# Chapter 2: Watershed Characterization

**Figure 2.1: Aerial photograph of the Niagara River/Lake Erie Watershed**

Source: Erie County Office of Geographical Information Services

The Niagara River/Lake Erie Watershed is located along the westernmost portion of New York State and drains into Lake Erie and the Niagara River. The Niagara River is the channel that connects two Great Lakes - Erie and Ontario – and divides the U.S. from Canada. The Watershed is highlighted in the aerial photograph shown in Figure 2.1. In total, the watershed encompasses 1,523,515 acres, 5,543 miles of watercourses[1], and several small lakes and ponds within Allegany, Cattaraugus, Chautauqua, Erie, Genesee, Niagara, Orleans and Wyoming counties.

## Watershed Boundary & Sub-watersheds

Within New York State, the Niagara River/Lake Erie Watershed is largely made up of eighteen smaller sub-watersheds (see Figure 2.2 on the following page), each of which has defined boundaries based upon a 10-digit Hydrological Unit Code (HUC). The U.S. Geological Survey established the hydrological unit system as a basis for watershed planning on science-based hydrologic principles, rather than favoring administrative boundaries or a particular agency. The codes are structured in a hierarchy system to identify smaller sub-watersheds nested within larger watersheds. The smaller number of digits correlates to a larger watershed. For instance, there is a 2-digit HUC for each of the twenty-one hydrologic regions in the United States. The Great Lakes (04) covers the entire Great Lakes drainage basin. As the number of digits increases, the area of delineation gets smaller. Sub-regions are represented by a 4-digit HUC (0412 eastern Lake Erie), basins are represented by a 6-digit HUC (041201 Niagara River/Lake Erie), sub-basins are represented by an 8-digit HUC (04120103 Buffalo-Eighteenmile), watersheds are represented by a 10-digit HUC (0412010305 Eighteenmile Creek), and sub-watersheds are represented by a 12-digit HUC (041201030501 located mostly in the town of Colden in the headwaters of Eighteenmile Creek). The nomenclature used in Phase 1 of this report has been continued in Phase 2 despite the disparity with U.S. Geological Survey naming

[1] According to the U.S. Geological Survey Hydrography Data Set

standards. In this report, the Niagara River/Lake Erie Watershed will refer to the 6-digit hydrologic unit and sub-watersheds will refer to the 10-digit hydrologic units.

Table 2.1 below lists the eighteen sub-watersheds that are part of the Niagara River/Lake Erie Watershed, their 10-digit HUC, and total acreage. The HUC's used in this report are based upon 2013 data. Since 2013 the U.S. Geological Survey has begun editing the hydrologic unit system in order to coordinate better with Canada. As of 2016, the edits were not finalized and had not been adopted by New York State agencies. Therefore, this report utilizes the 2013 HUC's for consistency between Phase 1[2] and Phase 2 of this project.

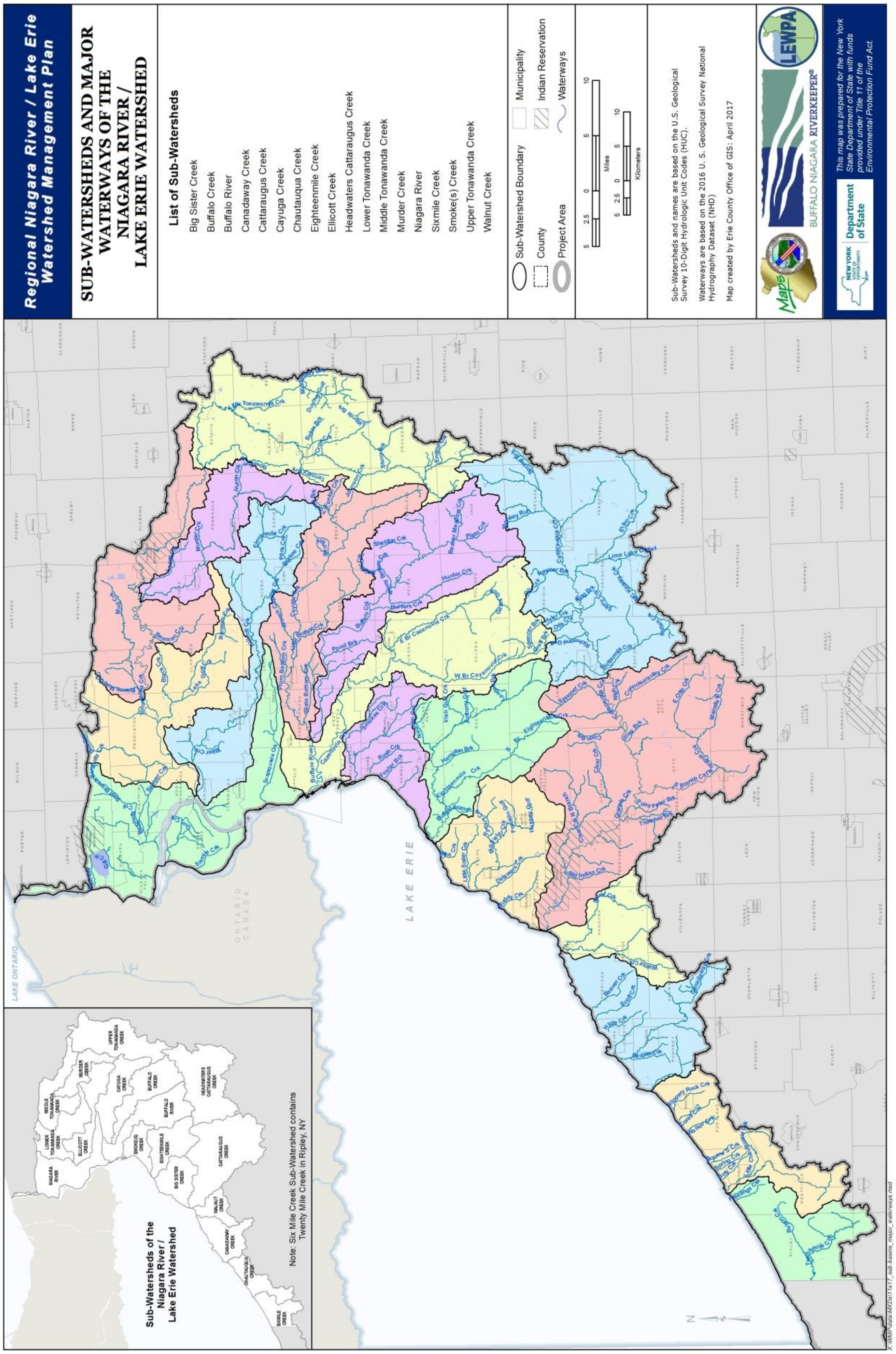
**Table 2.1: Sub-watersheds of the Niagara River/Lake Erie Watershed**

| Sub-Watershed Name | 10-Digit Hydrologic Unit Code (2013) | Acreage | Square Miles |
|---|---|---|---|
| Big Sister Creek | 0412010306 | 62,363.0 | 97.4 |
| Buffalo Creek | 0412010302 | 93,158.5 | 145.6 |
| Buffalo River | 0412010303 | 105,367.8 | 164.6 |
| Canadaway Creek | 0412010102 | 64,538.8 | 100.8 |
| Cattaraugus Creek | 0412010202 | 197,523.2 | 308.6 |
| Cayuga Creek | 0412010301 | 81,358.2 | 127.1 |
| Chautauqua Creek | 0412010103 | 51,266.3 | 80.1 |
| Eighteenmile Creek | 0412010305 | 76,834.0 | 120.1 |
| Ellicott Creek | 0412010404 | 76,824.3 | 120.0 |
| Headwaters Cattaraugus Creek | 0412010201 | 160,605.7 | 250.9 |
| Lower Tonawanda Creek | 0412010405 | 78,788.8 | 123.1 |
| Middle Tonawanda Creek | 0412010403 | 79,090.0 | 123.6 |
| Murder Creek | 0412010402 | 46,666.4 | 72.9 |
| Niagara River | 0412010406 | 102,812.1 | 160.6 |
| Sixmile Creek (within NYS) | 0412010104 | 43,537.6 | 68.0 |
| Smoke(s) Creek | 0412010304 | 39,522.8 | 61.8 |
| Upper Tonawanda Creek | 0412010401 | 127,237.9 | 198.8 |
| Walnut Creek | 0412010101 | 36,019.9 | 56.3 |
| **Watershed Total** | | **1,523,515.3** | **2,380.5** |

Source: U.S. Geological Survey Hydrologic Unit codes

[2] Phase 1 refers to the *Healthy Niagara: Niagara River Watershed Management Plan (Phase 1)* completed by Buffalo Niagara Riverkeeper in December 2014.

**Figure 2.2: Sub-watersheds and Major Waterways of the Niagara River/Lake Erie Watershed**



USGS's hydrological units were utilized to characterize the watershed because a watershed's boundary does not follow municipal boundaries. However there are 80 towns, 28 villages, and 8 cities located completely or partially within the Niagara River/Lake Erie Watershed's Boundary, including the major cities of Niagara Falls and Buffalo. These 116 municipalities include:

City of Batavia
City of Buffalo
City of Dunkirk
City of Lackawanna
City of Lockport
City of Niagara Falls
City of North Tonawanda
City of Tonawanda

Town of Alabama
Town of Alden
Town of Alexander
Town of Amherst
Town of Arcade
Town of Arkwright
Town of Ashford
Town of Attica
Town of Aurora
Town of Batavia
Town of Bennington
Town of Bethany
Town of Boston
Town of Brant
Town of Cambria
Town of Centerville
Town of Charlotte
Town of Chautauqua
Town of Cheektowaga
Town of Clarence
Town of Colden
Town of Collins
Town of Concord
Town of Darien
Town of Dayton
Town of Dunkirk
Town of Eagle
Town of East Otto
Town of Eden
Town of Ellicottville
Town of Elma
Town of Evans
Town of Farmersville
Town of Freedom
Town of Grand Island
Town of Hamburg
Town of Hanover
Town of Holland
Town of Java
Town of Lancaster
Town of Lewiston
Town of Lockport
Town of Machias
Town of Mansfield
Town of Marilla
Town of Middlebury
Town of Mina
Town of New Albion
Town of Newstead
Town of Niagara
Town of North Collins
Town of Orangeville
Town of Orchard Park
Town of Otto
Town of Pembroke
Town of Pendleton
Town of Perrysburg
Town of Persia
Town of Pomfret
Town of Porter
Town of Portland
Town of Ripley
Town of Royalton
Town of Rushford
Town of Sardinia
Town of Shelby
Town of Sheldon
Town of Sheridan
Town of Sherman
Town of Stafford
Town of Stockton
Town of Tonawanda
Town of Villenova
Town of Wales
Town of Warsaw
Town of West Seneca
Town of Westfield
Town of Wethersfield
Town of Wheatfield
Town of Yorkshire

Village of Akron
Village of Alexander
Village of Alden
Village of Angola
Village of Arcade
Village of Attica
Village of Blasdell
Village of Brocton
Village of Cattaraugus
Village of Corfu
Village of Delevan
Village of Depew

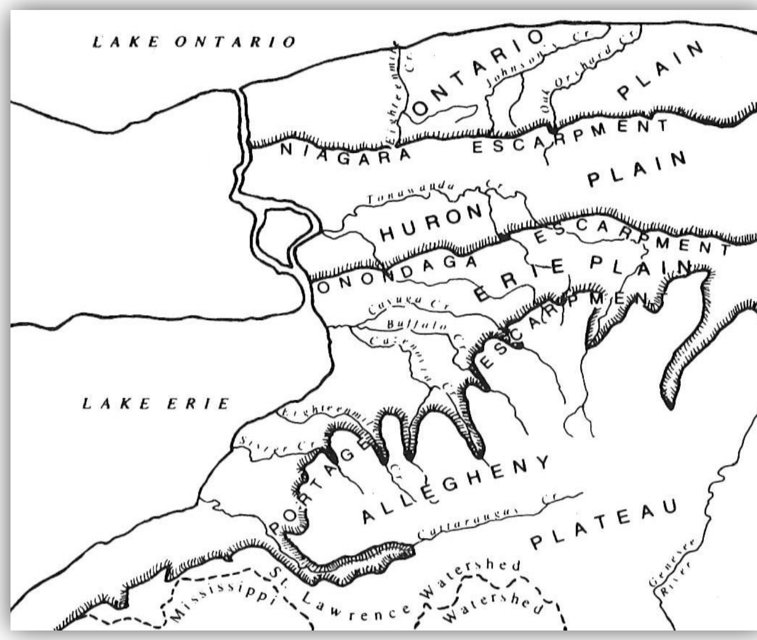
Village of East Aurora
Village of Farnham
Village of Fredonia
Village of Gowanda
Village of Hamburg
Village of Kenmore
Village of Lancaster
Village of Lewiston
Village of North Collins
Village of Orchard Park
Village of Silver Creek
Village of Sloan
Village of Springville
Village of Westfield
Village of Williamsville
Village of Youngstown

## Geology & Topography

In describing physical conditions of the Niagara River/Lake Erie Watershed it is useful to traverse from the headlands in the southeast in a northwest direction toward Lake Erie and the mouth of the Niagara River where it meets Lake Ontario. Refer to Figure 2.2: Sub-watersheds of the Niagara River/Lake Erie Watershed on a previous page for orientation with the following geology and topography descriptions of the watershed.

### Geology

**Figure 2.3: Western New York Geography**




In terms of bedrock geology, the Niagara River/Lake Erie watershed descends through four plains, from the Allegheny Plateau at over 2,000 feet above sea level in southwestern New York to the Lake Ontario Plain at 246 feet above sea level in northwestern New York (Figure 2.3[3]). An east-west trending escarpment marks each step down.

Southernmost and highest in elevation is the Portage Escarpment, the dissected northern border of the Allegheny Plateau. The fast flowing headwaters of the main tributaries—Twentymile, Chautauqua, Canadaway, Walnut, Cattaraugus, Eighteenmile, Cazenovia, Buffalo, Cayuga, and Tonawanda Creeks—originate here, flowing north and west toward Lake Erie and the Niagara River.

[3] Figure from Marian E. White, *Iroquois Culture History in the Niagara Frontier Area of NYS.*

**Figure 2.4: Serenity Falls, Scajaquada Creek**

Source: M. Wooster

Ten to twenty miles north of the Portage Escarpment, the Onondaga Escarpment marks a decrease in elevation across the watershed to the level of the Huron Plain. It creates waterfalls and barriers to fish migration on several Niagara River tributaries to the east of the watershed including Indian Falls on Tonawanda Creek near Akron, Glen Falls on Ellicott Creek in the Village of Williamsville, and Serenity Falls on Scajaquada Creek in Buffalo (Figure 2.4). Vernal pools at the base of these escarpments provide critical habitat for amphibians like spotted salamanders. The Onondaga Escarpment becomes much less pronounced as it progresses to the west until it reaches the Niagara River just north of the Peace Bridge where a 30 foot drop marks the rapids between Lake Erie and the upper Niagara River.

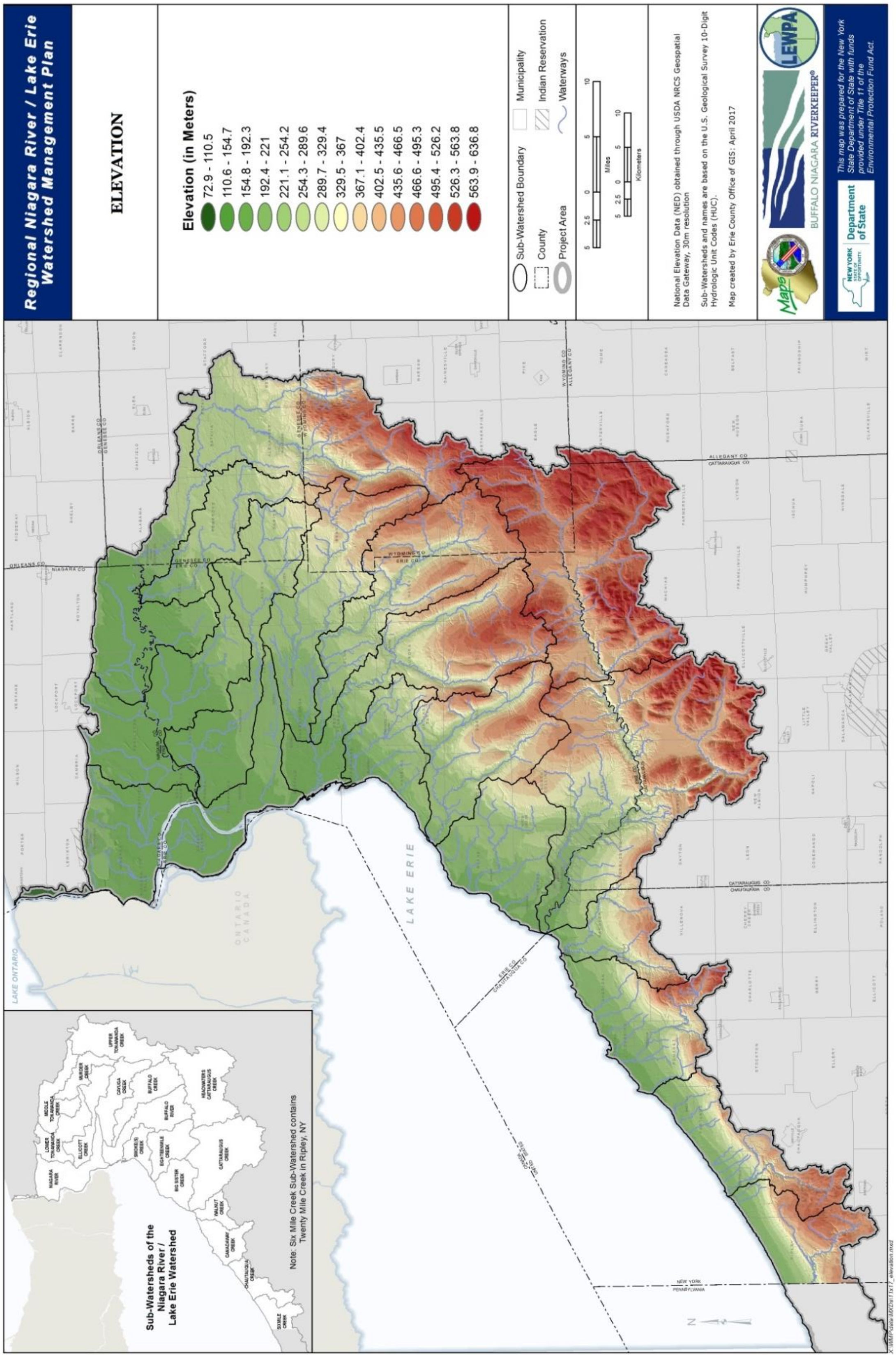
Northernmost is the Niagara Escarpment - a defining feature of the Great Lakes basin. The escarpment determines the northern boundary of the Watershed. It creates Niagara Falls and divides the Niagara River into two separate aquatic ecosystems.

The three escarpments can be identified in Figure 2.5, the watershed's Elevation Map. Bedrock throughout the entire watershed is shale with dolomite, sandstone, siltstone, and limestone intrusions visible at the escarpments.

## Landforms

The landforms also change across the Niagara River/ Lake Erie Watershed. There are two main physiographic regions. The southeastern portion in the upland headwaters of the Watershed consists of the *Allegheny Plateau*, which is characterized by broad ridges with "U"-shaped valleys. This dissected plateau is characterized by rolling hills of similar height and plateau toe slopes consisting of deposited materials at the bottoms of steep slopes. The northwest and lakeshore areas of the Watershed consist of the *Erie-Ontario Lake Plain*, which is generally flat with glacial deposits. An example of this is the lowland area of the Tonawanda Floodplain in the middle and lower Tonawanda Creek sub-watersheds.

**Figure 2.5: Elevation**



## Common Resource Areas

Figure 2.6 shows the Common Resource Areas (CRA) of the Niagara River/Lake Erie Watershed defined by U.S. Department of Agriculture as, "a geographical area where resource concerns, problems, or treatment needs are similar. It is considered a subdivision of an existing Major Land Resource Area (MLRA) map delineation or polygon. Landscape conditions, soil, climate, human considerations, and other natural resource information are used to determine the geographic boundaries of a Common Resource Area.[4] These generally follow the physiographic regions described above under "Landforms," however, a third designation, *Lake Erie Glaciated Plateau,* is added.

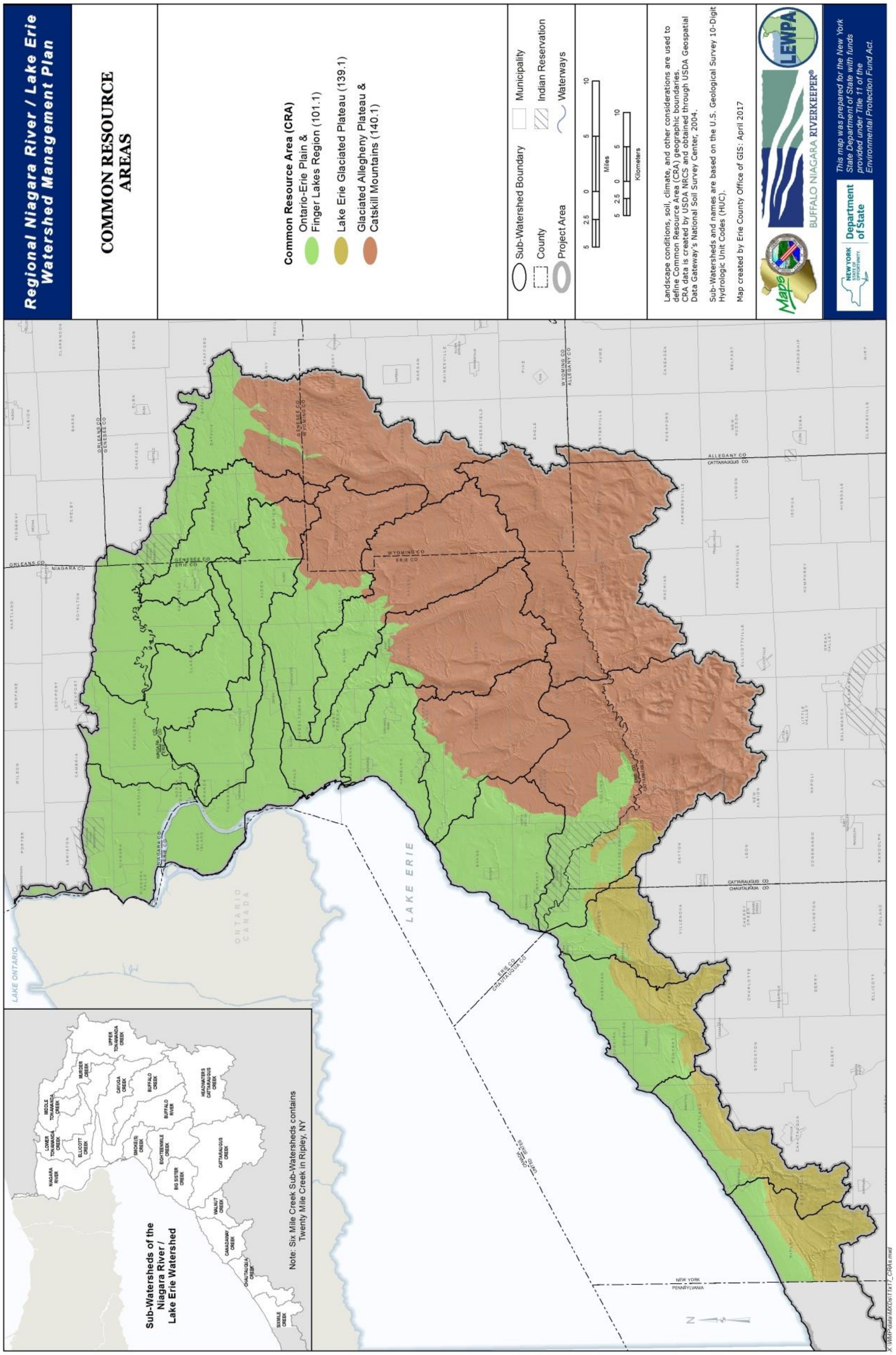
The *Glaciated Allegheny Plateau and Catskill Mountain* CRA is found in the southeastern portion of the Watershed. It is in the Southern New York Section of the Appalachian Plateaus Province of the Appalachian Highlands and includes narrow valleys with steep walls and glacial outwash deposits of sand and gravel on the valley floors. Bedrock is mostly shale and sandstone. Inceptisols are the dominant soils in this region as described in the soils section. There are about 165 freeze-free days per year. About 9% of the water withdrawals in this area are from ground water with 91% from surface waters.

The *Lake Erie Glaciated Plateau* can be found primarily in Chautauqua County including Dunkirk and Fredonia, with a small portion in Cattaraugus County. It is in the Eastern Lake Section of the Central Lowland Province of the Interior Plains and is fairly flat along Lake Erie with gently rolling dissected glaciated plateau in the southernmost headwaters of the Watershed. This area averages a 180-day freeze-free period and more precipitation than the other two CRA's within the Watershed. Soils are Alfisols that are primarily loamy or clayey. It supports mainly beech forest vegetation and bedrock is classified as mostly sandstone, siltstone, and shale. Approximately 2% of water withdrawals are from ground water while 98% is from surface water sources.

The *Ontario-Erie Plain and Finger Lakes Region* of the Niagara River/Lake Erie Watershed is in the Eastern Lake Section of the Central Lowland Province of the Interior Plains as well. It includes remnant glacial-worn beach ridges, such as seen in Hamburg and Eden, where sandier soils feature better drainage and faster warming in the springtime for productive farming. The freeze-free period is only 165 days on average. Dominant soils include Alfisols and Inceptisols as described below. Land use is primarily cropland and hardwood forests, as well as the urbanized areas around the cities of Buffalo and Niagara Falls. Roughly 3% of water withdrawals are from ground water sources with 97% from surface waters. Bedrock underlying this area consists of limestone, dolomite, sandstone, and shale.

[4] Information from the USDA and NRCS publication, "Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin." https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_050898.pdf

**Figure 2.6: Common Resource Areas**



## Soils

There are three main soil types found in the Watershed. Alfisols are very fertile soils that formed underneath old forests. They are moderately well drained, giving the soil a good balance of moisture. Alfisols have a layer of clay underneath the surface of the soil. Many of them are used for growing new forests or for agricultural purposes. Alfisols are primarily found in western and central New York.

The northern and western regions of the state are home to Histosols. These soils have a very dark layer directly underneath the surface. They have a large amount of organic material. They form in wetlands of all types, including swamps and marshes, anywhere that is poorly drained. Organic material in these places decays very slowly. Histosols are commonly called "peats," and are often mined and burned as fuel.

Inceptisols are found everywhere in the southern half of New York State. They have vaguely defined layers under the surface, and are found in all types of environments. These soils support approximately one fifth of the world's human population, more than any other type of soil.

Hydric soils are formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions and support the growth and regeneration of hydrophytic vegetation. The northern portion of the watershed, where historic Lake Tonawanda once existed hosts the largest swath of hydric soils. A map of the watershed's hydric soils is provided in Figure 2.7.

Prime farmland soils are designated by the U.S. Department of Agriculture as land that has the best combination of both physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops. It must also be available for these uses. Thus, once this land is developed, it is no longer considered prime farmland. These areas are generally not excessively erodible, are not saturated for long periods of time, and do not flood frequently. Notice the difference between Figures 2.7 and 2.8. There is little overlap between hydric soils and prime farmland soils. Where there are hydric soils, generally they are considered prime farmland only if they are drained.

## Erosion/ Slope

Steep slopes can affect water quality with the erosive force that increases as grade increases, allowing runoff to pick up and move more sediment, increasing downstream turbidity and further eroding upstream channels. In the watershed, the percentage of areas with steep slopes decreases as you move northwest across the watershed into the flatter plains. However, the uplands in the southeast, where many of the watersheds' headwaters originate, have a large amount of steep slopes, some being very steep or over 35% (See Figure 2.9). In the lowlands and lake plains in the north and west of the watershed most slopes are nearly level (0 – 2%).

**Figure 2.7: Hydric Soils**

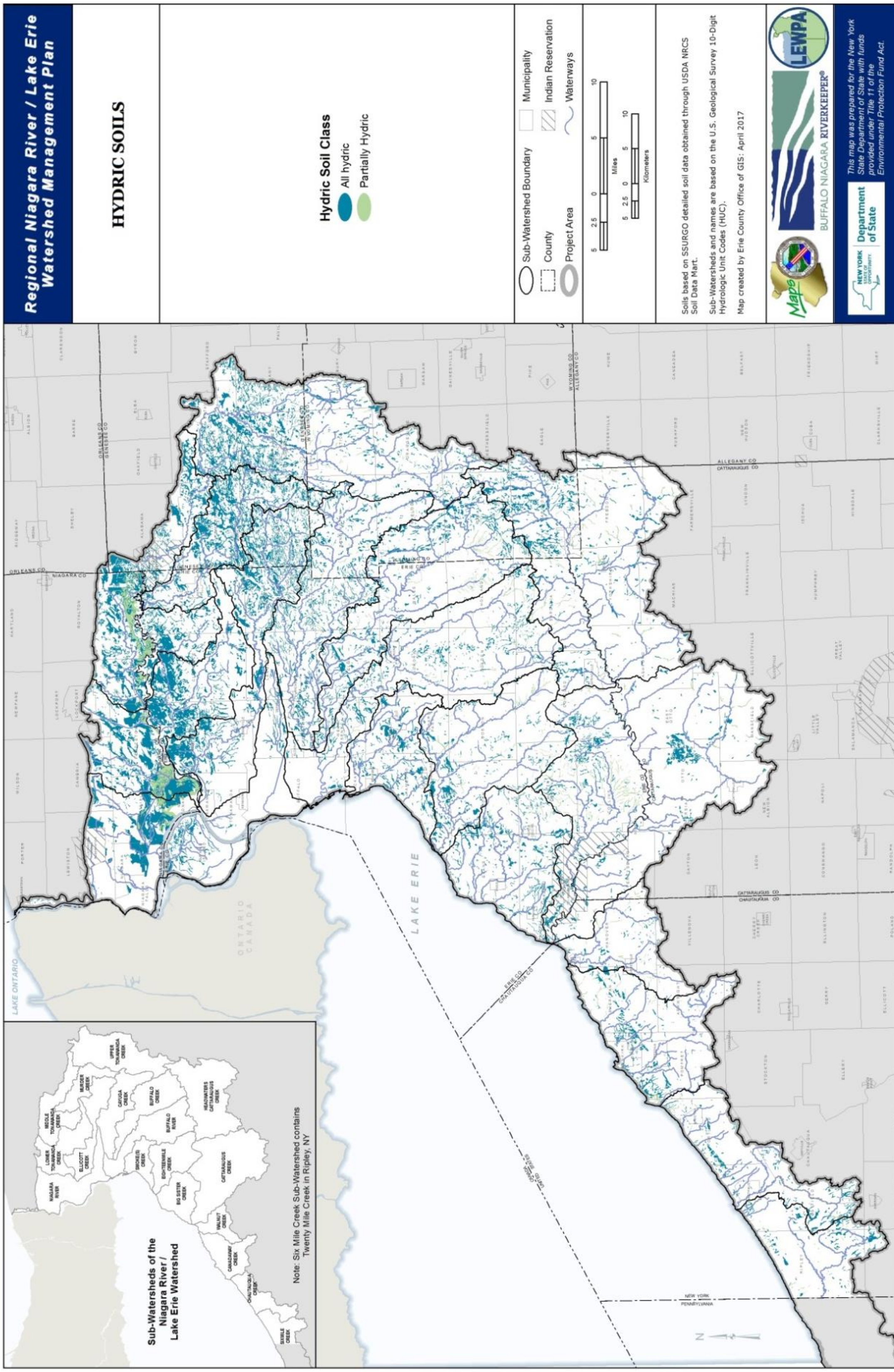


**Figure 2.8: Prime Farmland Soils**

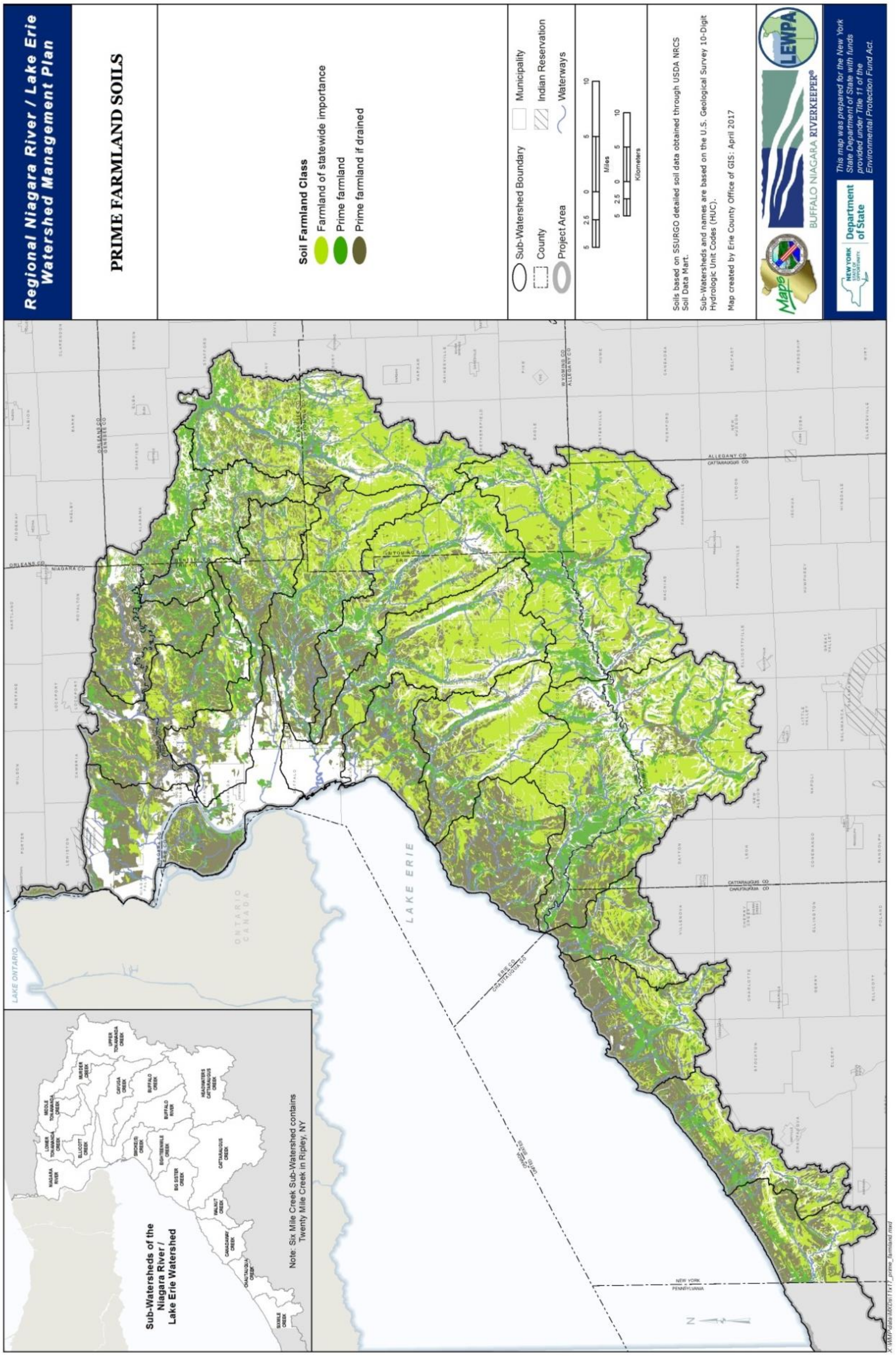
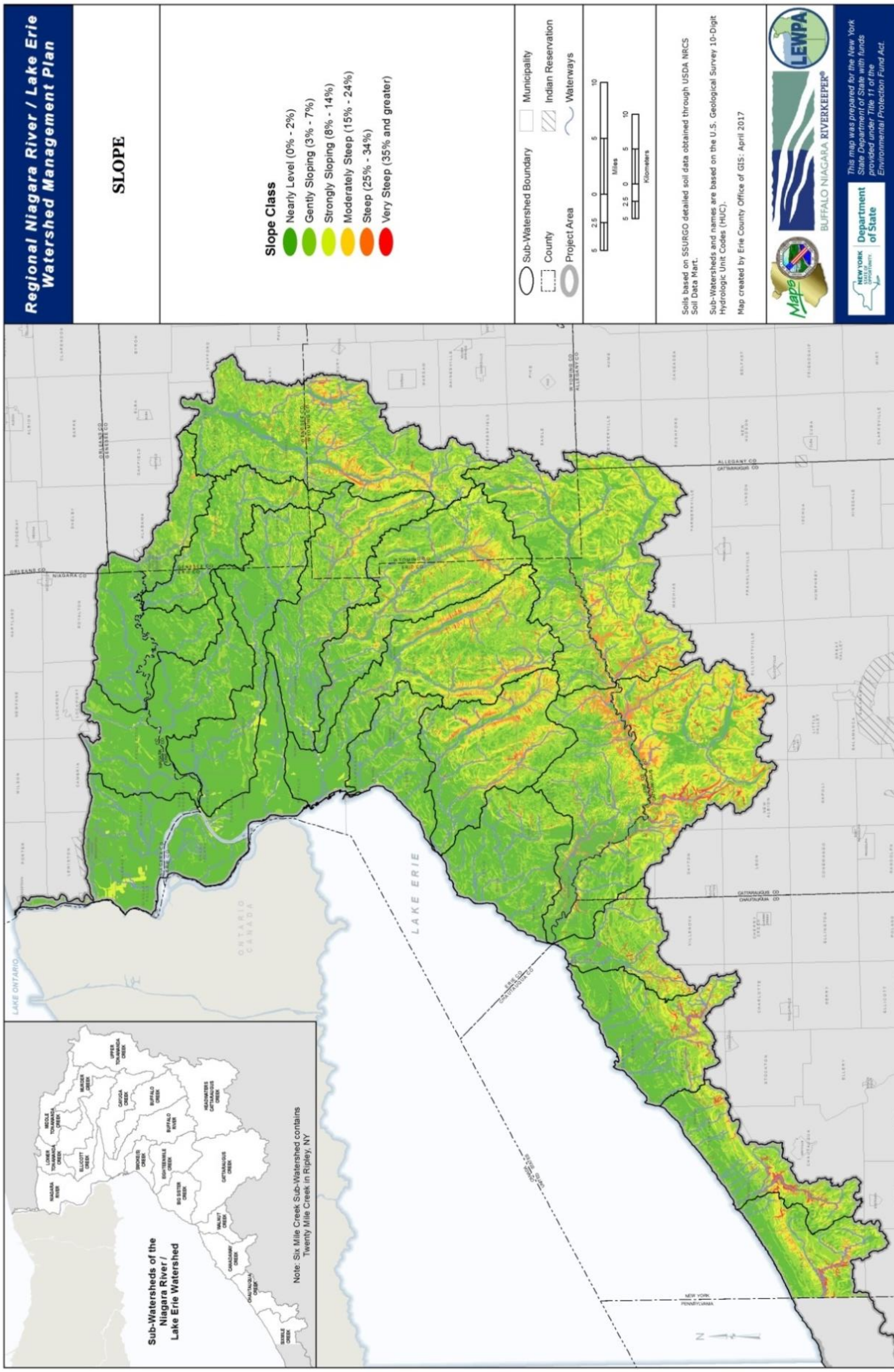


**Figure 2.9: Slope**



# Hydrography

## Surface Hydrology

Surface water is the water that collects on the ground, in a stream, river, lake or wetland. This water naturally increases with precipitation and is lost through evaporation, evapotranspiration, infiltration and runoff. The Niagara River/Lake Erie Watershed is primarily home to rivers, creeks, and streams, with some smaller ponds/reservoirs and the larger Lewiston Reservoir. The surface water located in the Niagara River/Lake Erie Watershed drains into Lake Erie and the Niagara River. The watershed covers an area of 1,523,515 acres drained across approximately 5,543 total miles[5] of waterways. The general direction of surface movement is from the highlands in the southeast flowing north and west to the floodplains, lowlands, or Lake Erie.

In the uplands, streams and creeks are much more clustered due to the slopes they traverse. Tributaries to Eighteenmile Creek, Buffalo River, and Buffalo Creek follow a parallel pattern down the steep slopes into their larger streams. In the lowland areas to the north, the waterways meander and run further apart in a dendric pattern. Along the Lake Erie shoreline, most streams run parallel to each other and perpendicular to Lake Erie. In the most urban areas, waterways have been filled, covered, or diverted for development. Several of the waterways have been channelized when they flow through the industrialized areas of Niagara Falls, the Tonawandas, Buffalo, and Dunkirk.

## Sub-watershed Descriptions from East to West

The **Upper Tonawanda Creek** Sub-watershed and its main tributary, Little Tonawanda, start on the Allegheny Plateau and flow northeast through steep wooded ravines as far as the village of Attica. After which both creeks meander through wetlands and farmed mucklands. Just south of the City of Batavia the two branches join on the Onondaga Escarpment and take a sharp turn left, flowing west into the Middle Tonawanda Creek Sub-watershed.

The **Middle Tonawanda Creek** Sub-watershed is located between the Lower and Upper Tonawanda Creek Sub-watersheds. The Middle portion covers Tonawanda Creek's 20 mile stretch from its confluence with Bowen Creek in the Town of Batavia west to the Town of Pendleton. In this section it travels through a broad floodplain and many wetlands which are the remaining imprint of the ancestral, 50-mile long, glacial Lake Tonawanda. Mud Creek and Beeman Creek are the major tributaries of this portion of Tonawanda Creek.

In the **Lower Tonawanda Creek** Sub-watershed the last 11.6 miles of the Tonawanda Creek was historically deep slack water but is now channelized and dredged to a width of 75 feet and a depth of 12 feet to accommodate the Erie-Barge Canal. A lock in Pendleton controls the

[5] Based on the USGS National Hydrography Dataset.

flow, and is also where the Creek diverges from the Erie Canal. Ransom Creek, Gott Creek and Black Creek are the major tributaries running north-northwest from the Clarence and Newstead Townships to the Canal section in the Creek in Pendleton. Bull Creek is the other primary tributary running southwest from the Niagara Escarpment through low-lying hydric soils to the Canal in the Town of Wheatfield.

Most of the waterways in the **Niagara River** Sub-watershed drain directly to the upper Niagara River. Many, like Two Mile Creek, have been channelized and turned into drainage ditches receiving runoff from industries, landfills and storm sewer systems. While others, have had their historic hydrology significantly altered from urban development. Several of the tributaries located on Grand Island are the last remaining minimally-altered waterways of this sub-watershed.

Historically fifteen-mile Scajaquada Creek, a primary tributary of the Niagara River sub-watershed, rose in spring-fed wetlands in the present Town of Lancaster and flowed almost due west through the Village of Depew, Town of Cheektowaga, and City of Buffalo to its mouth on the Black Rock Canal on the Niagara River. Its course was generally level except for a small falls over the Onondaga Escarpment in present day Forest Lawn Cemetery in North Buffalo. Originally the creek was wide, shallow and meandering. Much of the creek has been channelized and tunneled underground. Portions receive overflows from the City of Buffalo's combined sewer system and Town of Cheektowaga's sanitary sewer system. Springs recharge the creek not only at its source, but also downstream in Forest Lawn Cemetery. These springs are now a major component of the base flow of lower Scajaquada Creek.

Another major tributary of the Niagara River Sub-watershed, 7.6 mile long Gill Creek originates in the wetlands of the Tuscarora Nation and flows south to its mouth on the Little Niagara River approximately 1,000 feet above the upper Niagara River. The watershed is mainly flat and underlain with Lockport Dolomite covered by lake clays and silts. Today, the Lewiston reservoir occupies over half the upper watershed on Tuscarora Nation Land, with a discharge channel to Gill Creek to supplement low flows in the summer. The creek is ditched around the reservoir's southern end until it reaches the original stream bed and turns south. A dam about 1.2 miles upstream of the creek's mouth creates 30 acre Hyde Park Lake.

**Murder Creek** is its own sub-watershed but also the major tributary to Tonawanda Creek in the Middle Tonawanda Creek Sub-watershed. Located primarily in the southwestern portion of the Genesee County, Murder Creek also includes many low-lying areas and meanders through the Towns of Pembroke and Newstead.

**Ellicott Creek**, 47 miles long, flows northwest from its headwater wetlands in Genesee County through the Towns of Darien, Alden, Lancaster, and Amherst to join Tonawanda Creek about a half mile above its mouth at the Niagara River, in the Town of Tonawanda.

Many of the natural tributaries of Ellicott Creek have been channelized into stormwater conveyance systems in the urban and suburban areas of the Ellicott Creek Sub-watershed, and no longer include natural hydrologic features.

The **Cayuga Creek** Sub-watershed (in Erie County) includes Little Buffalo, Slate Bottom, and Plum Bottom creeks as tributaries. It begins in primarily farmland/wooded areas in higher elevation Wyoming County in the Towns of Sheldon and Bennington and passes through several residential areas in the Erie County Towns of Marilla, Alden, and Lancaster before its confluence with Buffalo Creek in Cheektowaga.

The 43-mile-long **Buffalo Creek** originates in the eastern portion of the watershed, in the Towns of Arcade, Java and Sheldon in Wyoming County, where higher elevations create a multitude of smaller feeder streams and tributaries, such as Plato Creek, Beaver Meadow Creek, Glade Creek, Sheldon Creek, Stoney Bottom Creek, Bender Creek, and Hunter Creek. Buffalo Creek itself flows northwest towards the City of Buffalo through Wales, Marilla, and Elma, joining Cayuga Creek 8 miles above Lake Erie in the Town of West Seneca, shortly after which Cayuga Creek flows into the Buffalo River.

The headwaters of the **Buffalo River** include the east and west branches of Cazenovia Creek and flow north-northwest to the lake plain. Cazenovia Creek joins the Buffalo River about 6 miles above Lake Erie. Its two major branches, an 18-mile long West Branch and a 24-mile long East Branch, pass through the Towns of Sardinia, Concord, Holland, Colden, Wales, and Aurora to join in the Village of East Aurora, 17 miles upstream from the confluence with the Buffalo River. At 1820 feet above sea level, the source of the East Branch is the Buffalo River Sub-watershed's highest elevation. The lower Buffalo River meanders across the flat Lake Erie Plain through Elma, West Seneca, and the City of Buffalo before draining into Lake Erie. Within the City of Buffalo, a portion of the Buffalo River is a federally-designated navigation channel and dredged to maintain a 22 foot depth. The average daily flow of the Buffalo River is about 355.5 million gallons daily.

The **Smoke(s) Creek** Sub-watershed includes several small tributaries draining directly to Lake Erie in the Town of Hamburg and City of Lackawanna. Smokes Creek, sometimes referred to as Smoke Creek or Smoke's Creek, begins in the Town of Orchard Park and flows west-northwest to its mouth on Lake Erie in the City of Lackawanna. The creek's one principal tributary is South Branch. It has the least number of waterway miles of the 18 sub-watersheds though it is not the smallest sub-watershed by area.

**Eighteen Mile Creek** drains into the eastern end of Lake Erie in the Town of Evans. Its principal tributary is the South Branch. The headwaters of both of these creeks start in the Town of Colden and meander through the Towns of North Collins and Boston. Middle reaches of Eighteenmile Creek flow through steep sided gorges in the Towns of Hamburg and

Eden. At its lower end it is a large meandering stream where the lower half mile is low gradient with a broad floodplain that forms the border between the Towns of Hamburg and Evans.

**Big Sister Creek** Sub-watershed has sometimes been referred to as the Seven Creeks Watershed. The main tributaries to Lake Erie in this sub-watershed include Big Sister, Little Sister, Delaware, and Muddy Creeks. The headwaters in the Towns of North Collins, Brant, and Eden include steep ravines in Franklin Gulf and Hussey Gulf, while the shoreline areas include several bathing beaches such as those found at Evans Town Park, Evangola State Park, and Erie County Bennett Beach Park.

The **Headwaters Cattaraugus Creek** Sub-watershed is the second largest of the 18 sub-watersheds with many of the tributaries generally characterized by steep valley walls. This sub-watershed, along with Cattaraugus Creek Sub-watershed, has some of the highest slopes and elevations in the overall Niagara River/Lake Erie Watershed. The headwaters start in Cattaraugus, Wyoming, and Allegany counties with tributaries such as Elton Creek flowing through the Towns of Farmersville, Freedom, Yorkshire, and the Village of Delevan and eventually into Cattaraugus Creek, which heads west toward Lake Erie and forms the boundary between Cattaraugus and Erie counties. There is a Spring Brook in the headwaters in the Towns of Arcade and Eagle in Wyoming County, as well as a Spring Brook in the Town of Concord and the Village of Springville in Erie County.

The largest of the 18 sub-watersheds is **Cattaraugus Creek** Sub-watershed, which starts mainly west of Springville, NY. Cattaraugus Creek continues flowing west toward Lake Erie through Zoar Valley, a 3,014 acre Multiple-Use Area managed by NYS DEC and known for its deep gorge and dense forests. Main tributaries include South Branch Cattaraugus and Connoissarauley Creeks in Cattaraugus County and Clear Creek in Erie County and the Seneca Nation Cattaraugus Reservation.

**Walnut Creek** Sub-watershed is the smallest of the 18 sub-watersheds. It includes Walnut Creek, which starts in the Town of Arkwright and flows north through the Towns of Sheridan and Hanover. Silver Creek begins in the Town of Villenova and flows through the Town of Hanover to join with Walnut Creek within the Village of Silver Creek.

**Canadaway Creek** Sub-watershed includes the City of Dunkirk. Canadaway Creek begins in the high elevations of the Chautauqua Ridge in the Town of Charlotte before flowing through the Towns of Arkwright, Pomfret, Dunkirk, as well as the Village of Fredonia. Several other tributaries to Lake Erie, such as Crooked Brook, Hyde Creek, Beaver Creek, and Scott Creek, flow north northwest to Lake Erie through the lower elevations of the Lake Plain.

The **Chautauqua Creek** Sub-watershed's largest tributary to Lake Erie is Chautauqua Creek. Little Chautauqua Creek joins with Chautauqua Creek in the Village of Westfield. Both of these streams' headwaters originate in the Chautauqua Ridge area of the sub-watershed. Several other smaller tributaries to Lake Erie flow through the Lake Plain including Slippery Rock Creek through the Village of Brocton.

**Sixmile Creek** Sub-watershed is the only sub-watershed that includes area outside of New York State. Approximately 43,500 acres occur in New York State while approximately 125,100 acres are located in Pennsylvania. It is named after Sixmile Creek, which is located in Pennsylvania, but the largest creek in the New York State portion is Twentymile Creek, which flows west into Pennsylvania before emptying into Lake Erie.

Table 2.2 shows the number miles of waterways in each sub-watershed. Cattaraugus Creek, Headwaters Cattaraugus Creek, and Upper Tonawanda Creek Sub-watersheds have the highest number of waterway miles within their limits. These are also the three largest sub-watersheds in acreage. The "% of total column" shows the percent of waterways in the entire Watershed that occur in that particular sub-watershed. Therefore, 15% of the waterways in the Niagara River/Lake Erie Watershed occur in the Cattaraugus Creek sub-watershed.

**Table 2.2: Watershed Waterway Miles**

| Sub-watershed Name | Miles | % of Total |
|---|---|---|
| Big Sister Creek | 186.65 | 3.37% |
| Buffalo Creek | 353.72 | 6.38% |
| Buffalo River | 318.02 | 5.74% |
| Canadaway Creek | 187.33 | 3.38% |
| Cattaraugus Creek | 837.00 | 15.10% |
| Cayuga Creek | 356.19 | 6.43% |
| Chautauqua Creek | 180.43 | 3.25% |
| Eighteenmile Creek | 274.28 | 4.95% |
| Ellicott Creek | 244.02 | 4.40% |
| Headwaters Cattaraugus Creek | 615.27 | 11.10% |
| Lower Tonawanda Creek | 216.63 | 3.91% |
| Middle Tonawanda Creek | 331.05 | 5.97% |
| Murder Creek | 222.21 | 4.01% |
| Niagara River | 223.02 | 4.02% |
| Sixmile Creek | 159.48 | 2.88% |
| Smoke(s) Creek | 119.86 | 2.16% |
| Upper Tonawanda Creek | 588.67 | 10.62% |
| Walnut Creek | 129.44 | 2.34% |
| **Total Watershed** | **5,543.28** | **100.00%** |

Source: USGS National Hydrography Data Set

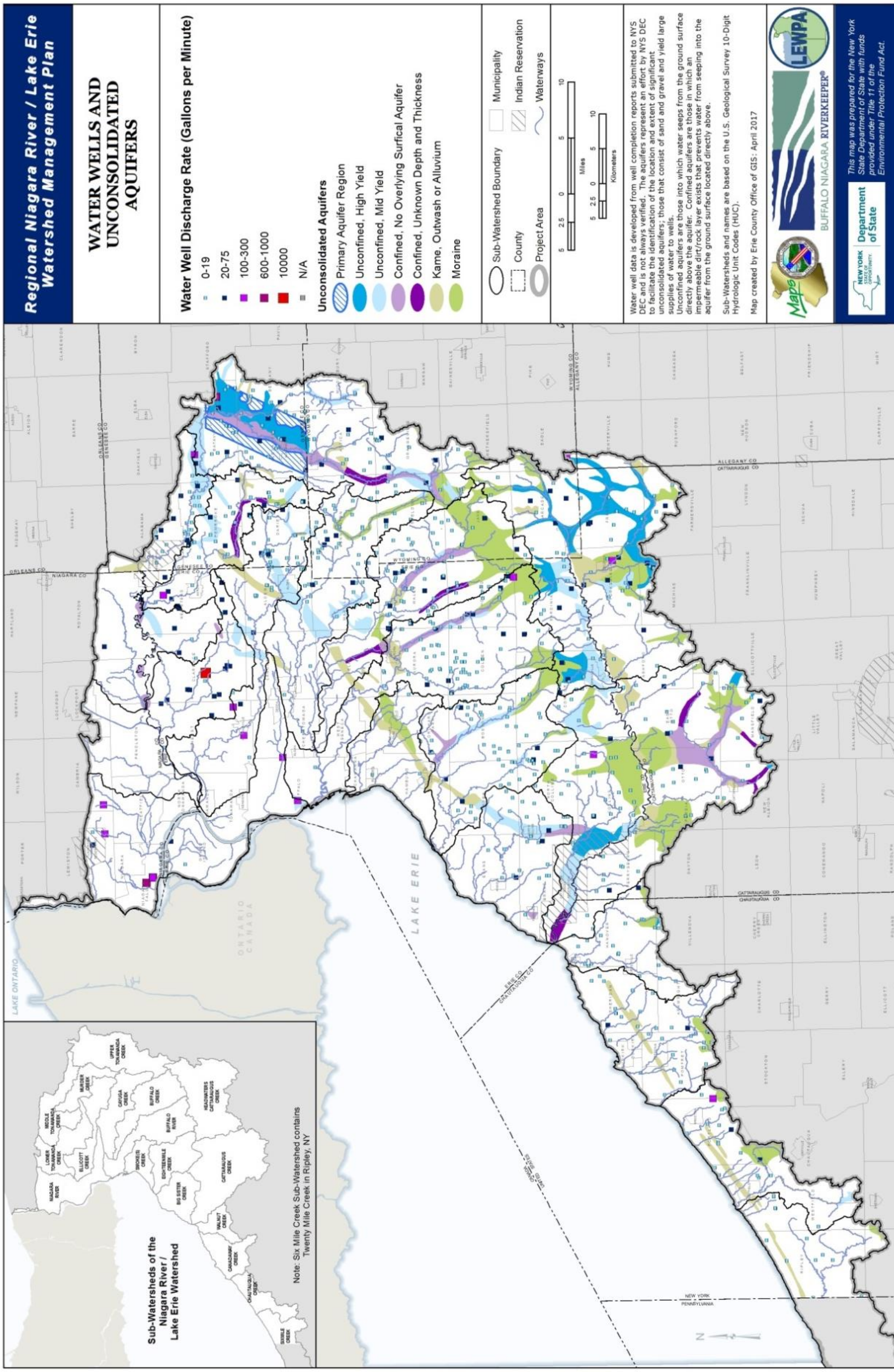
## Groundwater

Groundwater is the water located beneath the ground that fills the pore or void space in soils, or fractures of rock formations. These saturated soils and rock formations that store water in the subsurface are called aquifers. Aquifers can be sand and/or gravel, glacial tills, or layers of sandstone or cavernous limestone bedrock. Water stored in these aquifers moves within the subsurface through interconnected pore space. This movement of water is generally very slow and as a result groundwater can be much older than surface water, on the order of tens of thousands of years in some cases. In some cases, groundwater can also percolate into soil and rock layers in a matter of seconds. Once there, groundwater can move through fractures in rock layers, especially shale formations, if the fractures are interconnected. As a result, aquifers need to be closely managed to prevent excessive removal of water or potential contamination. Aquifers are recharged from precipitation on the land that infiltrates the surface, seepage from stream beds, and subsurface flow through the till and bedrock. Green infrastructure, such as permeable pavement or rain gardens, can allow stormwater runoff to infiltrate the ground.

In the north and west of the Niagara River/Lake Erie Watershed, groundwater is not the primary source of potable water supply due to the subsurface geology having poorly connected pore space and the proximity to a vast amount of surface water in the Great Lakes. There are exceptions to this rule, however. For example, the towns of Clarence and Newstead have several high-yield groundwater wells that sit on top of the Onondaga Aquifer. New York State Department of Environmental Conservation has mapped and identified a limited number of aquifers throughout the Watershed with most of them being in the east and south (Figure 2.10). The uplands in the southeast sub-watersheds have large moraine aquifers. There are also several productive aquifers within the Upper Tonawanda Creek sub-basin. In the southeastern portions of the Watershed, many public and private water sources are derived from groundwater wells and springs.

Groundwater also supports many ecologically important functions. When groundwater moves upward toward the land surface it forms springs, wetlands, and supports stream flow. These springs and wetlands support both vegetation and animal habitat for some of our most valued natural resources in the region. Springs feed Spring Brook near Springville, NY in southern Erie County. It is a one of a few native Brook Trout streams in the Watershed because of the cold, clear water. Groundwater discharge into streams is also an important component to stream flow during dry periods. This discharge of groundwater into streams is critical in small and large streams and has been shown to be between 41% and 45% of the total flow at stream gaging stations on Buffalo River, Cayuga Creek, and Cazenovia Creek.

**Figure 2.10: Water Wells and Unconsolidated Aquifers**



### Lake Seiches

Lake Erie experiences more large seiches (standing waves) than the four other Great Lakes due to how shallow it is and the fact that it is lined up with the typical prevailing wind direction. These large waves result in a sudden rise in water due to strong winds and rapid atmospheric pressure changes causing the water to be pushed from one end of the Lake to the other. These typically occur when the winds blow from southwest to northeast. In 1844, a 22-foot high seiche killed 78 people and dammed ice in the Niagara River, cutting off flow temporarily to Niagara Falls.[6] Seiches can cause intense flooding and erosion, as experienced in 2008 when 12-16 foot waves flooded the west side of Buffalo. As the winds die down, seiche waters can "slosh" back and forth across the Lake until water levels equilibrate. This water movement is so forceful that it can cause severe damage to shorelines.

## Wetlands

**Figure 2.11: Tifft Nature Preserve Wetland**

Wetlands occur where land and water meet for extended periods of time. They generally occur along water bodies, lakes, rivers, streams, etc., in low lying areas where water ponds, and even on hillsides where groundwater seeps to the surface. They provide natural open space and help to provide food and homes to fish, amphibians, shellfish, insects, birds, and other animals. Wetlands also clean our water by filtering pollution and recharging aquifers. They maintain dry season stream flows and stabilize shorelines from erosion.

Wetlands are particularly important for flood protection. They act as natural sponges that trap and slowly release surface water, rain, snowmelt, groundwater, and flood waters. The holding capacity of wetlands helps to control floods and prevent water logging of crops. Trees, root mats, and other wetland vegetation also slow the speed of flood waters and distributes them more slowly over the floodplain, reducing flash flooding and downstream inundation. This combined water storage and braking action lowers flood heights and reduces erosion. Wetlands within and downstream of urban areas are particularly valuable, counteracting the greatly increased rate and volume of surface water runoff from pavement and buildings (impervious cover). Figure 2.11 shows an example of a wetland in the Watershed.

[6] NOAA https://oceanservice.noaa.gov/facts/seiche.html

Wetlands are characterized as having a water table that stands at or near the land surface for a long enough period of time each year to support aquatic plants. These lands have hydric soils that are often saturated with water permanently or for part of the year. Most importantly they have plants and animals that can withstand this flooding.

The amount and the character of wetlands in the Niagara River/Lake Erie Watershed changes as you transit from the south to the north. Figure 2.12 shows that the headwater areas, which have steeper slopes, better drainage, and deeper riverbeds contain only small pockets of wetlands. The floodplains are very narrow in this area as well. As you pass north over the Portage escarpment the waterways start to meander more and the amount of wetlands increases.

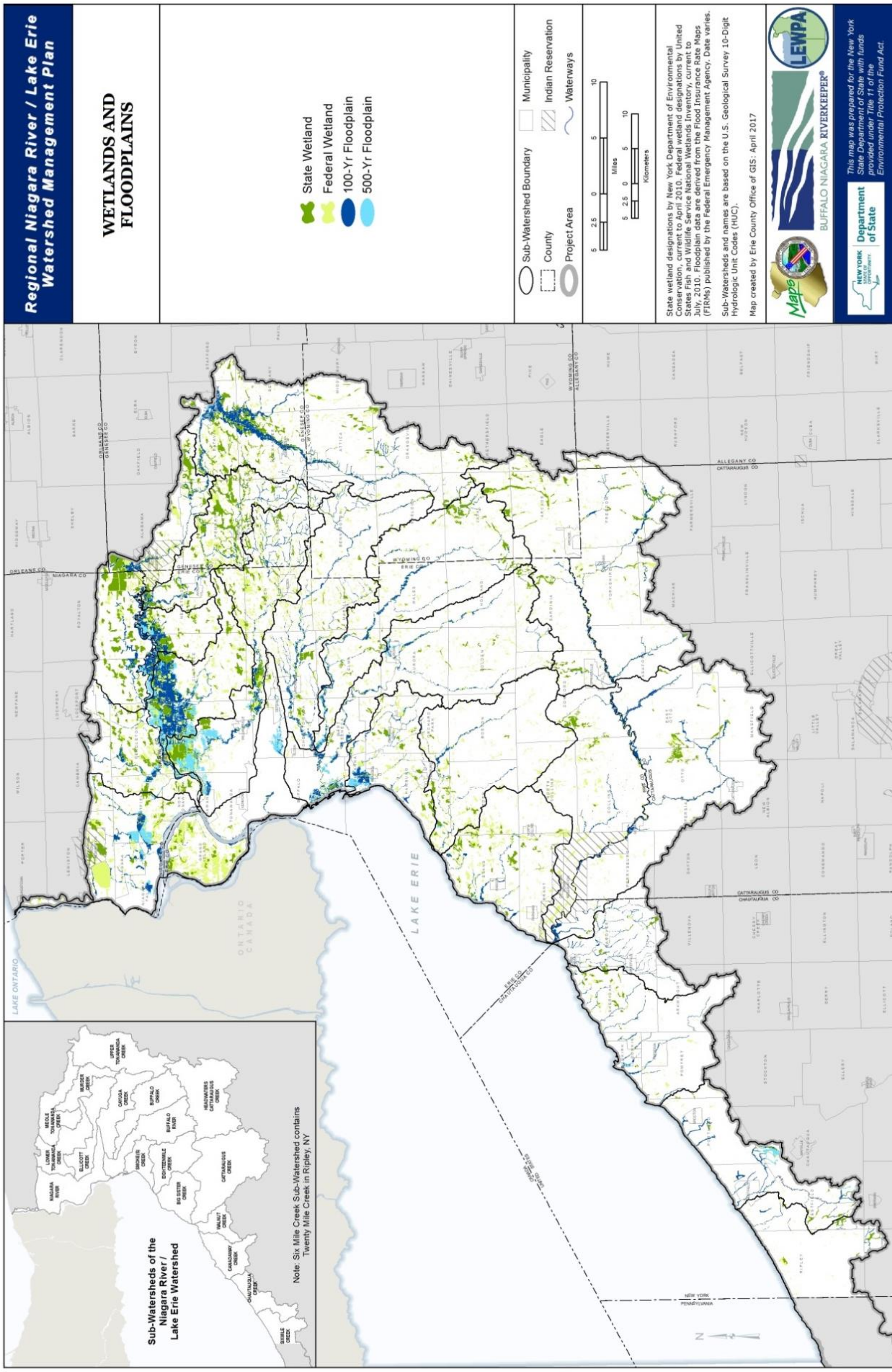
Table 2.3 outlines the acreage of wetlands as determined by the National Wetlands Inventory (NWI) and New York State Department of Environmental Conservation (NYS DEC) located within each sub-watershed. NWI and NYS DEC wetlands often overlap, which is why the "All Wetland Acres" category is not simply an addition of the two NWI and NYS DEC columns.

**Table 2.3: Wetlands by Sub-watershed**

| Sub-Watershed Name | All Wetland Acres* | NWI Acres | NYS DEC Acres | % of Sub-watershed Acreage as Wetlands | % of Wetlands Protected by NYS DEC |
|---|---|---|---|---|---|
| Sixmile Creek | 947 | 750 | 392 | 2.18% | 41.42% |
| Walnut Creek | 902 | 630 | 505 | 2.50% | 55.93% |
| Chautauqua Creek | 1,340 | 1,089 | 559 | 2.61% | 41.73% |
| Canadaway Creek | 1,852 | 1,529 | 611 | 2.87% | 33.02% |
| Cattaraugus Creek | 8,960 | 7,993 | 2,307 | 4.54% | 25.75% |
| Buffalo River | 5,366 | 4,894 | 1,041 | 5.09% | 19.40% |
| Headwaters Cattaraugus Creek | 9,166 | 8,118 | 3,438 | 5.71% | 37.51% |
| Eighteenmile Creek | 4,497 | 4,199 | 987 | 5.85% | 21.96% |
| Buffalo Creek | 6,218 | 5,432 | 1,967 | 6.67% | 31.64% |
| Cayuga Creek | 6,629 | 6,101 | 1,318 | 8.15% | 19.88% |
| Smoke(s) Creek | 3,876 | 3,491 | 1,059 | 9.81% | 27.32% |
| Big Sister Creek | 6,650 | 5,834 | 1,641 | 10.66% | 24.68% |
| Upper Tonawanda Creek | 13,662 | 11,748 | 5,763 | 10.74% | 42.18% |
| Ellicott Creek | 12,657 | 11,888 | 4,104 | 16.48% | 32.42% |
| Lower Tonawanda Creek | 14,356 | 13,145 | 5,452 | 18.22% | 37.98% |
| Niagara River | 20,865 | 20,463 | 3,308 | 20.29% | 15.85% |
| Middle Tonawanda Creek | 17,053 | 15,188 | 8,760 | 21.56% | 51.37% |
| Murder Creek | 10,680 | 9,203 | 5,252 | 22.89% | 49.18% |
| **Niagara River/Lake Erie Watershed** | **145,675** | **131,696** | **48,466** | 9.56% | 33.27% |

* Includes both State listed (Department of Environmental Conservation) and Federally listed (National Wetlands Inventory).

**Figure 2.12: Wetlands and Floodplains**



The table illustrates that the sub-watersheds in the northern portion of the Niagara River/Lake Erie Watershed, such as Tonawanda Creek and its tributaries, have the largest percentage of their total acreage as wetlands. The four sub-watersheds north of the Onondaga Escarpment (Lower & Middle Tonawanda, Ellicott Creek and Niagara River Sub-watersheds) have a significant amount of wetland habitat, hydric soils, and connection with underlying aquifers including the Onondaga Aquifer (See Figures 2.7, 2.10, and 2.12). Wetlands constitute an average of 18% of sub-watershed habitat within the three sub-watersheds of Tonawanda Creek, Murder Creek, Ellicott Creek, and the Niagara River sub-watersheds. Tonawanda Creek flows through the former lake bed of the prehistoric Glacial Lake Tonawanda, and many of the wetlands are remnants of that earlier time. On the northeastern edge of the Watershed, halfway between Lockport and Batavia, the Tonawanda Wetland Area is located in the Middle Tonawanda Creek Sub-watershed. It is a 5,600-acre wetland tract. From there, a broad floodplain sprinkled with wetlands, extends westward across the watershed until it meets and is stopped by the urban development in the City of Buffalo and the Tonawandas.

The amount of wetlands decreases generally as you move south through the Watershed. Sixmile Creek Sub-watershed has the least percentage of delineated wetlands within the New York state boundaries making up only 2.18% of the acreage of the sub-watershed. The 12 southern sub-watersheds not mentioned in the paragraph above average only 5.5% of their habitat as wetlands.

The final column of Table 2.3 shows the percent of all wetlands that are protected by the NYS DEC. It ranges from 15% to 55% of the wetlands within each sub-watershed. The amount of wetland acreage protected by the NYS DEC is much higher in the northern portion of the Watershed.

## Floodplains

The Niagara River/Lake Erie Watershed has approximately 107,818 acres of designated floodplain as depicted in Figure 2.12. These include both 100-year floodplains, which have a 1% chance of a flood occurring in any given year, and 500-year floodplains, which have a .02% chance of a flood occurring in a given year.

Presently the northern low-lying areas of the watershed host the largest acreage of floodplain (Table 2.4). Former Lake Tonawanda's boundary can be seen from Figure 2.12, spanning the large 100-year and 500-year floodplain complex sprawled across Tonawanda Creek from northern Amherst to the Tuscarora Reservation. The development in and around this floodplain complex has seen increased high-water flooding events in the downstream cities of Tonawanda and North Tonawanda. The other large floodplain complex existing along Tonawanda Creek in the Upper Tonawanda Creek Sub-watershed is located just south of the City of Batavia in Genesee County, where several tributaries converge.

The middle of the Niagara River Sub-watershed shows an area of 500-year floodplain just west of the Village of Depew in the Town of Cheektowaga. This area coincides with extensive commercial and residential development along Scajaquada Creek before it is channelized underground. In the northern section of the Niagara River Sub-watershed, a series of both 100-year and 500-year floodplains are located near Bull Creek, Bergholz Creek and Cayuga Creek in the Town of Wheatfield.

The lower Buffalo River meanders across the flat Lake Erie plain to the lake with a very wide floodplain extending up Buffalo Creek, Cayuga Creek, and Cazenovia Creek. The land area susceptible to 100 and 500-year flooding greatly expands as the river reaches the industrialized lower six miles of the Buffalo River in the urban areas of West Seneca and Buffalo. At the mouth are remnants of one of the most extensive and productive coastal marshes on Lake Erie.

Smokes Creek's floodplain, near the Lake Erie shoreline, expands as it goes through Lackawanna. This is mostly industrial land with very little wetlands to help mitigate the issues of impervious cover. This area of Smokes Creek also experiences a lot of erosion during high rain events as minimal riparian vegetation exists to stabilize banks.

**Table 2.4: Acreage of Floodplains by Sub-watershed**

| Sub-watershed | Total Acres | 100-Year Floodplain Acres | 500-Year Floodplain Acres | % of sub-watershed in 500 year floodplain |
|---|---|---|---|---|
| Walnut Creek | 127,237.9 | 1,639.14 | 1,681.67 | 1.32% |
| Sixmile Creek | 36,019.9 | 675.41 | 675.41 | 1.88% |
| Eighteenmile Creek | 76,834.0 | 1,470.88 | 1,576.03 | 2.05% |
| Canadaway Creek | 64,538.8 | 1,511.93 | 1,639.03 | 2.54% |
| Big Sister Creek | 62,363.0 | 1,490.25 | 1,635.18 | 2.62% |
| Headwaters Cattaraugus Creek | 160,605.7 | 4,206.78 | 4,224.85 | 2.63% |
| Cattaraugus Creek | 197,523.2 | 5,348.69 | 5,410.19 | 2.74% |
| Buffalo Creek | 93,158.5 | 3,837.01 | 4,343.78 | 4.66% |
| Buffalo River | 105,367.8 | 4,136.66 | 5,102.47 | 4.84% |
| Chautauqua Creek | 51,266.3 | 1,894.69 | 2,620.75 | 5.11% |
| Cayuga Creek | 81,358.2 | 4,310.91 | 4,709.35 | 5.79% |
| Smoke(s) Creek | 43,537.6 | 2,176.32 | 3,123.01 | 7.17% |
| Niagara River | 102,812.1 | 8,543.98 | 11,444.13 | 11.13% |
| Murder Creek | 46,666.4 | 6,157.37 | 6,233.78 | 13.36% |
| Ellicott Creek | 76,824.3 | 6,131.45 | 11,992.75 | 15.61% |
| Middle Tonawanda Creek | 79,090.0 | 11,410.38 | 12,661.27 | 16.01% |
| Lower Tonawanda Creek | 78,788.8 | 12,763.39 | 17,344.33 | 22.01% |
| Upper Tonawanda Creek | 39,522.8 | 11,152.59 | 11,399.68 | 28.84% |
| **TOTAL** | **1,523,515.3** | **88,857.8** | **107,817.7** | **7.08%** |

Source: FEMA Flood Insurance Rate Maps

Further south, narrow bands of floodplains can be seen along Cattaraugus Creek in the steep valleys, widening at the mouth. In addition, there is a swath of 500-year floodplains just north of the Village of Mayville in the Town of Chautauqua. These are the headwaters of Chautauqua Creek.

It is important to note that the Federal Emergency Management Agency's (FEMA) flood insurance rate maps were created for insurance purposes in developed areas and do not map farmland. FEMA maps may not be up-to-date with farmland that has been developed since the last map version. Therefore, communities should not rely solely on them for the most accurate floodplain information.

## Climate & Precipitation

The climate of the Niagara River/Lake Erie Watershed is typical humid continental, which is a climate type that exhibits large seasonal temperature contrasts, with cold winters and hot summers. These diverse climatic conditions are influenced by the region's location, the Great Lakes themselves, and air masses from other regions. The Great Lakes central position in North America exposes the region to alternating flows of warm, moist air from the Gulf of Mexico and cold, dry air from the Arctic. The Great Lakes are well-known for lake-effect snow, where cold Artic air masses move across the lakes picking up heat and moisture and depositing it in extreme rain or snowfall events on the downwind side of the lake. Despite this reputation for extreme snowfall events, winters are changeable and often there are periods of bare ground. Lake Erie shoreline areas are frequently cooler than inland areas due to breezes off the lake.

A review of 1981-2010 weather station normals (three-decade average) shows that the region typically experiences its first frost during the month of October when temperatures dip to 32°F (Table 2.5). Approximate last frost can be as late as May 20$^{th}$ in the valleys in the southern portion of the Watershed. On average the hottest month of the year is July, and the coldest month is January, though occasionally comparable lows can be found during February. Figure 2.13 shows the locations of the weather stations used in Tables 2.5 and 2.6.

Variations in local climate are demonstrated in Table 2.6. Areas located along the Lake Erie shoreline and in the northern portions of the Watershed generally have less precipitation than inland areas.

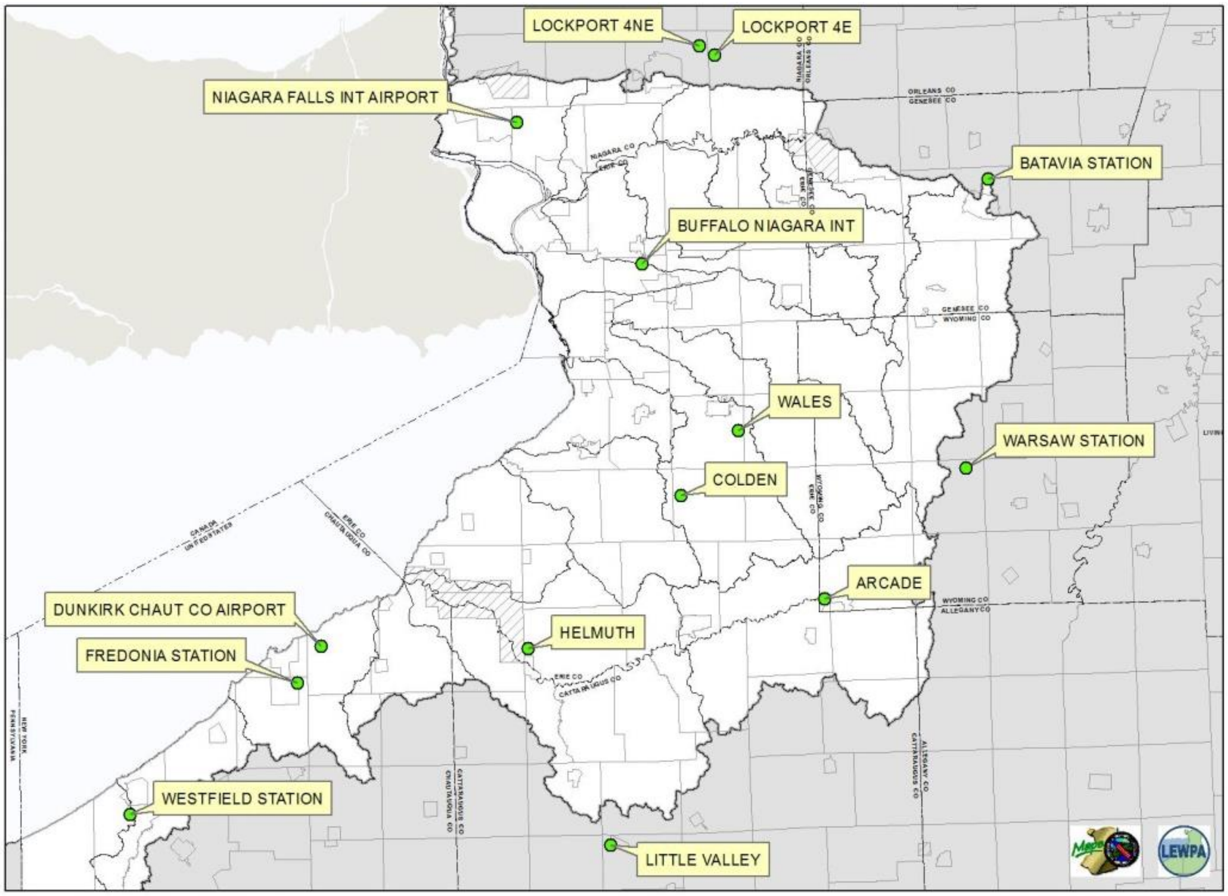
Weather stations located in the southern valleys see lower average temperatures than shoreline and northern stations. Based on data provided by the National Climatic Data Center, the average annual temperature for the watershed ranges from 44.1-50.2 °F.

**Table 2.5: Approximate First & Last Frost dates for the Niagara River/Lake Erie Watershed (1981-2010)**

| Measuring Station | Approximate First Frost | Approximate Last Frost |
|---|---|---|
| Arcade | October 2nd | May 13th |
| Batavia | October 7th | April 29th |
| Buffalo Niagara International Airport | October 22nd | April 24th |
| Colden | October 5th | May 14th |
| Dunkirk Chautauqua County Airport | October 26th | May 3rd |
| Fredonia | October 27th | April 27th |
| Helmuth | October 10th | May 10th |
| Little Valley | October 2nd | May 20th |
| Lockport 4E | October 21st | April 29th |
| Lockport 4NE | October 20th | April 28th |
| Niagara Falls International Airport | October 14th | May 2nd |
| Wales | October 7th | May 11th |
| Warsaw | October 6th | May 9th |
| Westfield | November 1st | April 24th |

Source: National Climatic Center Station Annual Normals (1981-2010) based on 50% probability of temperature reaching 32 degrees F.

**Figure 2.13: Map of weather stations**




data source: https://www.ncdc.noaa.gov/cdo-web/
6/2/2017X:\WMP\data\MXDs\85x11_ncdc_climate_stations.mxd

NOAA WEATHER STATIONS

Western New York's climate is strongly driven by Lake Erie. Early autumn can bring lake-effect rain. Intense lake-effect snow is common from November to January, sometimes resulting in historic storms, but lake-effect events taper off as the lake freezes over. The lake also modulates summer climate, resulting in the areas closest to the lake having more sunshine and fewer thunderstorms than inland areas in early summer, while late summer thunderstorms off the lake and closer to the shoreline are more common.

The average annual precipitation (rain and melted snow) for the Niagara River/Lake Erie Watershed ranges from 34.97 inches in Niagara Falls to 47.86 inches in Little Valley. Higher precipitation levels are found primarily in the areas with higher elevations toward the southern areas of the Watershed including the hills in the towns of Boston and Colden. This can be clearly seen in Watershed Precipitation maps in Figures 2.14 and 2.15. The precipitation levels decrease as you move north through the Watershed. Similar trends can be seen with snowfall, with the southern tier receiving considerably more snowfall than the northern end of the watershed.

However, since 1975, the number of days with land snow cover has decreased by 5 days per decade, and the average snow depth has decreased by 1.7 cm per decade. From 1973 to 2010, annual average ice coverage on the Great Lakes declined by 71%.[7] If this trend continues, reduced ice cover may result in increased lake-effect precipitation, which can lead to increased flooding. However, reduced ice cover can also increase evaporation, and decrease water recharge, leading to falling water levels, especially for Lake Erie.

**Table 2.6 Average Temperatures and Precipitation for the Niagara River Watershed (1981-2010)**

| Measuring Station | Temperature (Fahrenheit) | | | Average Annual Precipitation (Inches) |
|---|---|---|---|---|
| | Winter Average (Jan) | Summer Average (July) | Annual Average | |
| Arcade | 25.1 | 65.9 | 46.3 | 42.50 |
| Batavia | 26.9 | 69.5 | 48.9 | 35.34 |
| Buffalo Niagara International Airport | 27.1 | 69.0 | 48.3 | 40.48 |
| Colden | 24.4 | 65.6 | 45.5 | 46.91 |
| Dunkirk Chautauqua County Airport | 28.7 | 69.0 | 49.0 | 37.95 |
| Fredonia | 29.3 | 69.9 | 50.2 | 41.93 |
| Helmuth | No Data | No Data | No Data | No Data |
| Little Valley | 24.0 | 64.8 | 44.8 | 47.86 |
| Lockport 4E | 28.4 | 70.2 | 49.7 | 37.85 |
| Lockport NE | No Data | No Data | No Data | No Data |
| Niagara Falls International Airport | 26.2 | 68.8 | 47.7 | 34.97 |
| Wales | 24.8 | 65.7 | 45.8 | 42.35 |
| Warsaw | 22.6 | 64.8 | 44.1 | 45.85 |
| Westfield | No Data | No Data | No Data | No Data |

Source: National Climatic Center Station Normals, 2013

[7] Great Lakes Integrated Science Assessments, 2012

**Figure 2.14: Average Annual Precipitation (1971-2000)**

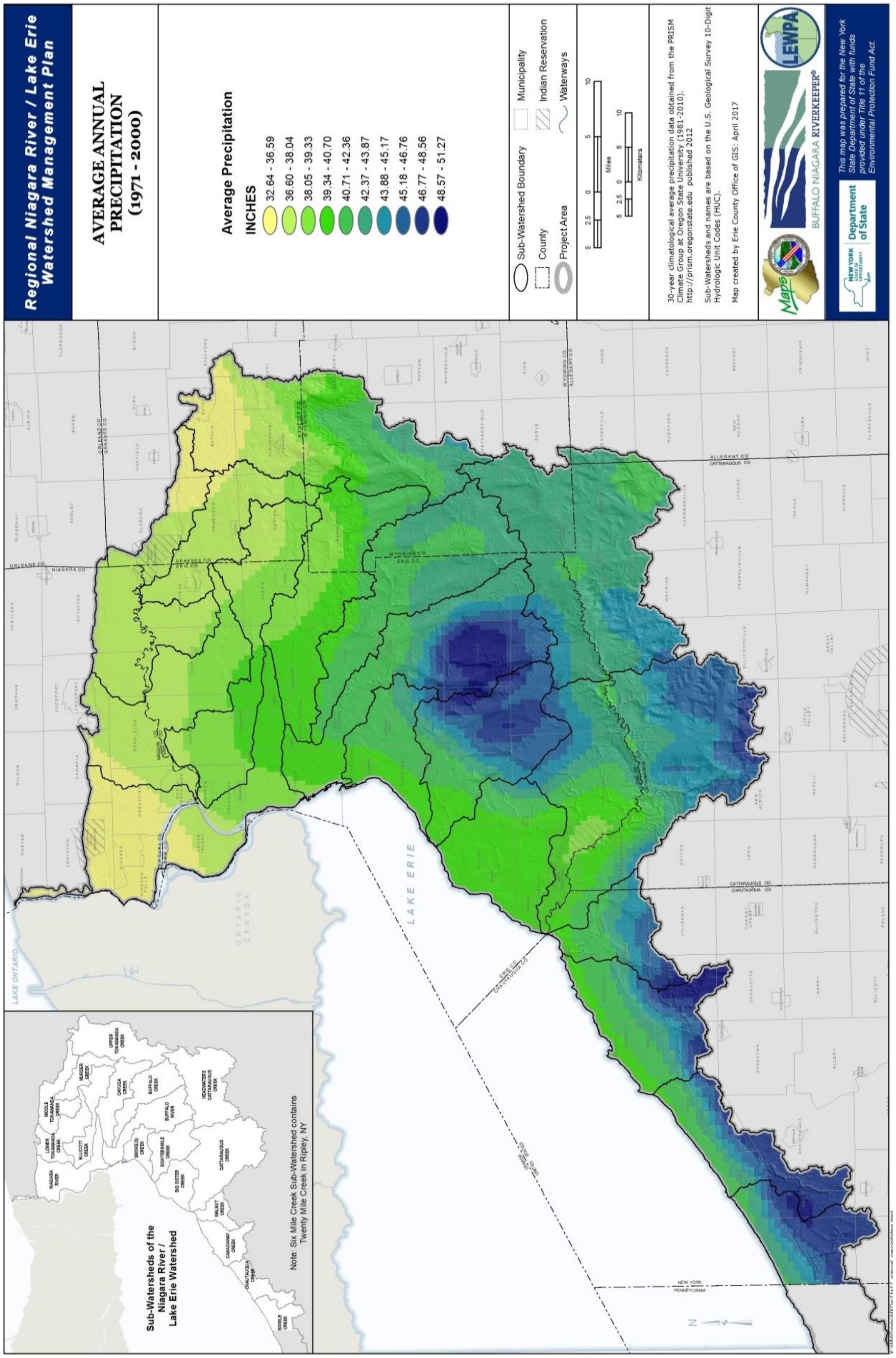
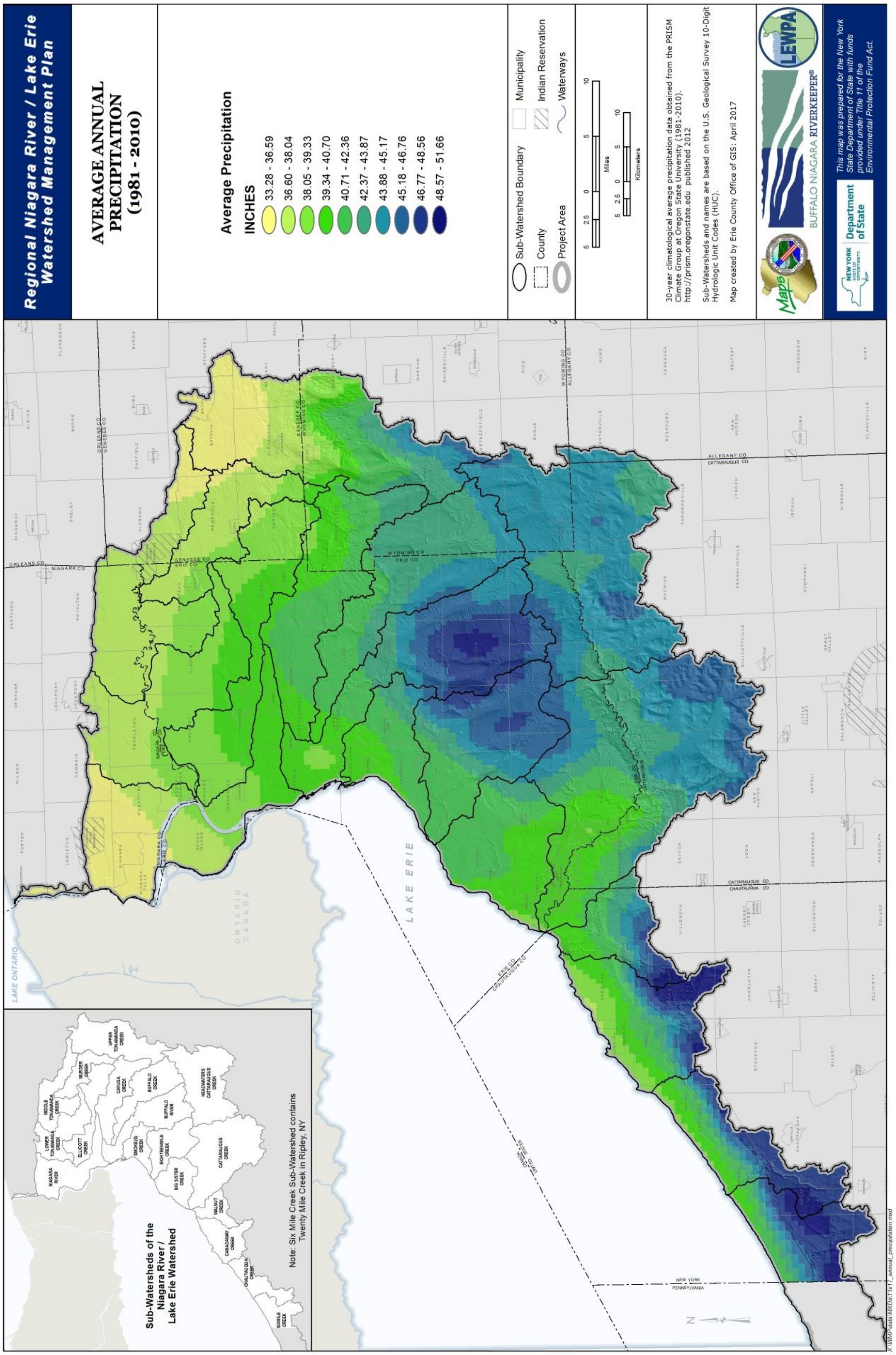


**Figure 2.15: Average Annual Precipitation (1981-2010)**



# Climate Change

The Earth's atmosphere is warming, and nearly all communities around the Great Lakes will need to adapt to changes in regional climate over the next century. These changes may include: warming air temperatures; shifts in the timing, frequency, and severity of precipitation events; higher water temperatures; reductions in lake ice cover; and fluctuating lake levels due to increased evaporation at times and increased precipitation events.

## Potential Emerging Climate Change Impacts

1. **Warming Temperatures, Heat Waves, and Reduced Cold Events**

   Recent climatological research indicates that regional temperatures are warming slightly, especially in the winter and spring, with spring showing the strongest warming. Summer and fall are not as affected by this trend, with the fall season even showing a slight cooling trend. Winter/spring warming results in shorter frost periods, and reduced ice cover on the lakes, which due to their weather modulating capabilities can significantly impact the region's seasons and climate. This can also explain why annual precipitation is increasing, while the ratio of snow to total precipitation is decreasing.[8]

   Heat waves are expected to become much more common in a region where they have historically been rare. This may have significant impact on the region's agricultural industries by changing growing conditions for staple crops, such as blueberries and apples, and by increasing irrigation demands. Projected warmer temperatures also can negatively impact the dairy industry, which is a significant economic driver in the watershed. Heat stress in cows can dramatically reduce milk production and slow birth rates.[9] Extreme cold events, defined both as the number of days per year with minimum temperature at or below 32°F and those at or below 0°F, are expected to decrease.[10] New York State modeling indicates that New York could be 3°F warmer by the 2020s.[11]

2. **Increased Rainfall**

   Climate change is expected to increase annual precipitation across the Great Lakes region. Relatively large increases in winter and spring precipitation are projected by the end of the century, with large decreases for summer months. The frequency of heavy rainfall events is expected to continue increasing with longer dry spells in between. Figure 2.16 shows the

[8] Alden, M., Mortsch, L., Sheraga, J. *Climate Change & Water Quality in the Great Lakes Region: Risks, Opportunities & Responses.* 2003

[9] US Global Change Research Program, *Global Climate Change Impacts in the United States*, 2009

[10] NYS's Open Space Conservation Plan, 2016

[11] http://www.dec.ny.gov/energy/94702.html

report from the U.S. Geological Survey on the Flooding that occurred in Goawanda and Silver Creek after 4 inches of rain fell in August 2009.

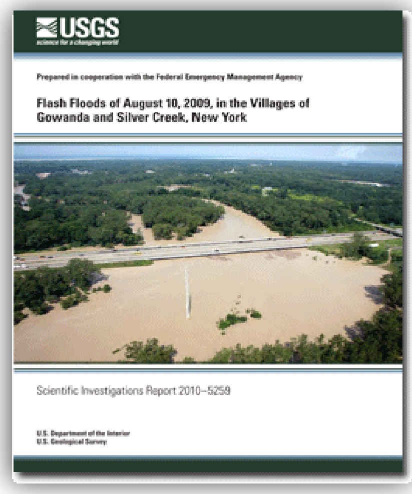



**Figure 2.16: USGS report on Gowanda and Silver Creek Floods**

3. **Increased Flooding**

An increase in flooding is considered one of the most probable impacts of climate change in this region. Factors that could influence flooding include shifts in the intensity and tracks of storms and changes in the type of precipitation. Land conditions such as smaller snow-packs, less soil moisture and frozen soil when large storms take place can also change and influence the intensity of flooding effects. According to the NYS Open Space Conservation Plan, "climatologists expect that even if the frequency of storms does not increase, the proportion of storms that become severe is likely to be greater."

A 2011 study did not come up with a clear pattern of how climate change will alter flooding in the future but did indicate that changes in snow packs, frozen ground, soil moisture, and storm tracks are all factors that could be altered by greenhouse gas concentrations and possibly alter current flooding patterns.[12] In the study the United States was divided into four large regions and the research showed some regional differences in the way that flooding has varied with CO2 levels over the past century. For the northeastern region that includes New York State, the study shows a tendency towards increases in flooding over this period.

4. **Changing Lake Levels**

As mentioned previously, warmer air and water temperatures along with reduced snowpack and shorter duration of ice cover may result in greater evaporation and overall lower Lake Erie levels. The frequency and duration of low water levels could increase, falling below historic low-water levels. However, increase in frequency and intensity of storm events may also raise lake levels at times. Water level change will not be equal among all of the Great Lakes. Considerable range in the change in lake levels is due to differences in precipitation patterns and evapotranspiration.

5. **Changing Winter Freeze and Thaw Dates**

In the Great Lakes Region, later ice-in dates may increase the frequency and intensity of lake-effect storms, very heavy snowfalls that occur when open water in the lakes is warmer than the

[12] Hirsch, R.M. and Ryberg, K.R., 2012. *Has the magnitude of floods across the USA changed with global CO2 levels?* Hydrolological Sciences Journal, 57 (1), 1–9.

surrounding land surface. If the lakes freeze-over later in winter (or not at all), more lake-effect events are expected. As the climate further warms, air and lake temperatures may remain closer, in which case, the frequency of lake-effect storms may actually decrease.[13]

6. **Extreme Weather Events**
   Studies have indicated that if current trends continue, the region's already variable climate could become increasingly volatile and unpredictable, with increases in both extreme wet and dry events.[14]

## Existing Infrastructure in the Watershed

### Dams

According to the NYS Dam Inventory (2009) there are 491 dams within the Niagara River/Lake Erie Watershed. The volume impounded by the dams at the elevation of a single or service spillway is 91,530 acre feet or over 29 billion gallons of water.[15] The oldest damn in the record was built in 1808 (South Branch Smokes Creek Dam) and the most recent dams were built in 2010 (Paul Snyder Pond Dam and Pierce Pond Dam). The earliest dams were built for irrigation, fire protection, and drinking water supply purposes between the mid 1800's and early 1900's. Many dams were built in the 1950's and 60's, with the vast majority of these dams built for "recreation" purposes. Figure 2.17 is a map of the watershed's dams and their designated purposes.

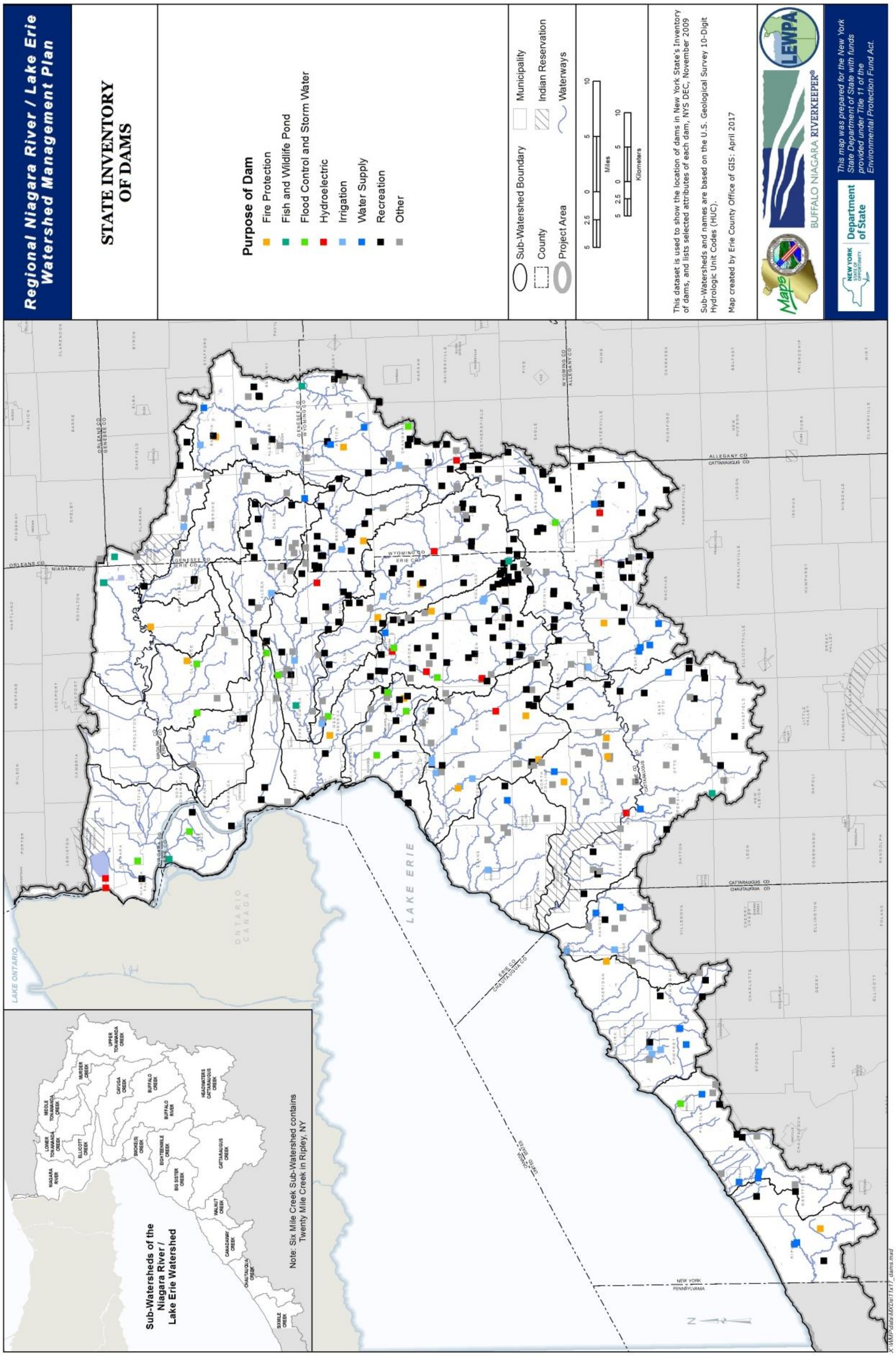
Most of the dams in the watershed are small earthen dams (71%), with the remaining consisting of timber crib, concrete, masonry, rockfill, laid up stone, and buttress style designs. The Lewiston Pump Generating Plant, shown in Figure 2.18, is the largest dam in the watershed and located in the Niagara River Sub-watershed. It was built by the NY Power Authority in 1960 and stores approximately 22 billion gallons of water to feed the Lewiston Hydroelectric generation facility. The Robert Moses-Niagara Dam is also located in the Niagara River Sub-watershed.

The other ten dams classified as hydroelectric in the watershed include:

- Sweewaldt Dam on Tonawanda Creek
- Haungs Dam on Cayuga Creek
- Depew & Lancaster Co Dam on Cazenovia Creek
- Yaws Mill Dam on the West Branch of Cazenovia Creek
- Grays Mill Dam on the West Branch of Cazenovia Creek
- Hyman Brothers Saw Mill Dam on Buffalo Creek
- Brunnen Mill Dam on Eighteen Mile Creek

[13] NYS Open Space Conservation Plan, 2016
[14] Ibid
[15] Normal storage capacity, NYS DEC Inventory of Dams, 2009

**Figure 2.17: State Inventory of Dams**



- Shermans Mills Dam on Cattaraugus Creek
- Goo & Hopkins Mill Dam on a tributary to Cattaraugus Creek
- Cattaraugus Creek Dam in Gowanda on Cattaraugus Creek

Most of the watershed's dams are in private ownership for irrigation, private stocked ponds, and other recreational purposes as shown in Table 2.7.

**Table 2.7: Number of Dams by Owner**

| Owner | Number of Dams |
|---|---|
| Public Utility | 2 |
| Local Government, Private | 4 |
| Not Found | 12 |
| State | 17 |
| Local Government | 60 |
| N/A | 162 |
| Private | 234 |
| **Total** | **491** |

Source: NYS DEC Inventory of Dams (2009)

**Table 2.8: Number of Dams by Subwatershed**

| Sub-watershed | Number of Dams |
|---|---|
| Sixmile Creek | 5 |
| Lower Tonawanda Creek | 6 |
| Big Sister Creek | 8 |
| Murder Creek | 11 |
| Canadaway Creek | 13 |
| Niagara River | 13 |
| Walnut Creek | 13 |
| Middle Tonawanda Creek | 15 |
| Chautauqua Creek | 16 |
| Smoke(s) Creek | 17 |
| Ellicott Creek | 24 |
| Eighteenmile Creek | 33 |
| Buffalo Creek | 39 |
| Cayuga Creek | 46 |
| Cattaraugus Creek | 53 |
| Upper Tonawanda Creek | 53 |
| Headwaters Cattaraugus Creek | 58 |
| Buffalo River | 68 |
| **Total** | **491** |

Source: NYS DEC Inventory of Dams (2009)

Table 2.8 outlines the number of dams located in each sub-watershed. The NYS Dam Inventory also classifies a dam's hazard class, which indicates the level of hazard the dam poses if it were ever to fail or be breached. Dam's hazard classes range from A-C, with A equaling a low-level hazard (minor damage to property) and C equaling a high-level hazard (causing loss of life, damage to public infrastructure, and property). Dams classified as D, are considered no longer functioning and therefore have a negligible or no hazard. There are a total of 287 dams classified as Hazard Level A (low-hazard), 25 as level B (moderate-hazard), 9 as level C (high-hazard), and 117 as class D (no-hazard). A hazard level has not been assigned to 53 of the dams in the Watershed. The Class C dams included in this inventory include:

- McKinley Mall Retention Pond Dam on Blasdell Creek
- Lewiston Hydroelectric Generation Dam on the Niagara River
- Robert Moses-Niagara Dam
- Green Lake Dam on South Branch Smoke Creek (work was completed on this dam in 2016)
- Attica Dam (upper) on Crow Creek
- Springville Dam on Cattaraugus Creek
- Clear Lake Dam on North Branch Clear Creek
- Fredonia Reservoir Dam on Canadaway Creek
- Brocton Reservoir Dam on Slipper Rock Creek

Owners of Class C dams are required to have an Emergency Action Plans and Inspection and Maintenance Plans in place, as well as regularly scheduled safety inspections.

### NYPA Niagara Power Project Impacts & Relicensing

Prior to the relicensing of the Lewiston Hydroelectric Generation facility by the NYPA in 2007 the generation facility, its reservoir, and other infrastructure were argued to be the cause of significant environmental impacts to the Niagara River. Findings from environmental studies completed as part of the relicensing effort identified major impairments caused by the water diversions necessary for the operations of the plant.[16] As of a 2005 study, water level draw-downs average 1.5 feet/day just above the intakes, up to 12 feet/day in the gorge area above the tailrace, up to 36 feet/day in the Lewiston Reservoir, and .6 feet/day at Lake Ontario.[17]

Due to the environmental impacts and the infrastructure's limitation of public access to the waterfront, relicensing included a settlement to waterfront (Greenway) communities of Western New York of $9 million/year for 50 years. The settlement provides three Standing Committees that

[16] Many sources can be found in the Regional Niagara River Lake Erie Watershed Management Plan Atlas and Bibliography at www.erie.gov/wmp.
[17] Niagara River Water Level and Flow Fluctuation Study (URS Corporation, 2005)

oversee disbursement of the funds for environmental and public access projects in the Greenway Communities, plus allocations to Erie and Niagara Counties.[18]

## Stormwater Infrastructure

The other primary man-made infrastructure impacting how water moves in the watershed is stormwater infrastructure. In the Niagara River/Lake Erie Watershed this encompasses both combined and separated storm sewer infrastructure. Combined Sewer Systems (CSS) are conveyance systems that are designed to collect stormwater runoff, domestic sewage, and industrial wastewater in the same pipe. Most of the time, combined sewer systems transport all of the wastewater to a sewage treatment plant, where it is treated before being discharged to a local waterbody. However, during heavy rain events, combined systems can be inundated and include overflow release points that discharge untreated water into the watershed. Presently the Cities of Buffalo, Dunkirk, Lockport, and Niagara Falls , as well as the Town and Village of Lewiston have Combined Sewer Systems, which are discussed more in chapter 4.

Municipal Separate Storm Sewer Systems, or MS4s for short, are storm water conveyance systems that are completely separate from sanitary sewer systems. MS4 infrastructure can include underground pipes, stormwater retention ponds and roadside ditches, all of which either store or convey water along man-made routes in the watershed. It is important to note that MS4 conveyed waters are not treated prior to entering their final destination, a waterbody or tributary in the watershed. Therefore, stormwater has the potential to contribute pollutants into the watershed, including animal waste, litter, roadway contaminants, yard clippings, fertilizers, and pesticides. Because of this pollution potential, the US Environmental Protection Agency (US EPA) regulates all municipal, industrial, and commercial stormwater discharges as part of the National Pollutant Discharge Elimination System (NPDES) under the Federal Clean Water Act. In New York State, the NYS DEC manages the State Pollutant Discharge Elimination System (SPDES) under the NPDES.

All municipalities have some type of stormwater infrastructure; however communities that meet a certain threshold for population density as outlined by the most recent US Census Urbanized Areas (see Chapter 3 for a map of the urbanized area), must meet additional requirements to manage their stormwater discharges in accordance with the NPDES. These municipalities are often referred to as "MS4 communities" because of this designation and include the following municipalities in the Niagara River/Lake Erie Watershed:

[18] A list of projects funded by NYPA Relicensing Greenway Funds is available online at http://niagara.nypa.gov

City of Buffalo
City of Lackawanna
City of Niagara Falls
City of North Tonawanda
City of Tonawanda

Town of Alden
Town of Amherst
Town of Aurora
Town of Boston
Town of Cambria
Town of Cheektowaga
Town of Clarence
Town of Eden
Town of Elma
Town of Evans
Town of Grand Island
Town of Hamburg
Town of Lancaster
Town of Lewiston
Town of Lockport
Town of Marilla
Town of Newstead
Town of Niagara
Town of Orchard Park
Town of Pendleton
Town of Porter
Town of Tonawanda
Town of West Seneca
Town of Wheatfield

Village of Alden
Village of Angola
Village of Blasdell
Village of Depew
Village of East Aurora
Village of Hamburg
Village of Kenmore
Village of Lancaster
Village of Lewiston
Village of Orchard Park
Village of Sloan
Village of Williamsville
Village of Youngstown

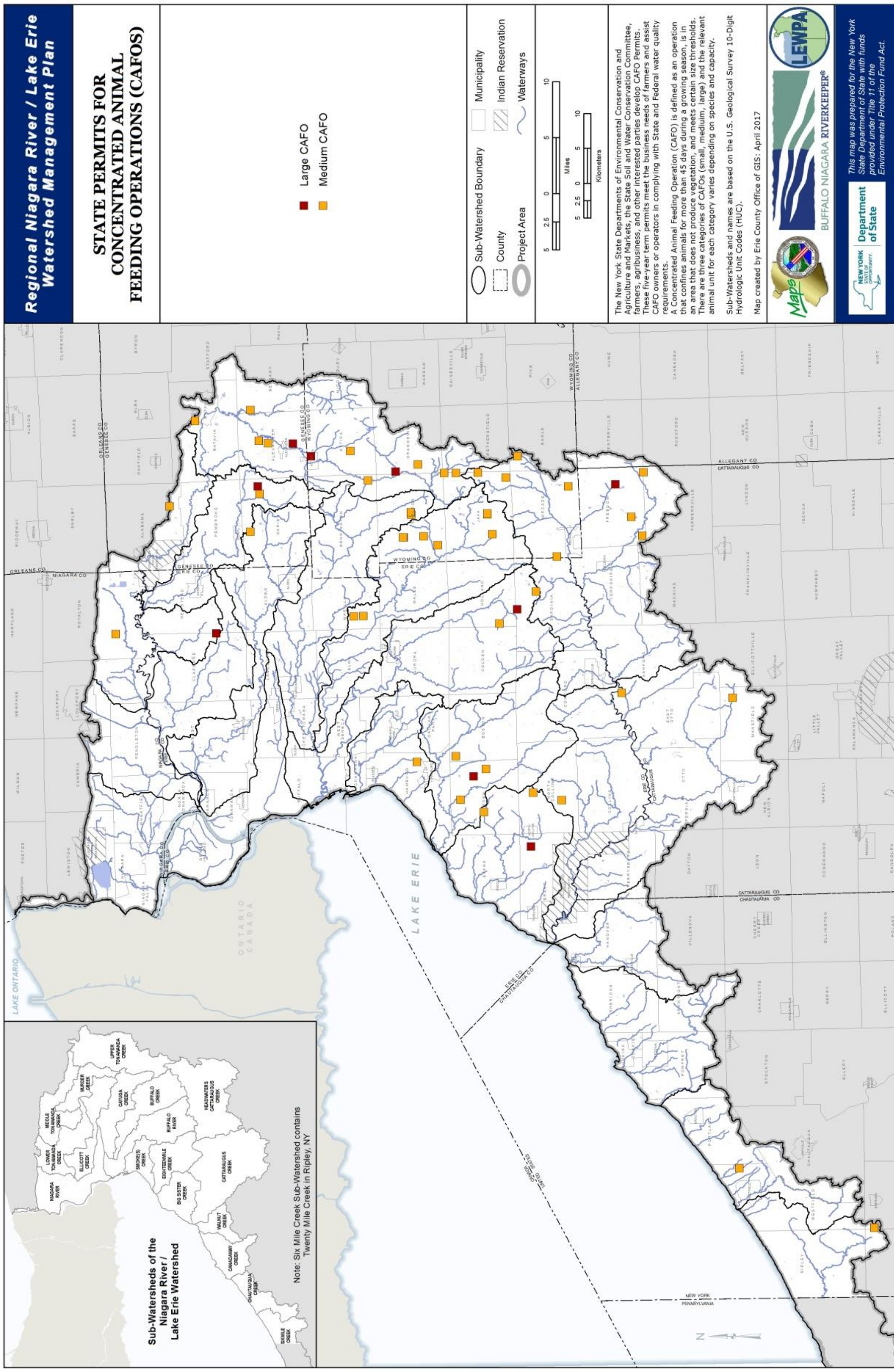
Presently, all of the designated MS4 communities are located within Erie and Niagara Counties. Forty-two regulated entities (municipalities and large-scale institutions) have joined together under the Western New York Stormwater Coalition (WNYSC) to share resources and work in partnership toward compliance with the U.S. Environmental Protection Agency's Phase II Stormwater requirements. The overall goal of WNYSC is to utilize regional collaboration to identify existing resources and develop programs to reduce the negative impacts of stormwater pollution.

A major MS4 mapping effort by the WNYSC has been underway since 2012 to inventory all MS4 infrastructure routes within these communities to identify the paths by which stormwater is directed in these systems and will be wrapping up shortly. The main purpose of this is to aid municipalities in track down of pollutants in these systems.

## Agriculture

Agricultural land used for cultivating the soil for crops, rearing animals, or producing products makes up a large portion of the Niagara River/Lake Erie Watershed. Approximately 36% of the land cover of Watershed acreage is classified as cultivated crops or pasture/hay. These agricultural lands are often located in the headwaters areas of the sub-watersheds as more urbanized areas are generally located closer to Lake Erie and the Niagara River. Land use and land classification is discussed further in Chapter 3.

**Figure 2.18 State Permits for Concentrated Animals Feeding Operations**



As part of the Clean Water Act, the US EPA regulates farms of a certain size, which are referred to as Consolidated Animal Feeding Operations (CAFOs) and considered a source of point source pollution. Figure 2.18 shows the state permits for medium- and large-sized CAFOs. These are defined based upon the number of each type of animal on premises, as well as whether or not an operation is found to be a significant contributor of pollutants by the New York State Department of Environmental Conservation.[19]

## Oil & Gas Production

The Medina sandstone rock stratum under the Allegheny plateau contains pockets of natural gas. Figure 2.19 shows the state-regulated gas wells in the Niagara River/Lake Erie Watershed. There are 5,006 gas wells in the Watershed ranging in depth from 0 to 7500 feet with 98% of those wells under 4000 feet in depth.[20]

Along with production wells, the area also houses underground vertical and horizontal gas storage wells. Natural gas produced elsewhere is pumped into and stored in these underground wells in the warm months when demand is low and then pumped out in the cold winter months when household demand is high.

Figure 2.20 shows state regulated oil, brine, and storage wells in the Niagara River/Lake Erie Watershed. Brine wells are clustered in the Upper Tonawanda Creek Sub-watershed. Storage wells are clustered mostly within the Allegheny Plateau. This map also lists wells that are not listed as gas, oil, brine, or storage. There are 7,470 total state regulated wells in the Watershed. The year all wells were drilled along with fault lines are shown in Figure 2.21. Clusters of wells drilled within the past decade can be found in Hanover, Collins, North Collins, Wales, and Darien.

## Utility Infrastructure and Right-of-Ways

Utilities such as cable, internet, electric, and natural gas often have infrastructure that follows roadways. In some cases, this infrastructure requires a separate right-of-way to reach its destination. These right-of-ways are often wide strips of land mowed annually to prevent trees from growing into pipelines or wires. This mowing can isolate native habitat and disrupt the ecosystem.

The proposed construction of the Northern Access Pipeline is an example of both utility infrastructure and a utility right-of-way that has generated controversy in recent years. This topic has come up repeatedly at public outreach events throughout the Watershed conducted during this project. National Fuel Gas Company applied to construct a 96.5-mile pipeline to connect natural gas supplies from Pennsylvania, through Western New York to Canada. The NYS Department of Environmental Conservation denied the permit in April 2017 citing concerns about the impacts of

[19] Definitions can be found here: https://www3.epa.gov/npdes/pubs/sector_table.pdf
[20] Data Source: NYS DEC, 2013 http://www.dec.ny.gov/energy/1603.html

**Figure 2.19: State Regulated Gas Wells**

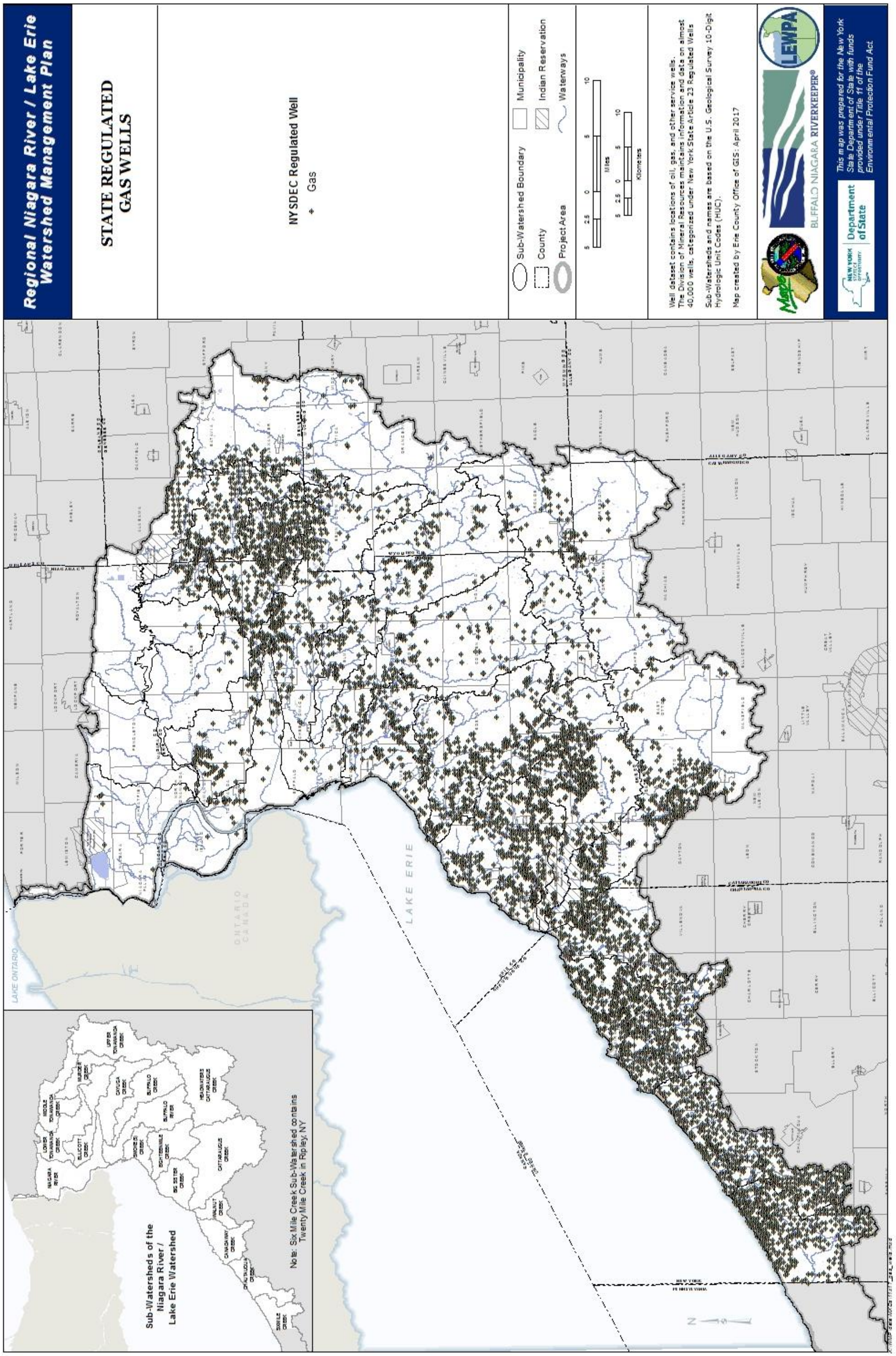


**Figure 2.20: State Regulated Oil, Brine, Storage, and Other Wells**

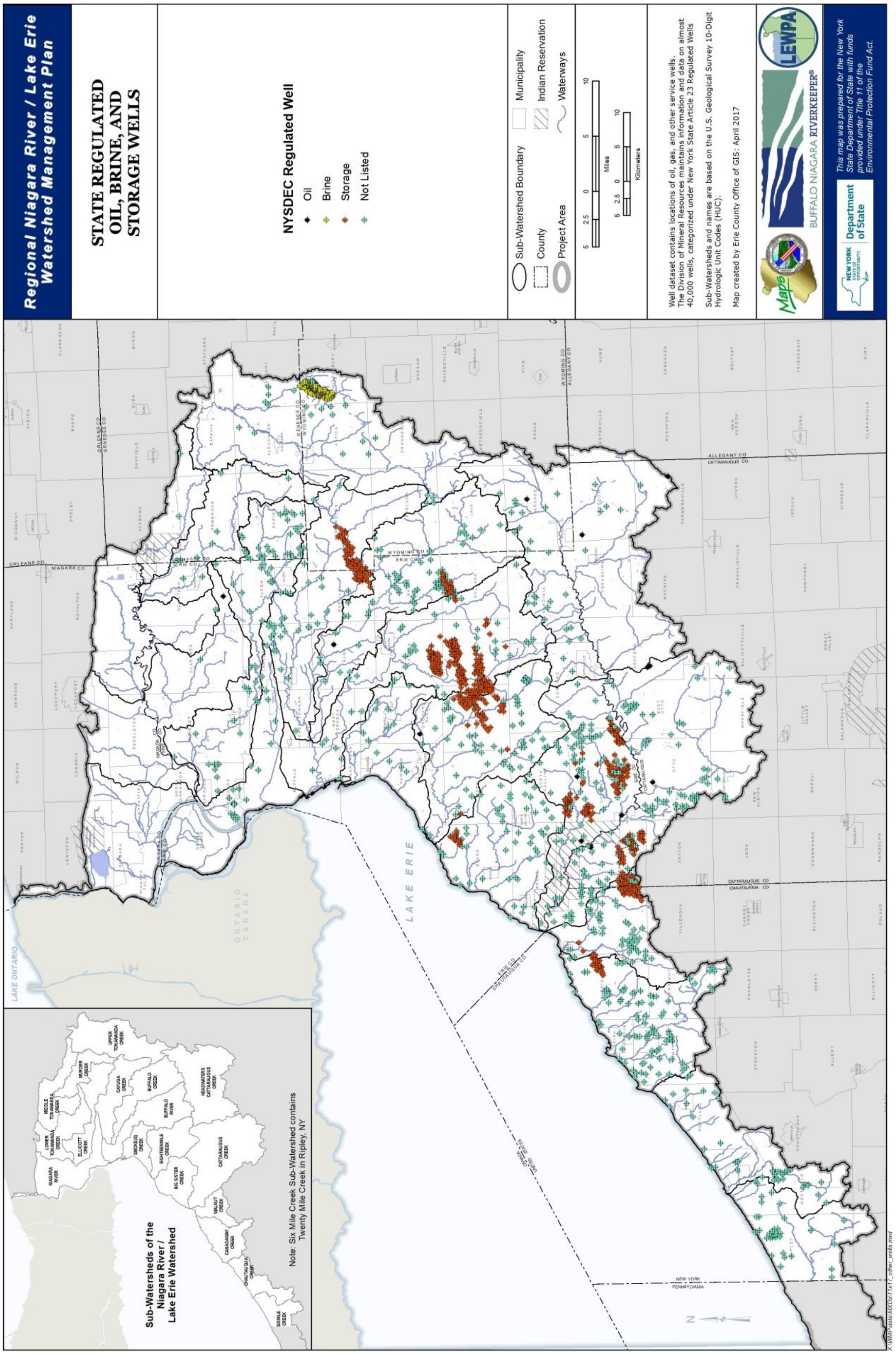
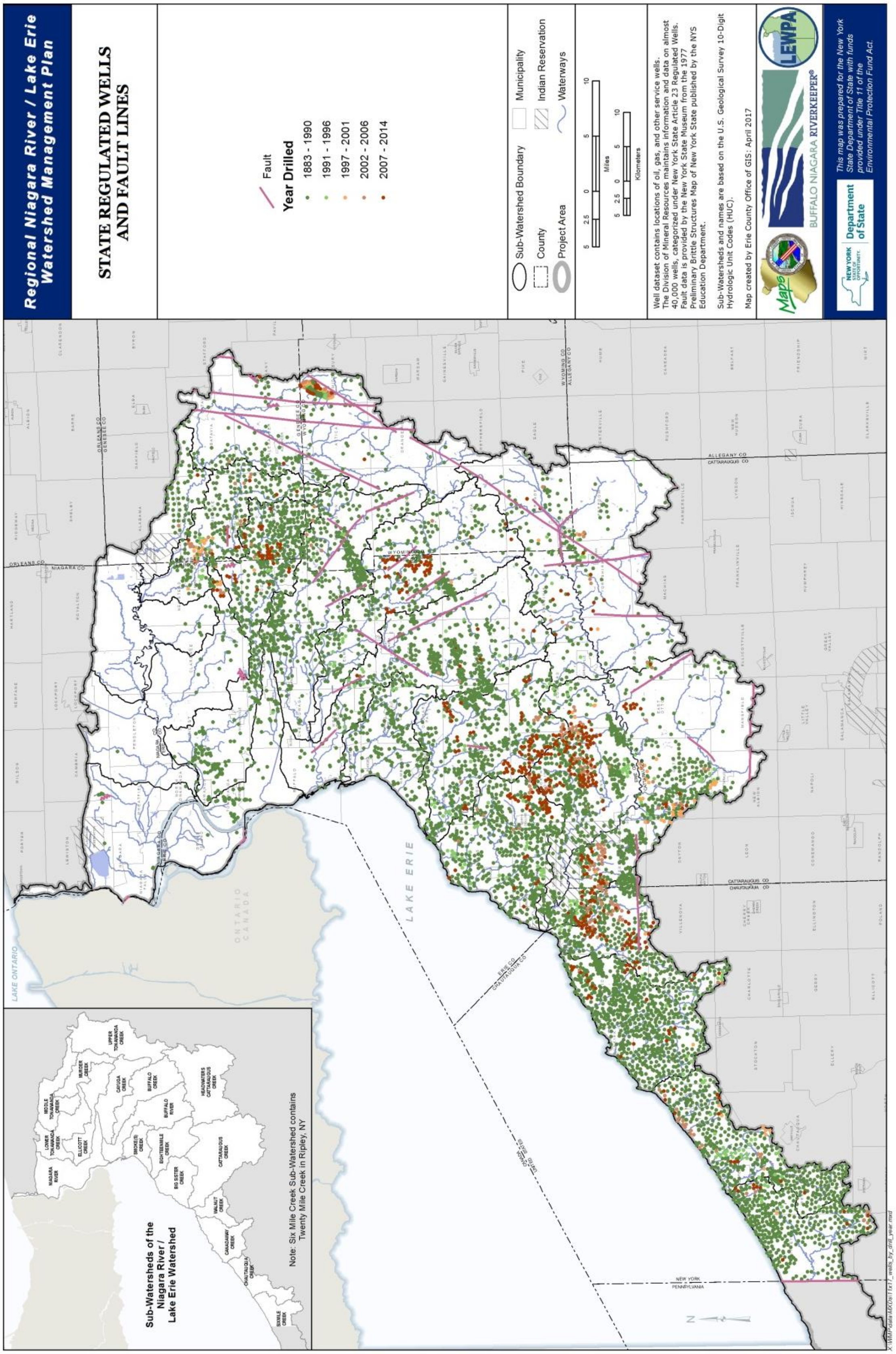


**Figure 2.21: State Regulates Wells and Fault Lines**



this infrastructure construction on wetlands, waterways, and aquatic habitat.[21] The Pipeline was slated to cross 192 streams and impact 73 acres of wetlands where several significant animal species are located, including the eastern hellbender and brown trout. The majority of the crossings would involve disrupting the stream flow to dig through the stream or wetland to bury the pipe.

## Transportation Infrastructure

Drainage for transportation infrastructure makes up the vast majority of MS4 infrastructure. Roadways are typically impervious and act as collection systems, collecting surface waters and diverting rainwater to underground stormwater pipes and roadside ditches, where water is often diverted quickly, and without treatment, to the nearest waterway. Most bridges over waterways also collect and directly convey stormwater into the waterway they cross over, allowing for minimal opportunities to filter and treat roadway runoff prior to its release into area waterways. Figure 2.23 documents the National Bridge Inventory locations where an automobile or railroad bridge exists to cross a waterway, highlighting the extent of direct runoff release points in the watershed.

## Navigational Channels, Harbors, and Shipping Infrastructure

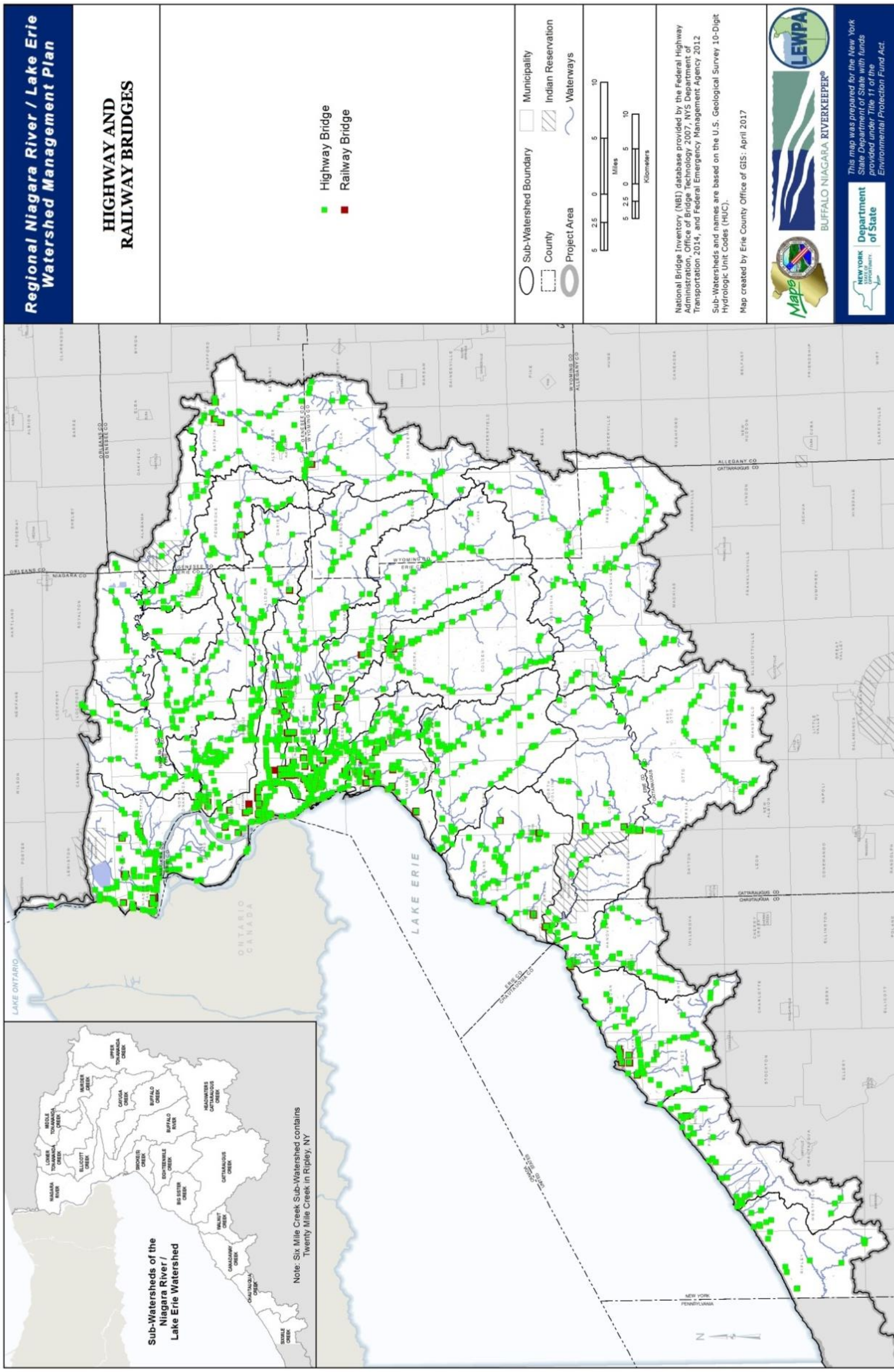
The City of Buffalo's historic growth in the late 19th and early 20th centuries was spurred by the establishment of major shipping routes via the Erie Canal and other Great Lakes connections afforded by its location at the eastern end of Lake Erie. As a major shipping economy, the city altered much of its natural shorelines to accommodate ship navigation, docking and the transfer of goods. Today, some of those alterations still exist in the landscape. A portion of Buffalo's shipping past is still active in certain sections of the waterfront as well.

**Figure 2.22: Historic Image of the Foot of Main Street, City of Buffalo (circa 1910)**

Presently the Buffalo River from its mouth at Lake Erie upstream 5.5 miles to the Mobile Oil and the Buckeye Terminals is an official navigation channel. Federal navigation channels are the responsibility of the U.S. Army Corps of Engineers to provide safe, reliable, efficient, and environmentally sustainable waterborne transportation systems. Large portions of the Buffalo River in this section have hardened

[21] http://www.dec.ny.gov/docs/permits_ej_operations_pdf/northaccesspipe42017.pdf

**Figure 2.23: Highway and Railway Bridges**



shoreline and docking areas mixed in with reinforced concrete and steel grain elevators that sit immediately adjacent to the water. The City Ship Canal is another navigational channel that runs off of the Buffalo River along the other side of Kelly Island. The City Ship Canal sees shipping traffic as far south as the Sand Products company located off of Fuhrmann Boulevard. Buffalo Harbor is a deep draft commercial harbor with over 4.5 miles of breakwater structures and confined disposal facility adjacent to the south entrance of the channel. The Black Rock Canal begins where Lake Erie meets the Niagara River and continues up the City of Buffalo's shoreline, ending at the US Army Corp of Engineers lock located at the northern end of Unity Island. The canal connects Buffalo Harbor and Tonawanda Harbor. This navigation channel hosts more recreational boaters than shipping vessels these days.

There are three additional navigation channels north of the City of Buffalo: Niagara River Channel, Tonawanda Channel, and Tonawanda Creek. The Tonawanda Channel continues from where the Black Rock Channel ends and continues north within the East Branch of the Niagara River along the shoreline of the Tonawandas before changing names to the Niagara River Channel near North Tonawanda. The Niagara River navigation channel continues north north-east around the Western side of Grand Island in the East Branch of the Niagara River. Due to dangerous currents near Niagara Falls the Niagara River navigation channel ends at the break walls off of Buckhorn Island State Park at the Northern tip of Grand Island. The navigation channel of Tonawanda Creek exists from its mouth at the Niagara River all the way upstream to where it splits off from the Erie Canal in the Town of Pendleton. This portion of the Creek is considered part of the Erie Canal and is overseen by the NYS Canal Corporation.

South of the City of Buffalo there are several harbors with federal navigational channels that require regular maintenance dredging and break wall maintenance. Sturgeon Point Marina is a harbor of refuge located on Lake Erie, 29 miles southwest of Buffalo in the Town of Evans. It is a shallow draft commercial/recreational harbor with 840 feet of breakwater structures and 580 feet of shoreline revetment. Cattaraugus Harbor is a harbor of refuge located at the mouth of Cattaraugus Creek. The recreational harbor has 2,450 feet of breakwaters and is located between the Seneca Nation and the Town of Hanover. Further southwest is Dunkirk Harbor in the City of Dunkirk. This deep draft harbor of refuge has over 1.3 miles of breakwater structure with the North breakwater structure requiring major repair. Barcelona Harbor is also a harbor of refuge in the Town of Westfield and is the last harbor in New York on Lake Erie heading southwest. It is protected by 1730 feet of breakwater structure.[22]

Aside from the main navigation channels there are several areas of the watershed where major shipping infrastructure exists. Buffalo's Outer Harbor hosts four main shipping canals, some of which can be utilized for docking major great lakes shipping freighters and barges. Farther south on Lake

[22] http://www.lre.usace.army.mil/Portals/69/docs/Navigation/FY2015/mar19factsheets.pdf

Erie, the City of Lackawanna has remediated and is reinvesting in the Lackawanna Canal, a major freighter docking facility. Only a few other opportunities exist for large ship docking in the watershed, including docks at the former Huntley Power Plant, Riverworld, and United Refinery on the Niagara River in the Town of Tonawanda. Dunkirk Harbor can also accommodate large vessels associated with the now closed NRG Power Plant. Major railroad infrastructure in the watershed is often found co-located with these major port areas as well, specifically along the City of Lackawanna and Town of Tonawanda waterfronts, Buffalo's Inner and Outer Harbor, the City Ship Canal, along the Buffalo River and along the Lake Erie waterfront including Dunkirk.