runoff (gallons)
1	0.330	2.364	245.310	1,812,375	13,557,505
2	0.494	2.389	388.180	2,741,762	20,509,801
3	0.596	2.162	245.370	2,993,564	22,393,414
4	0.336	2.320	189.560	1,810,981	13,547,078
5	0.187	2.194	132.250	953,158	7,130,116
6	0.080	2.288	72.880	425,239	3,181,005
7	0.575	2.773	268.740	3,704,284	27,709,971
8	0.247	2.098	157.570	1,203,896	9,005,769
9	0.093	2.267	108.440	489,803	3,663,978
10	0.148	2.402	139.880	825,888	6,178,074
11	0.065	2.393	75.110	361,362	2,703,177
12	0.149	2.151	164.840	744,583	5,569,870
13	0.810	1.554	273.820	2,924,305	21,875,319
14	0.154	0.071	0.820	25,402	190,019
All Subs	**4.263**	**2.122**	**1,836.290**	**21,015,867**	**157,209,602**

Table 4 – Runoff Volumes for Wet Soil Conditions.

a) 1 Year Rain Event (2.5 inches)

Sub-Watershed	Area (square miles)	Runoff (inches)	Greatest Flow Rate (ft3/sec.)	Runoff (cubic feet)	Runoff (gallons)
1	0.330	1.323	146.330	1,014,286	7,587,385
2	0.494	1.340	231.120	1,537,865	11,504,033
3	0.596	1.243	154.680	1,721,092	12,874,659
4	0.336	1.293	113.660	1,009,310	7,550,160
5	0.187	1.243	80.780	540,007	4,039,532
6	0.080	1.271	43.240	236,223	1,767,071
7	0.575	1.455	148.410	1,943,647	14,539,491
8	0.247	1.211	99.080	694,909	5,198,277
9	0.093	1.257	64.170	271,584	2,031,592
10	0.148	1.349	83.020	463,832	3,469,701
11	0.065	1.342	44.670	202,653	1,515,948
12	0.149	1.243	102.830	430,273	3,218,665
13	0.810	0.998	208.520	1,878,028	14,048,628

14	0.154	0.259	6.640	92,663	693,169
All Subs	**4.263**	**1.215**	**1,174.830**	**12,033,119**	**90,013,981**

b) 2 Year Rain Event (3.5 inches)

Sub-Watershed	Area (square miles)	Runoff (inches)	Greatest Flow Rate (ft3/sec.)	Runoff (cubic feet)	Runoff (gallons)
1	0.330	2.197	243.020	1,684,343	12,599,762
2	0.494	2.218	381.270	2,545,512	19,041,750
3	0.596	2.098	262.630	2,904,948	21,730,519
4	0.336	2.160	190.660	1,686,086	12,612,796
5	0.187	2.098	136.620	911,452	6,818,133
6	0.080	2.132	72.670	396,245	2,964,118
7	0.575	2.357	240.560	3,148,575	23,552,976
8	0.247	2.057	169.560	1,180,369	8,829,774
9	0.093	2.115	107.960	456,962	3,418,312
10	0.148	2.229	136.910	766,405	5,733,108
11	0.065	2.221	73.660	335,389	2,508,882
12	0.149	2.098	173.880	726,237	5,432,630
13	0.810	1.783	381.860	3,355,235	25,098,902
14	0.154	0.686	24.400	245,432	1,835,960
All Subs	**4.263**	**2.054**	**2,020.610**	**20,342,408**	**152,171,783**

Table 4 – Runoff Volumes for Wet Soil Conditions (continued).

c) 10 Year Rain Event (5 inches)

Sub-Watershed	Area (square miles)	Runoff (inches)	Greatest Flow Rate (ft3/sec.)	Runoff (cubic feet)	Runoff (gallons)
1	0.330	3.585	391.900	2,748,462	20,559,922
2	0.494	3.609	613.610	4,141,908	30,983,622
3	0.596	3.467	433.720	4,800,503	35,910,252
4	0.336	3.540	310.110	2,763,307	20,670,972
5	0.187	3.467	224.280	1,506,198	11,267,143
6	0.080	3.508	118.110	651,983	4,877,170
7	0.575	3.772	381.800	5,038,788	37,692,755
8	0.247	3.417	279.340	1,960,778	14,667,642
9	0.093	3.487	175.900	753,393	5,635,770
10	0.148	3.622	219.690	1,245,365	9,315,979
11	0.065	3.613	118.410	545,592	4,081,311
12	0.149	3.467	283.490	1,200,126	8,977,563
13	0.810	3.079	662.400	5,794,038	43,342,411

14	0.154	1.550	63.670	554,548	4,148,306
All Subs	**4.263**	**3.403**	**3,356.210**	**33,702,637**	**252,113,231**

d) 100 Year Rain Event (7.5 inches)

Sub-Watershed	Area (square miles)	Runoff (inches)	Greatest Flow Rate (ft3/sec.)	Runoff (cubic feet)	Runoff (gallons)
1	0.330	5.984	640.820	4,587,670	34,318,151
2	0.494	6.012	1,000.250	6,899,737	51,613,615
3	0.596	5.848	719.700	8,097,300	60,572,009
4	0.336	5.932	510.320	4,630,491	34,638,476
5	0.187	5.847	371.040	2,540,161	19,001,726
6	0.080	5.895	194.500	1,095,621	8,195,815
7	0.575	6.197	616.440	8,278,200	61,925,240
8	0.247	5.790	465.040	3,322,478	24,853,862
9	0.093	5.870	289.250	1,268,258	9,487,230
10	0.148	6.027	357.150	2,072,285	15,501,769
11	0.065	6.016	192.570	908,464	6,795,784
12	0.149	5.847	467.930	2,023,979	15,140,413
13	0.810	5.386	1,148.490	10,135,332	75,817,546
14	0.154	3.342	145.310	1,195,677	8,944,283
All Subs	**4.263**	**5.760**	**5,634.380**	**57,045,897**	**426,732,945**

Discussion

Generally speaking, the hydrographs show a normal distribution with the greatest flow rate occurring about an hour after the peak of a storm event. The delay is attributed to the time it takes the runoff to concentrate. Subwatersheds which are smaller (shorter distance for runoff to travel) or have steeper slopes will have the greatest flow rate occur earlier in comparison to large or minimally sloped watersheds.

Within a subwatershed and a given antecedent soil condition, the size of a storm has a large influence on the greatest flow rate and the amount of runoff generated. This is intuitive since once a soil becomes saturated with water all subsequent rainfall will be forced to run off. In subwatershed 1 under normal soil conditions, a 1 year 3.5 inch rainfall event will have a greatest flow rate of 54.75ft^3/second (Figure 7a) and generate a total runoff of approximately 440,827 ft^3 (Table 2a). However, during a 10 year 5.0 inch rainfall event the greatest flow rate will be 251.43ft^3/second (Figure 7a) and the total runoff will be 1,759,476ft^3 (Table 2c). Obviously, the greater amount of rainfall which exceeds the soil capacity, the greater amount of runoff is generated. An exception to this can be seen in subwatershed 14. Even in a 10 year rainfall event comparatively little runoff is generated (Table 2c) and in a smaller 1 year rainfall event no runoff is generated (Table 2a). The reason for this is because subwatershed 14 is largely comprised of sand which has an extremely high capacity to infiltrate water, and also the watershed is relatively flat.

Antecedent soil condition also has a significant impact on the hydrographs and runoff generated. In general when soils are dry they can absorb a significant portion of a rainfall event. If they are very moist or partially saturated with water, then they can absorb proportionately less rainfall. For a 2 year storm event in subwatershed 2, under dry soil conditions the greatest flow rate is 29.96ft^3/second (Figure 8b) and the total runoff is 374,137ft^3 (Table 3b). But with the same storm event under conditions where the soil was already wet prior to the rainfall, the greatest flow rate and total runoff increase to 381.27ft^3/second (Figure 8c) and 2,545,512 ft^3 (Table 4b) respectively. The antecedent soil condition also impacts the timing of when discharges commences. When the soil is already saturated prior to a rainfall event, the runoff/discharge starts earlier in comparison to when the soil was dry prior to the rainfall. Using subwatershed 2 during a 2 year rainfall event as an example, discharge starts around hour 12 (Figure 8b) when the soil was dry compared to hour 6 (Figure 8c) when the soil was already wet. This occurs because dry soil absorbs most if not all the early rainfall therefore causing the runoff to initiate later in the storm event.

Although there are some variations between rainfall events and antecedent soil conditions, in general subwatershed 2 had the highest greatest flow rates. This can be attributed to a number of factors including the size of the watershed (one of the larger ones), hydrological soil group composition (relatively small proportion of well draining sandy soils), and the significant slope of the watershed (approximately 140 foot drop in elevation). The greatest total runoff however in dry or average conditions comes from subwatershed 7. Although there are a couple of subwatersheds which are larger, subwatershed 7 generates the most runoff because of its size and almost complete absence of well draining sandy type soils. It's also worth noting that even though a large portion of it is undeveloped, subwatershed 13 generates a significant amount of runoff due to its large extent. Regardless of the size of the rainfall event and antecedent soil condition, subwatershed 14 always had the lowest flow rate and runoff volumes. This is partly attributed to its small size (though there are 5 smaller subwatersheds), but to a much greater degree to the fact that it is almost completely comprised of very well draining sand and is relatively flat.

When the runoff generated from all subwatersheds are added together, it can be seen that the total inputs to Lake Montauk are very significant. As would be expected, greater rainfalls and higher antecedent soil moisture conditions result in dramatically greater runoff volumes (Table 5). For example, for a 1 year rainfall event under normal soil moisture conditions there is 4,941,997 ft^3 of runoff, which equates to approximately 37 million gallons. Under worst case conditions, a 100 year rainfall event with wet antecedent soils, the runoff volumes increase to a staggering 57,045,897 ft^3 or approximately 427 million gallons.

Table 5 – Total runoff volumes for all subwatersheds.

Rainfall Event (Years)	Normal Soil (cubic feet)	Dry Soil (cubic feet)	Wet Soil (cubic feet)
1	4,941,997	554,613	12,033,119
2	10,527,741	2,624,507	20,342,408

10	20,797,983	8,012,175	33,702,637
100	40,635,298	21,015,867	57,045,897

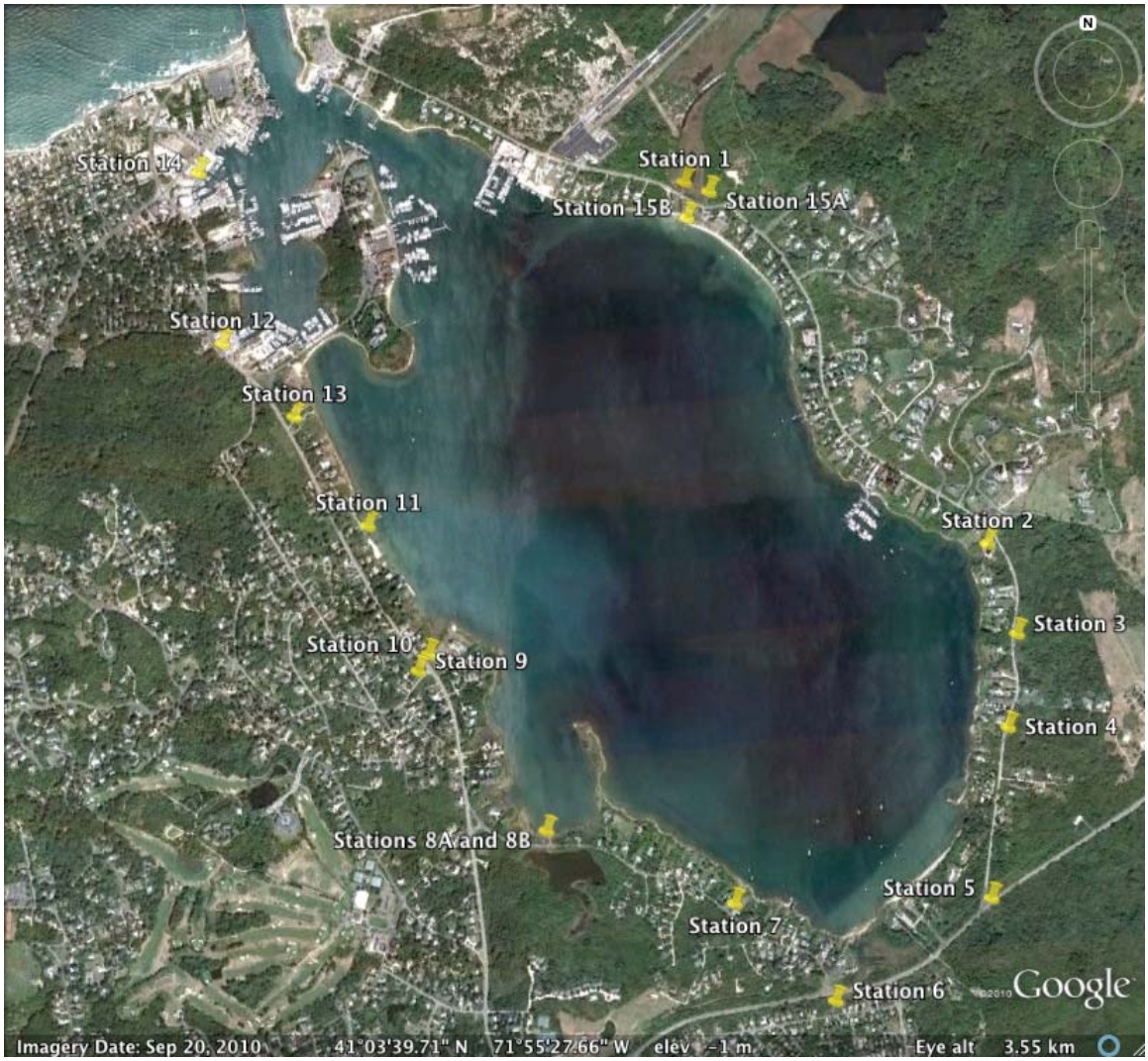
As mentioned previously, it's important to note that this analysis does not take into account stormwater water conveyance systems. This significantly impacts the values for both the greatest flow rates and total runoff produced. In some cases, greatest flow rates will occur earlier than predicted since conveyances carry water faster than natural runoff. Also, in most subwatersheds the peak discharges and runoff volumes have been over estimated since storage devices such as leaching basins and detention ponds are not taken into consideration. While a detailed analysis could not be incorporated into the model since it was beyond the scope of the project, a few examples highlight the significance of stormwater structures. As demonstrated in Table 6, detention ponds are able to prevent a significant amount of runoff from reaching Lake Montauk.

Table 6 – Examples Highlighting the Impact of Detention Ponds

Detention Pond Name	Subwatershed Number	Approximate Pond Area (ft^2)	Average Available Depth (ft)	Average Capacity (ft^3)	% of Runoff Absorbed
Glouchester West Lake	3	9,513	1	9,513	1.4
Drum Property	2	31,518	0.75	19,699	2.9
Ditch Plains	7	27,846	1.25	34,808	3.7

The provided examples assume average soil conditions and a 1-year rain event. As can be seen, the detention ponds capture between 1.4 and 3.7% of their respective subwatersheds' runoff. In antecedent dry conditions the percentages would increase since the water level in the ponds prior to the rainfall would be lower (thus increasing the available pond capacity) with the inverse being true during antecedent wet conditions. However, the positive impact of stormwater structures is greater than the percent of water captured. In addition to preventing some water from reaching Lake Montauk, detention basins also have the benefit of capturing some pollutants in the water that passes through due to the increased residence time which promotes particulate settling. Some leaching structures also capture what is referred to as the "first flush", which is thought to contain a higher proportion of pollutants. Finally, it's also worth mentioning that the additive effect of other existing stormwater structures such as leaching pools will further increase the percentage of absorbed water thus preventing the associated pollutants from being directly discharged into Lake Montauk.

Streamflow and Coliform Sampling Stations



Station 1: Reed Pond Outflow

Address: East Lake Drive
Location & Pipe Description: 36 in pipe discharging water from Little Reed Pond. There is a stream channel located below the pipe.

West side of East Lake Drive

Pipe into Lake Montauk

Aerial Photo of Site 1

Station 2: Bond Property

Address: East Lake Drive
Location & Pipe Description: Pipe is located in a headwall. Retention Pond constructed June-July, 2010.

N
© 2011 Google
Google earth
Imagery Date: 9/19/2010
1994
41°03'37.52" N 71°54'25.94" W elev 7 ft
Eye alt 488 ft

Station 3:

Address: 105 East Lake Drive
Location & Pipe Description: The pipe diameter was 12 inches. Channel present.

Aerial Photo of Site 3

Station 4:

Address: 61&67 East Lake Drive

Location & Pipe Description: Pipe diameter is 12 inches.

Pipe on eastern portion of road.

Pipe on western portion of the road. Note silt fence in front of pipe.

Aerial of Site 4

Station 5: Amsterdam Park

Address: Drains intersection of East Lake Drive and Montauk Highway

Location & Pipe Description: Pipe diameter is 24 inches. No bottom lip on pipe-cracked. Pipes and channels on both sides of the road.

Aerial of Site 5

Station 6: Ocean Side Drain

Address: Benson Drive

Location & Pipe Description: Two pipes found. One discharges directly into channel and the other is raised above the channel. The pipe that discharges into the channel was underwater and flowing. The pipe raised above the channel was dry. Water flows through wetland.

Pipe located above the channel.

Pipe that discharges directly into channel.

Aerial of Site 6

Station 7:

Address: 64 Old West Lake Drive
Location & Pipe Description: Have to lift cover to access pipe. Pipe approximately 16 inches. There is a channel across the street, but there is no pipe apparent.

Pipe located under cover to the left. There is no stream channel.

Looking down at pipe

Aerial of Site 7

Station 8: Stepping Stones Pond Outflow

Address: Old West Lake Drive
Location & Pipe Description: Pipes are two black 12 inch corrugated plastic.

Aerial of Site 8

Station 9: Peter's Run-Stream

Address: 8 Gloucester Avenue
Location & Pipe Description: Pipe diameter is 24 inches. There is a creek that the pipe discharges into. The stream has a sandy bottom.

Aerial of Site 9 and 10

Station 10: Peter's Run-Retention Pond

Address: West Lake Drive and Gloucester Avenue.
Location & Pipe Description: Discharge from the pond/lake.

Station 11:

Address: West Lake Drive and Glenmore Avenue
Location & Pipe Description: Pipe diameter is 18 inches. Pipe discharges directly to beach. No stream channel present.

Aerial Site 11

Station 12: Diamond Cove Marina

Address: Diamond Cove Marina, 364 West Lake Drive

Location & Pipe Description: Outfall discharges directly into lake through bulk heading at Diamond Cove Marina. Pipe on other side of the street is 16 in and has a small channel.

Aerial of Site 12. The red dot is of the pipe found across the street from the marina outfall

Station 13: Drum Property

Address: West Lake Drive

Location & Pipe Description: Outlet of the pond, located on the west side of the street. Pipe is 16 inches.

Aerial of Site 13

Station 14: Sea Otter/Uihlen's Marina

Address: 444 West Lake Drive
Location & Pipe Description: Pipe diameter is 4 ft. Discharges directly into lake from marina.

Aerial of Site 14

Station 15A and 15B: South of Reed Pond outfall

Address: East Lake Drive
Location & Pipe Description: Pipe diameter is 12 ft. Pipe runs from east side of East Lake Drive (15A) to outfall along beach (15B)

Aerial of 15B

Streamflow

In most cases flow readings were taken for pipes that were partially filled and using calculations to determine the average velocity of the water. To determine the partially filled portion of a pipe, measurements of the pipes' diameter as well as the portion of the pipe that was filled with water was recorded. Nearly all the pipes for the contributing streamlets had round pipes. Appendix A of the flow meter manual provided the calculations for partially filled round pipes. Water flow was measured using a Global Water Flow Probe.

Sampling procedures;

1. Point the propeller into the flow that is to be measured. The propeller must flow freely, so check for any debris to ensure proper functionality.
2. Pressing the reset button will start the flowmeter to record minimum, maximum and average velocities. Averages are updated once per second. Maintain flowmeter within the stream flow for one minute.
3. Record average velocity, pipe diameter and height of water within the pipe.

Using this data allows for volumetric flow calculations. From Global Water:

Global Water
800-876-1172 • globalw.com

Appendix A: Calculations for Partially Filled Round Pipes

B	C	B	C
0.01	0.0013	0.51	0.4027
0.02	0.0037	0.52	0.4127
0.03	0.0069	0.53	0.4227
0.04	0.0105	0.54	0.4327
0.05	0.0147	0.55	0.4426
0.06	0.0192	0.56	0.4526
0.07	0.0242	0.57	0.4625
0.08	0.0294	0.58	0.4723
0.09	0.0350	0.59	0.4822
0.10	0.0409	0.60	0.4920
0.11	0.0470	0.61	0.5018
0.12	0.0534	0.62	0.5115
0.13	0.0600	0.63	0.5212
0.14	0.0668	0.64	0.5308
0.15	0.0739	0.65	0.5404
0.16	0.0811	0.66	0.5499
0.17	0.0885	0.67	0.5594
0.18	0.0961	0.68	0.5687
0.19	0.1039	0.69	0.5780
0.20	0.1118	0.70	0.5872
0.21	0.1199	0.71	0.5964
0.22	0.1281	0.72	0.6054
0.23	0.1365	0.73	0.6143
0.24	0.1449	0.74	0.6231
0.25	0.1535	0.75	0.6318
0.26	0.1623	0.76	0.6404
0.27	0.1711	0.77	0.6489
0.28	0.1800	0.78	0.6573
0.29	0.1890	0.79	0.6655
0.30	0.1982	0.80	0.6736
0.31	0.2074	0.81	0.6815
0.32	0.2167	0.82	0.6893
0.33	0.2266	0.83	0.6969
0.34	0.2355	0.84	0.7043
0.35	0.2450	0.85	0.7115
0.36	0.2546	0.86	0.7186
0.37	0.2644	0.87	0.7254
0.38	0.2743	0.88	0.7320
0.39	0.2836	0.89	0.7384
0.40	0.2934	0.90	0.7445
0.41	0.3032	0.91	0.7504
0.42	0.3130	0.92	0.7560
0.43	0.3229	0.93	0.7612
0.44	0.3328	0.94	0.7662
0.45	0.3428	0.95	0.7707
0.46	0.3527	0.96	0.7749
0.47	0.3627	0.97	0.7785
0.48	0.3727	0.98	0.7816
0.49	0.3827	0.99	0.7841
0.50	0.3927	1.00	0.7854

H= Height of water; D= Diameter of pipe (in feet)

H/D = Column B

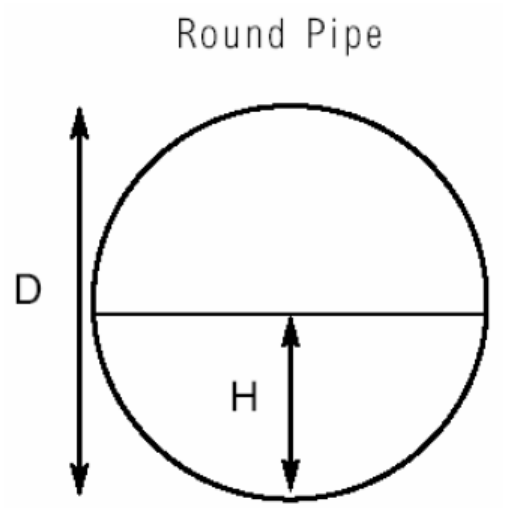
Read Column C adjacent to your pipe's B

C x D2 = Filled area, A (sq.ft.)

A x Average Velocity = Volumetric flow (CFS)

CFS x 448.83 = Gallons/minute (GPM)

GPM x 1440 = Gallons/day (GPD)



Alternatively, some stations did not have clearly evidence pipes, such as station 7. For early flow samples, the stream either had no measurable flow, or due to lack of rain flow, the stream bed was dry, with no flow. Flow samples taken in 2011 had mesurable flow, and a velocity-area

method/midsection method was used to calculate streamflow. In essence the stream is broken up into measurable segments and these partial flows are added to determine total discharge.

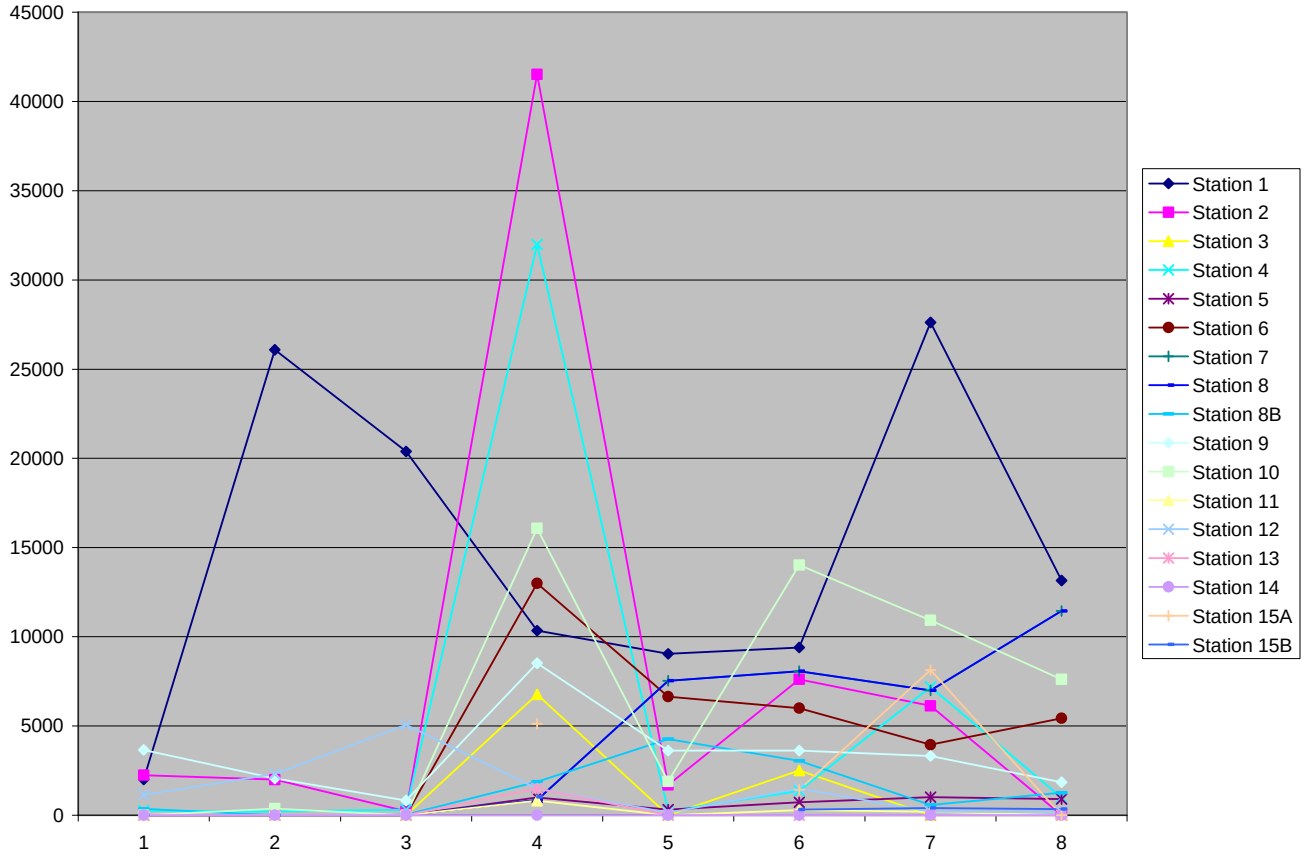
The partial discharge for each increment is: $q_x = v_x\ [(b_{(x+1)} - b_{(x-1)}/2]\ d_x$
v_x = mean stream velocity at observation point x
$b_{(x-1)}$ = distance from the datum to the preceding observation point
$b_{(x+1)}$ = distance from the datum to the next observation point
d_x = depth of the water at observation point x

Sum all partial discharges for total discharge of stream.

For a forecasted rainfall event, technicians were dispatched to Lake Montauk to capture the rainfall event.

Station	5/12/10	10/6/10	11/4/10	2/25/10	2/28/10	3/11/11	3/16/11	4/1/11
1	2014.564	26086.9	20387.69	10349.12	9050.352	9401.301	27613.49	13149.28
2	2239.734	1993.478	219.9267	41514.76	1692.053	7614.239	6125.129	0
3	0	0	0	6768.213	0	2504.148	0	0
4	260.1419	206.8209	316.6944	31986.79	237.5208	1361.786	7191.226	981.7528
5	0	0	0	992.0938	316.6944	722.5804	1007.39	904.8413
6	0	0	0	12991.51	6641.535	6003.622	3948.124	5437.845
7	0	0	0	852.7052	7540.344	8078.94	7001.748	11445.17
8A	0	0	0	2097.293	3245.687	372.2776	3050.608	1563.867
8B	348.3639	0	33.93155	1874.314	4264.065	3050.608	572.743	1264.193
9	3661.806	2058.514	828.1452	8524.251	3622.597	3622.597	3319.69	1850.4
10	0	364.9526	0	16074.51	1896.289	14016.21	10927.9	7614.239
11	0	0	0	818.4146	0	292.6596	194.0965	0
12	1140.1	2314.886	5073.574	1492.27	150.8069	1492.27	191.8838	172.3507
13	0	0	0	1501.39	0	0	0	0
14	0	0	0	0	0	0	0	0
15A	-	-	-	5125.926	-	1429.972	8140.125	0
15B	-	-	-	1017.516	-	311.0392	406.4245	337.1611
Rainfall	0.25”	0.57”	1.07”	1.70”	0.21”	0.66”	0.41”	0.35”

Figure 1.Flow rates of stream inputs to Lake Montauk during rainfall events. Data in Gallons Per Minute (GPM).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Station 10
Station 11
Station 12
Station 13
Station 14
Station 15A
Station 15B

24-hour Streamflow and coliform study

As part of the watershed plan 3 stations were chosen to be monitored during wet event over a 24-hour period .

The three streamlets were chosen based on data collected during the flow analysis and the data obtained during coiform analysis. Coincidently the stations chosen were from the western, eastern and southern portions of the lake.

The 24-Hour survey was conducted from June 22 to June 23 of 2011.

Coliform Enumeration

Using the membrane filtration method, streams were assayed for presence of E. coli bacteria. *E. coli* bacteria is used as an indicator organisms for the possible presence of pathogens in the water. Currently Suffolk County Health codes for bathing beaches use E. coli as their indicator organism for freshwater pathogens. Currently if a single water sample at a fresh water beach is above 235 CFU (colony forming units) per 100ml of sample, the beach is then closed.

Stations for analysis were chosen with collaboration of Cornell Cooperative Extension Marine Program and the Natural Resource Department of East Hampton, based on historical data and known problem areas.

To determine the load going in to the lake, the chosen streams were sampled 4 times during dry events (no rain in the preceding 72 hours), and 4 times during a wet event, for a total of 8 sampling events per station.

Station 1
Reed Pond
Notes:

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml	11	24	254	74	104	490	0	232

Station 2
Bond Property
Notes: 11/30/09: No Sample- Pipe under water
6/28/09: No Sample- New retention pond under construction

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml	3900	no sample	87	no sample	360	950	70	43

Station 3
105 East Lake Drive
Notes:

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml	1300	610	268	1350	1700	840	99	106

Station 4
61&67 East Lake Drive

Notes: 8/9/2010: No sample-no flow

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml	10800	62	74	5300	no sample	950	700	26

Highlighted samples indicate samples saved for DNA analysis.

Station 5
Amsterdam Park
Notes: 8/9/2010: No sample-no flow

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	Wet	dry	dry	wet	wet	wet
MPN/100ml	125	76	21	12	no sample	8400	11	82

Station 6
Ocean Side Drain
Notes:

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml	1020	710	540	14500	1800	3200	36	164

Station 7
#64 Old West Lake Drive
Notes: 6/28/2010: No Sample-no flow
8/9/2010: No Sample-no flow

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml	380	79	510	no sample	no sample	14300	48	214

Station 8A
Stepping Stones Pond (southern pipe)
Notes: 6/28/10: No Sample-no flow
8/9//10: No Sample-no flow

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml	274	55	95	no sample	no sample	590	no sample	0

Highlighted samples indicate samples saved for DNA analysis.

Station 8B
Stepping Stones Pond (northern pipe)
Notes: This pipe was not added to the sample list until the 6/28/09 sample event.

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml				124	28	320	0	1

Station 9
Peter's Run- 8 Gloucester Avenue
Notes:

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml	1300	85	99	1170	4300	3300	66	218

Station 10
Peter's Run- Retention Pond
Notes:

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml	242	96	138	240	60	580	12	188

Station 11
West Lake Drive & Glenmore Avenue
Notes: 8/19/2009- No Sample-no flow
6/28/210- No Sample-no flow
8/9/2010- No Sample-no flow
12/1/2010- No Sample-no flow

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml	no sample	33	340	no sample	no sample	11000	no sample	82

Highlighted samples indicate samples saved for DNA analysis.

Station 12
Diamond Cove Marina
Notes: 8/9/2010- No Sample-no flow

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml	2	37	17	58	no sample	240	19	39

Station 13
Drum Property
Notes: 12/1/2010- No Sample-no flow from creek. Pipe in marina under water.

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml	22	380	160	1330	190	550	no sample	148

Station 14
CR 77-Uihlen's Marina
Notes: 11/30/09- No Sample- tidal exchange in pipe/pipe under water.
4/20/10- No Sample- tidal exchange in pipe/pipe under water.
6/28/10- No Sample- tidal exchange in pipe/pipe under water.
8/9/10- No Sample- tidal exchange in pipe/pipe under water.
11/4/10- No Sample- tidal exchange in pipe/pipe under water.
12/1/10- No Sample- tidal exchange in pipe/pipe under water.
3/11/11- No Sample- tidal exchange in pipe/pipe under water.

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml	50	no sample	no sample	no sample	no sample	no sample	no sample	no sample

Highlighted samples indicate samples saved for DNA analysis.

Station 15A
Pipe south of Reed Pond (East Lake Drive, East Side)
Notes: 12/1/10: Pipe was not added to sample list until 12/1/10. No Sample-no flow.

Date	8/19/09	11/30/09	4/28/10	6/28/10	8/9/10	11/4/10	12/1/10	3/11/11	4/1/11
Condition	dry	dry	wet	Dry	dry	wet	wet	wet	wet
MPN/100ml							No sample	25	75

Station 15B
Pipe south of Reed Pond (Outfall)
Notes: 12/1/10: Pipe was not added to sample list until 12/1/10. No Sample-no flow.

Date	8/19/09	11/30/09	4/28/10	6/28/10	8/9/10	11/4/10	12/1/10	3/11/11	4/1/11
Condition	dry	dry	wet	Dry	dry	wet	wet	wet	wet
MPN/100ml							No sample	53	35

COLIFORM DISCUSSION

The largest coliform numbers were observed during summer and fall events. All coliform numbers that were above 1,000 (18 samples) came from samples obtained during these 2 seasons. Additionally, the next 9 highest samples, between 550 and 950, all came from fall sampling events. The highest count during a spring event was 540, and 232 for a winter sample.

The use of detention ponds to help alleviate bacterial flush into Lake Montauk can be evidenced by the detention pond located at West Lake Drive and Gloucester.

Station 9
Peter's Run- 8 Gloucester Avenue
Notes:

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	Wet	dry	dry	wet	wet	wet
MPN/100ml	1300	85	99	1170	4300	3300	66	218

Station 10
Peter's Run- Retention Pond
Notes:

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	Wet	dry	dry	wet	wet	wet
MPN/100ml	242	96	138	240	60	580	12	188

In most cases the coliform level dropped significantly from water taken from approximately 225 feet away.

Rain fall and lack of rain fall can have a large impact on the water entering the Lake. For the summer of 2010 (June 20th-Sepetember 20th) for instance, there was a total of 5.95" (June: 0.15"; July: 2.05", August: 0.86", September: 2.89"). The total rainfall for the same period this past year, 2011, was 19.28". The past 10 years the average for the summer season was 9.98" of rain (2000:8.31", 2001: 6.13", 2002: 4.22", 2003:8.33", 2004: 14.60", 2005: 3.68", 2006: 19.07", 2007: 8.02", 2008: 14.43", 2009: 13.00")The smaller amount of rainfall in 2010 was evidenced by the lack of any stream flow in the channel at several stations during 2010. Stations 5 and 7, had little to no flow during the June and August sampling events of 2010. The section on flow discusses in more detail the flow rates at the stations.
Rain fall for sampling events:

August 19, 2009: Dry sampling event.
Total rain for July 2009: 7.4"
Total rain for August 2009: 2.37"
Rainfalls within past month: 8/13:0.15"; 8/12:0.02; 8/2:0.09; 7/31:0.6; 7/30:0.05; 7/26:0.08; 7/25:0.06; 7/24: 0.91; 7/23:2.04;7/21:0.92

November 30, 2009: Dry sampling event.
Total rain for November 2009: 2.57"

11/27:0.42; 11/25:.04, 11/23:0.1;
11/20:0.68;11/15:0.01;11/14:0.4;11/13:0.66;11/5:0.1;11/4:0.04;11/2:0.01;11/1:0.04

April 28, 2010: Wet sampling event.
Total rain for April 2010: 2.21”
4/27:.04, 4/26:0.74; 4/25:0.30-March30:3.66;29:2.49;28:0.02

June 28, 2010: Dry sampling event.
Total rain for June 2010: 1.47”
6/23:0.03; 6/17: 0.02; 6/13:0.14; 6/12:0.16; 6/10:0.23;6/9:0.41;6/1:0.36

August 9, 2010: Dry sampling event.
Total rain for July 2010: 2.05”
7/29:0.2; 7/25:0.43;7/24:0.04;7/23:0.15;7/21:0.3;7/19:0.15;7/14:0.37;7/13:0.46;7/10:0.13

November 4, 2010: Wet sampling event.
Total rain for October 2010: 3.95” 10/27:1.0; 11/4:1.07

December 1, 2010: Wet sampling event.
Total rain for November 2010: 3.15”
12/1:0.35

March 11, 2011: Wet sampling event.
Total rain for February 2011: 3.30”
3/11:0.66;3/7:0.34;3/6:0.04; 2/28:0.21;2/27:0.09;2/25:1.7;2/21:0.18;

April 1, 2011. Wet sampling event.
Total rain for March 2011: 2.18”
3/31:0.48; 4/1:0.35.

November 4, 2010 rain event had the most significant numbers of bacteria. This sample event took place during a 1” rain event (1.07”), and came after a 1.0” rainfall event the week before (October 27).

24-hour Streamflow and coliform study

As part of the watershed plan 3 stations were chosen to be monitored during wet event over a 24-hour period .

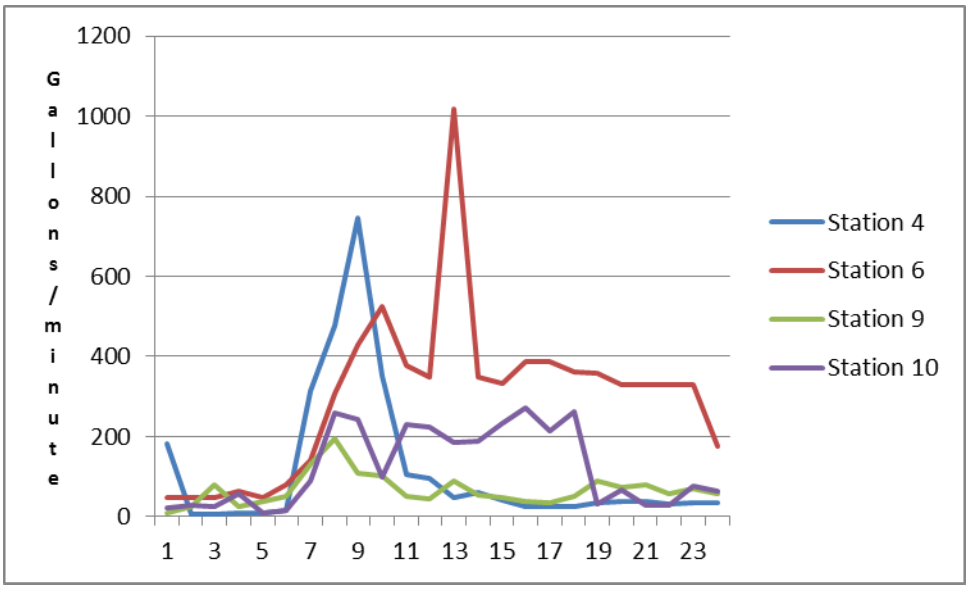
The three streamlets were chosen based on data collected during the flow analysis and the data obtained during coliform analysis. Coincidently the stations chosen were from the western, eastern and southern portions of the lake. Based on the coliform and streamflow data the following stations were determined to be part of the 24 hour study:

Station 4, along the eastern part of Lake Montauk.

Station 6, along the southern part of Lake Montauk.

Stations 9&10 (Peter's Run), along the western part of Lake Montauk.

The 24-Hour survey was conducted from June 22 to June 23 of 2011.



Station	Time	Flowmeter Average velocity	Diameter of Pipe	Height of water	Ratio of Height/Diameter	Column C (from Appendix A, Global Water Manual	Filled Area: Column C X (Diameter X 2)	Volumetric Flow: Filled Area X Ave Velocity
4	12:20	1.6	12	0.5	0.04	0.0105	0.252	0

4	13:00	1.1	12	0.5	0.04	0.0105	0.252	0.0
4	14:16	1.1	12	0.5	0.04	0.0105	0.252	0.0
4	15:00	2	12	0.5	0.04	0.0105	0.252	
4	16:00	1.7	12	0.5	0.04	0.0105	0.252	0.0
4	17:00	1.7	12	0.75	0.06	0.0192	0.4608	0.0
4	18:00	3.7	12	3.5	0.29	0.189	4.536	0
4	19:00	4.7	12	4	0.33	0.2266	5.4384	1.0
4	20:00	5	12	5.25	0.44	0.3328	7.9872	
4	21:00	4.6	12	3.25	0.27	0.1711	4.1064	0.1
4	22:03	3.9	12	1.5	0.13	0.06	1.44	
4	23:00	3.6	12	1.5	0.13	0.06	1.44	
4	0:00	3.6	12	1	0.08	0.0294	0.7056	0.1
4	1:00	3.2	12	1.25	0.10	0.0409	0.9816	0.1
4	2:00	3.2	12	1	0.08	0.0294	0.7056	0.0
4	3:04	3	12	0.75	0.06	0.0192	0.4608	0
4	4:00	3	12	0.75	0.06	0.0192	0.4608	0
4	5:00	2.9	12	0.75	0.06	0.0192	0.4608	0.0
4	6:00	2.7	12	1	0.08	0.0294	0.7056	0.0
4	7:00	2.9	12	1	0.08	0.0294	0.7056	0.0
4	8:02	2.8	12	1	0.08	0.0294	0.7056	0.0
4	9:01	2.5	12	1	0.08	0.0294	0.7056	0
4	10:00	2.7	12	1	0.08	0.0294	0.7056	0.0
4	11:15	2.6	12	1	0.08	0.0294	0.7056	0.0
6	12:12	0.3	14	6.5	0.46	0.3527	9.8756	0.1
6	13:07	0.3	14	6.5	0.46	0.3527	9.8756	0.1
6	14:12	0.3	14	6.5	0.46	0.3527	9.8756	0.1
6	15:03	0.4	14	6.5	0.46	0.3527	9.8756	0.1
6	16:08	0.3	14	6.5	0.46	0.3527	9.8756	0.1
6	17:07	0.5	14	6.5	0.46	0.3527	9.8756	0.1
6	18:07	0.7	14	7.75	0.55	0.4426	12.3928	0.2
6	19:05	1.2	14	9.5	0.68	0.5687	15.9236	0.6
6	20:07	1.6	14	10	0.71	0.5964	16.6992	0.9
6	21:07	1.7	14	11.5	0.82	0.6893	19.3004	1.1
6	22:10	1.3	14	10.75	0.77	0.6489	18.1692	0.8
6	23:06	1.2	14	10.75	0.77	0.6489	18.1692	0.7
6	0:05	3.5	14	10.75	0.77	0.6489	18.1692	2.2
6	1:06	1.2	14	10.75	0.77	0.6489	18.1692	0.7

6	2:06	1.1	14	11.25	0.80	0.6736	18.8608	0.
6	3:08	1.3	14	11	0.79	0.6655	18.634	0.
6	4:07	1.3	14	11	0.79	0.6655	18.634	0.
6	5:06	1.2	14	11.25	0.80	0.6736	18.8608	0.
6	6:06	1.2	14	11	0.79	0.6655	18.634	0
6	7:10	1.1	14	11	0.79	0.6655	18.634	0.
6	8:10	1.1	14	11	0.79	0.6655	18.634	0.
6	9:08	1.1	14	11	0.79	0.6655	18.634	0.
6	10:06	1.1	14	11	0.79	0.6655	18.634	0.
6	11:08	1.1	14	6.5	0.46	0.3527	9.8756	0.
9	12:00	0.3	24	3.5	0.15	0.0739	3.5472	0.
9	13:19	0.8	24	3.5	0.15	0.0739	3.5472	0.
9	14:00	2.4	24	3.5	0.15	0.0739	3.5472	0.
9	15:15	0.8	24	3.5	0.15	0.0739	3.5472	0.
9	16:25	0.8	24	4.5	0.19	0.1039	4.9872	0.
9	17:17	1.2	24	4.25	0.18	0.0961	4.6128	0.
9	18:18	2.4	24	5	0.21	0.1199	5.7552	0.
9	19:16	3.6	24	5	0.21	0.1199	5.7552	0.
9	20:12	2.3	24	4.5	0.19	0.1039	4.9872	0.
9	21:22	2	24	4.75	0.20	0.1118	5.3664	0
9	22:20	1.9	24	3	0.13	0.06	2.88	
9	23:15	1.7	24	3	0.13	0.06	2.88	
9	0:13	1.9	24	4.5	0.19	0.1039	4.9872	0.
9	1:13	1.6	24	3.5	0.15	0.0739	3.5472	0.
9	2:15	1.6	24	3.25	0.14	0.0668	3.2064	0.
9	3:18	1.3	24	3.25	0.14	0.0668	3.2064	0.
9	4:16	1.3	24	3	0.13	0.06	2.88	
9	5:12	1.7	24	3.25	0.14	0.0668	3.2064	0.
9	6:13	1.9	24	4.5	0.19	0.1039	4.9872	0.
9	7:16	1.8	24	4	0.17	0.0885	4.248	0
9	8:16	1.7	24	4.5	0.19	0.1039	4.9872	0.
9	9:16	1.7	24	3.5	0.15	0.0739	3.5472	0.
9	10:14	1.5	24	4.5	0.19	0.1039	4.9872	0.
9	11:03	1.7	24	3.5	0.15	0.0739	3.5472	0.
10	12:05	0.7	24	3.25	0.14	0.0668	3.2064	0.
10	13:16	0.9	24	3.25	0.14	0.0668	3.2064	0.
10	14:05	0.8	24	3.25	0.14	0.0668	3.2064	0.

10	15:10	1.9	24	3.25	0.14	0.0668	3.2064	0.
10	16:18	0.2	24	4.75	0.20	0.1118	5.3664	0.
10	17:20	0.4	24	4	0.17	0.0885	4.248	0
10	18:21	1.3	24	6	0.25	0.1535	7.368	0.
10	19:20	2.9	24	7.25	0.30	0.1982	9.5136	0.
10	20:18	2.4	24	8	0.33	0.2266	10.8768	0.
10	21:17	1.5	24	5.75	0.24	0.1449	6.9552	0.
10	22:28	2.6	24	7.25	0.30	0.1982	9.5136	0.
10	23:17	2.2	24	8	0.33	0.2266	10.8768	0.
10	0:19	1.9	24	7.75	0.32	0.2167	10.4016	0.
10	1:17	2.1	24	7.25	0.30	0.1982	9.5136	0.
10	2:22	2.3	24	8	0.33	0.2266	10.8768	0.
10	3:22	2.8	24	7.75	0.32	0.2167	10.4016	0.
10	4:25	2.4	24	7.25	0.30	0.1982	9.5136	0.
10	5:16	2.8	24	7.5	0.31	0.2074	9.9552	0.
10	6:17	0.9	24	3.75	0.16	0.0811	3.8928	0.
10	7:21	1.8	24	3.75	0.16	0.0811	3.8928	0.
10	8:21	1.1	24	3	0.13	0.06	2.88	
10	9:19	1.3	24	2.75	0.11	0.047	2.256	0
10	10:19	2.5	24	3.25	0.14	0.0668	3.2064	
10	11:00	1.9	24	3.5	0.15	0.0739	3.5472	0.

DNA

Various investigations conducted on Long Island (LI) such as the Nationwide Urban Runoff Program (NURP) (Koppelman and Tannenbaum, 1982), the Long Island 208 Waste Treatment Management Plan (Koppelman, 1978), the Brown Tide Comprehensive Assessment and Management Plan (Suffolk County, 1992), The Peconic Estuary Program Action Plan (Suffolk County, 1994), The Comprehensive Conservation and Management Plans of the Peconic Estuary Program and the LI Sound Study, and the LI South Shore Estuary Reserve Draft Comprehensive Management Plan have all contributed to a better understanding of the impacts of nonpoint source pollution upon surface water quality on Long Island. All of these studies have shown that nonpoint source pollution is the primary cause of reduced water quality in LI estuaries. One of the major components that lead to pollution of Long Island waters is coliform bacteria. Coliforms are an indicator of the possible presence of pathogenic organisms and are used by various agencies to determine water quality and to protect public health. The use of coliforms as a water quality standard has been in use since the late 1800s and has provided a good tool in protecting public health. Monitoring of bacterial counts in estuarine waters following storms shows that stormwater runoff accounted for at least 93% of the total and fecal coliform loading. The water quality standards applicable to shellfish growing areas are the highest standards developed for marine waters in New York State. Fecal coliforms are facultative anaerobic bacilli that ferment lactose with the production of gas within 48 hours at a temperature of 44.5^0 C. A prevalent and well-studied member of this group is *Escherichia coli* (*E. coli*).

Water quality is an important factor in Long Island's estuaries where extensive commercial and recreational fisheries exist for both finfish and shellfish. Shellfishing is particularly an important economic and cultural resource on LI, worth many millions of dollars in most years. Good surface water quality on Long Island, and the perception of good water quality, is also extremely important to the area's large and economically important tourist industry also worth millions of dollars annually.

Fecal coliform contamination from nonpoint sources has been recognized as a major threat to surface water quality (Geldrich, et al., 1968; Faust, 1976; Kay, et al., 1994, and others) and can lead to closure of surface waters for purposes of recreation and commercial shellfish harvest. Such closures can have serious negative impacts on the economy of local communities.

Often the most challenging aspect of mitigating nonpoint source pollution (NPS) is determining the exact source of pollutants, and then formulating the best techniques of controlling them. One of the sources generally regarded to be a major cause of shellfish closures has been human wastes coming from improperly functioning On-Site-Waste-Disposal-Systems (OSWDS) (Kator and Rhodes, 1993). Human wastes from boats have also been responsible for shellfish closures. While many studies have indicated that OSWDS (Reneau and Pettry, 1975; Hayes, et al., 1990, and others) and marine heads can be a source of potential contamination, other potential nonpoint sources of bacteria have been identified as run-off from agricultural areas (Faust and Goff, 1977), wild animals (Leonard, et al., 1989) and seagulls (Levesque, et al., 1993), as well as other waterbirds and domestic animals. The most successful remediation strategy is one that recognizes and mitigates each unique source, in itself, as each one may require a different type of remediation technique and different Best Management Practice (BMP). The more dispersed

wastes of domestic animals and wildlife are considered nonpoint sources of pollution because they originate in many locations and are transported to surface waters and to groundwater at many different points. The magnitude and character of the animal waste pollution problem depends upon several factors (Koppelman and Tannenbaum, 1982); however, the present study will focus on the species type providing the waste source. NPS problems in coastal communities are attributable to coliforms from humans as well as many species of waterfowl and local wild and domestic mammalian sources.

It is presently difficult to determine the exact source of bacteria found in contaminated areas. Consequently, most coliform mitigation strategies in use today are based on Best Management Practices directed at controlling the stormwater flows themselves, without regard to the specific animals or animal groups contributing to high levels of bacteria in those flows. The utility of the indicator organism concept is limited by its inability to track organisms associated with fecal contamination to their potential sources. Each year millions of dollars are spent on fecal and total coliform assays to determine the extent of bacterial and fecal pollution of aquatic environments and to satisfy increasingly rigid regulatory requirements concerning the microbiological quality of water. Knowing the sources rather than just monitoring the level of microbial pollution of surface waters would enable water quality professionals and watershed managers to better design and implement programs to control pollution and protect source water based on the source animals.

There is evidence now accruing that shows that *E. coli* bacteria found in the gastrointestinal systems of different species of animals and animal groups vary in genetic identity, and that these differences can be measured (Dombek, et al., 2000; Parveen, et al., 1997; Carson, et al., 2001; Samadpour and Chechowitz, 1995; Simmons and Herbein, 1997; Simmons, et al., 2000). The fecal bacteria in animals (including humans) are very much genetically the same. There are unique differences, but the differences are only in a small percentage of an organism's total DNA. The key to using molecular methods to differentiate between bacterial sources is finding these differences against a large background of similarity. It is thought that the distinctions between fecal bacteria from different animals (including humans) occur because the intestinal environments (selective pressures) are not the same, and fecal bacteria develop with detectable differences that can be related to sources. These genetic differences in different strains of *E. coli* may be able to be used to identify the animal species or animal group specific for that strain of *E. coli*. Populations of *E. coli*, like other bacteria, are composed essentially of a mixture of strains of clonal descent. Due to the relatively low rates of recombination, these clones remain more or less independent (Selander, et al. 1987). These clones or strains of bacteria, are uniquely adapted to their own specific environments. As a result, the *E. coli* strain that inhabits the intestines of one species should be genetically different from the strain that might inhabit another.

Researchers have recently begun to develop a variety of techniques in an attempt to identify sources of bacteria in surface waters. These techniques are generally called Bacterial Source Tracking (BST) or microbial source tracking and are divided between molecular methods (genotype), biochemical methods (phenotype) and chemical methods. The principal difference between methods is the subtyping methodologies. Molecular methods include pulsed field gel electrophoresis (PFGE), ribotyping (r-RNA) and polymerase chain reaction (PCR). Biochemical

methods include antibiotic resistance analysis (ARA), F-specific coliphage analysis, fatty acid analysis, nutritional patterns for carbon and nitrogen, and fecal bacteria ratios. Chemical methods include optical brightener detection, and caffeine detection. Molecular methods are all referred to as "DNA fingerprinting" and are based on the unique genetic makeup of different strains, or subspecies, of fecal bacteria. Biochemical methods are based on an effect of an organism's genes that actively produce a biochemical substance. The type and quantity of these substances produces what is actually measured. Chemical methods are based on finding chemical compounds that are associated with human wastewaters, and would be restricted to determining if sources of pollution were human or not. Molecular and biochemical methods of BST are dependent on building an initial database of profiles from a range of known sources, determining the differences/similarities between these known sources and then comparing unknowns isolated from contaminated waters to the database of known sources.

All of these various techniques show promise in helping to identify input sources of bacteria at some level. Some may be able to provide evidence to differentiate between human and non-human sources. Some may be able to provide evidence to identify large classes of sources such as human, livestock or wild animals. Still others may be able to provide evidence to identify for the specific animal host species of the bacteria (e.g. human, dog, horse, raccoon, deer, etc.)

Researchers are beginning to verify, with different techniques used and at various levels, the differences in E. coli (and other fecal bacteria) isolated from various host animals. Dombek, et al. (2000) found that rep-PCR DNA fingerprinting is a promising method for determining the source groups of E. coli. Paveen, et al (1997) found that multiple-antibiotic-resistance profiles could be used to differentiate between point source (human) and nonpoint source (non-human) sources of pollution. Paveen, et al. (1999) used ribotyping to differentiate between human and non-human source fecal pollution. Carson, et al. (2001) was able to distinguish E. coli ribotype patterns from human and seven individual non-human hosts. Samadpour and Chechowitz (1995) also used ribotyping to differentiate E. coli between humans and several non-human sources. Hagedorn, et al. (1999) used antibiotic resistance patterns of fecal streptococci to differentiate between waterfowl, humans, deer and beef cows. Simmons and Herbein (1997) and Simmons, et al. (2000) have used pulsed field gel electrophoresis to differentiate *E. coli* isolated from humans and some wildlife species in Virginia. Preliminary analysis by Hasbrouck (2000) of PFGE profiles of *E. coli* isolates from various animals on Eastern LI, is showing banding differences between some of those animals. Wiggins, et al (1999) using antibiotic-resistance analysis of fecal streptococci found differences from various source animals. Bernhard and Field (2000) have described a new PCR-based method for distinguishing human and cow fecal contamination based on *Bifidobacterium* and the *Bacteroides-Prevotella* group.

The field of BST is just beginning and no single method has arisen as the "best" method. BST development is so new that no research comparing BST methods or identifying their relative strengths and weaknesses has yet to be completed. Additionally, methods and techniques are being refined and developed as the process develops and new techniques are likely to be added into the mix. As the field of BST develops and expands, it is important for researchers and managers to determine not only which techniques work best under what conditions (or what questions can be answered by each technique) and for what suite of problems, but also how the

different techniques can be used in conjunction with each other to solve problems, as well as to compare results between techniques. As these studies develop, it is important to identify the usefulness of each BST technique over a range of applications so that each can be identified as a specific tool to be used as appropriate and where it best fits.

It is likely that molecular techniques will generate differences at a finer scale (specific animal host) whereas biochemical and chemical techniques will yield faster results but for larger groups of animals (humans, non-human).

PFGE is starting to show promising results in identifying specific host species for *E. coli* found in surface waters. The Cornell P.I. is beginning to produce localized BST results using PFGE. Additionally, Simmons and Herbein (1997) and Simmons, et al. (2000) have had localized BST results using PFGE. Hagedorn, et al. (1999) found that the potential to identify individual strains of different bacteria by genetic profiles indicates that molecular approaches may be suitable for source differentiation of fecal bacteria. However, several issues still need to be examined in order to refine PFGE as a viable tool for use in BST.

As a means of identifying individual coliform sources and developing a BST technique, a preliminary DNA library, specific to eastern Long Island, is being developed by the Cornell Investigator based on *E. coli* isolated from the scat of animals (including humans) which live in association with estuaries of eastern Long Island. This limited DNA library consists of "genetic fingerprints" PFGE of *E. coli* isolates. However, this *E. coli* DNA library needs to be developed, refined, expanded and statistically tested for its use as a BST tool to catalogue and identify bacteria sources found in impacted surface water bodies and in stormwater flows. PFGE has been used to resolve bacterial genomes ranging from microorganisms responsible for nosocomial infections (Allardet-Servant, et al., 1989) and *Vibrio* species colonizing oysters (Buchrieser, et al., 1995) to coliforms isolated from water distribution systems (Edberg, et al., 1994). We are exploring techniques to extend and develop the use of this method as a BST tool for identifying coliform sources in impacted embayments within coastal areas.

Through the limited work being done on developing BST by various researchers using different molecular, biochemical or chemical methods, several issues arise that need to be addressed. Work needs to be continued on clonal differences in order to continue to develop and refine BST as an effective tool in addressing NPS.

All of the molecular BST methods that are being developed rely on building a DNA library of source isolates against which to compare unknown samples. Once the known source library has been developed at a sufficiently large size, and correct source identifications are sufficiently high for the desired purpose, then the task of comparing fecal isolates from unknown origins against the library to obtain source identification can be accomplished.

Some researchers have found that correct classification rates to be higher when the numbers of groupings that the isolates are put into are reduced. For instance when Hagedorn, et al (1999) using ARA, pooled all animal sources into one category of non-human to contrast against human source, the rates of correct classification improved for both the known-source database and the unknown-source isolates from the watershed. Carson, et al. (2001) was able to distinguish *E.coli*

ribotype patterns from human and seven non-human hosts. However, classification accuracy was best when the analysis was limited to three host species. Parveen, et al. (1997) suggest that further research is needed to associate specific clusters with specific animal species.

It may also not always be desirable to source track coliforms to individual specific species hosts. Hagedorn, et al (1999) and Harwood, et al (2000) found that regulatory officials in some areas are satisfied if results could determine if human sources were present and then divide the animal sources between livestock (or domestic animals) and wildlife. Also, Samadpour and Chechowitz (1995) found a lack of landowner cooperation if the goal was to identify specific species rather than groups of species.

Station Data & Discussion

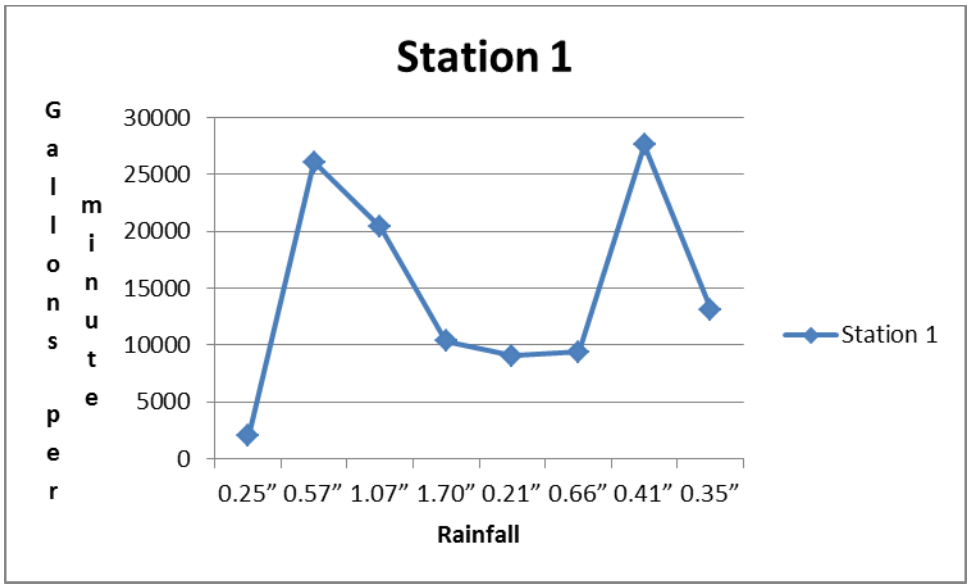
Station 1: Reed Pond Outflow

Address: East Lake Drive
Location & Pipe Description: 36 in pipe discharging water from Big Reed Pond. There is a stream channel located below the pipe.

This station is located at culvert on East Lake Drive, approximately 1500 feet south of Montauk Airport. The culvert is metal, 36 inches in diameter and connects Little Reed Pond to Lake Montauk. Readings for stream flow, coliform enumeration and bacterial source tracking were all taken from the western end of the pipe, where the pipe discharges toward the lake.

Streamflow Data:

2014.564	26086.9	20387.69	10349.12	9050.352	9401.301	27613.49	13149.28
0.25”	0.57”	1.07”	1.70”	0.21”	0.66”	0.41”	0.35”
5/12/2010	10/6/2010	11/4/2010	2/25/2010	2/28/2010	3/11/2011	3/16/2011	4/1/2011



Coliform:

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml	11	24	254	74	104	490	0	232

DNA:

CORNELL COOPERATIVE EXTENSION-MARINE
DNA ANALYSIS RESULTS
PREDICTED SOURCE BY ISOLATE
LAKE MONTAUK STATION 1-WET
(REED POND CULVERT)

Date	Predicted Source by Isolate
4/28/10	Not Human
4/28/10	Bird-Mute Swan
4/28/10	No Match
4/28/10	Not Human
4/28/10	Bird (Mallard Duck, Cormorant)
4/28/10	Possible Bird-Black Duck
4/28/10	Possible Bird-Black Duck
4/28/10	Not Human, Not Bird
4/28/10	Not Human
4/28/10	Not Human

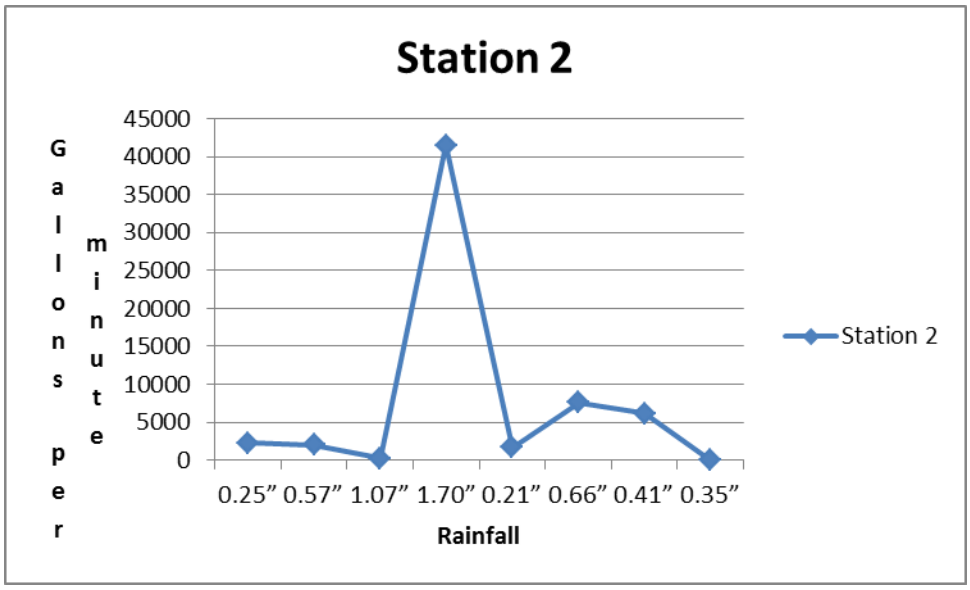
Station 2: Bond Property

Address: East Lake Drive

Location & Pipe Description: Pipe is located in a headwall. Retention Pond constructed June-July, 2010.

Streamflow Data:

2	2239.734	1993.478	219.9267	41514.76	1692.053	7614.239	6125.129	0
Rainfall	0.25”	0.57”	1.07”	1.70”	0.21”	0.66”	0.41”	0.35”
Station	5/12/2010	10/6/2010	11/4/2010	2/25/2010	2/28/2010	3/11/2011	3/16/2011	4/1/2011



Coliform:
Notes: 11/30/09: No Sample- Pipe under water
6/28/09: No Sample- New retention pond under construction

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml	3900	no sample	87	no \	360	950	70	43

DNA:

CORNELL COOPERATIVE EXTENSION-MARINE
DNA ANALYSIS RESULTS
PREDICTED SOURCE BY ISOLATE
LAKE MONTAUK STATION 2-WET
(BOND PROPERTY)

Date	Predicted Source by Isolate
11/4/10	Not Human, Possible Wildlife (Raccoon, Red Fox)
11/4/10	Not Human, Possible Bird (Mallard Duck)
11/4/10	Not Human, Possible Wildlife (Red Fox, Raccoon)
11/4/10	Not Human

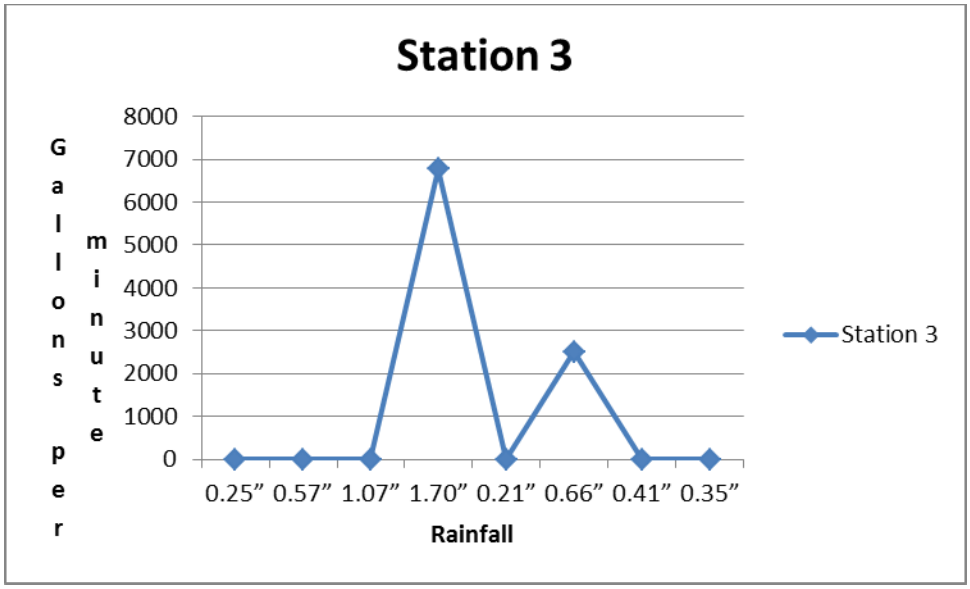
11/4/10	Domestic-Dog
11/4/10	Not Human, Possible Domestic (Dog)
11/4/10	Domestic-Dog
11/4/10	Probable Wildlife-Muskrat
11/4/10	Not Human-Possible Bird

Station 3:

Address: 105 East Lake Drive
Location & Pipe Description: The pipe diameter was 12 inches. Channel present.

Streamflow Data:

3	0	0	0	6768.213	0	2504.148	0	0
Rainfall	0.25”	0.57”	1.07”	1.70”	0.21”	0.66”	0.41”	0.35”
Station	5/12/2010	10/6/2010	11/4/2010	2/25/2010	2/28/2010	3/11/2011	3/16/2011	4/1/2011



Coliform:

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml	1300	610	268	1350	1700	840	99	106

DNA:

CORNELL COOPERATIVE EXTENSION-MARINE
DNA ANALYSIS RESULTS
PREDICTED SOURCE BY ISOLATE
LAKE MONTAUK STATION 3-DRY
(105 EAST LAKE DRIVE)

Date	Predicted Source by Isolate
8/9/10	Possible Wildlife (Raccoon)
8/9/10	Not Human (Possible Dog)

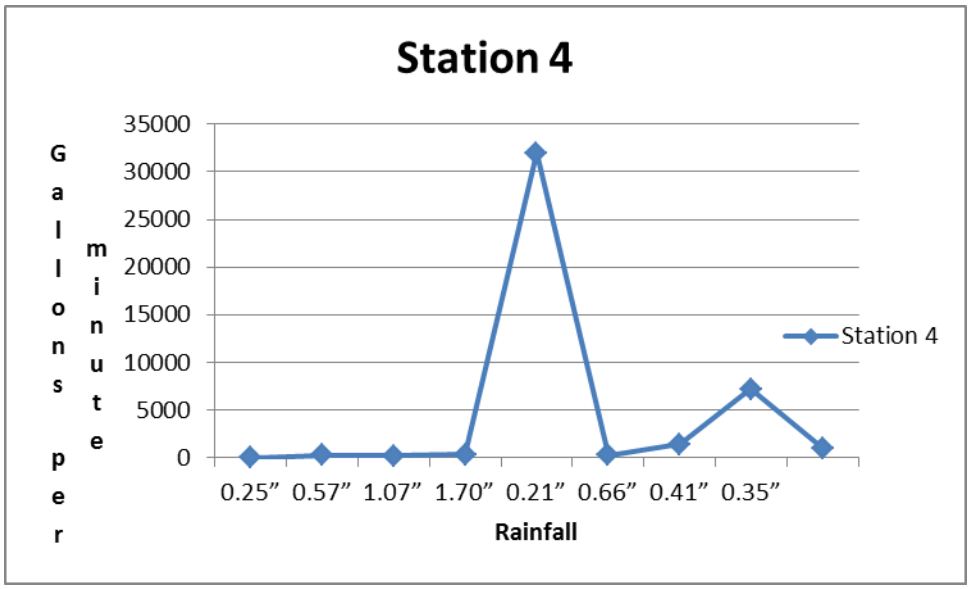
8/9/10	Bird-Possible Canada Goose, Cormorant
8/9/10	Possible Wildlife-Red Fox
8/9/10	Possible Wildlife-Raccoon

Station 4:

Address: 61&67 East Lake Drive
Location & Pipe Description: Pipe diameter is 12 inches.

Streamflow Data:

4	260.1419	206.8209	316.6944	31986.79	237.5208	1361.786	7191.226	981.7528
Rainfall	0.25”	0.57”	1.07”	1.70”	0.21”	0.66”	0.41”	0.35”
Station	5/12/2010	10/6/2010	11/4/2010	2/25/2010	2/28/2010	3/11/2011	3/16/2011	4/1/2011



Coliform:

Notes: 8/9/2010: No sample-no flow

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml	10800	62	74	5300	no sample	950	700	26

DNA:

CORNELL COOPERATIVE EXTENSION-MARINE
DNA ANALYSIS RESULTS
PREDICTED SOURCE BY ISOLATE
LAKE MONTAUK STATION 4-WET
(61&67 EAST LAKE DRIVE)

Date	Predicted Source by Isolate

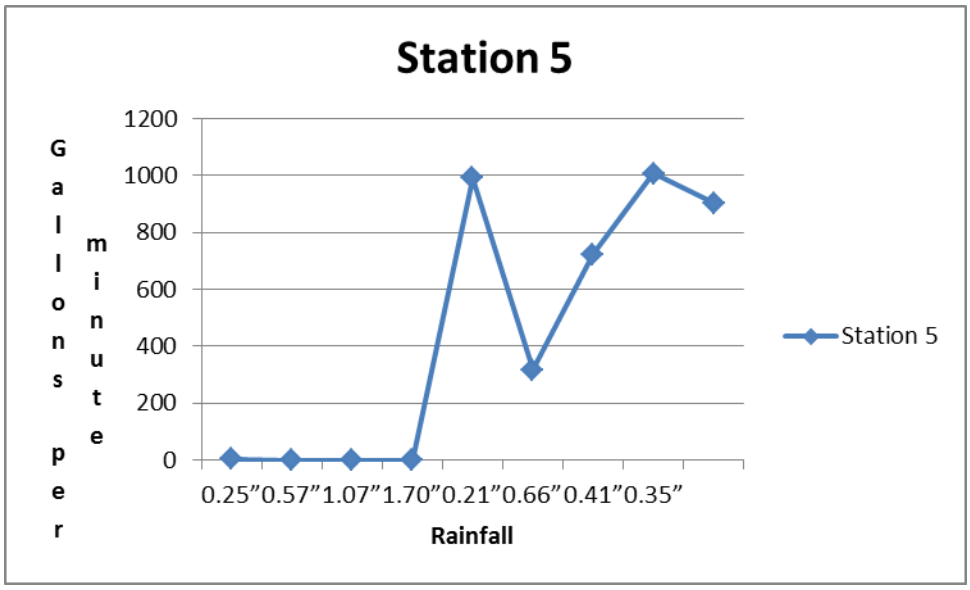
12/1/10	Probable Bird-Canada Goose
12/1/10	Possible Wildlife-Raccoon
12/1/10	Possible Wildlife-Deer
12/1/10	Bird-Canada Goose

Station 5: Amsterdam Park

Address: Drains intersection of East Lake Drive and Montauk Highway
Location & Pipe Description: Pipe diameter is 24 inches. No bottom lip on pipe, it's cracked. Pipes and channels on both sides of the road.

Streamflow Data:

5	0	0	0	992.0938	316.6944	722.5804	1007.39	904.8413
Rainfall	0.25"	0.57"	1.07"	1.70"	0.21"	0.66"	0.41"	0.35"
Station	5/12/2010	10/6/2010	11/4/2010	2/25/2010	2/28/2010	3/11/2011	3/16/2011	4/1/2011



Coliform:

Notes: 8/19/2009: Sample taken from broken pipe on East Lake Drive
11/30/2009: Sample taken from broken pipe on East Lake Drive
8/9/2010: No sample-no flow

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml	125	76	21	12	no sample	8400	11	82

DNA:

CORNELL COOPERATIVE EXTENSION-MARINE
DNA ANALYSIS RESULTS
PREDICTED SOURCE BY ISOLATE
LAKE MONTAUK STATION 5-WET

(AMSTERDAM)

Date	Predicted Source by Isolate
11/4/10	Wildlife-Raccoon
11/4/10	Wildlife-Raccoon
11/4/10	Not Human, Not Bird
11/4/10	Wildlife-Raccoon
11/4/10	Wildlife-Raccoon
11/4/10	Not Human, Not Bird

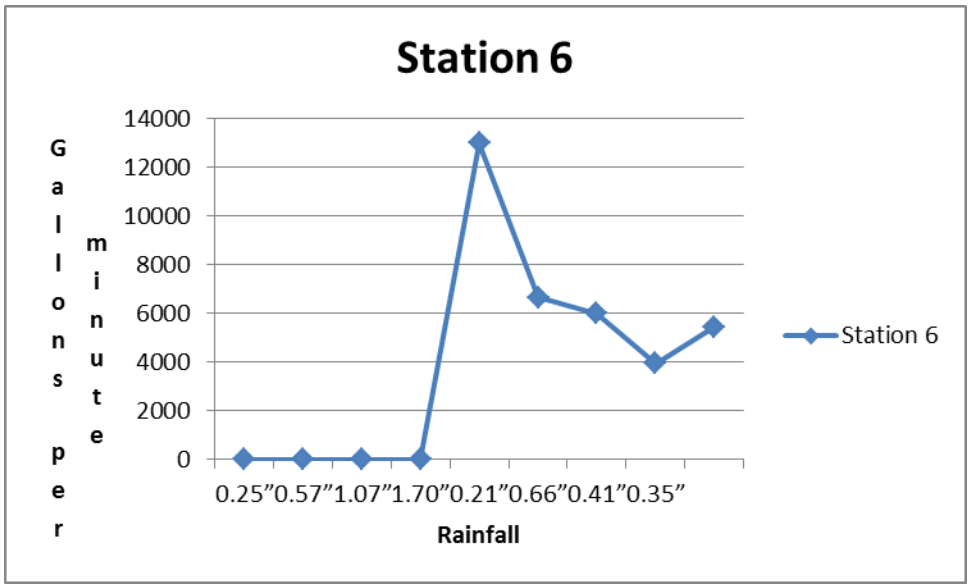
Station 6: Ocean Side Drain

Address: Benson Dr

Location & Pipe Description: Two pipes found. One discharges directly into channel and the other is raised above the channel. The pipe that discharges into the channel was underwater and flowing. The pipe raised above the channel was dry. Water flows through wetland.

Streamflow Data:

6	0	0	0	12991.51	6641.535	6003.622	3948.124	5437.845
Rainfall	0.25”	0.57”	1.07”	1.70”	0.21”	0.66”	0.41”	0.35”
Station	5/12/2010	10/6/2010	11/4/2010	2/25/2010	2/28/2010	3/11/2011	3/16/2011	4/1/2011



Coliform:

Notes: 8/19/2009: Sample taken from culvert under Route 27
11/30/2009: Sample taken from culvert under Route 27

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml	1020	710	540	14500	1800	3200	36	164

DNA:

CORNELL COOPERATIVE EXTENSION-MARINE
DNA ANALYSIS RESULTS
PREDICTED SOURCE BY ISOLATE
LAKE MONTSUK STATION 6-DRY

(BENSON DRIVE)

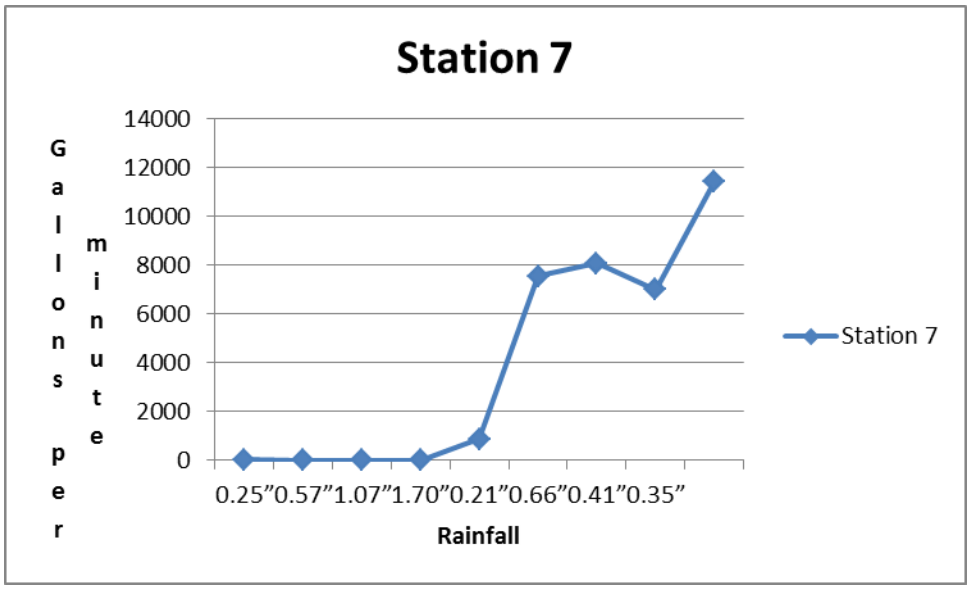
Date	Predicted Source by Isolate
6/28/09	Not Human, Possible Wildlife (Red Fox)
6/28/09	Not Human
6/28/09	Human
6/28/09	Probable Bird (Herring Gull or Mute Swan)
6/28/09	Wildlife-Muskrat
6/28/09	Bird-Herring Gull, Greater Black-Backed Gull
6/28/09	Human

Station 7:

Address: 64 Old West Lake Drive
Location & Pipe Description: Have to lift cover to access pipe. Pipe approximately 16 inches. There is a channel across the street, but there is no pipe apparent.

Streamflow Data:

7	0	0	0	852.7052	7540.344	8078.94	7001.748	11445.17
Rainfall	0.25”	0.57”	1.07”	1.70”	0.21”	0.66”	0.41”	0.35”
Station	5/12/2010	10/6/2010	11/4/2010	2/25/2010	2/28/2010	3/11/2011	3/16/2011	4/1/2011



Coliform:

Notes: 6/28/2010: No Sample-no flow
8/9/2010: No Sample-no flow

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml	380	79	510	no sample	no sample	14300	48	214

DNA:

CORNELL COOPERATIVE EXTENSION-MARINE
DNA ANALYSIS RESULTS
PREDICTED SOURCE BY ISOLATE
LAKE MONTAUK STATION 7-WET

(#64 OLD WEST LAKE)

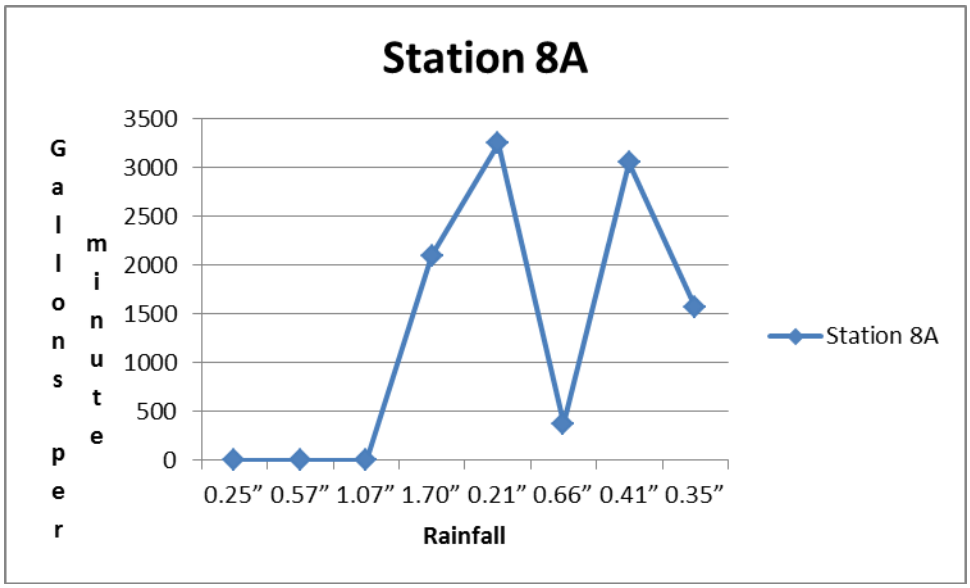
Date	Predicted Source by Isolate
4/28/10	Domestic-Dog
4/28/10	Bird-Canada Goose
4/28/10	Bird-Mute Swan

Station 8: Stepping Stones Pond Outflow

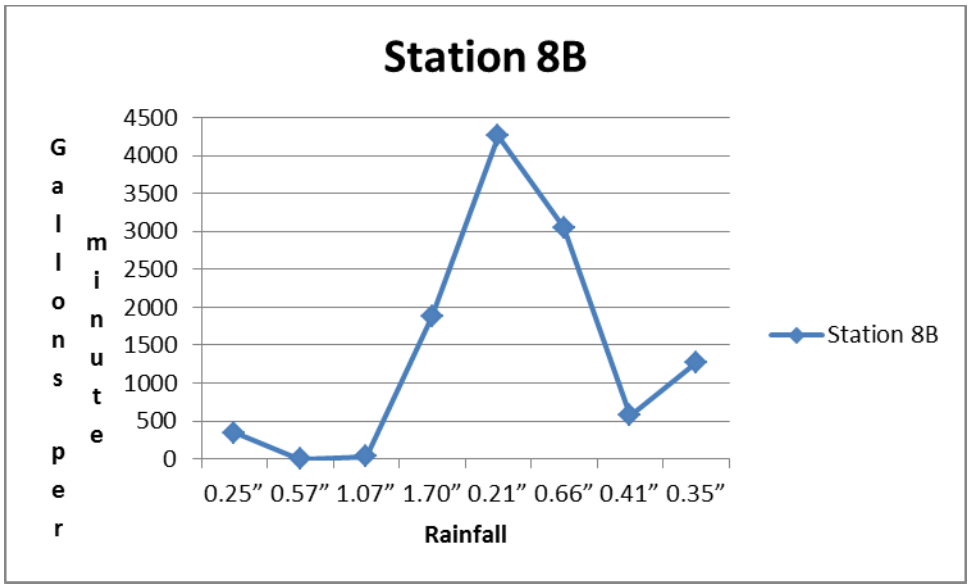
Address: Old West Lake Drive
Location & Pipe Description: Pipes are two black 12 inch corrugated plastic.

Streamflow Data:

8A	0	0	0	2097.293	3245.687	372.2776	3050.608	1563.867
Rainfall	0.25”	0.57”	1.07”	1.70”	0.21”	0.66”	0.41”	0.35”
Station	5/12/2010	10/6/2010	11/4/2010	2/25/2010	2/28/2010	3/11/2011	3/16/2011	4/1/2011



8B	348.3639	0	33.93155	1874.314	4264.065	3050.608	572.743	1264.193
Rainfall	0.25”	0.57”	1.07”	1.70”	0.21”	0.66”	0.41”	0.35”
Station	5/12/2010	10/6/2010	11/4/2010	2/25/2010	2/28/2010	3/11/2011	3/16/2011	4/1/2011



Coliform:

Station 8A
Stepping Stones Pond (southern pipe)
Notes: 6/28/10: No Sample-no flow
8/9//10: No Sample-no flow

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml	274	55	95	no sample	no sample	590	no sample	0

Notes: This pipe was not added to the sample list until the 6/28/09 sample event.

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml				124	28	320	0	1

DNA:

CORNELL COOPERATIVE EXTENSION-MARINE
DNA ANALYSIS RESULTS
PREDICTED SOURCE BY ISOLATE
LAKE MONTAUK STATION 8A-WET
(STEPPING STONES POND-SOUTH PIPE)

Date	Predicted Source by Isolate
11/4/10	Wildlife-Deer
11/4/10	Not Human, Not Wildlife, Possible Domestic (Horse)

11/4/10	Not Human, Possible Bird (Cormorant, Black Duck)
11/4/10	Probable Wildlife-Deer

CORNELL COOPERATIVE EXTENSION-MARINE
DNA ANALYSIS RESULTS
PREDICTED SOURCE BY ISOLATE
LAKE MONTAUK STATION 8B-WET
(STEPPING STONES POND-NORTH PIPE)

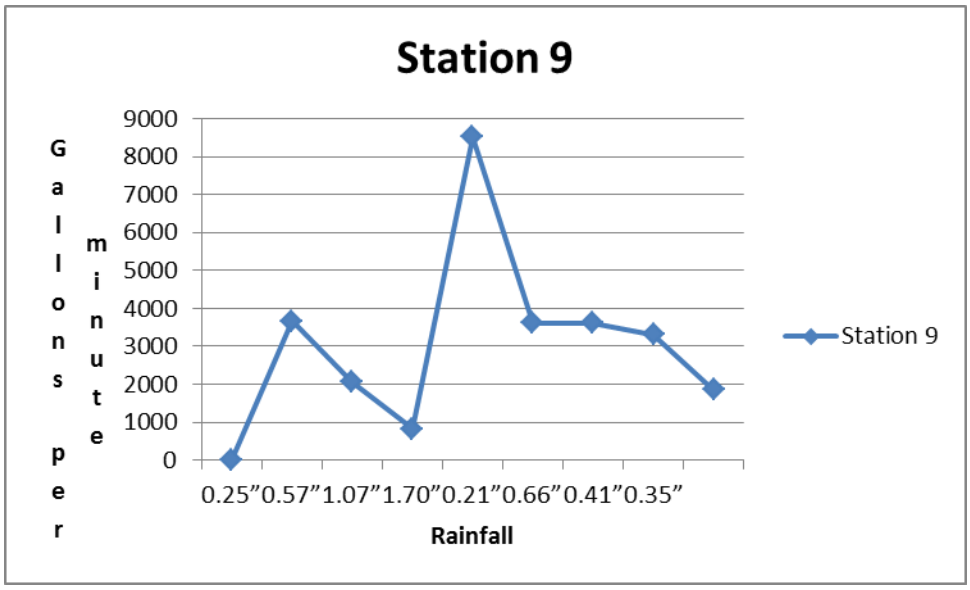
Date	Predicted Source by Isolate
3/11/11	Probable Domestic-Dog
3/11/11	Not Human-Possible Domestic (Dog)
3/11/11	Not Human-Possible Domestic (Dog)

Station 9: Peter's Run-Stream

Address: 8 Gloucester Avenue
Location & Pipe Description: Pipe diameter is 24 inches. There is a creek that the pipe discharges into. The stream has a sandy bottom.

Streamflow Data:

9	3661.806	2058.514	828.1452	8524.251	3622.597	3622.597	3319.69	1850.4
Rainfall	0.25"	0.57"	1.07"	1.70"	0.21"	0.66"	0.41"	0.35"
Station	5/12/2010	10/6/2010	11/4/2010	2/25/2010	2/28/2010	3/11/2011	3/16/2011	4/1/2011



Coliform:

Station 9
Peter's Run- 8 Gloucester Avenue
Notes:

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml	1300	85	99	1170	4300	3300	66	218

DNA:

CORNELL COOPERATIVE EXTENSION-MARINE
DNA ANALYSIS RESULTS
PREDICTED SOURCE BY ISOLATE
LAKE MONTAUK STATION 9-DRY
(PETER'S RUN-GLOUCESTER)

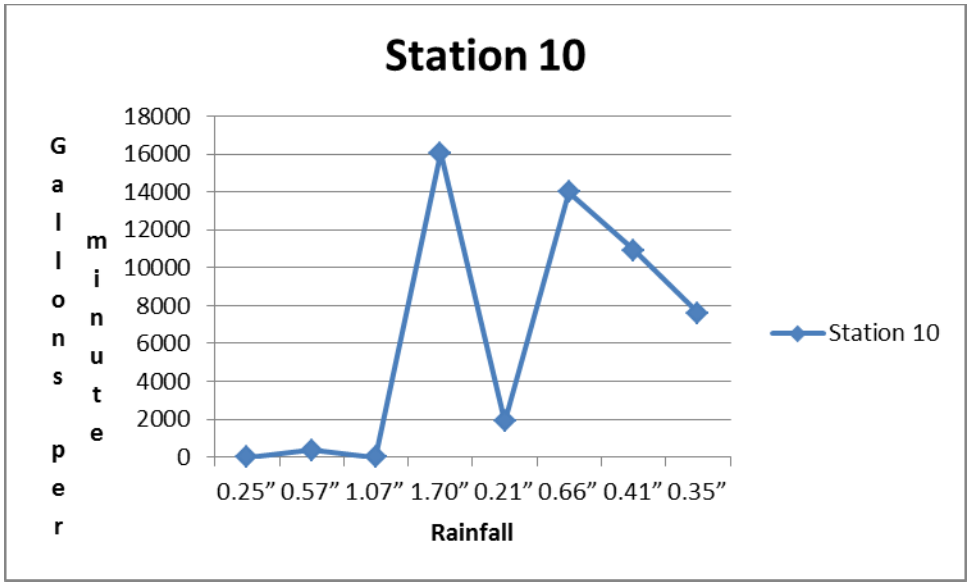
Date	Predicted Source by Isolate
8/9/10	Not Human, Possible Bird (Canada Goose)
8/9/10	Not Human, Possible Bird (Canada Goose)
8/9/10	Bird-Canada Goose
8/9/10	Bird-(Herrin Gull, Mallard Duck)
8/9/10	Bird-Canada Goose
8/9/10	Bird-Canada Goose
8/9/10	Possible Bird-(Canada Goose)
8/9/10	Not Human
8/9/10	Bird-Canada Goose
8/9/10	Bird-Canada Goose

Station 10: Peter's Run-Retention Pond

Address: West Lake Drive and Gloucester Avenue.
Location & Pipe Description: Discharge from the pond/lake.

Streamflow Data:

10	0	364.9526	0	16074.51	1896.289	14016.21	10927.9	7614.239
Rainfall	0.25"	0.57"	1.07"	1.70"	0.21"	0.66"	0.41"	0.35"
Station	5/12/2010	10/6/2010	11/4/2010	2/25/2010	2/28/2010	3/11/2011	3/16/2011	4/1/2011



Coliform:

Station 10
Peter's Run- Retention Pond
Notes:

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml	242	96	138	240	60	580	12	188

DNA:

CORNELL COOPERATIVE EXTENSION-MARINE
DNA ANALYSIS RESULTS
PREDICTED SOURCE BY ISOLATE
LAKE MONTAUK STATION 10-WET
(PETER'S RUN-RETENTION POND OUTFLOW)

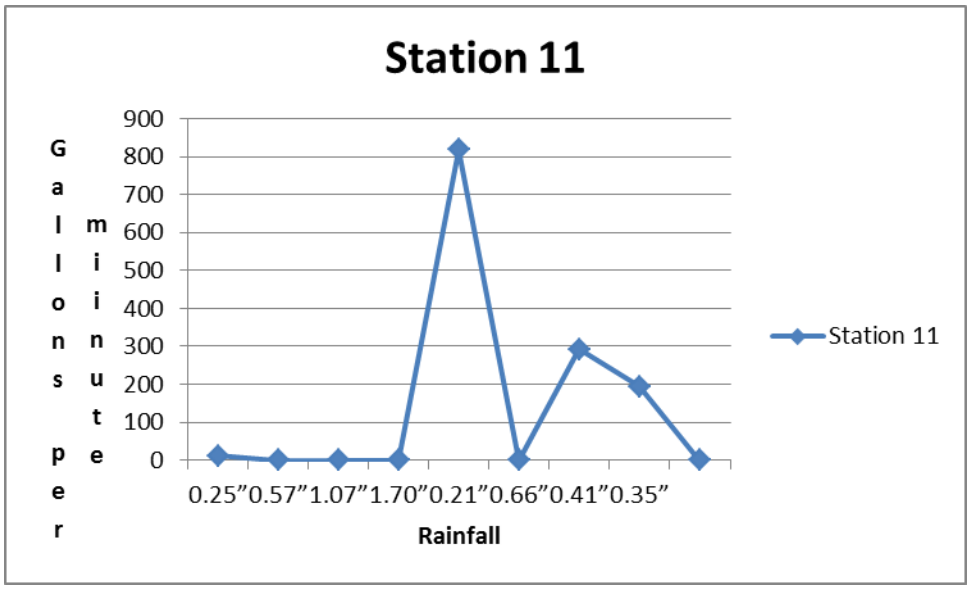
Date	Predicted Source by Isolate
3/11/11	Probable Wildlife-Raccoon
3/11/11	Domestic-Dog
3/11/11	Bird-Mute Swan
3/11/11	Domestic-Dog
3/11/11	Possible Domestic (Horse)

Station 11:

Address: West Lake Drive and Glenmore Avenue
Location & Pipe Description: Pipe diameter is 18 inches. Pipe discharges directly to beach. No stream channel present.

Streamflow Data:

11	0	0	0	818.4146	0	292.6596	194.0965	0
Rainfall	0.25”	0.57”	1.07”	1.70”	0.21”	0.66”	0.41”	0.35”
Station	5/12/2010	10/6/2010	11/4/2010	2/25/2010	2/28/2010	3/11/2011	3/16/2011	4/1/2011



Coliform:

Notes: 8/19/2009- No Sample-no flow
6/28/210- No Sample-no flow
8/9/2010- No Sample-no flow
12/1/2010- No Sample-no flow

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml	no sample	33	340	no sample	no sample	11000	no sample	82

DNA:

CORNELL COOPERATIVE EXTENSION-MARINE
DNA ANALYSIS RESULTS

PREDICTED SOURCE BY ISOLATE
LAKE MONTAUK STATION 11-WET
(WEST LAKE&GLENMORE)

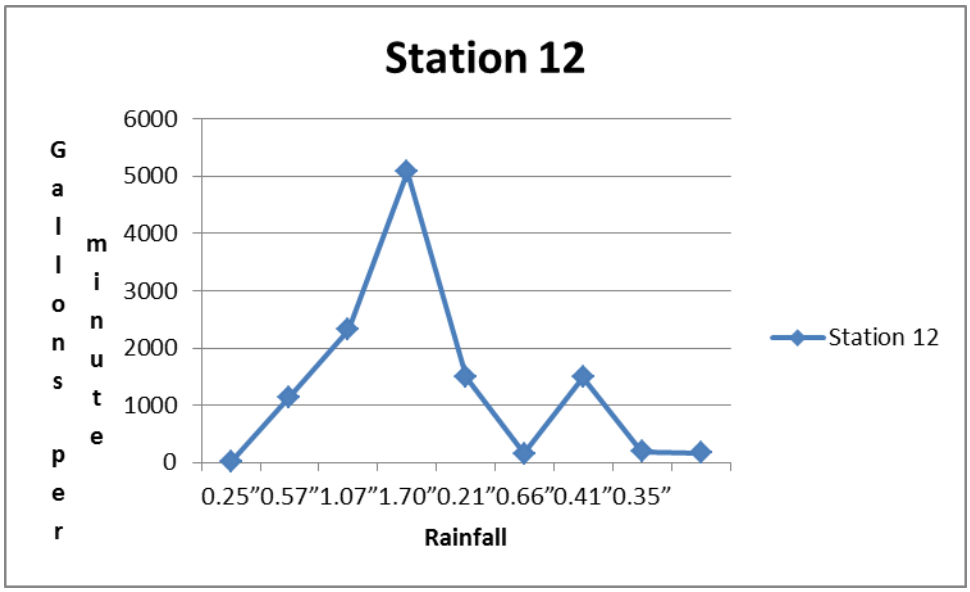
Date	Predicted Source by Isolate
4/28/10	Probable Bird (Herring Gull)
4/28/10	Not Human
4/28/10	Probable Bird (Herring Gull, Cormorant)
4/28/10	Not Human
4/28/10	Not Human
4/28/10	Domestic-Probable Dog
4/28/10	Domestic-Probable Dog
4/28/10	Not Human
4/28/10	Possible Domestic

Station 12: Diamond Cove Marina

Address: Diamond Cove Marina, 364 West Lake Drive
Location & Pipe Description: Outfall discharges directly into lake through bulk heading at Diamond Cove Marina. Pipe on other side of the street is 16 in and has a small channel.

Streamflow Data:

12	1140.1	2314.886	5073.574	1492.27	150.8069	1492.27	191.8838	172.3507
Rainfall	0.25”	0.57”	1.07”	1.70”	0.21”	0.66”	0.41”	0.35”
Station	5/12/2010	10/6/2010	11/4/2010	2/25/2010	2/28/2010	3/11/2011	3/16/2011	4/1/2011



Coliform:

Notes: 8/9/2010- No Sample-no flow

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml	2	37	17	58	no sample	240	19	39

DNA:

CORNELL COOPERATIVE EXTENSION-MARINE
DNA ANALYSIS RESULTS
PREDICTED SOURCE BY ISOLATE
LAKE MONTAUK STATION 12-DRY
(DIAMOND COVE)

Date	Predicted Source by Isolate
6/28/10	Not Human, Possible Bird (Black Duck, Mute Swan)
6/28/10	Not Human, Possible Bird (Black Duck, Mute Swan)
6/28/10	Not Human, Possible Bird (Black Duck, Mute Swan)
6/28/10	Not Human, Possible Bird (Black Duck)
6/28/10	Bird-Mute Swan
6/28/10	Wildlife-Raccoon
6/28/10	Bird (Black Duck, Mute Swan)
6/28/10	Bird (Black Duck, Mute Swan)
6/28/10	Bird (Black Duck, Mute Swan)

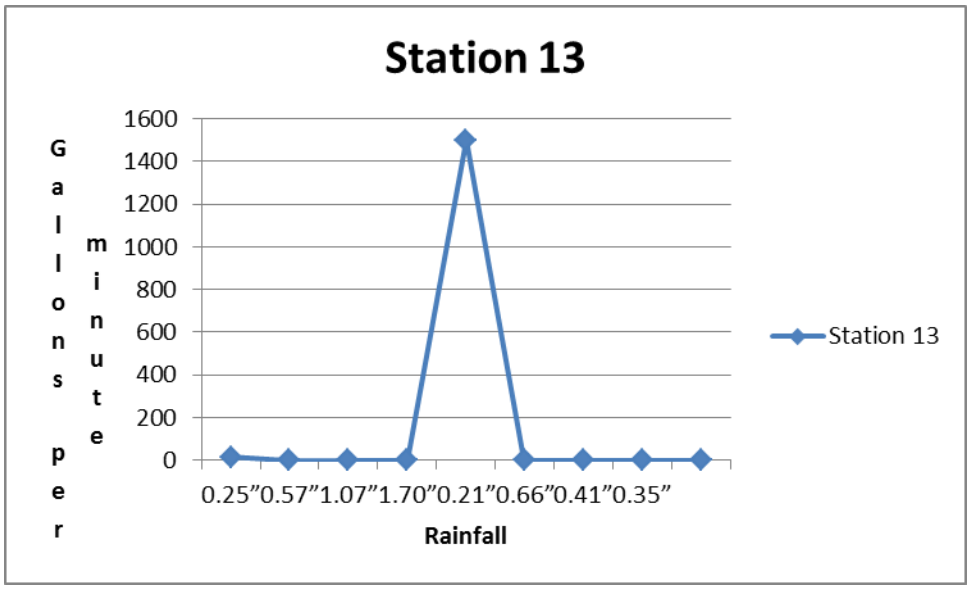
Station 13: Drum Property

Address: West Lake Drive

Location & Pipe Description: Outlet of the pond, located on the west side of the street. Pipe 16in.

Streamflow Data:

13	0	0	0	1501.39	0	0	0	0
Rainfall	0.25”	0.57”	1.07”	1.70”	0.21”	0.66”	0.41”	0.35”
Station	5/12/2010	10/6/2010	11/4/2010	2/25/2010	2/28/2010	3/11/2011	3/16/2011	4/1/2011



Coliform:

Notes: 12/1/2010- No Sample-no flow from creek. Pipe in marina under water.

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml	22	380	160	1330	190	550	no sample	148

DNA:

CORNELL COOPERATIVE EXTENSION-MARINE
DNA ANALYSIS RESULTS
PREDICTED SOURCE BY ISOLATE
LAKE MONTAUK STATION 13-DRY

(DRUM PROPERTY)

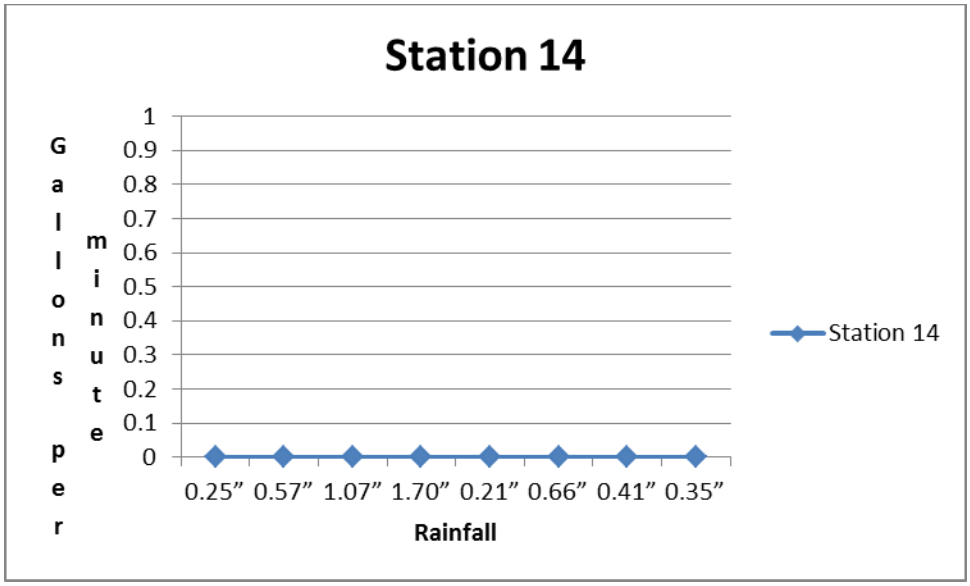
Date	Predicted Source by Isolate
6/28/10	Not Human, Possible Bird (Mallard Duck)
6/28/10	Not Human

Station 14: Sea Otter/Uihlen's Marina

Address: 444 West Lake Drive
Location & Pipe Description: Pipe diameter is 4 ft. Discharges directly into lake from marina.

Streamflow Data:

14	0	0	0	0	0	0	0	0
Rainfall	0.25"	0.57"	1.07"	1.70"	0.21"	0.66"	0.41"	0.35"
Station	5/12/2010	10/6/2010	11/4/2010	2/25/2010	2/28/2010	3/11/2011	3/16/2011	4/1/2011



Coliform:

Notes: 11/30/09- No Sample- tidal exchange in pipe/pipe under water.
4/20/10- No Sample- tidal exchange in pipe/pipe under water.
6/28/10- No Sample- tidal exchange in pipe/pipe under water.
8/9/10- No Sample- tidal exchange in pipe/pipe under water.
11/4/10- No Sample- tidal exchange in pipe/pipe under water.
12/1/10- No Sample- tidal exchange in pipe/pipe under water.
3/11/11- No Sample- tidal exchange in pipe/pipe under water.

Date	8/19/2009	11/30/2009	4/28/2010	6/28/2009	8/9/2010	11/4/2010	12/1/2010	3/11/2011
Condition	dry	dry	wet	dry	dry	wet	wet	wet
MPN/100ml	50	no sample	no sample	no sample	no sample	no sample	no sample	no sample

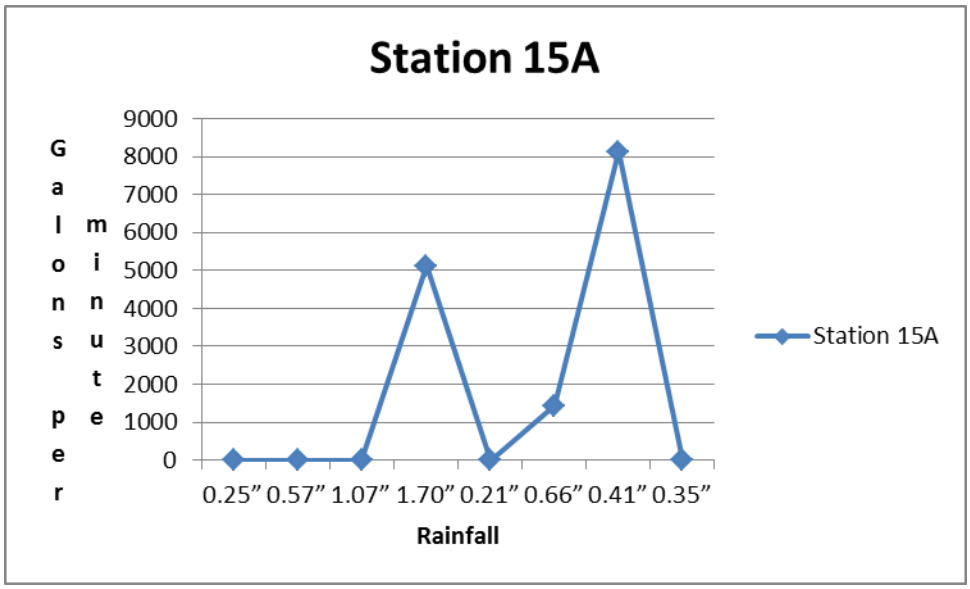
DNA:

Station 15A and 15B: South of Reed Pond outfall

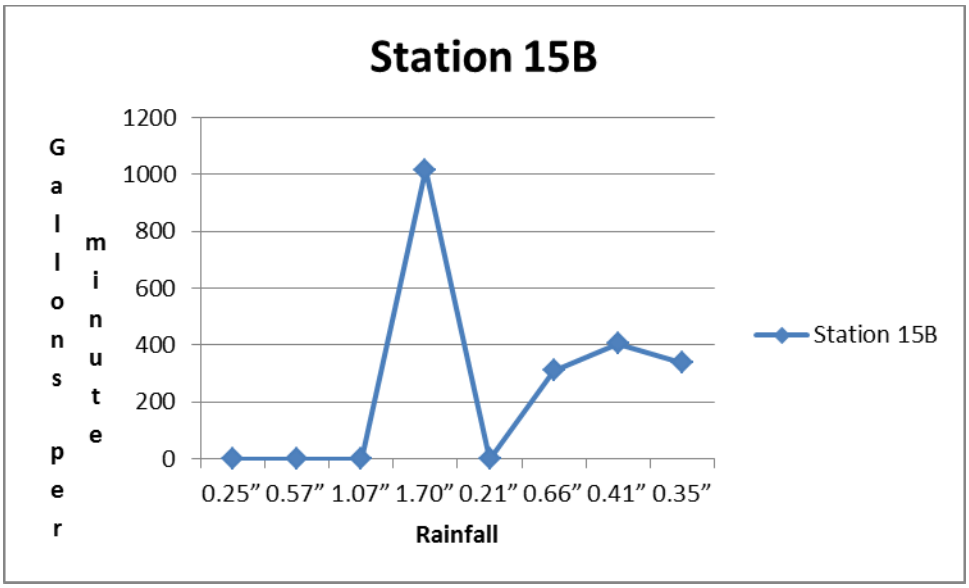
Address: East Lake Drive
Location & Pipe Description: Pipe diameter is 12 ft. Pipe runs from east side of East Lake Drive (15A) to outfall along beach (15B)

Streamflow Data:

15A	-	-	-	5125.926	-	1429.972	8140.125	0
Rainfall	0.25”	0.57”	1.07”	1.70”	0.21”	0.66”	0.41”	0.35”
Station	5/12/2010	10/6/2010	11/4/2010	2/25/2010	2/28/2010	3/11/2011	3/16/2011	4/1/2011



15B	-	-	-	1017.516	-	311.0392	406.4245	337.1611
Rainfall	0.25”	0.57”	1.07”	1.70”	0.21”	0.66”	0.41”	0.35”
Station	5/12/2010	10/6/2010	11/4/2010	2/25/2010	2/28/2010	3/11/2011	3/16/2011	4/1/2011



Coliform:

Notes: 12/1/10: Pipe was not added to sample list until 12/1/10. No Sample-no flow.

Date	8/19/09	11/30/09	4/28/10	6/28/10	8/9/10	11/4/10	12/1/10	3/11/11	4/1/11
Condition	Dry	dry	wet	dry	dry	wet	wet	wet	wet
MPN/100ml							No sample	25	75

Notes: 12/1/10: Pipe was not added to sample list until 12/1/10. No Sample-no flow.

Date	8/19/09	11/30/09	4/28/10	6/28/10	8/9/10	11/4/10	12/1/10	3/11/11	4/1/11
Condition	Dry	dry	wet	dry	dry	wet	wet	wet	wet
MPN/100ml							No sample	53	35

DNA:

CORNELL COOPERATIVE EXTENSION-MARINE
DNA ANALYSIS RESULTS
PREDICTED SOURCE BY ISOLATE
LAKE MONTAUK STATION 15A-WET
(SOUTH OF REED POND-EAST LAKE DRIVE)

Date	Predicted Source by Isolate
3/11/11	Domestic-Dog
3/11/11	Not Human
3/11/11	Possible Domestic (Dog)
3/11/11	Domestic-Dog
3/11/11	Not Human, Not Bird
3/11/11	Wildlife-Muskrat
3/11/11	Wildlife-Muskrat
3/11/11	Wildlife-Muskrat
3/11/11	Wildlife-Muskrat

CORNELL COOPERATIVE EXTENSION-MARINE
DNA ANALYSIS RESULTS
PREDICTED SOURCE BY ISOLATE
LAKE MONTAUK STATION 15B-WET
(SOUTH OF REED POND-LAKE OUTFALL PIPE)

Date	Predicted Source by Isolate
3/11/11	Probable Domestic-Dog
3/11/11	Probable Domestic-Dog
3/11/11	Probable Domestic-Dog
3/11/11	Probable Domestic-Dog
3/11/11	Probable Domestic-Dog
3/11/11	Probable Domestic-Dog
3/11/11	Probable Domestic-Dog
3/11/11	Probable Domestic-Dog
3/11/11	Probable Domestic-Dog

Preliminary Report: Sediment and Infauna Analysis for Lake Montauk, East Hampton

Twenty stations were selected for sediment grain size analysis, percent organic matter and infauna analysis in Lake Montauk, East Hampton. All twenty stations were sampled between 23 September and 30 October 2008. Figure 1 shows the location of the 15 benthic infauna and sediment survey sites, while Figure 2 presents the stations established for the eelgrass eelgrass survey.

A 2" PVC corer was used for sampling by SCUBA diving or snorkeling. Two cores were taken at each station, one for sediment grain size and organic analysis, and one for infauna analysis. Cores were driven into the sediment to a depth of 15 cm. Infauna analysis was conducted in the field by wet sieving the sample immediately after collection through a 1mm mesh sieve. After washing, all specimens retained in the screen were collected and transferred into labeled plastic ziplock bags with seawater. Sediment grain size/ organic samples were obtained, the excess seawater was decanted and the samples were emptied into labeled plastic ziplock bags. All samples were stored in a cooler with ice packs for transport to the lab. Once back at the lab, all sediment samples were frozen until analysis and infauna samples were refrigerated until analysis. Sediment grain size distribution was determined by wet sieving and pipette analysis (Folk, 1961). Organic content of the samples was measured as the weight lost after combustion at 450 degrees C for four hours. Infauna analysis was performed in the days immediately after collection to ensure specimens remained live to ease identification. The animals were identified and counted with the aid of a dissecting microscope.

Figure 1. The sediment and infauna survey stations (LMS) for Lake Montauk.

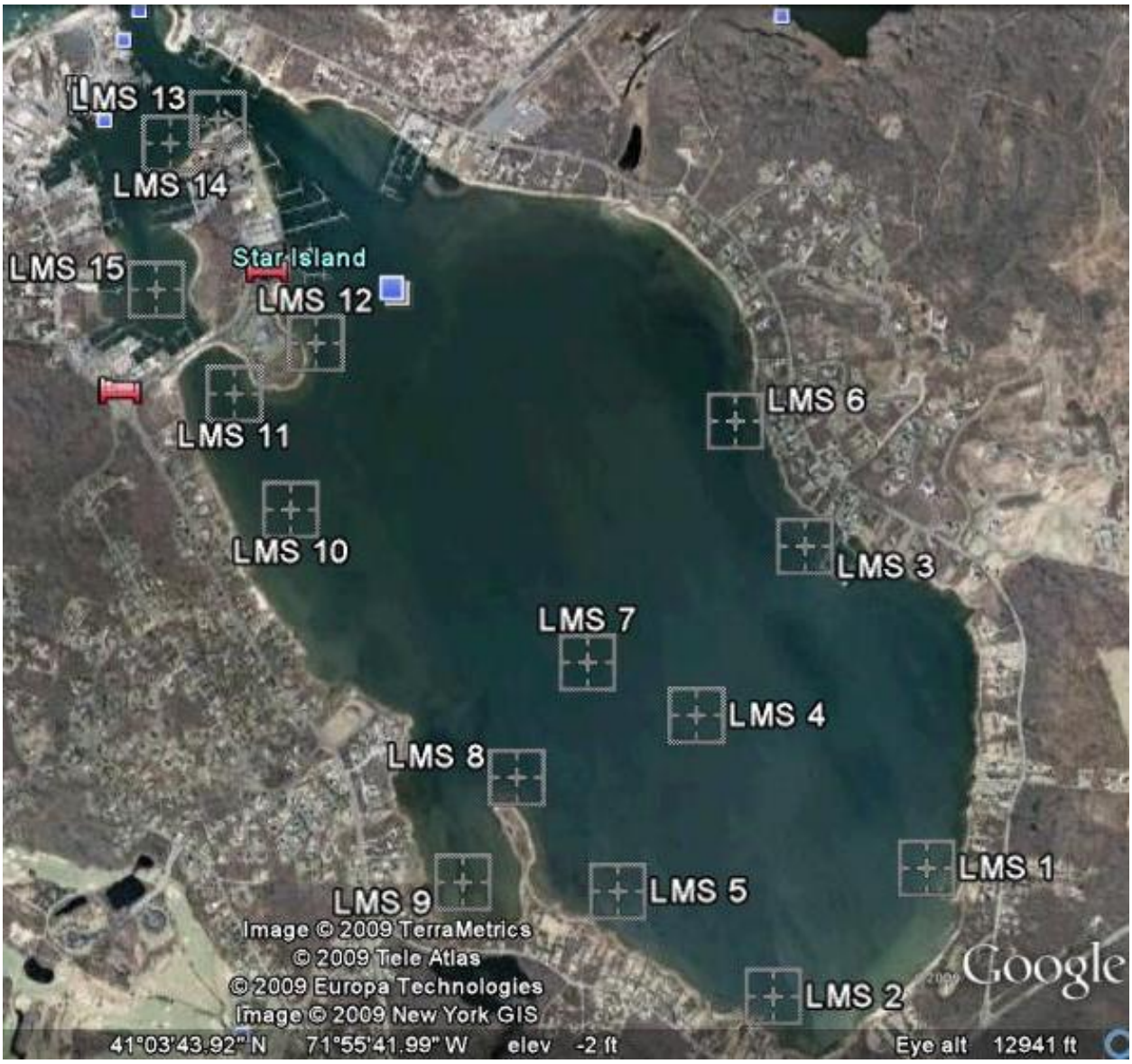


Figure 2. The eelgrass survey stations (Coast Guard [CG] and Lake Montauk [LM]), indicated within the red boxes, for the Lake Montauk Watershed Project.

Results

Sediment Data

Lake Montauk Sediment Analysis for Monitoring Stations
Sampled: Sept 23, 2008
*note: seagrasses tend to prefer sediment with <15% silt and clay and <8% organic matter

Channel Flat Station 1:
Avg % Organics: 0.952%
Avg % Grain Size:
5.326% gravel
82.039% sand
12.635% silt and clay

Channel Flat Station 2:
Avg % Organics: 1.181%
Avg % Grain Size:
3.886% gravel
87.436% sand
8.678% silt and clay

Channel Flat Station 3:
Avg % Organics: 0.626%
Avg % Grain Size:
11.672% gravel
83.440% sand
4.557% silt and clay

Channel Flat Station 4:
Avg % Organics: 0.857%
Avg % Grain Size:
5.004% gravel
90.912% sand
4.083% silt and clay

Coast Guard Station 1:
Avg % Organics: 1.370%
Avg % Grain Size:
0% gravel
87.549% sand
12.451 % silt and clay

Coast Guard Station 2:
Avg % Organics: 1.206%
Avg % Grain Size:
0 % gravel

90.160% sand
9.040% silt and clay

Coast Guard Station 3:
Avg % Organics: 1.486%
Avg % Grain Size:
5.236% gravel
77.012% sand
17.752% silt and clay *high for seagrass

Coast Guard Station 4:
Avg % Organics: 1.239%
Avg % Grain Size:
0.481% gravel
88.699% sand
10.910% silt and clay

Coast Guard Station 5:
Avg % Organics: 0.875%
Avg % Grain Size:
3.049% gravel
92.357% sand
4.593% silt and clay

***No replicates were done for the LMS stations

LMS 1
Organics: 1.31%
Grain Size:
0% gravel
86.79% sand
13.21% silt and clay

LMS 2
Organics: 0.97%
Grain Size:
0% gravel
83.09% sand
16.91% silt and clay
LMS 3
Organics:0.35 %
Grain Size:
0.05% gravel
98.44% sand
1.50% silt and clay
LMS 4

Organics: 4.10%
Grain Size:
- 0% gravel
- 6.20% sand
- 93.80% silt and clay

LMS 5
Organics: 0.56%
Grain Size:
- 17.93% gravel
- 76.86% sand
- 5.21% silt and clay

LMS 6
Organics: 0.68%
Grain Size:
- 1.41% gravel
- 92.59% sand
- 6.00% silt and clay

LMS 7
Organics: 4.05%
Grain Size:
- 0% gravel
- 31.53% sand
- 68.47% silt and clay

LMS 8
Organics: 0.67%
Grain Size:
- 1.16% gravel
- 87.86% sand
- 10.98% silt and clay

LMS 9
Organics: 1.27%
Grain Size:
- 0% gravel
- 73.08% sand
- 26.92% silt and clay

LMS 10
Organics: 2.94%
Grain Size:
- 0% gravel
- 46.77% sand
- 53.23% silt and clay

LMS 11
Organics: 4.30%
Grain Size:
- 0% gravel
- 38.38% sand

61.62% silt and clay
LMS 12
Organics: 4.75%
Grain Size:
0% gravel
16.68% sand
83.32% silt and clay
LMS 13
Organics: 1.41%
Grain Size:
0.57% gravel
84.51% sand
14.91% silt and clay
LMS 14
Organics: 1.48%
Grain Size:
0% gravel
78.33% sand
21.67% silt and clay
LMS 15
Organics: 6.68%
Grain Size:
0% gravel
33.54% sand
66.46% silt and clay

Infauna Survey
LM1: total- 4 worm casings, 1 tiny thread worm, Family Capitellidae
- large tube built of large grained sand/cobble
- 1 "ice-cream cone" tube ***Pectinaria gouldi***
- 1 tiny thread worm, **Family Capitellidae**
- 2 long, thin tubes, one mud colored, 1 rust colored
Note: eelgrass seed

LM3: total- 3 worms, 1 tube
-1 spaghetti mouthed worm (***Pista palmata***, Family **Terebellidae**)
-1 tiny blood worm about 1 cm long **Family Glyceridae**
-1 large poly. **Family Nereidae** (clam worm)
- large tube built of large grained sand/cobble

LM4: total 1 worm case , 1 bivalve
-1 large tube built of large grained sand/cobble
-1 atlantic awningclam ***Solemya velum***

LM-CG3: total- multiple tube fragments
-tube frags muddy, w/o "skin"

LM-CG5: total- 2 worms, multiple tube fragments
-1 large clam worm **Family Nereidae**
-1 opal worm, **Family Lumbrineridae**
-3 fragments of tube built of fine grained sand, flexible

LMS1: total 3 worms
-1 blood worm about 1 cm long **Family Glyceridae**
-2 tiny thread worms, **Family Capitellidae**

LMS2: total 1 worm, 1 bivalve, fragments of P. gouldi
-1 clam worm **Family Nereidae**
-1 atlantic awningclam ***Solemya velum***
-Multiple fragments of ***Pectinaria gouldi*** tube
Note: bittiolum looking shells (2 collected)

LMS3: total- 2 worms Family Orbiniidae, frag. of "ice cream cone worm" *Pectinaria gouldi* tube
-2 half pinkish half yellowish worms , both Family **Orbiniidae, though 1 missing head**
- frag. of ***Pectinaria gouldi*** tube

LMS4: fragments of tube
-multiple fregments of a mud covered tube with "skin"

LMS5: 1 worm, frag of P. gouldi tube,
-1 clam worm **Family Nereidae (**pretty sure it's ***Neanthes (=Nereis) succinea*****)**
-Fragment of tube from ice cream cone worm ***Pectinaria gouldi***

LMS6: total 1 worm
-dead, but looks like a blood worm (**Family Glyceridae**)
Note: bittiolum looking shells (4 collected)

LMS7: total- 1 worm and fragments of muddy tubes
-1 large (@2.5 cm) worm (think Family Maldanidae,)
-multiple fragments of muddy tube, one containing "skin"

LMS8: total- 5 tubes from 3 spp.
-3 "ice cream cone worm" tubes – ***Pectinaria gouldi,*** family **Pectinariidae**
- fragments of a tube built of sand that is less rigid and made of finer sand
-one tiny, thin tube, mud colored

LMS9: total 4 worms of 3 families
-1 small (1cm) bamboo worm **Family Maldanidae**
-2 small bloodworms **Family Glyceridae**
-1 threadworm **Family Capitellidae**

LMS10: total- 1 "ice cream cone worm" *Pectinaria gouldi*, 1 muddy tube

LMS11: 1 worm, several fragments of muddy tube
-1 ribbon worm, **Phylum Nemertea**- probably ***Procephalothrix spiralis***
-multiple fragments of muddy tube with "skin"

LMS12: total- multiple fragments of at least 1 tube
-frags of at least 1 large, mud colored tube with "skin"

LMS13: 2 worms, several tubes
-2 polychaetes of the genus ***Lumbrinerides*** (**Family Lumbrineridae**) a.k.a. opal worms
-several fragments of fine sand covered tubes, flexible

LMS14- total: 1 tiny worm Family **Syllidae**; multiple fragments of tubes, at least from 2 spp.
-tiny polychaete (<1cm) Family **Syllidae**
-Multiple fragments of tubes with "skin"
-1 frag of tube made with fine grained sand, flexible

LMS15: total 1 tube
-1 tube with "skin"

Infauna Species List
Note: P= polychaete, B= bivalve, R= ribbon worm

Species/Family/Phylum	**Site(s) Observed and # per site**	**Notes**
	1 per site unless indicated in ( ) after	
Pectinaria gouldi (P)	LMS10 [tube only: LM1,LMS2,LMS3,LMS5,LMS8(3)]	ice cream cone worm - Family Pectinariidae
Procephalothrix spiralis (R)	LMS11	ribbon worm - Phylum Nemertea
Pista palmate (P)	LM3	spaghetti mouthed worm - Family Terebellidae
Solemya velum (B)	LM4, LMS2	atlantic awningclam - Family Solemyidae
Family Capitellidae (P)	LM1, LMS1(2), LMS9	thread worm
Family Glyceridae (P)	LM3, LMS1, LMS6, LMS9(2)	blood worm

Family Lumbrineridae (P)	LM-CG5, LMS13(2)	opal worm
Family Maldanidae (P)	LMS7, LMS9	bambooworm
Family Nereididae (P)	LM3, LM-CG5, LMS2, LMS5	clam worms, LMS5 is *Neanthes (=Nereis) succinea*
Family Orbiniidae (P)	LMS3(2)	burrowing deposit feeders
Family Syllidae (P)	LMS14	small predators of hydroids, sponges and tunicates

Alternatives to Traditional Septic Systems

A typical Onsite Wastewater Treatment System (OWTS) on Long Island consists of a septic tank and leaching pool(s). The septic tank is used to settle and decompose sewage; and the leaching pool allows the liquid from the septic tank (referred to as effluent) to be released into and filtered by the surrounding soils. Please see **Figure 1** for an illustration.

Septic systems generally work well if they are installed in areas with appropriate soils and hydraulic capacities (capacity of soil to absorb and move effluent); designed to treat the incoming waste load to meet public health, ground water, and surface water performance standards; installed properly; and maintained to ensure long-term performance (USEPA, 2002). However, many times these criteria, especially proper maintenance, are not met.

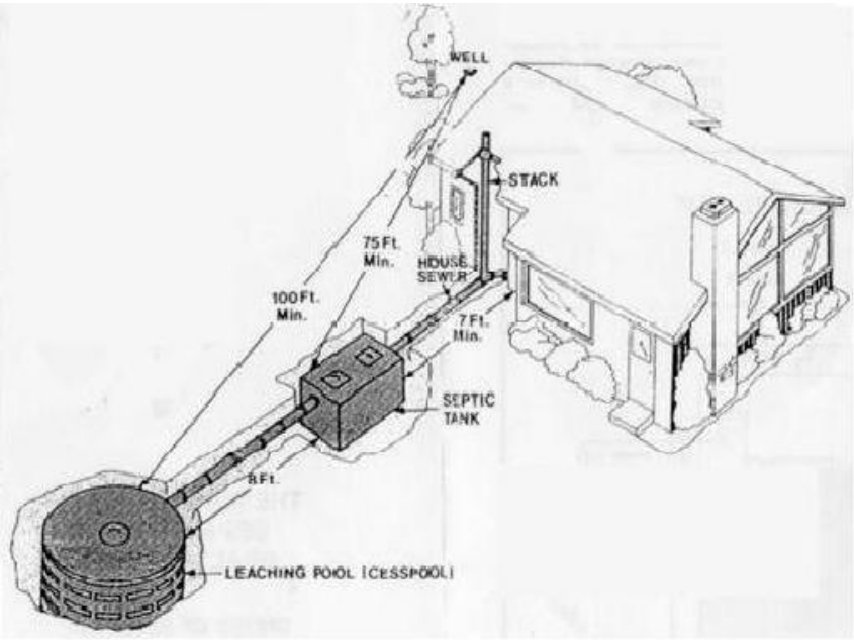
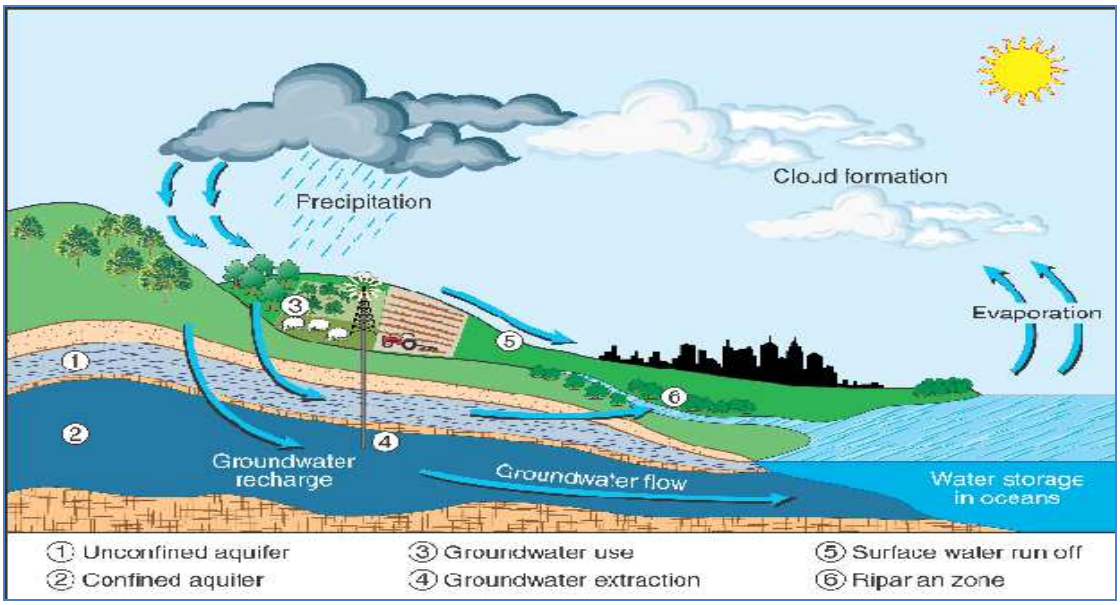


Figure 1: Coventional Sewage Disposal System, Source: http://www.geo.sunysb.edu/groundwater/xuan_xu.htm

Another major shortcoming of septic systems is their inability to remove much of the nitrogen in human waste. According to studies, only 20% of nitrogen that passes through conventional septic systems is effectively removed (Siegrist and Jenssen, 1989; Gold et al., 1990). It is not uncommon for the effluent leaving a typical system to have a total nitrogen concentration of 40-60 mg/L, primarily in the form of ammonia (NH_3) and organic nitrogen. Upon entering the soil, the ammonia is quickly nitrified (converted to Nitrate, NO_3 by oxygen in the soil). Once converted to nitrate, further breakdown is limited due to a lack of organic carbon in the soil, which is required by the microorganisms to breakdown nitrate.

In addition to nitrogen, septic tank effluent also contains phosphates and pathogens (bacteria, parasites, and viruses); which discharge along with nitrogen to the soil. The nitrogen, phosphates, and pathogens not taken out of the effluent by soil filtration; flow into groundwater

and travel via groundwater flow to surface waterbodies. See **Figure 2** for an illustration of the hydrologic cycle and how water flows underground.



Source: http://www.willoughby.nsw.gov.au/Groundwater.html

Figure 2: Fate of effluent discharged to soil

Impacts

Nitrogen is the primary pollutant of concern in coastal areas of the eastern United States (USEPA, 2010). This is because in most coastal estuarine and marine waters, nitrogen is the limiting nutrient. Elevated inputs of nitrogen (nitrates) can cause excessive algal growth and lead to eutrophication and low dissolved oxygen levels in estuarine waters (lakes, harbors, and bays). If high concentrations of nitrates leach into groundwater that is used for drinking, it poses many health risks, particularly to babies (methemoglobinemia –blue baby syndrome) and pregnant women.

Phosphorus is mainly a concern when it enters freshwater; streams, rivers, and lakes. In freshwater systems, phosphorus is the limiting nutrient and elevated levels can cause excessive algal growth, eutrophication, and low dissolved oxygen levels.

Pathogens reaching surface or groundwater present health risk as they are capable of causing human disease through contaminated drinking water, recreational contact, or consumption of contaminated shellfish.

Septic system density and distance to groundwater and surface water also affect how well they work. If septic systems are installed at a high density or close to groundwater or surface water, the chance of nutrient and bacterial contamination of surface and groundwater increases.

Alternative Technologies

In an effort to deal with the water contamination issues (pathogens, nitrogen, phosphorus) posed by traditional septic systems and increased hydraulic flows, a wide range of "alternative"

treatment technologies have been developed. These systems typically work in combination with the septic tank. The septic tank serves to equalize hydraulic flows; retain oils, grease, and settled solids; and provide some anaerobic (without oxygen) digestion of settleable organic matter. The alternative treatment technology then provides an environment (e.g., sand, peat, artificial media, and oxygen) that promotes additional biological treatment and removes pollutants through filtration, absorption, and adsorption.

A wide variety of alternative treatment technologies exist, many of which use a combination of treatment applications in order to maximize pollutant removal, especially nutrient removal. These technologies can achieve significant pollutant removal rates. However, the performance of various treatment technologies ranges with climate, site conditions, hydraulic loads, and pollutant loads. Local studies are critical in determining the acceptability of specific treatment technologies.

**It is important to note that Suffolk County has not approved any of the alternative treatment technologies discussed in this section. Local studies have to be conducted to determine the effectiveness and feasibility of using these systems in Suffolk County.

Alternative Technologies for Nitrogen Removal

As mentioned above, many alternative technologies use a combination of treatment applications in order to maximize pollutant removal. This is especially true for technologies that remove nitrogen from wastewater. Nitrogen-reducing onsite systems add treatment processes to conventional systems to facilitate the biological processes necessary for nitrogen reduction.

The main treatment processes that onsite nitrogen removal technologies use is sequential nitrification/denitrification. The first step in the sequence uses aerobic processes to transform the organic nitrogen and ammonia products in the septic tank effluent to nitrate (nitrification step). Various treatment devices can achieve this aerobic process, such as sand or gravel filters or aerobic treatment units. The second step requires changing the process from an aerobic environment (with dissolved oxygen) to an anoxic environment (no dissolved oxygen) and providing a source of organic carbon. This allows species of bacteria to grow that will utilize the nitrate formed in the first step to oxidize organic matter and in the process transform the nitrate to nitrogen gas (Washington State Department of Health, 2005). These processes (aerobic treatment, sand/media filters, add-on anoxic filters) are described below.

<u>Aerobic Treatment:</u> the aerobic treatment process involves providing a suitable oxygen rich environment for organisms that reduce the organic portion of the waste into carbon dioxide and water. Aerobic systems are similar to septic systems in that they both use natural processes to treat wastewater, but unlike septic systems, the aerobic treatment process requires oxygen. In an aerobic treatment unit, wastewater enters a compartment where solids settle and are partially digested by microorganisms. In another compartment, a motor pumps air into the chamber and mixes the liquid, allowing air diffusion and provides oxygen for aerobic bacteria that further degrade wastewater. The treated effluent is then either recirculated for further treatment or discharged to a soil absorption field.

Three main types of aerobic systems have been adapted for onsite use: suspended growth, fixed film, and sequencing batch reactor. In suspended growth systems, the microorganisms responsible for the breakdown of wastes are maintained in a suspension with the waste stream. These units contain a main compartment called an aeration chamber in which air is mixed with wastewater. The air mixes with wastewater in the aeration chamber and the oxygen supports the growth of aerobic bacteria that digest solids in the wastewater. The solids that the bacteria cannot breakdown settle out as sludge in a secondary chamber called a settling chamber or clarifier. The settled out sludge is then returned to the aeration chamber, either by gravity or pumping, for further breakdown. See **Figure 3** for a diagram of a suspended growth system.

In fixed film/attached growth systems (sometimes called trickling filters or media filters); the microorganisms grow on sand, peat, or a specially designed synthetic material. Wastewater is exposed to the media in usually one of two ways. In some systems the media is moved relative to the wastewater, alternating immersing the film and exposing it to air. In other systems the media is stationary and wastewater is sprayed or dosed on to the media so the film is alternately submerged and exposed to air. The submersion/immersion of the media in wastewater allows for anoxic processes to take place, whereas exposing it to air allows for aerobic processes to occur. Sand/media filters are discussed more below. See **Figure 4** for a diagram of a fixed film/attached growth system.

In a sequencing batch reactor, aerobic decomposition, settling, and return occur in the same chamber. Air is bubbled through the liquid in the decomposition cycle. The bubbler then shuts off and the wastewater goes through a settling cycle. The bubbler then turns back on and the tank reenters the decomposition cycle and the settled bacteria mix back into the aerobic environment. After settling of bacteria and solids, the treated effluent is discharged to the soil.

Capital costs for a conventional on-site suspended growth system ranges from $7,500 to $15,000 per dwelling unit. The operation and maintenance costs are $400 to $800 per dwelling until when all the suggested operation and maintenance tasks are performed (USEPA, 2010). Capital costs for single-pass filters range from $5,500 to $13,000 per dwelling unit with operation and maintenance costs of $200 to $400.

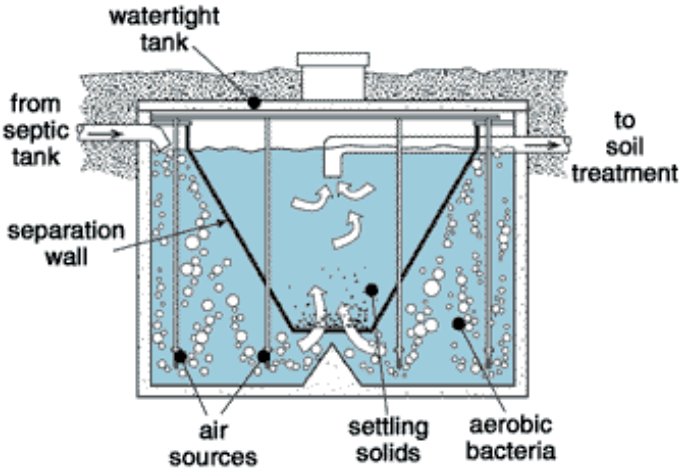


Figure 3: Suspended Growth Aerobic Treatment

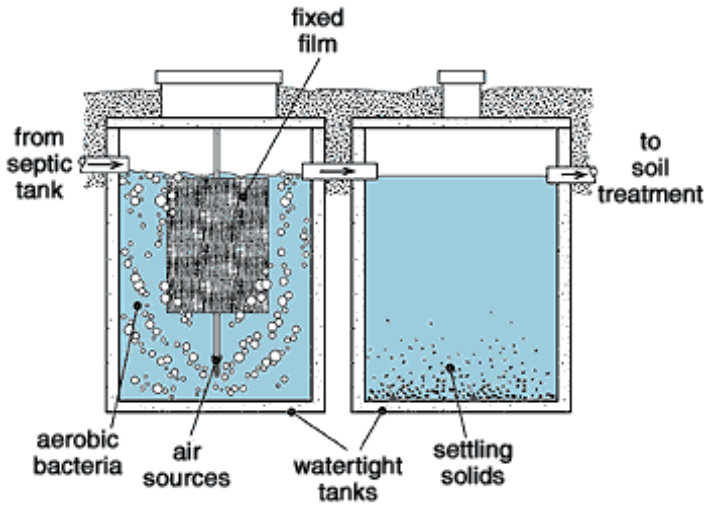


Figure 4: Fixed Film Aerobic Treatment

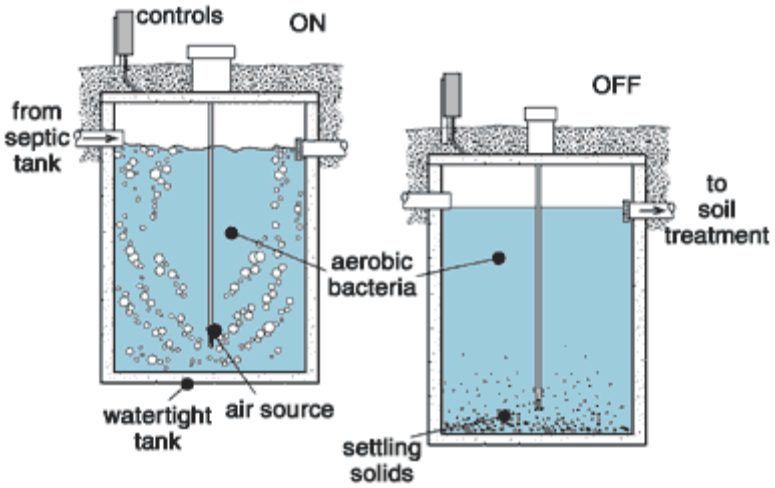
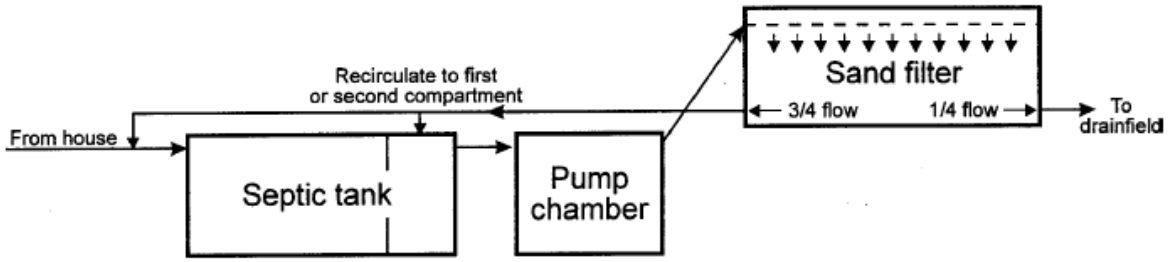


Figure 5: Sequencing Batch Reactor

<u>Sand /Media Filters</u>: Sand/media filters are used to provide further treatment of septic tank effluent, particularly for enhanced nitrogen and bacteria removal. These filters are also used in conjunction with aerobic treatment, as mentioned above.

Effluent from the septic tank is pressurized and sprayed on a volume of sand or other media. Microorganisms in the media promote the removal of nitrogen from wastewater through the bacterial conversion of ammonia and organic nitrogen to nitrates (nitrification) and the reduction of nitrates to gaseous nitrogen (denitrification). Many types of media can be used in these filters, however; washed, graded sand is the most common medium used. Other granular media include gravel, anthracite, crushed glass, expanded shale, and bottom ash from coal-fired power plants. Foam chips, peat, and synthetic textile materials have also been used, mostly in proprietary units.

Two types of filter designs are common, "intermittent (single-pass)" and "recirculating." Intermittent filters discharge treated septic tank effluent to the leachfield after one pass through the filter medium. Recirculating filters collect and recirculate the filtrate through the filter medium several times before discharging it to leachfield, see **Figure 6**. Intermittent filters are most frequently used for smaller applications, sites where bacteria removal is needed, and sites where nitrogen removal is not required. Recirculating filters are used for both large and small flows and are used where nitrogen removal is necessary. Recirculating sand filters generally outperform intermittent filters in removal of biochemical oxygen demand (BOD), total suspended solids (TSS), ammonia, and nitrate.



Source: Piluk and Peters, 2000
Figure 6: Sand Filter

Add-On Anoxic Filters: This technology passes nitrified effluent, from a sand filter or other aerobic treatment unit, through a low-oxygen, carbon-rich environment before soil dispersal. One commercially available product, NITREX, has been shown to regularly produce effluent with nitrogen concentrations of less than 5 mg/L (Heufelder et al., 2007). The Nitrex™ unit is filled with a proprietary wood byproduct mixture that promotes the breakdown of nitrate. Wastewater containing nitrate is applied to the surface of the Nitrex™ filter, as the wastewater moves through the filter, microorganism's breakdown the nitrate to nitrogen gas. With adequate aerobic pretreatment, the manufacturer claims near complete removal of nitrate nitrogen from wastewater. A Nitrex™ unit was installed at the Scully Estate – Environmental Center in Islip, NY in 2008. The wastewater treatment process consists of the following sequence: Septic Tank → BioFilter → NitrexTM → Drainfield.
For a single family home, the cost of a Nitrex filter can range from $4,000 - $7,000. However, this does not include the cost of the septic system, aerobic treatment unit, or soil dispersal system. Operation and maintenance costs of the Nitrex filter is less than $100 a year.
Please see **Figure 7** below for an overview of the removal efficiencies of the technologies discussed above. The removal efficiencies were obtained from the publications cited below the figure.

Figure 7: Biological Nitrogen Removal Performance

Technology examples	TN removal efficiency (%)	Effluent TN (mg/L)
Suspended growth		
Aerobic units w/ pulse aeration	25%–61%[a]	37–60[a]
Sequencing batch reactor	60%[b]	15.5[b]
Attached growth		
Single-Pass Sand Filters (SPSF)	8%–50%[c]	30–60[c]
Recirculating Sand/Gravel Filters (RSF)	15%–84%[d]	10–47[d]
Multi-Pass Textile Filters (AdvanTex AX20)	64%–70%[e]	3–55[e]
RSF w/ Anoxic Filter	40%–90%[f]	7–23[f]
RSF w/ Anoxic Filter & external carbon source	74%–80%[g]	10–13[g]
RUCK system	29%–54%[h]	18–53[h]
NITREX	96%[i]	2.2[i]

Source: Adapted from Washington Department of Health 2005

Notes: Overall performance can vary, depending on system configuration and other factors. For detailed descriptions of treatment processes and technologies, see http://www.psparchives.com/publications/our_work/hood_canal/hood_canal/n_reducing_technologies.pdf.

a. California Regional Water Quality Control Board 1997; Whitmeyer et al. 1991

b. Ayres Associates 1998

c. Converse 1999; Gold et al. 1992; Loomis et al. 2001; Nolte & Associates 1992; Ronayne et al. 1982

d. California Regional Water Quality Control Board 1997; Gold et al. 1992; Loomis et al 2001; Nolte & Associates 1992; Oakley et al. 1999; Piluk and Peters 1994; Ronayne et al. 1982

e. NSF International 2009

f. Ayres Associates 1998; Sandy et al. 1988

g. Gold et al. 1989

h. Brooks 1996; Gold et al. 1989

j. Rich et al. 2003

Other Systems

Leachfield Aeration: This technology involves intermittent aeration of the leach field and surrounding soils, which promotes oxidation of excess organic material and supports conditions for removal of nitrogen, phosphorus, organic carbon, and fecal coliform bacteria. This technology allows for the rejuvenation of a failed or failing leach field and enhances removal of total nitrogen, fecal coliform bacteria, and biochemical oxygen demand (BOD_5, amount of dissolved oxygen consumed in five days by bacteria that perform biological degradation of organic matter).

SoilAir™ is one technology that has been extensively tested. The SoilAir™ technology injects air into the leach field and the air travels into the surrounding soil. The oxygen in the air allows the microorganisms in the soil to thrive and reach high population levels. The microorganisms then eat the accumulated organic matter in the leach field, which assists with unclogging the leach field. The microorganisms also eat the bacteria in wastewater and breakdown nitrogen, thereby reducing bacteria and nitrogen levels in the leach field. In a study conducted by Amador et al (2007), intermittent aeration resulted in improved septic tank effluent infiltration, increased levels of dissolved oxygen and NO_3, lower concentrations of NH_4 and iron (Fe II), and more

acidic pH in drainage water. Removal of total nitrogen increased from less than 10% to greater than 50%.

The SoilAir™ System includes a blower with a discharge pipe and either a timer or a microprocessor based controller in an enclosure. The enclosure is connected to a power supply and the blower discharge pipe supplies air to the leach field.

In terms of cost, SoilAir™ is less expensive than the treatment units discussed above. Equipment costs for a typical residential SoilAir™ application ranges from $1,800 to $5,000, depending on system requirements. Installation costs are site-specific, but tend to be around $2,500. Operating costs are limited to energy to power the blower, with a typical system drawing approximately 280 Watts (Amador et al., 2007).

Vegetated Submerged Bed (VSB, also referred to as Constructed Wetlands): A VSB consists of a gravel bed that is planted with wetland vegetation. A septic tank begins the treatment process by retaining organic solids. The effluent flows out of the septic tank and into the VSB and is distributed into and across the width of the bed. The water level in the VSB is maintained below the top of the gravel in the bed. Microbes attach to the subsurface substrates such as the gravel and plant roots. The microbes purify the wastewater by breaking down the chemical components and settling out solids (sand). **Figure 8** provides an illustration of a VSB.

The VSB is capable of removing most of the suspended and larger colloidal particles, BOD, and organic forms of nitrogen. Since the VSB is largely anaerobic, it's not capable of nitrification and therefore nutrient removal. If nitrogen removal is necessary, a separate ammonia removal process would have to be used in conjunction with the VSB.

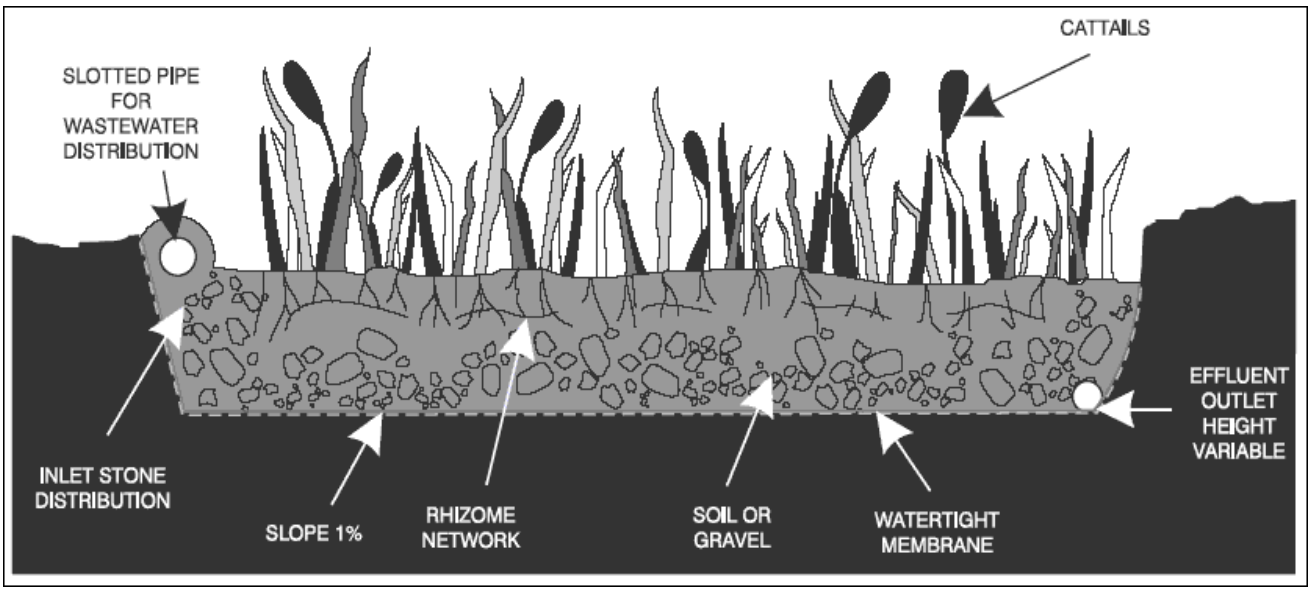


Figure 8: Vegetated Submerged Bed (Source: USEPA, 2010)

Another option for reducing wastewater impacts on groundwater and surface water is to reduce wastewater generation. This could be done through the use of a composting toilet in the home. A brief description of this technology is below.

Composting Toilet: A composting toilet is a well-ventilated container that provides the optimum environment for biological and physical decomposition of human excrement. The process takes place under aerobic (oxygen is present) conditions. Large composting toilets require a basement for installation, but small household composting toilets are more like small self-contained appliances that can be located on the bathroom floor. The composting process involves the transformation of organic matter into an oxidized, humus-like end product by bacteria and fungi. These organisms thrive by aeration, without the need for water or chemicals.

For treatment of high nitrate levels already in groundwater, permeable reactive barriers are an option.

Permeable Reactive Barrier (PRB): PRB's consist of a trench filled with a degradable carbon source (e.g. sawdust, newspaper) and are sited to intercept high-nitrate groundwater plumes before they enter surface waters. As the plumes pass through the low-oxygen, carbon-rich barrier, bacteria break down nitrate molecules thereby removing nitrate from the groundwater entering local surface waters. **Figure 9** provides an illustration of a PRB. Nitrex™, mentioned above, also develops PRB's. The patented Nitrex™ groundwater nitrogen removal technology was installed at two locations on Cape Cod, MA in the Waquoit Bay watershed. **Figure 10** below illustrates the decrease in algae seen after the installation of the PRB. **Table 1** details the performance of the PRB.

Costs for a PRB range from approximately $5,000 to $15,000 per dwelling unit in the plume area (EPA, 2010). The estimated lifetime of a PRB is greater than 15 years.

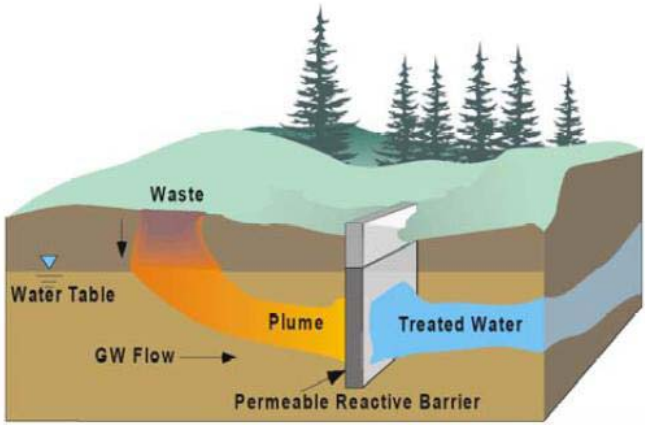


Figure 9: Permeable Reactive Barrier (Source: USEPA, 1998)

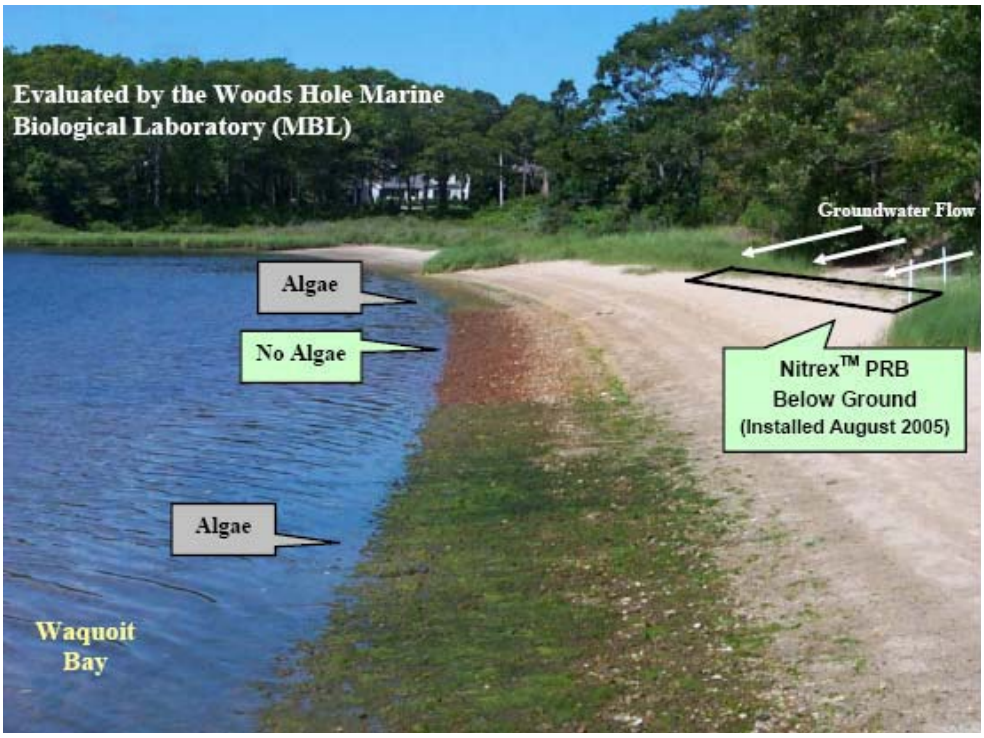


Figure 10: Nitrex PRB Installation shows decrease in algae growth

Table 1: Nitrex Nitrate Removal Efficiency

Site	Influent Nitrate-N (mg/l)	Effluent Nitrate-N (mg/l)
Waquoit Bay, MA	1.74	0.007
Childs River, MA	7.19	0.568

Test Centers/Evaluation of Alternative Treatment Technologies

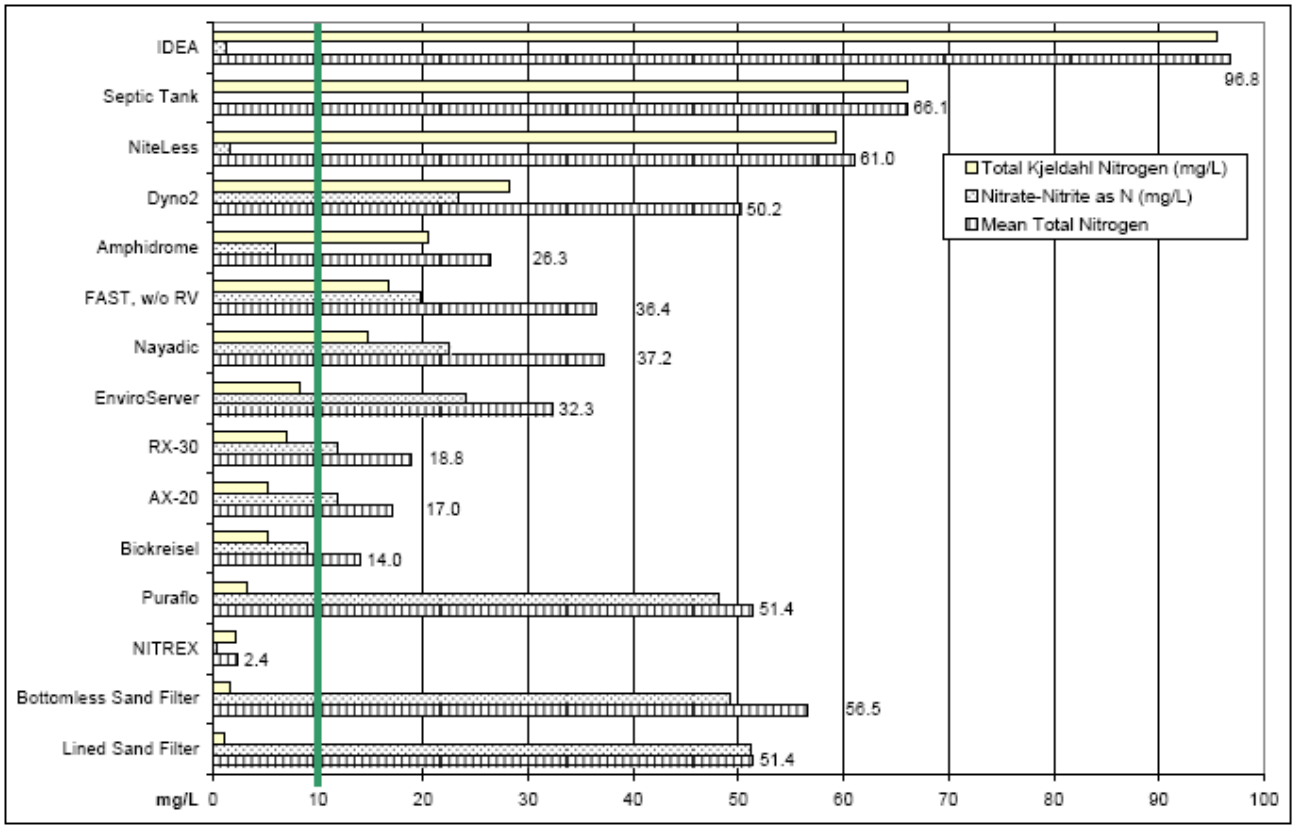
The Environmental Technology Verification (ETV) is a program funded by the United States Environmental Protection Agency (USEPA). The program is being conducted by the Massachusetts Alternative Septic System Test Center (MASSTC) in partnership with NSF International. Under the ETV program, the Test Center is establishing national protocols for

evaluation of nitrogen removal and septic system stress testing. The program tests one unit of technology for 14 months. Currently, six products have completed the ETV process for nitrogen reduction in domestic wastewaters from individual residential homes. The State of Maryland currently recognizes ETV verified technologies for use in the State as part of the State's Chesapeake Bay Restoration Program, where grants are given to homeowners to upgrade septic systems to nitrogen removing technologies. Please see **Table 2** below for an overview of the products.

For a review of the field performance of various alternative technologies, refer to the La Pine Decentralized Wastewater Demonstration Project (Rich, 2005). The La Pine Decentralized Wastewater Demonstration Project has provided some of the most comprehensive field data on the performance of various alternative systems. The project was funded by the EPA and conducted by the Deschutes County, Oregon, Environmental Health Division; Oregon Department of Environmental Quality; and the U.S. Geological Survey. The performance of 15 systems was monitored between 1999 and 2005. **Figures 11-15** below summarize some of the key results.

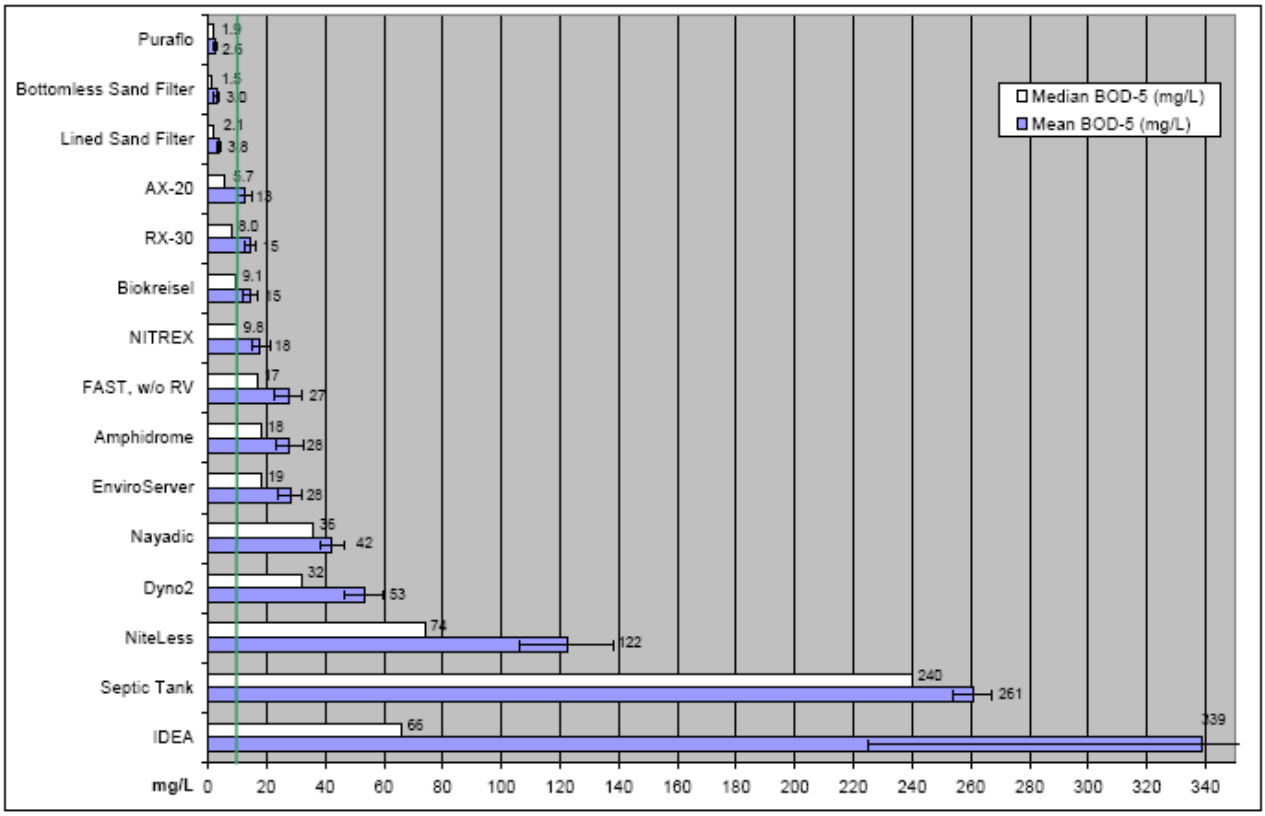
Another good source of information is the Conservation Technology Information Center. From November 9, 2010 to December 14, 2010 the Conservation Technology Information Center, U.S. Environmental Protection Agency, and Tetra Tech hosted a webinar series titled "Decentralized Wastewater Treatment: Treatment Technologies, System Design and Management Strategies." The series included a range of topics, including wastewater treatment processes and technologies, system design, management approaches, and integrating decentralized systems into a new paradigm for managing water resources. The webinars along with the PowerPoint presentation slides can be found at:
https://engineering.purdue.edu/~iwla/webinars/wastewater2010/index.html.

Figure 11: Nitrogen concentrations in the effluent discharged from each treatment unit against the performance standard for the field test of 10 mg/l.



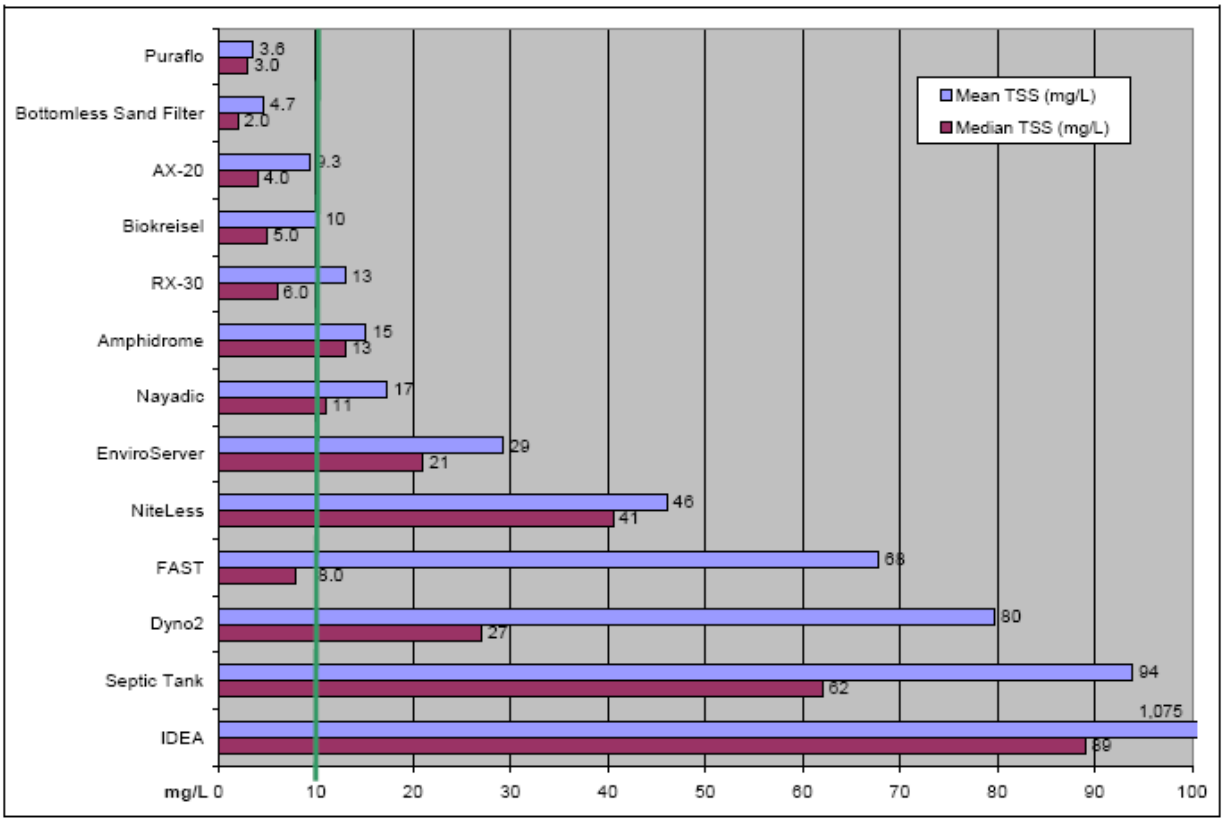
Source: Rich, 2005

Figure 12: Biological Oxygen Demand (BOD_5) of effluent discharged from each treatment unit against the performance standard for the field test of 10 mg/l.



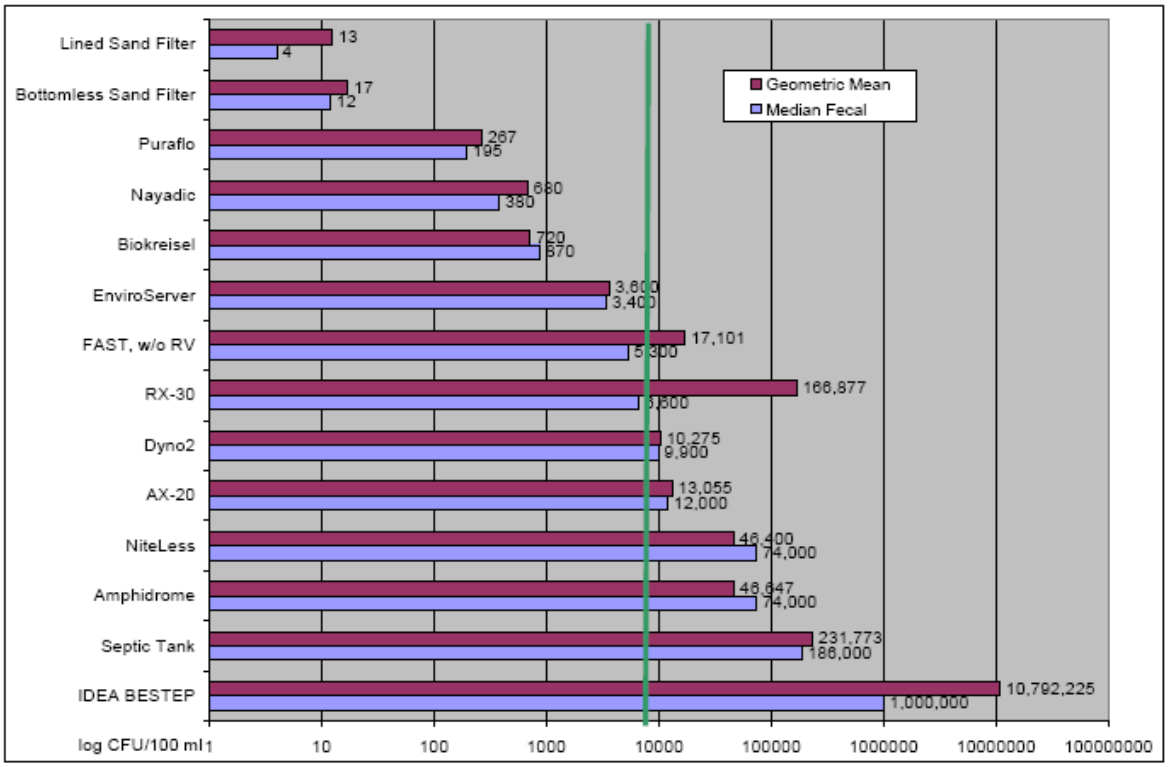
Source: Rich, 2005

Figure 13: Total Suspended Solids in the effluent discharged from each treatment unit against the performance standard for the field test of 10 mg/l.



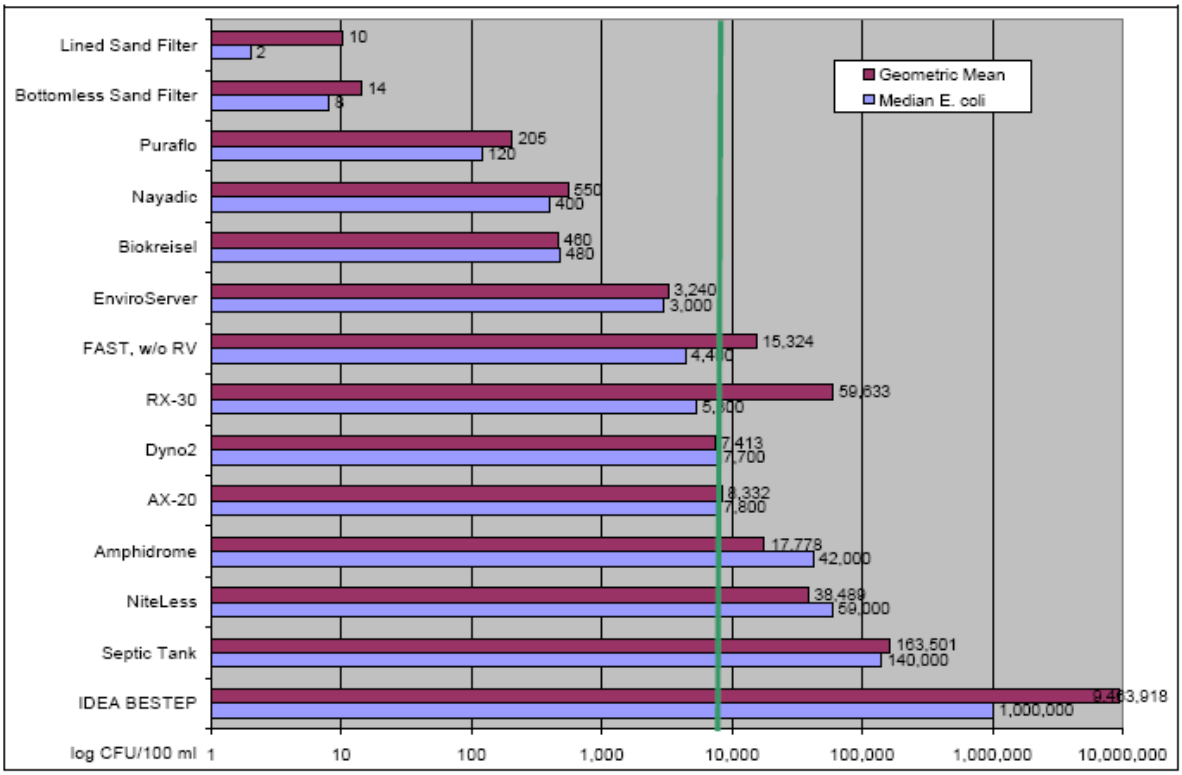
Source: Rich, 2005

Figure 14: Median fecal coliform reduction achieved by each treatment unit.



Source: Rich, 2005

Figure 15: Median E. coli reduction achieved by each treatment unit.



Source: Rich, 2005

Table 2: Products that have completed the ETV process for nitrogen reduction in domestic wastewater from individual residential homes (As of May 16, 2005).

System Name	Technology	Description of Process	Performance	Cost
Waterloo Biofilter® Model 4-Bedroom Waterloo Biofilter Systems, Inc.143 Dennis St.; PO Box 400 Rockwood, Ontario Canada, N0B 2k0 http://www.nsf.org/business/water_quality_protection_center/pdf/Waterloo-VS-SIGNED.pdf	Fixed film trickling filter.	The biofilter unit utilizes a patented lightweight open-cell foam that provides a large surface area. Settled wastewater from a primary septic tank is applied to the surface of the biofilter with a spray distribution system. The system can be set up using a single pass process (without any recirculation of biofilter treated effluent) or can utilize multi-pass configurations. The ETV testing results were generated by returning 50% of the biofilter effluent back to the primary compartment of the septic tank.	It averaged 62% removal of total nitrogen with an average total nitrogen effluent of 14 mg/l over the 13-month testing period. Earlier testing of this product in a single pass mode demonstrated that it could produce a 20-40% TN reduction.	$13,000-17,000 for total system installation. The Waterloo Biofilter® unit only would cost approximately $7,000.
Amphidrome™ Model Single Family System: F.R. Mahony & Associates, Inc. 273 Weymouth St. Rockland, MA 02370 http://www.nsf.org/business/water_quality_protection_center/pdf/Amphidrome_VS.pdf	Submerged growth sequencing batch reactor (SBR) in conjunction with an anoxic / equalization tank and a clear well tank for wastewater treatment	The bioreactor consists of a deep bed sand filter, which alternates between aerobic and anoxic treatment. The reactor operates similar to a biological aerated filter, except that the reactor changes from aerobic to anoxic conditions during sequential cycling of the unit. Air, supplied by a blower, is introduced at the bottom of the filter to enhance oxygen transfer.	It averaged 59% removal of total nitrogen with an average total nitrogen effluent of 15 mg/l over the 13-month testing period at MASSTC.	$7500 for unit only. The manufacturer estimates it would cost $12,000-15,000 for a total installation.
Septitech® Model 400 System: Septitech, Inc. 220 Lewiston Road Gray, Maine 04039 http://www.nsf.org/business/water_quality_protection_center/pdf/SeptiTech_VS.pdf	Two stage fixed film trickling filter using a patented highly permeable hydrophobic media.	Clarified septic tank effluent flows by gravity into the recirculation chamber of the SeptiTech unit. A submerged pump periodically sprays wastewater onto the attached growth process and the wastewater percolates through the patented packing material. Treated wastewater flows back into the recirculation chamber to mix with the contents. Treated water flows into a clarification chamber and is periodically discharged to disposal unit (drainfield, drip irrigation, etc.).	Averaged 64% removal of total nitrogen with an average total nitrogen effluent of 14 mg/l over the 12-month testing period at MASSTC.	$11,000 for Septitech unit includes shipping and installation. The manufacturer estimates that a total system with pressure distribution drainfield would cost approximately $20,000.

Adapted from Washington Department of Health, 2005.

Table 3: Products that have completed the ETV process for nitrogen reduction in domestic wastewater from individual residential homes (As of May 16, 2005).

System Name	Technology	Description of Process	Performance	Cost
Bioclere™ Model 16/12: Aquapoint, Inc. 241 Duchanine Blvd New Bedford, MA 02745 http://www.nsf.org/business/water_quality_protection_center/pdf/Bioclere-VS-SIGNED.pdf	Fixed film trickling filter.	Septic tank effluent flows by gravity to the Bioclere clarifier unit from which it is sprayed or splashed onto the fixed film media. Treated effluent and sloughed biomass are returned to the clarifier unit. A recirculation pump in the clarifier periodically returns biomass to the primary tank. Oxygen is provided to the fixed film by a fan located on the top of the unit.	Averaged 57% removal of total nitrogen with an average total nitrogen effluent of 16 mg/l over the 13-month testing period at MASSTC.	$7500 for unit itself. Price for total system would need to include primary septic tank, Bioclere unit and disposal option, with costs in the range of $12,000 -15,000. The manufacturer recommends use in clusters to reduce per home costs and facilitate maintenance. Experience with 27 home cluster resulted in costs of $6800-8,000 per home.
Retrofast® 0.375 System: Bio-Microbics 8450 Cole Parkway Shawnee, KS 66227 http://www.nsf.org/business/water_quality_protection_center/pdf/Biomicrobics-FinalVerificationStatement.pdf	Submerged attached-growth treatment system, which is inserted as a retrofit device into the outlet side of new or existing septic tanks.	The RetroFAST® 0.375 System is inserted in the second compartment of the septic tank. Air is supplied to the fixed film honeycombed media of the unit by a remote blower. Alternate modes of operation include recirculation of nitrified wastewater to the primary settling chamber for denitrification. Intermittent use of the blower can also be programmed to reduce electricity use and to increase denitrification.	Averaged 51% removal of total nitrogen with an average total nitrogen effluent of 19 mg/l over the 13-month testing period at MASSTC.	Product and installation cost for the Retrofast® 0.375 System ranges is estimated to be from $4,000-5,500 depending on existing tankage. That cost includes the FAST unit, blower, blower housing and control panel. The local representative for Bio-Microbics units believes costs could be as low as $3,500 for multiple units.

Adapted from Washington Department of Health, 2005.

Table 4: Products that have completed the ETV process for nitrogen reduction in domestic wastewater from individual residential homes (As of May 16, 2005).

System Name	Technology	Description of Process	Performance	Cost
Recip® RTS-500 System: Bioconcepts, Inc. P.O. Box 885 Oriental, NC 28571-0885 http://www.nsf.org/business/water_quality_protection_center/pdf/Bioconcepts_Verification_Statement.pdf	Fixed film filter	This is the newest product to complete ETV testing. It is a patented process developed by the Tennessee Valley Authority (TVA) and utilizes a fixed film filter medium contained in two adjacent, equally dimensioned cells. Timers on each of the two reciprocating pumps control the process.	Averaged 58% removal of total nitrogen with an average total nitrogen effluent of 15 mg/l over the 12-month testing period at MASSTC.	Very limited experience with this particular single-family unit. The unit built for ETV testing was a prototype. The cost per unit, by itself, is estimated to be $8,000-10,000. Cost of the septic tank and disposal unit would be extra and the cost would depend on site conditions. Conservatively, cost for a total system could be $11,000-15,000.

Source: Adapted from the Washington Department of Health, 2005

Alternative Systems in Suffolk County

Currently, the only "alternative system" Suffolk County Department of Health allows is the mound system in areas of high groundwater. Otherwise, they require a conventional septic tank and leaching pool system. If a homeowner was interested in installing one of the treatment technologies listed above, the homeowner would be required to obtain a variance. However, variances are very rarely granted.

The main issue with the "alternative" treatment technologies listed above is that they function differently in different environments with different climate, site conditions, hydraulic loads, and pollutant loads. Therefore, Suffolk County would have to conduct a comprehensive study of alternative systems to determine performance and feasibility for use in Suffolk County before alternative systems could be used.

References

Amador, J.A., G.W. Loomis, D. Kalen, E.L. Patenaude, J.H. Gorres and D. A. Potts. 2007. Evaluation of leachfield aeration technology for improvement of water quality and hydraulic function in onsite wastewater treatment systems. Final Report to NOAA/UNH Cooperative Institute for Coastal and Estuarine Environmental Technology (CIDEET). Grant No. NA04NOS4190109. Univ. of New Hampshire. 27 pp.
Center for Watershed Protection. Dealing with Septic System Impacts. Watershed Protection Techniques 32(1): 233-238.
Chesapeake Bay Restoration Fund Website:
http://www.mde.state.md.us/Water/CBWRF/brf bat.asp.
Costa, J.E., G. Heufelder, S. Foss, N.P. Milham, and B. Howes. 2002. Nitrogen removal efficiencies of three alternative septic technologies and a conventional septic system. Environment Cape Code 5(1): 15-24.
Gold, A.J., W.R. DeRagon, W.M. Sulllivan, and J.L. Lemunyon. 1990. "Nitrate-Nitrogen Losses to Groundwater From rural and Suburban Land Uses." Journal of Soil and Water Conservation. 45(2):305-310.
Magliaro, J., Lovines, A. 2004. Valuing Decentralized Wastewater Technologies: A Catalog of Benefits, Costs, and Economic Analysis Techniques. Rocky Mountain Institute.
National Small Flows Clearinghouse (NSFC). 2000. Small Flows Quarterly. Vol. 1, No. 4, Summer 2000. National Environmental Service Center, West Virginia University. Morgantown, WV.
Piluk, R., Peters, E. Recirculation Sand Filters: An Alternative to Conventional Septic Systems. Watershed Protection Techniques. 2(1): 288-290.
Rich, B. 2005. La Pine National Demonstration Project Final Report, 1999–2005. U.S. Environmental Protection Agency and supported by the Deschutes County, Oregon, Environmental Health Division, Oregon Department of Environmental Quality, and the U.S. Geological Survey.
Siegrist, R.L. and P.D. Jenssen. 1989. "Nitrogen Removal During Wastewater Infiltration as Affected by Design and Environmental Factors." R.W. Seabloom and D. Lenning (eds). Proc. 6th Northwest On-site Wastewater Treatment Short Course, pp. 304-318. Seattle, WA, 18-19 September 1989. ASAE, St. Joseph, MI.
USEPA (U.S. Environmental Protection Agency). 1998. Permeable Reactive Barrier Technologies for Contaminant Remediation. U.S. Environmental Protection Agency, Office of Research and Development, Office of Solid Waste and Emergency Response, Washington, DC.
USEPA (U.S. Environmental Protection Agency). 2001. A Citizen's Guide to Permeable Reactive Barriers. EPA 542-F-01-005. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC.
USEPA (U.S. Environmental Protection Agency). 2002. Onsite Wastewater Treatment Systems Manual. EPA/625/R-00/008. U.S. Environmental Protection Agency, Office of Water.
USEPA (U.S. Environmental Protection Agency). 2010. Guidance for Federal Land Management in the Chesapeake Bay Watershed, Chapter 6: Decentralized Wastewater Treatment Systems. EPA841-R-10-002. U.S. Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2010. Onsite Wastewater Treatment Systems Technology Fact Sheet 9: Enhanced Nutrient Removal-Nitrogen. EPA 625/R-00/008. U.S. Environmental Protection Agency, Office of Water, Washington, DC.
USEPA (U.S Environmental Protection Agency). 2010. Onsite Wastewater Treatment Systems Technology Fact Sheet 5: Vegetated Submerged Beds and Other High-Specific-Surface Anaerobic Reactors. EPA 625/R-00/008. U.S. Environmental Protection Agency, Office of Water, Washington, DC.
Washington State Department of Health: Office of Environmental Health and Safety. (2005). Report to the Puget Sound Action Team: Nitrogen Reducing Technologies for Onsite Wastewater Treatment Systems.