WTM Modeling Report:

A Summary of Pollutant Loads and Project Cost Estimations for Five Irondequoit Creek Sub-Watersheds

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Acronyms and Abbreviations

WTM	Watershed Treatment Model
BM	Basic Model
EM	Enhanced Model
IC	impervious cover
TN	total nitrogen
TP	total phosphorous
TSS	total suspended solids
FC	fecal coliform
RV	runoff volume
WQv	water quality volume
GIS	geographic information system

Section 1. Assessment Overview

In 2011 the Stormwater Coalition of Monroe County received funding from the NYS Environmental Protection Fund to conduct a series of Rapid Green Infrastructure Assessments on local watersheds. These assessments provided baseline watershed information and ranking of potential stormwater projects and management facilities (Figure 1). Once these assessments had been completed for a number of target watersheds, further analysis which included modeling of pollutant loads and the estimation of project cost was undertaken, and are contained within this report.

Five watersheds were selected for further analysis; Densmore Creek, Glen Haven, Tufa Glen, Thomas Creek, and White Brook. The modeling of the target watersheds was completed using the Watershed Treatment Model (WTM), an Excel based model developed by the Center for Watershed Protection. In addition to the modeling, cost estimation were also calculated for the various stormwater projects identified by the Rapid Assessments of the watersheds. The ultimate goal is to have retrofit plans and pollutant loads modeled on all urbanized watersheds in the County. Once this is completed, the results will be used to establish achievable and realistic targets for pollutant reduction through the development of a County-wide comprehensive Stormwater Master Plan. This plan will ensure that all applicable stormwater regulations are being met, as well as to maintain the health and vitality of local waterways.

This summary report will present the results of the WTM that was done on each of the target watersheds. An interpretation and comparison of all the modeling and assessments will be conducted at a later date as a part of a more comprehensive report. The purpose of this report is to provide baseline watershed pollutant loads, estimated future pollutant loads, and approximate the cost associated with the recommended actions and retrofits.

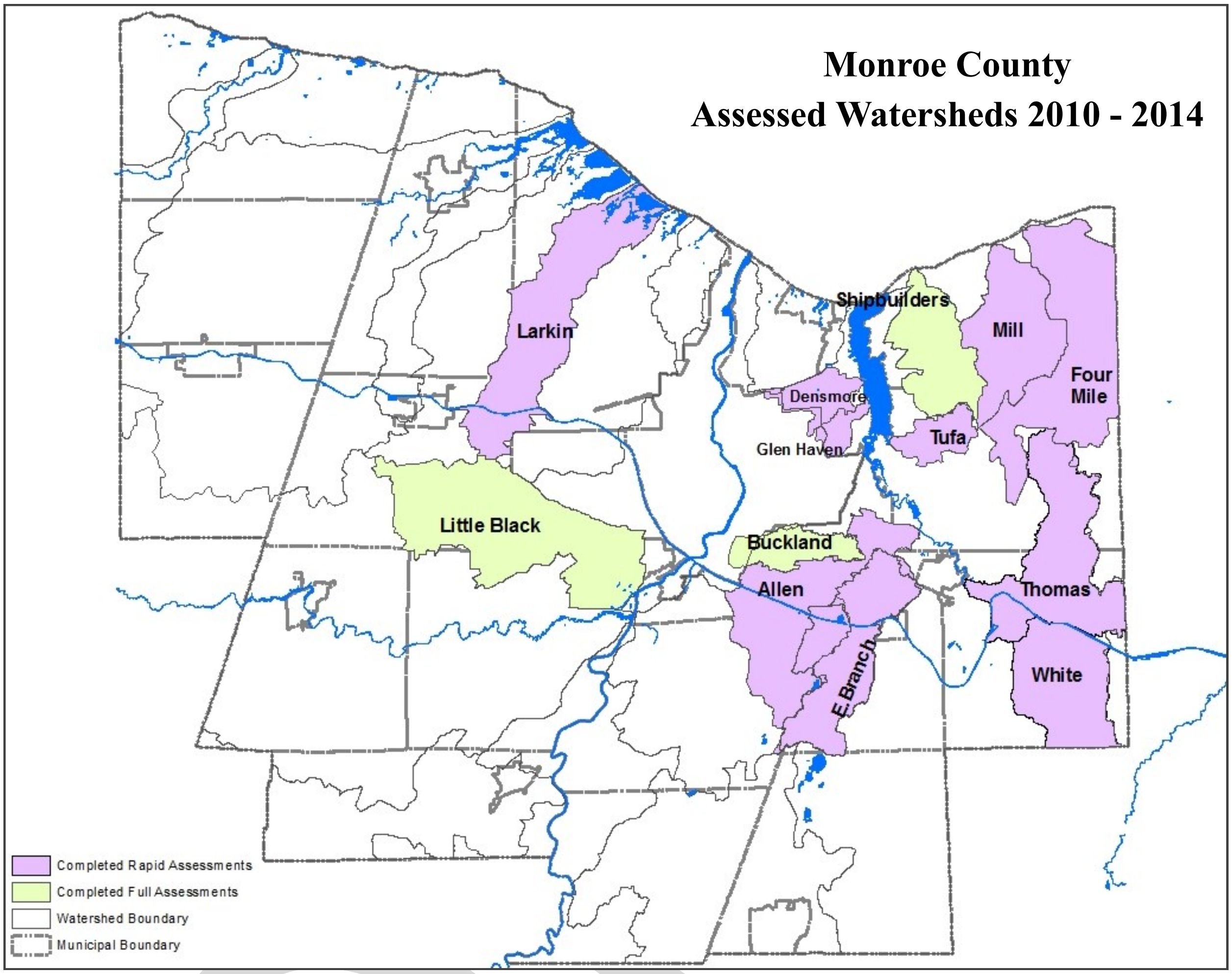

Figure 1. Assessed Watersheds within Monroe County.

Section 2. Watershed Modeling Methods

2.1 The Watershed Treatment Model

The Watershed Treatment Model (WTM), which was developed by the Center for Watershed Protection, is used to estimate existing and future nutrient, total suspended solids, bacteria loads, and runoff volume within a watershed. Monroe County has adopted the use of the WTM to provide modeling consistency across all the assessed watersheds.

The WTM, is an Excel spreadsheet model that:

- Estimates annual pollutant loading under current watershed conditions for Total Nitrogen (TN), Total Phosphorus (TP), Total Suspended Solids (TSS), Fecal Coliform (FC), and Runoff Volume (RV)
- Determines the effects of current stormwater facilities and management practices
- Estimates potential load reductions associated with the implementation of structural and non -structural management practices

The basic components of the WTM can be divided into existing conditions and future conditions (Figure 2). The existing conditions of a watershed include primary and secondary sources and existing management practices. Primary sources include land use, watershed area, rainfall, stream length and soil information. Secondary sources involve miles of stormwater or sewer pipes, illicit connections, livestock, road sanding, and on-site sewage disposal systems. Existing management practices provide the regulations, policies, and stormwater related facilities already in the watershed. Based upon the input of these different variables, and calculations and assumptions made by the WTM, estimated existing pollutant loads are calculated.

Once the existing pollutant loads have been calculated, this provides a baseline upon which to estimate how changes of existing, or introduction of new, stormwater practices may alter the watershed pollutant load. The future conditions of the watershed are estimated by implementing changes to existing practices or introducing new practices. An example would be increasing street sweeping frequency or changing from a mechanical sweeper to a more efficient vacuum assisted sweeper.

The second component of the future conditions is the improvement of existing stormwater management facilities or construction of new ones. Using basic information such as; project type, drainage area, impervious cover, pre-existing or new project, and soil information, the WTM calculates an annual pollutant reduction. The WTM then calculates the annual pollutant load with the future conditions taken into account. By comparing the existing and future pollutant loads, we can see the annual load differences and percent improvement.

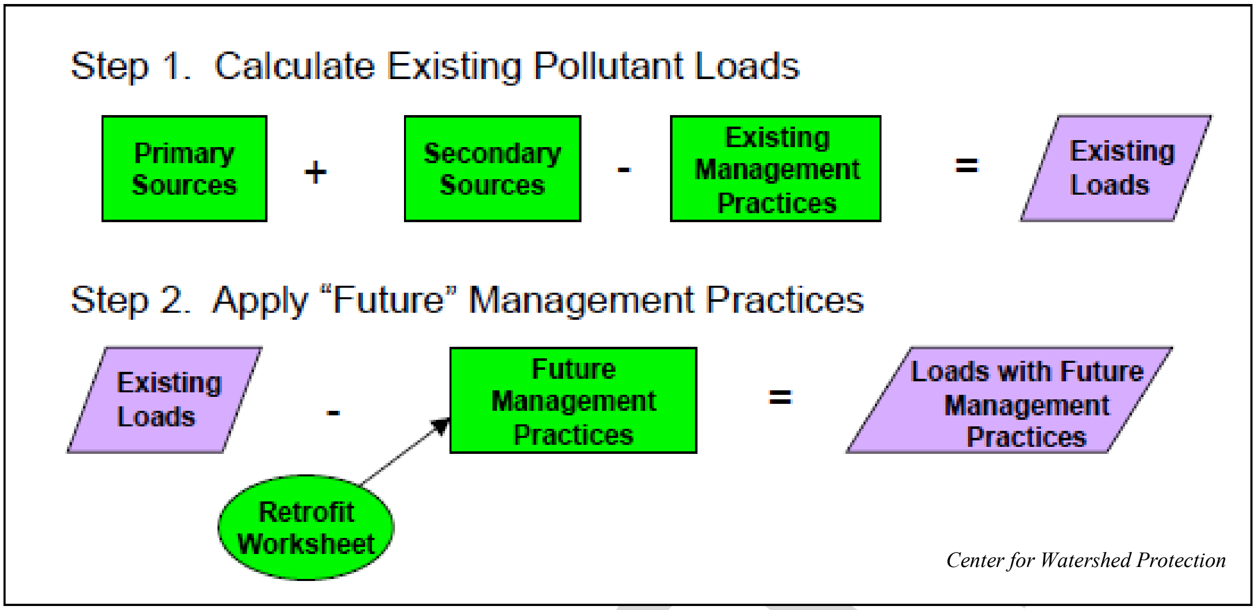

Figure 2: Diagram of the basic elements of the Watershed Treatment Model (WTM).

The following caveats should be considered while reviewing results of the WTM:

1. The WTM is a planning level model primarily for urban/suburban applications. There are many simplifying assumptions made by the WTM, and the model results are not calibrated. Therefore, the results of the model simulations should be compared on a relative basis rather than used as absolute values. Often, the application of existing treatment practices in a watershed is based on GIS data, best professional judgment, and default values associated with the WTM.
2. Some variables that are input into the WTM are not readily available, or cannot practically be determined at a watershed level. In these instances professional judgment and extrapolation of available data were used.

In order to best evaluate the effectiveness of various stormwater management facilities and retrofits that could be implemented in the target watersheds, two "models" were used. These models consisted of the same stormwater management facility construction or retrofit projects, however, various program efficiency values, reduction goals, and completion percentages were changed. For example, in program areas such as lawn care and pet waste education, the Basic Watershed Treatment Model (BWTM) would assume a smaller percentage of people would be aware of said education message. The Enhanced Watershed Treatment Model (EWTM) assumed higher awareness and greater behavior change. This would lead to greater reductions in pollutant loads.

2.2 Determining Planning Level Project Costs

The cost of designing, installing, and maintaining stormwater management facilities is one of the most important considerations involved in large scale stormwater planning and water quality projects. A related component of the cost of a project is also the cost effectiveness, as it pertains to specific factors such as water quality volume or pollutant removal. Determining the cost-effectiveness of projects also provides a means to compare different types of stormwater facilities, such as bioretention and wet ponds, based upon specific pollutant removal rates and the associated cost per lbs of removal.

Using the Center for Watershed Protection's Manual 3, project cost estimations were calculated by applying a specific unit cost based upon project type. Table 1 shows the cost per unit of impervious acres or cubic feet of water treated for the different stormwater management and green infrastructure projects identified in the target watersheds. The acres of impervious cover within each projects drainage areas was calculated as one of the many variables input into the WTM. The WTM calculated the Water Quality volume (WQv) in gallons for each project and this value was converted to cubic feet in order to estimate project cost.

Table 1: Unit Cost per Unit Treated

Project Type	Calculation Unit	Cost if Existing Project	Cost if New Project
Bioretention	Impervious acres	$25,400	-
Dry Pond	Impervious acres	$3,800	$11,400
Wet Pond	Impervious acres	$8,350	$14,612
Modify Existing Pond	Impervious acres	-	$11,150
Wetland	Impervious acres	$2,900	$10,150
Impervious Cover Conversion	Cubic feet treated	$20	-
Permeable Pavers	Cubic feet treated	$120	-
Porous Concrete	Cubic feet treated	$65	-

Section 3. WTM Results

3.1 Densmore Creek

The Densmore stream system is comprised of its main branch and tributary, Hobbie Creek (Figure 3). The headwaters of the main branch originate in the northeastern area of the City of Rochester. Hobbie Creek begins in the lower central area of Town of Irondequoit, along Route 104. The streams flow through the Town of Irondequoit in an easterly direction then merge just east of I-590 before discharging into Irondequoit Bay.

The watershed is highly urbanized with approximately 42 percent impervious cover and over half its length piped or channelized with concrete lined walls. As would be expected with a high impervious cover percentage, dense residential and commercial development dominate the land use of the watershed. The actual watershed size of 1640 acres is much smaller than would naturally drain to this stream, due to the upstream portion within the City of Rochester flowing into a combined sewer system. This effectively removes these portions from the watershed drainage area.

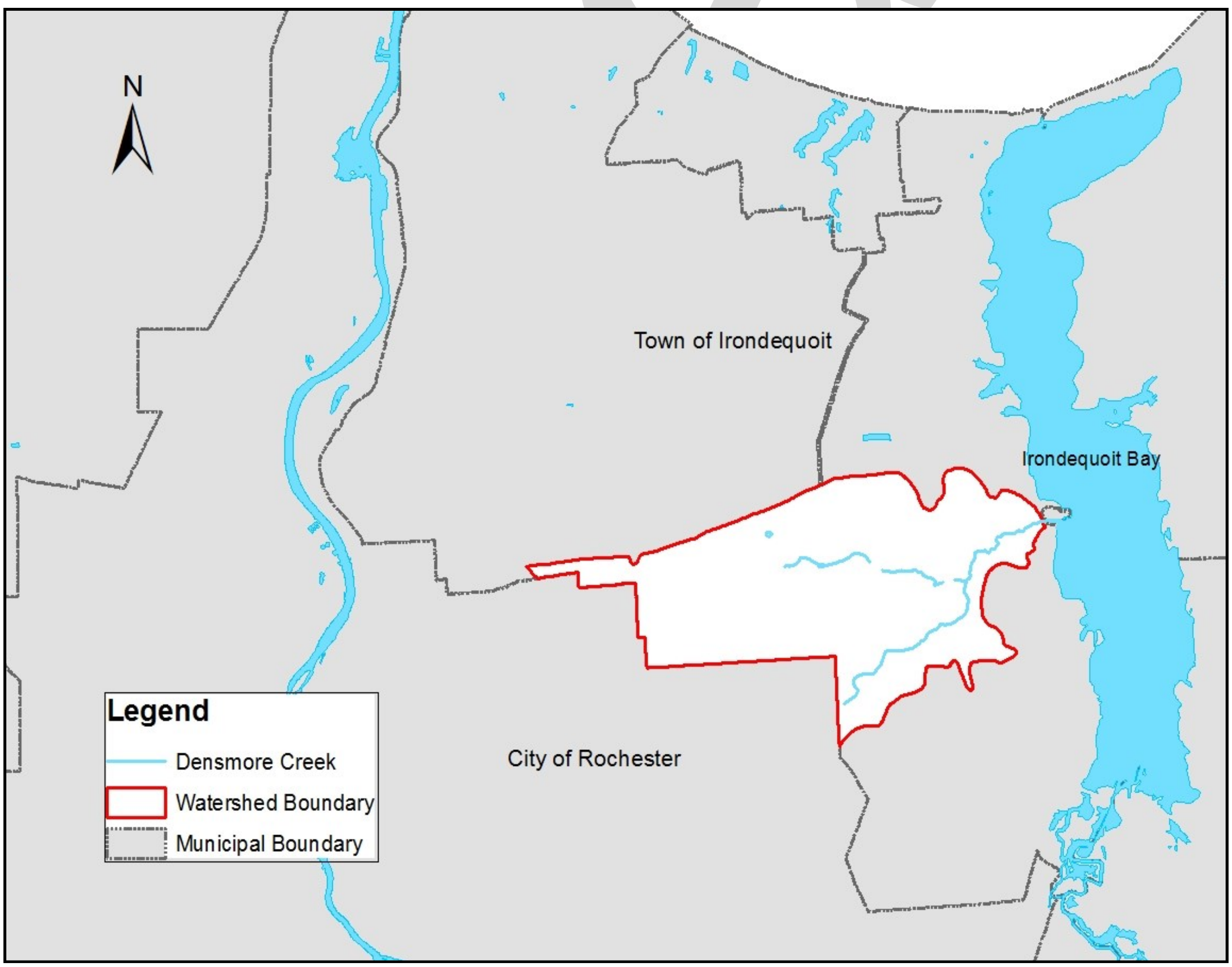

Figure 3: Map of the Densmore Creek watershed and surrounding municipalities.

There are a number of different sources of pollutants within the Densmore Creek watershed, as shown in Table 2. There are also land uses or secondary sources that account for a large proportion of the total yearly loads. The resulting pollutant loads are subdivided into Total Storm Load and Total Non-Storm Load. Sources of storm loads occur mostly during storm events, where stormwater runoff collects pollutants as it flows over surfaces. Sources of non-storm loads are usually a more direct source, and are frequently independent of storm events. Examples include illicit connects or permitted discharges.

Urban land use contributes the greatest amount of Total Nitrogen (TN) yearly, approximately 15,700 lbs/yr, or almost 75% of the TN. The Total Phosphorus (TP) yearly load is more evenly divided between Urban land use and channel erosion, which accounts for almost 90% of the TP yearly. Again, results also indicated that urban land use and channel erosion are the greatest contributors to Total Suspended Solids (TSS), roughly 96% of the yearly load. Approximately 41% of the Fecal Coliform (FC) yearly loads is attributed to illicit connections throughout the watershed. An additional 31% is result of urban land use and another 26% from storm sewer overflows. Urban land use was attributed to the all of the Runoff Volume (RV) in the watershed.

Table 2: Existing Loads in Densmore Creek Watershed

Pollutant Source	Total Nitrogen (lbs/yr)	Total Phosphorus (lbs/yr)	Total Suspended Solids (lbs/yr)	Fecal Coliform (billion/yr)	Runoff Volume (acre-feet/year)
Urban Land	15,720	2,724	401,817	626,882	2,702
Active Construction	-	-	-	-	-
Sanitary Sewer Overflow	705	117	4,700	533,434	-
Combined Sewer Overflow	-	-	-	-	-
Channel Erosion	1,683	1,599	420,662	-	-
Road Sanding	-	-	-	-	-
Forest	1	-	27	3	-
Rural Land	840	128	18,258	7,121	-
Livestock	-	-	-	-	-
Illicit Connections	1,197	257	8,354	819,250	-
Marinas	-	-	-	-	-
Point Sources	-	-	-	-	-
Septic Systems	43	7	286	147	-
Open Water	-	-	-	-	-
Total Storm Load	18,175	4,471	841,286	900,722	2,702
Total Non-Storm Load	2,013	361	12,818	1,086,114	-
Total Load to Surface Waters	**20,188**	**4,832**	**854,105**	**1,986,836**	**2702**

Pollutant load reductions for the Basic WTM (BWTM) are shown in Table 3. Results indicate that the implementation of the BWTM projects and practices may reduce target pollutant loads between 2.5 to 20.0%, depend upon the pollutant. The largest reduction was in the pollutant FC, with the lowest reduction coming from RV. A particular pollutant of concern, TP, saw a 6.2% reduction yearly, or 302 lb/yr.

Table 3: Future Loads in Densmore Creek Watershed (Basic WTM)

Pollutant Source	Total Nitrogen (lbs/yr)	Total Phosphorus (lbs/yr)	Total Suspended Solids (lbs/yr)	Fecal Coliform (billion/yr)	Runoff Volume (acre-feet/year)
Urban Land	13,425	2,487	361,719	421,647	2,630
Active Construction	-	-	-	-	-
Sanitary Sewer Overflow	441	73	2,937	333,396	-
Combined Sewer Overflow	-	-	-	-	-
Channel Erosion	1,683	1,599	420,662	-	-
Road Sanding	-	-	-	-	-
Forest	1	-	27	3	-
Rural Land	840	128	18,258	7,121	-
Livestock	-	-	-	-	-
Illicit Connections	748	160	5,221	512,031	-
Marinas	-	-	-	-	-
Point Sources	424	71	2,828	320,913	-
Septic Systems	18	3	117	93	-
Open Water	-	-	-	-	-
Total Storm Load	15,748	4,211	800,307	595,469	2,630
Total Non-Storm Load	1,831	309	11,463	999,735	-
Total Load to Surface Waters	17,579	4,521	811,770	1,595,204	2,630
Percent Load Reduction	12.9%	6.4%	5.0%	19.7%	2.7%
Load Reduction	**2,609**	**312**	**42,335**	**391,632**	**72**

The results of the Enhanced WTM (EWTM) showed larger reductions for all pollutant loads as compared to the BWTM (Table 4). The greatest difference between the EWTM and BWTM was seen in FC, where the EWTM resulted in a 17% additional reduction. Both TSS and runoff volume showed only a 0.7% additional reduction as compared to the BWTM. The EWTM resulted in a almost 8.0% additional reduction of TN. The TP load using the EWTM provided an additional 3.0% of removal, or 145 lb/yr.

Table 5 displays the phosphorus loads and percent reductions for the BWTM and EWTM. The EWTM resulted in approximately 66.0% more phosphorus reduction compared to the BWTM however, this translates to only a little over 3.0% overall annual load reduction.

Table 4: Future Loads in Densmore Creek Watershed (Enhanced WTM)

Pollutant Source	Total Nitrogen (lbs/yr)	Total Phosphorus (lbs/yr)	Total Suspended Solids (lbs/yr)	Fecal Coliform (billion/yr)	Runoff Volume (acre-feet/year)
Urban Land	12,109	2,405	353,913	268,860	2,613
Active Construction	-	-	-	-	-
Sanitary Sewer Overflow	176	29	1,175	133,358	-
Combined Sewer Overflow	-	-	-	-	-
Channel Erosion	1,683	1,599	420,662	-	-
Road Sanding	-	-	-	-	-
Forest	1	-	27	3	-
Rural Land	840	128	18,258	7,121	-
Livestock	-	-	-	-	-
Illicit Connections	299	64	2,089	204,812	-
Marinas	-	-	-	-	-
Point Sources	848	141	5,656	641,826	-
Septic Systems	-	-	-	-	-
Open Water	-	-	-	-	-
Total Storm Load	14,300	4,108	791,620	342,663	2,613
Total Non-Storm Load	1,656	259	10,160	913,318	-
Total Load to Surface Waters	15,956	4,367	801,780	1,255,981	2,613
Percent Load Reduction	**21.0%**	**9.6%**	**6.1%**	**36.8%**	**3.3%**
Load Reduction	**4,232**	**466**	**52,325**	**730,855**	**89**

Table 5: Densmore Creek Phosphorous Removal

	Basic Model	Enhanced Model
Baseline Annual Loads (lbs)	4,832	4,832
Load Reduction (lbs)	312	466
Total Load (lbs)	4,521	4,367
Percent Load Reduction	6.4%	9.6%

The preliminary costs were estimated for the 21 retrofit projects (Table 6). Finding the most cost-effective solutions from a water quality perspective was a critical ranking criterion. The cost of stormwater restoration projects varies greatly, from several hundred to hundreds of thousands of dollars. Projects were prioritized because they were simple projects that could be implemented by municipal staff, or were relatively inexpensive retrofits such as pond retrofits. An additional consideration however, is the volume of stormwater treated and the amount of pollutants that are removed. The priority pollutant in most urban streams in Monroe County is phosphorus. Once the estimate of a retrofit cost is made, that cost can be applied to the model output for phosphorus removal of that retrofit.

Due to phosphorus being a pollutant of concern within the watershed, a cost per pound of phosphorus removed becomes a useful value for comparison of projects (Table 6).

Table 6: Summary of Retrofit Project Cost Estimates in Densmore Creek

Proposed Project	Drainage Area (acres)	Impervious Cover (acres)	Existing Stormwater Management Facility	Water Quality Volume (gallons)	Planning Level Cost	Cost of WQv Treated	Annual Total Phosphorous Load (lb/yr)	Cost per lb Phosphorous Removal
Wet Pond	1.5	0.9	Wet Pond	2,832	$10,035	$3.54	0.7	$14,601
Wet Pond	1.5	1.4	Dry Pond	3,871	$15,253	$3.94	1.4	$10,588
Wet Pond	1.7	1.5	Dry Pond	4,355	$17,160	$3.94	1.6	$10,588
Bioretention	0.9	0.7	N/A	2,140	$18,999	$8.88	1.3	$14,158
Bioretention	6.2	1.2	N/A	6,581	$31,445	$4.78	3.9	$8,091
Bioretention	1.5	1.3	N/A	3,782	$33,833	$8.95	2.2	$15,146
Wet Pond	10.9	4.4	N/A	15,887	$36,540	$2.30	6.4	$5,686
Wet Pond	3.8	3.6	Dry Pond	10,124	$40,357	$3.99	3.8	$10,712
Bioretention	2.4	1.7	N/A	5,115	$42,316	$8.27	3.0	$14,009
Permeable Pavement	3.3	1.5	N/A	5,416	$47,067	$8.69	3.4	$13,772
Wet Pond	16.8	6.7	N/A	24,923	$55,978	$2.25	10.1	$5,552
Wet Pond	6.2	5.6	Dry Pond	15,765	$62,618	$3.97	5.9	$10,673
Bioretention	3.4	2.5	N/A	7,540	$63,818	$8.46	4.5	$14,332
Bioretention	3.3	2.6	N/A	7,658	$66,650	$8.70	4.5	$14,736
Permeable Pavement	14.5	10.8	N/A	32,208	$86,124	$2.67	21.5	$4,006
Bioretention	4.5	3.6	N/A	10,431	$91,237	$8.75	6.5	$13,950
Bioretention	6.1	5.5	N/A	15,577	$140,132	$9.00	9.8	$14,348
Wet Pond	42.4	25.4	N/A	82,426	$212,224	$2.57	33.3	$6,365
Permeable Pavement	12.2	8.2	N/A	25,475	$221,390	$8.69	16.1	$13,772
Permeable Pavement	13.8	9.4	N/A	28,711	$249,517	$8.69	18.1	$13,772
Cul-de-sac Impervious Cover Conversion	15.1	11.3	N/A	33,986	$295,352	$8.69	21.4	$13,772
				TOTAL - $1,751,920				

3.2 Glen Haven

Glen Haven is a small tributary to Irondequoit Bay. The Creek originates in the northeast portion of the city of Rochester NY, flows northeasterly through the town of Irondequoit, down a long embankment of mature hardwoods to Irondequoit Bay (Figure 4). Approximately half of its length is protected in Irondequoit Bay Park West—a 147 acre county park. The remaining half of the stream flows through primarily residential areas. The actual watershed size of 885 acres is considerably smaller than would naturally drain to this watershed since a portion drains to the Rochester Combined Sewer System. The watershed's predominate land use is residential with some commercial area along Empire Blvd. There is 50 percent impervious cover and most of its length piped. Un-piped sections of the stream are predominantly located in a county park toward the mouth of the stream before emptying into the Bay.

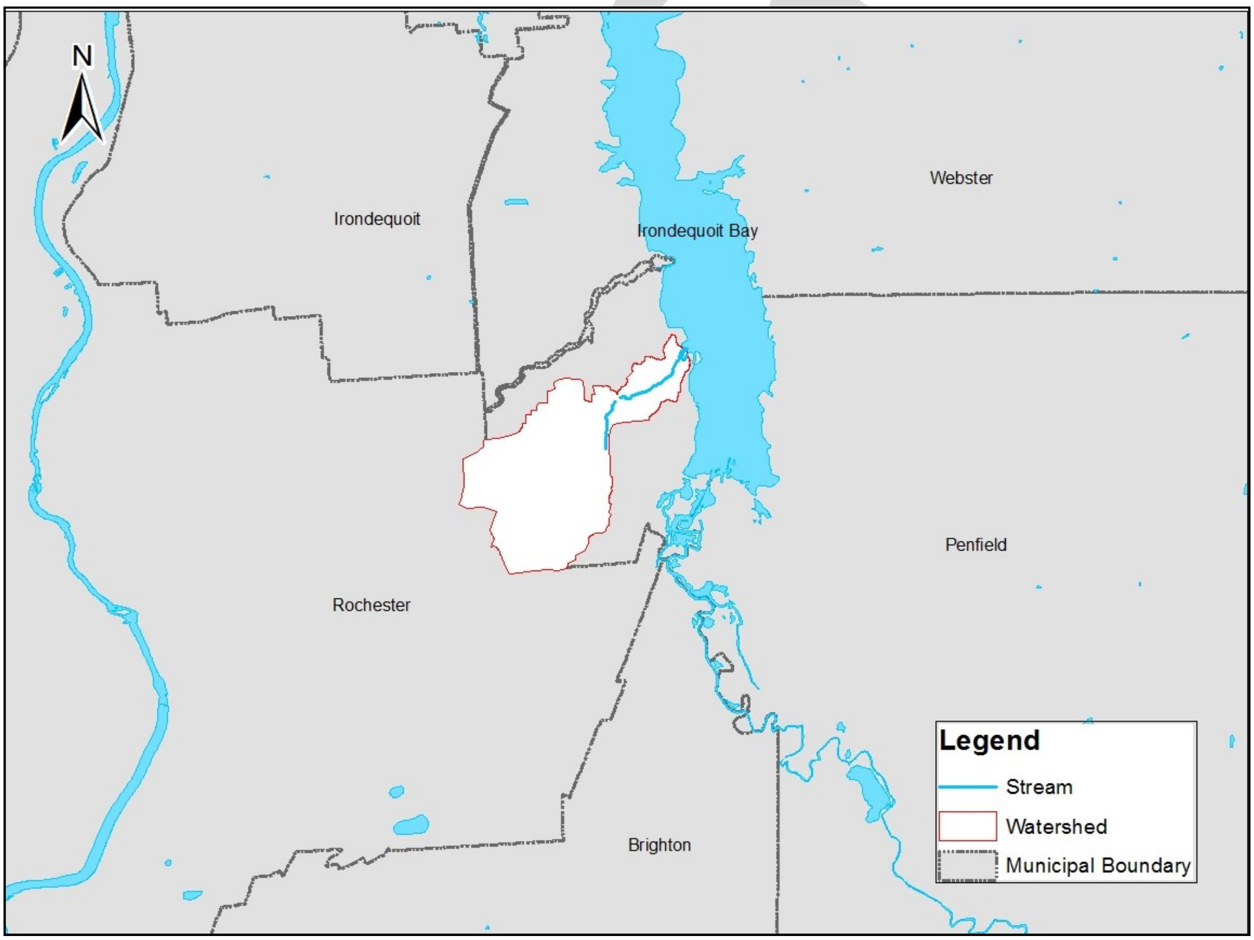

Figure 4: Map of the Glen Haven watershed and surrounding municipalities

Urban land use was the greatest contributor of nitrogen and phosphorus in the Glen Haven watershed (Table 7). It was also a significant contributor of suspended solids, just behind the annual suspended solids load of channel erosion. Illicit connections were the greatest source of FC loads in the water, with small additional contributions from urban land use and stormwater sewer overflows. Urban land use resulted in nearly the total amount of RV within the watershed. Given the dense residential make-up of the watershed, it is not surprising that urban land is a major source, if not the largest source, of pollutant loads. The predominant source of TP, a pollutant of concern in the watershed, was just under 2,000 lbs/yr.

Table 7: Existing Loads in Glen Haven Watershed

Pollutant Source	Total Nitrogen (lbs/yr)	Total Phosphorus (lbs/yr)	Total Suspended Solids (lbs/yr)	Fecal Coliform (billion/yr)	Runoff Volume (acre-feet/year)
Urban Land	4,894	1,099	123,276	169,028	836
Active Construction	-	-	-	-	-
Sanitary Sewer Overflow	159	27	1,062	120,499	-
Combined Sewer Overflow	-	-	-	-	-
Channel Erosion	559	531	139,631	-	-
Road Sanding	-	-	-	-	-
Forest	185	15	7,398	888	5
Rural Land	388	59	8,429	3,287	-
Livestock	-	-	-	-	-
Illicit Connections	1,023	190	6,949	745,069	-
Marinas	-	-	-	-	-
Point Sources	-	-	-	-	-
Septic Systems	0	0	2	1	-
Open Water	-	-	-	-	-
Total Storm Load	5,819	1,694	277,681	233,453	841
Total Non-Storm Load	1,390	225	9,065	805,319	-
Total Load to Surface Waters	**7,209**	**1,920**	**286,746**	**1,038,772**	**841**

Under the Basic WTM (BWTM) conditions, all annual pollutant loads dropped, as seen in the percent load reduction in Table 8. FC annual loads saw the greatest reduction, approximately 39%, resulting from significantly less contributions from urban land use, stormwater sewer overflows, and particularly illicit connections. TN was reduced by slightly more than 22% as compared to existing conditions, mostly stemming from a more than 1,000 lb/yr difference in urban land contributions under existing conditions. TSS and RV did not have significant reductions, less than 3.0% and 2% respectively, resulting from urban land changes. A more than 7.0% reduction of annual TP loading was seen as a result of urban land and illicit connection improvements.

Table 8: Future Loads in Glen Haven Watershed (Basic WTM)

Pollutant Source	Total Nitrogen (lbs/yr)	Total Phosphorus (lbs/yr)	Total Suspended Solids (lbs/yr)	Fecal Coliform (billion/yr)	Runoff Volume (acre-feet/year)
Urban Land	3,699	1,042	117,837	87,151	826
Active Construction	-	-	-	-	-
Sanitary Sewer Overflow	100	17	664	75,312	-
Combined Sewer Overflow	-	-	-	-	-
Channel Erosion	559	531	139,631	-	-
Road Sanding	-	-	-	-	-
Forest	185	15	7,398	888	5
Rural Land	388	59	8,429	3,287	-
Livestock	-	-	-	-	-
Illicit Connections	640	119	4,343	465,668	-
Marinas	-	-	-	-	-
Point Sources	3	1	23	2,588	-
Septic Systems	0	0	1	0	-
Open Water	-	-	-	-	-
Total Storm Load	4,594	1,633	272,043	128,982	832
Total Non-Storm Load	979	150	6,281	505,912	-
Total Load to Surface Waters	5,573	1,782	278,325	634,894	832
Percent Load Reduction	**22.7%**	**7.1%**	**2.9%**	**38.9%**	**1.1%**
Load Reduction	**1,636**	**137**	**8,421**	**403,878**	**9**

Future pollutant loads under the EWTM conditions were all less than using the BWTM conditions (Table 9). TP and FC saw pollutant load reductions near double the BWTM values, 13.6% and 75.2% respectively. The EWTM showed a roughly 17.0% improvement in TN loads. There was a 2.1% improvement in the TSS loading under EWTM conditions, and a 1.3% improvement in RV.

Additional reductions of annual TP loads under EWTM conditions as compared to BWTM conditions was mostly the result of illicit connection improvements within the watershed. There was a 72 lbs/yr increase in TP removal between the different models, the greatest among all contributing pollutant sources. Total reduction for the annual pollutant load of phosphorus per year under EWTM conditions was 125 lbs/yr more than BWTM (Table 10).

Table 9: Future Loads in Glen Haven Watershed (Enhanced WTM)

Pollutant Source	Total Nitrogen (lbs/yr)	Total Phosphorus (lbs/yr)	Total Suspended Solids (lbs/yr)	Fecal Coliform (billion/yr)	Runoff Volume (acre-feet/year)
Urban Land	2,956	998	114,923	32,206	815
Active Construction	-	-	-	-	-
Sanitary Sewer Overflow	40	7	265	30,125	-
Combined Sewer Overflow	-	-	-	-	-
Channel Erosion	559	531	139,631	-	-
Road Sanding	-	-	-	-	-
Forest	185	15	7,398	888	5
Rural Land	388	59	8,429	3,287	-
Livestock	-	-	-	-	-
Illicit Connections	256	47	1,737	186,267	-
Marinas	-	-	-	-	-
Point Sources	7	1	46	5,176	-
Septic Systems	-	-	-	-	-
Open Water	-	-	-	-	-
Total Storm Load	3,821	1,583	268,931	51,444	821
Total Non-Storm Load	569	74	3,498	206,506	-
Total Load to Surface Waters	4,390	1,658	272,429	257,949	821
Percent Load Reduction	**39.1%**	**13.6%**	**5.0%**	**75.2%**	**2.4%**
Load Reduction	**2,819**	**262**	**14,317**	**780,822**	**20**

Table 10: Glen Haven Phosphorous Removal

	Basic Model	Enhanced Model
Baseline Annual Loads (lbs)	1,920	1,920
Load Reduction (lbs)	137	262
Total Load (lbs)	1,782	1,658
Percent Load Reduction	**7.1%**	**13.6%**

Projects in the Glen Haven watershed were somewhat limited, due to the lack of open space and dense residential land use that comprises much of the watershed area. Dry pond conversions to wet ponds were found to be the most cost efficient projects, based upon the water quality volume treated (Table 11). However, when considering the pollutant phosphorus, a permeable pavement project was the most cost effective.

Table 11: Summary of Retrofit Project Cost Estimates in Glen Haven

Proposed Project	Drainage Area (acres)	Impervious Cover (acres)	Existing Stormwater Management Facility	Water Quality Volume (gallons)	Planning Level Cost	Cost of WQv Treated	Annual Total Phosphorous Load (lb/yr)	Cost per lb Phosphorous Removal
Wet Pond	2.3	0.5	Dry Pond	2650	$5,218	$1.97	1.3	$4,011
Wet Pond	2.8	0.6	Dry Pond	3149	$6,199	$1.97	1.5	$4,011
Wet Pond	9.2	0.9	N/A	7307	$7,640	$1.05	3.9	$1,959
Bioretention	0.4	0.4	N/A	1124	$10,058	$8.95	0.9	$11,481
Bioretention	1.1	0.4	N/A	1678	$11,074	$6.60	1.3	$8,473
Cul-de-sac Impervious Cover Conversion	3.4	2.6	N/A	7578	$20,264	$2.67	6.7	$3,037
Wet Pond	5.6	2.0	Dry Pond	8079	$21,932	$2.71	4.0	$5,530
Bioretention	2.0	1.8	N/A	5111	$45,720	$8.95	4.0	$11,481
Permeable Pavement	4.4	3.5	N/A	10420	$90,559	$8.69	8.7	$10,439
				TOTAL - $218,665				

3.3 Tufa Glen

The entire approximately 1900 acres Tufa Glen Creek watershed lies in the Town of Penfield (Figure 5). The creek's headwaters begin in the area East of Five Mile Line Road and south of Scribner Road in the Winchester Woods Subdivision. The main land use throughout the watershed is residential with a small agricultural area in the northeast, and results in approximately 21% of the watershed containing impervious cover.

Given the high proportion of urban land use in the watershed, it is not surprising to find that of the 5 pollutant sources that the WTM calculates, the greatest source of 4 pollutants (TN, TP, TSS, RV) is urban land (Table 12). Illicit connections were the largest source of annual FC loads, followed by urban land use. Rural land also contributed a significant amount of TN and TSS annual loads.

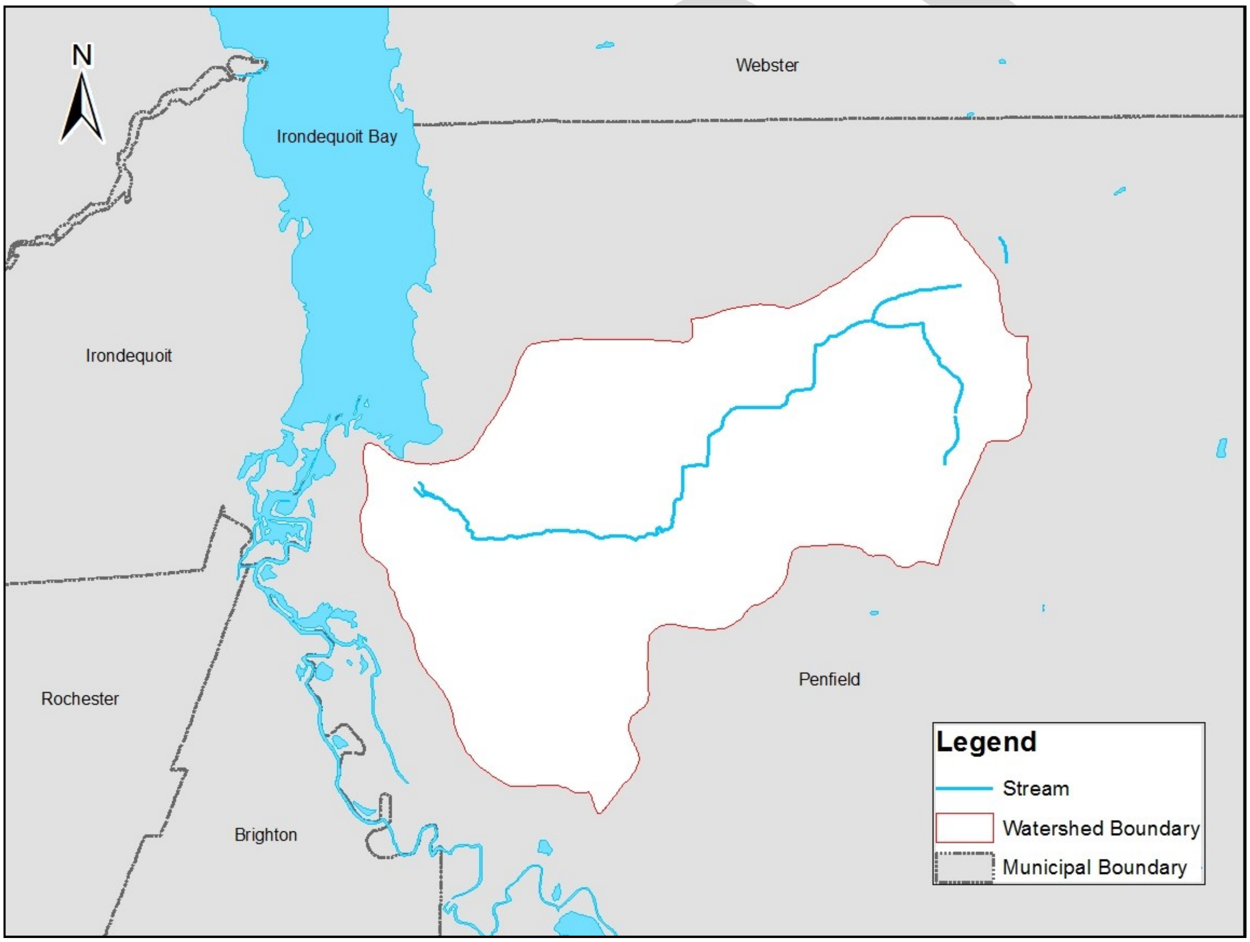

Figure 5: Map of the Tufa Glen watershed and surrounding municipalities

Table 12: Existing Loads in Tufa Glen Watershed					
Pollutant Source	Total Nitrogen (lbs/yr)	Total Phosphorus (lbs/yr)	Total Suspended Solids (lbs/yr)	Fecal Coliform (billion/yr)	Runoff Volume (acre-feet/year)
Urban Land	9,477	2,097	207,825	318,657	1,444
Active Construction	-	-	-	-	-
Sanitary Sewer Overflow	201	34	1,343	152,410	-
Combined Sewer Overflow	-	-	-	-	-
Channel Erosion	343	326	85,801	-	-
Road Sanding	-	-	-	-	-
Forest	52	4	2,075	249	2
Rural Land	1,858	283	40,381	15,749	-
Livestock	-	-	-	-	-
Illicit Connections	775	134	5,194	579,217	-
Marinas	-	-	-	-	-
Point Sources	-	-	-	-	-
Septic Systems	114	19	761	816	-
Open Water	280	11	3,396	-	-
Total Storm Load	11,156	2,652	335,904	410,860	1,445
Total Non-Storm Load	1,944	256	10,871	656,238	-
Total Load to Surface Waters	**13,100**	**2,907**	**346,776**	**1,067,098**	**1,445**

The BWTM resulted in an approximately 86% reduction in TN, TP and TSS from the channel erosion pollutant source (Table 13). However, the largest lbs/yr reduction in nitrogen loads was seen in urban land, almost 1500 lbs/yr, whereas the most lbs/yr for TP and TSS was seen in channel erosion reduction. Illicit connection improvements resulted in the greatest reduction in FC loads under BWTM conditions.

The sole source of RV reduction in the watershed was from urban land improvements however, the improvement was small at 1.8%.

Table 13: Future Loads in Tufa Glen Watershed (Basic WTM)

Pollutant Source	Total Nitrogen (lbs/yr)	Total Phosphorus (lbs/yr)	Total Suspended Solids (lbs/yr)	Fecal Coliform (billion/yr)	Runoff Volume (acre-feet/year)
Urban Land	7,986	1,917	185,056	215,694	1,418
Active Construction	-	-	-	-	-
Sanitary Sewer Overflow	126	21	839	95,256	-
Combined Sewer Overflow	-	-	-	-	-
Channel Erosion	47	45	11,835	-	-
Road Sanding	-	-	-	-	-
Forest	52	4	2,075	249	2
Rural Land	1,858	283	40,381	15,749	-
Livestock	-	-	-	-	-
Illicit Connections	484	84	3,246	362,011	-
Marinas	-	-	-	-	-
Point Sources	-	-	-	-	-
Septic Systems	92	15	616	661	-
Open Water	280	11	3,396	-	-
Total Storm Load	9,332	2,184	238,917	279,320	1,419
Total Non-Storm Load	1,594	195	8,527	410,300	-
Total Load to Surface Waters	10,926	2,380	247,444	689,620	1,419
Percent Load Reduction	**16.6%**	**18.1%**	**28.6%**	**35.4%**	**1.8%**
Load Reduction	**2,174**	**527**	**99,332**	**377,478**	**26**

The EWTM resulted in a 11.0% additional removal of nitrogen from the watershed, as compared to the BWTM. TSS loads were reduced by 30.9%, mostly as a result of channel erosion and urban land improvements (Table 14). The annual FC load reduction under the EWTM conditions was almost double the load reduction under BWTM conditions, while the RV load reduction was doubled.

An additional 157 lbs/yr of phosphorus, or 5.4% of the BWTM TP load reduction, resulted from the EWTM conditions (Table 15).

Table 14: Future Loads in Tufa Glen Watershed (Enhanced WTM)

Pollutant Source	Total Nitrogen (lbs/yr)	Total Phosphorus (lbs/yr)	Total Suspended Solids (lbs/yr)	Fecal Coliform (billion/yr)	Runoff Volume (acre-feet/year)
Urban Land	6,931	1,833	180,046	146,689	1,397
Active Construction	-	-	-	-	-
Sanitary Sewer Overflow	50	8	336	38,102	-
Combined Sewer Overflow	-	-	-	-	-
Channel Erosion	47	45	11,835	-	-
Road Sanding	-	-	-	-	-
Forest	52	4	2,075	249	2
Rural Land	1,858	283	40,381	15,749	-
Livestock	-	-	-	-	-
Illicit Connections	194	33	1298	144,804	-
Marinas	-	-	-	-	-
Point Sources	-	-	-	-	-
Septic Systems	34	6	228	245	-
Open Water	280	11	3,396	-	-
Total Storm Load	8,239	2,094	233,655	181,738	1,398
Total Non-Storm Load	1,208	129	5,940	164,100	-
Total Load to Surface Waters	9,447	2,224	239,595	345,839	1,398
Percent Load Reduction	**27.9%**	**23.5%**	**30.9%**	**67.6%**	**3.2%**
Load Reduction	**3,653**	**684**	**107,181**	**721,260**	**47**

Table 15: Tufa Glen Phosphorous Removal

	Basic Model	Enhanced Model
Baseline Annual Loads (lbs)	2,907	2,907
Load Reduction (lbs)	527	684
Total Load (lbs)	2,280	2,224
Percent Load Reduction	**18.1%**	**23.5%**

Similar to Glen Haven, the small size of the watershed and large proportion of residential land use limited stormwater project planning. Most of the projects that were identified were either existing wet or dry ponds which would entail modification to realize improvements. The modification of dry ponds to wet ponds were estimated to cost the least as well as provide the most cost efficiency (Table 16). When the cost efficiency of phosphorus is calculated, the infiltration practices rank as the most cost effective.

Table 16: Summary of Retrofit Project Cost Estimates in Tufa Glen

Proposed Project	Drainage Area (acres)	Impervious Cover (acres)	Existing Stormwater Management Facility	Water Quality Volume (gallons)	Planning Level Cost	Cost of WQv Treated	Annual Total Phosphorous Load (lb/yr)	Cost per lb Phosphorous Removal
Wet Pond	5.6	3.3	Dry Pond	10,651	$37,263	$3.50	5.6	$6,620
Wet Pond	8.7	3.5	Dry Pond	12,592	$38,624	$3.07	6.7	$5,804
Wet Pond	6.9	4.1	Dry Pond	12,996	$46,027	$3.54	6.9	$6,701
Wet Pond	26.5	6.6	Dry Pond	29,875	$73,841	$2.47	15.8	$4,677
Bioretention	4.2	3.7	N/A	10,571	$94,869	$8.97	9.0	$10,515
Wet Pond	20.8	12.5	Wet Pond	39,233	$138,951	$3.54	11.9	$11,650
Cul-de-sac Impervious Cover Conversion	25.5	19.1	N/A	56,858	$152,039	$2.67	54.8	$2,772
Wet Pond	35.5	17.7	Wet Pond	60,323	$197,745	$3.28	18.3	$10,783
Wet Pond	31.7	23.8	Wet Pond	70,175	$264,924	$3.78	21.3	$12,418
				TOTAL - $1,044,283				

3.4 Thomas Creek

The Thomas Creek watershed is located on the eastern side of Monroe County along the border with Wayne County. The topography of the watershed is consistent with the region which is characterized by past glacial activity, namely drumlins. From its head waters in the Town of Penfield the creek and its tributaries flow south and into the Town of Perinton. Upon reaching the Erie Barge Canal, Thomas Creek turns and flows west and through the Village of Fairport. It then continues on until emptying into the Irondequoit Creek (Figure 6). Approximately 60% of the Thomas Creek watershed is contained within the Town of Penfield with the remaining 40% in the Town of Perinton. The Village of Fairport lies almost entirely within the Thomas Creek watershed.

The watershed is dominated by residential land use, particularly in the Town of Perinton, accounting for the majority of the approximately 20% impervious cover in the watershed. Further north the land use gives way to more agricultural activity. The small amount of industrial and commercial land use is concentrated along the Erie Barge Canal area. Residential land use accounts for 46% of the overall watershed land use, with Vacant Land and Agricultural land use making up 20% and 18% of the watershed, respectively.

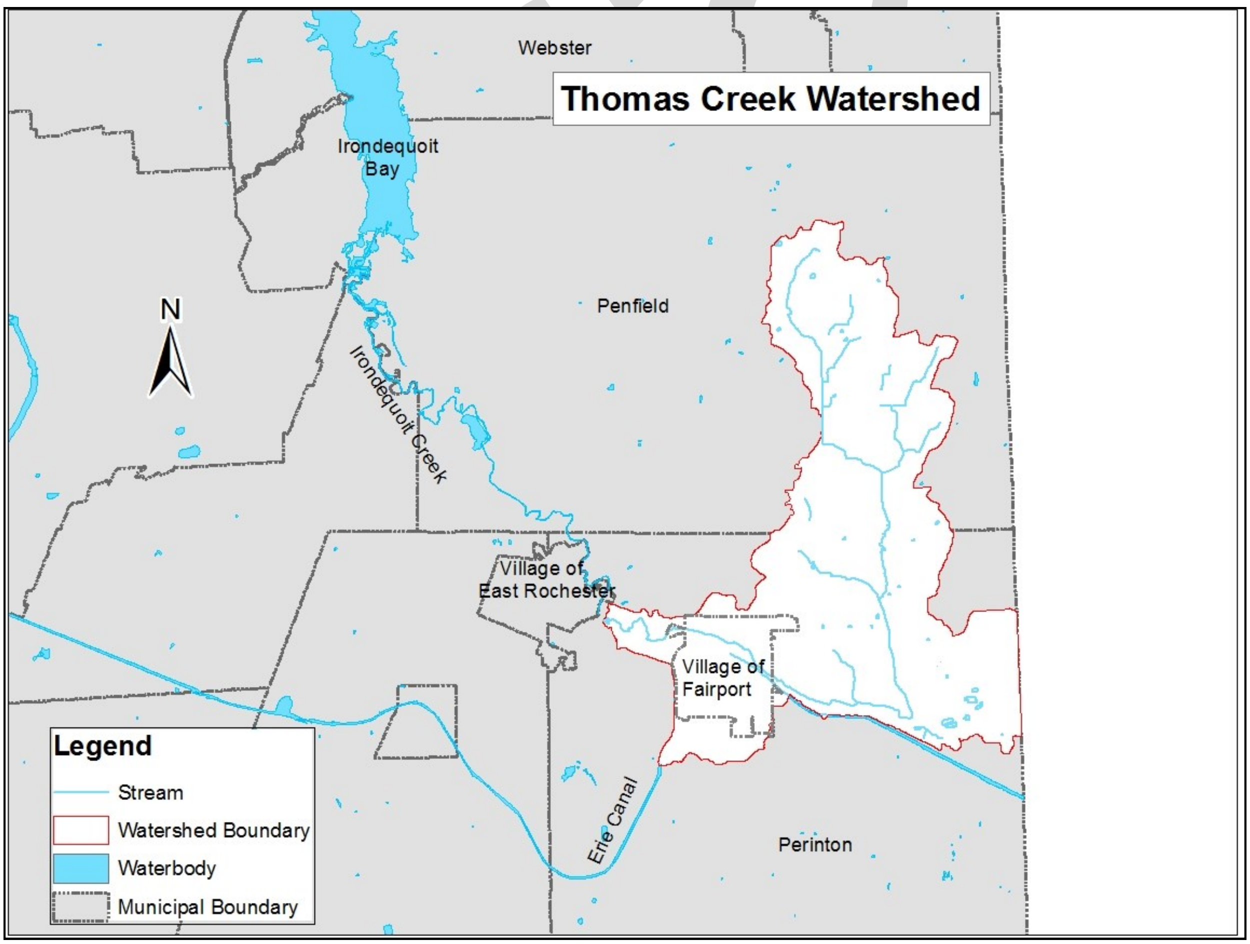

Figure 6: Map of the Thomas Creek watershed and surrounding municipalities

The predominant source of nitrogen in the Thomas Creek watershed is from urban land, followed by rural land (Table 17). Channel erosion was the largest contributor of TSS, with urban land being the second largest contributor. Illicit connection and urban land were the major contributors of FC, and urban land was almost the only source of RV.

Urban land contributed about 50.0% of the TP load in the watershed, with channel erosion accounting for a further 27.0%

Table 17: Existing Loads in Thomas Creek Watershed

Pollutant Source	Total Nitrogen (lbs/yr)	Total Phosphorus (lbs/yr)	Total Suspended Solids (lbs/yr)	Fecal Coliform (billion/yr)	Runoff Volume (acre-feet/year)
Urban Land	37,788	8,530	821,285	1,221,117	5,609
Active Construction	-	-	-	-	-
Sanitary Sewer Overflow	316	53	2,107	239,093	-
Combined Sewer Overflow	-	-	-	-	-
Channel Erosion	4,704	4,469	1,175,984	-	-
Road Sanding	-	-	-	-	-
Forest	201	16	8,043	965	4
Rural Land	16,502	2,511	358,739	139,908	-
Livestock	5,985	684	-	22,800	-
Illicit Connections	2,135	416	14,624	1,524,652	-
Marinas	-	-	-	-	-
Point Sources	-	-	-	-	-
Septic Systems	978	163	6,522	23,129	-
Open Water	-	-	-	-	-
Total Storm Load	56,986	15,478	2,328,426	1,504,337	5,614
Total Non-Storm Load	11,623	1,363	58,877	1,667,327	-
Total Load to Surface Waters	**68,609**	**16,841**	**2,387,302**	**3,171,664**	**5,614**

BWTM conditions resulted in load reduction at or below 5.5% for all pollutant categories other than FC (Table 18). Urban land improvement accounted for the largest proportion of pollutant load reductions for TN, TP, TSS, and RV. The greatest reduction of FC was from illicit connection improvements.

Table 18: Future Loads in Thomas Creek Watershed (Basic WTM)

Pollutant Source	Total Nitrogen (lbs/yr)	Total Phosphorus (lbs/yr)	Total Suspended Solids (lbs/yr)	Fecal Coliform (billion/yr)	Runoff Volume (acre-feet/year)
Urban Land	35,105	8,066	768,390	1,063,630	5,521
Active Construction	-	-	-	-	-
Sanitary Sewer Overflow	197	33	1,317	149,433	-
Combined Sewer Overflow	-	-	-	-	-
Channel Erosion	4,704	4,469	1,175,984		-
Road Sanding	-	-	-	-	-
Forest	201	16	8,043	965	4
Rural Land	16,502	2,511	358,739	139,908	-
Livestock	5,985	684	-	22,800	-
Illicit Connections	1,334	260	9,140	952,907	-
Marinas	-	-	-	-	-
Point Sources	-	-	-	-	-
Septic Systems	792	132	5283	18,735	-
Open Water	-	-	-	-	-
Total Storm Load	54,244	15,004	2,275,136	1,302,020	5,526
Total Non-Storm Load	10,577	1,167	51,759	1,046,359	-
Total Load to Surface Waters	64,821	16,171	2,326,894	2,348,379	5,526
Percent Load Reduction	**5.5%**	**4.0%**	**2.5%**	**26.0%**	**1.6%**
Load Reduction	**3,788**	**670**	**60,408**	**823,285**	**88**

The EWTM conditions did not result in drastic additional reductions of the pollutants TN, TP, TSS and RV, as compared to the results of the BWTM results (Table 19). The largest difference between the two models was seen in the FC load reductions, where the EWTM decreased FC loads by an addition 25.5% over the BWTM.

Phosphorus loads in the Thomas Creek watershed were reduced by an additional 248 lbs/yr under the EWTM conditions (Table 20).

Table 19: Future Loads in Thomas Creek Watershed (Enhanced WTM)

Pollutant Source	Total Nitrogen	Total Phosphorus	Total Suspended Solids (lbs/yr)	Fecal Coliform (billion/yr)	Runoff Volume (acre-feet/year)
Urban Land	32,300	7,840	757,952	925,309	5,457
Active Construction	-	-	-	-	-
Sanitary Sewer Overflow	79	13	527	59,773	-
Combined Sewer Overflow	-	-	-	-	-
Channel Erosion	4,704	4,469	1,175,984	-	-
Road Sanding	-	-	-	-	-
Forest	201	16	8,043	965	4
Rural Land	16,502	2,511	358,739	139,908	-
Livestock	5,985	684	-	22,800	-
Illicit Connections	534	104	3,656	381,163	-
Marinas	-	-	-	-	-
Point Sources	-	-	-	-	-
Septic Systems	293	49	1,956	6,939	-
Open Water	-	-	-	-	-
Total Storm Load	51,380	14,768	2,264,303	1,118,868	5,461
Total Non-Storm Load	9,218	918	42,554	417,988	-
Total Load to Surface Waters	60,598	15,686	2,306,857	1,536,857	5,461
Percent Load Reduction	**11.7%**	**6.9%**	**3.4%**	**51.5%**	**2.7%**
Load Reduction	**8,011**	**1,156**	**80,445**	**1,634,807**	**153**

Table 20: Thomas Creek Phosphorous Removal

	Basic Model	Enhanced Model
Baseline Annual Loads (lbs)	16,841	16,841
Load Reduction (lbs)	670	1,156
Total Load (lbs)	16,171	15,685
Percent Load Reduction	**4.0%**	**6.9%**

Bioretention and pond modification projects were the least costly to implement however, bioretention projects are not as cost effective as pond modifications, likely due to the quantity of water that the projects can treat (Table 21). The total estimated cost to construct all of these projects was $2,279,617. The cost effectiveness of these project with respect to phosphorus removal favored cul-de-sac infiltration projects and some pond modifications.

Table 21: Summary of Retrofit Project Cost Estimates in Thomas Creek

Proposed Project	Drainage Area (acres)	Impervious Cover (acres)	Existing Stormwater Management Facility	Water Quality Volume (gallons)	Planning Level Cost	Cost of WQv Treated	Annual Total Phosphorous Load (lb/yr)	Cost per lb Phosphorous Removal
Bioretention	0.8	0.5	N/A	1,558	$12,192	$7.83	1.3	$9,622
Bioretention	1.1	0.5	Dry Swale	1,772	$13,462	$7.60	0.8	$17,441
Wet Pond	1.5	1.3	Wet Pond	3,719	$14,651	$3.94	1.1	$13,599
Bioretention	1.0	0.7	N/A	2,126	$18,288	$8.60	1.8	$9,959
Wet Pond	2.1	1.9	Dry Pond	5,316	$20,873	$3.93	2.5	$8,233
Wet Pond	4.0	2.0	Dry Pond	7,030	$22,467	$3.20	3.4	$6,702
Bioretention	1.9	0.9	N/A	3,146	$23,495	$7.47	2.6	$9,181
Wet Pond	6.0	2.4	Wet Pond	8,782	$26,938	$3.07	2.5	$10,589
Wet Pond	6.5	2.6	Wet Pond	9,392	$28,812	$3.07	2.7	$10,589
Wet Pond	6.3	3.2	Dry Pond	10,563	$35,234	$3.34	4.3	$8,161
Wet Pond	11.6	3.5	Wet Pond	14,392	$38,936	$2.71	4.2	$9,338
Wet Pond	7.5	3.8	Dry Pond	12,771	$41,868	$3.28	6.1	$6,874
Wet Pond	9.9	4.0	Wet Pond	14,365	$44,065	$3.07	4.2	$10,589
Bioretention	3.6	1.8	N/A	6,034	$45,847	$7.60	5.2	$8,799
Wet Pond	10.3	4.1	Wet Pond	14,975	$45,938	$3.07	4.3	$10,589
Bioretention	2.2	1.9	N/A	5,400	$47,930	$8.88	4.7	$10,278
Infiltration Practices	1.5	0.8	N/A	2,585	$51,698	$20.00	2.2	$23,932
Bioretention	3.6	2.2	N/A	6,903	$55,016	$7.97	5.6	$9,798
Wet Pond	17.1	5.1	Wet Pond	21,168	$57,266	$2.71	6.1	$9,338
Wet Pond	10.5	5.2	Dry Pond	17,788	$58,315	$3.28	8.5	$6,874
Wet Pond	9.0	5.4	Dry Pond	16,962	$60,076	$3.54	6.9	$8,666
Wet Pond	11.3	5.7	Dry Pond	19,217	$62,998	$3.28	9.7	$6,509
Wet Pond	14.7	6.6	Wet Pond	23,033	$73,958	$3.21	6.7	$11,083
Wet Pond	10.4	7.3	Dry Pond	21,927	$81,250	$3.71	9.0	$9,066
Wet Pond	18.3	7.3	Wet Pond	26,592	$81,573	$3.07	7.7	$10,589
Wet Pond	23.7	10.7	Wet Pond	37,003	$118,814	$3.21	10.7	$11,083
Wet Pond	24.2	12.1	Dry Pond	41,154	$134,915	$3.28	19.6	$6,874
Wet Pond	34.2	15.4	Dry Pond	53,489	$171,749	$3.21	21.9	$7,856
Wet Pond	37.4	16.8	Dry Pond	58,459	$187,705	$3.21	23.9	$7,856
Wet Pond	28.2	19.8	Wet Pond	59,483	$220,413	$3.71	17.2	$12,790
Cul-de-sac Impervious Cover Conversion	58.7	49.9	N/A	143,184	$382,875	$2.67	131.6	$2,909
				TOTAL - $2,276,617				

3.5 White Brook

White Brook is located on the eastern side of Monroe County within the Town of Perinton (Figure 7). The headwaters of White Brook are outside of Monroe County in Ontario County. The Creek flows north until reaching the Erie Barge Canal. At this junction it is conveyed under the Canal and flows into Thomas Creek, which then flows to the Irondequoit Creek.

Land use in the Monroe County portion of the watershed is dominated by residential, particularly in the north and west. Approximately 40% of this residential land pre-dates 1975 National Pollutant Discharge Elimination System (NPDES) Stormwater Program regulations. Vacant land and agricultural land make up 21% and 19% of the watershed, respectively. Agricultural activity accounts for a large portion of the land use in the southern reaches of the watershed, close to the borders with Ontario and Wayne County. These land uses constitute a majority of the watersheds approximately 6,500 acres. The small amount of commercial land within the watershed is concentrated along Pittsford-Palmyra Road, with a few outliers throughout the watershed.

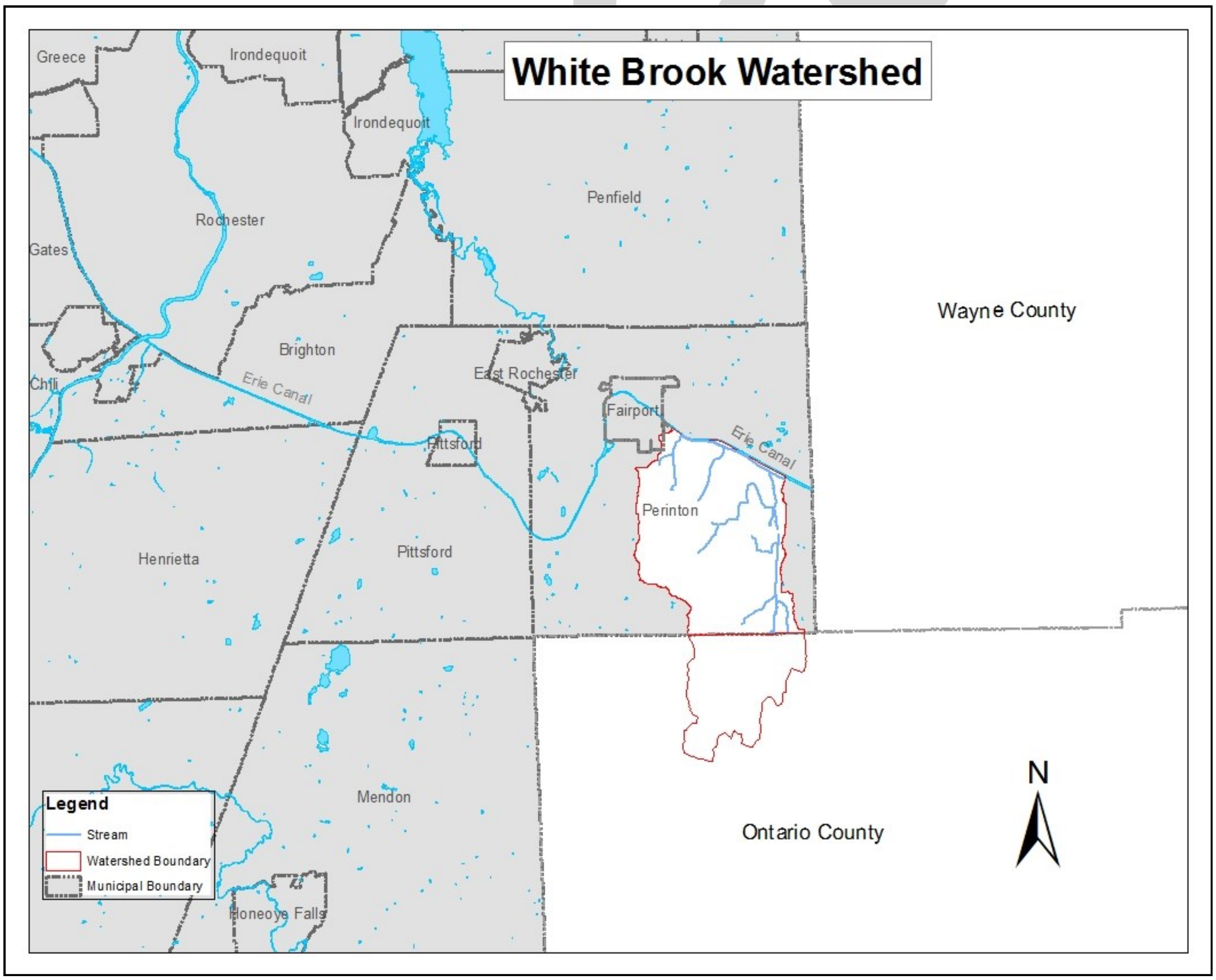

Figure 7: Map of the White Brook watershed and surrounding municipalities

Parcel data was not available to determine accurate land use in the Ontario County portion of the watershed. A basic review of aerial photos however, shows a similar land use distribution as in Monroe County with a slightly higher percentage of agricultural land. Residential land appears to be dominated by single family homes on large parcels, half an acre or bigger.

Urban land is the main pollutant source of nitrogen in the watershed, accounting for approximately 49.0% of the total annual load (Table 22). Rural land also is a major contributor of nitrogen, providing 28.0% of the annual load. Urban land is almost the sole source of annual RV loads. Channel erosion contributes the most to annual TSS loads, followed by urban land. Up to 44.0% of annual FC loads are from illicit connections with urban land contributing an additional 35.0%. Annual TP loads are made up of almost entirely urban land, channel erosion, and rural land, accounting for 48.0%, 26.0%, and 18.0% of the total load respectively.

Table 22: Existing Loads in White Brook Watershed

Pollutant Source	Total Nitrogen (lbs/yr)	Total Phosphorus (lbs/yr)	Total Suspended Solids (lbs/yr)	Fecal Coliform (billion/yr)	Runoff Volume (acre-feet/year)
Urban Land	22,421	5,281	487,195	722,510	3,295
Active Construction	-	-	-	-	-
Sanitary Sewer Overflow	380	63	2,530	287,197	-
Combined Sewer Overflow	-	-	-	-	-
Channel Erosion	3,051	2,898	762,732	-	-
Road Sanding	-	-	-	-	-
Forest	109	9	4,343	521	3
Rural Land	12,913	1,965	280,722	109,482	-
Livestock	3,938	450	-	15,000	-
Illicit Connections	1,238	229	8,397	902,222	-
Marinas	-	-	-	-	-
Point Sources	-	-	-	-	-
Septic Systems	626	104	4,172	8,665	-
Open Water	776	30	9,399	-	-
Total Storm Load	36,886	10,073	1,517,149	991,111	3,297
Total Non-Storm Load	8,564	957	42,341	1,054,486	-
Total Load to Surface Waters	**45,450**	**11,030**	**1,559,490**	**2,045,596**	**3,297**

Under the conditions of the BWTM, annual watershed pollutant loads were decreased from existing loads (Table 23). Urban land improvements resulted in the largest reduction of TN, almost a 1700 lbs/yr reduction, followed by illicit connection improvements that reduced TN by a further 464 lbs/yr. TSS annual loads were reduced the most through urban land improvements, and to a lesser extent by illicit connection improvements. FC load reductions were most impacted by improvement to illicit connections, as well as saw the greatest percent reduction. RV saw load reductions only from urban land improvements.

TP annual loads were the most improved through urban land improvements, with smaller reductions resulting from illicit connection and stormwater sewer overflow improvements. These improvements combined for 401 lbs/yr reduction in TP loads.

Table 23: Future Loads in White Brook Watershed (Basic WTM)

Pollutant Source	Total Nitrogen (lbs/yr)	Total Phosphorus (lbs/yr)	Total Suspended Solids (lbs/yr)	Fecal Coliform (billion/yr)	Runoff Volume (acre-feet/year)
Urban Land	20,726	5,009	459,972	609,656	3,227
Active Construction	-	-	-	-	-
Sanitary Sewer Overflow	237	40	1,581	179,498	-
Combined Sewer Overflow	-	-	-	-	-
Channel Erosion	3,051	2,898	762,732	-	-
Road Sanding	-	-	-	-	-
Forest	109	9	4,343	521	3
Rural Land	12,913	1,965	280,722	109,482	-
Livestock	3,938	450	-	15,000	-
Illicit Connections	773	143	5,248	563,889	-
Marinas	-	-	-	-	-
Point Sources	-	-	-	-	-
Septic Systems	507	84	3,380	7,019	-
Open Water	776	30	9,399	-	-
Total Storm Load	35,120	9,789	1,489,452	824,408	3,229
Total Non-Storm Load	7,910	839	37,925	660,657	-
Total Load to Surface Waters	43,030	10,629	1,527,377	1,485,064	3,229
Percent Load Reduction	**5.3%**	**3.6%**	**2.1%**	**27.4%**	**2.1%**
Load Reduction	**2,420**	**401**	**32,113**	**560,532**	**68**

Under the EWTM conditions, all pollutant reductions increased from the BWTM loads (Table 24). TN annual loads were reduced by an additional 6.2%. TSS annual loads saw the least amount of reduction, decreasing by 1.3% for a total of 3.4%. RV annual loads also did not decrease greatly, reducing by another 1.9% more that the BWTM load. FC annual loads saw the greatest additional decrease, 28.0%.

TP annual loads almost doubled from the BWTM reduction of 3.6% to 7.0%, an additional 368 lbs/yr of phosphorus (Table 25).

Table 24: Future Loads in White Brook Watershed (Enhanced WTM)

Pollutant Source	Total Nitrogen	Total Phosphorus	Total Suspended Solids (lbs/yr)	Fecal Coliform (billion/yr)	Runoff Volume (acre-feet/year)
Urban Land	18,840	4,804	445,175	487,590	3,163
Active Construction	-	-	-	-	-
Sanitary Sewer Overflow	95	16	633	71,799	-
Combined Sewer Overflow	-	-	-	-	-
Channel Erosion	3,051	2,898	762,732	-	-
Road Sanding	-	-	-	-	-
Forest	109	9	4,343	521	3
Rural Land	12,913	1,965	280,722	109,482	-
Livestock	3,938	450	-	15,000	-
Illicit Connections	309	57	2,099	225,556	-
Marinas	-	-	-	-	-
Point Sources	-	-	-	-	-
Septic Systems	188	31	1,252	2,599	-
Open Water	776	30	9,399	-	-
Total Storm Load	33,163	9,572	1,474,181	648,493	3,166
Total Non-Storm Load	7,055	689	32,174	264,055	-
Total Load to Surface Waters	40,218	10,261	1,506,354	912,547	3,166
Percent Load Reduction	**11.5%**	**7.0%**	**3.4%**	**55.4%**	**4.0%**
Load Reduction	**5,232**	**769**	**53,136**	**1,133,049**	**132**

Table 25: White Brook Phosphorous Removal

	Basic Model	Enhanced Model
Baseline Annual Loads (lbs)	11,030	11,030
Load Reduction (lbs)	401	769
Total Load (lbs)	10,629	10,261
Percent Load Reduction	**3.6%**	**7.0%**

The least costly projects overall consisted of a number of pond modifications, most dry pond to wet ponds (Table 26). However, the cheapest project was a small infiltration project. Another infiltration project involving cul-de-sacs was the most expensive but was also one of the most cost effective in terms of stormwater treated. While there is variation in the planning level cost of the same types of projects, there is much less variation in terms of the cost of the stormwater treated. In terms of phosphorus removal cost effectiveness the most expensive project from Table 26, cul-de-sac impervious cover removal and infiltration practices, would be the top choice, along with a small infiltration practice. Again, pond modifications made up a large proportion of the top projects for phosphorus removal cost effectiveness.

Table 26: Summary of Retrofit Project Cost Estimates in White Brook

Proposed Project	Drainage Area (acres)	Impervious Cover (acres)	Existing Storm-water Manage-ment Facility	Water Quality Volume (gallons)	Planning Level Cost	Cost of WQv Treated	Annual Total Phospho-rous Load (lb/yr)	Cost per lb Phosphorous Removal
Infiltration Practices	1.4	0.7	N/A	2,363	$6,318	$2.67	2.2	$2,860
Bioretention	0.4	0.3	Dry Pond	883	$7,722	$8.75	0.6	$12,025
Wet Pond	1.0	0.9	Dry Swale	2,592	$10,236	$3.95	0.3	$30,043
Wet Pond	1.4	1.0	Dry Pond	2,948	$10,927	$3.71	1.2	$8,917
Wet Pond	1.3	1.1	Dry Pond	3,090	$11,864	$3.84	1.3	$9,237
Wet Pond	2.5	1.5	N/A	4,905	$12,625	$2.57	2.8	$4,543
Wet Pond	1.4	1.1	Dry Pond	3,281	$12,756	$3.89	1.4	$9,354
Wet Pond	2.2	1.8	Dry Pond	5,112	$19,624	$3.84	2.1	$9,237
Wet Pond	2.7	1.9	Wet Pond	5,770	$21,386	$3.71	1.7	$12,580
Bioretention	1.4	1.1	N/A	3,200	$27,635	$8.64	2.6	$10,442
Bioretention	1.5	1.1	N/A	3,332	$28,194	$8.46	2.8	$10,230
Bioretention	1.5	1.1	N/A	3,377	$28,575	$8.46	2.8	$10,230
Wet Pond	3.3	2.6	Wet Pond	7,621	$29,258	$3.84	2.2	$13,031
Grass (open) Channel	1.0	0.5	N/A	1,534	$30,678	$20.00	0.7	$44,126
Wet Pond	4.4	3.1	Dry Pond	9,224	$34,186	$3.71	3.8	$8,917
Bioretention	1.5	1.4	Grass Channel	3,863	$34,747	$9.00	2.6	$13,617
Wet Pond	3.9	3.1	Wet Pond	9,085	$34,877	$3.84	2.7	$13,031
Wet Pond	4.1	3.3	Dry Pond	9,480	$36,394	$3.84	3.9	$9,237
Bioretention	3.8	1.5	N/A	5,823	$38,405	$6.60	4.8	$7,974
Wet Pond	5.2	3.6	Wet Pond	10,845	$40,196	$3.71	3.2	$12,580
Bioretention	2.0	1.8	Grass Channel	5,057	$45,491	$9.00	3.3	$13,617
Wet Pond	6.7	4.7	Dry Pond	14,152	$52,450	$3.71	5.9	$8,917
Wet Pond	9.4	4.7	Dry Pond	15,754	$52,572	$3.34	6.5	$8,029
Wet Pond	13.6	6.8	Dry Pond	23,728	$75,876	$3.20	11.5	$6,594
Bioretention	3.8	3.1	Wet Swale	8,967	$78,029	$8.70	6.4	$12,113
Cul-de-sac Impervious Cover Conversion	49.3	37.0	N/A	109,903	$293,881	$2.67	102.7	$2,860
				TOTAL - $1,074,899				

Section 4: Report Summary

Watershed modelling of pollutants loads and cost estimations for stormwater projects within targeted watersheds was completed. The Excel based Watershed Treatment Model (WTM) was used to estimate annual loads of nitrogen, phosphorus, suspended solids, fecal coliform, and runoff volume for five selected watersheds. The WTM was created by the Center for Watershed Protection. Cost estimations for projects that were previously identified in Rapid Assessments that were conducted on the selected watersheds utilizing documentation from the Center for Watershed Protection.

The total estimated cost to implement the various types of stormwater projects in the selected watersheds is displayed in Table 27. Individual projects cost estimations may be found in the main body of this report. It should be noted that these costs may not reflect the actual cost of project implementation, and per project costs may change with additional variables. Also, the total cost listed in Table 27 is specifically for the stormwater projects, and does not reflect the cost of watershed management, regulation, or policy changes that is an additional component of the modeling process.

The WTM provides existing annual watershed pollutant load estimations. It order to compare the pollutant loads across the five watersheds analyzed, each watershed pollutant load was divided by its area (acres), providing a per acre pollutant load (Table 28).

It is recommend that future work could be focused on applying costs to policy changes within the watersheds, increasing the accuracy of stormwater project cost estimations, and modeling of additional watersheds.

Table 27: Total Cost of All Projects

Watershed	Total Project Cost
Densmore Creek	$1,751,920
Glen Haven Creek	$218,665
Tufa Glen Creek	$892,245
Thomas Creek	$2,279,617
White Brook	$1,074,899

Table 28: Per acre Pollutant Loads of Target Watersheds

Watershed	Total Nitrogen (lbs/yr/acre)	Total Phosphorus (lbs/yr/acre)	Total Suspended Solids (lbs/yr/acre)	Fecal Coliform (billion/yr/acre)	Runoff Volume (acre-feet/yr/acre)
Densmore Creek	**10.6**	**2.5**	**449.5**	1045.7	**1.4**
Glen Haven Creek	8.1	2.2	324.0	**1173.8**	1.0
Tufa Glen Creek	7.0	1.6	185.8	571.9	0.8
Thomas Creek	7.3	1.8	252.9	336.1	0.6
White Brook	7.0	1.7	240.5	315.5	0.5

References

Center for Watershed Protection, Manual 3, "Urban Stormwater Retrofit Practices" August 2007

Center for Watershed Protection, Appendix I: Retrofit Design Sheets