SUBWATERSHED REPORT

1. Introduction

The *Oatka Creek Watershed Prioritization of Subwatersheds* provides a description of Oatka Creek's natural features such as hydrology, floodplains, and wetlands, along with consideration of water quality within the subwatersheds or stream segments. Some of the consideration of natural features and water quality were addressed in the *Oatka Creek Watershed Characterization Report*. Also included in this report is more recent analysis based on water quality information found in *"Oatka Creek Water Quality Assessment: Identifying Point and Nonpoint Sources of Pollution with Application of the SWAT Model"*, Dale Matthew Pettenski (2012) in a thesis submitted to the Department of Environmental Science and Biology of the State University of New York College at Brockport, *Theses. Paper 38*." The report acknowledges the United States Department of Agriculture for funding the project and the Research Foundation of SUNY and Dr. Joseph Makarewicz for the opportunity to work as a graduate assistant.

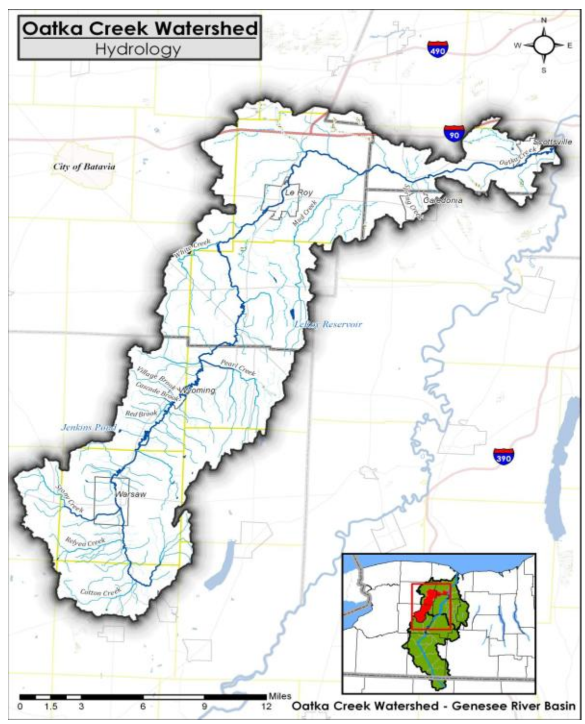
This *Oatka Creek Watershed Prioritization of Subwatersheds* is the second component of a comprehensive watershed management plan for the Oatka Creek watershed. The subwatershed prioritization includes:

- Description of the watershed and its constituent subwatersheds including population density, hydrology, floodplains, impervious cover, land cover, riparian cover, and wetlands;
- Evaluation of existing water quality data, run-off characteristics and pollutant loadings; and
- Identification of pollution sources, sources of water quality impairment, and potential threats to water quality and watershed hydrology and ecology.

This *Oatka Creek Watershed Prioritization of Subwatersheds* report evaluates subwatersheds according to impairments and/or threats to water quality and habitat, and identifies priority subwatersheds for focused nonpoint source pollution management action.

2. General Characteristics

Map 1: Hydrology

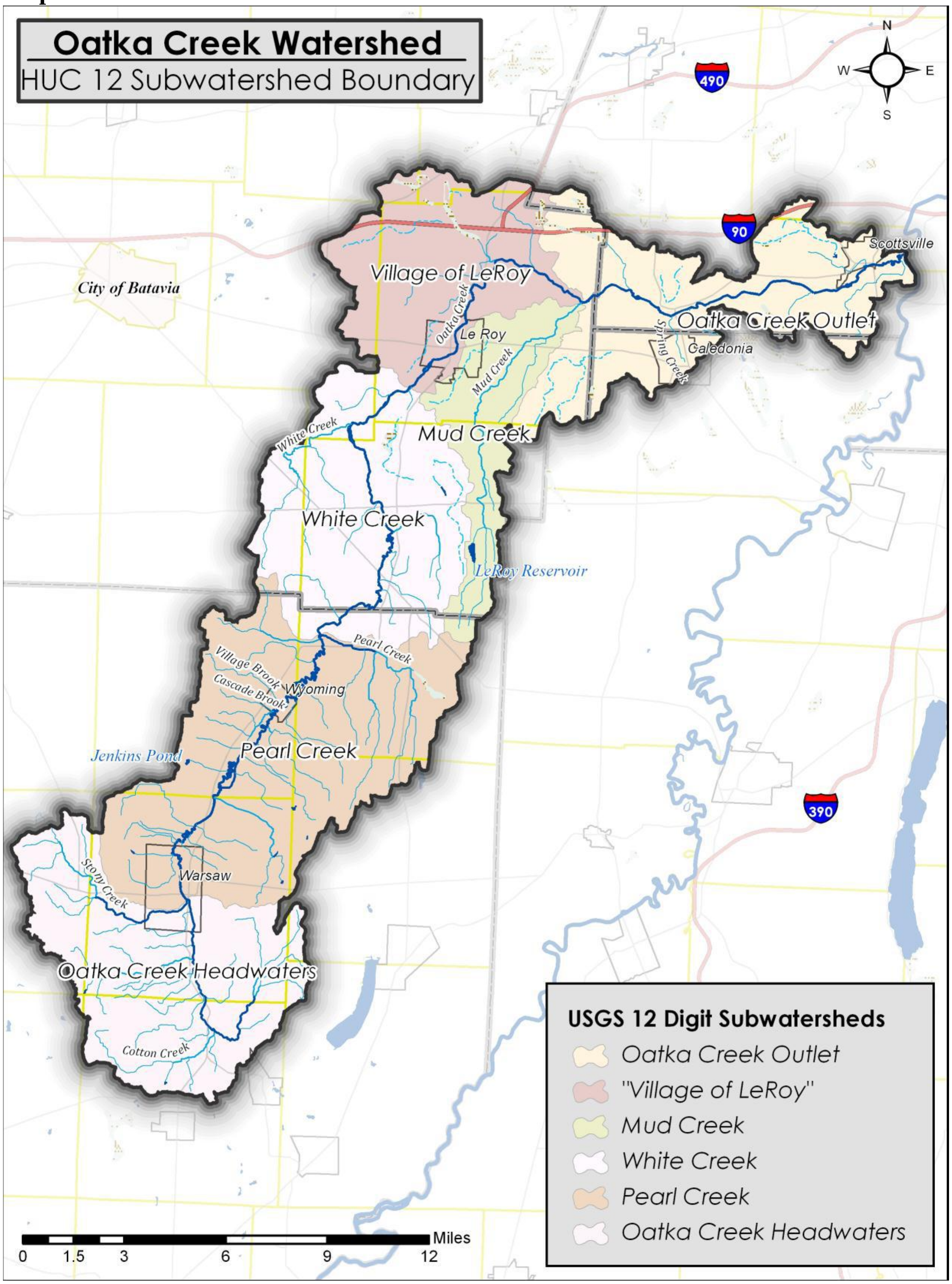


Hydrology

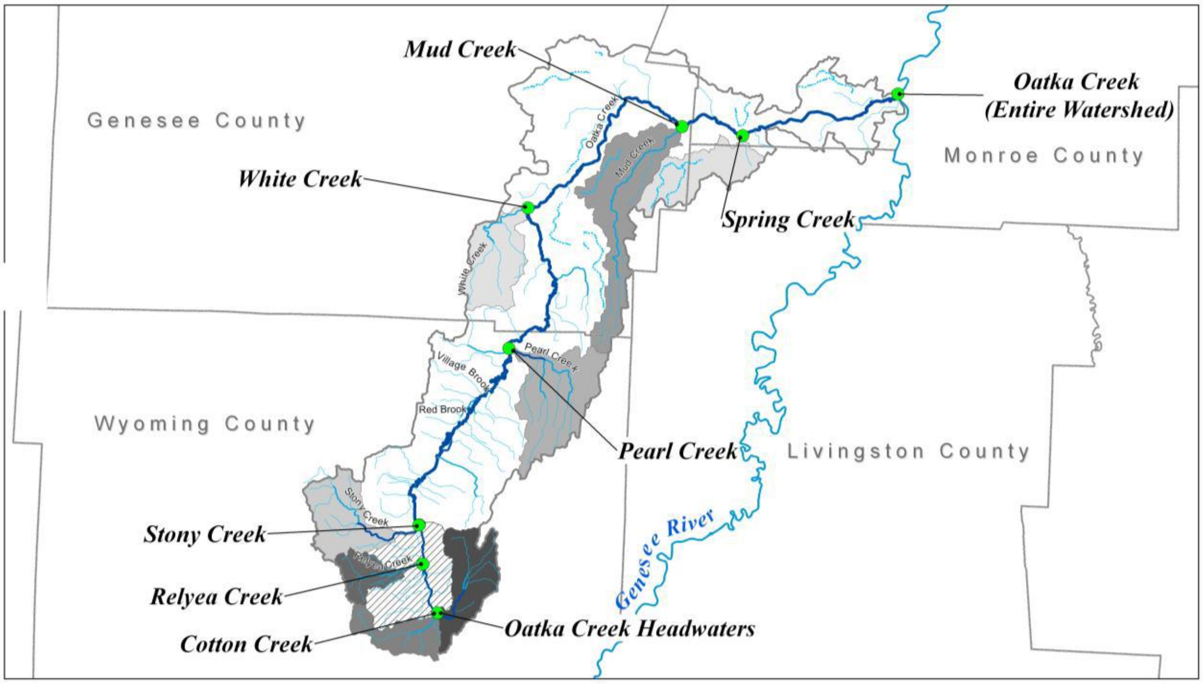
Hydrology is determined by a complex interaction between geology, groundwater, climate, physiography, and land cover. The general hydrology of the Oatka Creek watershed is shown in Map 1. Perhaps the most distinctive trait that characterizes the topography and, in turn, hydrology of the Oatka Creek watershed is that it lies within an area of North America that has been largely influenced by prolonged periods of glaciation. As a general rule, groundwater flow beneath western New York is northward from the Allegheny Plateau through the Eastern Great Lakes Lowlands with ultimate discharge into Lakes Erie and Ontario. Local deviations from this regional northward flow pattern may occur in response to small changes in topography caused by drumlins, beach ridges, recessional moraines, or bedrock escarpments. In addition, shallow groundwater flow paths may locally be affected by discharges into surface waters or withdrawal from surface waters.

The subwatersheds used in this report relate to Map 2: USGS HUC 12 Watershed Boundaries and the stream segments discussed can be seen in Map 3: Streams and Associated Watersheds.

Map 2: HUC 12 Subwatershed Boundaries



Map 3: Streams and Associated Watersheds



The following sections describe the hydrologic features and properties of the Oatka Creek watershed and how their function relates to watershed management.

An excellent overview of the hydrology of the Oatka Creek watershed is provided on the website of the Oatka Creek Watershed Committee:

> Tributaries in central Wyoming County, the eastward trending ***Cotton Creek*** in Gainesville, and ***Relyea*** and ***Stony Creeks*** in Warsaw drain the western highlands; small streams drain the eastern highlands, and the junction of this drainage creates ***Oatka Creek***. As the Oatka progresses north through the Wyoming Valley, several unnamed seasonal tributaries drain west and east valley walls, bringing water from the hilltops at [approximately 1,900] feet elevation to 950 feet in the valley. The Oatka Creek itself falls only about five feet as it winds its way from Warsaw to Wyoming. ***Pearl Creek***, originating in Covington at an elevation of [1,400] feet, joins the Oatka Creek a short distance south of the Genesee County line. ***White Creek*** drains the towns of Bethany (elevation 1,020 feet) and Pavilion (elevation 910 feet). ***Mud Creek***, rising southeast of the LeRoy Reservoir (elevation 1,058 feet), drains in a NE direction before joining Oatka Creek 2 1/2 miles east of Buttermilk Falls [elevation 775 feet at crest] at an elevation of 630 feet. Few significant tributaries enter the Oatka between ***Mud Creek*** and the Hamlet of Mumford, where ***Spring Creek*** and some smaller limestone spring-fed streams that rise in the Onondaga limestone in Caledonia enter from the south, infusing the stream with high purity water and moderating both winter and summer water temperatures in the downstream reaches. Oatka Creek joins the ***Genesee River*** east of Scottsville at an elevation of [512] feet.[1]

Further valuable information on the LeRoy Reservoir was noted in *The Oatka Creek Watershed State of the Basin Report*:

> The Village of LeRoy use[d] a small reservoir, [***LeRoy Reservoir***], located on Mud Creek….The reservoir was built in 1915 and…has a surface area of approximately 59 acres, a maximum depth of 25 feet and an average depth of 10.5 feet. Daily water use range[d] seasonally from approximately 700,000 gallons per day to occasionally over 1,300,000 gallons per day in summer months... [***LeRoy Reservoir***] serves as a settling basin for nutrients and sediment that enter it from the headwaters of Mud Creek. These materials probably remain in Lake LeRoy and do not flow downstream toward Oatka Creek. The water level in the reservoir is usually below the top of the spillway except in the late winter and spring months. At those

times, water from the headwater regions of Mud Creek and from [***LeRoy Reservoir***] will flow downstream in Mud Creek and, ultimately, to Oatka Creek.[2]

LeRoy Reservoir is no longer used as a public drinking supply and was sold to Noblehurst Farms in 2009.

General flow statistics and other fundamental characteristics of the hydrologic network in the Oatka Creek have been summarized in Table 1. These data were derived from two primary sources – GIS analysis of the National Hydrography Dataset (NHD) and through the web-based USGS New York StreamStats GIS application. StreamStats allows users to obtain streamflow statistics, basin characteristics, and descriptive information for USGS data-collection stations and user-selected ungauged sites.[20] The program can estimate streamflow statistics for ungauged sites either on the basis of regional regression equations or on the basis of the known flows for nearby stream-gauging stations. All of the flow statistics provided in Table 1 are estimates that were derived through a combination of these approaches.

Table 1: Characteristics of Streams and Associated Subwatersheds in the Oatka Creek Watershed

	Oatka Creek Watershed	Spring Creek	Mud Creek	White Creek	Pearl Creek	Upstream of Warsaw (including Stony Creek)	Stony Creek	Relyea Creek	Cotton Creek	Headwaters (above Cotton Creek)
Drainage Area (Miles^2)	**216**	8.62	16.3	9.2	13.7	39	9.3	4.06	5.1	8.6
Main Channel Stream Length (Miles)*	**62.5**	9.68	14	7.9	8.6	11.5	7.8	5.31	5.85	6.4
Total Stream Network Length (Miles)	**430.2**	17.2	25.1	16.3	37.2	102	22	13.1	25	55.9
Mean Annual Precipitation (inches)	**33.7**	30.4	31.6	34.7	33.1	37.3	38.6	39.1	37.9	35.2
Mean Annual Runoff (inches)	**14.2**	10.4	12	15	14.1	18.2	19.4	19.9	18.8	15.9
Basin Lag Factor (hours)	**3.42**	.33	.36	.24	.2	.22	.07	.04	.09	.19
Basin Storage**	**.62**	.26	.68	.27	.35	.54	.4	.81	.61	.95
Average basin slope (feet per mi.)	**277**	101	161	238	394	335	320	300	305	264
Minimum daily flow (cfs)	**13**	--	--	--	--	--	--	--	--	--
Maximum daily flow (cfs)	**6,500**	--	--	--	--	--	--	--	--	--
Average daily stream flow (cfs)	**215.386**	--	--	--	--	--	--	--	--	--
Mean Annual Flow (cfs)	**213**	--	--	--	--	--	--	--	--	--

*Stream lengths vary here from those listed in other sections due to variations in calculation method. StreamStats includes braided channels and other intermittent stream reaches, creating greater stream lengths in some cases
**Defined as the percentage of total drainage area of identified lakes, ponds and swamps

Table 2 shows the general characteristics of the Oatka Creek subwatersheds. The upstream portion of the watershed includes the Oatka Creek Headwaters and Pearl Creek subwatersheds. Pearl Creek is the largest subwatershed. In general these two subwatersheds are relatively undeveloped with a low percent of impervious cover, high percent of forest cover, riparian cover and agricultural uses, and fairly low population density.

The mid-section of the Oatka Creek Watershed, the White Creek and Mud Creek subwatersheds, are characterized by relatively low impervious cover and forest cover, a high percentage of wetlands in the case of the White Creek subwatershed and agricultural uses, and fairly low population density.

The downstream portion of the Oatka Creek Watershed, the Village of LeRoy and Oatka Outlet subwatersheds are large subwatersheds relatively high population density and agricultural uses, relatively low forest and riparian cover, and in the case of the Oatka Creek Outlet subwatershed, very high impervious cover.

Table 2: General Characteristics of the Subwatersheds of the Oatka Creek Watershed

	Oatka	Oatka Crk Out	Oatka Crk Headwaters	Pearl Creek	White Creek	Mud Creek	Village of LeRoy
Total Area (Acres)	169582.15	**27817.42**	25029.90	**40488.98**	28363.76	11645.09	**36237.02**
Total Area (square miles)	1068.45	175.26	157.70	**255.10**	178.71	73.37	**228.31**
Impervious Cover (acres)	17270.72	7936.25	1196.85	2188.60	1798.25	859.07	3291.70
% Impervious Cover	10.18%	**28.53%**	4.78%	5.41%	6.34%	7.38%	9.08%
Forest Cover (acres)	34323.94	3888.89	9931.90	8732.82	4695.63	1847.10	5227.59
% Forest Cover	20.24%	13.98%	**39.68%**	**21.57%**	16.56%	15.86%	14.43%
Turf Cover (acres)	114386.53	17247.41	15881.92	28383.85	20207.54	7685.77	24980.05
% Turf Cover	67.45%	62.00%	63.45%	**70.10%**	**71.24%**	66.00%	68.94%
Riparian Cover (acres)	15828.80	1708.9	3521.88	5479.76	2711.17	1084.00	1323.09
% Riparian Cover	9.33%	6.14%	**14.07%**	**13.53%**	9.56%	9.31%	3.65%
Wetlands (acres)	11111.20	1769.6	1612.5	2809.3	2689.3	715.2	1515.3
% Wetlands	6.55%	6.36%	6.44%	6.94%	**9.48%**	6.14%	**4.18%**
Floodplains (acres)	6059.59	1655.14	289.56	1818.50	1045.58	316.07	934.74
Public Lands (acres)	676.84	**485.22**	50.24	77.20	12.39	13.77	38.02
Population	28231.00	**8609**	3726	**5753**	2982	1582	**5579**
Density-Population[a]	26.42	**49.12**	23.63	22.55	**16.69**	21.56	24.44
Commercial Land	668	136	136	**182**	43	19	**152**
Industrial Land	105	**26**	**26**	25	2	11	15
Aquifers (acres)	6924	58.82	**5367.06**	**1458.90**	39.67	0.00	0.00
Road Stream Crossings	75	12	**18**	12	13	4	**16**
SPDES	8	2	0	2	1	0	**3**
Large Parcels [b]	2204	350	350	**461**	**461**	205	377
[a]Density-Pop/Square Miles							
[b] Large Parcel≥ 10 acres							

Land Use and Land Cover

Land activities and water quality are inherently linked to one another. The type of activities that take place on the land will directly influence the quality and characteristics of the water that runs off of it. Understanding the characteristics of the land within a watershed area is therefore a central aspect of watershed planning. Land use characteristics such as public lands, commercial land, industrial land, developed open space, developed low intensity, developed medium intensity, developed high intensity, barren land, along with general agricultural land categories are listed in Tables 2 and 4.

Land Cover

Land cover refers to the type of features present on the surface of the earth. For example, agricultural fields, water, pine forests, and parking lots are all land cover types. Land cover may refer to a biological categorization of the surface, such as grassland or forest, or to a physical or chemical categorization such as concrete.

Land cover was assessed in the Oatka Creek watershed utilizing imagery associated with the National Land Cover Dataset. This dataset was developed by the Multi-Resolution Land Characteristics (MRLC) Consortium, a group of federal agencies who first joined together in 1993 to purchase satellite imagery for the conterminous U.S. to develop the NLCD. In 1999, a second-generation MRLC consortium was formed to purchase three dates of satellite imagery for the entire United States (MRLC 2001) and to coordinate the production of a comprehensive land cover database for the nation called the National Land Cover Database (NLCD 2001).[3] The latest NLCD version available was completed in 2006 and is used throughout this report.

The Oatka Creek watershed is dominated by agricultural land cover, with 31.2% devoted to "Cultivated Crops" and 31.3% of lands devoted to "Pasture/Hay." Forest cover accounts for approximately 21% of total land cover, while "developed" land accounts for a total of 6.8% of land cover within the Oatka Creek watershed. Natural land cover – defined here by NLCD categories 41 (Deciduous Forest), 42 (Evergreen Forest), 43 (Mixed Forest), 90 (Woody Wetlands) and 95 (Emergent Herbaceous Wetlands) – are important components of a healthy watershed. As stated in the EPA manual, *Identifying and Protecting Healthy Watersheds:*

> Natural vegetative cover stabilizes soil, regulated watershed hydrology, and provides habitat to terrestrial and riparian species. The type, quantity, and structure of the natural vegetation within a watershed have important influences on aquatic habitats…Conversely, agricultural and urban landscapes serve as net exporters of sediment and nutrients, while increasing surface runoff and decreasing infiltration to ground water stores.[4]

A summary of 2006 NLCD data focusing on natural land cover categories by subwatershed is shown in Table 3 and can be seen in the Forest Cover (acres), % Forest Cover, Turf Cover (acres), % Turf Cover, Riparian Cover (acres), and % Riparian Cover categories.

Table 3: 2006 NLCD Natural Land Cover within the Oatka Creek Watershed

HUC 12 Subwatershed	Subwatershed Area (Acres)	*% Forest*	*% Wetland*	Natural Cover Total
Oatka Creek Headwaters	24,945.36	*35.7%*	*2.7%*	38.4%
Pearl Creek	36,308.63	*21.6%*	*2.7%*	24.3%
White Creek	25,435.30	*16.6%*	*5.8%*	22.4%
Mud Creek	10,442.77	*15.9%*	*6.5%*	22.3%
Village of LeRoy	18,462.55	*15.2%*	*6.4%*	21.6%
Oatka Creek Outlet	22,445.64	*15.5%*	*7.3%*	22.8%
Oatka Creek Watershed	**138,033.14**	***20.9%***	***4.8%***	**25.7%**

As the figures indicate, natural cover is relatively low throughout the watershed, with the highest percent natural cover found in the headwaters in Wyoming County. This is another indication of the watershed's intensive agricultural character. A full explanation of 2006 NLCD categories and results by subwatershed are provided in Table 4: 2006 NLCD Land Cover – Subwatersheds of Oatka Creek Watershed.

Table 4: 2006 NLCD Land Cover – Subwatersheds of Oatka Creek Watershed												
	Headwaters		**Pearl Creek**		**White Creek**		**Mud Creek**		**Village of LeRoy**		**Outlet**	
NLCD Category	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**
11 - Open Water	33.58	0.1%	50.93	0.1%	12.23	0.0%	75.61	0.7%	63.38	0.3%	27.13	0.1%
21 - Developed, Open Space	915.82	3.7%	1,481.59	4.1%	1,244.97	4.9%	552.43	5.3%	902.92	4.9%	1,135.77	5.1%
22 - Developed, Low Intensity	135.44	0.5%	374.96	1.0%	305.79	1.2%	179.03	1.7%	703.66	3.8%	495.72	2.2%
23 - Developed, Medium Intensity	22.02	0.1%	89.40	0.2%	56.71	0.2%	38.92	0.4%	213.50	1.2%	133.44	0.6%
24 - Developed, High Intensity	0.89	0.0%	16.68	0.0%	5.12	0.0%	14.23	0.1%	70.28	0.4%	23.57	0.1%
31 - Barren Land	16.90	0.1%	23.57	0.1%	0.00	0.0%	358.95	3.4%	80.73	0.4%	41.37	0.2%
41 - Deciduous Forest	6,576.44	26.4%	6,854.21	18.9%	3,411.09	13.4%	1,459.35	14.0%	2,401.42	13.0%	2,632.27	11.7%
42 - Evergreen Forest	594.68	2.4%	91.63	0.3%	39.14	0.2%	18.24	0.2%	21.35	0.1%	54.71	0.2%
43 - Mixed Forest	1,735.35	7.0%	885.35	2.4%	760.59	3.0%	178.81	1.7%	374.51	2.0%	800.40	3.6%
52 - Shrub/Scrub	1,155.34	4.6%	1,858.33	5.1%	629.82	2.5%	523.52	5.0%	715.89	3.9%	781.27	3.5%
71 - Grass/Herbaceous	56.04	0.2%	123.21	0.3%	57.16	0.2%	54.93	0.5%	79.17	0.4%	109.42	0.5%
81 - Pasture Hay	7,435.10	29.8%	13,039.45	35.9%	9,376.83	36.9%	2,138.55	20.5%	5,593.23	30.3%	5,853.65	26.1%
82 - Cultivated Crops	5,595.68	22.4%	10,432.32	28.7%	8,057.37	31.7%	4,175.24	40.0%	6,060.48	32.8%	8,722.33	38.9%
90 - Woody Wetlands	623.82	2.5%	930.28	2.6%	1,329.25	5.2%	648.50	6.2%	1,122.65	6.1%	1,566.99	7.0%
95 - Emergent Herbaceous Wetlands	48.26	0.2%	56.71	0.2%	149.23	0.6%	26.46	0.3%	59.38	0.3%	67.61	0.3%
Total	24,945.36		36,308.63		25,435.30		10,442.77		18,462.55		22,445.64	

Land Cover in the Riparian Zone

The land area directly adjacent to streams is considered to be among the most dynamic and sensitive components of a watershed and has a significant influence on water quality. A stream surrounded by tree cover and vegetation, for example, will benefit from the cooling effects of shade from the tree canopy above and bank stabilization from tree roots and other types of plant cover below. Detritus from surrounding plants will also be contributed to the stream as a source of nutrition and habitat for a variety of animals and organisms. Conversely, streams surrounded by impervious, hard, non-vegetative cover or agricultural cover will likely experience greater soil loss and more impacts from nonpoint source pollution.

Table 5: Analysis of Natural Land Cover within a 300' Buffer of All Streams, by Subwatershed					
HUC 12 Subwatershed	Riparian Buffer Area (Acres)	*% Forest*	*% Wetland*	Natural Cover Total	*% Impervious*
Oatka Creek Headwaters	4,034.2	42.4%	7.5%	50%	<1%
Pearl Creek	6,345.1	32.4%	5.3%	37.7%	<1%
White Creek	3,198.9	26.4%	18.8%	45.2%	<1%
Mud Creek	1,368.8	19.2%	21.0%	40.2%	<1%
Village of LeRoy	1,511.2	18.5%	26.2%	44.7%	2.3%
Oatka Creek Outlet	1,960.2	27.5%	27.4%	54.9%	<1%
Oatka Creek Watershed	**18,389.61**	**30.9%**	**13.4%**	**44.3%**	**<1%**

In an effort to ascertain the level of natural cover within areas surrounding streams, a 300' buffer was created around each tributary within the watershed (150' linear distance perpendicular from the stream on both sides of the stream). The riparian buffer linear distance of 150' (45.7m) was selected in an effort to accommodate 30m² cells used by the NLCD raster grid. While correlations exist between various riparian buffer widths and specific ecological, chemical and stream morphological conditions, no such implications are made here with this selection of the 150' linear distance. Rather, the goal is simply to provide a snapshot of land cover in and around the riparian zone throughout the watershed.[32]
It is again important to emphasize that NLCD land cover classification is generalized on a 30x30 meter scale (.22 acres). Random ground-truthing of NLCD land cover pixels against aerial photography generally reveals a diverse array of actual land cover types within a given NLCD 30x30 meter pixel area. Results of this analysis should therefore be viewed with a degree of caution. Full results by subwatershed are provided in Table 6.

As Table 5 illustrates, the lands adjacent to stream corridors within the Oatka Creek watershed have a modest percentage of natural cover within them, ranging from 40.2% natural cover in the Mud Creek subwatershed to 54.9% natural cover in the Oatka Creek Outlet subwatershed, with an overall total average of 44.3% natural cover throughout the entire Oatka Creek watershed. In the absence of natural cover, agricultural land cover – mainly pasture hay and cultivated crops – is often found to be the predominant land cover type (refer to full figures in Table 6).

Table 5 also includes the percentage of impervious cover, which is a good indicator of aquatic system health.[33] This particular measure of impervious cover is a statistical average of the four "development" subcategories of the NLCD. Impervious cover is very low throughout the riparian area across the entire Oatka Creek watershed, with the highest level of riparian area impervious cover found in the 'Village of LeRoy' subwatershed at 2.3%.

Table 6: 2006 NLCD Land Cover – 300' Riparian Buffer Analysis within Subwatersheds of Oatka Creek Watershed

	Headwaters		Pearl Creek		White Creek		Mud Creek		Village of LeRoy		Outlet	
NLCD Category	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**
11 - Open Water	20.0	0.5%	23.1	0.4%	10.0	0.3%	35.4	2.6%	44.3	2.9%	14.2	0.7%
21 - Developed, Open Space	173.2	4.3%	185.9	2.9%	135.4	4.2%	57.2	4.2%	74.1	4.9%	55.2	2.8%
22 - Developed, Low Intensity	28.7	0.7%	52.3	0.8%	30.9	1.0%	8.7	0.6%	50.9	3.4%	21.6	1.1%
23 - Developed, Medium Intensity	8.7	0.2%	16.2	0.3%	10.2	0.3%	1.1	0.1%	17.3	1.1%	5.6	0.3%
24 - Developed, High Intensity	0.2	0.0%	1.1	0.0%	1.8	0.1%		0.0%	2.2	0.1%	1.6	0.1%
31 - Barren Land	3.1	0.1%	8.5	0.1%		0.0%	0.2	0.0%		0.0%	0.2	0.0%
41 - Deciduous Forest	1,224.1	30.3%	1,793.6	28.3%	592.7	18.5%	209.9	15.3%	168.4	11.1%	258.9	13.2 %
42 - Evergreen Forest	114.3	2.8%	9.8	0.2%	5.1	0.2%	1.1	0.1%	7.8	0.5%	10.5	0.5%
43 - Mixed Forest	374.1	9.3%	251.8	4.0%	247.7	7.7%	51.8	3.8%	103.0	6.8%	268.9	13.7 %
52 - Shrub/Scrub	235.7	5.8%	297.3	4.7%	107.4	3.4%	87.8	6.4%	71.2	4.7%	59.2	3.0%
71 - Grass/Herbaceous	4.4	0.1%	16.0	0.3%	5.1	0.2%	6.2	0.5%	1.1	0.1%	8.9	0.5%
81 - Pasture Hay	1,047.9	26.0%	1,907.9	30.1%	971.6	30.4%	311.1	22.7%	295.1	19.5%	301.1	15.4 %
82 - Cultivated Crops	515.3	12.8%	1,466.0	23.1%	490.4	15.3%	346.7	25.3%	324.5	21.5%	430.8	22.0 %
90 - Woody Wetlands	260.2	6.4%	299.1	4.7%	518.8	16.2%	250.2	18.3%	326.9	21.6%	499.3	25.5 %
95 - Emergent Herbaceous Wetlands	24.2	0.6%	16.5	0.3%	71.6	2.2%	1.3	0.1%	24.5	1.6%	24.5	1.2%
Total	4,034.2		6,345.1		3,198.9		1,368.8		1,511.2		1,960.2	

Impervious Cover
The Center for Watershed Protection (CWP) defines impervious cover as "any surface in the urban landscape that cannot effectively absorb or infiltrate rainfall."[5] It is the sum of roads, parking lots, sidewalks, rooftops, and other impermeable surfaces of the urban landscape. The impacts of impervious cover on aquatic systems are well documented.[5] In 1994, CWP published the paper *The Importance of Imperviousness,* which outlined the empirical evidence showing the relationship between impervious cover and stream quality. Among the conclusions drawn from that paper:

- Impervious surfaces reduce infiltration of stormwater and increase stormwater runoff volumes and velocities;
- Impervious surfaces increase stream channel instability which, in turn, triggers a cycle of streambank erosion and habitat degradation;
- Impervious surfaces collect and accumulate pollutants deposited from the atmosphere, leaked from vehicles or derived from other sources and quickly directs those pollutants into receiving waterbodies in a concentrated fashion;
- Impervious surfaces along with other associated factors (such as decreased tree cover) amplify stream warming;
- Increases in impervious surfaces are associated with a decrease in the diversity, richness and composition of the aquatic insect community, such as macroinvertebrates; and
- Levels of subwatershed imperviousness in excess of 10 to 15% can have a negative impact on the abundance and diversity of fish communities as well as the richness of both the wetland plant and amphibian community.

Impervious cover (IC) is therefore a key indicator of stream quality and watershed health. The CWP has integrated these research findings into a general watershed-planning model, known as the Impervious Cover Model (ICM). The ICM predicts that most stream quality indicators decline when watershed IC exceeds 10%, with severe degradation expected beyond 25% IC. While the actual stream response to the level of IC will vary based on a variety of conditions (local topography and physiology, other prevailing land cover characteristics, stormwater practices, watershed history), IC has nonetheless been identified as a significant contributor to aquatic system decline and therefore a reliable indicator of urban hydrologic stress.[6]

Impervious cover is obviously highest in urbanized areas within the watershed, such as the Villages of Warsaw, LeRoy, Caledonia and Scottsville. The density of buildings and streets creates a high degree of impervious cover in these areas. Because the catchment boundary in the Caledonia area is large, the ratio of impervious cover to open space is reduced, creating a low IC value. Overall, IC is not a major concern across the Oatka Creek watershed when measured by this standard, even in most villages. The Village of LeRoy does have several small catchments with a high %IC. The ICM therefore provides a starting point for further research into how these areas affect local aquatic health.

Floodplains
The National Flood Insurance Program (NFIP) is a federal program that enables property owners to purchase affordable flood insurance. Before the NFIP, flood insurance was generally unavailable. The program is based on a partnership between communities and the federal government in which the community adopts floodplain management regulations to reduce flood risks and the federal government makes flood insurance available within the community.

The National Flood Insurance Program uses the 100-year flood as the standard on which to base its regulations. This is a national standard used by virtually every Federal and most state agencies, including New York State agencies, in the administration of their programs as they relate to floodplains. The technical and engineering methods involved in determining the magnitude of these floods are well established. Although the 100-year flood is the event that is estimated to have a one percent chance of being equaled or exceeded each year, there is no guarantee that a flood of this magnitude could not occur in fewer than 100 years or that one will necessarily occur in each 100 year period at a precise location.

Flood Insurance Rate Maps (FIRM) are produced by the Federal Emergency Management Agency and provide the official record of special flood hazard areas. While paper or flat FIRM maps are generally available online for every community in the Oatka Creek watershed, corresponding digital GIS data pertaining to the flood boundary is not available for every Oatka Creek watershed community through state or federal agencies. Furthermore, some portions of watershed communities have never been mapped by FEMA at all, creating significant and sometimes perplexing gaps in the floodplain record. (In order to create efficiencies in the mapping process, FEMA likely elected to skip certain areas that were not prone to frequent flooding or had low population density). Information provided by FEMA has been combined with information created by local offices and agencies in an effort to provide comprehensive picture of the 100-year flood zone across the entire Oatka Creek watershed.

Map 4 illustrates those areas identified as within the 100-year flood zone. While these boundaries are generally very close to the actual boundaries as indicated on official FIRM maps, some variation is evident from place to place. Maps and associated data are therefore for planning purposes only and should not be used to determine the level of flood hazard in any particular area.

Map 4: Floodplains

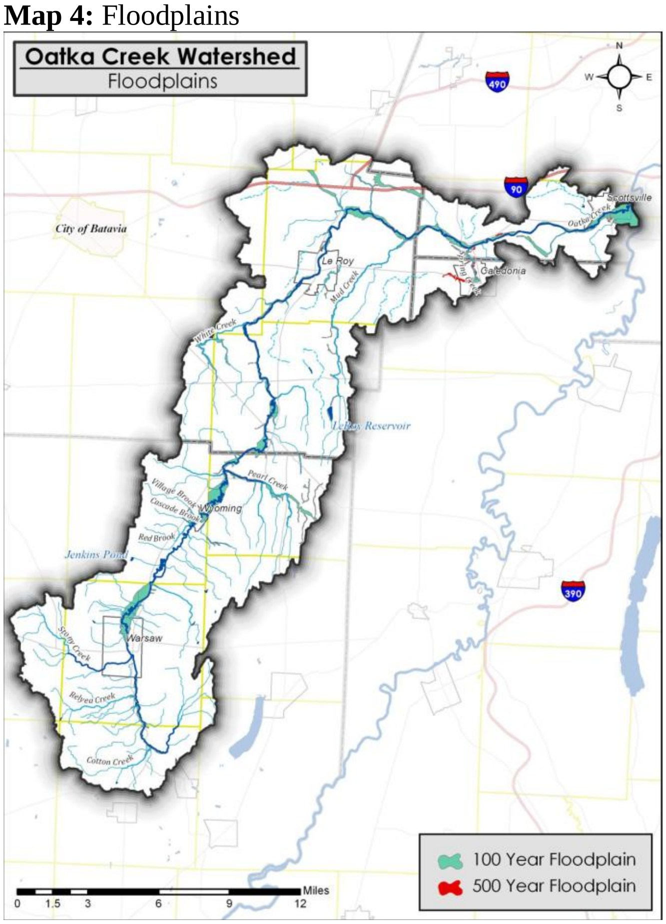


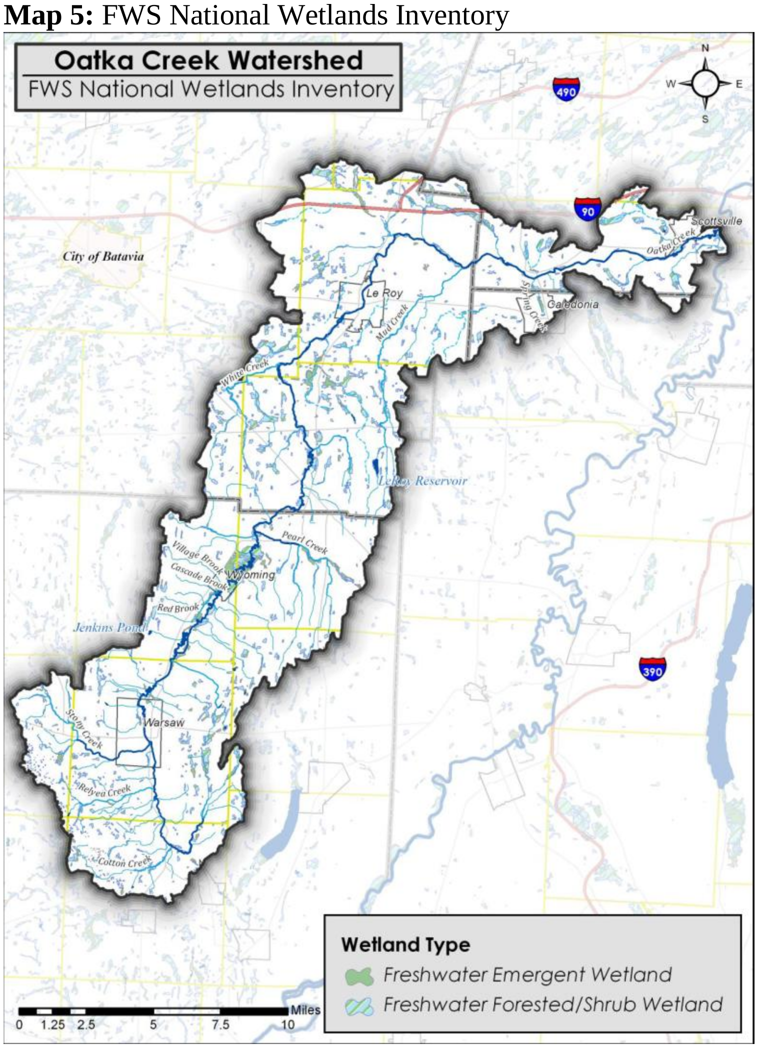
Table 7: Analysis of 100-Year Flood Zone in the Oatka Creek Watershed			
Subwatershed	**Acres at or below 100-year flood elevation**	**% of Subwatershed Area**	**% of Oatka Creek Watershed Area**
Oatka Creek Headwaters	289.56	1.2%	0.2%
Pearl Creek	1,818.05	5.0%	1.3%
White Creek	1,045.58	4.1%	0.8%
Mud Creek	316.07	3.0%	0.2%
Village of LeRoy	934.74	5.1%	0.7%
Oatka Creek Outlet	1,655.14	7.4%	1.2%
Oatka Creek	**6,059.14**	**4.4%**	**--**

Analysis of the 100-year base flood elevation (1% flood risk) indicated that 4.4% of the total land area within the Oatka Creek watershed is within this zone. The Oatka Creek Outlet subwatershed has the highest concentration of lands in the 100-year floodplain, with 1,655 acres accounting for 1.2% of total watershed area. Full results of this analysis are provided in Table 7.

Wetlands

Wetlands serve a number of important functions within a watershed, including sediment trapping, chemical detoxification, nutrient removal, flood protection, shoreline stabilization, ground water recharge, stream flow maintenance, and wildlife and fisheries habitat.

Map 5: FWS National Wetlands Inventory



In 1986, the Emergency Wetlands Resources Act mandated that the US Fish and Wildlife Service complete the mapping and digitizing of the nation's wetlands. The result is the Wetlands Geospatial Data Layer of the National Spatial Data Infrastructure. This digital data provides highly detailed information on freshwater wetlands and ponds with numerous classifications and sub-classifications. Federal wetlands (referred to as the National Wetlands Inventory (NWI)) in the Oatka Creek watershed are illustrated on Map 5. A subwatershed analysis of the NWI geospatial information is provided in Table 8.

Table 8. US Fish and Wildlife Service National Wetlands Inventory for Oatka Creek Watershed							
Subwatershed	**Total Acreage**	*Freshwater Emergent Wetland*	*Freshwater Forested/Shrub Wetland*	*Freshwater Pond*	*Lake*	*Other*	*Riverine*
Oatka Creek Headwaters	1,612.5	264.5	1,183.5	164.4	*0*	0.1	*0*
Pearl Creek	2,809.1	766.2	1,808.5	198.0	*0*	*0*	36.5
White Creek	2,689.3	259.7	2,264.1	56.0	*0*	0.3	109.2
Mud Creek	715.2	16.8	581.8	61.8	47.8	7.0	
Village of LeRoy	1,515.3	231.1	1,163.7	51.0	23.4	1.5	44.6
Oatka Creek Outlet	1,769.6	202.7	1,311.8	65.0	*0*	107.7	82.4
Oatka Creek Watershed	11,111.0	1,741.1	8,313.3	596.2	71.2	116.7	272.6

3. Water Quality

Priority Waterbodies List (PWL)

States must complete periodic assessments of water quality and habitat conditions in order to evaluate whether standards are met, and whether the designated uses are supported. In New York, surface waters exhibiting symptoms of degradation are placed on a Priority Waterbodies List (PWL), and categorized based on the severity of water quality and/or habitat degradation.

The most recently published Priority Waterbodies List (2003) evaluates 5 segments of Oatka Creek: upper, middle (Genesee Co.), middle (Wyoming Co.), lower Oatka Creek, each with its associated minor tributaries, and the LeRoy Reservoir (Table 9). [7]

Table 9: Priority waterbody listings (PWL) for segments of Oatka Creek and its tributaries (NYSDEC PWL 2003).				
Oatka Creek Segment	**Use Impairment**	**Cause Source**	**Class**	**W B Category**
Lower Oatka Ck & Minor Tribs.	Aquatic Life suspected of being **stressed** Aesthetics suspected of being **stressed** Public bathing suspected of being **stressed**	algal/weed growth; silt/sediments agriculture; stream-bank erosion	B	minor impacts
Middle Oatka Ck & Minor Tribs. (Wyoming Co.)	Recreation suspected of being **stressed** Aesthetics suspected of being **stressed**	algal/weed growth; nutrients; silt/sediment agriculture; stream-bank erosion	C	Minor Impacts
Middle Oatka Ck & Minor Tribs. (Genesee Co.)	Recreation suspected of being **stressed** Aesthetics suspected of being **stressed**	algal/weed growth; nutrients; silt/sediment agriculture; stream-bank erosion	C	minor impacts
Upper Oatka Ck & Minor Tribs.	Recreation suspected of being **stressed** Aesthetics suspected of being **stressed**	algal/weed growth; nutrients; silt/sediment agriculture; stream-bank erosion	C	minor impacts
LeRoy Reservoir (Sect. 303(d) listed waterbody)	Water supply known to be **stressed.** Aesthetics known to be **stressed**.	water level/flow, nutrients, pathogens hydro modification; failing on-site systems		minor impacts

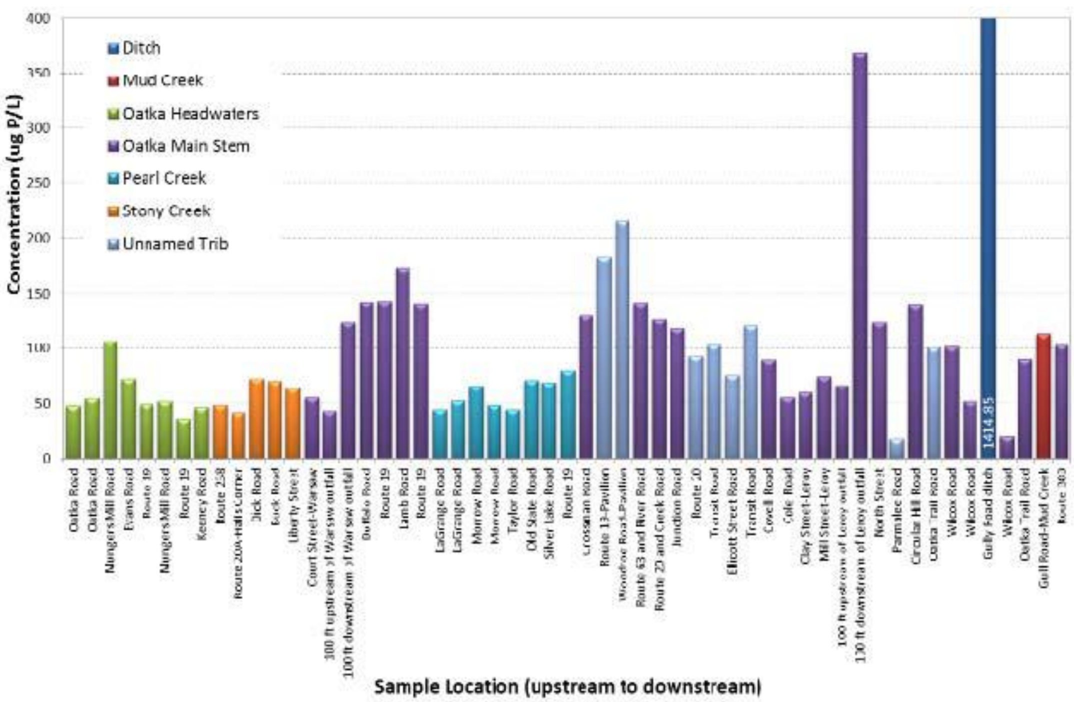
Section 303(d) Listing

In New York, waterbodies with designated uses considered precluded or impaired are eligible for placement on the 303(d) list. This list is named for the section of the Clean Water Act requiring states, territories, and authorized tribes to assess water-quality conditions within their jurisdictions and compare the data to promulgated standards. The 303(d) list is a product of this assessment; water bodies are placed on the list when additional controls are needed to bring water quality into compliance with standards and criteria.

The Final New York State (June 2010) Section 303(d) List of Impaired Waters Requiring a TMDL/Other Strategy (http://www.dec.ny.gov/docs/water_pdf/303dlistfinal10.pdf) lists no segments of Oatka Creek with impairments significant enough to require TMDL development or other controls.

Water chemistry
The Oatka Creek Watershed State of the Basin Report (2002) noted few, if any, water quality parameters that fall outside ambient water quality standards or guidance values. However, concentrations of phosphorus, an important nutrient, and of suspended solids that contribute to turbidity, are especially high at times of high flow. The report recommends regular monitoring of these parameters of potential concern.

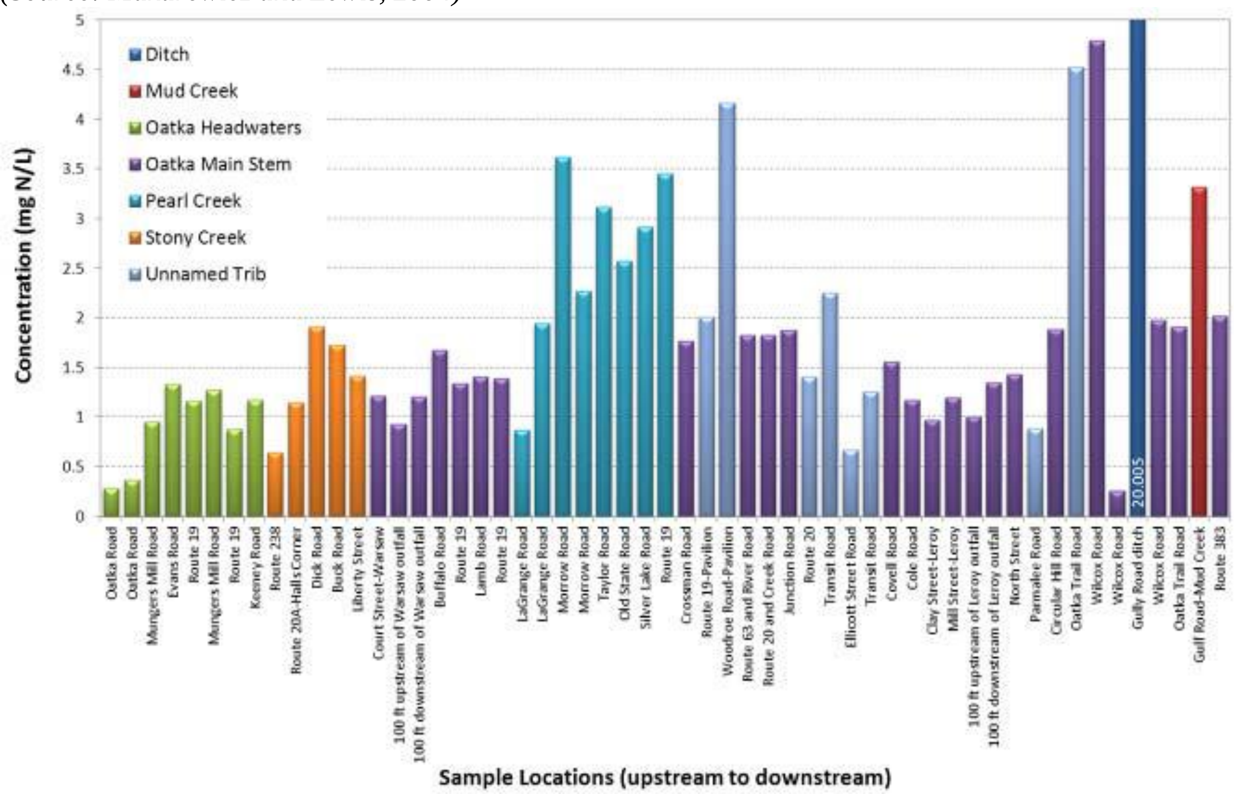
Figure 1: Total Phosphorus Average Concentrations, 2003-2004, from upstream (left) to downstream (right) on Oatka Creek. *(Source: Makarewicz and Lewis, 2004)*



As a follow-up to this recommendation, Makarewicz and Lewis (2004) collected grab samples at multiple sites along the main stream and a number of tributaries on eight dates between Sept. 2003 and May 2004, measuring total and soluble reactive phosphorus (TP (Figure 1) and SRP), nitrate and total Kjeldahl nitrogen (NO3-N (Figure 2) and TKN), sodium and total suspended solids (TSS) in order to locate sources of point and nonpoint pollution. This study identified seven areas affected by nonpoint sources of pollution on tributaries or the main stream. In each case, the sites were in proximity to agricultural lands. In addition, the study was able to discern the effects of the wastewater treatment plants at Warsaw and at LeRoy on in-stream concentrations of phosphorus and nitrogen. Makarewicz and Lewis (2004) recommend that landowners and managers in the watershed work together to implement best management practices (BMP) on agricultural lands in the watershed, especially at the sites they note as "stressed". The two wastewater treatment plants were operating within their current State Pollution Discharge Elimination

System (SPDES) permits during the study period. The investigators recommended stakeholder discussions to consider the potential for the effects of increased population growth and associated increased point source loading on Oatka Creek.

Figure 2: Nitrate Average Concentrations, from upstream (left) to downstream (right) on Oatka Creek. *(Source: Makarewicz and Lewis, 2004)*



Watershed Runoff Export Coefficients

An approach utilizing an export coefficient model to estimate annual loss of water and materials from the landscape was described in the Oatka Creek Watershed Characterization. Because limited data are available to calibrate or verify a model of chemical and sediment loss from the landscape (i.e., pollutant load) in Oatka Creek, a simple landscape approach was used with regionally-appropriate export coefficients based on land cover and soil hydrologic class. The export coefficient modeling approach is typically used to characterize rural landscapes, with nonpoint sources of pollution and limited - if any - stormwater collection and point source discharges.

This is an empirical modeling approach; the export coefficients were derived from field investigations of watersheds with a range of land cover and soil hydrologic class conditions. We endeavored to select export coefficients from areas with physiographic, climatic and soil conditions comparable to those found in the Oatka Creek watershed. The analysis estimates the annual export of material, and results are reported in units of mass per area per time (kg/ha/yr). For the purposes of this analysis, we focused on export of phosphorus from the landscape. Analysis of export for other parameters may be conducted in the future as needed.

The USGS estimated the phosphorus yield of the Oatka Creek watershed from the median concentrations for a six-year period (2003-2008). The yields were not available on a subwatershed basis, so the yield for the entire Oatka Creek watershed was used. Annual yields ranged from 0.32 to 0.42 kg/ha, and averaged

0.36 kg/ha. The average annual load of phosphorus, based on a 200 square mile watershed area, was 18,446 kg.

Phosphorus loading estimated from land cover types incorporated export coefficients with land cover area to derive total loading for the subwatersheds (Table 10), as described above. Areas within 100m of streams were weighted. The dominant land cover type related to agricultural uses – Cultivated Crops and Hay/Pasture account for 63% of total watershed land cover, and 50% of land cover within 100m of streams. The second most-common land cover type is Deciduous Forest, which accounts for 17% of the total watershed land cover, and 23% of land cover within 100m of streams.

Table 10: Summary of P Load Estimate for Land Cover, by Subwatershed (weighted to 0.25 for area >100m)

Subwatershed	Land Cover TP Load Estimate (kg/yr)	Percent of Total
Oatka Headwaters	2,860	16%
Pearl Creek	5,419	30%
White Creek	3,245	18%
Mud Creek	1,585	9%
Village of LeRoy	2,186	12%
Oatka Outlet	2,951	16%
Oatka Creek Total	18,248	

Estimates of phosphorus loading were made for two of the five municipal and industrial dischargers to Oatka Creek, based on data availability (Table 11).

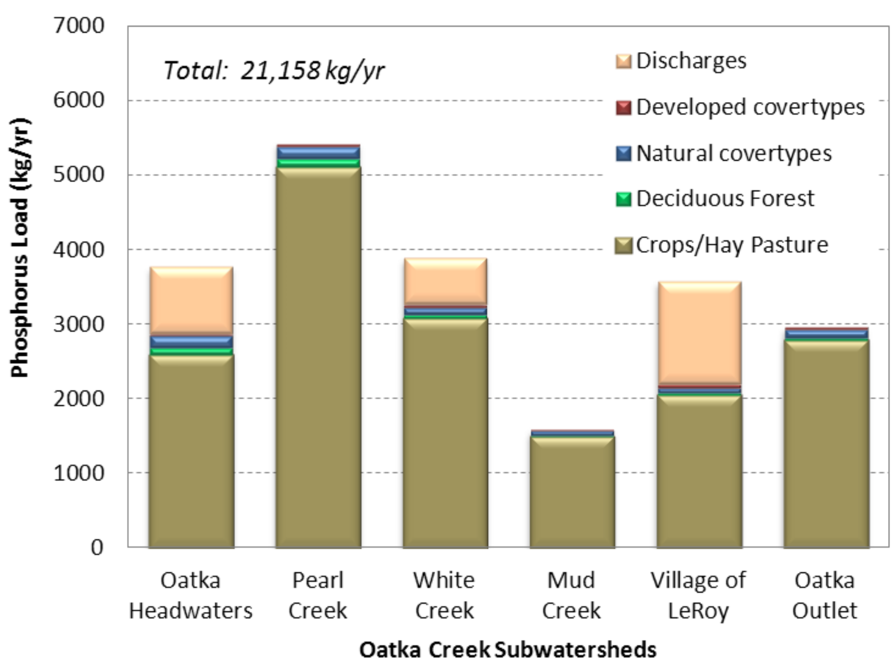
Table 11: Summary of P Load Estimate for Dischargers, by Subwatershed.

Subwatershed	Point Source TP Load Estimate (kg/yr)	Percent of Total
Oatka Headwaters	898	39%
Pearl Creek		
White Creek		
Mud Creek		
Village of LeRoy	1,382	61%
Oatka Outlet		
Oatka Creek Total	2,280	

Finally, these phosphorus loading estimates were compared with the USGS yields data. The initial analysis, using export coefficients representing average values from several sources, estimated the TP load substantially higher than that reported by the USGS. Weighting the land cover types farther than 100m from streams was conducted iteratively, until the phosphorus estimate calculated in this model approached the value obtained from the USGS yields. Ultimately, the weighting of one-quarter (0.25) of the export coefficient was applied for the land cover more than 100m from streams, which may be thought of as a quarter of the export from those areas actually reaches the stream (Table 12).

Table 12: Phosphorus Load Yield Estimates Compared to USGS Yield Data					
Subwatershed	Phosphorus Load From USGS (2003-2008) Tributary Yields (kg/year)	Estimated Non-Point Phosphorus Load From Land Use (kg/year)	Estimated Point Source Loading From SPDES Permits (kg/year)	Estimated Total (kg/year)	Difference in Measured vs. Estimated
Oatka Headwaters	--	2,862	898	3,760	--
Pearl Creek	--	5,419	--	5,419	--
White Creek	--	3,245	630	3,875	--
Mud Creek	--	1,585	--	1,585	--
Village of LeRoy	--	2,186	1,382	3,567	--
Oatka Outlet	--	2,951	--	2,951	--
Oatka Creek	18,446	18.248	2,910	21,158	2,712

Figure 3: Estimated P Loading, Oatka Creek Watershed



Water Quality Analysis
A consideration when prioritizing the Oatka Creek subwatersheds is the work done by Pettenski[8]. The objectives of the study are listed as:

> Objective 1: Conduct segment analyses throughout the Oatka Creek watershed to identify sources of nutrients and sediment.
>
> Objective 2: Evaluate nutrient and sediment load contributions of segments of Oatka Creek and its tributaries within the basin and to the Genesee River using discharge measurements and weekly water chemistry monitoring.

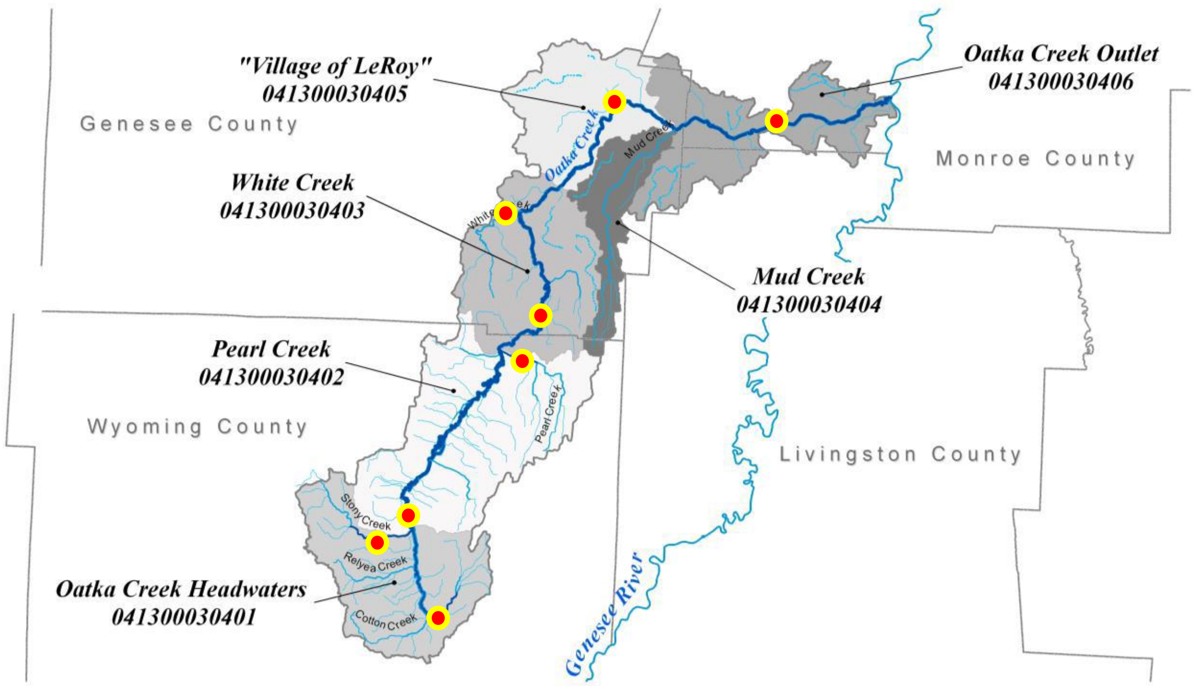
Objective 3: Create, calibrate and validate a Soil Water Assessment Tool (SWAT) model to evaluate allocated source contributions, and sources identified via segment analysis and flux (load) measurements and suggest remediation strategies to reduce phosphorus loads and concentrations in Oatka Creek.

The study design incorporates a comprehensive watershed–based approach to evaluate current water quality in the Oatka Creek Watershed. There are several components to the investigations that can be described as a series of "firsts", in terms of applying methods and techniques to the study of water quality and the sources contributing to its degradation in this watershed.

This is the first investigation to include in its design a set of sites that were routinely sampled weekly for an entire year. At these eight sites, water quality samples were collected for analysis to monitor levels of nutrients, sediment, and bacteria. The only prior study that has attempted a watershed-wide approach to monitoring the water quality in the Oatka Creek Watershed was also undertaken by researchers associated with SUNY Brockport. Makarewicz and Lewis[9] used the Stressed Stream Analysis technique to pinpoint sources of water quality impairment along the Oatka Creek mainstem and in the Stony Creek, Pearl Creek, and White Creek tributaries similar to Pettenski's sampling plan. However, the sampling done in 2003 and 2004 was limited to only a few samples at the most from any particular monitoring site and the entire sampling effort extended for only six months Sept–Nov 2003 and Mar–May 2004.

Map 6 shows the location of eight sampling sites in relationship to subwatersheds (12-digit Hydrologic Unit Code (HUC) that comprises the Oatka Creek watershed). Four of the sites are on the mainstem (main channel) of Oatka Creek and four sites are located on tributary streams flowing into Oatka Creek. Water samples were collected from each of the eight sites every week for a year from June 2010 through May 2011. The weekly samples were analyzed for soluble reactive phosphorus (SRP), nitrate, total phosphorus (TP), total nitrogen (TN), total, suspended solids (TSS), and total coliform bacteria. See Table 13 for information on these individual water quality parameters that were included in this study.

Map 6: Sample Sites



The 8 weekly sampling sites related to the HUC 12 digit subwatersheds in the Oatka Creek watershed. The four mainstem (circles) and 4 tributary (squares) were sampled weekly for a 12 month period from June 2010 through May 2011. Analysis of samples included: four nutrient parameters, total suspended solids, and total coliform bacteria. Also see Table 14, for other subwatershed classification systems.

Table 13. Parameters Included in Water Quality Monitoring, (Modified and Expanded from Makarewicz & Lewis (2004))

Total Phosphorus (TP) - A measure of all forms of the element phosphorus. Phosphorus is a nutrient required by plants and animals. It is naturally limited in most fresh water systems (lakes, ponds, streams, rivers, and wetlands) because it is not as abundant as carbon and nitrogen; introducing a small amount of additional phosphorus into a waterway can have adverse effects. Increases in nutrients like phosphorus and nitrogen can lead to eutrophication in waterbodies, where there is an overproduction of plants and algae growth. The excessive plant growth is accompanied by low dissolved oxygen levels in the water due the higher respiration rates of algae, bacteria, plants and animals and the decomposition of plant material. Sources of phosphorus include soil and rocks, wastewater treatment plants, runoff from fertilized lawns and cropland, runoff from animal manure spreading and storage areas, disturbed land areas, drained wetlands, water treatment, decomposition of organic matter, and commercial cleaning preparations. Some forms of phosphorus are more available to, and cause more immediate activity in, plants. Total Phosphorus concentration is usually given in micrograms of Phosphorus per liter (μg P/L). If in milligrams of Phosphorus per liter (mg P/L), a value of 10 μg P/L, would appear as .010 mg P/L.
Soluble Reactive Phosphorus (SRP) – SRP is a soluble form of phosphorus transported with water and is primarily present as orthophosphate. SRP, because it is soluble, is the form of phosphorus most easily used by algae and plants for growth. Usually reported as micrograms of Phosphorus per liter (μg P/L).
Total Nitrogen (TN) - A measure of all forms of the element nitrogen. Nitrogen is an essential nutrient for plants and animals. Total nitrogen is the sum of total kjeldahl nitrogen (ammonia, organic and reduced nitrogen) and nitrate -nitrite. Although nitrogen is essential to life, an excess amount of nitrogen in a waterway may lead to low levels of dissolved oxygen and negatively alter various plant life and organisms. Sources of nitrogen include: wastewater treatment plants, runoff from fertilized lawns and croplands, failing septic systems, runoff from animal manure spreading and storage areas, and industrial discharges that contain corrosion inhibitors. Usually reported in milligrams of Nitrogen per liter (mg N/L)
Nitrate + Nitrite (NO_3) - A measure of the soluble forms of nitrogen used readily by algae and plants for growth.

Sources of nitrates in the environment are many and include sewage, barnyard waste and fertilizer. Usually reported as milligrams Nitrogen per liter (mg N/L).

Total Suspended Solids (TSS) - A measure of the loss of soil and other materials suspended in the water from a watershed. Water-borne sediments act as an indicator, facilitator and agent of pollution. As an indicator, they add color to the water. As a facilitator, sediments often carry other pollutants, such as bacteria, nutrients and toxic substances. As an agent, sediments smother organisms and clog pore spaces used by some species for spawning. Concentrations usually reported as milligrams per liter (mg/L)

Total Coliform Bacteria - The presence of coliform bacteria in the water indicates that the water may have been contaminated with sewage or animal waste (i.e. manure). Coliform bacteria can be found in the aquatic environment, in soil and on vegetation; they are universally present in large numbers in the feces of warm-blooded animals. The result from a total coliform bacteria test is reported as the number of colony forming units in 100 milliliter (CFU/100 ml) sample.

In Pettenski (2012) the names given to the tributary sites are the names of roads and not the names of the streams sampled. See Table 14 for a comparison of the names used by Pettenski for his eight routinely sampled sites and the names that appear on USGS Topographic Quadrangle maps for the water features. Table 14 also provides, for each of the eight sites, the 12 digit Hydrologic Unit Code (HUC) Subwatershed and the NYS DEC watershed segment that the sites are located in.

Table 14: Sampling Site Names and Relationship to the Traditional USGS Stream Hydrographic Names and Drainage Features Found on Topographic Maps

DOWNSTREAM ↓ UPSTREAM	**Pettenski (2012)** **Weekly Sampling Sites**	**Traditional USGS Stream Hydrographic Name & Drainage Feature**	**HUC 12 Subwatershed**	**NYS DEC WI/PWL Watershed Segment**
	Evans Rd.	Oatka Creek Mainstem	Oatka Creek Headwaters	Upper
	Buck Rd. Tributary	Stony Creek Tributary	Oatka Creek Headwaters	Upper
	Warsaw	Oatka Creek Mainstem	Oatka Creek Headwaters	Upper
	Wyoming Rd. Tributary	Pearl Creek Tributary	Pearl Creek	Middle (Wyoming Co.)
	Ellicott Rd. (Rt. 63 Bridge in Hamlet of Pavilion)	Oatka Creek Mainstem	White Creek	Middle (Genesee Co.)
	Roanoke Rd. Tributary	White Creek Tributary	White Creek	Middle (Genesee Co.)
	Parmelee Rd. Tributary	No Name Tributary	Village of LeRoy	Middle (Genesee Co.)
	Garbutt	Oatka Creek Mainstem	Oatka Creek Outlet	Lower

Pettenski's 8 weekly sampling site names and how they relate to the traditional USGS Stream Hydrographic names and drainage features found on topographic maps. The table also identifies the sampling site's location related to whether the drainage area is delineated using 12-digit HUC subwatersheds or NYSDEC's Water Inventory (WI)/Priority Waterbody List (PWL) – Upper, Middle, and Lower Oatka Creek Watershed Segments.

The NYS Department of Environmental Conservation's (NYS DEC) Upper, Middle (Genesee County), Middle (Wyoming County) and Lower watershed segment designations for Oatka Creek are used in NYS DEC's Waterbody Inventory/Priority Waterbodies List (WI/PWL) that is found in the 2001 Genesee River Basin Report, published in 2003 (see Priority Waterbodies List (PWL) section above). Subsequent to NYS DEC's use of watershed segments, a system to map smaller subwatersheds was developed, called 12-digit Hydrologic Unit Code (HUC), which has now been incorporated into the standardized National Watershed Boundary Dataset used for GIS applications.

For the Oatka Creek Watershed, NYS DEC's Upper and Lower watershed segments are, respectively, the same as the Oatka Creek Headwaters and the Oatka Creek Outlet 12-digit HUC subwatersheds. NYS DEC's Middle (Wyoming County) watershed segment covers the same area as the Pearl Creek 12-digit

HUC subwatershed. Within NYS DEC's Middle (Genesee County) watershed segment are incorporated three of the Oatka Creek's 12-digit HUC subwatersheds: Mud Creek, Village of LeRoy, and White Creek.

For the purpose of this Report, Pettenski (2012) uses the USGS names for Oatka Creek's tributary streams and it will also relate the highlights of Pettenski (2012) to the 12-digit HUC Subwatershed names. The Parmelee Road Tributary name will be used because there is no other USGS name for this drainage feature.

At the 8 weekly sampling locations measurements were made of stream channel depth and width to calculate the cross-sectional area and then velocity measurements across the channel were made to determine the discharge in cubic meters per second. From multiple discharge calculations at the sites, rating curves were established to allow estimations of discharge by recording only the depth at a site. The concentrations of nutrients and total suspended solids derived from sampling and the discharge calculation allowed Pettenski to determine loadings of nutrients and suspended sediments at each of the eight sites. This study is the first time any comprehensive pollution loading information has been available for most of the length of Oatka Creek's mainstem or for its major tributaries.

A Stream Segment Analysis was performed, which included an initial one day sample of the 8 routine sites as well as an additional 15 sites covering the entire length of the main channel of Oatka Creek. Subsequent sampling was undertaken in areas where the initial sampling identified sources located in upstream locations and the process continued until the sources were identified. Separate sampling efforts were undertaken to identify impacts from point sources, principally the four Waste Water Treatment Plants (WWTPs) and important nonpoint sources like the activities of Confined Animal Feeding Operations (CAFOs).

Pettenski (2012) is also the first time a modellike the Soil Water Assessment Tool (SWAT) has been applied to the Oatka Creek Watershed. After calibrating and validating the model by using observed water quality, discharge and loading results from sampling sites, the Oatka Creek (OC) SWAT model was then used to quantify the contributions that individual point and nonpoint sources made to nutrient loads in the Oatka Creek Watershed. Model simulations also helped to determine an achievable target for reductions of the average watershed concentration of Total Phosphorus and the model was then used to determine what combinations of management options could be effective in reducing TP concentrations to meet the target concentration.

One last "first" in Pettenski (2012) was the use of biological monitoring to assess the degree of nutrient enrichment of Oatka Creek in the Lower Watershed Segment (Oatka Outlet Subwatershed) at the Garbutt mainstem sampling site. Following NYS DEC standard procedures for collection, subsampling and analysis of benthic macroinvertebrate samples from streams, two Nutrient Biotic Indices (one for Phosphorus and one for Nitrogen) were used to make an assessment of whether there was any impairment to the biological community at the Garbutt site.

As noted, this is a watershed dominated by agriculture and as such much of the issues evident in the evaluation and prioritization of the subwatersheds is based on that dominate land use.

Pettenski (2012) indicates the following watershed-wide:

- Past reports, Tatakis (2002)[10] and Makarewicz and Lewis (2004)[9], have identified the principal water quality concerns within the Oatka Creek Watershed as being nutrient enrichment, due to increases in concentrations of phosphorus and nitrogen containing compounds, and increases in sediment from soil and stream bank erosion. As a result of the yearly sampling from June 2010 through May 2011, the magnitude of the nutrient and suspended sediment losses experienced in the Oatka Creek Watershed can be calculated from the weekly samples collected and analyzed from the furthest downstream Oatka Creek mainstem sampling site, at the Garbutt USGS gaging station, approximately 4.5 miles upstream from the confluence of Oatka Creek into the Genesee River. Annual losses observed were 15 Metric Tons (MT) for Total Phosphorus; 677.5 MT for Total Nitrogen; and nearly 5,007 MT for Total Suspended Solids.

- Of the 8 sites sampled weekly for a year, the annual average concentrations of Soluble Reactive Phosphorus (SRP), Total Phosphorus (TP) and total coliform were highest at: the White Creek tributary site in the White Creek Subwatershed (SRP: 32.5 µg P/L; TP: 86.8; total coliform: 11,129 CFU/100 mL); the Ellicott Road (a.k.a. NYS Route 63 at Pavilion) Oatka Creek mainstem site (SRP: 47.5 µg P/L; TP: 100.3 µg P/L; total coliform: 8,770 CFU/100 mL), also located in the White Creek Subwatershed; and the Pearl Creek Tributary site (SRP: 27.5 µg P/L; TP: 74.4 µg P/L; total coliform: 8,237 CFU/100 mL) in the Pearl Creek Subwatershed, when compared to the annual average concentrations found for all 8 sites (SRP: 20.2 µg P/L; TP: 61.0 µg P/L; total coliform: 6,977 CFU/100 mL). See Table 15.

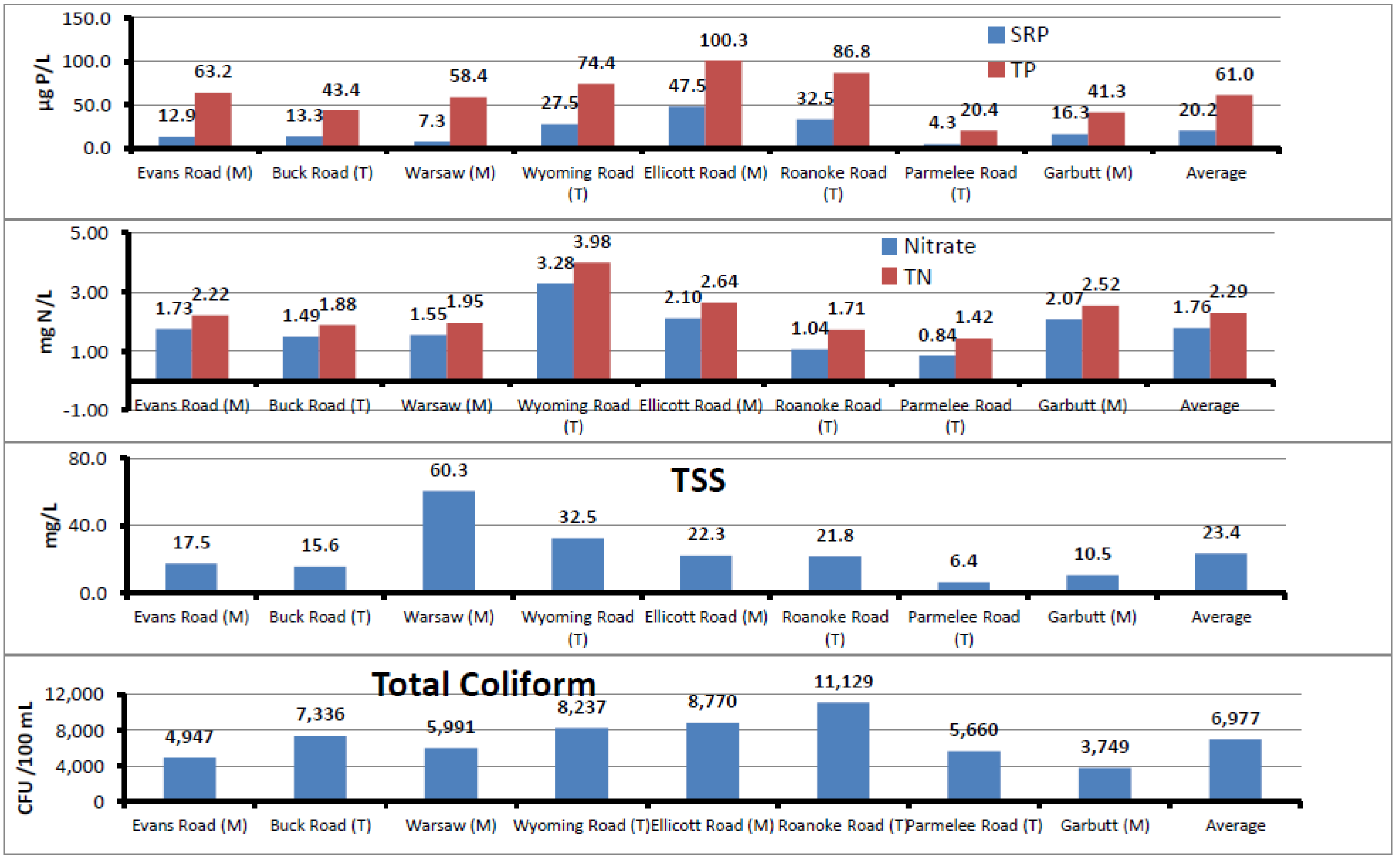
  Further evidence suggesting that Pearl Creek Tributary may be a concern are elevated annual average nitrogen concentrations (nitrate: 3.28 mg N/L; TN: 3.98 mg N/L) compared to the annual average for all eight sites (nitrate: 1.76 mg N/L; TN: 2.29 mg N/L).

  Although the Ellicott Road site is within the White Creek Subwatershed, it is located just 4 miles downstream from the boundary (immediately downstream from the confluence of Pearl Creek with Oatka Creek) between White Creek Subwatershed and the Pearl Creek Subwatershed. Water quality conditions at the Ellicott Road mainstem site would be expected to be affected by the upstream water quality within the Pearl Creek Subwatershed, particularly the Pearl Creek tributary.

- Nutrient loading (kg/yr) for each parameter (SRP, TP, Nitrate and TN) increased incrementally at each of the four mainstem site moving from upstream to downstream sites. Sediment loading (kg TSS/yr) did not follow this trend for mainstem sites. At Warsaw the TSS loading increased 1,882% over the load calculated at the upstream Headwaters site at Evans Road, but at the next downstream mainstem site at Ellicott Road there was a 51% decrease in TSS load, compared to Warsaw. Between Ellicott Road and the furthest downstream site at Garbutt, the TSS load increased by 78%.

  A reason for the apparent reduction in sediment load between Warsaw and Ellicott Road was not suggested in Pettenski's study. The reduction may be attributable to deposition in the low gradient Oatka Creek mainstem channel and its adjacent floodplain and wetland areas that are common features of the watershed segment between the Village of Warsaw and the Hamlet of Pavilion. Other possible features in the watershed that could provide temporary storage for both sediment and nutrients and therefore may affect both the observed and model predictions of downstream load calculations are the two impoundments on Oatka Creek's main channel in the Village of LeRoy.

Table 15. Average Annual Concentrations of SRP, TP, N, TN, TSS and Total Coliform Abundances



Average annual concentrations of soluble reactive phosphorus (SRP), total phosphorus (TP), nitrate, total nitrogen (TN), total suspended solids (TSS) and total coliform abundances at all eight weekly monitoring locations from June 2010 to May 2011, Oatka Creek. M = mainstem. T = tributary From Pettenski (2012). **See Table14 for the USGS waterbody names, 12-digit HUC Subwatershed names, and NYS DEC watershed segments associated with these site locations. Buck Rd = Stony Creek Tributary; Wyoming Rd. = Pearl Creek Tributary; and Roanoke Rd. = White Creek Tributary.**

- Seasonal trends in nutrient concentrations were investigated using monthly average concentrations from all eight sites sampled weekly for a year. Highest monthly concentrations of Total Phosphorus (TP) for the four mainstem sites occurred in December 2010, February 2011 and May 2011, due to the high amount of stormwater and melt water event runoff during the winter and spring. For the four tributary sites, a similar trend of high TP monthly average concentrations was associated with event conditions in winter and spring months, as well as in September 2010. At all sites, concentrations of SRP, TP, and TSS, as well as total coliform abundances showed large increases in concentrations during event conditions, compared to nonevent conditions. However, this was not indicated for nitrate and TN, which showed small increases and even lower concentrations during event conditions. In the case of TP, it is known that particulate (inorganic) phosphorus can become bound to soil particles and as TSS increases during a storm event, because of soil erosion and re-suspension of sediment, there will also be an increase in bound particulate P that will result in a higher concentration of total phosphorus being present in the water samples.

- The calibrated and validated Oatka Creek Soil Water Assessment Tool (OC SWAT) was used to predict the Oatka Creek annual Total Phosphorus loading allocations for the individual sources of

P in the watershed. The largest source, which contributes 31% of the downstream transport of phosphorus in the watershed, was agriculture-related activities [Agriculture Fields = 2,305 kg TP/yr (17.9%); Farm Animals (CAFO) = 1,310 kg TP/yr (10.2 %) and Tile Drainage = 438 kg TP/yr (3.4%)]. The four municipal wastewater treatment facilities operated by the Villages of Warsaw, LeRoy, Scottsville and the Town of Pavilion contribute 26.2 % (3,375 kg TP/yr) of the total phosphorus load from the watershed. On-site residential septic systems, urban runoff and the NYS DEC Caledonia Fish Hatchery contribute, respectively, 6.9% (890 kg TP/yr), 4.4 % (439 kg TP/yr), and 2 % (260 kg TP/yr) to the Total Phosphorus in Oatka Creek.

The above sources are all the result of human activities and are referred to as anthropogenic sources, which in this case, result in over 70 % of the total phosphorus entering the Oatka Creek Watershed. Natural sources of phosphorus also contribute. Groundwater was found to be the largest natural source, contributing 25.2 % (3,244 kg TP/yr), followed by stream bank erosion 4.4 % (563 kg TP/yr), and the combined contribution of forest and wetlands, which is 0.33% (37 kg TP/yr) of the Total Phosphorus load leaving the watershed.

- Water Quality impacts of the four Municipal Wastewater Treatment Plants (WWTPs) were investigated by collecting water samples from locations both upstream and downstream of the discharge point for the treated effluent from each these plants, as well as collecting a grab sample of their treated effluent.

  The Village of LeRoy WWTP, is a secondary treatment plant with the highest maximum discharge (3,785 m^3/day) and highest TP load (9.0 kg P/day) of the four WWTPs in the Oatka Creek Watershed. SRP, TP, nitrate, and TN were found to have downstream concentrations that were significantly higher than their concentration upstream of the plant's effluent discharge point. This WWTP discharges to Oatka Creek within the Village of LeRoy Subwatershed (12-digit HUC).

  The Village of Warsaw WWTP is a secondary treatment plant with the second highest discharge (2,650 m^3/day) and TP Load (4.9kg P/day). Concentrations of SRP, TP, nitrate, and TN found in the Oatka Creek downstream from this WWTP were significantly higher than upstream of the plant's treated effluent discharge. This WWTP discharges to Oatka Creek within the Pearl Creek Subwatershed (12-digit HUC).

  The Village of Scottsville WWTP is a secondary treatment plant with the third highest discharge (2,461 m^3/day) and TP Load (3.9 kg P/day). The analysis of the plant's treated effluent showed that it had the lowest concentrations of nutrients and total coliform abundances (SRP: 1,405.7 µg P/L; TP: 1,597.8 µg P/L; nitrate: 4.13 mg N/L; TN: 6.98 mg N/L; total coliform: 150,000 CFU/100mL) when compared to the other three plants. SRP, TN, and total coliform abundances found in Oatka Creek downstream from the WWTP were significantly higher than upstream of the plant's treated effluent discharge. This WWTP discharges to Oatka Creek within the Oatka Creek Outlet Subwatershed (12-digit HUC).

  The Pavilion WWTP, is a secondary treatment plan with the lowest maximum discharge (303 m^3/day) and the lowest TP load (1.1 kg/day). However, when the effluent sample was analyzed from this secondary treatment plant, it had the highest concentrations of nutrients and total coliform abundances (SRP: 3,425.9 µg P/L; TP: 3,591.8 µg P/L; nitrate: 19.09 mg N/L; TN: 20.44 mg N/L; total coliform: 52,000 CFU/100mL) compared to the other three plants. This WWTP discharges to Oatka Creek within the White Creek Subwatershed (12-digit HUC). Concentrations of SRP, TP, nitrate, TN, and total coliform abundances found in Oatka Creek downstream from the WWTP were significantly higher than upstream of the plant's treated effluent discharge.

- The OCSWAT model was used to predict what changes in TP concentration and loading would result from either upgrading all WWTPs to tertiary treatment, or closing the WWTPs because the sanitary wastewater from the served communities could be transferred out of the Oatka Creek watershed for treatment. The tertiary treatment included chemical addition and a two-stage filtration system. This system is used at two WWTP in New York (Stamford WWTP, capacity .5mgd; Walton WWTP, 1.55 mgd). The WWTPs with this tertiary treatment had effluent concentration for phosphorus of 10 μg/L [11]

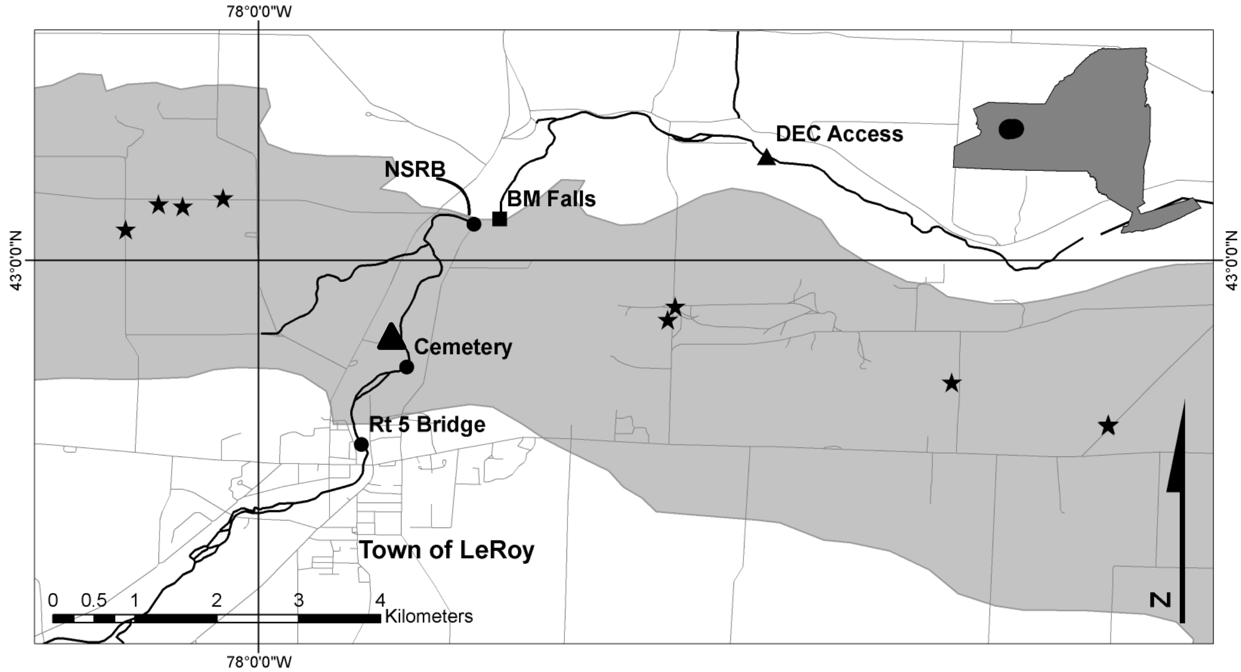
  The model simulation predicted that if all four WWTPs were upgraded to tertiary treatment, a 24.9 % reduction in TP loading in the watershed and a 38.8 μg P/L average watershed concentration could be achieved. Surprisingly, the model simulation associated with closing all of the WWTP resulted in almost the same predictions; a 25 % reduction in phosphorus loading and a 38.7 μg P/L average watershed concentration. The similar predictions probably result from the high level of phosphorus removal that is attributable to the tertiary treatment method. While the impact of closing or upgrading the WWTPS may have the same level of water quality improvements when phosphorus is considered, closing of WWTPs would result in many improvements, beyond just phosphorus, because all contaminants currently in their effluent discharges would not be entering Oatka Creek.

  The following information was not included in Pettenski (2012) but is important to a consideration of the current status and options potentially available for water quality improvements related to the WWTPs in the Oatka Creek Watershed. Transferring sanitary flows from an aging Municipal Wastewater Treatment Plant for treatment at another system has already occurred in the Village of Churchville in the Black Creek watershed, which is immediately adjacent to the Oatka Creek Watershed to the west and north. The Village's WWTP was closed in 2004 and flows were diverted to the Monroe County Pure Waters System, whose WWTPs discharge their treated effluent directly to Lake Ontario. In the Oatka Creek Watershed, the Village of Scottsville is in the process of completing the same type of transfer of its sanitary flows to the Monroe County Pure Waters System. A forcemain and pump station are in place and are being commissioned and tested, it is anticipated that diversion of sanitary flows will begin in the first half of 2014, with the subsequent closing of the Village of Scottsville WWTP.

  Even though OCSWAT modeling predicts that both upgrading WWTPs to tertiary treatment and total removal of WWTP effluent through diversion would have similar effects, some additional considerations in the case of the Village of Le Roy's facility may indicate the latter option offers additional water quality benefits to Oatka Creek. The discharge location for the Village of LeRoy's wastewater treatment plant is within that portion of Oatka Creek that flows over the Onondaga Escarpment, which is primarily limestone bedrock.

  The following information is from a report from Jill Libby[12] ,who as a student at SUNY–Brockport, investigated the surface water and groundwater interactions between Oatka Creek and the Onondaga Escarpment. The area of Oatka Creek underlain by the Onondaga Escarpment extends from a point immediately downstream of Route 5 Bridge in the Village of LeRoy to Buttermilk Falls, which has was created by Oatka Creek's erosion of the Escarpment. Map 7 is a map of the study area from Libby's 2010 report, which has been modified to add the location of the Village of LeRoy's WWTP. The Onondaga Escarpment is composed of limestones which contain fractures, joints, and bedding planes that allow surface water to enter the bedrock and the groundwater aquifer.

Map 7: Study Area Near LeRoy, New York.



Outcrop of the Onondaga formation is shaded gray. Stars represent wells that were used for groundwater sampling. Circles represent sites used for surface water sampling at Rt 5 Bridge, Cemetery and NSRB (North Street Road Bridge) sites. The square represents the location of Buttermilk Falls (BM Falls) and the triangles represent sampling at the DEC access site. The dark black line through these points is Oatka Creek. Light gray lines represent roads. The large black triangle located north of the Cemetery is the location of the Village of Leroy's WWTP. Modified from Libby, J. (2010) report.

The limestone of the Onondaga Escarpment is also easily dissolved and this process widens the fractures, joints and bedding planes and also causes large sink holes to form which enable larger amounts of water to enter the bedrock aquifer and to move quickly through the bedrock. The type of geology and terrain caused by the dissolution of limestone is referred to as karst. As Oatka Creek flows over the Onondaga limestone formation, it begins to lose water to the bedrock. This begins throughout limestone bedrock area, but a large sinkhole in Oatka Creek near the Cemetery on North Street and upstream from the Village's WWTP hastens the process. During the summer months, except during large storm events, the channel of Oatka Creek loses so much water to the bedrock that most of the channel between the WWTP and Buttermilk Falls becomes dry. Some water from the groundwater aquifer returns to Oatka Creek downstream of Buttermilk Falls and additional groundwater is discharged from springs and seeps that are located along Oatka Creek near Circular Hill Rd., as it flows through the town of LeRoy in Genesee County, on its way to the Town of Wheatland in Monroe County, where it receives its greatest input of water originating from groundwater when Spring Creek enters Oatka Creek in the Hamlet of Mumford. Although Oatka Creek regains flow downstream of Buttermilk Falls in the summer months, the rate of gain is less than the rate of loss of the flow that was available upstream of the effects of the Onondaga Escarpment.

The loss of Oatka Creek flow to the limestone bedrock aquifer that is described in Jill Libby's report would also apply to the loss to the bedrock aquifer of the treated effluent discharged by the Village of LeRoy's WWTP to Oatka Creek. If sanitary flows from LeRoy could be diverted to and treated by Monroe County Pure Waters, any potential concern with contamination of the limestone aquifer from the plant's treated effluent discharge would be eliminated.

- Use of OCSWAT – Watershed-based Achievable TP limits, BMPs for nutrient, and Management Options.

  Achievable target concentrations for reducing Total Phosphorus in the Oatka Creek watershed were discussed in the Pettenski (2012). New York has an existing ambient water quality guidance value of 20 µg P/L for phosphorus applicable to ponds, lakes, and reservoirs. There have also been a series of three papers, which investigate the establishment of numerical nutrient (phosphorus and nitrogen) criteria for flowing waters, which have been co-authored by NYS DEC staff from the Department's Stream Biomonitoring Unit (Smith et al. 2007[13] ; Smith & Tran. 2010[14] ; and Smith et al. 2013[15]). In the 2007 paper a phosphorus concentration of 65 µg /L TP for wadeable streams was recommended. However, in the two later papers lower concentrations have been recommended. Smith & Tran 2010 proposed a phosphorus concentration of 30 µg/L TP for large rivers. In the Smith et al. (2013) paper, a phosphorus concentration of 17 µg/L TP was identified for streams in Ecoregion VII, which includes the Oatka Creek watershed. This low concentration was considered to be a protective level for aquatic life in streams because higher concentrations were found to have a higher probability of causing biological impairment through significant changes that occurred to the community structure of the aquatic life living in streams. The 2010 and 2013 papers were not available for review in conjunction with the studies covered in Pettenski (2012).

  In the case of Oatka Creek, the average concentration of Total Phosphorus from the eight main stem and tributary sites that were sampled on a weekly basis for a year, was 61 µg P/L (See Table 15), which is under the 65 µg P /L target concentration. If only the averages from the four mainstem sites are considered the average for the watershed is 65.8 µg /L, which just barely exceeds the target concentration. The OCSWAT model was used to simulate what the watershed's total phosphorus concentration would be if all human disturbances were removed and only natural vegetation cover (i.e. forest and wetland) was present. The predicted concentration for this "Natural" Model simulation was 22.9 µg P/L at the Garbutt site and this value was considered the minimal concentration that could be attained in the Oatka Creek watershed. It is possible that within the Oatka Watershed there are still areas which may have lower concentrations of TP, see average for the Parmelee Tributary in Table 15, or streams where wide forested buffers still exist, e.g. Cotton Creek in the Oatka Creek Headwater Subwatershed. Where they exist, these least disturbed areas of the watershed should be identified and protected as much as possible.

  Given the minimal attainable predicted concentration of 22.9 µg P/L and the observed average concentration for the watershed was at or below the 65 µg P/L target concentration, Pettenski (2012) decided to use the OCSWAT Model to run simulations to predict what set of management practices could achieve a median water quality target of 45 µg P/L for Total Phosphorus (TP) for the Oatka Creek Watershed. See Table 16 for a comparison of observed values and predicted values from the OCSWAT Base and Natural Model Simulations for TP concentrations at each of the four mainstem sites on Oatka Creek.

Table 16. Main Stem TP And TSS Concentrations From Measured Values, SWAT Base Model Simulated, and SWAT Natural Forested Simulated Data

Site Location on Oatka Creek Mainstem	TP (µg P/L) Observed	TP (µg P/L) Base Simulation	TP (µg P/L) Natural	TSS (mg/L) Observed	TSS (mg/L) Base Simulation	TSS (mg/L) Natural
Garbutt (Oatka Ck. Outlet Subwatershed)	41.3	51.6	22.9	10.5	21.1	20.8
Ellicott Rd. (White Ck. Subwatershed)	97.1	49.2	22.9	24.5	12.6	12.0
Warsaw (Oatka Ck. Headwaters Subwatershed)	58.4	81.4	41.5	60.3	95.0	96.5
Evans Rd. (Oatka Ck. Headwaters Subwatershed)	63.2	65.1	20.2	17.5	15.1	0.3

Main stem total phosphorus (TP) and total suspend solid (TSS) concentrations from measured values, SWAT "base model simulated, and SWAT natural forested simulated data. Modified from Pettenski (2012) by adding 12-digit HUC Subwatershed names.

Table 17 shows the management options that were chosen in the five simulation scenarios that did result in predicted phosphorus reductions sufficient to achieve watershed-wide total phosphorus concentrations lower than 45 µg P/L. Two of the scenarios involved applying one specific management option. The first scenario used the OCSWAT model to simulate reductions in TP from upgrading of the four WWTPs to tertiary treatment. This resulted in TP reduction that achieved a 38.8 µg P/L average watershed concentration. This scenario was already discussed above in conjunction with a more comprehensive discussion of impacts and potential improvements related to the four WWTPs in the watershed. The second scenario simulated the intensive use of grassed waterways, one of the agricultural best management practices (BMPs) for reducing nutrient concentrations and loads in the entire watershed. Using the OCSWAT model, use of grassed waterways was applied to all agricultural areas of the Oatka Creek Watershed. The model predicted that this scenario would result in reducing the average watershed TP concentration to 42.3 µg P/L.

Three scenarios involved combining management options and practices to achieve an average watershed concentration for TP below the 45 µg P/L target. The first of these was a very intense application of measures, including the tertiary treatment upgrade for all four WWTPs and the application of grassed waterways and buffer strips on all agricultural land in the Oatka Creek Watershed. The model prediction was that this scenario would result in a significant reduction of 53% in TP load and reduce the average watershed TP concentration to 29.6 µg P/L. While these results are impressive, Pettenski cautioned that this scenario would not be recommended for basin-wide management due to the cost and time it would take to implement. Rather the use of grassed waterways and buffer strips may be better utilized in areas where significant impairment exists and where intensive remediation is needed. The second combined management scenario is an example of this recommended use. Using the OCSWAT model the scenario implemented the use of cover crops (rye) throughout the entire Oatka Creek Watershed and also applied the use of grassed waterways and buffer strips to the significantly impaired tributary watersheds of Pearl Creek and White Creek. This scenario achieved a predicted average watershed TP concentration of 44.3 µg P/L, which is below the target concentration. The third combined management scenario applied the use of cover crops and buffer strips to all agricultural land in the Oatka Creek Watershed and achieved a predicted average watershed TP concentration of 44.4 µg P/L.

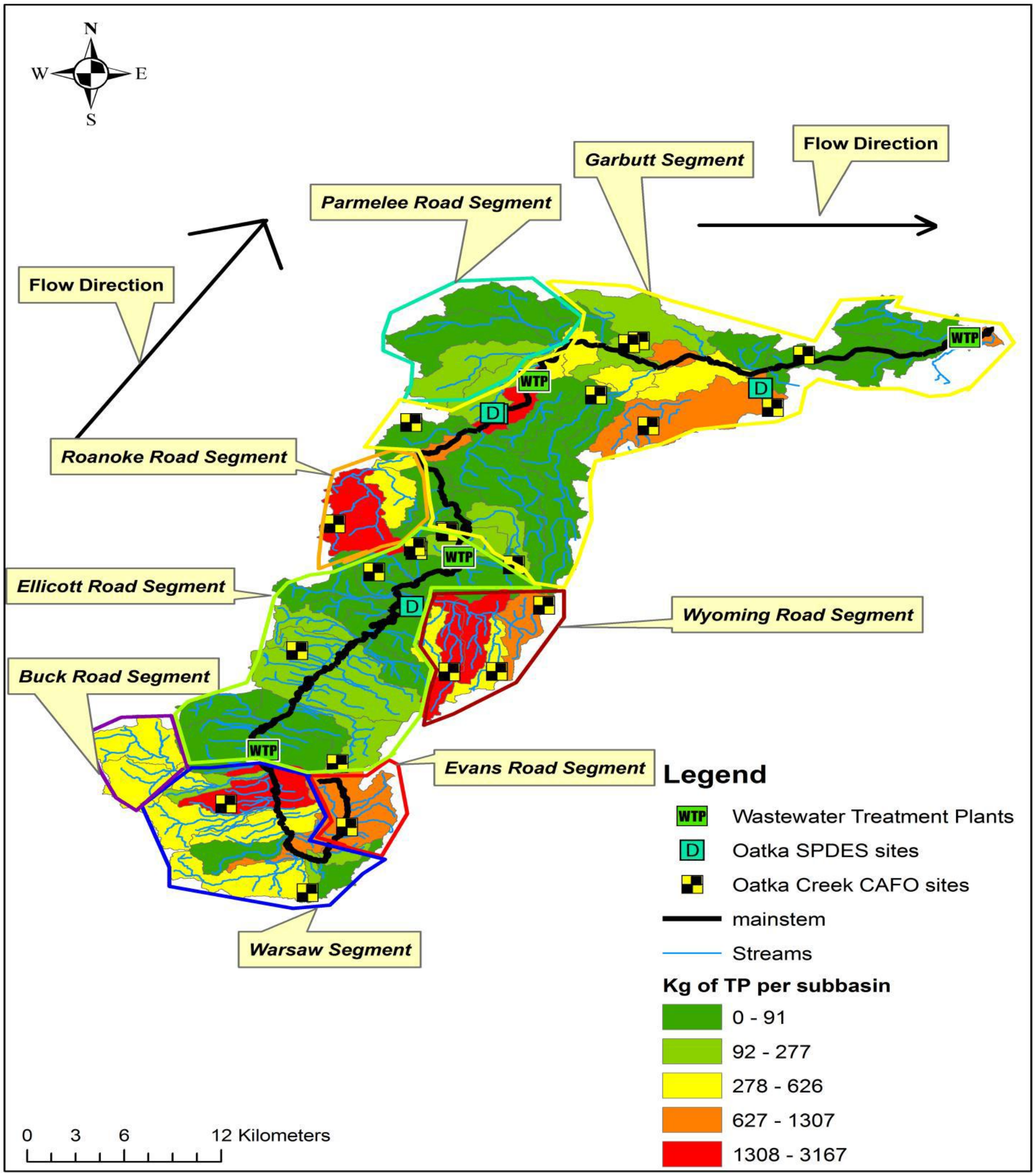
Pettenski's recommendations for reducing Total Phosphorus loading to Oatka Creek, would be to first set an average watershed target concentration of 45 µg P/L for Total Phosphorus. To achieve this target he suggests implementing two management approaches. The first and most effective would be to upgrade all WTWTPs to tertiary treatment. Then to address nonpoint sources he suggests implementing agricultural best management practices such as grassed waterways, buffer strips, and cover crops in the watersheds of the two most impaired tributaries to Oatka Creek, Pearl Creek in Wyoming County and White Creek in Genesee County.

Table 17. Phosphorus Load Reductions for Agricultural Management Scenarios

Management Scenario	Evans Road (Oatka Creek) (Load kg P/yr) Oatka Ck. Headwaters Subwatershed	Pearl Ck. Tributary (Load kg P/yr) Pearl Creek Subwatershed	White Creek Tributary (Load kg P/yr) White Ck. Subwatershed
Base Model	657.9	4,115.0	2,347.0
Buffer Strips	592.5 (9.9%)	3157.7 (23.3%)	1,527.9 (34.9%)
Grassed Waterways	500 (24.0%)	1016.4 (75.4%)	97.7 (95.8%)
Cover Crops	542.9 (17.5%)	3912.5 (4.9%)	2,816.2 (+20.0%)

Agricultural management scenarios conducted on Evans Road (Oatka Creek), Pearl Creek Tributary and White Creek Tributary watersheds. Percent TP load reductions are indicated for each scenario. Modified from Pettenski (2012) by adding USGS Stream Names and 12-digit HUC Subwatershed names.

Map 8: Phosphorus Loads in Oatka Creek Subwatersheds Resulting From OCSWAT Model



Graphical Comparison of Total Phosphorus Loadings from Subwatersheds in the Oatka Creek Watershed

Map 8 provides a graphical means to view the levels of phosphorus losses (kilograms of total phosphorus per year) from different subwatersheds (not 12-digit HUC) of Oatka Creek Watershed. The Map is Figure 60 on page 189 of Pettenski (2012) [8]. The map is generated with the help of the OCSWAT model and data from sampling undertaken in Pettenski's Theses investigations. A limitation of this kind of map is that it will only provide information on subwatersheds that have been investigated. Areas shown as having low TP loadings, may just represent areas where there has been no information added to refine the model because these areas are ones that have yet to be investigated. Still the map does help visualize the degree to which Total Phosphorus is a problem in different subwatersheds. In particular, Pearl Creek and White Creek Tributaries and the Oatka Creek Headwaters Subwatershed are areas for focusing remedial activities using the management practices discussed in the Table 17, above.

Oatka Creek Headwaters

For the purposes of this summary and subwatershed comparisons, the OC Warsaw site results will be discussed under the Oatka Creek Headwaters Subwatershed, even though this sampling site is 2000 feet downstream of the subwatershed boundary and actually in the Pearl Creek Subwatershed. OC-Warsaw site is considered to be in a very good location to indicate the overall water quality of Oatka Creek as it leaves the Oatka Creek Headwaters Subwatershed and the characteristics of the stream channel, in terms of its slope and stony bottom, is more similar to conditions in the Oatka Creek Headwaters than the Pearl Creek subwatershed.

Summary:

- The mainstem site in Warsaw, which was sampled on a weekly basis for a year, showed high TSS values. The annual average of all samples was 60.3 mg/l and the average for all event samples collected at this site was 207.7 mg/l. These were the highest averages seen for any of the 8 weekly sampled sites. Calculated annual sediment loading associated with these TSS concentrations was 5, 791.046 kg/yr (5791 MT) of sediment lost as a result of stream bank and soil erosion from the Oatka Creek Headwater Subwatershed.
- A soil erosion inventory was conducted on July 28 2011. The segment from Site C (Oatka Creek at Kenny Road, see Pettenski 2012, Figure 29, Page 158) downstream to the Warsaw Site, an area of agriculture and residential use that had showed most increase 203% in TSS during sampling, was compared to a segment from Site H (Rte. 19 crossing near Dutton Rd intersection, see Pettenski 2012, Figure 29, Page 158) to the Evans Rd. mainstem site, a forested area, which showed minimal increases (37%). The survey found that 27.3% (1.09 km of 4.00 km) of the stream bank between Site C and Warsaw site was highly erodible, while only 10% (0.40 km of 3.59 km) of the stream bank between Site H and Evans Rd. was highly erodible.
- There may be other portions of the Oatka Creek Headwater Subwatershed contributing to the TSS levels at the Warsaw site. On March 8, 2011, a runoff event stream segment analysis was undertaken on 15 mainstem and tributary sites in the subwatershed. The three highest TSS concentrations were at Relyea Creek (Site D, see Pettenski 2012, Figure 29, Page 158), 75.5 mg/l, Stony Creek at Buck Road, 97.3 mg/l, and at Warsaw, 123.8 mg/l.
- Using the OCSWAT Model, the most effective best management practices simulated for streambank erosion was streambank stabilization. Streambank stabilization techniques have already been implemented in some of the problem areas upstream from Warsaw. Including more of these techniques in the highly erodible areas will have a beneficial impact on reducing the TP and TSS loading in this segment of Oatka Creek.
- Two stream segment analyses were conducted to investigate unidentified sources of nutrient and sediment losses from this subwatershed. One involved 8 sites located in three stream segment subwatersheds upstream of the Evans Road mainstem site and the other involved using 15 sites to investigate the subwatersheds of the two upstream branches of Stony Creek, upstream of the Buck Road site (see Pettenski 2012, Figures 26-28, Pages 155-157).
- Sampling to collect stream water quality during runoff event and non-event periods were conducted at 9 sites (Evans Rd and 8 upstream sites). In the runoff event sampling (see Pettenski 2012, Figure 19, Page 148), the two sites (B & B-1) in Subwatershed # 1 contained the highest phosphorus concentrations SRP (B = 111.4 μg P/L; B-1 = 96.8 μg P/L) and TP (B=171.5 μg P/L; B-1= 122.7 μg P/L), compared to the averages for the remaining 7 sites of SRP= 29.5 μg P/L and ; TP = 42.8 μg P/L. Site B also had concentrations of Nitrate (5.30 mg/l) and TN (6.14 mg/l, that were more than 5 times higher than occurred at any of the other 8 sites. Also the sites with the highest total coliform were B (98,000 CFU/100 ml) and B-1 (50,000 CFU/100). Site B-1 (29.1 mg/l) had the highest concentration of TSS(29.1 mg/L) of all sites. Site B-1 is likely influenced by drainage from agricultural fields and Site B is immediately downstream of Double B Farms, a CAFO (Concentrated Animal Feeding Operation), from which the sampled stream would receive drainage during runoff events because its

channel flows adjacent to the CAFO property. Under nonevent conditions (see Pettenski 2012, Figure 21, Page 150) the stream that drains Subwatershed #1 had no flows, so only under runoff conditions would this watershed be a source of high loading of nutrients, sediment and bacteria.

- In Subwatershed #2 , upstream of Evans Road , the most upstream site D-2 (see Pettenski 2012, Figure 21, Page 150) had high phosphorus concentrations (SRP = 228.2 µg P/L, TP = 295 µg P/L) during non-event sampling. The high nutrients levels were determined to be from agriculture sources (i.e. field drainage). The phosphorus concentration decreased rapidly at two downstream locations, D-1 (SRP= 8.2 µg P/L, TP 53.7 µg P/L) and D (SRP= 6.0 µg P/L, TP 48.3 µg P/L). The decrease was attributable to a wetland located at site D-1, which served as a sink for the nutrients.

  Stony Creek (Buck Rd.) Tributary - Sampling on March 15, 2011 only investigated nonevent conditions in two subwatersheds located upstream of Stony Creek Buck Rd. site. For sampling site locations within the two subwatersheds and the water quality results for all samples see Figures 26, 27, and 28 in Pettenski (2012). In Subwatershed #1, two streams were sampled. The most upstream sampling site for each stream showed effects of nonpoint pollutants, but they were not the same. Site F-1 had high nutrient concentrations (SRP: 42.4 µg P/L; TP: 54.6 µg P/L; nitrate: 4.92 mg N/L;TN: 5.10 mg N/L) suggesting a likely source of nutrients upstream from site F-1.The most upstream site in the other stream, Site G-1, had a high TSS (23.8 mg /L) concentration, suggesting a likely source of erosion upstream from site G-1.

  In Subwatershed #2, nutrient and TSS levels were not as high as they were in Subwatershed #1. But two sites had elevated TSS concentrations [Site E-3 (13.3 mg/L) and Site D-1 (11.7 mg/L)] and another site higher nitrogen concentrations [Site C (nitrate: 2.91 mg N/L; TN: 3.03 mg N/L)], relative to the other sites in Subwatershed #2.

  Probable source areas upstream from sites G-1, F-1, and C were due to manure applications on cropland.

- On March 8, 2011, a segment analysis under event conditions was conducted on the Oatka Creek (OC) mainstem and tributaries upstream from Warsaw. Out of the fifteen samples taken, five mainstem (OC Evans Road, OC Warsaw, sites C, E, and H) and ten tributary sites [Stony Creek at Buck Rd. (a.k.a. Buck Road), sites A, B, D, F, G, I, J, K and L] were selected. See in Pettenski (2012) Figures 29 and 30 for site locations and sampling results.

  Concentrated animal feeding operation (CAFO) sites upstream from tributary sites B (Swiss Valley Farms) and L (Broughton Farm Operation) are likely causes of elevated soluble reactive phosphorus and TP concentrations at sites B (SRP: 30.3 µg P/L; TP: 223.6 µg P/L) and L (SRP: 32.5 µg P/L; TP: 109.1 µg P/L). The CAFO upstream from site B may be a proximate cause for high TP concentrations observed at Stony Creek at Buck Road (211.1 µg P/L) (Fig. 29, Pettenski (2012).

  Along the Oatka Creek mainstem, both TP and TSS concentrations concurrently increased at two locations. One upstream, Site H (TP = 36.5 µg P/L, TSS = 13.3 mg/L) to Site E (TP = 66.5 µg P/L, TSS = 48.3 mg/L) and one downstream from Site C (TP = 66.8 µg P/L, TSS = 40.8 mg/L) to furthest downstream site at OC Warsaw (TP = 103.3 µg P/L, TSS = 123.8 mg/L). The already identified contributions of phosphorus from Tributary B and Stony Creek, which enter the Oatka Creek mainstem between Site C and OC Warsaw would explain the downstream increase in TP.

  There was also a high concentration of TSS (97.7 mg/L) found at the Stony Creek-Buck Rd site that would have flowed into Oatka Creek upstream of the OC Warsaw site. The high TSS in the mainstem of Oatka Creek above Warsaw and its relationship to stream bank erosion was already discussed in an earlier bullet.

  Nitrate and TN concentrations were high at two tributary sites, Site A (nitrate: 5.89 mg N/L; TN:

6.05 mg N/L) and Site I (nitrate: 10.23 mg N/L; TN: 10.32 mg N/L). At the mainstem sites a 24.8% increase in nitrate was identified between upstream mainstem site OC Evans Road (nitrate: 2.62 mg N/L) and the downstream mainstem site H (3.27 mg N/L). The likely source of nitrate is tributary site I (nitrate: 10.23 mg N/L).

Pettenski gives no possible sources for the high nitrate levels in tributary I. Tributary I is a relatively short stream, under a mile long. A USGS Topographic Map with an aerial photo base map, shows that the upper reaches of tributary I flows through some agriculture fields, however just before entering Oatka Creek, its lower reaches flow through a relatively highly developed area including residences, the Wyoming County Public Works facility and other commercial property. While agricultural fields could be the source for the high nitrate levels, another contributing source could be from on-site wastewater treatment systems serving these properties.

- On March 15 2011, under nonevent conditions, a Segment Analysis of two CAFOs upstream from Warsaw was conducted along with sampling of four headwater streams (Pettenski 2012, Figure 31, Page 160).

  Stream water quality samples taken from the vicinity of the Swiss Valley Farms CAFO indicated that phosphorus levels and total coliform abundances downstream were lower than upstream, while nitrogen and TN concentrations significantly increased downstream (nitrate: 6.83 mg N/L; TN: 6.85 mg N/L), compared with upstream (nitrate: 0.14 mg N/L; TN: 0.37 mg N/L). This indicated that during nonevent conditions, Swiss Valley Farms was not a source of phosphorus and coliform bacteria, but was a significant major source of nitrogen. While TSS in the downstream sample (15.4 mg/L), compared to upstream (12.8 mg/l), this may not be as significant an increase as that found for nitrogen. The upstream value of 12.8 mg/l for TSS, is fairly high and likely indicates sources of sediment from upstream eroded area are present.

  Soluble reactive phosphorus and TP concentrations were high in Trib. L downstream from Broughton Farms Operation CAFO (SRP: 151.9 µg P/L; TP: 443.0 µg P/L) when compared to the headwater sites on the same day (mean – SRP: 11.0 µg P/L; TP: 53.6 µg P/L). Broughton Farms appears to be a likely source of phosphorus under nonevent conditions.

  Note that in the sampling on March 8, 2011, during a runoff event, the tributaries that flow from the Swiss Valley Farms, Trib. B, and Broughton Farm Operations, Trib. L, were both discharging high concentrations of phosphorus into Oatka Creek.

  Nitrate and TN concentrations were high at headwater stream site B (nitrate: 8.54 mg N/L; TN: 10.44 mg N/L) (Fig. 31. Pettenski 2012), when compared to the other three headwater sites (mean – nitrate: 0.65 mg N/L; TN: 1.01 mg N/L). Manure smell on cultivated cropland was noticeable upstream from headwater stream site B and is the likely source of nitrogen.

  The sampling conducted upstream from Warsaw indicates that cultivated fields and CAFOs are major sources of nutrients in the Oatka Creek Headwaters Subwatershed.

Pearl Creek Subwatershed

For the purposes of this summary and subwatershed comparisons, the OC Ellicott Rd. (Route 63) site results will be discussed under the Pearl Creek Subwatershed. Even though this sampling site is located within the White Creek subwatershed it is located just 4 stream miles from the Pearl Creek Subwatershed boundary and its water quality is very much influenced by the quality of water flowing from the Pearl Creek Subwatershed, particularly the contributions from Pearl Creek. For this reason, the Ellicott Road Site will be included in the Pearl Creek Subwatershed summary. The Pearl Creek Subwatershed extends from the point where Stony Creek enters Oatka Creek, near the southern area of the Village of Warsaw, to the point where the Pearl Creek Tributary enters Oatka Creek in the hamlet of Pearl Creek near the boundary between Genesee and Wyoming Counties. Influences of two Wastewater Treatment Plant (WWTP) facilities are included in this section of the Oatka Creek Watershed downstream of the OC

Warsaw, the Warsaw WWTP and the Pavilion WWTP. The discussions of these and other WWTP in the Oatka Creek Watershed can be found in the summary of watershed-wide highlights (see pages 25-27).

- When examining the annual average results for the eight sites (see Table 18), which were sampled weekly for a year, the Ellicott Rd. and Pearl Creek at Rte. 19 sites had the highest levels for most parameters. For phosphorus, Elliott Rd. had the highest level (SRP 47.5 μg P/L, TP = 100.3 μg P/L, and Pearl Creek at Rte. 19 had the third highest (SRP = 27.5 μg P/L, TP = 74.4 μg P/L) annual averages. For nitrogen , Pearl Creek at Rte. 19 had the highest level (Nitrate = 3.28 mg N/L, TN = 3.98 mg N/L) and Ellicott Rd. had the second highest level (Nitrate = 2.21 mg N/L, TN = 2.64 mg N/L). For TSS, Pearl Creek had the second highest level (32.5 mg/L) and Ellicott Rd. had the fourth highest (22.3 mg/L). For Total Coliform, Ellicott Rd. had the second highest level (8770 CFU/100 ml) and Pearl Creek at Rte. 19 had the third highest (8,237 CFU/100 ml).

  The Pearl Creek tributary had the highest areal tributary load for SRP, TP, nitrate, TN, and TSS (SRP: 311 g P per ha/yr; TP: 1,098 g P per ha/yr; nitrate: 27.7 kg N per ha/yr; TN: 34.5 kg N per ha/yr; TSS: 692.4 kg per ha/yr). This tributary is clearly a source and an area of concern for nutrients and soil erosion and represents an area to focus management practices.

- A Stream Segment Analysis was conducted on seven subwatersheds of the Pearl Creek Tributary (see Pettenski 2012, Figures 38-43, pages 167-172), under both runoff event and nonevent conditions. In Subwatershed 2a, the Bowhill Farms CAFO cow barn, which is upstream of the retention pond, drains runoff from the barn into the pond. This pond is the proximate source of nutrients and coliform bacteria in Subwatershed 2a, while the Bowhill Farms CAFO site is the ultimate source. The Logwell Acres Inc. CAFO upstream from Subwatersheds #6 and #7 and the Victory Acres CAFO site, located in Subwatershed #4, were also sources of nutrients and sediment in the Pearl Creek tributary's watershed. The dominant land uses in the watershed of the Pearl Creek tributary are related to agricultural activities and some of these activities are the causes of the degraded water quality in the watershed.

White Creek Subwatershed

The White Creek subwatershed extends from the confluence of Pearl Creek in the Town of Covington, Wyoming County, to the point where the first tributary enters Oatka Creek from the east bank, downstream of the Cole Road Bridge in the Town of LeRoy, Genesee County.

- On the White Creek (Roanoke Rd.) Tributary, the OC Roanoke Rd sampling site was one of the eight weekly sampled sites. This site had the second highest annual average for Total Phosphorus (86.8 μg P/L), the third highest annual average for Total Nitrogen (1.71 mg/l), and the highest annual average for Total Coliform (11,129 CFU/100 ml). Similar to the Pearl Creek Tributary, white Creek had high SRP (306 g P per ha/yr) and TP (877 g P per ha/yr) areal loads. As with Pearl Creek , these relatively high losses of phosphorus and other analytes from White Creek indicate areas of concern on which to focus management practices.

- A segment analysis was performed on the White Creek tributary to identify point and nonpoint sources of pollution. The main sources of nutrients, sediment, and coliform bacteria were from Subwatershed 2a where Barniak Farms is located upstream of site C-1. Barniak Farms is a likely cause for elevated nutrient and bacteria levels in the White Creek Tributary.

Village of LeRoy Subwatershed

The Village of LeRoy Subwatershed begins upstream of the Village of LeRoy at the point where the first tributary enters Oatka Creek from the east bank downstream of the Cole Road Bridge. This subwatershed includes all of the Village of LeRoy that drains to Oatka Creek. The subwatershed extends north of LeRoy, including the location of the Village of LeRoy WWTP and the carbonate bedrock area and

Buttermilk Falls, and then east past Circular Hill Road until the confluence of Mud Creek, where the Oatka Creek Outlet Subwatershed begins. The impact of the Village of LeRoy WWTP was discussed under the watershed-wide highlights found in Pettenski (2012).

- Of the four tributary sites that were sampled for a year, the Parmelee Rd. Tributary had the lowest areal contribution (SRP: 12 g/ha/yr; TP: 54 g/ha/yr; nitrate: 3.0 kg/ha/yr; TN: 4.0 kg/ha/yr) to the total losses of the watershed (see Table 15).

- A segment analysis was performed on the Oatka Creek Parmelee Road tributary to identify sources of coliform abundances previously encountered on July 12, 2010, June 7, 2011, and August 3, 2011 (see Pettenski 2012, Figures 49-51, Pages 178-180). Agriculture (corn) is listed as the dominant land use of this area, and a windshield survey in the Parmelee Road tributary confirmed that agricultural practices were widespread and the most likely cause for elevated nutrients and coliform abundances observed. However, a single residence was found to be a source of coliform bacteria and is also a partial source of nutrients in this tributary's watershed. The residence was again visited on August 10, 2011 and it was determined that the waste treatment method was a septic tank.

Oatka Creek Outlet Subwatershed
The Oatka Creek Outlet Subwatershed begins at the point where Mud Creek joins with Oatka Creek in the Town of LeRoy in Genesee County and extends to the point where Oatka Creek flows into the Genesee River, downstream from the Village of Scottsville in Monroe County. Within this subwatershed, in addition to Mud Creek, the main stem of Oatka Creek is joined by Beulah Creek, Spring Creek, Guthrie Creek and several other small, unnamed streams. Just prior to entering the Genesee River, treated effluent from the Village of Scottsville WWTP enters Oatka Creek. The influence of the Scottsville WWTP and other WTTPs in the watershed is presented under the watershed-wide highlights (See discussion on Pages 24-25 of this report).

Trout Fishery
For most of the distance that Oatka Creek flows through the Oatka Creek Outlet subwatershed, it supports a brown trout fishery of regional importance. Only the last 1.5 mile section of Oatka Creek, from the Rt. 251 Bridge in the Village of Scottsville to the Genesee River, is not considered a trout stream. The Spring Creek and Guthrie Creek tributaries are also trout streams. These tributaries drain portions of the Town and Village of Caledonia in Livingston County before flowing north to join Oatka Creek in the hamlet of Mumford in the Town of Wheatland, Monroe County.

One important reason for the success of a trout fishery in these streams is the cool groundwater being discharged from seeps and springs that supplement the stream flow in these streams. The addition of groundwater results in these streams having more consistent stream flows year round. Streams where the only significant source of stream flow is stormwater runoff from their watersheds are susceptible to having greatly reduced stream flow in the summer months, when rainfall events become infrequent.

In addition to constancy of stream flow in the summer months, groundwater entering streams will keep water temperatures much cooler, than the water in streams where there is no groundwater discharge and where summer water temperature is solely determined by the temperature of the air. Cooler water temperatures allow more oxygen to be dissolved in the water, than is possible at warmer temperatures. Trout require high oxygen levels and the cooler water, provided by the groundwater, is responsible for this habitat requirement being available for the entire year, including the warm summer months.

Spring Creek is such a dependable source of quantities of cold water that for almost 150 years it has served as the water source for a fish hatchery operation. In 1864, Seth Green, called the father of the science of fish culture, established his fish hatchery on the banks of Spring Creek in Caledonia. In 1870 the Caledonia Fish Hatchery was acquired by New York State and it is currently operated by the NYS Department of Environmental Conservation. [16]

The following is Seth Green's description of Spring Creek from the Appendix, entitled "Fish Farm in Caledonia NY", from his book called "Trout Culture", published in 1870. [17]

"Caledonia is noted for its creek, which rises entirely from springs, is fed along its whole course by springs in its beds, and at our fish-farm, which is about three-quarters of a mile from the source, it runs about eighty barrels of water per second, 4,800 per minute, or something over 200,000,000 of gallons in twenty-four hours. Quite a respectable quantity of water, and the whole of it available for our ponds, if we wish to use it. The ground in the neighborhood being very level, no surface drainage of any account washes into the creek, and the water looks pure as crystal. It is, in reality, slightly tinctured with lime and sulphur; but must agree with the fish, as the creek has always been noted for its Trout, and still abounds in them."

Using the On-Line Conversion website [18], the 200 million gallons per day would be equivalent to stream discharge of 309 cubic feet per second (cfs); and a barrel per second was found to be equivalent to 4.2 cfs, resulting in 80 barrels/sec equivalent to a stream discharge of 337 cfs. This is definitely quite respectable, especially if this streamflow was consistently maintained throughout the year. It would be interesting to compare the details of Seth Green's description to streamflows and other characteristics of Spring Creek and its watershed today.

Bedrock Geology

Before entering Oatka Creek, Spring Creek and Guthrie Creek in the Caledonia and Mumford area, groundwater flows through bedrock. Within the Oatka Creek Outlet Subwatershed, the most common types of bedrock and their components that underlie the soils are: Camillus Shale (shale, gypsum, dolomite), Akron Bertie limestone (limestone & dolostone), and Onondaga Limestone. Where all three occur together, the Onondaga Limestone overlies the Akron Bertie Limestone, which overlies the Camillus Shale. All these bedrock types are examples of sedimentary rocks and contain carbonate derived rocks to varying degrees. Carbonate rocks are formed from sediments rich in the minerals calcite and dolomite, i.e. limestone and dolostone [19].

In the western portion of the Oatka Creek Outlet subwatershed, between the confluence of Mud Creek and just west of Mumford and Caledonia, only the immediate valley of Oatka Creek and areas north of the Oatka Creek valley have Camillus Shale and Akron Bertie Limestone as bedrock types. In the eastern portion of the Oatka Creek Outlet Subwatershed, from Mumford and Caledonia (including Spring Creek channel) to the Genesee River, the Oatka Creek channel and the northern areas of the subwatershed are over Camillus Shale and the southern areas of the subwatershed are over Akron Bertie Limestone.

The Onondaga Limestone represents the cap of the bedrock, south of the Oatka Creek valley, in the western portion of the Oatka Creek Outlet Subwatershed, between Mud Creek and just west of Mumford and Caledonia. Onondaga Limestone is also the cap bedrock in portions of two other 12-digit HUC subwatersheds; Mud Creek subwatershed, where it occurs in the lower subwatershed, from the NYS Rt. 5 corridor to just south of the Oatka Creek valley, and the Village of LeRoy subwatershed, where it occurs from downstream of the falls at Rt. 5 Bridge in the Village to Buttermilk Falls north of the Village.

Onondaga Limestone can represent up to four overlying layers of different kinds of limestone, the entire group is called the Onondaga Formation. The limestone making up the Onondaga Formation is relatively resistant to erosion compared to the rock above and below it, so it commonly stands above the rest of the landscape as an escarpment that runs east to west across the State [19]. Because of its characteristic hardness, the Onondaga Formation limestone is quarried extensively in New York, mainly for crushed stone, which is used in concrete and for other purposes [19].

Oatka Creek Shale of the Marcellus Formation becomes the cap bedrock at the southern extent of the Onondaga Formation. Oatka Creek shale underlies only a small area of the Oatka Creek Outlet Subwatershed and this area is located southwest of Caledonia. However, Oatka Creek Shale and other shales of the Marcellus Formation form the cap bedrock in the upper portions of both Mud Creek and the Village of LeRoy subwatersheds [21]. Oatka Creek Shale is the bedrock that forms the falls on Oatka Creek near the Rt. 5 Bridge in the Village of LeRoy [22].

For a depiction of the areal extent of the carbonate and shale bedrock underlying the Oatka Creek Watershed, see Map 15, page A-29 (Page 165 of complete pdf document), Appendix A of Oatka Creek Watershed Characterization [20]. More detail on bedrock geology in the Oatka Creek Outlet subwatershed can be found on the Niagara Bedrock Geology Map (scanned jpeg), which can be viewed and downloaded from the NYS Museum's GIS Webpage [21].

Movement of Contaminants and the Importance of areas influenced by the combination of Onondaga Limestone Karst Geology, Surface Water & Groundwater interactions, and Shallow Soils
The Onondaga Formation limestone has already been mentioned in this report, as it relates to the potential for groundwater contamination associated with the diversion of streamflow to the limestone bedrock along the Oatka Creek channel, immediately downstream from the Village of LeRoy WWTP. See pages 25-26 in the watershed-wide highlights from Pettenski (2012) study. This previous section included a summary of the findings of Jill Libby's investigation [12] of the groundwater-surface water interactions that occur in the Oatka Creek channel, both upstream and downstream from Buttermilk Falls, as a result of the dissolution of the limestone in the Onondaga Formation.

Although limestone is considered hard rock, it can be dissolved by water, weak acids naturally found in rain and soil water slowly dissolve the tiny fractures in the soluble bedrock, enlarging the joints and bedding planes. When limestone contains small fractures and joints, these can allow surface water or water infiltrating through soils to move into the limestone. Over time the passageways, provided by fractures and joints, become widened and can allow substantial quantities of surface water to be re-routed through the limestone and to travel considerable distances relatively quickly before re-entering surface water through seeps and springs. Other geological features that are associated with the dissolution of limestone include: disappearing and reappearing streams; springs; sinkholes; caves; and sometimes large caverns. The landscape including these features and resulting from the dissolution of limestone is called karst topography or karst terrain. Although karst landscape most commonly develops on limestone, it can develop on several other types of rocks, such as dolostone (magnesium carbonate or the mineral dolomite), gypsum, and salt [23].

Ms. Libby's investigation is one example of several thesis investigations of various aspects of the groundwater-surface water relationships characteristic of the karst hydrogeology associated with the Onondaga Formation, which have been undertaken between 2008 and 2010 by students under the direction of Professor Paul Richards, PhD in the Department of Earth Sciences at the State University of New York's Brockport campus. The work Dr. Richard's and his students (Richards et al 2010) have done has been brought together and summarized in a final report that was completed in April, 2010 and that is entitled, Prediction of Areas Sensitive to Fertilizer Application in Thin-soiled Karst [24].

Before proceeding with a more detailed discussion of Mud Creek and Spring Creek, it will be advantageous to consider what Dr. Richards and his students have learned about the hydrogeological characteristics of the karst topography found in the catchment areas of these two streams. Sufficient quantity and quality of water resources for the trout fishery, the fish hatchery, and for drinking water provided by residential wells are dependent on the interactions of surface water and groundwater and the dissolution channels in the bedrock and the potential for contamination from a number of sources. Understanding and identifying the sources that can lead to contamination of surface water and groundwater is the first step, but this needs to be followed by implementation of best management practices and land use and development controls designed to ensure that the adverse impacts from sources of contamination are eliminated or significantly minimized.

The Richards et al 2010 report involved a careful analysis of surface depressions, fracture trace features, and aerial photography in conjunction with field surveys in order to identify karst features that are sensitive to groundwater contamination [24]. The need for finding better ways of identifying the location of these karst features was prompted by an incident in 2007 where bacterial contamination of 35 residential wells occurred in the Town of Stafford in Genesee County. The source of the contamination was determined to be manure applied to the land in an area where there was a small and inconspicuous depression that when more closely investigated contained a zone of fractured limestone. This instance was not located within the Oatka Creek watershed, but karst geology and soils are similar in both watersheds.

The area covered by the study included all of Genesee County over the Onondaga Formation and extended into Livingston County to include the Caledonia area.

Some of the findings from the study and associated investigations include:

- Sixty-three suspicious features were inspected in the field. These were separated into six categories: solution sinkholes, pattern ground sinkholes, glacially enhanced sinkholes, exposed bedrock, glacial depressions, and anthropogenic. Figure 4 of the report shows the location of the features, along with the location of fracture traces and shallow soil zones that occur within the Oatka Creek Watershed.
- Solution sinkholes are steep-walled depressions that commonly contain blocks of limestone floating in sediment at the bottom. Three are located in the Town of LeRoy at the intersection of fracture traces south of Gulf Road and between Church Road to the east and Mud Creek to the west. One of these is in the channel of Mud Creek south of Gulf Road. Another solution sinkhole is near Mackay Springs on Spring Street in Caledonia. Solution sink holes are interpreted as collapse features representing the mature stage of sinkhole development. All sites classified as solution sinkholes were in areas showing evidence for shallow bedrock.
- Pattern ground sinkhole depressions tend to be more rounded and less steep than solution sinkholes. They are an example of an immature stage of sinkhole development, where not enough material has dissolved to form a steep collapse feature. These features occur in areas with evidence of shallow soils. There are 7 examples of pattern ground sinkholes between Mud Creek and Caledonia. Two of the pattern ground sinkholes have swallets (an opening into which a stream goes underground) in them. Several of the pattern ground sinkholes flood in the spring.
- Exposed bedrock surfaces are areas where there is little or no soil where fractured rock is exposed at the surface. These are difficult to find because they do not have depressions associated with them, are usually covered with vegetation, and are not identifiable through aerial photography. They are commonly found in glacial outwash channels and are always associated with evidence of shallow soil. The only way to confirm their presence was by walking out in the field and observing them directly. Two areas with exposed bedrock surfaces were identified in the Oatka Creek Outlet Subwatershed.
- Anthropogenic depressions are thought to be caused by quarrying operations or other land use changes. Talking to residents that are familiar with local history is crucial for identifying these. Some of the features may be considered to be sensitive to surface runoff if fractured bedrock is exposed at their base.

- Glacial depressions are gently sloped topographic depressions with no evidence of shallow bedrock and are not located or aligned with fractures traces. They are interpreted to be depressions caused by glacial processes. They are not considered sensitive to surface runoff because of the presence of thick glacial overburden. One glacial depression feature was identified in the Oatka Creek Outlet Subwatershed. There were no Glacial Enhanced Sinkholes identified in the Oatka Creek Outlet Subwatershed.
- The Onondaga Formation in its position at the base of the Alleghany plateau and its capacity to intercept northward flowing streams has made it especially sensitive to groundwater contamination. Highlands to the south provide extensive recharge areas and high water table gradients which cause the Onondaga formation to intercept large groundwater flows. The Onondaga formation dips to the south. Overlying the Onondaga Formation to the south are Oatka Creek Shale, Stafford Limestone and Levanna shale. Groundwater flows from the highland areas following a series of northeast fracture traces and flowing in the top portion of the Oatka Shale, because the shales are not very permeable. When the groundwater flow meets the Onondaga Formation the major groundwater flow is to the east through fractures flowing towards the springs in Caledonia, which feed Spring Creek [25]. The Onondaga Formation is heavily fractured within the study area and a study by Fronk 1991 [26] suggested that many are wide (up to 10 cm. or almost 4 inches wide)
- In addition to groundwater flow from the highland areas in the south, fracture traces and sinkholes associated with the Onondaga Formation capture several north flowing streams and local runoff and reroute these flows to the groundwater zone. This water recharges the Onondaga Formation and moves down into the Akron Bertie and maybe the Camillus Shale where it moves east and re-emerges at the MacKay and Big Springs in Caledonia [27].
- Transducer data and water level measurements collected by this study suggest water tables are extremely dynamic, with water tables rising in the early spring as fast as 50 feet per day. These tend to occur between January and April. Not all wells show water table fluctuations of this magnitude, but many have water table rises that are 15 feet or more per day and all have large annual ranges. The precise timing of water table fluctuations in wells and sinkholes separated by large distances, combined with the lack of apparent relationships between karst related-flooding and precipitation and snow melt variables imply that these water table rises are a large scale (regional) phenomenon and not due solely to local hydrogeological characteristics.
- Capture and transport of contaminants, such as fertilizers, manure, and septic system effluents, can occur when surface runoff and snowmelt containing the contaminants is diverted in dissolution channels in the Onondaga Formation. But high water tables and flooding events can also cause soils and sinkholes to be flushed of these contaminants. This is particularly a concern in areas where there are thin soils associated with shallow depths to bedrock. The study identifies five hydrological mechanisms that are capable of moving nutrients into the groundwater table from karst-related features. They are: contact flooding, groundwater mounding, perched water table transfer, rapid recharge into vertical fractures, and swallet flooding.
- Sites classified as solution sinkholes, pattern ground sinkholes and fractured bedrock that are hydrologically active, should be considered priority targets for management measures.
- Sinkholes are associated with major fracture traces (evidence of fracture visible on rock surface). Large collapse-type sinkholes appear to be located at the intersection of major fracture traces. Therefore all intersections of fracture traces should be mapped and considered important locations of concern.
- Water quality analyses of groundwater fracture flow confirm that subsurface flowpaths are capable of transporting significant amounts of phosphorus [12] and several samples show suspended solid concentrations that are similar to concentrations in surface waters.

Subsequent to the completion of Richards et al 2010 final report, other documents were produced that show that the frequency of well contamination in the karst regions of Genesee County had resulted in more attention being paid to efforts to identify sensitive areas of thin soils, exposed bedrock and hydrologically active karst-related features.

In conjunction with the NYS DEC, USGS published a scientific investigation map and report developed by James Reddy and William Kappel, [28] which compiled existing hydrogeologic and geospatial data useful for the assessment of focused recharge to the carbonate –rock aquifer in the central part of Genesee County. This document includes the features identified in Richards, et al, 2010 report, as well as information from Federal and State agencies, local highway departments, and the Genesee County Soil and Water Conservation District. The study area includes only Genesee County and does not include portions of the carbonate-rock aquifer that occur in Livingston County. Maps accompanying the report show karst-related features, shallow soils with high infiltration rates, soils with lower infiltration rates, but that have a history of groundwater contamination, known locations of groundwater contamination, and land that is used for cropland/hay/pasture. While the report includes a caution that it should not be used as a substitute for site-specific hydrogeologic investigation, the information contained in the report would be useful as a guide in how to proceed with an inventory of sensitive areas that have not yet been mapped.

In 2011, new manure management practices for the karst area of Genesee County were outlined in Cornell University's Animal Science Public Series No. 240 [29]. They referenced the USGS publication identified above and listed some initial steps to be taken to identify whether fields used for manure spreading were in the karst area, whether the fields contained sensitive soils, and whether the fields contained sensitive karst features. The document presented NYS DEC's guidelines for Agricultural Environmental Management (AEM) planners providing services in Genesee County. AEM planners should: identify if fields are in a karst area; identify if any karst-related features are present; identify if fields are in drainage area for any karst-related features and update the farm's Comprehensive Nutrient Management Plan (CNMP) to reflect additional requirements. The additional requirements include: 100 foot setback from drinking water wells in karst area; providing a 30 foot vegetative buffer and 100 foot setback for sinkholes and swallet features, incorporation the same calendar day for manure that is less than 12% solids applied from January 1 to April 15 on fields with surface depressions that contain sensitive soils (Aurora, Benson, Newstead, Rubbleland, or Wassaic), or rock outcrops or shallow bedrock; or that contributes drainage to karst features (i.e. sinkholes, swallets, depressions), the specific soils listed above, rock outcrops, and/or shallow bedrock. The document includes additional precautionary measures that should be followed. The document indicates that these risk reduction practices may be effective in karst and other sensitive areas throughout New York State.

In 2010, NYS DEC revised its New York State Stormwater Design Manual [30], which is used for the design of Stormwater Management Practices to protect the waters of the State of New York from the adverse impacts of urban stormwater runoff. In the 2008 version of the manual there was only one reference to karst geology, in 2010 version there are five references. Principal concern is to avoid the use of large infiltration basins in areas with karst geology. Infiltration measures are typically used to meet runoff reduction criteria and to utilize local soils to provide some treatment before stormwater is recharged into groundwater. However it karst geology, thin soils and shallow bedrock will not provide the benefits normally expected from infiltration practices. The manual recommends a geotechnical assessment to determine whether small scale infiltration and recharge would be effective. Using porous pavement on karst geology would require a liner to be used and therefore the full runoff reduction value will not be provided by the practice. Also in karst geology, infiltration is not recommended as a practice to meet Enhanced Phosphorus Removal Standards without adequate geotechnical testing.

Karst topography represents an important element to address in the Oatka Creek Watershed Management Plan. It provides substantial groundwater resource to sustain fisheries and for drinking water, but at the same time it is very susceptible to widespread contamination. Some watershed management recommendations could include: completing karst area inventories in Livingston and Monroe County to identify areas sensitive to contamination (karst-related features, areas of thin soils or soils with significantly high infiltration rates, and areas with shallow bedrock); implementation of management practices for agriculture-related activities; and adoption of project review procedures that would ensure that stormwater management measures are protective of both surface water and groundwater quality and that site has sufficient depth of soils and other conditions (soil infiltration rate) to provide time for treatment and assimilation of wastewater from leach lines.

Mud Creek Subwatershed

Mud Creek has two principal headwater streams, a west branch and an east branch. Both begin in the Town of Covington, Wyoming County. Flowing north, less than a mile, they enter into the Town of Pavilion in Genesee County. The west branch flows into and out of the LeRoy Reservoir, which has an area of approximately 48 acres. Although this waterbody is still labeled on maps as the LeRoy Reservoir, it is now privately owned and has no public water supply function. The west and east headwater branches join to form the middle portion of Mud Creek about ¾ of a mile downstream of the outlet for LeRoy Reservoir. Mud Creek continues to flow north and enters the Town of Leroy at the point it crosses under U.S. Route 20. From its headwaters to a mile south of NY Route 5 (East Main Street) in the Town of LeRoy, the middle portion of Mud Creek is flowing over primarily shale bedrock, but it then flows over Onondaga Limestone for the remaining 3.5 miles until its channel joins Oatka Creek.

Map 9 shows the lower portion of Mud Creek, with NYS Route 5 to the south and a small portion of the Oatka Creek channel to the northeast. The presence of the Onondaga Limestone is evident from the amount of land that has been devoted to quarry operations in this part of the watershed. In older topographic maps, the early quarries can be seen, but there was still a lot of natural terrain and there were tributary streams that flowed across the areas that are now part of the quarries. The ground water that is captured in the quarries typically must be pumped out so that quarry operations can continue. The water most likely would be pumped to Mud Creek. In Map-9 the closeness of the contour lines indicate that Mud Creek is passing through a relatively steep sided valley just before it reaches Oatka Creek. This is where Mud Creek's channel has eroded through the Onondaga Escarpment on its way to Oatka Creek. The channel has been impounded by the property owner and a pond is now located in the Mud Creek channel at this location.

Sinkholes in Karst Geology of Onondaga Limestone

The locations of two sinkholes are shown on Map-9. Professor Paul Richards, who is with the Department of Earth Sciences at SUNY Brockport, submitted comments on each of these as part of his responses on a review of a draft version of the Oatka Creek Watershed Characterization report in 2012. His comments are included in the following descriptions. In terms of the golf course sinkhole, Dr. Richards' comments were, "Flow in the stream just west and south of the Leroy Country Club enters a sinkhole on the first fairway. This site has been engineered to flow into the inactive Hanson quarry located behind it during excessively high stream flows. Some of it reemerges at a spring in this quarry with a very impressive travertine deposit. The flow goes back into the aquifer or evaporates. There is no direct connection with Oatka Creek except perhaps by groundwater flow paths."

Older maps of the area show that prior to the engineering work and quarry, this stream was probably a tributary of Mud Creek and when high flows occurred, that exceeded the sinkhole's capacity, they would have been able to flow on to Mud Creek.

Map 9: Lower Portion of the Mud Creek Subwatershed

The second sinkhole is located directly in the channel of Mud Creek, north of an abandoned railroad right-of-way and south of where Mud creek crosses Gulf Road. This sink hole has also been investigated by Professor Richards and he provided the following comments, "Most of the flow in Mud Creek is lost in a sinkhole just north of the Lehigh Valley Right of Way. Discharge measurements taken at the mouth of this stream, just before Mud Creek joins Oatka Creek, suggest that flows are very minor. The highest flow we measured there was a few cubic feet per second. Flow data we collected at the sinkhole suggests that only at very high water levels does water make it past this sinkhole. This can also be seen in discharge per unit watershed area graph based on our spring flow data. Hydrologic gradient is towards the east, which is also supported by the TCE plume, which is oriented toward the east. As a consequence phosphorus flux calculations are probably over estimated in Mud Creek in the report (refers to draft version of the Oatka Creek Watershed Characterization Report). Mud Creek is a minor player at best. No farming occurs at all downstream of this sinkhole."

1970 TCE Spill and Groundwater Flow Direction

As Professor Richards mentioned in his comments, the TCE Spill contamination also was found to be directed east as well. The following is some additional information regarding this spill which occurred 44 years ago.

The December 9, 1970 Lehigh Valley Railroad Derailment spill occurred within the Mud Creek subwatershed. Between 30,000 and 35,000 gallons of Trichloroethene (TCE) was spilled from derailed cars, at a location approximately 500 feet northwest of the channel of Mud Creek and in the same general area of the large sinkhole, which is responsible for re-routing most of the stream flows in Mud Creek from surface water to groundwater. The location of both the TCE spill and the sink hole on Mud Creek are shown in Map - 9 of this report and they are also shown on Plate 6, Map 1-LeRoy of the USGS report by Reddy and Kappel, 2010. [28]

The most up-to-date information on this spill can be found in a summary fact sheet on USEPA's website[31]. The information includes: site description; threat and contaminants; cleanup approach; cleanup progress; and site repositories. The major effect of this spill was groundwater contamination, with TCE being ultimately detected in approximately 50 residential drinking water wells. Residences within the area are now served by public water lines. The site of the spill, which remains the source of the groundwater contamination, is still being remediated. As determined from the location of residential wells where TCE has been detected and from samples collected from extensive array of monitoring wells, the areal extent of the groundwater contamination takes the form of a broad plume moving in an east and southeast direction. The plume extends four miles from the spill site and the leading edge extends to the west bank of Spring Creek, from Mumford to the north and Caledonia to the south. TCE was detected in Spring Creek in 1993 at a level less than 3.0 mcg/L (micrograms per liter, or, parts per billion) which is below levels of public health concern [32].

In 2008, Lehigh Valley Railroad (LVRR) began a vapor intrusion investigation and sampled thirty-five properties, eleven of which were found to need vapor intrusion mitigation systems. LVRR has continued its vapor intrusion investigation efforts and the mitigations have been found to be effective in controlling Site related vapors. EPA continues to require that homes which overlay the TCE groundwater plume area are monitored for vapor intrusion issues each heating season. The most recent vapor intrusion investigation and checks on existing mitigation systems was in March of 2013.

Water Quality Sampling In Mud Creek Subwatershed.

Two studies involving water quality assessments have included a monitoring location on Mud Creek at Gulf Road. This location is downstream from the sinkhole in Mud Creek. The two studies are Makarewicz and Lewis 2004 [9], and Pettenski 2012 [8]. Four visits to the site were made by Makarewicz and Lewis, three were visits during rainfall or snowmelt conditions and one was during nonevent conditions. Pettenski made one visit during nonevent conditions.

Table 18 provides the results of these sampling visits. For two of the four visits made to the Gulf Road site by Makarewicz and Lewis, the channel of Mud Creek was dry and no sample could be collected. In his only visit to Mud Creek, Pettenski could not collect a sample either because the channel was dry. All three instances of a dry channel at Gulf Road occurred during summer sampling period, Makarewicz and Lewis in September and Pettenski in July. Neither study mentioned the possibility of the sinkhole being responsible for the no flow conditions.

The two visits where Makarewicz and Lewis were able to collect samples were in November and March. Higher phosphorus and nitrate concentrations were found in the rainfall event sampling in November, than were found in the snowmelt sample in March.

Table 18: Results of Sampling Visits to Mud Creek at Gulf Road – Combination of both Makarewicz & Lewis 2004 [9] and Pettenski 2012 [8]

Sampling Date – Study and Stream Condition	Total Phosphorus (TP) (µg P/L)	Soluble Reactive Phosphorus (SRP) (µg P/L)	Nitrate (NO_3) (mg/L)	Total Kjeldahl Nitrogen (TKN) (µg/L)	Total Suspended Solids (TSS) (mg/l)	Sodium (Na) (mg/L)
Sept. 17 2003 (Makarewicz & Lewis) – Nonevent	DRY – NO FLOW IN CHANNEL					
Sept. 23 2003 (Makarewicz & Lewis) – Rain Event	DRY – NO FLOW IN CHANNEL					
Nov. 20 2003 (Makarewicz & Lewis) - Rain Event	155.7	52.5	4.26	180	10	15.8
Mar. 3 2004 (Makarewicz & Lewis) – Snow Melt	71.6	36.8	2.38	860	12.3	16.83
Jul. 12 2010 (Pettenski) Nonevent	DRY – NO FLOW IN CHANNEL					

Professor Richards' comment (see above under Mud Creek sinkhole discussion) and caution about using these sample results to estimate phosphorous fluxes (loadings) to Oatka Creek would seem warranted given his studies that indicate that significant flow from Mud Creek only infrequently during a year will make it to Oatka Creek because of the diversion of stream flow to groundwater through the sinkhole. Most of the time the nutrient loads carried by Mud Creek will be re-routed east as groundwater flowing through the Onondaga Limestone towards Spring Creek in Caledonia and Mumford. A portion of these loadings will likely make it to Oatka Creek but via Spring Creek, as a result of the groundwater discharge to Spring Creek from seeps and springs in Caledonia and Mumford.

Spring Creek

The length of the Spring Creek channel currently is less than 2 miles long. However, Spring Creek is dominantly groundwater fed and the area that contributes to its flow extends for a considerable distance west and southwest of Caledonia. Several of the streams that would appear to be flowing in the direction of Caledonia end abruptly in sinkholes with swallets. Based on previous information in this report the eastern flow of groundwater within the Onondaga Limestone would bring groundwater to Spring Creek that could have originated in several surface water streams, like Mud Creek, or was groundwater that originated in flow from the highlands to the south , which was intercepted in the Onondaga Limestone and flowed east. There are two main spring areas in Caledonia that contribute groundwater discharges to Spring Creek; these are the Mackay Springs, located on the west side of Spring Street near the intersection with NYS Route 5, and Big Spring, located adjacent to Tenant Park. Both of these sources are in the Village of Caledonia. There are probable more seeps and springs that discharge directly into Spring Creek between Caledonia and Mumford before Spring Creek enters Oatka Creek. Unpublished information provided by Professor Richards indicates, because its flows are mainly contributed by groundwater discharges, Spring Creek is not very responsive to meteorologic events, e.g. rainfall events do not result in large, short-term increases in stream flow. Also, Spring Creek has seasonal flows that are controlled by regional groundwater table and these are highest in the months from February through April.

Spring Creek Sampling – Pettenski 2012 report

Spring Creek, called Big Spring Creek in Pettenski (2012), was sampled three times during Pettenski's thesis investigations. On July 12, 2010, samples were collected from two branches of Spring Creek in the hamlet of Mumford approximately 1,000 feet upstream of the confluence with Oatka Creek. In his thesis, Dale Pettenski called the Hamlet of Mumford "Genesee Country Village", probably because of the signs he saw in Mumford for the Genesee Country Village and Museum facility that is located just to the west of the Hamlet. The July 12 samples were collected under nonevent conditions and on the same day as the initial set of 21 samples Pettenski collected for his watershed-wide segment analysis study. The average phosphorus concentrations (SRP = 5.65 µg P/L) and TP = 25.75 µg P/L) for the two Spring Creek samples were low compared to the average phosphorus concentrations (SRP = 34.4 µg P/L, TP = 70.5 µg P/L) for the other 21 samples collected on the same date from locations throughout the Oatka Creek watershed. The average nitrogen concentrations (Nitrate = 2.02 mg N/L, TN = 2.33 mg N/L) for the two Spring Creek samples were high compared to the average nitrogen concentrations (Nitrate = 1.15 mg N/L, TN = 1.84 mg N/L) for the other 21 samples collected on the same date from locations throughout the Oatka Creek watershed. The Spring Creek samples were also low in terms of Total Suspended Solids (3.95 mg/L) and Total Coliform bacteria (1550 CFU/100 mL), when compared to the average levels (TSS = 9.09 mg/L, Total Coliform = 8326 CFU/ 100 mL) for the other 21 samples collected on the same date from locations throughout the Oatka Creek watershed.

Follow-up segment analyses, under both nonevent and event conditions, were conducted on January 4, 2011 and May 3, 2011, respectively, for the Spring Creek tributary to further identify sources of the high nitrogen concentrations that were observed on July 12, 2010. Three sites were sampled, identified as A, B, and C, from downstream to upstream. Site A represented the location sampled initially on July 12, 2010 in the Hamlet of Mumford, which was located downstream from the Fish Hatchery wastewater treatment facility's discharge pipe. Site B was located in the Village of Caledonia and is upstream of the Fish Hatchery. Further upstream in the Village of Caledonia, Site C was located on Mill St. at the road culvert for the western outlet of Big Spring, one of the groundwater sources for Spring Creek. Another site, Site D, located further upstream from Site C, was added for the May 3, 2011 event sampling. [See Figure 53, page 182, and Figure 54, page 183 in Pettenski (2012) [8]]

Results for both nonevent and event sampling were similar to the earlier July 12, 2010 monitoring, in that, phosphorus, TSS, and Total Coliform bacteria levels were low and nitrogen levels were high when compared to the range found for each of these water quality parameters in watershed–wide sampling. However when the sampling locations in the Spring Creek watershed are compared relative to each other, they provide information on potential sources for contamination. In terms of phosphorus found in the Spring Creek sampling, under both non-event and event sampling, relatively high levels of SRP and TP were found at the upstream sampling site (Site C) and these levels decreased to their lowest levels in samples collected at Site B upstream from the Caledonia Fish Hatchery. At Site A, downstream of the hatchery, SRP and TP increased again in both nonevent and event conditions. In terms of nitrogen, in the nonevent sampling, the highest levels of Nitrate and TN were in the most upstream site (Site C= Nitrate: 2.73 mg P/L, TN: 2.86 mg P/L) and these levels slightly decreased at Site B and further downstream at Site A , where they were, Nitrate = 2.56 mg P/L and TN = 2.76 mg/L . Under event conditions, nitrogen levels were found to be higher at all sites, compared to nonevent conditions. The furthest upstream site, Site D, had Nitrate = 2.78 mg P/L and TN = 2.97 mg P/L. But the highest nitrate was found at Site B, 3.06 mg P/L, and the highest TN was found at Site C, 3.17 mg/L. Nitrogen levels during the event condition at Site A, the most downstream sample and the sample downstream of the Caledonia Fish Hatchery, were reduced (Nitrate = 2.80 mg P/L, TN = 2.85 mg P/L) compared to upstream samples. For both the nonevent and event conditions the highest TSS sample results for Spring Creek, were recorded from the furthest downstream location, Site A, and the second highest TSS sample results were from Site B, upstream of the Caledonia Fish Hatchery (Nonevent: Site B – TSS = 2.1 mg/L, Site A – TSS = 3.6 mg/L and Event: Site B – TSS = 3.0 mg/L, Site A - TSS = 11.1 mg/L). For Total Coliform Bacteria, under nonevent sampling, only Site A had a detectable level (400 CFU/100 ml). Under event conditions, the furthest upstream site, Site D, had the highest amount of bacteria 36,000 CFU/100 ml, site C had 1,800 CFU/100 ml, Site B had 200 CFU/100 ml, and the furthest downstream Site A had 500 CFU/100 ml.

A comparison of the results from the nonevent and event sampling of Spring Creek at Site B and Site A indicates that downstream (Site A) of the Caledonia Fish Hatchery wastewater treatment plant discharge, Spring Creek has higher phosphorus, TSS, and Total Coliform bacteria, but lower nitrogen, than upstream (Site B). Two sets of samples, on two separate days were collected from the fish hatchery's water intake pipe from Spring Creek and the fish hatchery's treated wastewater discharge pipe to Spring Creek. Table -19 compares the average levels of water quality parameters for the intake pipe and discharge pipe samples. Treated water leaving the fish hatchery has a 342 % increase in SRP, a 503 % increase in TP, and a 397% increase in Total Coliform Bacteria compared to the Spring Creek water pumped into the facility. Levels of Nitrate and TSS in the treated water discharge were lower by 3% and 35%, respectively, compared to the intake water from Spring Creek. TN was slightly higher (1 %) in the discharge pipe, compared to the intake water. Based on the analysis of both the samples from Spring Creek and the fish hatchery's discharge pipe, the Caledonia Fish Hatchery is a source of phosphorus, coliform bacteria and possibly TSS to Spring Creek.

Table 19: Water Quality of Influent and Effluent from Caledonia Fish Hatchery

SITE	SRP µg P/L	TP µg P/L	NITRATE mg/L	TN mg/L	TSS mg/L	TOTAL COLIFORM CFU / 100mL
Influent	3.85	8.25	1.58	1.89	1.3	6250
Effluent	13.15	41.5	1.54	1.94	0.85	24,800
% Difference	+ 342%	+503%	-3%	1%	-35%	397%

Comparing the average values from samples collected on September 1 and September 7, 2011. (Revised from Table 5 on Page 117, Pettenski 2012)

There is evidence that nonpoint sources exist in the Spring Creek watershed and are affecting the water quality at Sites B, C, and D. Relative to Site A, the furthest downstream site, higher nitrogen levels were found at Site B, C, and D. During event conditions levels of nitrogen, total coliform bacteria and phosphorus increased at the upstream sites, Sites C and B, while the highest abundance of coliform bacteria was found at the most upstream site, Site D. A potential source for higher nutrients and coliform could be agricultural field drainage that enters karst geology in the Onondaga Limestone Formation and enters Spring Creek via discharges of groundwater from the bedrock springs. Another possible source for the higher levels of nitrogen, phosphorus, and coliform could be septic systems. Sites C and B are located within the Village of Caledonia, where all residences are served by on-site wastewater treatment facilities with septic tanks and leach lines or pits. The Village does not have a municipal wastewater treatment facility. The high nutrients may be an indication that the wastewater treatment systems are failing, but it may be also an indication that there may be insufficient depth to soils to allow leaching effluent to be retained in the soils long enough to be acted upon by soil bacteria.

Benthic Macroinvertebrate Sampling at the Garbutt Sampling Location – Pettenski (2012)

On August 10, 2011, in the vicinity of the Hamlet of Garbutt weekly sampling location near the USGS Streamflow gaging station in the Town of Wheatland, Monroe County, a sample of benthic macroinvertebrates was collected from the channel of Oatka Creek. The purpose of the sample was to use biological monitoring techniques to assess the degree of nutrient enrichment of Oatka Creek in the Lower Watershed Segment (Oatka Creek Outlet Subwatershed). Using NYSDEC protocols[33,] a random sample of 100 specimens were picked from the larger sample. Only 90 specimens were used, because the remaining 10 specimens were taxonomic groups for which nutrient tolerance values had not yet been established. Nitrogen and Phosphorus Nutrient Tolerance Values for macroinvertebrate taxonomic groups (mostly at the level of genus and species) are listed in NYSDEC procedures [33].

Using the nitrogen and phosphorus tolerance values for each kind of macroinvertebrate and the number of that kind of macroinvertebrate in the subsample, two Nutrient Biotic Index numbers for the subsample were calculated, one for Nitrogen and one for Phosphorus.

There is one Nutrient Biotic Index for Phosphorus (NBI-P) and one Nutrient Biotic Index for Nitrogen (NBI-N). The results, for both NBI-P and NBI-N are placed on a scale of eutrophication from 0 to 10 and are as follows: Oligotrophic 0-5, Mesotrophic 5-6, Eutrophic 6-10. Oligotrophic waterbodies have low amounts of dissolved nutrients and mesotrophic waterbodies have a moderate amount of dissolve nutrients. Eutrophic waterbodies, or water bodies that are in a condition of eutrophication, have become enriched in dissolved nutrients that stimulate growth of aquatic plant life usually resulting in the depletion of dissolved oxygen.

The results reported for the Garbutt site were a NBI-Phosphorus value of 5.9 and a NBI–Nitrogen value of 5.2, both indicating a mesotrophic condition.

Incorporation of biological monitoring to assess stream health and potential impacts on aquatic life uses in the Oatka Creek Watershed should be more comprehensively implemented throughout the watershed as part of the Watershed Management Plan.

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