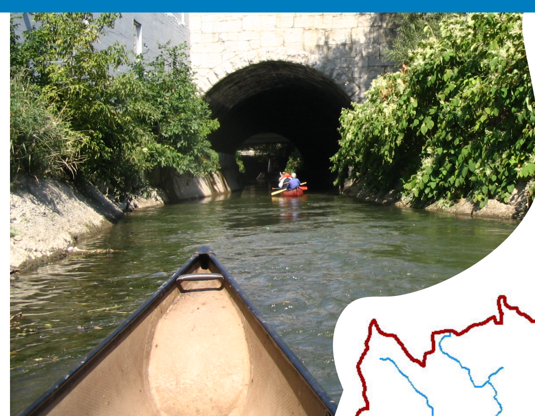
Onondaga Creek
CONCEPTUAL REVITALIZATION PLAN

The State of Onondaga Creek
FACT SHEETS



Onondaga Environmental Institute

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Introduction

Onondaga Creek Fact Sheets

The State of Onondaga Creek Fact Sheets were produced by Onondaga Environmental Institute as a work product of the Onondaga Creek Conceptual Revitalization Plan Project (OCRP).

Visit www.esf.edu/onondagacreek for more information.

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The Onondaga Lake Partnership (OLP) sponsors the Onondaga Creek Conceptual Revitalization Plan Project with federal funds from Congressman James T. Walsh granted through the U.S. Environmental Protection Agency.

Visit www.onlakepartners.org for more information about OLP.

These Fact Sheets are a compilation of publicly available data and research conducted by a number of governmental agencies, academic institutions, and research organizations. Information sources are footnoted and/or listed on the last page of each fact sheet under references. Fact Sheet content does not necessarily reflect the views of each or any Onondaga Lake Partnership member.

The Onondaga Creek Fact Sheets describe the current state of Onondaga Creek, based on a literature search conducted by staff scientists at Onondaga Environmental Institute. The Fact Sheets were used by the Onondaga Creek Working Group as an interactive planning tool in the development of the revitalization plan for Onondaga Creek. The goal of the OCRP project was to develop a community-based revitalization plan for the Onondaga Creek watershed, providing a guide for future development, water quality, and habitat improvements that can enhance environmental, social, and economic conditions along Onondaga Creek.

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onondaga creek
CONCEPTUAL REVITALIZATION PLAN

Onondaga Environmental Institute

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Geography

Onondaga Creek Fact Sheet

INTRODUCTION

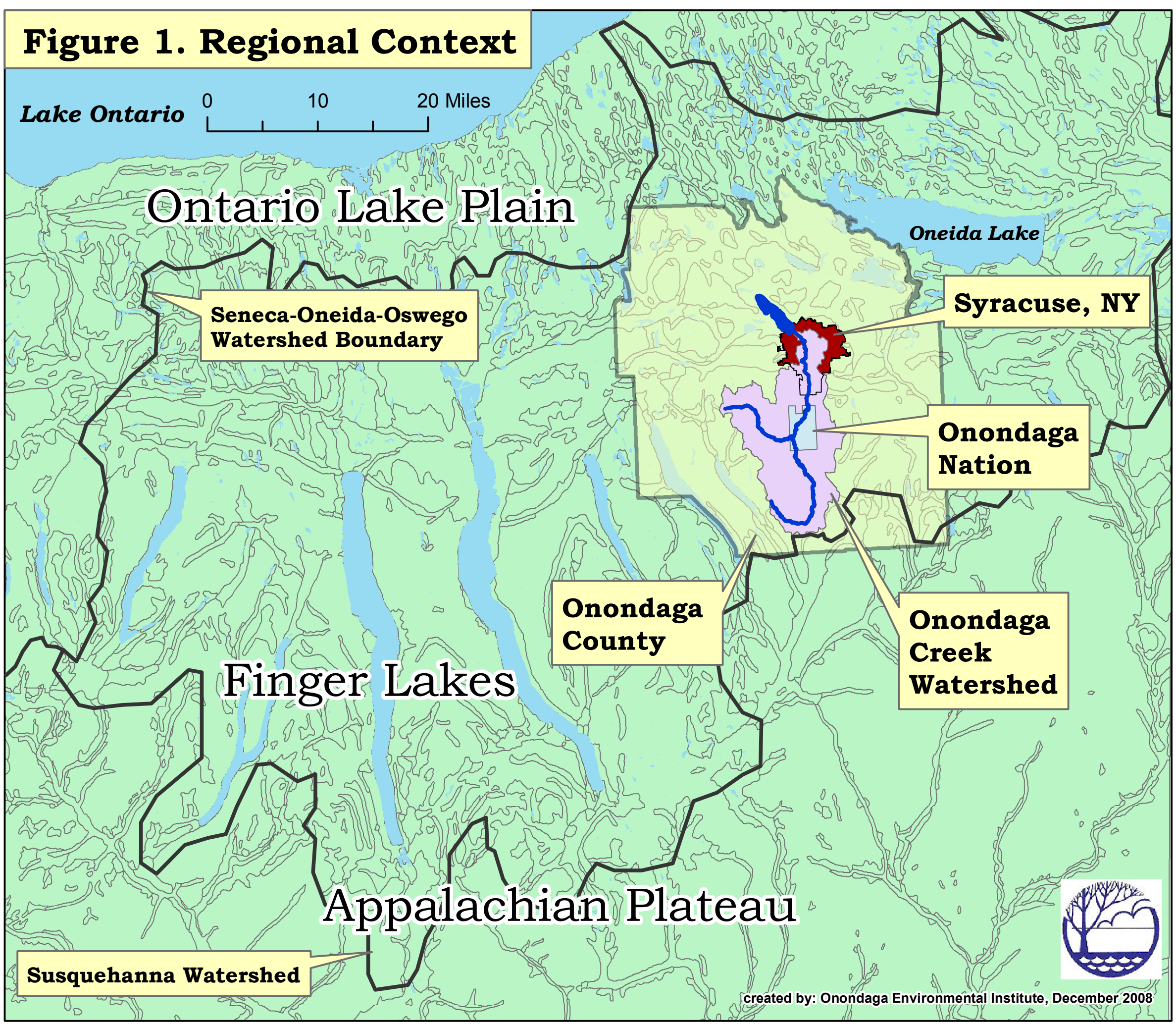
Onondaga Creek is part of the Seneca-Oswego-Oneida River basin. Two main branches of Onondaga Creek, one in Tully Valley and one in West Branch/Cedarvale, join near the Onondaga Nation border.

Watershed flow is generally northward towards Onondaga Lake.

Outflow from Onondaga Creek is nearly forty per cent of the water flowing into Onondaga Lake. (EcoLogic LLC, 2003) Onondaga Lake outflows to the Seneca River, which joins the Oneida River at the Three Rivers junction near Phoenix, NY, to form the Oswego River, a major tributary of Lake Ontario.

Major watersheds Lake Ontario, part of the Great Lakes system, outflows to the St. Lawrence River/St. Lawrence Seaway that empties into the North Atlantic Ocean. Small-scale shipping and recreational vessels can thus reach the mouth of Onondaga Creek from a vast region.

Political boundaries Centrally located in the watershed is the Onondaga Nation, which has a treaty relationship with the U.S.A. Surrounding the Onondaga reservation, the creek watershed is situated in Onondaga County, NY (Figures 1, 2, and 3).



FINDINGS

Creek Length Currently, the maximum creek length is estimated in a range of 27.1 to 27.4 miles (W. Coon, 2005) to 33.04 miles (USGS and USEPA, 2004). Historically the creek was much longer and more sinuous. In 1927, the section of the creek upstream (south) of Seneca Road (Turnpike) was said to have a "tortuous channel [of] about 28 miles (Syracuse, 1927)." The companion section from Seneca Turnpike downstream (north) to the outlet is currently (in 2006) around six miles. Due to the dynamic changes in meanders through relatively flat land, channel shape and length can change quickly in the non-engineered sections of the creek, so lengths should be viewed as approximate. This composite of at least 34 miles around 1927 is significantly longer than the current approximation of 27.2 miles. This suggests that projects that increased the creek depth and channeled its banks shortened its overall length. A GIS summation of measured small segments (Onondaga Environmental Institute analysis of data from USGS and USEPA, 2004) shows a creek length of 33.04 miles, which may reflect the greater sensitivity to meanders in the small scale measurements. Due to the sinuous pattern of the upland reaches, the creek's headwater near Bailey Rd. in Otisco, NY, is only about sixteen miles "as the crow flies" from the mouth at Onondaga Lake.

Tributaries Onondaga Creek has over sixty-six tributaries altogether. Over fifty of them are tributaries of the South and West branches (NYSDEC-DOW, 1996). The east fork has thirty-nine tributaries; the major ones include Emerson Gulf, Falls Creek in Rattlesnake Gulf, and Rainbow Creek. The west fork, which is technically a tributary of the main channel, has over eleven tributaries (NYSDEC-DOW, 1996), with two major ones being Peppermill Gulf and Pumpkin Hollow (see Figure 3). Downstream of the junction of the two forks, the main channel has sixteen identified natural tributaries (NYSDEC-DOW, 1996). The natural streams Hemlock/Kennedy Creek, Commissary Creek, and William Creek join Onondaga Creek inside the Onondaga Nation. Downstream of the Nation, the partially-covered (culverted) streams, Kimber Brook, Cold Brook, Furnace Brook, and some unnamed streams such as the former Town-Line Creek, join the creek within the City of Syracuse.

Table 1. Watershed Dimensions for Onondaga Creek

WATERSHED DIMENSIONS	METRIC UNITS	Ref	ENGLISH UNITS	Ref
Onondaga Lake Watershed	738 square km.		285 square miles	1
Onondaga Creek Watershed	288 sq. km		111 square miles	2
North –South maximum watershed width	30.7 km.		Eighteen miles	3
East-West maximum watershed width	16 km.		Ten miles	3
Onondaga Creek (Otisco to Onondaga Lake):				
Main Channel length, reported	44.2 km.	4	27.2 miles	5
Main Channel length, summed small segments (captures more detail of curves)	53.18 km.		33.05 miles	6
North Branch, main channel length, summed	25 km.		15.54 miles	
South Branch, main channel length, summed	28.18 km.		17.51 miles	
West Branch, main channel length, summed	15.43 km.		9.59 miles	7
Highest elevation in watershed, Dutch Hill			1879 ft.	
Highest tributary elevation, Dutch Hill			1760 ft.	
Headwater elevation, Bailey Rd., Otisco, NY			1483 ft.	8
Elevation at mouth at Onondaga Lake			363 to 365+ ft	9

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1 William Kappel, US Geological Survey. Personal communication. (2006)
2 US Army Corps of Engineers (1987) cited in Higgins.
3 Measuring tool at www.ongov.net GIS site
4 Onondaga County (2001)Ambient Monitoring Program Report.
5 Pers. Comm. W. Coon, USGS, Ithaca, NY.
6 Addition of stream stretches in USGS GIS
7 Addition of stream stretches in USGS GIS. This differs from other mapping in that the Pumpkin Hollow wetland is not treated as open stream
8 US Geological Survey, 1955 Otisco Valley Quadrangle.
9 New York State Barge Canal Bridge data. - http://www.canals.state.ny.us/

Figure 2. Major Subwatersheds

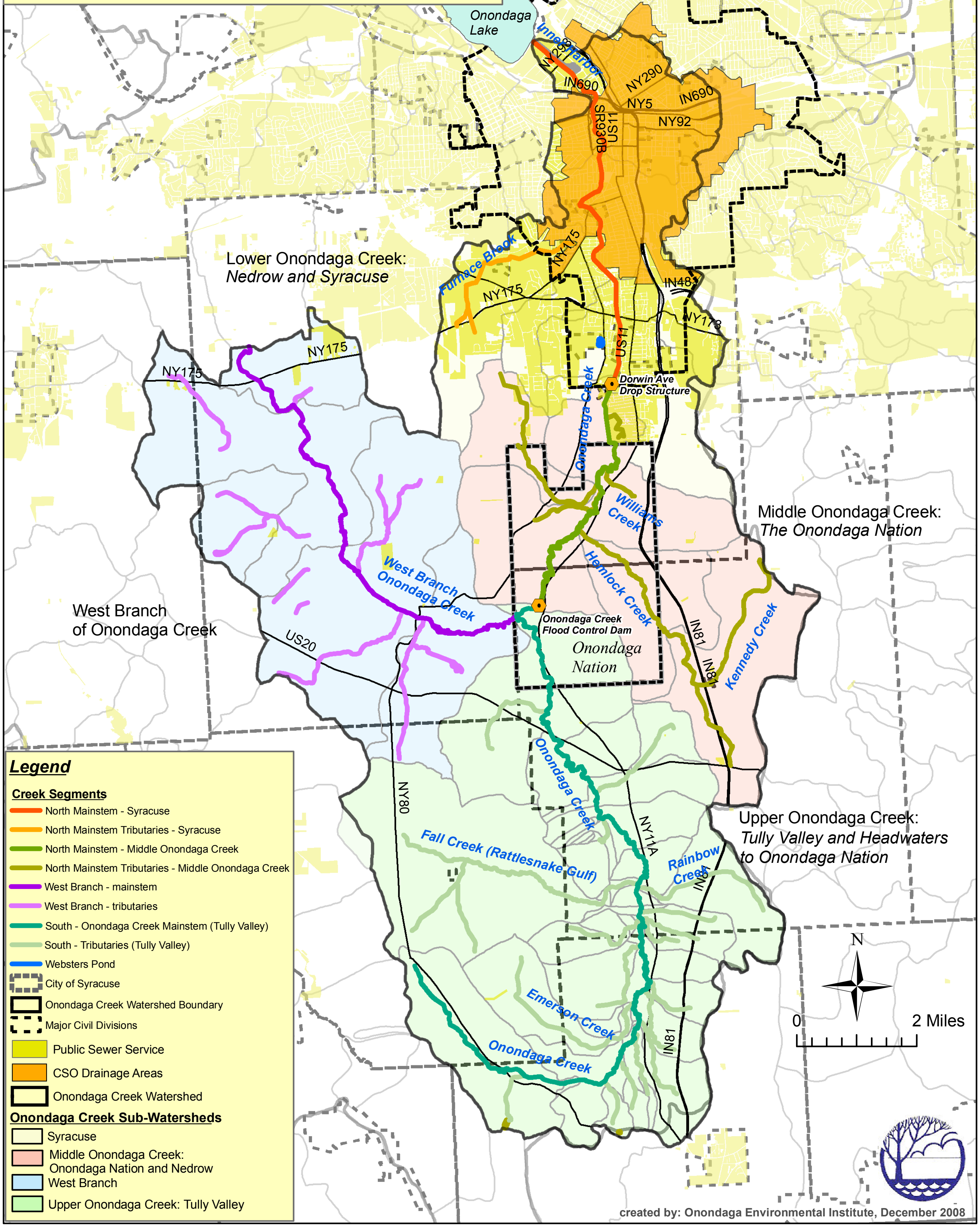
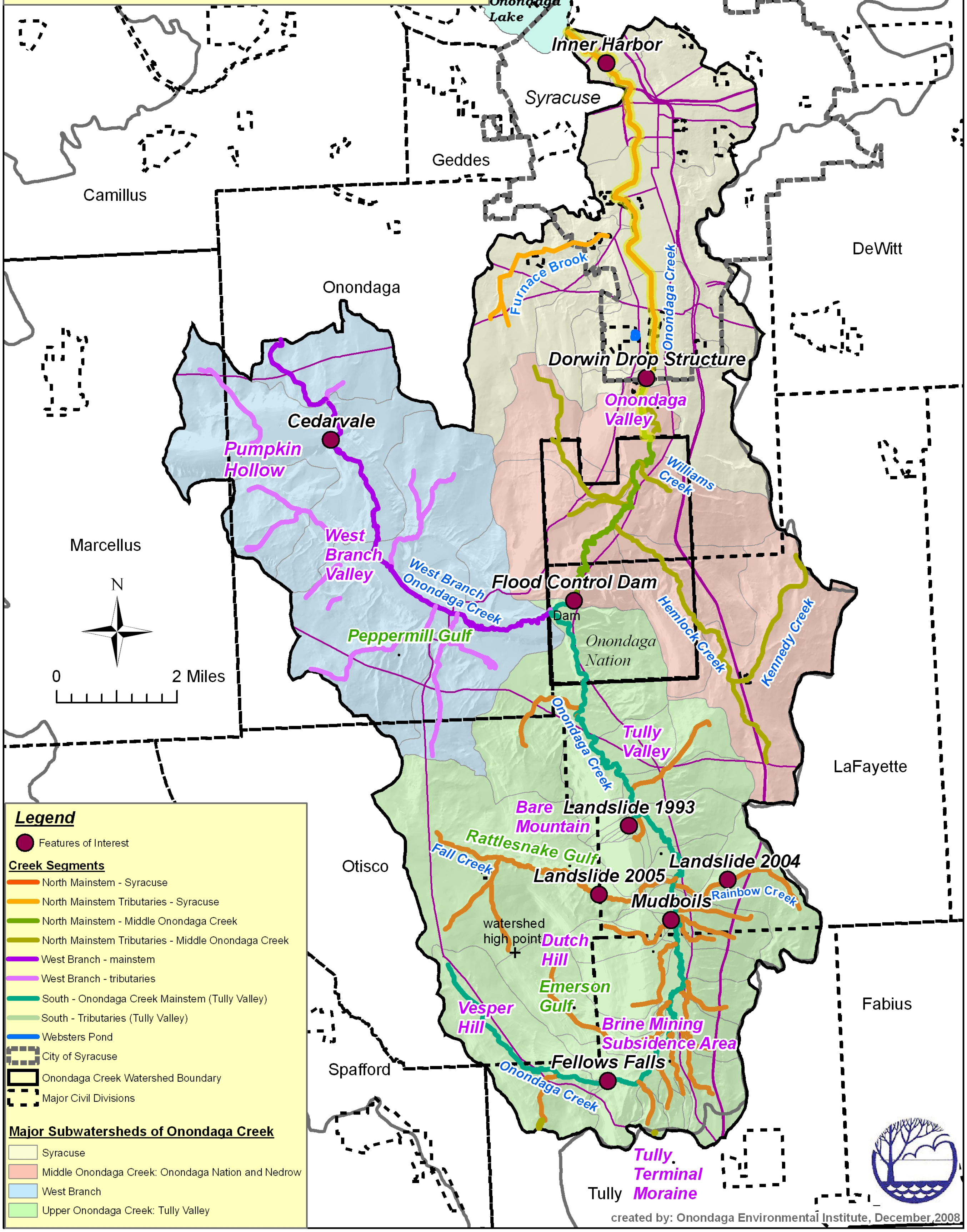


Figure 3. Features of Interest



The urban stretch (see Figures 2 and 3) of the main creek channel receives water from forty-nine overflow points in the urban sewer system (Onondaga Lake Improvement Project webpage, Aug. 9, 2007), approximately seven natural tributaries, and numerous bridge and road run off drains. The conversion of combined sewers to separated sewers is ongoing. More information is available at http://www.lake.onondaga.ny.us. In the city, several natural tributaries are routed underground and re-emerge as surface water at the main channel of the creek.

Sewers See Figure 2 that shows the extent of municipal sewers. The rest of the watershed has either septic systems or no constructed sanitation (NYSORPS, 2005).

Inner Harbor and the Barge Canal (New York State Canal Corporation) In Syracuse, much of the creek channel has been relocated since the initial settlement of the city in the early 1800s (Holmes, G.D., 1926). Circa 1867, the mouth of Onondaga Creek was reconstructed to the southwest of its natural outlet, at first to speed up sewage discharge to the lake (Bruce, 1891), and later further altered to develop a commercial barge harbor on Onondaga Lake (Whitford, 1906). Today, the Inner Harbor (Figure 3) is an inactive terminal of the New York State Barge Canal System (New York State Canal System, 2006). The Barge Canal system includes the Seneca and Oswego Rivers as far as the Port of Oswego on Lake Ontario.

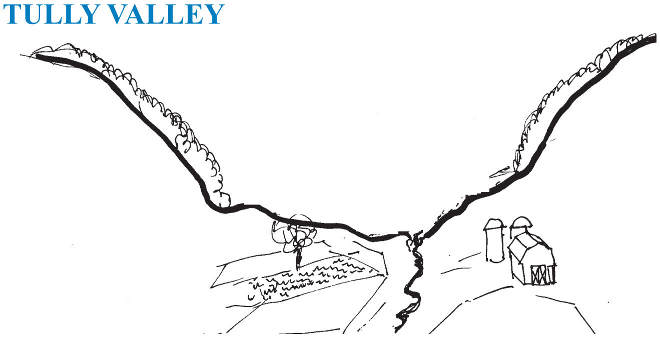
Hydrologic Location The New York State Department of Transportation closely regulates water levels in the Barge Canal sections of the Seneca, Oneida, and Oswego Rivers. On Onondaga Creek, a dam, channel sections constructed with increased flow capacity, and water monitoring gauges all function as part of a flood control plan for the creek that was developed to retain canal water levels while simultaneously preventing flooding in urban areas (Syracuse NY Intercepting Sewer Board. and G. D. Holmes [1927]).

Characteristic shape of the watershed Wide "bowl-like" watersheds tend to flood more than narrow "trough-like" watersheds. The Onondaga Creek watershed contains both features. Its major branches are trough-like, yet they join together to form a more bowl-like drainage basin. Drainage in steeply-sloped watersheds tends to be more rapid and transient, while shallow slopes contribute to water accumulation and slower removal.

In southern Onondaga County, the upland headwater of the creek is fed by steeply-sloped tributaries with waterfalls, rapid flow, and stream bank erosion, all characteristic of the hanging valleys in the Appalachian Plateau. The tributaries receive water from forested and agricultural uplands above the hanging valleys. The tributaries drop steeply, with some waterfalls, to the two main branches in the valley bottoms that join to form the creek's main channel. On the floors of the Tully and Onondaga Valleys, the water typically moves more slowly, forming natural meanders with a history of flooding. The bottoms of the two branch valleys and the main channel are on an ancient lake bed, (Kappel, W. M. and T. Miller, 2005) surfaced with silt loams and wetland soils (Hutton, 1977). On that relatively flat surface, the two creek branches join near the southwest border of the Onondaga Nation, through which the main branch meanders northward, passing through a flood control dam about 518 meters downstream of the junction between the two branches (Higgins, 2005). Downstream of the Onondaga Nation, an engineered, incised channel controls creek flow through urban areas in the Town of Onondaga and the City of Syracuse. The artificially deep and sloped channel was built to make the water run faster, as well as deeper, and thus reduce or eliminate floods in populated areas. The creek outlet is part of the Inner Harbor on Onondaga Lake, and located on the lake shoreline between the METRO sewage treatment facility to its west and Carousel Mall to its east.

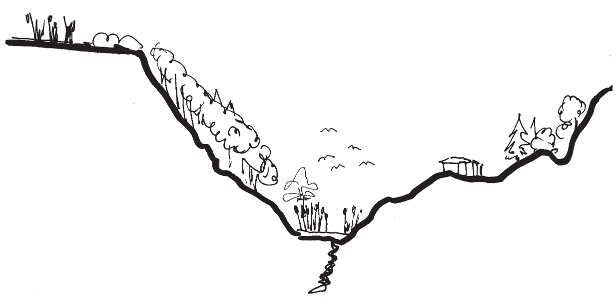
Four Land Use Areas in the Onondaga Creek Watershed (Figures 2 and 3) roughly correspond to four functional assemblages of subwatersheds. Sketches are cartoons, and not to scale.

TULLY VALLEY



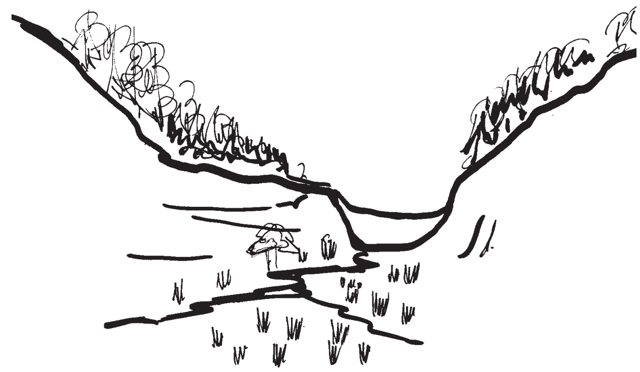
Tully Valley and its uplands contain the south (or east) branch of the creek. In the southern part of the valley, deep rich soil of the valley floor supports dairy farms and field crops, and in the northern part of the valley, fruit orchards and wetlands are adjacent to the creek. Valley walls are typically forested. At the southern end of the valley, the valley walls and bedrock beneath them contain fractures that resulted from the former brine well operations. North of the Valley Heads moraine, a section of the valley floor has sunk from the salt removal that occurred beneath it. The uplands of the Tully Valley have mixed use, with hill-top farms, exurban homes, patches of woodlot forest, apple orchards, and upland wetlands. Surface geologic features include the terminal glacial moraine at Tully, hills that are part of the Appalachian Plateau, mining land subsidence across the upper Tully Valley, active landslides in the Rainbow Creek and Rattlesnake Gulf tributaries, mudboils in the valley floor near Otisco Road, and infrequent landslides along the main valley's walls. Tributary streams fall steeply from forested hanging valleys, providing the cool water, oxygenation and gravelly stream bottoms that are appropriate for trout existence and in some cases, trout spawning.

WEST BRANCH/CEDARVALE



West Branch is located in a typically narrow valley, less than a half mile wide, with two wider areas of flat bottom land. The upper of the two flats is near Tanner Road and is now largely occupied by a golf course. The lower flat land is at the junction with the east branch and is part of the flood plain upstream of the Onondaga Flood Control Dam. The whole West Branch valley is series of natural wetlands, including an open pond that supports diverse wildlife near Red Mill Road. The uplands have dairy farms, apple orchards, woods, exurban housing, and perched wetlands. The headwater is in the Pumpkin Hollow wetland. Similar to the Tully Valley, the West Branch and several of its tributary streams are appropriate for trout, with some tributaries appropriate for spawning.

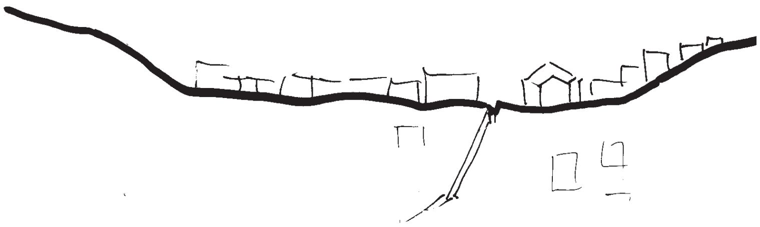
ONONDAGA NATION



Onondaga Nation is centrally located in the watershed, and includes part of the junction of the three valleys. At the nation's western boundary, west and south branches join to form the upper end of the Onondaga Valley channel. To the northeast, about a thousand feet downstream of the junction, the Onondaga Flood Control Dam is a massive structure over a quarter-mile wide with a conduit for stream flow through the east end of its base. About ten percent of the time, water accumulates behind the dam when stream flow is in excess of the conduit's capacity. A spillway for extreme flood events, located near the top of the east end of the dam, has not been used in the 57 years since completion of the dam in 1949. The dam's maximum retention basin (a constructed flood plain, made higher in elevation by the dam, and therefore more extensive than the pre-existing natural flood plain) includes the wetlands to the south and west. To the north downstream of the dam, the main channel of the creek meanders through bottom lands that include both wetlands and agriculture. Surface tributaries that join the creek inside the nation flow to it from several types of headwaters. From within the nation, springs from deep glacial sediments along the valley walls are typically sources of high quality water. Tributaries that originate outside the nation come from mixed sources of springs and upland wetlands located among suburban developments, farms and wood lots. These tributaries include Commissary Creek, Williams Creek, and Hemlock Creek, which is named Kennedy Creek upstream of the nation. The Onondaga Nation in general is more forested than the surrounding areas where agricultural fields and suburban development predominate.

Nedrow is the suburban section of Onondaga Valley and its uplands. The constructed creek channel begins in Nedrow at the southern boundary of Nedrow with the Onondaga Nation. The channel is typically widened and deepened, with several straightened sections that have grassy banks and no fencing. It is near to power lines, the inactive brine line, a former farm, a quarry and residential area. Nedrow is also part of the centrally located subwatersheds that join the creek within the Onondaga Nation.

CITY OF SYRACUSE



The City of Syracuse occupies the lowest section of Onondaga Valley and nearby uplands. The oldest part of the city, now a financial, governmental and cultural area, centers on a former wetland of the creek. To the east and west rise sloped valley walls with several carbonate-bedrock sourced natural springs[1] and tributaries located in forest "islands" among residential housing and local businesses. The City of Syracuse is on the edge of the Appalachian Plateau to the south, and the city includes the southern edge of Onondaga Lake in the edge of the Ontario Lake Plain to the north.

Before the city developed, the creek formed many meanders on the flat land, and frequently flooded the area. The creek bottom and banks have been redesigned to provide straight, smooth, and fast flow, with the capacity to contain most flows within its banks. Runoff from the cityscape is very rapid due to hard surfaces, little vegetation or soft ground, many slopes, and drains that minimize ponding. (See water quality and hydrology fact sheets)

In downtown Syracuse, with its skyscrapers, sidewalks and streets built over glacial and alluvial soils, historic creek tributaries, such as Yellow Brook in the Washington Street area, have been completely absorbed into the city sewer system. South of downtown, creek tributaries are open natural streams as they come down the slopes of the eroding escarpment of the plateau. Where the tributaries cross the valley floor towards the creek's main channel, they are covered over, and confined to culverts that pass under residential and commercial areas. An exception is the small stream from Dorwin Springs. It is exposed to light and only briefly culverted where it passes under an access road in the Kelly Brothers Memorial Park. Named surface tributaries include Kimber Brook, Cold Brook (formerly known as Peck Brook or Trout Brook), Hopper Brook (Harrison Brook), City Line Brook, and Furnace Brook. From the valley floor, the tributaries join the main creek channel via outflow pipes. With the exception of Dorwin Springs, the covered channels of tributaries receive some water from the city storm water sewers. (V. Esposito, 2006)

In the Onondaga Creek watershed, city storm runoff can bypass tributaries and reach the creek by two sewer pathways. The city storm sewers have direct outfalls to creek. Modified older combined sewers (in which storm flow mixes with sanitary sewage) discharge to the creek when high storm runoff overwhelms their capacity, typically after an inch or more of rainfall in a day.

The wide scoop shape of the lower Onondaga Valley watershed means that water from more natural tributaries on the rim of the basin may contribute an otherwise unexpected improvement in water quality (e.g. temperature) in the urban stretch of the creek main channel as it flows through Syracuse to Onondaga Lake.

1 Carbonate-bedrock springs occur in the Onondaga Creek watershed in the urban stretch, and alluvial fan springs occus in the West Branch Valley. Bands of carbonate springs extend along the west and east valley walls from Nedrow in the south to Furnace Brook/Elmwood Park in the north. A large number of smaller springs along the western valley wall tax the storm sewers capacity in wet weather. The larger springs in this area include (from south to north) Dorwin and Kimber springs, which formerly supplied drinking water to the southern part of the City, and Hopper Brook and Furnace Brook, which are similarly spring-fed. On the east wall, Rockwell Spring, with other springs and seeps, feed the Cold Brook (Peck Brook) tributary in the Valley section of Syracuse. In the West Branch valley, springs drain alluvial sand and gravel deltas that formed during deglaciation, and these springs may also receive ground water from the carbonate (Onondaga Limestone) bedrock (Winkley 1989, Syracuse NY and G. D. Holmes 1927, Kappel 2007).

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This fact sheet and additional information about the Onondaga Creek Revitalization Plan project can be found on the World Wide Web at www.esf.edu/onondagacreek/.

Hydrology

Onondaga Creek Fact Sheet

INTRODUCTION

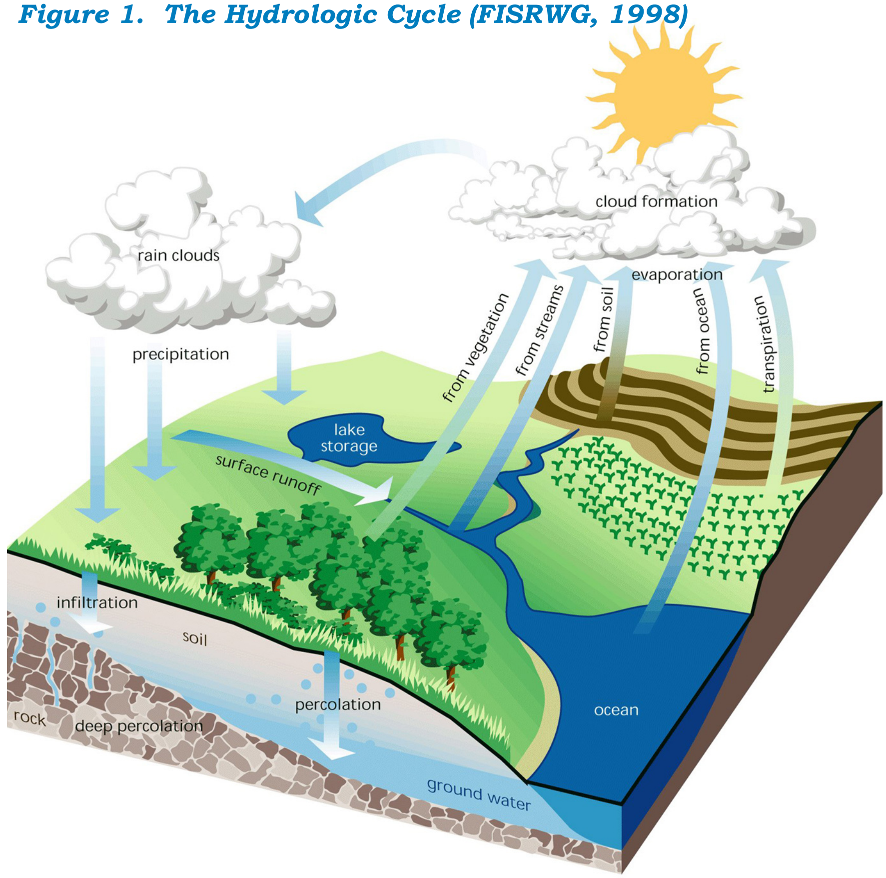
Water flowing in Onondaga Creek could have originated as precipitation within the last few minutes or as centuries-old groundwater. Onondaga Creek collects water from storm runoff, snowmelt, groundwater, and sewers.

Creek hydrodynamics are governed by the hydrologic cycle (Figure 1). Many factors affect water levels and flow rates in a stream: topography, soils and sub-soils, soil saturation, precipitation, water table height, evapotranspiration rates, temperature, and runoff (terms are defined below). Ultimately, weather patterns and land cover (such as forests, crops, lawns, buildings, or pavement) control the quantity and quality of the water in the creek.

Definitions:

- **Precipitation:** rain, sleet, hail, dew, and snow.
- **Evapotranspiration (ET):** sum of evaporation from open water and surfaces, and transpiration from plants.
- **Runoff:** water originating as precipitation, snowmelt, or irrigation water which finds its way into local waterways. Run off is often expressed as the depth to which a drainage area would be covered if all runoff were uniformly distributed over it (USGS glossary).
- **Groundwater recharge:** the precipitation which is not lost via ET or runoff, and thus seeps into groundwater. This replenishes groundwater which is lost as seepage into local waterways.
- **Hydrodynamics:** water movement and the forces it exerts on suspended materials and ground surfaces.

Figure 1. The Hydrologic Cycle (FISRWG, 1998)



Central New York precipitation averages about 40 in/yr, with a range of 27 to 58 inches (Hancock International Airport data, 1951-2004). The rate of evapotranspiration is about 19 in/yr, leaving approximately 20 in/yr for annual runoff (Randall, 1995).

The primary factor controlling runoff is ground cover. Vegetated areas intercept most precipitation, while impervious surfaces (roads, parking lots, roofs) retain almost none.

Typical runoff rates are:[1]

- Forest cover 5%
- Turf (grass) cover 5 – 30%
- Impervious cover 95%

1 Center for Watershed Protection, 2005; Appendix A. Values shown are derived from actual measurements.

Topography controls the speed of water in streams. Water runs down steep slopes faster than shallow slopes. Thus, a stream tends to drain quickly at the headwaters while accumulating water in flatter downstream reaches.

Measuring flow in a stream Stream flow (a.k.a. "discharge") measurements are typically made at gaging stations operated by the US Geological Survey (USGS). Discharge at each station is calculated by measuring current velocities (ft/s) across the width of the stream, and multiplying by the cross-sectional area (width x depth, ft^2). The resulting volumetric flow is expressed as cubic feet per second (cfs) or cubic meters per second (m^3s^{-1}). After numerous manual measurements over a wide range of flows at a given location (rating curve between stage [depth] and discharge [flow]) can be established. The flow is reported based on automatic recordings of the stream depth ("gage height").

Historically, flows were recorded by the city of Syracuse at Temple Street (1901-1939?) and by the USGS at Atlantic Ave/Ballantyne Ave (1939-1949). Flows in Onondaga Creek are currently recorded continuously at three locations (see Table 1).

Table 1: USGS gaging stations on Onondaga Creek

Name	USGS Number[1]	Drainage area (sq. miles)	Period of record	Gage datum[2] (ft.)
Route 20, near Cardiff	04237962	33.9	Oct.1, 2001 – present	unknown
Dorwin Ave, Syracuse, NY	04239000	88.5	May 16, 1951 – present	414.2
Spencer Street, Syracuse, NY	04240010	110.0	Sept. 1, 1970 – present	362.3

1 Real-time and historical data are available at http://waterdata.usgs.gov/ny/nwis

2 Gage datum is the elevation, in feet above sea-level, of the bottom of the stream channel.

Fluctuations in flow Variation of flow over time is shown in a hydrograph, with time-scales ranging from hours to years. In general, streams which receive primarily surface runoff tend to be highly variable or "flashy." Hard surfaces and artificial drainage systems (e.g. storm sewers) increase "flashiness."

FINDINGS

The Onondaga Creek Watershed

Characteristics

- 114 square miles (301 km^2) Endreny (2004)
- Elevation at headwaters: 1445 ft (587 m) Endreny (2004)
- Elevation at outlet (Onondaga Lake): 363 ft (111 m) Effler (1996)

An exaggerated profile of the creek is shown in Figure 2. Selected tributaries--Hemlock Creek, Kennedy Creek, Rainbow Creek, Fall Creek in Rattlesnake Gulf (R1, R2, R3), and an unnamed tributary in Emerson Gulf are also shown.

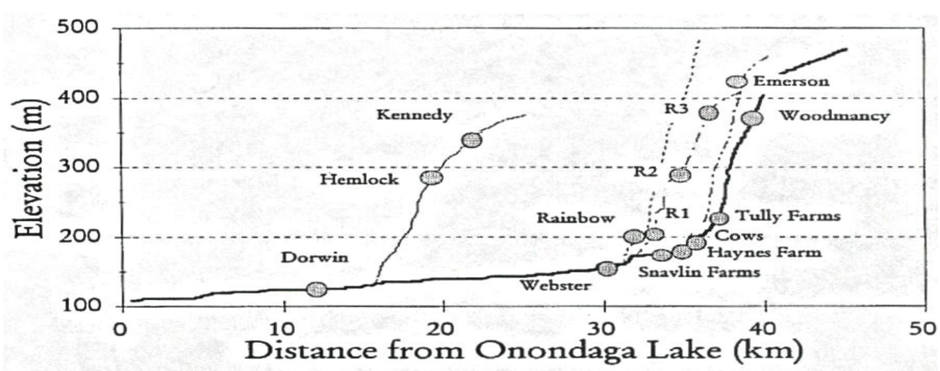


Figure 2. Stream profile of Onondaga Creek and selected tributaries, showing elevation as a function of distance from Onondaga Lake. The vertical exaggeration is approximately 70x. Source: Danehy (1994). Site labels Dorwin, Webster, Tully Farms, and Woodmancy refer to road crossings; Snavlin Farms, Haynes Farm, and Cows are other sampling sites along the mainstem of Onondaga Creek.

Table 2: Precipitation at weather stations in and near the Onondaga Creek watershed

No.	Location	Period of record	annual average precip., in.[1]
1.	Syracuse Hancock Airport, DeWitt, NY	1929 – present (historical data since 1896)	40.0
2.	City of Syracuse Water Deptartment, Skaneateles, NY	1948 – present (historical data since 1893)	41.5
3.	ESF Heiberg Forest, Cortland County, NY	1966 – present	45.8
4.	Mudboil site, Otisco Road, LaFayette, NY	1991 – present	31.9
5.	Route 20 gaging station, near Cardiff, Town of LaFayette, NY	2002 – present	not calculated
6.	Metro. sewage treatment plant, Syracuse, NY	2000 – present	not calculated
7.	SUNY – ESF campus, Syracuse, NY	2000 – present	not calculated

1 Sources: NOAA (2002) and Coon (2006). 1971-2000 data used for computing annual averages at locations 1-3. All available data used for site #4.

Climate and Precipitation

Precipitation data are collected at a number of locations near (#1-3 in Table 2) and within (#4-7 in Table 2) the Onondaga Creek watershed.

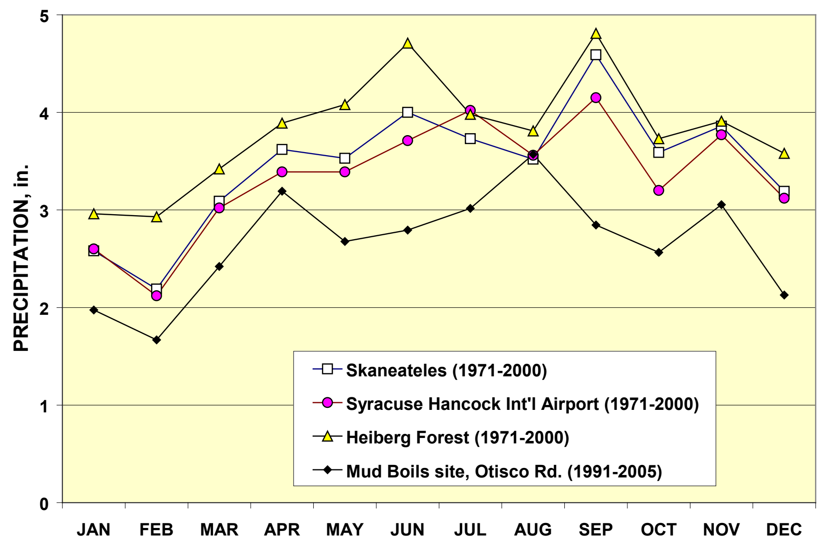


Figure 3: Central New York seasonal trends in precipitation. Sources: NOAA (2002) and Coon (2006)

Long-term (> 30 years) precipitation data for central New York are available from sites #1-3. Annual averages for these sites, listed in Table 2, range from 40-46 inches. In contrast, the Tully Valley (site #4) gets consistently less precipitation through the year (annual average ~32 in). Although precipitation varies between sites, monthly averages, depicted in Figure 3, follow a consistent pattern. In general, precipitation is relatively constant across the seasons, although monthly averages dip in February (1.6-3 in) and crest in June and September (2.8-4.8 in).

Storm events An important rainfall parameter is the size of a storm event. Large and intense rains can cause severe erosion, damage to roads and bridges, and flooding. The probability of a large storm occurring is defined by the term "recurrence interval." For example, a two-year storm is one which occurs, on average, once in a two-year period. This term should not be construed as meaning "every two years." One could have three two-year storms landing in one year, followed by five years of no such storms. That would fit the definition, since three storms had occurred in a six-year period.

Table 3 shows how the intensity of rainfall, based on general rainfall patterns, increases as the probability of occurrence decreases. Note that these predictions are based on pre-1964 data. Recent shifts in climate are therefore not taken into account. Climate change models suggest that the eastern U.S. may become wetter and more prone to flooding (Harder, 2005).

Table 3: Central New York rainfall over a 24-hour period, at select recurrence intervals.
Note: Values are interpolated from maps in the Rainfall Atlas, TP-40 (National Weather Service, 1964).

Recurrence Interval	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
Number of events in a 100-year interval	50	20	10	~4	~2	~1
Rainfall amount (in)	2.6	3.2	3.8	4.5	4.8	5.2

Stream Flow

Changes in flow throughout the year Figure 4 shows rainfall recorded at the Metropolitan sewage treatment plant (downward peaks) plotted against a year-long hydrograph for Dorwin Ave (upward peaks). The creek's base flow is indicated by the background level between the peaks. From late fall to early summer when vegetation is mostly dormant and the ground may be frozen, base flow was high, and the creek responded rapidly to rain events. The creek's rapidly rising and falling flows are evidenced by tall, narrow peaks. From summer thorough early-mid fall, rainfall was largely intercepted by vegetation, evaporated, or percolated into the ground. Consequently, base flows were low and flow response to rainfall was minimal.

Figure 5 depicts typical monthly average flows at the three USGS gaging stations along Onondaga Creek. Flow increases from upstream to downstream, as evidenced by the flow increase for every month, beginning at Route 20, to Dorwin Ave, and finally to Spencer Street. Note also that the flow pattern in Figure 4 mimics that in Figure 3. Stream flow is maximum in the spring due to the release of stored water from snow melt, high water table, and saturated soil conditions. Furthermore, vegetation has not yet leafed out, and temperatures are low, so evapotranspiration is minimal. In summer and early fall, exposed leaves provide large surface areas to collect and store water on or within plants. Warm temperatures promote both evaporation and transpiration of water. Hence, runoff is minimal, water tables drop, and stream flow is minimal. As weather turns colder, evaporation diminishes and transpiration shuts down. Thus, moisture accumulates in soil, the water tables rise, and runoff increases. Runoff reaches a maximum in December because temperatures are not consistently below freezing, and less precipitation is stored as snow compared to January and February.

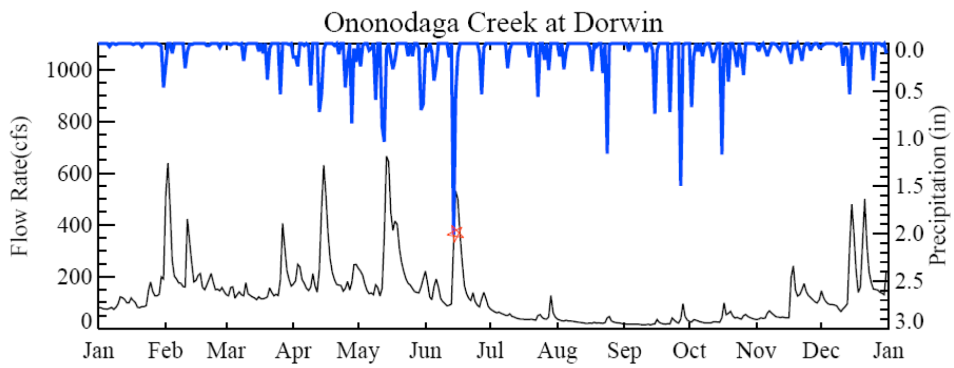


Figure 4: Daily streamflow at Dorwin Ave. (upward scale) and rainfall, as recorded at the Metro sewage treatment plant (downward scale) for calendar year 2002.

Source: Ecologic et al. 2003; Appendix 4

Peak Flows Maximum flows generally occur during storms, but can also be caused by rapid melting of snow on the ground. For example, following a heavy snowfall in March 1993, warm weather caused rapid melting and widespread flooding. The maximum flow during a single year is the peak annual discharge. Annual peaks, as recorded at various gaging stations over the past century, are shown in Figure 6.

The highest flow, 6000 cfs, occurred in 1920, the result of a combination of rain on snow (Amos *et al.*, 1927). Forest cover was at a low point at this time, so there was little vegetation to intercept rainfall (see below). This flood caused considerable property damage (see Flood Control Fact Sheet). Since construction of a flood control dam in 1947-48, the highest flow recorded was just over 4000 cfs at Spencer Street. Stream gage monitoring at the dam show that the dam has reduced peak flows in the city of Syracuse (see Flood Control Fact Sheet). It should be noted that during the period 1925-1980, substantial reforestration occurred in Onondaga County. This would also be expected to substantially reduce peak flows. Other factors, such as increased urbanization and changing weather, make a quantitative comparison of pre- and post-dam conditions nearly impossible.

- varying precipitation amounts,
- increasing temperatures,
- reforestation of rural areas, and
- urban expansion.

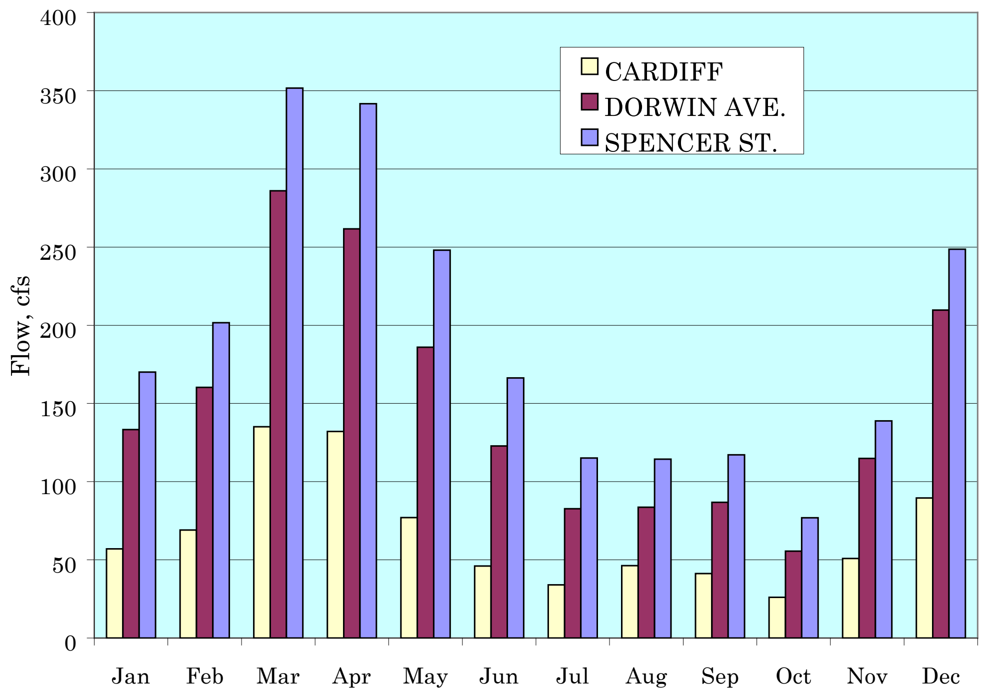


Figure 5: Monthly average stream flows at 3 USGS gaging stations on Onondaga Creek: Cardiff (Route 20), Dorwin Ave, and Spencer Street, for the period Oct. 1, 2001 to Sept. 30, 2004

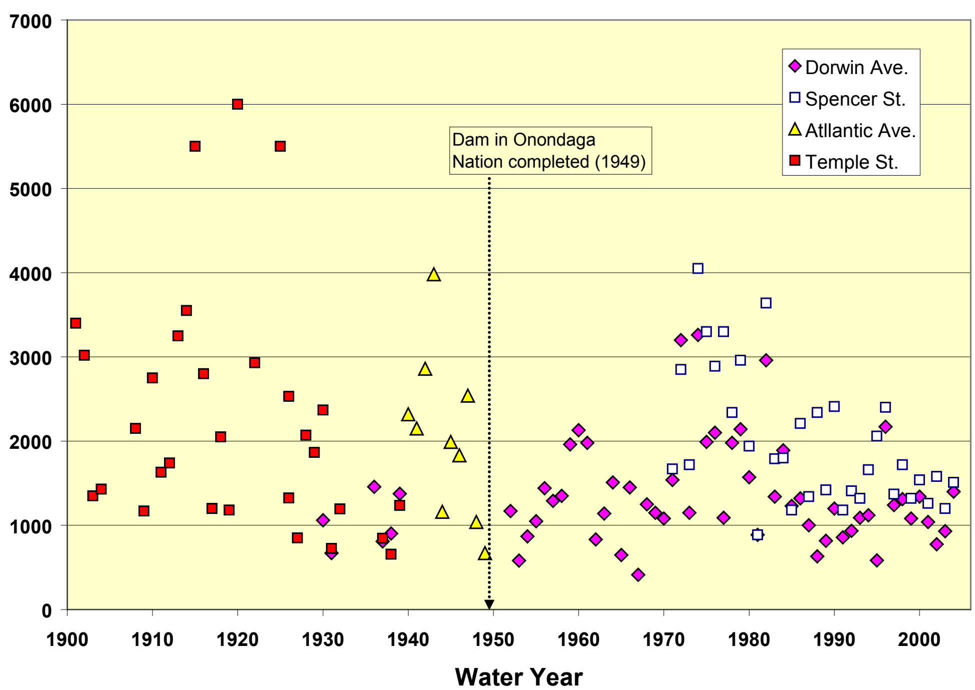


Figure 6: Peak flows observed in Onondaga Creek, at 4 gaging stations, all in Syracuse, NY

Note: The record prior to 1950 may be incomplete due to missing records.
Sources: Amos et al. 1927; USGS on-line data base http://waterdata.usgs.gov/ny/nwis; City of Syracuse, gaging data.

The probability of a high flow occurring can be predicted using statistical analysis (see Table 4). This is similar to prediction of a large rainfall event: historical data are compiled and fit to a probability curve. Extreme events, like 25-year or 100-year peak flows are extrapolated from the historical record. The USGS, which provides official estimates of peak flows, cautioned that the values presented in 1990 (Table 4) were not reliable due to changing conditions in the watershed.

Peak flows are analogous to extreme storms, but they are not synonymous. A 5-year storm event does not directly translate to a 5-year high-flow event. While a storm can be regarded as a relatively random event, there are numerous additional factors which affect the size and duration of a peak flow, including:

- time of year (during warm weather, trees intercept and transpire precipitation),
- prior conditions, such as
    - saturated soils
    - snow cover,
- distance of rainfall from stream outlet, and
- the presence of drainage structures in the storm area.

The 100-year peak flow is of special significance because this is used by the Federal Emergency Management Agency (FEMA) for delineation of flood-prone areas where flood insurance is required. High flows are associated with high water levels and swift currents. Photos of Onondaga Creek at high flows during the past two years are shown in Figures 7 and 8 below.

Table 4: Flood frequency distribution for Onondaga Creek

Sources USGS (1990) and Higgins (2005)

	Dorwin Ave (cfs)		Spencer St. (cfs)
	USGS1	Higgins[2]	USGS[1]
Years of data: / Frequency	1952-1988	1952-2004	1971-1988
2-yr	1360	1250	2250
5-yr	1980	1800	3100
10-yr	2380	2190	3600
25-yr	2880	2700	4160
50-yr	3250	3100	4540
100 -yr	3600	3510	4890

1 USGS, letter from J.B. Campbell, USGS Water Resources Div., Ithaca NY to Thomas Dussing, Calocerinos & Spina (Jan. 17, 1990). USGS cautioned that the data did not meet the assumptions necessary for a valid statistical analysis due to "extensive …urbanization and the construction of a reservoir that appreciably alters flood flows."

2 Higgins (2005), p. 20; Table 6.

Figure 7. Onondaga Creek at pedestrian bridge upstream of Spencer Street on July 12, 2006, about 1pm.

Note: Flow ~1100 cfs, and depth = 5.7 ft. The peak flow occurred at 5 pm with a flow of 2230 cfs (a 2-year flood).

Figure 8. Creek at Dorwin Ave gage station, April 5, 2005

Note: Average flow on this date was 1090 cfs. Gage height was approx. 4.3 ft.

Short-term changes Stream flow changes quickly in Onondaga Creek, as illustrated by the three hydrographs shown in Figure 9. These hydrographs reflect a moderate rainstorm on July10th – July11th and a large rainstorm on July 12th, 2006.

Anatomy of a rain event: the July 10-11, 2006 rain storm at Cardiff

- At Otisco Road (mud boil area), it begins raining about 10pm on July 10th. 0.48 inch falls during the first hour; another 0.06 inch during the next two hours. Total = 0.54 inch
- Creek starts rising almost immediately.
  - Base flow = 31 cfs
  - First increase (0.7 cfs) noted at 10:30pm
  - Maximum flow (54 cfs) at 4:15-4:45 am, July11th
  - Returns to almost base flow (32 cfs) by 2 am, July 12th
- Total volume discharged (above base flow) = 710,000 cubic feet.
- It is difficult to know how much rain fell across the watershed upstream of Route 20 without analyzing meteorological radar data.[2] As a crude estimate, one could assume 0.54 inch fell across the whole drainage area. On this basis, about 42 million cubic feet of rain fell during this one storm, of which <2% was observed in the creek at Route 20.

General observations: July 10 - 11 and July 12 storms

- Stream flow at Spencer is very "spiky." This is due to the urban character of the watershed; in particular the presence of CSOs (Combined Sewer Overflows) and storm sewers which empty into the creek
- Stream flow at Dorwin exhibits a normal hydrograph under moderate flow conditions (first storm), but shows the influence of the upstream dam during the second storm. Flow does not return to pre-storm conditions for an extended period of time because water is stored behind the dam. This effect is also seen at Spencer St. Dorwin does not show sharp spikes since it is upstream of nearly all urban drainage.
- Stream flow at Cardiff (Route 20) exhibits normal hydrographs during both storms.

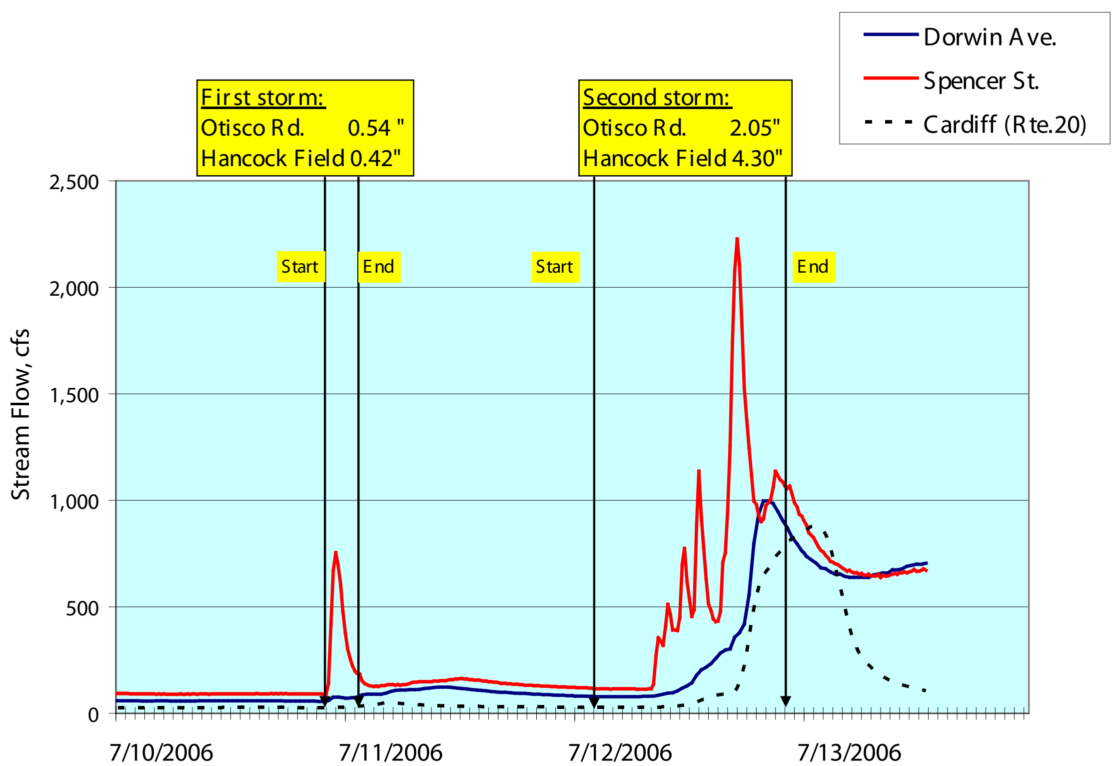


Figure 9. Hydrographs from Onondaga Creek at Cardiff, Dorwin Ave, and Spencer Street

Source: USGS web site for stream flow data: http://nwis.waterdata.usgs.gov/ny/nwis/

2 Radar data from the NEXRAD station in Binghamton, NY can be used to track precipitation over the Onondaga Creek watershed. However, this requires performing a considerable amount of data analysis.

Human Interventions That Affect Hydrology

Land use Originally, the Onondaga Creek watershed was almost completely forested. Based on surveys done in the 1790s of the Central New York Military Tract, Marks and Gardescu (1992) conclude that over 97% of the area was forested. Clearing for European farms, settlements and the salt industry commenced in the early 1800s (Nyland *et al.*, 1986; Sly, 1991). Nyland *et al.* (1986) compiled a series of historical sources to conclude that, by 1855, only 23% of Onondaga County was covered by forest. Deforestation continued such that, by 1925, forest cover was reduced to 9%, dipping to a low of 8% in 1930. Nyland *et al.* attributed the clearing of land cover in the early 1900s to expansion of grazing pasture for dairy farms. Since 1930 forest cover has increased, reaching 40% of land area in Onondaga County by 1980 (Nyland *et al.*, 1986).

Much of the city of Syracuse—in particular downtown and the Onondaga Creek valley—was historically a wetland. Subsequently, it was drained and transformed into an urban landscape with many impervious surfaces. Hence, runoff rates are high in the northern part of the watershed. Current land usage in the watershed is, from south to north:

- mixed (deciduous and evergreen) forest,
- fruit orchards and other agricultural lands, and
- residential, commercial, and industrial usages.

As a result, the quantity of water produced per unit land area increases dramatically as one moves from south to north through the watershed.

Sewers and drainage In rural areas, drainage tiles were once commonly used to drain agricultural lands. They are now only occasionally used where drainage is difficult. Drainage tiles help promote the movement of rainfall to the creek, once it percolates through the overlying soils.

The northern portion of the watershed, including Nedrow, other parts of the Town of Onondaga, and Syracuse, are drained with a complex set of sewer systems. These consist of:

- separated sewers (Town of Onondaga, including Nedrow, and Syracuse south of Ballantyne Ave) Storm water is conveyed directly to Onondaga Creek.
- combined sewers (Syracuse north of Ballantyne Ave) Storm water is combined with wastewater. During small rain events, all water is conveyed to the Metro sewage treatment plant. During medium and large rain events, a fraction of the combined sewage (which is mostly storm water) spills into the creek.

During rain events in the northern part of the watershed, storm water is quickly discharged to the creek, causing sharp spikes in creek flow downstream. When precipitation exceeds 0.20-0.5 in/hr (6-20 mm/hr), CSOs are triggered, quickly discharging additional storm water and sewage into the creek (S. Martin, pers. comm.). This was shown previously in the hydrograph for the Spencer Street gaging station during the two rain events in July 2006 (see Figure 9).

Channelization The lower 8 miles of Onondaga Creek has been completely re-channelized, extending from its mouth at Onondaga Lake, through Syracuse, to the northern boundary of the Onondaga Nation (Calocerinos & Spina, 1990; USGS maps). In addition, the course of the creek up and down-stream of the flood control dam has been heavily altered (see Flood Control fact sheet). Physically, the creek channel has been altered from a relatively shallow, meandering one to one which is much straighter and deeper (incised). While this has had little effect on the hydrology of the upper, rural, parts of the watershed, it has significant effects on the downstream sections. These impacts include:

- possibility of flooding is greatly reduced,
- the passage of water downstream is accelerated, and
- water currents are faster.

As a result, water flow through Syracuse is more like that of an open pipe than a natural stream. There are few, if any, opportunities for deposition of suspended sediment. Also, peaks in the hydrograph continue downstream with little change since there are no areas for water to spread out, such as in a natural floodplain or wetlands. The danger of drowning in the creek is greatly increased due to the strong currents and narrow channel.

Dams The flood control dam on the Onondaga Nation (see Flood Control fact sheet) acts a regulating valve on stream flow. The dam contains an underflow pipe which limits flow downstream. Water starts backing up behind the dam at a flow of ~250 cfs (7 m^3/s). As the water depth behind the dam builds, the flow through the pipe increases to a maximum of 1,270 cfs (36 m^3/s)[3]. This effectively reduces peak flows which could emerge from the Tully Valley and West Branch, such that the hydrograph is "flattened" and spread out over a longer time period. As a consequence, the area upstream of the dam, up to 860 acres (2.43 km^2) of forested lands largely in the Onondaga territory, is subject to flooding.

The drainage area above the dam is 67.7 square miles, which represents 61% of the entire watershed. Much of this area is either forested or agricultural, so runoff rates are much lower than for the downstream areas.

IMPLICATIONS

Land use has an enormous impact on the amount of runoff reaching the creek. Forested watersheds produce about one-tenth as much runoff as urban watersheds. Agricultural and suburbanized areas also produce more runoff than forests. Therefore, control of runoff, and consequently flooding, can be reduced through land-use practices and zoning laws that emphasize maintenance of existing forest canopy, planting trees, limits to urban sprawl, and best management practices on farms.

The speed that water reaches the creek depends on a variety of factors, some of which are under human control:

Factor	Effect
planting and maintaining existing vegetation	slows runoff
impervious surfaces	accelerates runoff
removal of drainage tiles	slows runoff
stormwater and CSO detention	slows runoff
sewer separation (without detention)	accelerates runoff

Peak flows, which are the cause of flooding, are controlled by the combination of runoff speed and volume. Peak flow, with the attendant risk of flooding, drowning, increased pollutant loads, and ecological impacts, can be reduced by

- reforestation,
- use of pervious rather than impervious surfaces,
- limiting urban and suburban development,
- maintaining or constructing wetlands,
- eliminating use of drainage tiles, and
- storm water detention.

By judicious selection of those factors which decrease runoff, potential for downstream flooding can be reduced. In particular, the detention of stormwater and combined sewage in Syracuse would be very effective in reducing the sharp peak flows which are seen at Spencer Street. Retention and detention methods include in-line storage, such as the Erie Blvd. Storage System, constructed wetlands, and rain barrels. Green strategies which eliminate storm water by evaporating or precolating runoff include green roofs, rain gardens, urban trees, and permeable pavement (Stoner, Kloss and Calarusse, 2006).

The flood control dam and downstream channelization effectively reduces flooding in Nedrow and Syracuse, but increases flooding upstream of the dam. Also, the dam and the Dorwin drop structure act as barriers for upstream movement of fish (see Fish and Aquatic Habitat Fact Sheets). Artificial stream channels have negative impacts on stream ecology, due to loss of natural habitat diversity and increased water velocity (FISWRG, 1998).

3 The dam also has an overflow weir which would come into use only after the 18,200 acre-feet (22.5 million m^3) reservoir behind the dam was filled to capacity. This has never happened since the dam opened in 1949.

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Sources of Data

NOAA, National Climatic Data Center

1. Annual precipitation at Hancock airport
2. Monthly precipitation at Hancock airport
3. Monthly precipitation, temperature climate normals (1971-2001) for

a. Syracuse Hancock Airport, in the Town of DeWitt

b. City of Syracuse Water Department, in Skaneateles

c. ESF Heiberg Forest, in Tully

USGS

1. Daily precipitation at
    - a. Otisco Road (1991-2005)
    - b. Route 20 (2002-2005)
2. Average daily discharge at
    - a. Near Cardiff (2002-2005
    - b. Dorwin Ave (1951-2006)
    - c. Atlantic Ave (1940-49)
    - d. Spencer Street (1970-2006)
3. Annual and monthly mean streamflow –
    - a. Near Cardiff (2002-2005)
    - b. Dorwin Ave (1951-2004)
    - c. Spencer Street (1970-2004)
4. Instantaneous streamflow

    Can be downloaded from USGS NWIS site

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The Onondaga Lake Partnership (OLP) sponsors the Onondaga Creek Revitalization Plan project with funds from the U.S. Environmental Protection Agency. Visit www.onlakepartners.org for more information about the OLP.

This fact sheet and additional information about the Onondaga Creek Revitalization Plan project can be found on the World Wide Web at www.esf.edu/onondagacreek/.

Water Quality

Onondaga Creek Fact Sheet

INTRODUCTION

Water quality includes a wide variety of parameters that environmental scientists use to measure the "health" and character of natural waters. Water quality technicians, scientists, and citizens make physical and chemical measurements, including:

- temperature
- dissolved oxygen
- salinity (specific conductivity; total dissolved solids)
- alkalinity and pH
- suspended solids and turbidity
- hardness (calcium and magnesium)

With the exception of hardness, each of the above is discussed in a Fact Sheet to follow. Hardness is simply the sum of calcium and magnesium ions; both are components of salinity.

More specific measurements can be made of both dissolved and particle-bound substances. While too numerous to list, the more important of these include:

- major ions (e.g. chloride, sulfate)
- nitrogen species (ammonia, nitrate, organic nitrogen)
- various forms of phosphorus
- trace metals (e.g. copper, iron)
- trace organic chemicals (e.g. pesticides, PCBs, herbicides)

Concentrations of these substances cover an extremely wide range, from part-per-trillion levels (e.g. dissolved mercury) to part-per-thousand levels (e.g. chloride ion). The major ions are addressed in the Fact Sheet on salinity, while nitrogen and phosphorus are discussed at length in individual Fact Sheets. Trace metals are discussed in a section on regulatory compliance in the Summary Fact Sheet. Organic chemicals have been omitted due to the absence of data.

Finally, pathogenic micro-organisms can make a waterbody unsuitable for recreation. These are commonly measured through the use of indicator bacteria, such as fecal coliforms and enterococci, as discussed in the Pathogens Fact Sheet.

Water quality investigations

Many organizations and individuals have collected a large body of water quality data from Onondaga Creek. Water samples are predominantly collected manually. Sampling sites are shown in Figure 1. The great majority of sampling effort has been concentrated in the urbanized lower section of Onondaga Creek. Table 1 summarizes data collected during the period 1988-2004. Data for the middle portion of the creek (Onondaga Nation) are limited to a study conducted by Upstate Freshwater Institute over the period July 2002 – May 2003. USGS has conducted, and continues to conduct, a number of investigations in the Tully Valley. Very few data exist for the West Branch of Onondaga Creek sub-watershed.

In addition, huts with automated data collection equipment have been established at three locations along the creek (Table 2). Each of these automated samplers is associated with a USGS gaging station.

In the Fact Sheets that follow, the primary sources of data are:

1. Onondaga County monitoring program for years 1993-2004
2. Onondaga Nation Monitoring Program (July 2002 - May 2003)
3. U.S. Geological Survey water quality data (1987 – 2002), and
4. A detailed study of phosphorus conducted in 1989-1990

Secondary sources of data include investigations by graduate students, and citizen-based monitoring efforts (Project Watershed).

Table 1. Major Sample Collection Efforts in Onondaga Creek.

Stream Reach	Time period	Locations	No. of samples	Investigating organization
LOWER ONONDAGA CREEK: Nedrow and Syracuse	1970? –1998 2000-present	Spencer St.	~850	Onondaga County (see annual monitoring reports)
	1998-present	Kirkpatrick St.	181	
	1992-present	Dorwin Ave.	374	
	July 2002 - May 2003	Spencer St.	24	Upstate Freshwater Institute (UFI, 2004)
		Kirkpatrick St.	24	
		Dorwin Ave.	24	
	1993-1994	Kirkpatrick St.	26	Upstate Freshwater Institute (Effler *et al.* 1995a and 1995b)
		Dorwin Ave.	26	
	Apr. 1988- Sept. 1990	Kirkpatrick St.	1058	Upstate Freshwater Institute (Heidtke 1992)
		Dorwin Ave.	1076	
MIDDLE ONONDAGA CREEK: Onondaga Nation	July 2002 - May 2003	Two main-stem sites; four tributary sites	126	Upstate Freshwater Institute (UFI, 2004)
WEST BRANCH, ONONDAGA CREEK	July 2002 - May 2003	W. Branch at Hitchings Rd.	21	Upstate Freshwater Institute (UFI, 2004)
UPPER ONONDAGA CREEK: Tully Valley and Headwaters	1988-present	Tully Valley, four sites on main-stem	85	U.S. Geological Survey (Kappel *et al.* 1996 and USGS database)
	July 2002 - May 2003	Three main-stem sites	72	Upstate Freshwater Institute (UFI, 2004)

Table 2. Automated Sample Collection Huts along Onondaga Creek. The highlighted entry has data which are currently accessible via the Internet.

Location	Agency	Period of operation	Data access	Parameters measured[1]
near Cardiff (Route 20)	Onondaga County	started May 2006	not currently available[2]	DO, T, ORP, pH, SC
Syracuse at Dorwin Ave.	UFI	Aug. 22, 2003 – present	on-line[2]	T, SC, T_N, C_{660}
Syracuse at Spencer St.	UFI	March 2006 – present	to be posted[2]	T, SC, T_N, C_{660}
	Onondaga County	July 2004 – present	published[3]	DO, T, pH, SC, T_N

[1] Parameters are: dissolved oxygen (DO), temperature (T), oxidation-reduction potential (ORP), hydrogen ion potential (pH), specific conductivity (SC), turbidity (TN), and beam attenuation coefficient, λ = 660nm (C660).
[2] Go to www.ourlake.org for Dorwin Ave. data. Spencer St. data are not posted as of August 2007.
[3] See Onondaga County's 2005 Ambient Monitoring Program report.

Water quality results

Water quality data are summarized in the following Fact Sheets:

1. Temperature
2. Dissolved oxygen
3. Salinity
4. Alkalinity and pH
5. Turbidity and suspended solids
6. Nitrogen
7. Phosphorus
8. Pathogens
9. Compliance with water quality standards
10. Summary

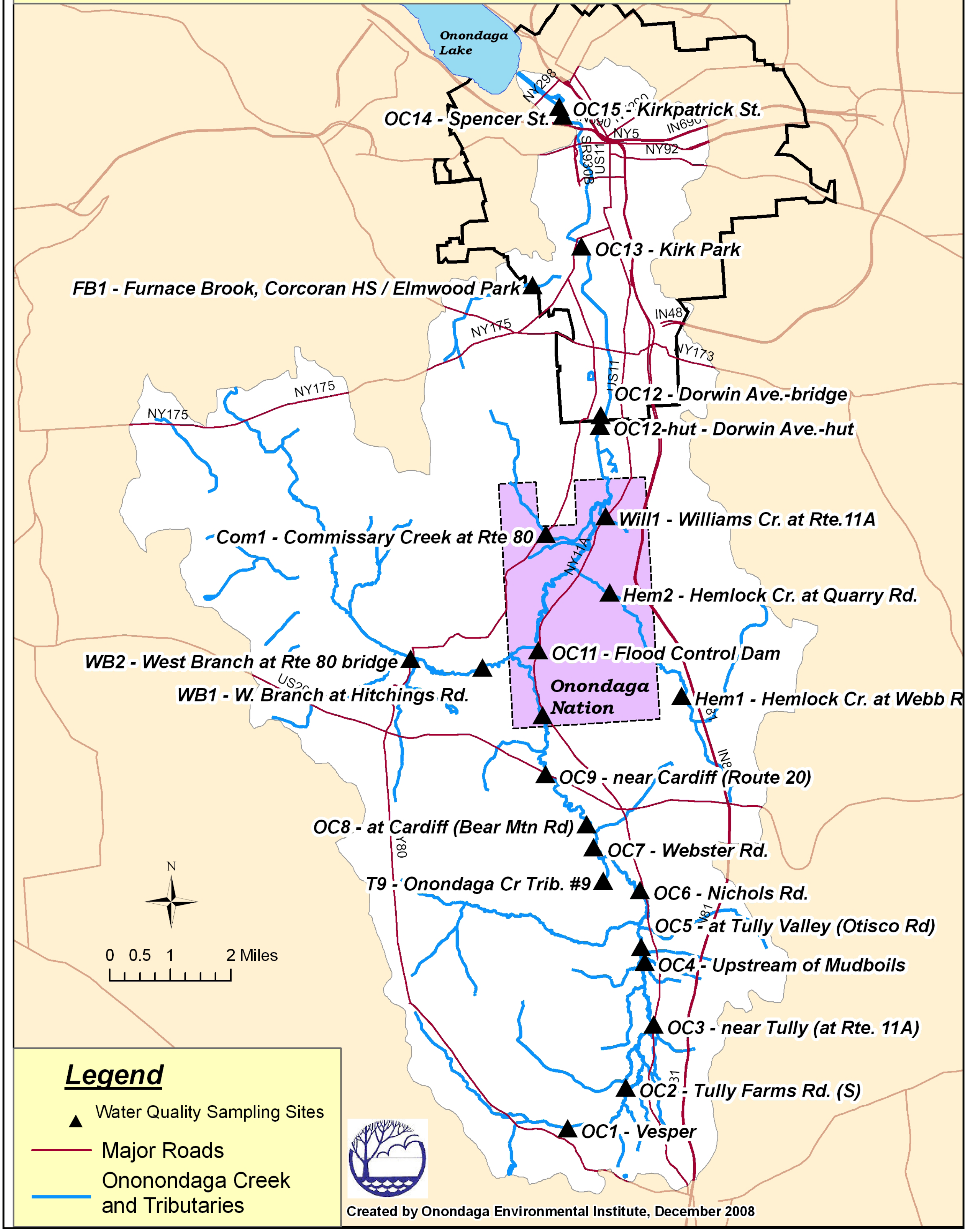

Figure 1. Water Quality Sampling Sites

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Temperature

Water Quality Series

Onondaga Creek Fact Sheet

INTRODUCTION

Water temperature in Onondaga Creek is largely a function of season, varying between a low of freezing (32º F; 0º C) in the winter to upwards of 73º F (23º C) in the summer. Temperature can be locally influenced by:

- seepage of groundwater --a relatively constant year-round temperature ~50º F (10º C)
- domestic or industrial wastewater, and
- overhanging and canopy vegetation which provides shade.

Trout require low temperatures year-round. Excessive heat in the summer can limit the available habitat and/or threaten the sustainability of fish populations.

FINDINGS

Water temperature throughout the Onondaga Creek watershed was measured as part of the Onondaga Nation study (UFI, 2004) (see Figure 1). UFI findings are as follows, by season:

- **Summer 2002:** There is a progressive increase in temperature as the creek flows through the Tully Valley, reaching a maximum of ~68º F (20º C) at Dorwin. Tributaries have similar temperatures, except Williams Creek which is probably spring-fed. There is a 4º F (2º C) drop at Spencer and Kirkpatrick St. sites, reflecting the influence of spring-fed tributaries (e.g. Furnace Brook) and direct fresh and saline springs within Syracuse (W. Kappel, pers. comm.., 2006). The highest temperature recorded during the study, 73º F (23º C), occurred in the West Branch, at Hitchings Road.
- **Winter 2002/3:** Creek temperature is ~32º F (0º C) until Dorwin. The 4º F (2º C) increase in Williams Creek and downstream of Dorwin probably reflects springs which are warmer than the creek.
- **Fall 2002 and Spring 2003:** Creek temperature is relatively constant throughout. Tributaries have temperatures comparable to the main stem.

Temperature data collected by Onondaga County between 1993 and 2004[1] show:

- **Dorwin:** Summer temperatures equaled or exceeded 77º F (25ºC) in 1995, 1998, and 1999. The highest temperature recorded was 83.5º F (28.3ºC) on July 6, 1999.
- **Spencer:** The maximum temperature recorded was 70.4º F (21ºC)
- **Kirkpatrick:** The maximum temperature recorded was 71.1º F (22ºC)

IMPLICATIONS

- As water temperature approaches 70º F (21ºC), trout are less able to compete with other fish species for food. Lethal temperatures for trout range from 73ºF to 79ºF (23º– 26ºC)(Cushing and Allen, 2001). Data collected by UFI in 2002-03 show that temperatures remain relatively cool (<70ºF) in the upper parts of the watershed, in certain tributaries (Hemlock Creek and Williams Creek), and in the furthest downstream site (e.g. Spencer). County data confirm that Spencer and Kirkpatrick remain cool during the summer. However, County data also show that temperatures at Dorwin are often inhospitable to trout during the summer. The 70ºF threshold was exceeded every summer during the 1993-2004 interval.
- The elevated temperatures observed by UFI at Cardiff and by both UFI and the County at Dorwin Ave. are probably related to the relative lack of vegetation in these sections of the creek.
- Water temperatures at Spencer, Kirkpatrick and locations upstream of the flood control dam would appear to support a cold-water fishery.
- Temperature has implications for dissolved oxygen (DO), as explained in the DO Fact Sheet.

1 Onondaga County data throughout this water quality series are taken from annual monitoring reports listed under Water Quality References (Stearns & Wheler 1994-1997; EcoLogic, LLC *et al*. 1999-2005).

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Dissolved Oxygen

Onondaga Creek Fact Sheet

INTRODUCTION

Dissolved oxygen (D.O.) is one of the most important water quality indicators because nearly all aquatic life, ranging from bacteria to fish, requires oxygen. Even plants, which produce oxygen via photosynthesis during the daylight hours, need oxygen to respire. Only certain forms of microorganisms do not require oxygen to survive. In addition to its critical biological role, oxygen also regulates chemical reactions in aquatic systems.

D.O. is highest (13-15 mg/L) in cold weather, and lowest in the summer (8-9 mg/L) because the solubility (the ability to dissolve in water) of oxygen decreases as temperature goes up. High salinity decreases D.O. solubility as well.

New York State Department of Environmental Conservation (NYS DEC) sets a regulatory standard of 4 mg/L absolute minimum concentration, and 5 mg/L measured as a daily average anywhere in the creek watershed. For waters designated for trout, which includes most of Onondaga Creek and its tributaries[2], the minimum daily average is 6 mg/L. For waters designated for trout spawning, which includes some tributaries of Onondaga Creek, the minimum is 7 mg/L (NYS DEC, 1999).

Oxygen Sources:

- aeration from the atmosphere
- aquatic plants, algae (photosynthesis)

Oxygen Sinks (inputs which remove oxygen):

- sewage inputs
- carbonaceous (organic) matter
- sediment oxygen demand

FINDINGS

Oxygen levels in Onondaga Creek are generally healthy throughout its length. D.O. is highest in the headwaters and most tributaries, and decreases as the creek flows through the Tully Valley, reaching a minimum at the flood control dam on the Onondaga Nation. D.O. increases at Dorwin, possibly due to aeration at the dam's outflow, but also reflecting the input of highly oxygenated waters from Hemlock, Williams, and Commissary Creeks. D.O. reaches another minimum at Spencer/Kirkpatrick (see Figure 2).

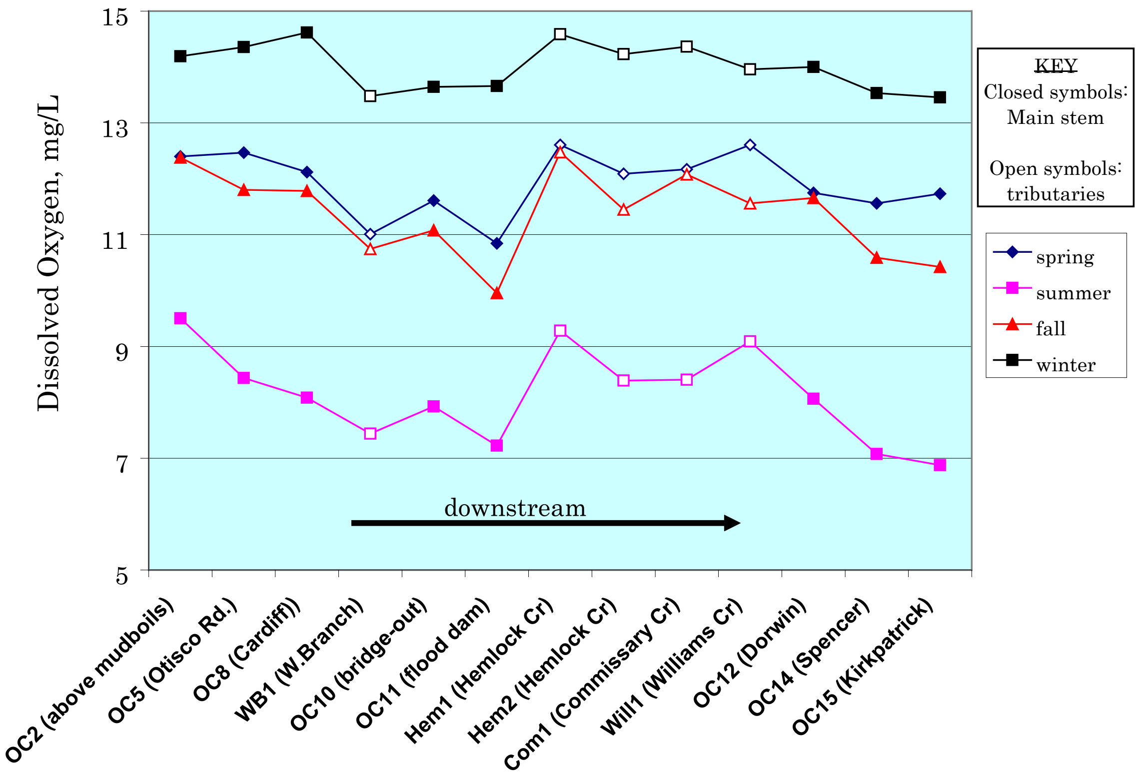
In 1994 and 1995, Onondaga County, at the city of Syracuse's request, sampled the waters of the Inner Harbor. It was found that water at the surface was well-oxygenated, but that water at depth (1-foot above the sediments) frequently fell below the New York State (NYS) standard of 4 mg/L. The deep waters within the South Pier were almost devoid of oxygen during the entire summer. (Stearns and Wheler, 1996) Factors such as high sediment oxygen demand (SOD), stagnation in terminal bays, and density stratification from brine springs could all contribute to low D.O.

IMPLICATIONS

Onondaga Creek is generally well-oxygenated throughout its length, sufficient to support most fish species. At times, D.O. levels drop below the 6 mg/L NY state standard for trout. Poor oxygen conditions which exist in parts of the Inner Harbor during the summer would preclude fish and macro-invertebrates in those specific areas. It is likely these conditions would lead to an odor problem due to putrefaction.

2 The Onondaga Creek mainstem from the Onondaga Nation south to its headwaters, and several tributaries including the West Branch, Hemlock Creek and Kennedy Creek are all designated as trout streams.

Figure 2. Average dissolved oxygen concentrations in Onondaga Creek and four tributaries, 2002-2003. For sampling locations, see map (Figure 1 in Temperature Fact Sheet). Seasonal averages are for spring [March 20–May 27, 2003], summer [July 3 –Sept. 9, 2002], fall [Sept. 23–Dec. 17, 2002], and winter [Jan. 7 –March 6, 2003]. (UFI, 2004)



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Salinity

Water Quality Series

Onondaga Creek Fact Sheet

INTRODUCTION

Natural waters contain dissolved solids, primarily inorganic salts. Salinity is the concentration of salts in water. These salts consist of:

Major Positive Ions	Major Negative Ions
calcium (Ca^{++})	bicarbonate (HCO_3^-)
magnesium (Mg^{++})	sulfate ($SO_4^=$)
sodium (Na^+)	chloride (Cl^-)
potassium (K^+)	

Other dissolved inorganic constituents, including nitrate (NO_3^-), silica (SiO_2) and iron oxides (e.g. Fe_2O_3), occur at relatively minor concentrations. Dissolved salts do not affect the appearance of water, as long as they remain in solution. Dissolved salts above 500 mg/L can affect the usefulness of water as a source of drinking water and above 1000 mg/L for agricultural purposes. Salts can adversely affect some freshwater organisms. (Allan, 1995)

Salinity (saltiness) can be measured as:

- "Total dissolved solids" (TDS) [units = mg/L]
- specific conductivity (or conductance) [units = microSiemens per cm (µS/cm)]
- sum of individual ions (e.g. chloride) [units = mg/L]

Table 3 provides the reader with a frame of reference for differing levels of salinity in the environment.

Table 3. Typical concentrations of TDS and chloride[3] ion in various types of water.

Water	mg/L TDS	mg/L Cl^-
Rainwater	5-15	
pristine mountain stream	10-20	
"Average world river"	110	8
Otisco Lake	250	14
drinking water, recommended maximum	500	
Onondaga Lake	1200	480
seawater	34,500-35,500	23,500
spring at Kirkpatrick St.	104,000	64,000

3 Note that CHLORIDE is not the same as CHLORINE, which is used to disinfect drinking water, and wastewater.

Salinity Sources:

- mudboils and sulfur springs, Tully Valley
- salt springs near Spencer Street

Road salt also contributes to higher salinity in local waterways. Researchers studying the Mohawk River basin in New York State concluded that the two major components of road salt, sodium and chloride, had increased by 130 and 240%, respectively over the period 1952-1998 (Godwin *et al.* 2002). [Other constituents in the water had either decreased or remained constant.] However, in absolute terms, the observed increase was less than 13 mg/L for each ion, which is insignificant in relation to Onondaga Creek.

Salinity Sinks: none

FINDINGS

The salinity of Onondaga Creek experiences two major increases as it flows downstream. The first occurs in the Tully Valley, as the creek flows past the mud boils and Bare Mountain, the site of a landslide in 1993 and several historic landslide sites (W. Kappel, pers. comm., Wieczorek *et al.* 1998). The USGS measured specific conductivity and major ions on July 20, 1998. Sodium and chloride concentrations in the Tully Valley are compared to the Mohawk River basin below:

	Sodium, mg/l	Chloride, mg/l
Mohawk R. basin average, 1990s[1]	13.2	20.4
Onondaga Cr., upstream of mudboils, 1998[2]	15-50	20-50
Onondaga Cr., downstream of mudboils, 1998[2]	175-340	270-525

[1]Godwin *et al.* (2002). [2] McKenna *et al.*(1998)

As Onondaga Creek flows past the mudboils and Bare Mountain, salinity increases by a factor of four (see Figure 3A). Sodium and chloride increased up to ten times. Data collected in 2002-2003 by UFI (2004) show less substantial, but similar, increases, depending on season (Figure 3B).

A second major increase in salinity occurs as the creek flows through the city of Syracuse. Figure 3B shows a consistent year-round increase in salinity between Dorwin (the southern boundary of the city of Syracuse) and the two downstream sites (Spencer and Kirkpatrick). The increase between Spencer and Kirkpatrick is due to a known salt spring entering Onondaga Creek with a salinity *three times that of seawater.* (EcoLogic LLC, *et al.*, 2004, 2005)

For Onondaga Creek, the major ions and quantities transported downstream each year to Onondaga Lake are given in Table 4, as sampled at Kirkpatrick between 1998-2004. (EcoLogic, *et al.*, 2000-2005)

IMPLICATIONS

Salinity concentrations increase in Onondaga Creek due to inputs from the mudboils and the 1993 landslide in Tully Valley. Given the low levels of sodium and chloride in the Mohawk River, which is only affected by road salt, compared to the much higher levels in Onondaga Creek it may be concluded that road salt is not a significant source of salinity in the Onondaga Creek basin.

Salinity concentration increases again due to highly saline groundwater discharge to Onondaga Creek in the Spencer and Kirkpatrick area. It should be noted that salt springs have historically been present where the creek enters Onondaga Lake. As such, it seems likely that indigenous organisms, at least in these areas, are tolerant of elevated salinity.

Chloride is high in this system relative to others (UFI, 2004). Chloride concentrations in natural waters are typically low, and generally lower than bicarbonate concentrations (Hem, 1985). Onondaga Creek is unusual in that chloride concentrations are much higher than bicarbonate concentrations.

Table 4. Average loadings of dissolved solids in Onondaga Creek (1998-2004).

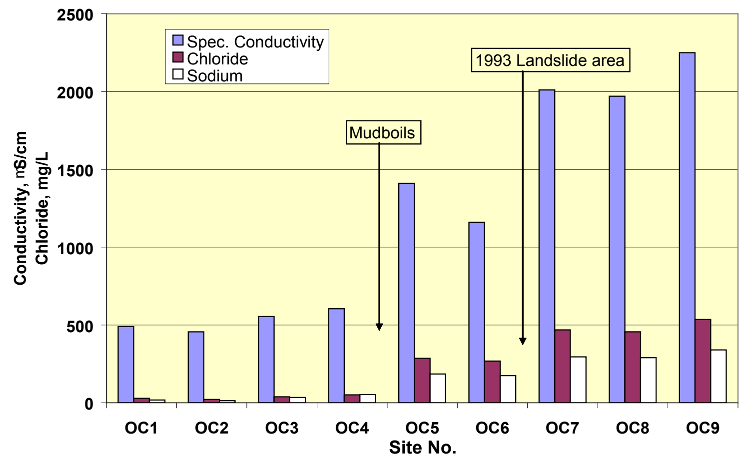


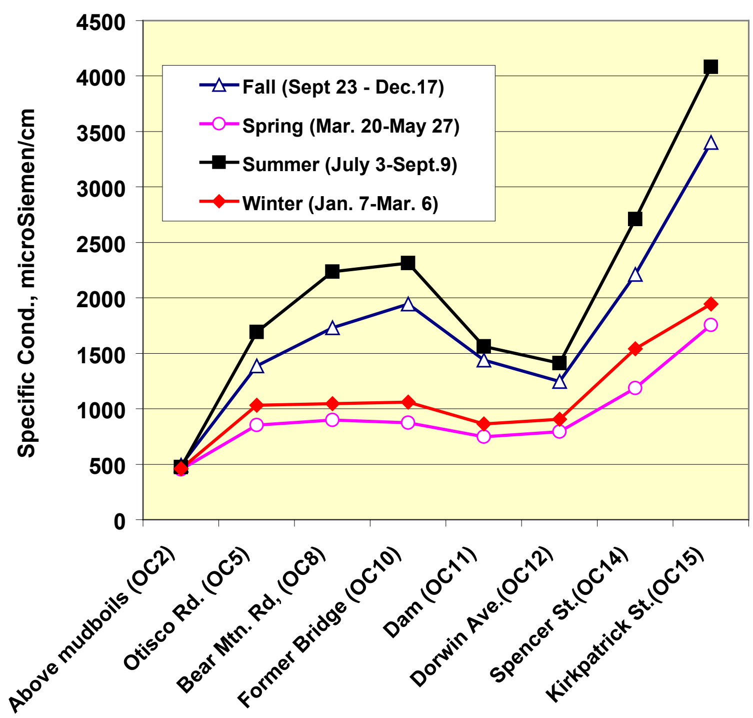
Figure 3A. Specific conductivity, sodium and chloride concentrations in the Tully Valley on July 20, 1998. (USGS web site waterdata.usgs.gov/nwis)

	Percentage (by weight)	Average loading (metric tons)*
Chloride	35%	61,900
Bicarbonate	21%	38,600
Sodium	21%	37,040
Sulfate	11%	18,500
Calcium	10%	17,100
Magnesium	2%	3,600

* 1 metric ton = 1000 kg = 2,205 lb

INTRODUCTION

FIGURE 3B. Seasonal averages of specific conductance along Onondaga Creek. (UFI, 2004)



Alkalinity & pH

Water Quality Series

Onondaga Creek Fact Sheet

Alkalinity is a measurement of ions that control the pH of water. A pH of 7 is considered neutral. A pH value above 7 is considered alkaline and below 7 is considered acidic. Alkalinity is determined primarily by the amount of bicarbonate and carbonate ions in water. Water draining from land characterized by limestone (calcium carbonate) rock can be strongly alkaline. Generally, alkaline waters are more biologically productive than acidic waters (Cushing and Allan, 2001).

FINDINGS

The Onondaga Creek watershed has a higher than normal amount of carbonate-enriched glacial sediments due to erosion of limestone bedrock in the north-central part of the Onondaga Creek valley (roughly Nedrow through the Onondaga Hill area), which gives the water relatively high concentrations of bicarbonate. As a result, the water is somewhat alkaline, with pH typically in the range 7.5 – 8.7, and an overall average of 8.0 (UFI, 2004). Figure 4 shows average, minimum, and maximum pH values measured throughout the watershed.

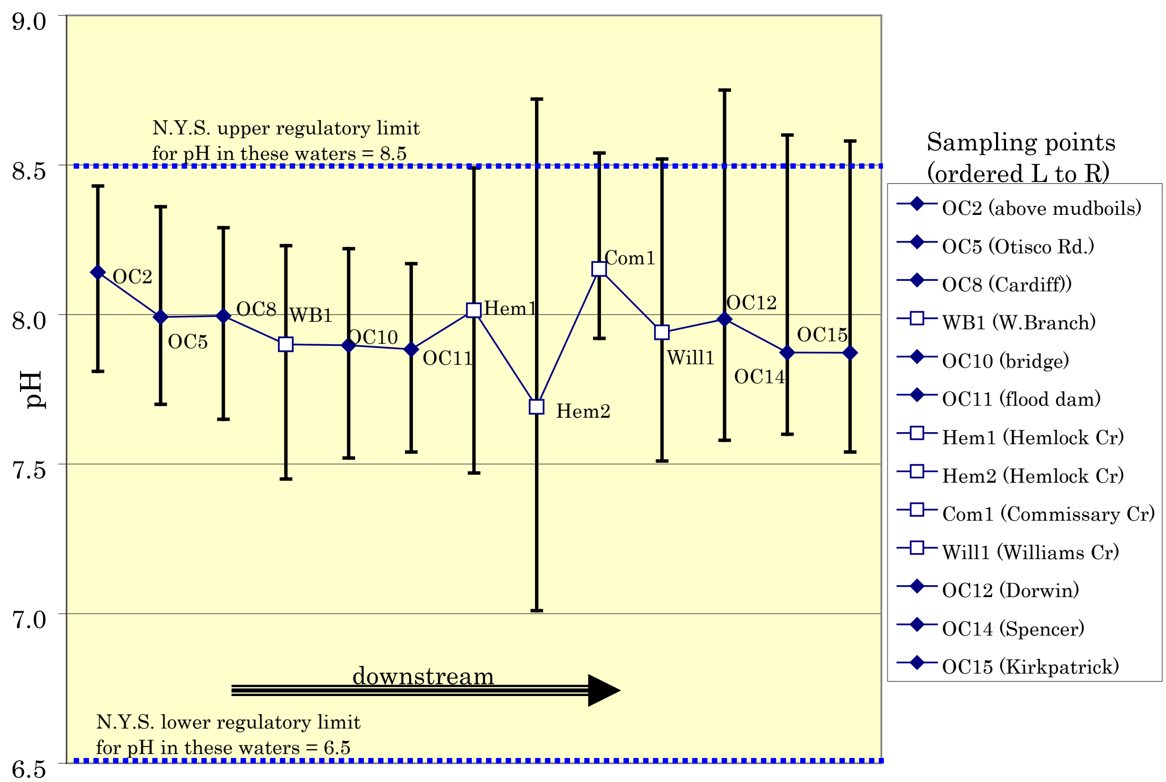


Figure 4. Average pH measured at eight locations along Onondaga Creek, and four tributaries from July 3, 2002-May 23, 2003. Error bars indicate maximum and minimum observations. (UFI, 2004)

Note that pH in rural settings (OC2 through OC11) tended to experience less fluctuations than those in an urban environment (OC12, OC14, and OC15). Hemlock Creek stands out as an exception to this generalization: the upstream site (Hem1) varied a full pH unit, while Hem2 was the most variable site of all sites, ranging from pH 7.0 to pH 8.7. The high variability at the downstream site (Hem2) may be related to the presence of a landfill between these two sites. (UFI, 2004)

Total alkalinity measured by Onondaga County at Dorwin has averaged 222 mg/L as $CaCO_3$ (4.4 meq/L) over the time period 1993-2004.

IMPLICATIONS

The Onondaga Creek watershed is dominated by limestone and glacial sediments, which give the water a stable pH. It is not susceptible to acid rain, as are streams and lakes in the Adirondacks. Local inputs of acids, such as from the landfill on Hemlock Creek, could cause a localized drop in pH. Elevated pH can cause ammonia toxicity to fish. The creek pH does exceed the NYS standard of 8.5 on occasion.

A survey of Fish and Wildlife Service literature[4] shows that the pH values (maximum = 8.7) observed in Onondaga Creek are unlikely to adversely affect fish populations. The optimal pH range for brook and rainbow trout extends to pH 8.0, but the range of tolerance extends to 9.8. Brown trout can tolerate up to pH 9.5.

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4 US Fish and Wildlife Service, Habitat Suitability Index Models: Brown trout. Biological Report 82(10.124) (1986); Rainbow trout. Biological Report 82(10.60) (1984); Brook trout. Biological Report 82(10.24) (1982); and others.

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Turbidity & Suspended Solids

Water Quality Series

Onondaga Creek Fact Sheet

INTRODUCTION

Particles in water are measured two different ways: turbidity (Tn) and total suspended solids (TSS). Tn and TSS are well-correlated (the presence of one predicts the other) and very dynamic: they are ***low*** when stream flow is constant, ***high*** during storm events.

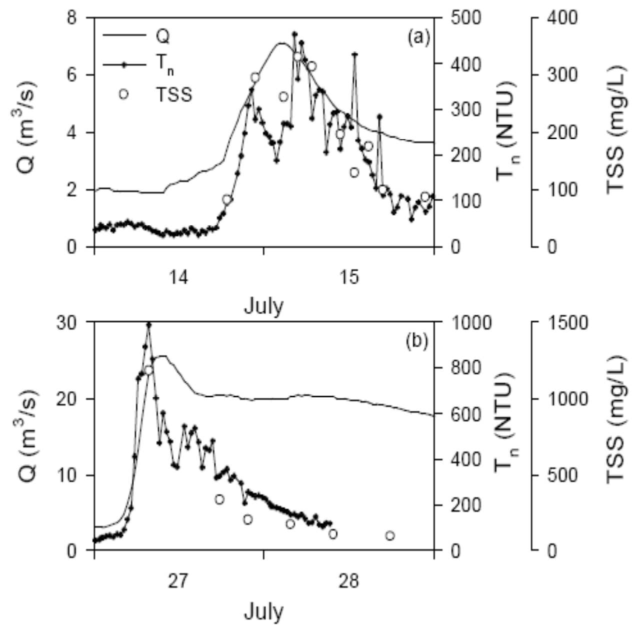
FINDINGS

Sources of Suspended Solids:

- **Existing sediments** in Onondaga Creek are resuspended during storm events (see Figure 5A).
- **Mudboils** have contributed large quantities of sediments (see Figure 5B).
- **Erosion of soils** from farming, streambanks and roadbanks, and intermittent but persistent landslides (Blatchley and Reese 2000; W. Kappel, pers. comm..) (see Figure 5B).
- **Urban run-off** (storm sewers and combined sewer overflows).
- **Particles** are primarily inorganic; organic matter is not a big contributor.

Deposition of Suspended Solids:

- Flood control dam may intercept sediments when water backs up behind the dam (<1 times per year).
- "Copious quantities of sediment cover the stream bottom and the banks of the creek downstream of the 'mud boils'" (Effler *et al.*, 1992)
- Deposition of suspended sediment likely occurs at the Inner Harbor.
- Wetlands upstream and downstream of the dam potentially intercept sediment.
- Deposition is unlikely in urban, channelized sections where flow velocities are high.



Variables shown:	Graph symbol	Graph axis
Flow = Q (m^3/s)*	solid line	left side
Turbidity = Tn (NTU)	small dots + line	right side
Total Suspended Solids = TSS (mg/L)	open circles	right side
Date		bottom

*Flow units are cubic meters per second [1 m^3/s = 35.3 cubic feet per second].

Figure 5A. Two storm events in 2004 (July 14-15 and July 27-28) show highly dynamic nature of suspended matter in Onondaga Creek at Dorwin. (Prestigiacomo et al., in press)

Note: The vertical scale in the bottom graph is much greater than the top graph.

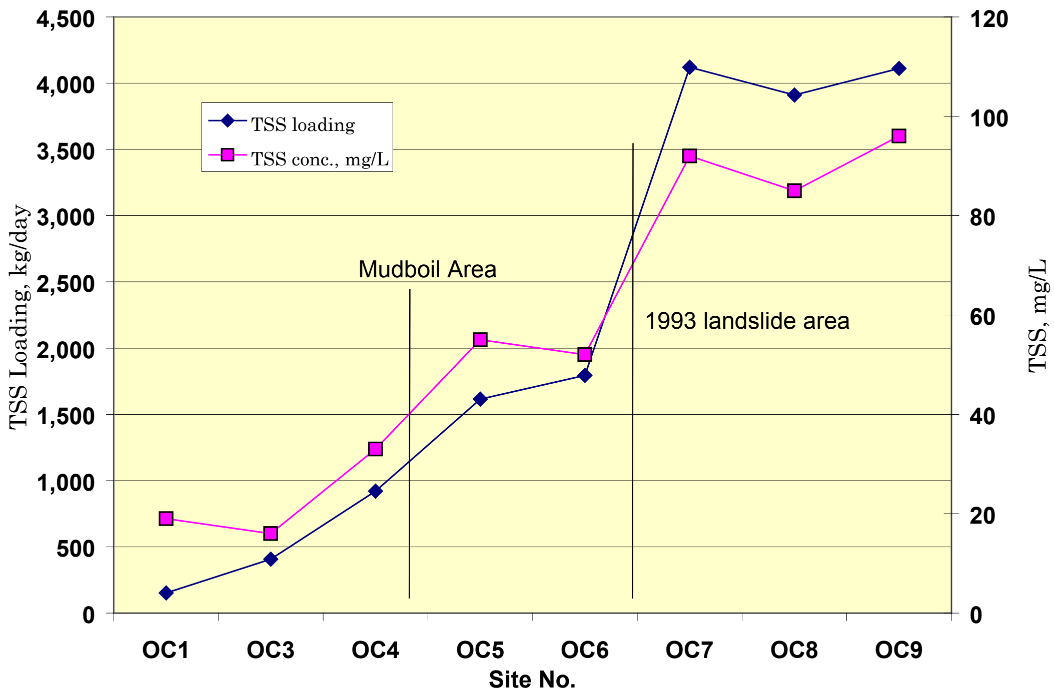


Figure 5B. Suspended Sediment in Tully Valley, July 20, 1998.

Data source: USGS web site waterdata.usgs.gov/nwis

IMPLICATIONS

- High turbidity may be a natural feature of Onondaga Creek, due to persistent mudboils (see Mudboil Fact Sheet). However, mudboil activity is reported to have increased greatly over the years 1936-1951 (Rubin *et al.*, 1991). In addition, the oral history of the Onondagas relates that water in the creek ran clear prior to the 1940s (Smardon, 1998).
- A major portion of Onondaga Creek (from the mudboils to the mouth) has been identified as impaired for public bathing, aquatic life support, and aesthetics due to the presence of excessive silt and sediment (NYSDEC, 2005).
- Ecological effects of fine suspended solids include:
  - suffocation of aquatic insect eggs/larvae (macroinvertebrates),
  - interfere with fish reproduction,
  - clog and abrade fish gills.
- Aesthetically displeasing.
- Serves as transport mechanism for toxic substances (e.g. pesticides), pathogens, and phosphorus.
- Can interfere with navigation by filling in channels (FISRWG, 1998)
- A large quantity of suspended sediment is added daily to Onondaga Lake; further study is needed to better quantify this.

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Nitrogen

Water Quality Series

Onondaga Creek Fact Sheet

INTRODUCTION

Nitrogen and phosphorus are essential nutrients for all forms of life, but can be detrimental if present in too high concentrations. In freshwater, phosphorus is generally the nutrient that limits the growth of aquatic plants and algae.

Nitrogen (N) is cycled through streams, lakes. and soil in a variety of forms (Table 5).

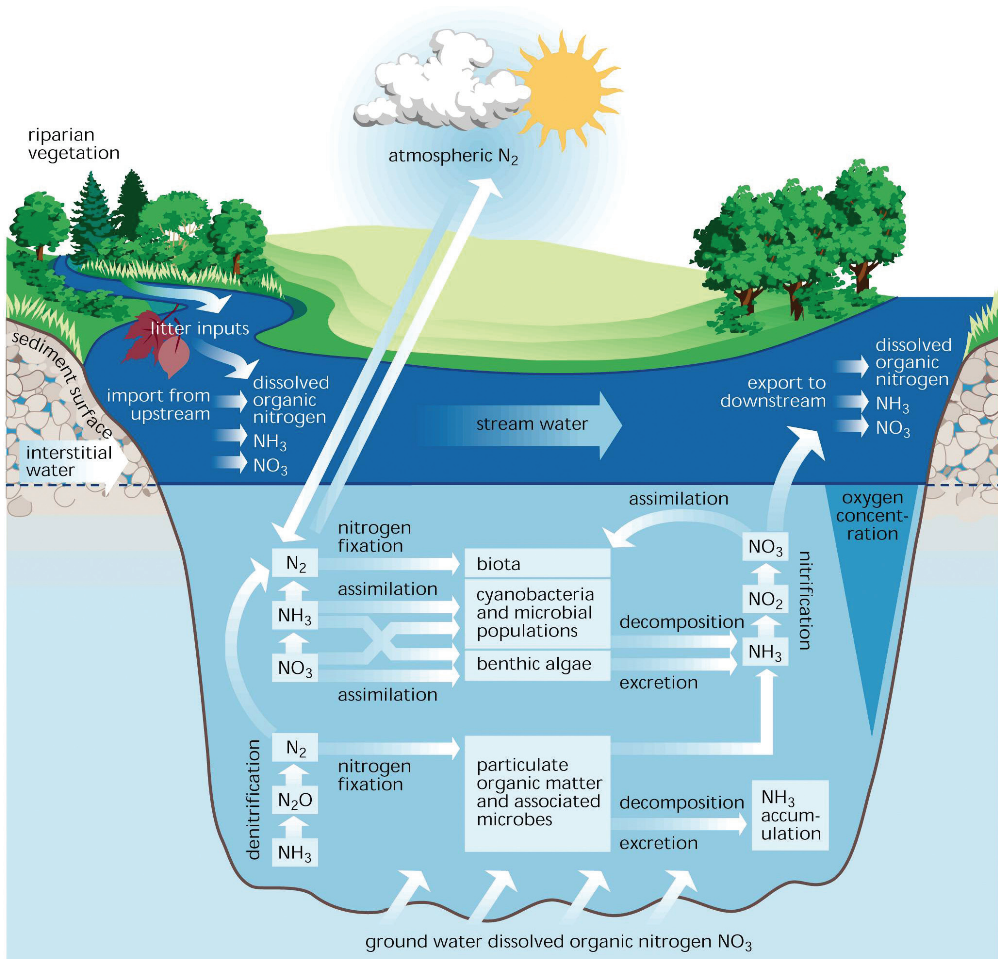
Different microbes in soil or water can decompose wastes containing organic N to various forms according to a step-wise progression. First ammonia is formed, which can be oxidized to nitrite. Nitrite is easily converted to nitrate. Nitrate is the form which tends to accumulate in groundwater and surface waters. (ATSDR, 2001)

Humans have had a profound impact on the global nitrogen cycle (see Figure 6). Surface waters, such as Onondaga Creek, can become polluted with organic N, ammonia, and nitrate through fugitive release of fertilizers from farms and landscaping uses, via storm water runoff and groundwater discharge, animal or human wastes from agricultural operations, septic tanks, combined sewer overflows, leaky sewer pipes, sewage treatment facilities, and atmospheric deposition from the combustion of fossil fuels (Cushing and Allan, 2001).

Table 5. Forms of nitrogen found in aquatic environments

Form	Symbol	Significance
Nitrogen gas	N_2	diffuses from the atmosphere and remains as an inert gas dissolved in water; used only by N-fixing bacteria
Organic N		organic matter which can be decomposed
Ammonia	NH_3	excreted by many organisms; utilized by plants, algae; toxic to fish
Nitrite	NO_2^-	an intermediate form; toxic to fish
Nitrate	NO_3^-	utilized by plants; can be toxic at high concentrations to fish and humans, especially infants, i.e. drinking water levels > 10mg/L

Figure 6. Dynamics and transformations of nitrogen in a stream ecosystem (FISRWG, 1998).



Onondaga Creek
CONCEPTUAL REVITALIZATION PLAN

FINDINGS

Dissolved nitrogen gas: not measured, since it's inert.

Organic N: Onondaga County data from 1985-2004 show average organic-N concentrations of 0.28-0.55 mg/L at Spencer and/or Kirkpatrick St., with an overall average of ~0.3 mg/L. During storm events, organic N levels have risen as high as 5 mg/L, probably indicating inputs of nitrogen-rich organic matter contained in sewage.

Ammonia: Onondaga County data from 1985-2004 show average ammonia concentrations of 0.080-0.27 mg/L at Spencer and/or Kirkpatrick St., with an overall average of 0.14 mg/L. Concentrations are quite variable, ranging up to 0.32 mg/L at Dorwin Ave., and up to 1.46 mg/L at downstream locations. UFI data for the period July 2002 – May 2003 show an overall average of 0.038 mg/L ammonia for all locations. For the rural stream segments, the highest values of 0.15 mg/L and 0.17 mg/L were observed just downstream of the mudboils, and in the West Branch, respectively. In the urban downstream segment, a maximum of 0.80 mg/L was observed at Kirkpatrick.

New York State (NYS DEC, 1999) has adopted USEPA's 1984 water quality standards for ammonia, based on toxicity. These chronic toxicity criteria vary as a function of pH and temperature. An analysis of data collected by UFI between 2002 and 2003 throughout the watershed reveals no violations of this standard. Onondaga County reported no violations of this standard in Onondaga Creek for the years 1993-2003. Compliance was 93% in 2004.

Nitrite: Nitrite (NO_2^-) is typically present at very low concentrations in water, as it is readily converted to nitrate by bacteria. The concentrations of nitrite in Onondaga Creek for 1993-2004 are summarized below:

Concentration (mg/L)	Dorwin	Spencer/ Kirkpatrick
Min (detection limit)	<0.01	<0.01
Max	0.41	0.18
Average	0.018	0.017

Source: Onondaga County Ambient Monitoring Program, 1993-2004

NYSDEC (1999) has established two water quality standards for nitrite:

- 0.10 mg/L warm water fishery
- 0.02 mg/L cold water fishery

Both standards apply to Onondaga Creek.

Both warm and cold water fish inhabit Onondaga Creek. Many warm water fish species, such as mottled sculpin, white suckers, and creek chub occur throughout the Onondaga Creek watershed. Cold water loving species, such as brown and brook trout, are stocked throughout Onondaga Creek by Onondaga County. Fish surveys by NYSDEC and others have documented the presence and reproduction of cold water fish in the upstream portions of Onondaga Creek (e.g. Tully Valley, West Branch). Coldwater fish have been documented in the Dorwin Ave /Nedrow area also. Warm water fish predominate north of Dorwin Ave. Trout are stocked at Dorwin, and in Furnace Brook, and Cold Brook.

Nitrite levels have been in compliance with the warm water standard almost 99% of the time at both upstream and downstream monitoring sites. The cold water standard appears to be appropriate for Dorwin Ave. Thus, the compliance rate drops to 87 to 88%.

Nitrate: Nitrate (NO_3^-) can enter aquatic systems through multiple pathways, identified in the introduction. Nitrate, like N_2 gas, is a very stable form of nitrogen. Its concentration tends not to vary. This is evident in Onondaga Creek, where concentrations average about 0.9 mg/L for the period from 1985 to 2004. Nitrate on the creek follows a yearly cycle, reaching a maximum concentration of 1.3 to 2 mg/L in the winter, and minimum of ~0.5 mg/L in the summer. This pattern is documented by long-term monitoring conducted by Onondaga County. (Onondaga County, 1993-2004)

Data collected by UFI (2004) throughout the watershed show similar results, with an overall average concentration of 0.84 mg/L with little variation from upstream to downstream. Certain tributaries such as Williams Creek and Commissary Creek, were significantly lower than the main channel. Conversely, the West Branch had somewhat higher levels of nitrate.

Nitrate above 10 mg/L is prohibited by USEPA in drinking water supplies, as it can be toxic to infants (ATSDR, 2001). High levels of nitrate in natural waters can potentially cause death of fish. Over 30 mg/L of nitrate can inhibit growth, impair the immune system, cause stress, and reduce energy levels in fish. Onondaga Creek nitrate levels are too low to exhibit these effects.

IMPLICATIONS

In the urban Onondaga Creek stream corridor:

- **High organic N** levels during storm events indicate that discharges and runoff containing N-rich wastes such as sewage and/or manure are entering the creek.
- **Ammonia** levels are below NYS toxicity standards, but occasionally reach concentrations which are close to these standards.
- **Nitrite** meets the standard for a warm water fishery. The standard for a cold water fishery is exceeded 12% of the time at Dorwin Ave.
- **Nitrate** levels in the rural and urban stream segments are similar (see below).

Monitoring data upstream of Dorwin are limited to a one year study (UFI, 2004), so it is difficult to draw definitive conclusions regarding nitrogen in the rural stream segments of Onondaga Creek:

- **High organic N**. No data are available
- **Ammonia** levels upstream of Dorwin tend to be lower than in the urban corridor. However, sporadic instances of elevated ammonia occurred in the West Branch and at Bear Mountain Rd., which may be associated with fertilizer inputs.
- **Nitrite.** No data are available
- **Nitrate** levels tend to be consistent throughout the watershed, except that some tributaries (e.g. Williams Creek) are lower, while others (West Branch) are higher. The overall pattern is consistent with other watersheds where nitrate is closely tied to agricultural land use.

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Phosphorus

Water Quality Series

Onondaga Creek Fact Sheet

INTRODUCTION

Like nitrogen, phosphorus (P) is a nutrient that exists in a variety of forms. The many forms of P can be categorized into four major groups as shown in Table 6.

Table 6. Major categories of phosphorus in the aquatic environment.

	Dissolved	Particulate
Inorganic	**soluble reactive P** (SRP) free phosphates & some condensed phosphates e.g. *fertilizer, detergents, and fecal matter*	**inorganic P** which is attached to particles e.g. P adhering to *clays & silts*
Organic	**dissolved organic P** A by-product of natural decay. (Generally a small fraction of total phosphorus [TP].)	**organic P** which is attached to particles e.g. *algal cells and more complex compounds within fecal matter*

Plants use P as an essential nutrient, with SRP being the form most readily available to plants. However, the amount of TP is the single most important water quality parameter, since this represents the sum of all forms that could ultimately become available. Generally, concentrations of P are very low—(5-30 µg/L [part-per-billion]) in unpolluted waters.

High concentrations of TP can lead to algae blooms and excessive plant growth (a phenomenon referred to as eutrophication). NYS has established a guidance value of 20 µg/L to prevent eutrophication in lakes, but has no equivalent guideline for streams.

EcoLogic, a consultant for Onondaga County, has documented both rural and urban stream segments of Onondaga Creek, where the creek appears to suffer from "nutrient enrichment." This is characterized by:

- greenish water,
- overabundance of lush aquatic vegetation, and/or
- abundant algal growth.

Nutrient enrichment is typically due to excessive phosphorus.

Potential sources of P in the Onondaga Creek watershed include:

- septic tank and sewer pipe leakage
- soil erosion
- fertilizers (agricultural and lawn)
- street and highway runoff
- CSOs

Silts and clays (e.g., mud boil sediment) can remove soluble phosphorus by the processes of adsorption, followed by deposition. This material, if resuspended, reintroduces the phosphorus into the water column. In this manner it can act as a latent source of TP.

FINDINGS

Phosphorus concentrations

A UFI (2004) study conducted between 2002 and 2003 found:

- TP is predominantly in the particle phase throughout the watershed. On average, 75% of P was particulate. The remainder was dissolved.
- Total P upstream of the mudboils (OC2) was lower than at the next downstream location (OC5-Otisco Rd).
- The average level of total P in the tributaries was 14 µg/L, compared with 36 µg/L in the creek's *mainstem*.

Onondaga County data collected biweekly, from 1993 to 2004, showed the following average TP concentrations:

- 48 µg/L at Dorwin, and
- 64 µg/L at Spencer and Kirkpatrick

During storm events, short-term increases of TP can reach concentrations up to 500 µg/L. These levels occur at Dorwin and at the two downstream sites (see Figure 7).

Phosphorus loadings

The total quantity of phosphorus delivered by Onondaga Creek to Onondaga Lake per day or year is referred to as the loading. A rigorous estimate of TP loading was performed by Heidtke (1992). Based on over 2100 samples collected from April 1988 to September 1990, Heidtke estimated an annual output of 30,000 kg. The data also showed, on average, 38% coming from rural sources (upstream of Dorwin) and 62% from urban sources (between Dorwin and Spencer). Urban sources consist primarily of combined sewer overflows and storm sewer runoff. A HSPF Surface Watershed Model has been developed by The USGS. This model, if supported by adequate monitoring data, should provide more up-to-date loading estimates.

IMPLICATIONS

Phosphorus concentrations in Onondaga Creek appear to be high enough to cause excessive plant growth. Efforts that would help reduce this problem include:

- reduction of fertilizer usage (agricultural and residential)
- streambank stabilization
- interception, treatment or reduction of storm water
- reduction/elimination of CSO releases
- control of other potential sources (see list on p. 1)

The *loading* of TP from Onondaga Creek to Onondaga Lake is of special significance because phosphorus loadings to Onondaga Lake are under intense scrutiny by state regulators (NYSDEC). A major reduction in P loading to the lake has been achieved with the construction of a new treatment process at the Metro sewage treatment plant. However, further reductions are needed to reach target levels in the lake.[5] This has ramifications for watershed management, because Onondaga Creek has been identified as a major source of phosphorus. Other strategies for reducing TP loading are listed above.

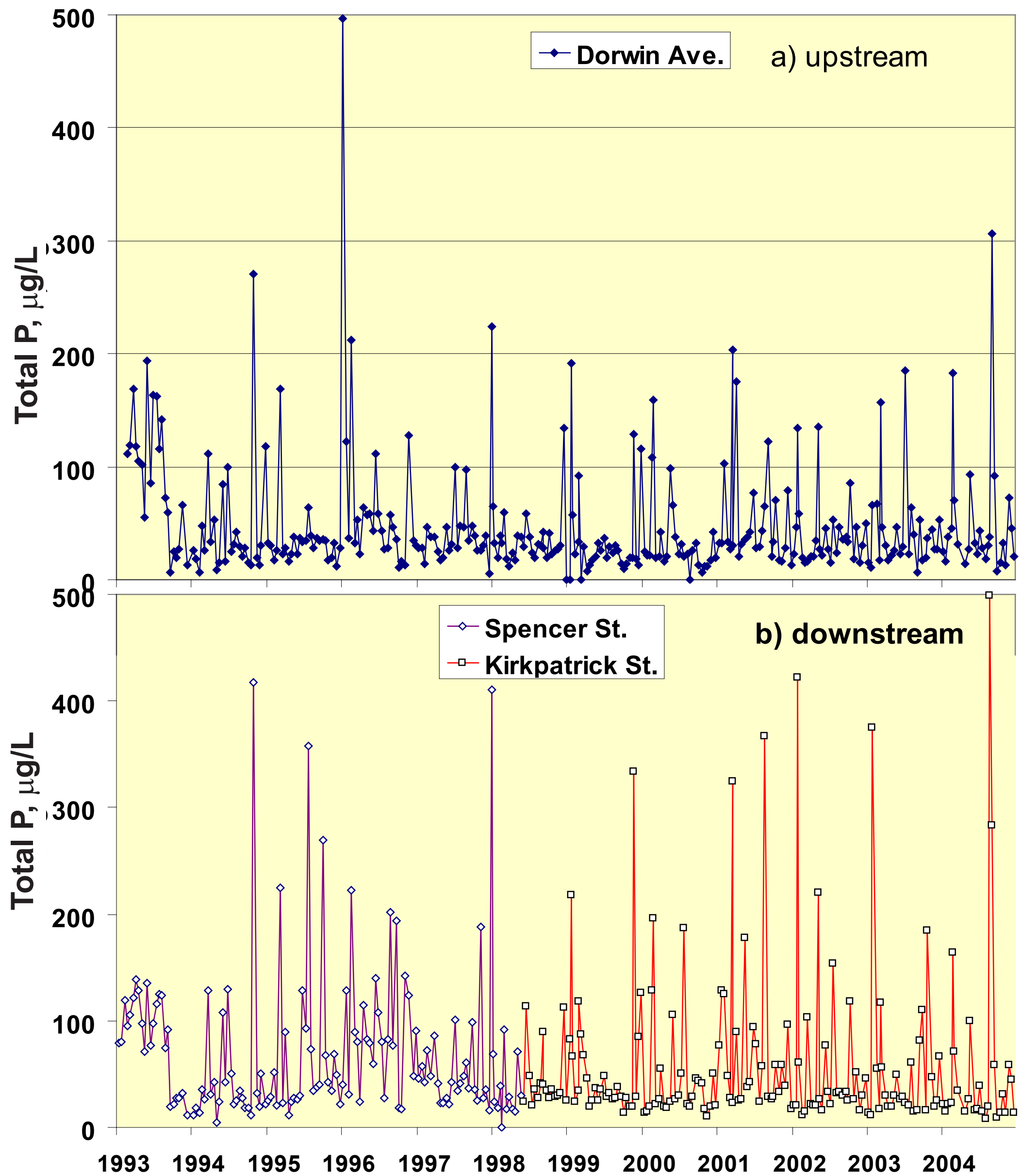
5 The target level for TP in the lake is 20 µg/L, a level which is expected to eliminate excessive growth of algae. A Total Maximum Daily Load (TMDL) for phosphorus was issued by NYSDEC in 1998, and is due to be revised by 2009. The existing TMDL calls for a 50% reduction in TP from all of the lake's tributaries.

Figure 7. Total phosphorus concentrations in Onondaga Creek, 1993-2004, at a) Dorwin and b) Spencer and Kirkpatrick.

Each point represents an individual sample. Detection limit = 1 µg/L.

Non-detects shown at the detection limit.

Sources: O.C. Ambient Monitoring Reports for years 1993-2004 (EcoLogic et al. 1999-2005; Stearns & Wheler, 1994-1997).



INTRODUCTION

Pathogens are microorganisms--bacteria, viruses, and protozoans--which cause disease. Pathogens are commonly associated with decomposing carcasses and fecal material from animals of all kinds (human, other mammals, birds) . Sources of fecal contamination to surface waters include untreated sewage, on-site septic systems, domestic and wild animal manure, and storm runoff. (USEPA, 1997)

Two bacteria groups, coliforms[6] and fecal streptococci, are used as indicators of possible sewage contamination because they are commonly found in human feces. Although generally not harmful, they indicate the potential presence of pathogens that also live in human and animal digestive systems. It is not practical to test for every pathogenic organism, so water is tested for indicator bacteria instead. (USEPA, 1997)

The fecal bacteria indicators tested in Onondaga Creek are:

1. **fecal coliforms:** a subset of total coliform bacteria, are more fecal-specific in origin than total coliforms.
2. ***Escherichia coli:*** a species of fecal coliform bacteria that is specific to fecal material from humans and other warm-blooded animals. Testing for harmful strains of *E. Coli* is possible, but not commonly practiced.
3. **fecal streptococci:** generally occur in the digestive systems of humans and other warm-blooded animals.
4. **Enterococci:** a subgroup within the fecal streptococcus group. Enterococci are typically more human-specific than the larger fecal streptococcus group.

Note that **none of these tests distinguish between human and animal fecal contamination.** More sophisticated tests (DNA sequencing) which distinguish between the two exist, but are expensive. DNA testing was conducted in the nearby Owasco Lake watershed to determine sources of fecal contamination. Multiple sources of E. coli were identified, including humans, waterfowl, farm animals, deer, and pets (Pezzolesi, 2000).

Regulatory guidelines are:

- USEPA recommends use of *E. coli* and enterococci as the best indicators of health risk, but actual standards are at the discretion of individual states and localities.
- New York State DEC has set a numerical water quality standard (monthly mean) of 200 units/100ml based on the fecal coliform test. This is the legal limit for all waters in the Onondaga Creek Watershed.
- New York State Dept of Health (NYSDOH) has set limits for bathing beaches based on: fecal coliforms, enterococci, and E.coli (see table below). These legally do not apply to Onondaga Creek, since no bathing beaches are present, but serve as a useful point of reference.

Table 7 NYS Department of Health Upper Limits for Indicator Bacteria at Bathing Beaches (Ref: NYSDOH, 2004

Indicator test	Single sample (#/100 ml)	Monthly mean (#/100 ml)[1]
Fecal coliform bacteria	1,000	200
enterococci	61	33
E. coli	235	126

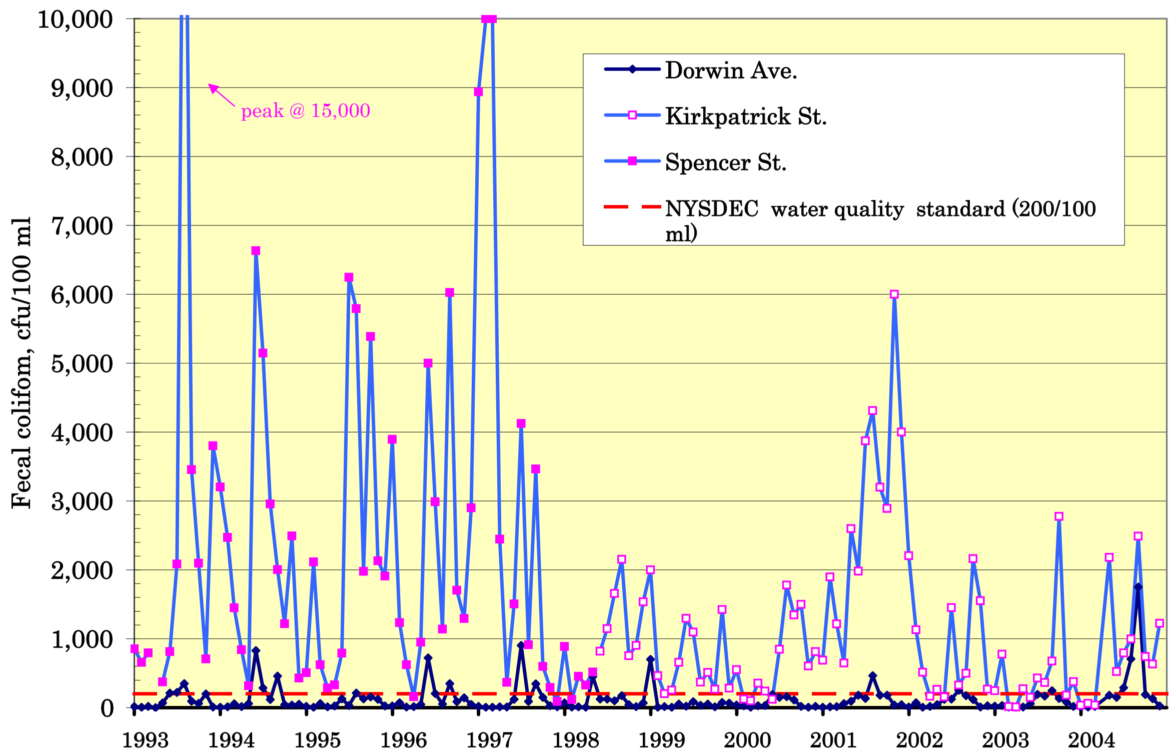
[1]Based on the geometric mean of the total number of samples collected in a 30-day period. No minimum number of samples is specified in the regulations.

6 Coliforms, as the name suggests, are bacteria having a form similar to E. Coli, which is a major bacterium present in the intestinal tract of humans and other warm-blooded animals.

FINDINGS

Routine monitoring

Fecal coliforms: Onondaga County has monitored fecal coliforms in Onondaga Creek upstream (Dorwin Ave.) and downstream (Spencer and Kirkpatrick Streets) of the city of Syracuse biweekly. Monthly averages[7] computed for the period 1993-2004 are shown in Figure 8. Concentrations downstream greatly exceed the upstream concentrations



in nearly all pairs of samples, indicating a persistent source (or sources) of contamination. The NYSDEC monthly standard for fecal coliforms was exceeded 14% of the time at Dorwin Ave., and 89% of the time at Spencer St.

A general reduction in fecal coliforms at Spencer St. is evident after mid-1998. Since 1998, Onondaga County has implemented improved quality controls for its ambient monitoring program (Ecologic LLC *et al*, 2000). However, Onondaga County (Office of the Environment, pers. comm. 2007) has indicated that no change in bacteria sampling protocols has occured. Over the period July 1998 through May 1999, Onondaga County upgraded deteriorated siphons which carry sewage underneath Onondaga Creek. Each pipe was inspected and relined, thereby reducing leakage of sewage into the creek (OCDDS 2000). Onondaga County initiated some upstream sewer separation projects and a CSO storage system (under Erie Blvd.) which may have helped reduce bacteria levels; however, most of these improvements did not take effect until 2002.

The Spencer St./Kirkpatrick St. sampling site is downstream of nearly all combined sewer overflows (CSOs) which discharge into Onondaga Creek. We hypothesized that high levels of fecal coliform resulted from CSO discharges prior to sampling. However, an investigation of the relationship between rainfall (which triggers CSO events) and fecal coliform concentration showed a poor correlation. Fecal coliforms are often high (>1000 units/100 ml) when no rain fell on either the sampling date or the two days prior.

7 Geometric means are shown, in keeping with the NYSDEC regulatory standard. However, regulations specify the collection of five samples per month. County data used in the analysis, which included both routine and high-flow events, had a frequency of 2-4 samples per month.

We also hypothesized that temperature might influence fecal coliform levels, since fecal bacteria tend to die off more quickly at higher temperatures (Auer *et al.* 1996). Again, no relationship was found. It is recognized that sediments can harbor large quantities of micro-organisms over long periods of time (Davies *et al.*, 1995). Therefore, resuspended sediment could be a major source of fecal coliforms to the water column. An analysis of suspended solids and fecal coliforms showed a moderate degree of correlation at Dorwin Ave., but poor correlation at Spencer St./Kirkpatrick St. Finally, it is possible that sewers continue to leak into the creek during dry periods. Further testing would be required to find the true sources of bacteria. Bacteria at Dorwin Ave. were significantly higher during summer months compared to winter, which suggests agricultural sources.

Limited data have been collected by Project Watershed in the Tully Valley, the West Branch, and Furnace Brook. High fecal coliforms were recorded at Bear Mountain Road/Tully Farms Rd. (up to 10,000 units/100 ml). Since 2001, fecal coliforms appear to have declined at this site which is an active agricultural area. Fecal coliforms in the West Branch (1998-2006) and at Kirk Park (2004-2006) were consistently below 200 units/100 ml but few samples were collected at these two locations.

Enterococci: Onondaga County conducted routine monitoring of enterococci from January 1999 to April 2001. Results are summarized in the table below. As a means of evaluating the suitability of the creek for contact recreation, these data were compared with the NYSDOH standard for bathing beaches, 61 units/100 ml in a single sample (NYSDOH, 2004).

Enterococci (units/100ml)	Dorwin Ave.	Kirkpatrick St.
Average concentration	115	940
Fraction > 61	38%	82%

These data indicate:

- Significant fecal contamination is entering the creek between the up- and down-stream sites, reinforcing the findings of the fecal coliform testing;
- When compared to state health department standards, the frequency of exceedances at the upstream site is greater for enterococci than for fecal coliforms.

Storm event monitoring

Onondaga County has also measured pathogens (fecal coliform, *E.coli*, and enterococci) at four locations[8] during selected storm events. The data show:

- levels of bacteria vary greatly over short periods (1-5 days)
- bacteria are usually much higher downstream compared to upstream
- rainfall intensity has a strong influence on severity of contamination: intense storms lead to greater concentrations of bacteria in the creek
- high levels of fecal coliforms (>60,000 units/100 ml), *E.coli*, and other indicators at Route 20, as well as downstream locations, occur during heavy rainstorms. These results corroborate the findings of Project Watershed, which indicate significant sources of bacteria in the Tully Valley prior to 2001.

8 Route 20 (near Cardiff), Dorwin Ave., Kirkpatrick St., and Hiawatha Blvd.

IMPLICATIONS

Water quality violations Pathogenic bacteria are a concern in Onondaga Creek, especially in the downstream (urban) section. The state water quality standard for fecal coliform bacteria is routinely and grossly exceeded. Enterococci data support these findings. Consequently, contact recreation is precluded at the downstream sites (Spencer and Kirkpatrick Sts.) nearly all of the time, and at the upstream site (Dorwin Ave.) about 15% of the time, based on the NYSDEC and NYSDOH standards.

Combined sewer overflows CSOs are a known source of untreated sewage to the downstream section of Onondaga Creek. Elimination of untreated CSO discharges will help reduce bacterial inputs the creek. Onondaga County is undertaking a CSO abatement program which will significantly reduce the quantity of bacteria discharged into the creek. Projects include the Midland Ave Regional Treatment Facility (RTF) which is under construction, and the Clinton St./Armory Square RTF, which is under design.

Other urban sources High fecal coliform levels at Spencer and Kirkpatrick Streets did not correlate well with rainfall, which implies a source other than CSO discharges. Suspended sediments show a weak correlation at Spencer and Kirkpatrick Streets. Leaky sewers are another possible source. A combination of factors is suspect. Further investigation will be required to determine the sources of bacteria in the urban part of Onondaga Creek.

Stormwater There are numerous storm water outfalls which direct street runoff into the creek. The extent to which these outfalls contribute bacterial contamination to Onondaga Creek is unknown.

Rural areas High levels of fecal coliform bacteria have been measured in the Tully Valley, probably reflecting agricultural sources. Field application of manure and the intrusion of dairy cattle into local streams are likely sources of fecal contamination. Leaking septic systems and wild or domestic animal feces are other possible sources.

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INTRODUCTION

New York State has issued two types of water quality standards: narrative and numerical. The narrative standards are descriptive in nature, such as the narrative standard for turbidity: "no increase that will cause a substantial visible contrast to natural conditions" (NYS DEC, 1999). Numerical standards establish chemical concentrations or other quantitative measures (e.g. pH) which are not to be exceeded. Dissolved oxygen is an exception in that standards set minimal concentrations.

In the preceding Fact Sheets, we have touched on compliance with New York State water quality standards for a number of parameters, namely: dissolved oxygen, fecal coliform bacteria, ammonia, and nitrite. In this Fact Sheet, compliance with these standards, as well as several heavy metals and cyanide, are summarized.

New York State has established water quality standards for organic chemicals, such as DDT and PCBs. In reviewing the available literature, OEI has found little or no data for these chemicals. Thus, compliance for these chemicals is largely unknown.

FINDINGS

Compliance with numerical standards over a 13-year period (1993-2005) is summarized in Table 8. Compliance rates are primarily taken from Onondaga County monitoring reports for 1993- 2005.[9] In these reports, compliance in Onondaga Creek is calculated based on combined data from Dorwin Avenue, Spencer St. and Kirkpatrick St. These are the values presented in Table 8, with the exception of nitrite and fecal coliform bacteria. OEI-computed compliance rates are shown for these two parameters at the upstream and downstream sites separately to more accurately portray water quality issues.

General water quality parameters

Non-compliance issues exist primarily for fecal coliforms and nitrite. The DEC water quality standard for fecal coliform bacteria was violated routinely at Spencer and Kirkpatrick Streets (averaging eight out of every nine months), and less often at Dorwin Avenue (one out of every nine months).[10] Nitrite was out of compliance about 1% of the time at Spencer and Kirkpatrick Streets and 12% at Dorwin Ave.

Heavy metals and cyanide

These substances, which have not been discussed in the Fact Sheets, are monitored due to their toxicity to fish and other aquatic life. Water quality standards for several metals (cadmium, chromium, copper, lead, nickel, and zinc) vary with the hardness of the water.[11] **Arsenic, cadmium, chromium, nickel**, and **zinc** were 100% compliant at all three monitoring sites. **Cyanide** and **lead** were nearly 100% compliant: in each case a single sample exceeded the standard during the entire 1993-2005 interval. **Copper** was occasionally non-compliant during two years: 2000 and 2005.

Iron was largely out of compliance with the 300 µg/L standard: between 45% and 100% of all samples in a given year were above this regulatory limit. NYSDEC has recently proposed withdrawing iron as a regulated parameter, and may replace the 300 µg/L standard with a 1000 µg/L guidance value (NYSDEC, 2007). While the waters of Onondaga Creek would often be above the guidance value, these would no longer be considered water quality violations. Iron has ranged from 1,500 to 14,000 µg/L in the Tully Valley, based on sampling performed by USGS in 1989 and 1990, indicating that this is not an urban phenomenon. Iron is known to occur in the local shales and the glacially derived sediments, and hence in water discharging from shale bedrock and from the Tully Valley floor (W. Kappel pers. comm., 2007).

The water quality standard for **mercury** is extremely low: 0.0007 µg/L. This is significantly below the detection limit achieved by Onondaga County's analytical laboratory (0.2 µg/L prior to 2003; 0.02 µg/L 2003-2005). Hence it is not possible to quantify compliance. A sample containing, say, 0.01 µg/L mercury would be reported as

9 Stearns & Wheler (1994, 1995, 1996, 1997) and EcoLogic LLC et al. (1999, 2000a, 2000b, 2001, 2003a, 2003b, 2004, 2005, 2006).

10 It is assumed, in calculating compliance rates, that the standard of 200 cfu/100 ml (monthly geometric mean) applies year-round.

11 Hardness has averaged 314 mg/L as $CaCO_3$ at Dorwin Ave., and 415 mg/L as $CaCO_3$ at Spencer/Kirkpatrick St.

"non-detected," but would exceed the water quality standard by a factor of 14. However, it is possible to make some general observations. Over the time interval 1993-2004, mercury has been detected once at Dorwin Ave. (0.2 µg/L) and three times at Spencer/Kirkpatrick St. (0.02 – 1.1 µg/L).[12]

While somewhat dated, the most reliable source of mercury data for the waters of Onondaga Creek comes from graduate research conducted at Syracuse University by Gbondo-Tugbawa (1999). The creek was sampled approximately monthly between October 1995 and September 1996. Rigorous bottle preparation and clean-sampling procedures were employed to prevent potential sample contamination. Laboratory analysis achieved a detection limit under 1 ng/L (1 part-per-trillion).[13] The 15 samples collected from Onondaga Creek near Spencer St. ranged from 5.0 - 14.5 ng/L, indicating persistent non-compliance with the 0.7 ng/L water quality standard for mercury.

Table 8. Compliance with water quality standards in Onondaga Creek, for the period 1993 – 2005, based on monitoring data collected by Onondaga County. Cells are shaded green when compliance >90%; yellow, between 65% and 89%, and orange, <65%.

Parameter	**Current WQ Standard**[1]	**Compliance Rate** [2]	
General water quality		**Dorwin Ave.**	**Spencer/ Kirk. St.**
Dissolved Oxygen, minimum daily average	> 5 mg/L	100%(1993 -2005), except: 92-96% (1995-1997)	
Dissolved Oxygen, minimum at all times	> 4 mg/L	100% (1993 -2005), except: 92%(1997); 96% (1995)	
Fecal coliform (monthly avg)	< 200 #/100mL	86% [3]	11% [3]
Ammonia	< 0.3-2.4*	100% (1993-2005), except 2004 (93%)	
Nitrite (warm water fishery)	< 100 µg/L	N/A[4]	99%
Nitrite (cold water fishery)	< 20 µg/L	88%	N/A[4]
Heavy metals & cyanide			
Arsenic	< 150 µg/L	100% (1993 -2005)	
Cadmium	< 3.5-5.6 µg/L**	100% (1993 -2005)	
Chromium	<300-500 µg/L**	100% (1993 -2005)	
Cyanide, free	< 5.2 µg/L	100% (1993 -2005), except one sample in 2002	
Copper	< 16-26 µg/L**	75 - 100% (1993 -2005)	
Iron	< 300 µg/L	0% - 55% (1993 -2005)	
Lead	< 7-14 µg/L**	100% (1993 -2005), except one sample in 2002	
Mercury	< 0.0007 µg/L	<100% (cannot be quantified due to analytical limitations) (1993 -2005)	
Nickel	<90-150 µg/L**	100% (1993 -2005)	
Zinc	<140-240 µg/L**	100% (1993 -2005)	

Notes:
1 Water quality (WQ) standards are from Rules and Regulations 6 NYCRR Part 703 (NYSDEC 1999). Typical ranges are shown where the standard depends on conditions at the time of sampling, as noted below:
*The ammonia standard varies as a function of temperature and pH
**Standards for cadmium, chromium, copper, lead, nickel, and zinc vary with hardness.
2 Compliance rates shown were determined by Stearns & Wheler (1994-1997) and EcoLogic LLC (EcoLogic LLC et al. 1999-2006) for the period 1993-2005, except for fecal coliform and nitrite, which were determined by OEI using available monitoring data (1993-2004).
3 NYSDEC regulations specify that compliance be based on the geometric mean of 5 (or more) samples collected per month; typically Onondaga County collects 2-4 samples per month. Compliance was evaluated by computing the geometric mean of the samples collected in each calendar month, exclusive of storm samples.

4 See Fisheries Fact Sheet.

12 A value of 1900 µg/L, reported for June 15, 1994, has been rejected as being invalid.
13 Analysis of total mercury was done by oxidation, purge and trap, and cold-vapor atomic fluorescence spectrometry (CVAFS). Laboratory blanks were always <1.0 ng/L

IMPLICATIONS

Urban watershed Onondaga County collects water samples and evaluates water quality compliance in the downstream, urban part of the watershed (i.e. Dorwin Ave. and points downstream). OEI has supplemented the county's evaluation with independent analysis, based on county data.

Water quality compliance in Onondaga Creek at Dorwin Avenue, Spencer St. and Kirkpatrick St , 1993-2005, has been 100% for a number of parameters, including: arsenic, cadmium, chromium, nickel, and zinc. Several parameters have been nearly 100% compliant: ammonia, cyanide, and copper. Dissolved oxygen was out of compliance numerous times during the period 1995-1997, but otherwise in compliance with both the 4 and 5 mg/L standards. Iron was largely out of compliance, with violations of the existing 300 µg/L standard as high as 100% (1993). Iron may be a natural phenomenon, but there are no supporting data from the headwaters (upstream of mudboils area), or major tributaries including the West Branch, or the Onondaga Nation.

Nitrite was in compliance with the warm water fishery standard of 100 µg/L at Dorwin Ave., and Spencer and Kirkpatrick Streets. However, fish monitoring indicates that the cold water standard is probably applicable at Dorwin Ave. (see *Fish Fact Sheet*). On this basis, compliance at Dorwin Ave. was 88% (1993-2004).[14] Little or no data exists to evaluate compliance in the upstream portions of the watershed, most of which are designated as trout streams. More monitoring is needed to determine the source(s) of nitrite, and the degree of compliance upstream of Dorwin Avenue.

The fecal coliform standard has been routinely violated at all three sites sampled by Onondaga County for all 13 years of monitoring reported herein. The violations are most frequent and most severe at the downstream sites (see Pathogens Fact Sheet). There is little doubt that this is linked to the combined sewer overflows (EcoLogic LLC *et al.* 2006 and prior years), but, as noted in the Pathogens Fact Sheet, there is little direct correlation between CSO events and fecal coliform concentrations. More intensive monitoring of fecal coliforms within the city of Syracuse is needed to develop a better understanding of the sources of these bacteria. In addition, sampling is needed in upstream rural communities to check compliance and determine sources of contamination.

It is impossible to determine compliance for mercury based on the existing data. Several exceedances have been observed when concentrations exceeded the analytical detection limit achieved by Onondaga County (currently 0.02 µg/L). However, much more sensitive techniques exist. The CESE laboratory at Syracuse University, for example, achieves a detection limit of 0.0002 µg/L.

Rural watershed In its review of available data, OEI has not located any past or on-going evaluation of water quality compliance in the rural watershed. Data collected by UFI (2002-2003) and USGS (1989-2001) were deemed too limited to adequately evaluate compliance in the rural watershed, although OEI did evaluate compliance with ammonia standards using data collected by UFI. Thus, compliance with water quality standards in the upstream, rural watershed is essentially not determined.

14 Under current NYSDEC stream classification, water at Dorwin Ave. is not designated for trout, a cold water species. Thus, from a strict interpretation of regulation, this stream reach is a warm water fishery. From a planning perspective, evaluation against the cold water standard is also appropriate.

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Summary of Water Quality

Onondaga Creek Fact Sheet

INTRODUCTION

This final Fact Sheet summarizes the quantitative water quality parameters discussed previously (Table 9A), along with some qualitative parameters, such as water appearance and odor (Table 9B). The creek was divided into four reaches (see Figure 9) to allow a comparison among different parts of the watershed.

Quantitative parameters: Sufficient data exist to provide a general assessment of certain parameters throughout the watershed, namely temperature, dissolved oxygen, salinity, pH, turbidity, and nitrate. However, data for ammonia, nitrite, fecal coliforms, and phosphorus are generally adequate to assess water quality only in lower Onondaga Creek (Nedrow and Syracuse).

In Table 9A, water quality in Onondaga Creek was largely assessed in terms of its suitability for cold-water fish, such as trout. This criterion is based on a number of factors:

1. The ability of a stream to support naturally reproducing and surviving cold water fish populations reflects on the degree of degradation of the whole stream ecosystem. Cold water fish are an important sentinel species due to the water quality and habitat requirements necessary for reproduction and survival.
2. Water quality parameters represented in the table are usually measured in order to assess suitability for aquatic biota (such as cold water fish) and human recreational use.
3. Much of the creek watershed is classified by New York State for supporting trout [C(t)] or trout spawning [C(ts)]. These classifications apply to the creek mainstem south of Commissary Cr., the entire West Branch, and numerous tributaries and sub-tributaties. Fish survey data support the state classifications (see Fish and Habitat fact sheets).
4. O*nondaga Lake: A Plan for Action* recommends, over the long term, "a suitable year-round habitat for a sustainable consumptive warm and coldwater fishery in the Lake and its tributaries" (OLMC, 1993). This plan was adopted by the Onondaga Lake Partnership in 2000 (OLP, 2000) and is the current management plan for the Onondaga Lake watershed.

Water quality was also evaluated for "impairment" based on criteria established under the Great Lakes Water Quality Agreement, as amended in 1987 (IJC, 1987). Specific criteria relevant to Onondaga Creek include: loss of fish and wildlife habitat, degradation or decline of fish populations, degradation of aesthetics, restrictions on fish and wildlife consumption, and undesirable algae.

A color scheme was developed to help interpret overall water quality conditions in the four reaches of Onondaga Creek. Green denotes those reaches where the parameter appears to be suitable for cold-water fish, or is not expected to lead to impairments. Yellow denotes areas where data show restrictions for cold-water species, or limited impairments. Red indicates definite and severe impairments. Reaches with inadequate data are white.

Reference streams are used for comparative purposes. They do not necessarily represent pristine or background conditions, but would be expected to have similar physical, chemical and biological characteristics. OEI was able to locate only two publications which established reference streams to Onondaga Creek. The Owasco Inlet, in Cayuga County, New York was used as a reference stream in research examining the survival and energetics of stocked Atlantic salmon (Coughlin and Ringler 2005). It was selected for relatively low human impact, and hydrology that was broadly similar to Onondaga Creek. The W. Branch of the Tioughnioga River, located upstream of Cortland, New York, was used by the USEPA (1996) as a reference for a study examining macroinvertebrate community assessment in detecting water quality impairment due to combined sewer overflows in Onondaga Creek. Water quality data in these publications are quite limited. A comprehensive comparison with an appropriate reference stream would entail considerable research effort, and is beyond the scope of this project.

Qualitative parameters: The appearance and odor of a stream are more than just aesthetic issues, they are important indicators of ecosystem health as well. Excessive algae indicate eutrophic conditions; slime deposits indicate excessive organic matter; hydrogen sulfide odors indicate a lack of oxygen. Data on appearance and odor were gathered from Project Watershed, a citizen-based water monitoring program, and stream mapping reports produced for Onondaga County (EcoLogic LLC, 2001 and 2003).

Notes for Table 9A:

1 Interpretation of information for this table was made using best professional judgment based on limited or potentially incompatible data. For definitions of terms used in the table, see next page. For detailed water quality and chemistry information for Onondaga Creek, see the corresponding fact sheets.

2 Owasco Inlet, Cayuga County, New York and the West Branch of the Tioughnioga River, Cortland County, New York, are the only two streams used as reference streams to Onondaga Creek that could be located in the available literature (Coghlan, 2004, USEPA, 1996). A reference stream is used for comparative purposes. It does not necessarily represent pristine or background conditions, but would be expected to have similar physical, chemical and biological characteristics.

3 Evidence of eutrophication is cited in stream mapping reports produced for Onondaga County's Department of Water Environment Protection (EcoLogic, LLC, 2001, 2003).

Definitions of Terms Used:

Suitable: based on the requirements for cold-water fish, such as trout. Rationale for this criterion is given on p.1.

Unsuitable: unlikely to meet the requirements for cold-water fish and other sensitive organisms.

Impaired: stream water quality demonstrates natural and/or anthropogenic change in the chemical, physical or biological integrity sufficient to cause loss of fish and wildlife habitat, degradation or decline of fish populations, degradation of aesthetics, restrictions on fish and wildlife consumption, undesirable algae, and other negative impacts to beneficial uses (adapted from Great Lakes Water Quality Agreement of 1978, Amended 1987, (IJC, 1987)).

Unimpaired: no measured or readily apparent lowering of water quality.

Elevated: data shows consistent increase as compared to other sections of Onondaga Creek.

No data: data not located in available literature.

Limited data: data in available literature is inadequate to draw conclusions.

Pulse: elevation of parameter of limited and definable time duration (Allan, 1995)

Eutrophication: the process by which waters become rich in mineral and organic nutrients (most commonly nitrogen and phosphorus) that promote a proliferation of plant life, especially algae, that, via respiration and decomposition, reduces dissolved oxygen content and can cause the asphyxiation death of other organisms. (USEPA, 2001; USGS, 2002).

Table 9A. Summary of Quantitative water quality parameters by stream reach[1]

					Reference Streams to Onondaga Creek[2]	
Parameter:	**Upper Onondaga Creek: Tully Valley& Headwaters**	**Major Tributary: The West Branch of Onondaga Creek**	**Middle Onondaga Creek: The Onondaga Nation**	**Lower Onondaga Creek: Nedrow and Syracuse**	**Owasco Inlet: Multiple Sampling Sites (2002-2003) (Coghlan, 2004)**	**West Branch of Tioughnioga River, Homer, NY Downstream of Rte 11 Bridge (EPA, 1996)**
Temperature	Suitable for cold-water fish	Suitable for cold-water fish	Suitable for warm-water fish; Periodically unsuitable for cold-water fish	Spencer Street: Suitable for cold-water fish Dorwin Avenue: Periodically unsuitable for cold-water fish	Upper Onondaga Creek is generally cooler; Lower Onondaga Creek is comparable	Single data point (13 C) indicates comparable to Onondaga Creek
Dissolved Oxygen (DO)	Suitable for cold-water fish	Suitable for cold-water fish	Suitable for cold-water fish; DO at dam on Onondaga Nation is lower than upstream	Suitable for cold-water fish; Inner Harbor has impaired DO at depth	Overall, DO is somewhat higher than Onondaga Creek.	Single data point (10mg/L) is comparable to Onondaga Creek
Salinity	Unimpaired above mudboils; Elevated levels downstream of mudboils on Bare Mtn.	Unimpaired	Elevated levels	Increased concentrations downstream of Spencer Street due to groundwater discharge	Upper Onondaga Creek is comparable; Lower Onondaga Creek is 3-4x more saline	No data
pH	Suitable range (7.0 – 8.5)	Suitable range (7.0 – 8.5)	Occasionally high pH (>8.5) Hemlock Creek: variable	Sporadically high pH (>8.5)	Systems were comparable; reported pH range 8.0-8.9	Single data point (pH=8) is comparable to Onondaga Creek
Turbidity	Impaired downstream of mudboils and landslides	Unimpaired	Impaired	Impaired	Comparable high turbidity during storm events, up to 440 NTU. Significantly lower under baseflow conditions.	No data
Nitrogen:						
Ammonia	No data	Slightly elevated via sporadic pulses, but non-toxic to fish	Slightly elevated at times, but non-toxic to fish	Higher than upstream; occasionally approaches toxicity standard	No data	No data
Nitrite	No data	No data	No data	Suitable for warm-water fish; Periodically unsuitable for cold-water fish	No data	No data
Nitrate	Unimpaired	Unimpaired	Unimpaired	Unimpaired	No data	No data
Total Phosphorus	Limited data, evidence of eutrophication[3], increases below mudboils	Limited data	Limited data	Abundant data, evidence of eutrophication, pulses during storm events	No data	No data
Pathogens (Fecal Coliforms)	Route 20: Most storm samples exceed contact recreation standards	No data	No data	Spencer Street: Exceeds contact recreation standards 89% of the time Dorwin Avenue: Exceeds contact recreation standards 14% of the time	No data	No data

* See notes on previous page

Table 9B. Summary of Qualitative Descriptors of Onondaga Creek Waters

Qualitative Description	Upper Onondaga Creek: Tully Valley	Major Tributary: The West Branch of Onondaga Creek	Middle Onondaga Creek: The Onondaga Nation	Lower Onondaga Creek: Nedrow and Syracuse
Water Appearance[1]	**Project Watershed:**			
	Solvay Road: Clear (1999-2004)	Route 80: Clear, foamy (1998-2004)	No data	Near Dorwin Ave.: Clear or brownish, muddy (2003-2006)
	Bear Mountain Road: Clear or brownish, muddy (1999-2005)			Furnace Brook: Clear (1991, 1997-2003)
				at Kirk Park: Clear-brownish, muddy (2004)
	Onondaga County: (2000,2002)			
	Vesper: Ranked poor	No data	Multiple sites ranked poor (assessed in 2000 only)	Dorwin to Seneca Turnpike: Ranked Fair
	Fellows Falls to north of Solvay Road: Ranked Fair to Excellent;			Newell to East Adams: Ranked Poor to Fair
	Otisco Road to Rt. 20: Ranked Poor			Kirkpatrick to above Spencer: Ranked Fair
Odor[1]	**Project Watershed:**			
	Solvay Road: No odor to occasionally musky (1999-2004)	Route 80: No odor (1998-2004)	No data	Near Dorwin Ave.: No odor
				Furnace Brook: No odor
	Bear Mountain Road: No odor			at Kirk Park: No odor
	Onondaga County: (2000,2002)			
	Sulfur odor noted at one site	No data	No data	Sewage odor noted from Midland Avenue to Spencer Street

1 Water appearance and odor information was extracted from the Project Watershed Central New York database (http://projectwatershed.org, accessed in September and October, 2006) and stream mapping reports produced for Onondaga County's Department of Water Environment Protection (EcoLogic, LLC, 2001 and 2003). For protocols used to evaluate qualitative water quality parameters, see references.

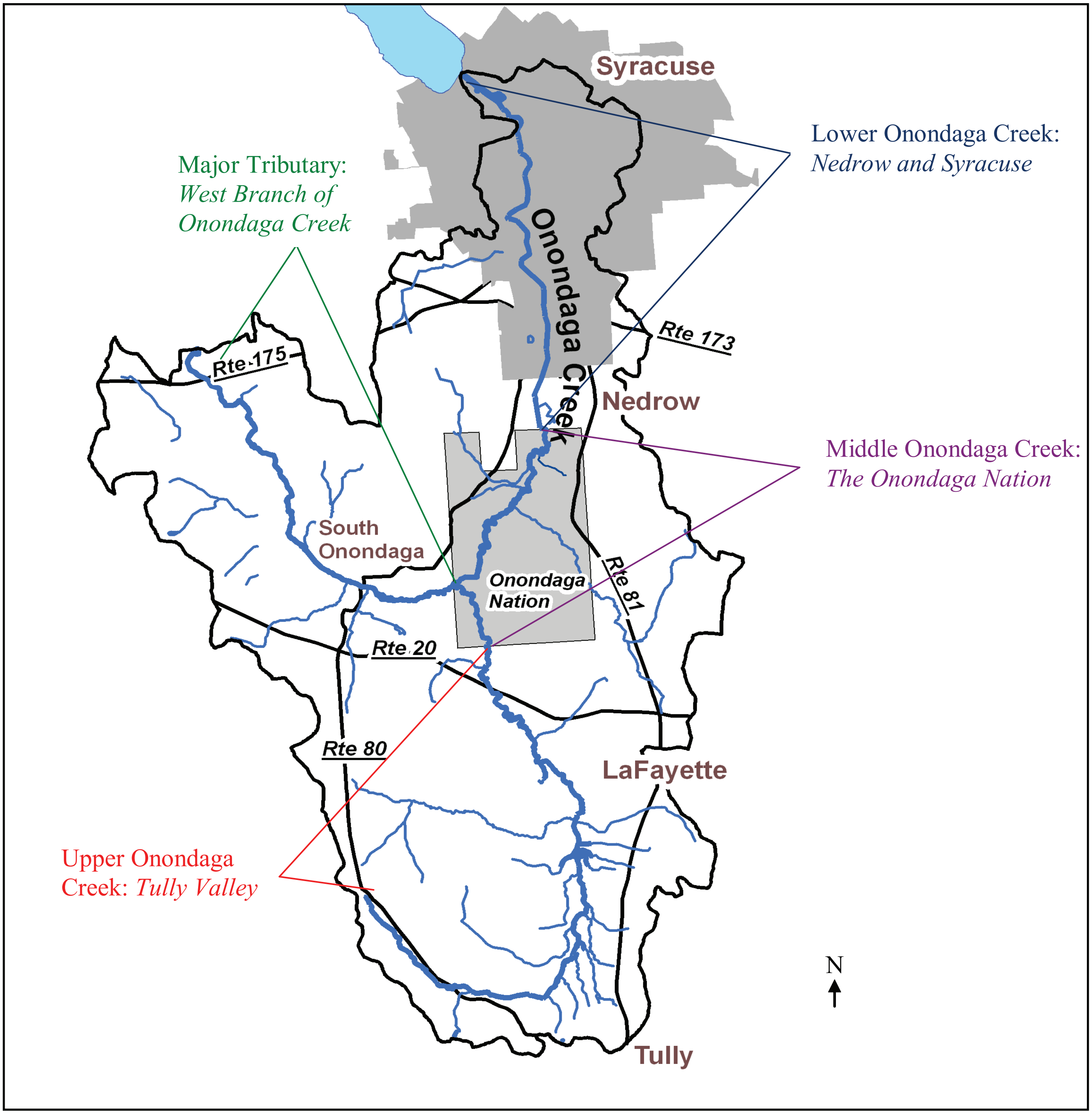

Figure 9: The four reaches of Onondaga Creek as described in the Onondaga Creek Water Quality Summary Fact Sheet.

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The Onondaga Lake Partnership (OLP) sponsors the Onondaga Creek Revitalization Plan project with funds from the U.S. Environmental Protection Agency. Visit www.onlakepartners.org for more information about the OLP.

This fact sheet and additional information about the Onondaga Creek Revitalization Plan project can be found on the World Wide Web at www.esf.edu/onondagacreek/.

Access

Onondaga Creek Fact Sheet

INTRODUCTION

This Fact Sheet addresses:

1. Access to and egress from Onondaga Creek's streambed and stream banks
2. Navigation within the stream

Gaining access to Onondaga Creek and its tributaries is important for a variety of reasons. People use the creek for fishing, hunting, wading, canoeing or kayaking, gathering of medicinal and food plants, bird watching, and research. At present, creek access is difficult for a variety of reasons. In the southern part of the watershed, including the creek headwaters, West Branch, and Tully Valley, land is largely privately owned, so permission must typically be obtained from the landowner. Road crossings afford some degree of access in these parts of the watershed. The creek flows through the Onondaga Nation, where permission must be obtained from the Council of Chiefs. Much of the remainder of the creek, from Nedrow to the outlet at Onondaga Lake, while publicly owned, is physically fenced off.

Once access is gained to the creek, riparian law generally allows one to navigate up- and down-stream, for example in a kayak, regardless of land ownership on either side. However, there are legal caveats (discussed below). Also, this does not extend into the Onondaga Nation, which is a sovereign territory.

FINDINGS

Access to and from the creek

Access to the creek is legal:

- via a public access point,
- by permission of the riparian landowner, or
- through land which is "unimproved and apparently unused" and which is neither fenced nor posted against trespass.[1]

Figure 1 depicts the entire watershed, showing all properties within 300 feet of Onondaga Creek and the larger tributaries.[2] This map also serves as a key to detail maps (Figures 2A-2D; 3A; and 3B) described below. Since properties can change hands at any time, and databases are subject to data entry and other errors, all maps should be regarded as subject to change.

Properties are classified according to assessor codes in a New York State parcel database (NYS ORPS, 2003 and 2006). For the purposes of this Fact Sheet, these properties have been divided into three major categories, with subcategories as noted:

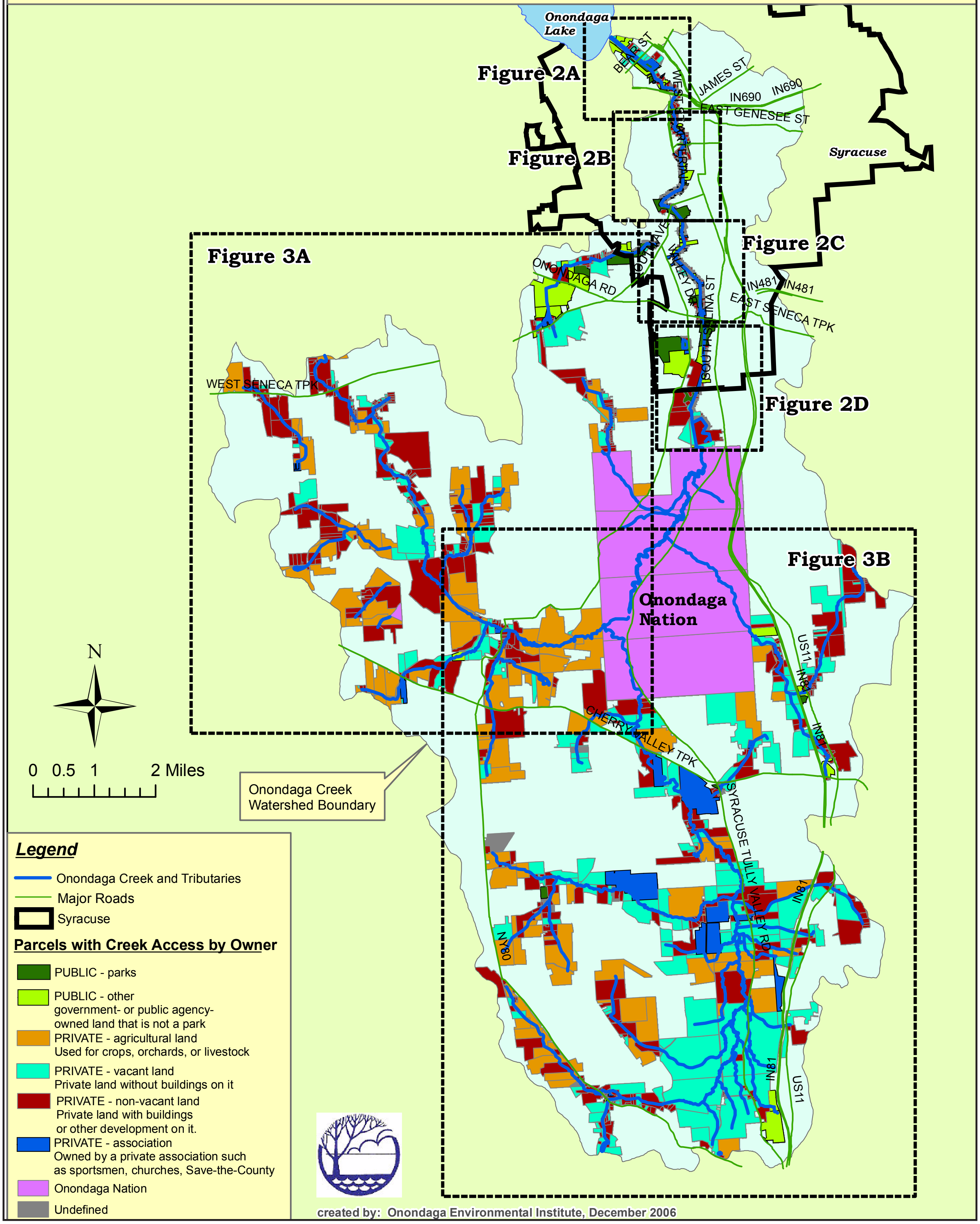
- Onondaga Nation
- Private
  - **vacant land:** private property without buildings or other development
  - **non-vacant land:** private property with buildings or other development
  - **agricultural land:** private property used for crops, orchards, or livestock
  - **private association:** property owned by a private association, such as sportsmen's clubs, churches, and conservation groups (i.e. Save-the-County, Inc.)
- Public
  - **parks**
  - **other:** non-park land owned by any unit of government (e.g. city of Syracuse, Onondaga County), governmental agency (e.g. Syracuse Urban Renewal Agency), public school, or public benefit corporation (e.g. Industrial Development Agencies)

Of these, only public parks, some nature preserves and public roads are openly accessible to the general public. Save the County's (STC) nature preserves that are open to the public are listed in Table 1. Two STC properites provide waterway access. However, other properties, such as public and private vacant land may offer opportunities for access to the creek if they are not fenced or posted. Access to the creek and its tributaries is often available at public road bridge crossings as well, except where physical barriers (such as fences or great height) exist.

1 OEI does not endorse this approach, due to possible legal complications. Obtaining permission from the landowner is recommended.

2 Property coordinates were obtained from Onondaga County Water Authority in 2006.

Figure 1. Location Key for Detail Maps
Accessibility in the Onondaga Creek Watershed



Urban Segments of Onondaga Creek

The Onondaga Creek corridor through Syracuse and Nedrow is shown in detail in Figures 2A-2D:

- Fig. 2A Inner Harbor to Armory Square
- Fig. 2B Armory Square to W. Brighton Ave.
- Fig. 2C W. Colvin St. to Meachem Field
- Fig. 2D Clary Middle School to N boundary of the Onondaga Nation

The creek flows through a corridor largely owned by the city of Syracuse between Dorwin Avenue and Kirkpatrick St. , and by the state of New York north of Kirkpatrick St. (Inner Harbor area). Private land intrudes into the creekbed north of Seneca Turnpike (e.g. Zen Center) and in small, isolated sections in downtown Syracuse.

Despite public ownership, access to the creek is largely precluded due to the presence of chain link fences on both sides of the creek. Exceptions exist in Franklin Square and at the Inner Harbor. Bridge crossings in Syracuse are typically fenced and thus do not provide access. Fences were installed between 1963 and 1973 to prevent children from playing in and drowning in the creek (Lee, 1962; Anon., 1973) The creek had become especially dangerous in the first half of the twentieth century due to flood- and sewage-control measures which created a narrow concrete-lined channel in residential areas. Channelization accelerated the flow of water by eliminating meanders and increasing the slope of the creek.

Rural Segments of Onondaga Creek Watershed

Rural segments of the watershed are detailed in Figures 3A and 3B. Road crossings in the rural parts of the watershed are indicated as triangles. Much of the rural landscape is privately held. Opportunities for access to the creek include purchasing easements, or simply asking permission.

Permission to access the creek, or navigate on the creek within the Onondaga Nation should be obtained from the Onondaga Council of Chiefs (258C Route 11A, Onondaga Nation, Nedrow, NY 13120)[3].

Navigation

Once access to the creek is obtained, it is considered a "public highway" as long as it is "navigable." Navigability is variously defined by Federal regulations, New York State Navigation Law, and several court decisions. Thus there is no simple definition of navigability.

A general definition is provided by U.S. Army Corps regulations (33 CFR 329):

"Navigable waters of the United States are those waters that .... are presently used, or have been used in the past, or may be susceptible for use to transport interstate

3 Onondaga Nation Communications Center phone: 469-4717. Onondaga Nation office: 498-9950.

Table 1. Save the County properties located in the Onondaga Creek watershed.
(see www.savethecounty.org/properties.html for more information)

Name	Acreage	Access to waterway	Road Access	Location & Description
Cherry Valley Preserve	47	Onondaga Creek	Good, from US Route 20.	Town of Lafayette, fronts on US 20 west of I-81. It has a small pond and walking trails.
Herbert Luke Sanger Wildlife Preserve	23	None	Very difficult.	Town of Onondaga, off Amber Road.
Lockwood Properties	83	None	2 of the 5 parcels, are accessible from Amber Road and Stevens Road	Town of Onondaga. Mixed woods with cross country ski trails.
Mason Hill	90	None	accessible from Eager Rd.	Town of LaFayette, on west side of Mason Hill. Contains open fields, 2nd-or 3rd-growth forest and old maple trees along the hedge rows and fence lines; two created ponds; some maintained trails and old roads; great songbird and raptor habitat.
South Onondaga Marsh	6	W. Branch, Onondaga Creek	Accessible from Hogsback Road	Town of Onondaga; Contains a wetland; no trails. W.Branch of Onondaga Cr. flows through this property.

Figure 2A. Detail Map
Accessibility in the Onondaga Creek Watershed

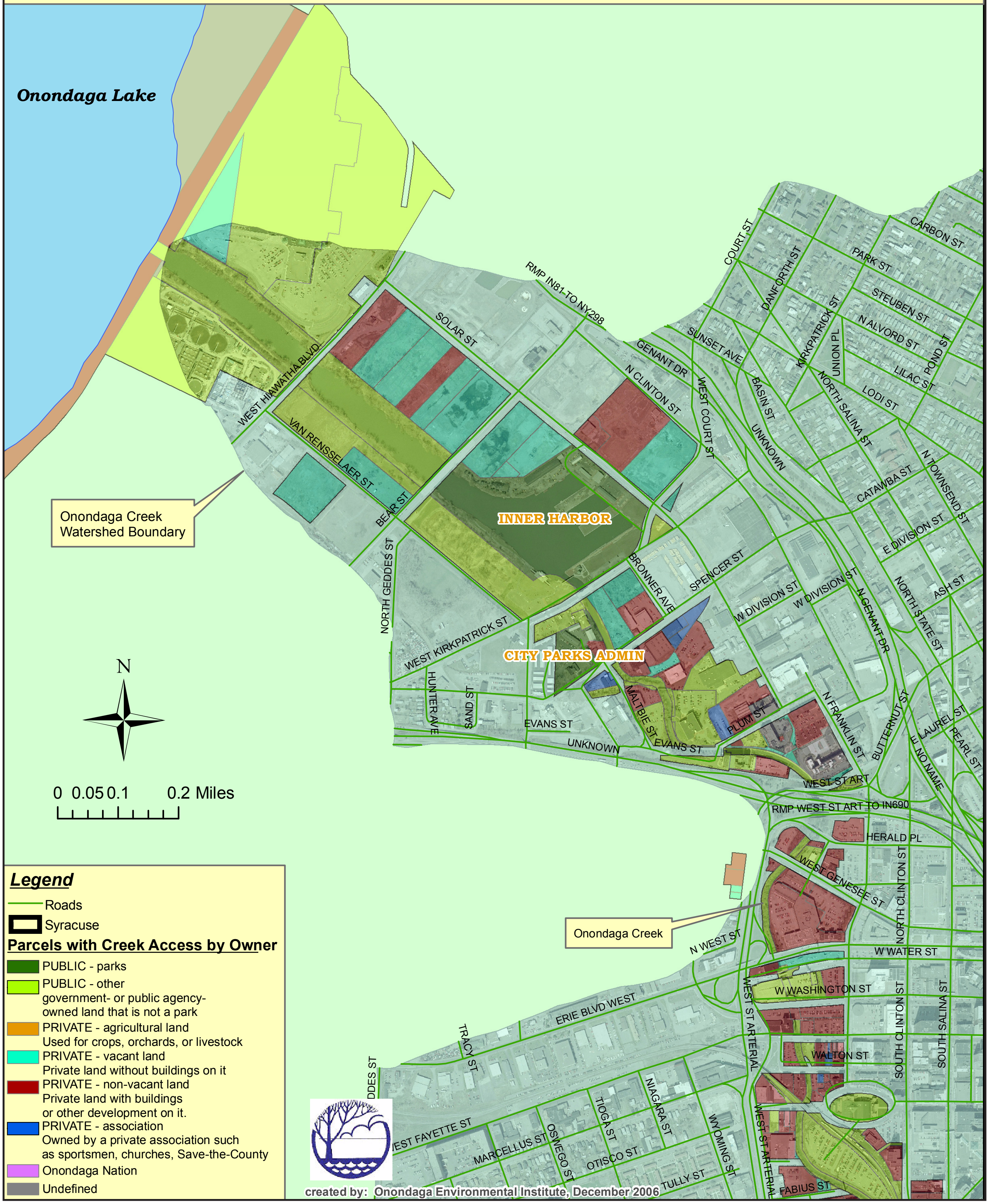


Figure 2B. Detail Map
Accessibility in the Onondaga Creek Watershed

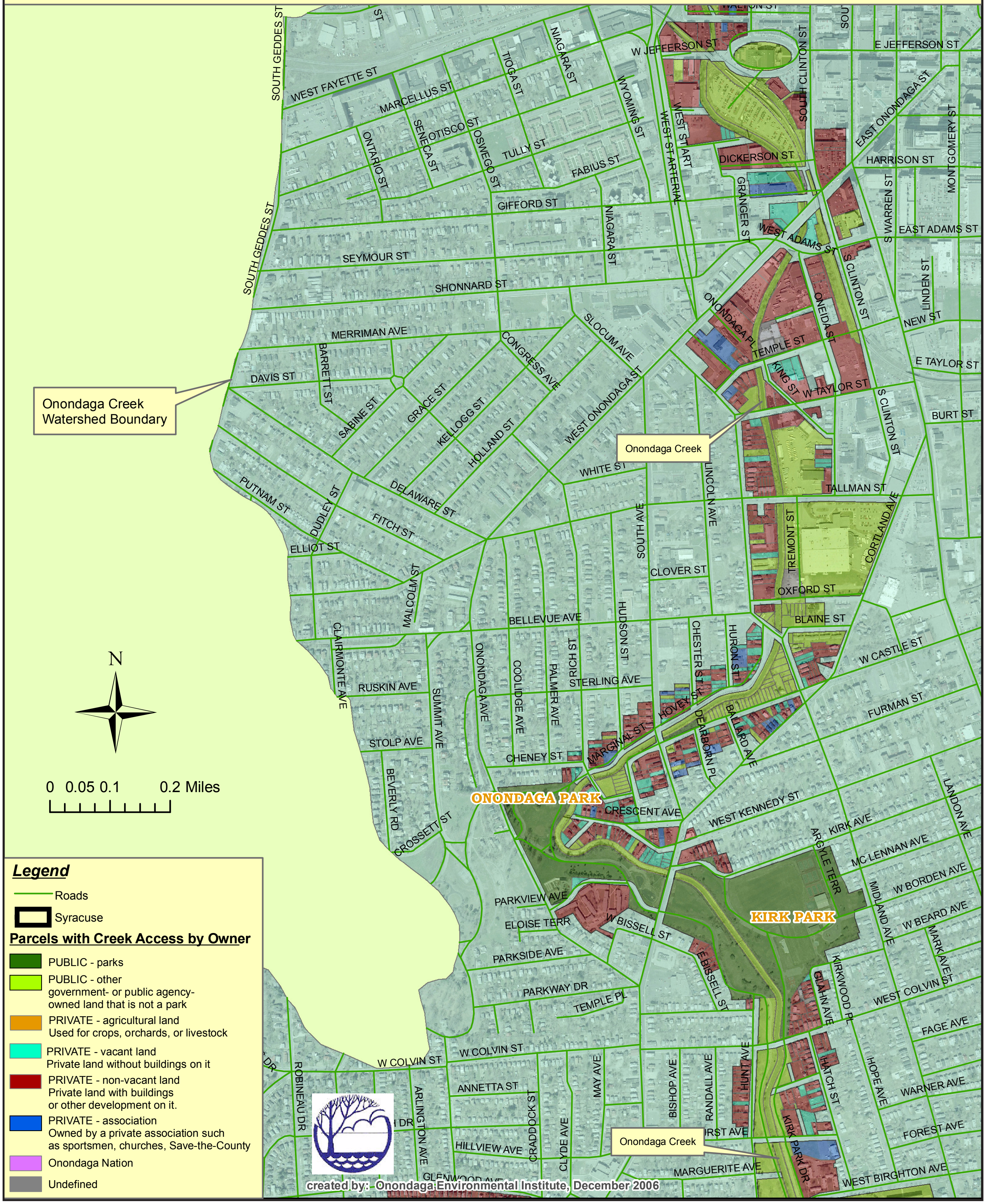


Figure 2C. Detail Map
Accessibility in the Onondaga Creek Watershed

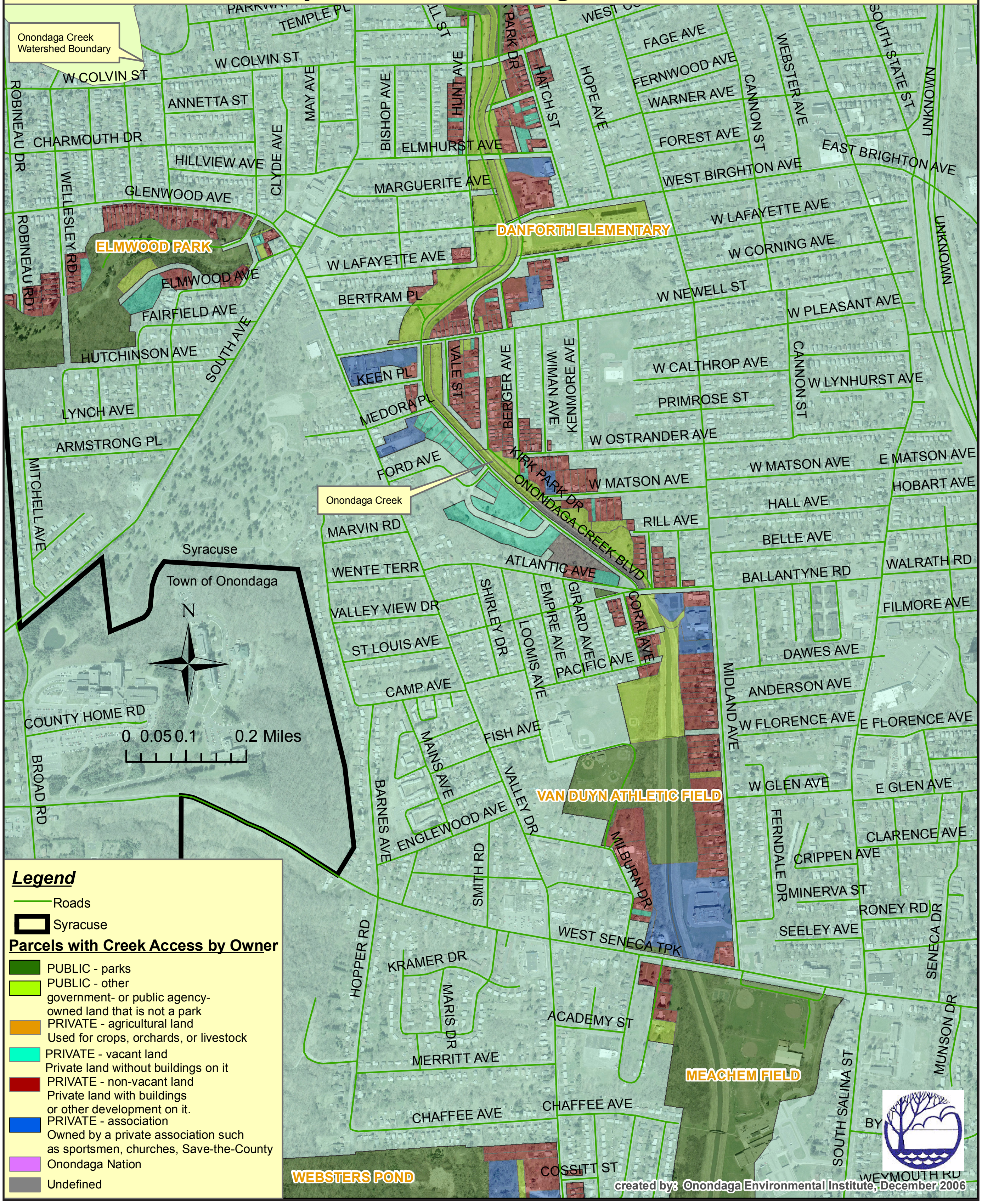


Figure 2D. Detail Map
Accessibility in the Onondaga Creek Watershed

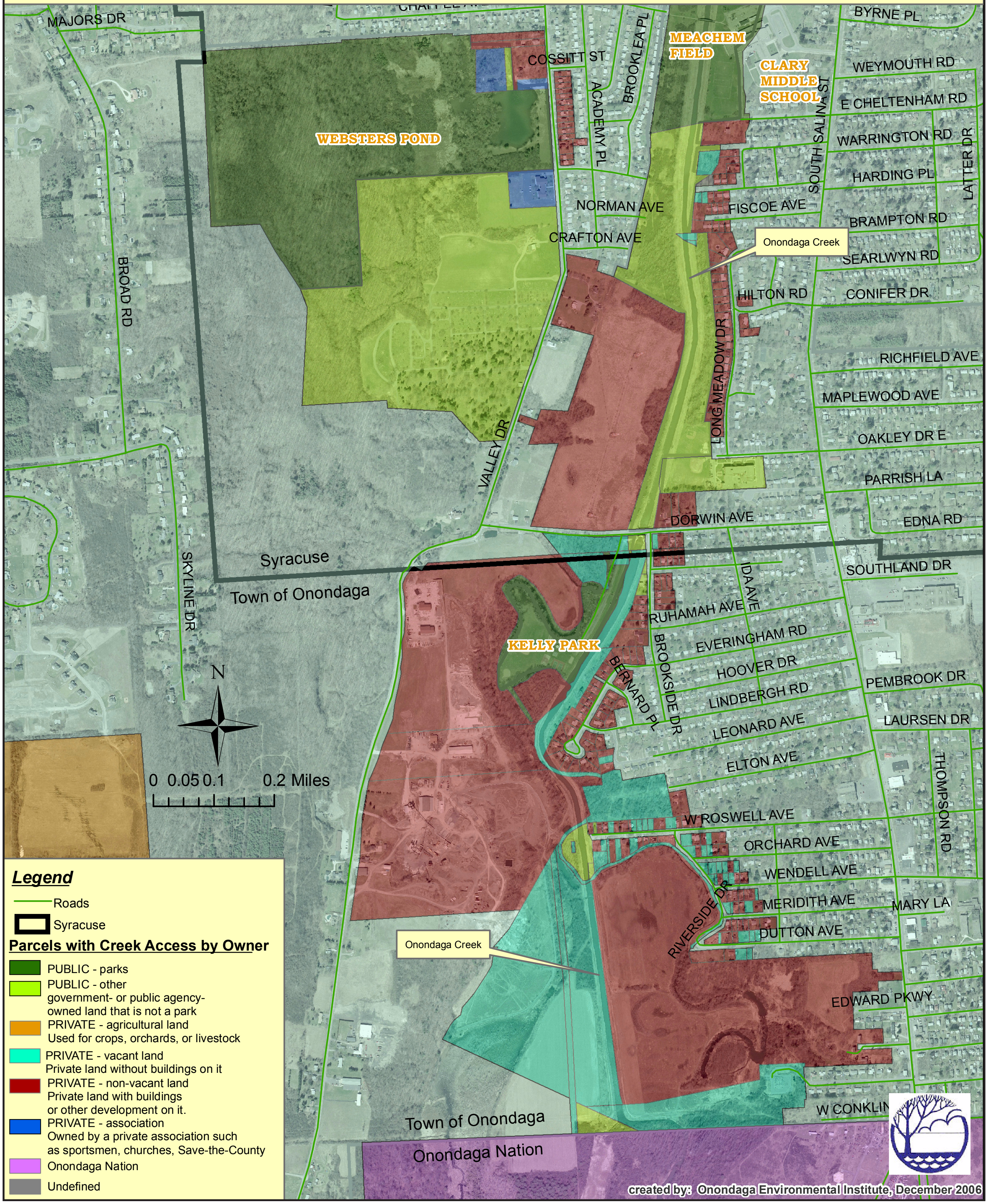


Figure 3A. Detail Map
Accessibility in the Onondaga Creek Watershed

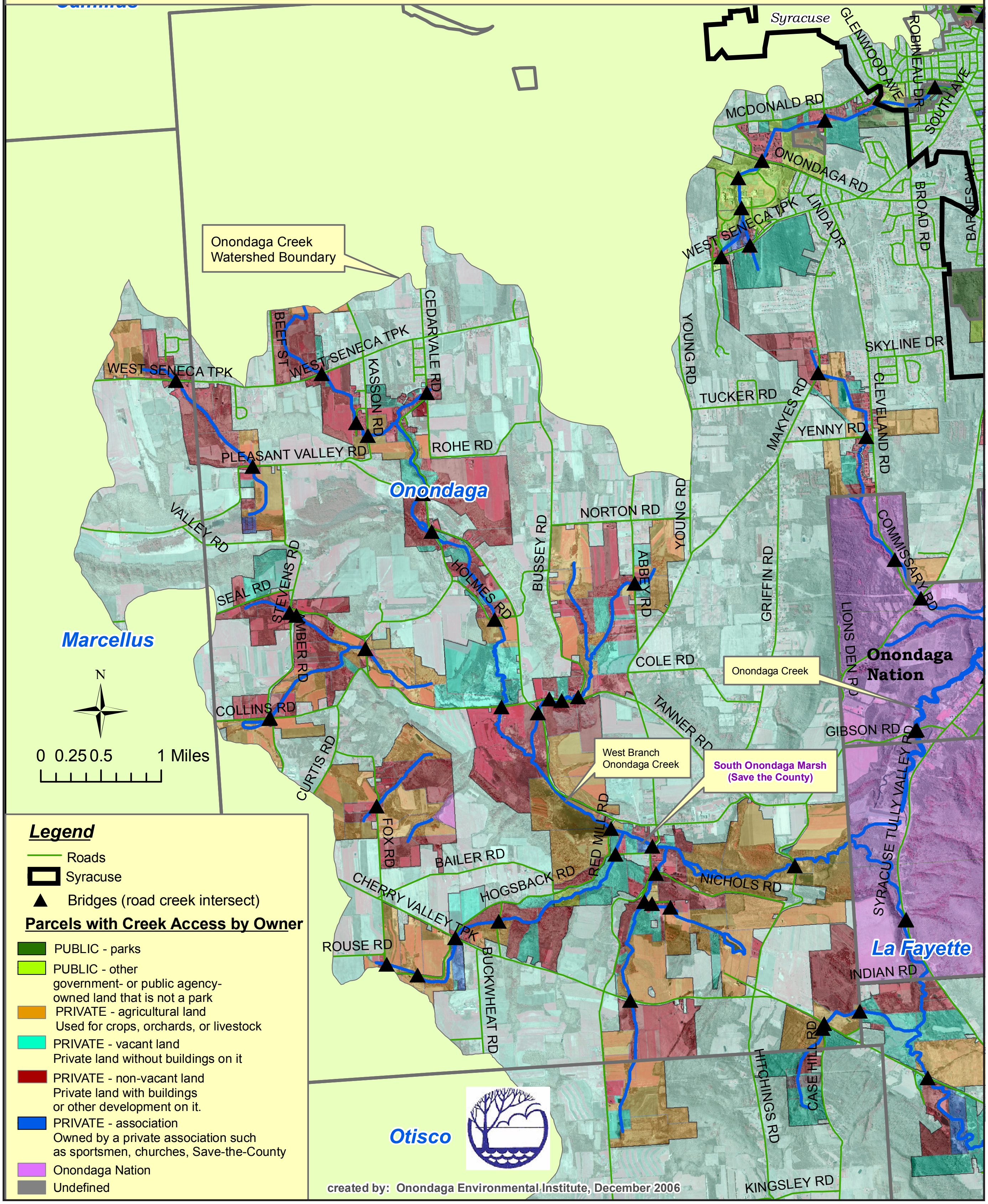
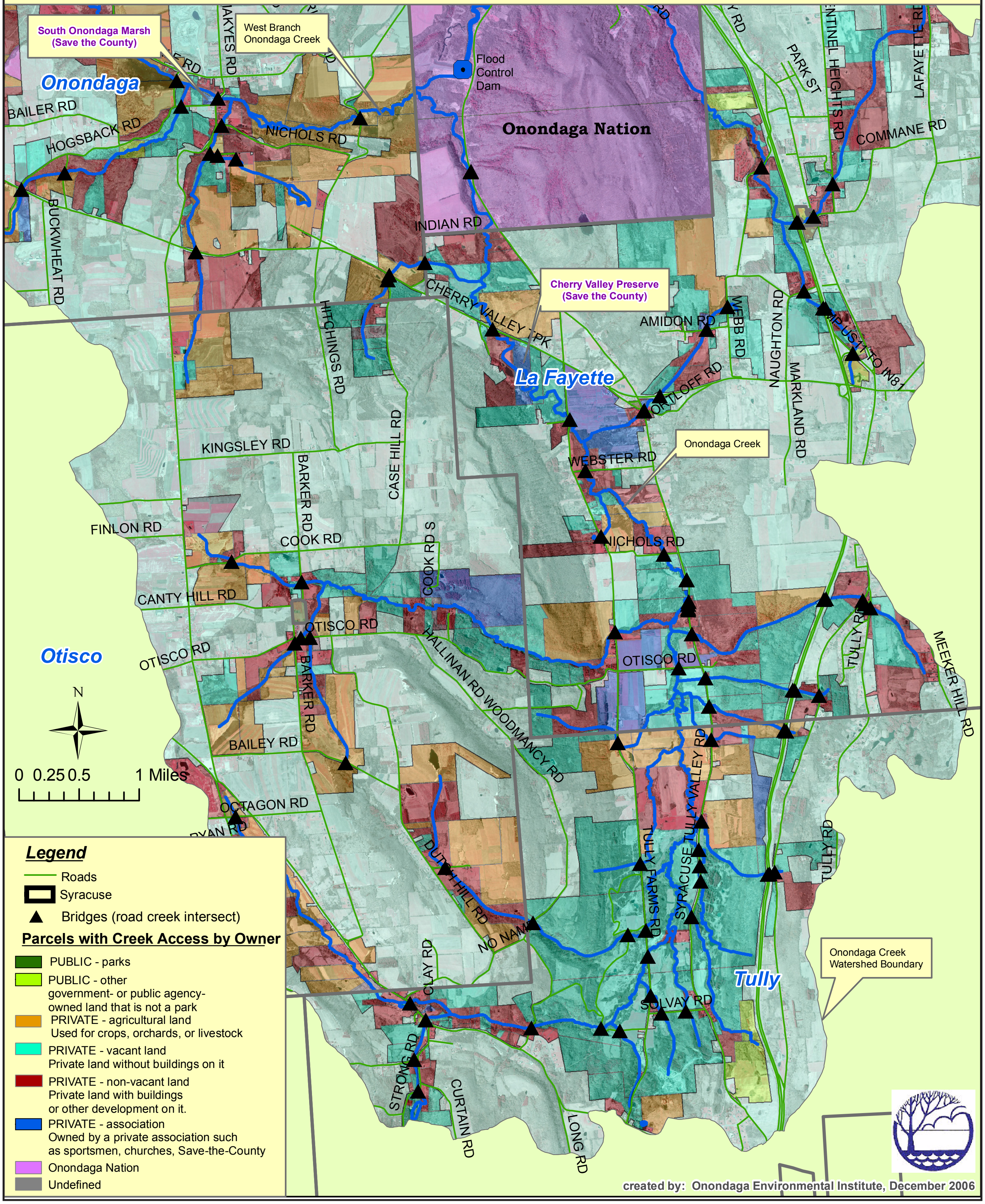


Figure 3B. Detail Map
Accessibility in the Onondaga Creek Watershed



or foreign commerce. A determination of navigability, once made, applies laterally over the entire surface of the waterbody, and is not extinguished by later actions or events which impede or destroy navigable capacity."

Practically speaking, nearly any waterway in the United States which is capable of carrying a recreational watercraft, such as a canoe, would be considered navigable. However, navigation rights constitute a complex legal issue due to conflicting interpretations of state and Federal laws and regulations. Historic use of a waterway, especially for getting goods to market, plays a role in these decisions.[4]

The geographic limits of a stream are established by the "ordinary high water mark," defined as:

"the line on the shore established by the fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the bank; shelving; changes in the character of soil; destruction of terrestrial vegetation; the presence of litter and debris; or other appropriate means that consider the characteristics of the surrounding areas." (33 CFR 329.11(a))

IMPLICATIONS

The general lack of access makes it difficult for the public to enjoy Onondaga Creek. In the rural areas, access can potentially be gained by permission of the landowner, or in the case of the Nation territory, the Onondaga Council of Chiefs. Access can be gained via a number of bridge crossings in the towns of Lafayette, Onondaga, Tully and Otisco, and via two STC properties.

In the city of Syracuse, access is currently possible only at selected bridges, the Zen Center (with permission), Franklin Square, and the Inner Harbor. Access to the creek could be markedly expanded with the removal or modification of fences, especially where adjacent lands are public (see Figures 2A-2D). Currently the city of Syracuse is developing an expanded creekwalk which would increase access from Armory Square northward to the creek's outlet to Onondaga Lake (NYSDOT, 2004). Further plans are underway to extend the creekwalk south to Kirk Park.

Increasing access to the creek is intimately tied with concerns about the health and safety of the public, liability of the city or private landowners, flood control, storm water and combined sewer management, and ecological restoration. For example, creation of a more natural channel with meanders and shoals would diminish velocities in the creek, making it safer. Access might be constrained where habitat is protected. Routing storm water directly to the creek results in increased flows, higher velocities, and consequently, greater safety and liability concerns. Ultimately, there are many factors to consider for any restoration plan which increases access to the creek.

4 For example, "'[A] river is, in fact, navigable, on which boats, lighters or rafts may be floated to market… [Additionally,] the public may have a right of way in every stream which is capable, in its natural state and its ordinary volume of water, or transporting, in a condition fit for market, the products of the forests or mines, or of the tillage of the soil upon its banks...'" *Adirondack League Club, Inc. v. Sierra Club*, 92 N.Y.2d 591 (N.Y. 1998)., quoting *Morgan v. King*, 35 N.Y. 454

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OEI wishes to thank Thane Joyal for her input on this Fact Sheet.

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Land Use and Land Cover

Onondaga Creek Fact Sheet

INTRODUCTION

'Land Use' (LU) refers to *human* land use. Land use terminology tends to describe economic activity, and reflects cultural influence on the environment. The term 'Land Cover' (LC) is distinct from, but related to 'Land Use' by the fact that it describes material on the land surface rather than the activity. Land cover refers to both anthropogenic cover such as a building, and to naturally occurring cover such as a forest. Land Use is the interface between human society and the environment, and it can lead to changes in Land Cover. Together they are commonly referred to as LU/LC.

Humans have always settled near sources of water. As the population density has increased, and as technology allows more extreme modifications of the environment, human impacts have severly impacted the structure and reduced the functioning of natural waterways. In order to mitigate adverse impacts of altered land cover, it often becomes necessary to change land use.

Land use forms patterns on the landscape that typically reflect the most profitable economic land use; often with disregard for environmental consequences. In studying land use patterns within the Onondaga Creek Watershed we can see how the arrangement of the physical geography and the creek corridor determines the economic 'utility' of the land, which in turn determines where certain land use activities occur.

FINDINGS

The Sub-Watersheds of Onondaga Creek

There are four major subwatersheds within the Onondaga Creek watershed:

1. Upper Onondaga Creek: Tully Valley
2. Middle Onondaga Creek: Onondaga Nation and Nedrow
3. West Branch
4. Syracuse

The Upper Onondaga, Middle Onondaga, and West Branch subwatersheds are mainly put to agricultural and residential use, with the Middle Onondaga subwatershed also containing a majority of the Onondaga Nation's land.

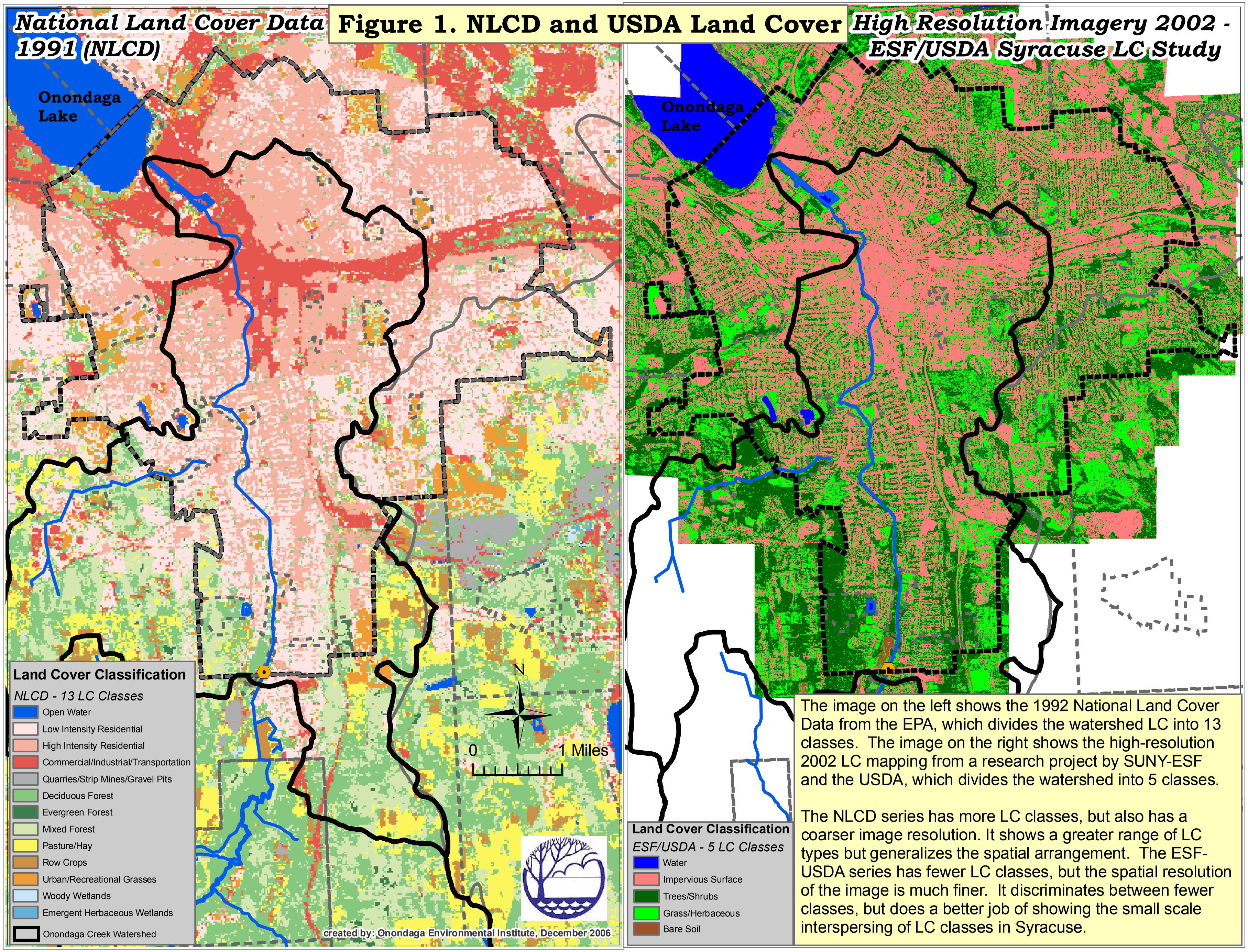
The Syracuse subwatershed is a mix of low and high intensity residential land use in the south part of the subshed and becomes high intensity commercial and industrial land use in the northern downstream part of the subshed.

Land Use and Land Cover Patterns Land cover echoes the land use pattern. Figure 1 shows land cover images of the city of Syracuse, created a decade apart in 1992 and 2002. The land cover map on the left side of Figure 1 was created using the EPA National Land Cover Data (NLCD) from 1992. The image on the right used high resolution imagery from the USDA taken in 2002. This image illustrates how land cover classification can be based upon different resolution images and using different classification criteria, yet the same basic pattern emerges.

The side-by-side map in Figure 2 contrasts land use on the left with land cover on the right. The Upper, Middle, and West Branch subwatersheds have very similar land use and land cover patterns, while development within the Syracuse subshed is substantially different.

Urban versus rural land use is the major distinction between the upper watershed in Tully to the lower watershed where Onondaga Creek empties into the Lake. The land in the upper watershed is rural and the pattern is one of larger plots of land used for agriculture, left vacant, wooded, or increasingly, residential. The parcels on this map are colored by NYS Office of Real Property Services (ORPS) land use 'property type'. Note that since the real property data is updated periodically, the information may **not** be counted on to be absolutely accurate for any one parcel at any one time. When viewed as a group however the trends in data are reliable. Much of the Onondaga Creek watershed is in municipalities that update their assessment inventory every 1 or 3 years, so it is estimated that about 85% of the parcel records for Onondaga County are current and accurate at any one time (Karen Karney, Onondaga County Office of Real Property Tax Services, pers. comm.).

Figure 1. NLCD and USDA Land Cover



The image on the left shows the 1992 National Land Cover Data from the EPA, which divides the watershed LC into 13 classes. The image on the right shows the high-resolution 2002 LC mapping from a research project by SUNY-ESF and the USDA, which divides the watershed into 5 classes.

The NLCD series has more LC classes, but also has a coarser image resolution. It shows a greater range of LC types but generalizes the spatial arrangement. The ESF-USDA series has fewer LC classes, but the spatial resolution of the image is much finer. It discriminates between fewer classes, but does a better job of showing the small scale interspersing of LC classes in Syracuse.

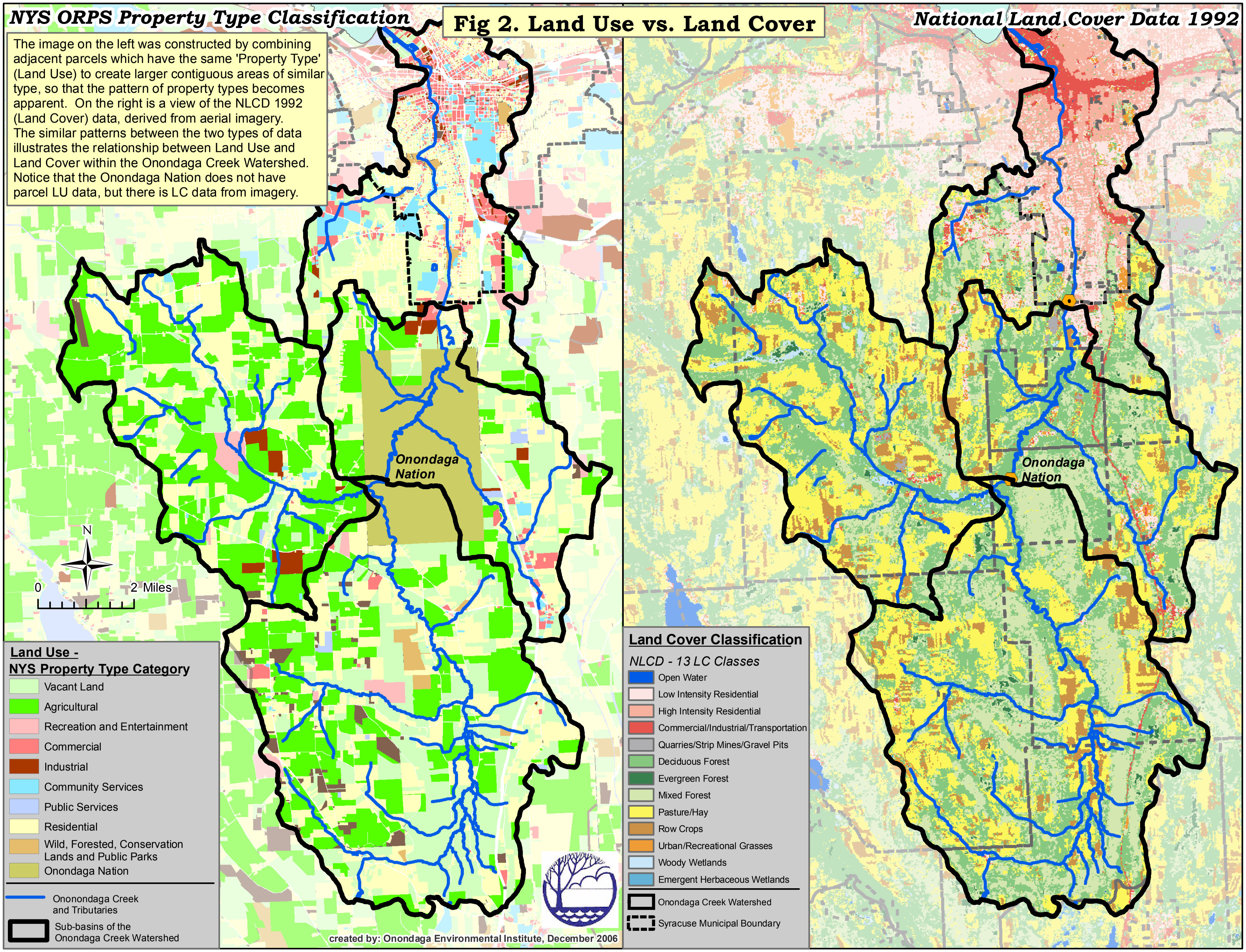


Fig 2. Land Use vs. Land Cover

The side-by-side maps in Figure 2 show a land cover pattern which follows that of land use, thereby demonstrating the empirical relationship between land use and land cover. At the northern part of the watershed, from Nedrow through Syracuse, the pattern becomes urban. Lot sizes are much smalleer in the urban areas than parcels in the southern rural part of the watershed.

Within the city of Syracuse there are two distinct types of urban areas. From Nedrow to Syracuse's central business district (CBD) the land use is predominately residential and this is where the greatest density and number of people live near the creek. Onondaga Creek then flows through the CBD urban area of Syracuse, with less tree canopy and more impervious hard surfaces. The CBD is active during business hours but few people reside downtown. So not only is the land cover different amongst the urbanized areas, but the times when the heaviest human activity occurs are also different.

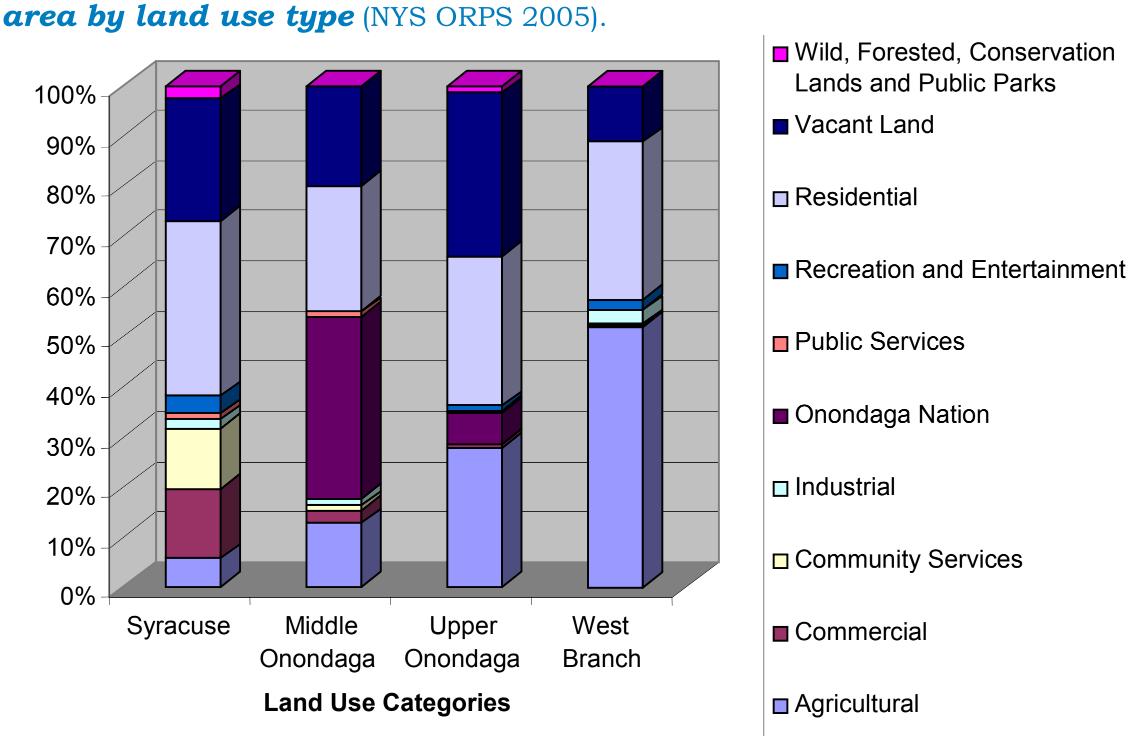
Variations within Land Use Types Different land use types possess different dynamics. Table 1 breaks down the four subwatersheds of Onondaga Creek by ORPS land use categories. Figure 3 shows this same information in graph form. Agricultural land use for economic production of crops or livestock is probably dependent on some economy of scale where a farm must be of a certain size to be profitable. According to Table 1, irrespective of which Onondaga Creek subwatershed,the average agricultura parcle size is about 40 acres.

Residential land use, on the other hand, has a parcel size that varies with the density of development within the subwatersheds. Thus, residential parcels are an average size of 0.25 acres in the Syracuse subwatershed, and range up to 8.05 acres on average in the upper watershed in the Tully Valley. Table 1 provides evidence that the vast majority of commercial activity is located in the city of Syracuse, with 2,935 commercial parcels vs. 77 commercial parcels in the Middle Onondaga Creek subwatershed, which is the next most commercially developed subwatershed. Consequently, commercial land use in Syracuse is likely a regional resource and probably generates trips between the city and surrounding areas. Thus, how a community is structured can determine how it functions, in particular, based upon the arrangement and allocation of land to particular land uses.

Land Cover Impacts of Land Use Types An understanding of land use pattern helps us establish relationships between land cover and water quality in Onondaga Creek and its tributaries.

Land is typically cleared for agricultural and residential use, as is much of the upper watershed and West Branch watershed. Forest canopy has been removed and replaced with expanses of a single type of plant, such as turf or rows of the same crop. Fertilizer and herbicides can runoff more easily due to reduced tree cover, tilling the soil can increase sediment mobility, and animal waste can more easily reach the creek.

Figure 3. Relative percentages of Onondaga Creek subwatershed area by land use type (NYS ORPS 2005).



Land Use (NYS ORPS)	Number of Parcels	Total Acres	Avg Parcel Size	% of SubShed
Syracuse	**22,241**	**11,284.657**	**0.51**	**100.00%**
Agricultural	16	648.865	40.55	5.75%
Commercial	2,935	1,560.222	0.53	13.83%
Community Services	349	1,366.357	3.92	12.11%
Industrial	86	186.842	2.17	1.66%
Public Services	63	132.717	2.11	1.18%
Recreation and Entertainment	41	413.793	10.09	3.67%
Residential	15,959	3,933.335	0.25	34.86%
Vacant Land	2,736	2,745.786	1.00	24.33%
Wild, Forested, Conservation Lands and Public Parks	56	296.740	5.30	2.63%
Middle Onondaga Creek, Onondaga Nation, and Nedrow	**1,868**	**12,260.323**	**6.56**	**100.00%**
Agricultural	38	1,558.934	41.02	12.72%
Commercial	77	320.224	4.16	2.61%
Community Services	17	113.296	6.66	0.92%
Industrial	8	171.952	21.49	1.40%
Onondaga Nation	3	4,433.851	1477.95	36.16%
Public Services	14	119.310	8.52	0.97%
Recreation and Entertainment	9	43.495	4.83	0.35%
Residential	1,332	3,061.396	2.30	24.97%
Vacant Land	369	2,433.893	6.60	19.85%
Wild, Forested, Conservation Lands and Public Parks	1	3.972	3.97	0.03%
Upper Onondaga Creek Tully Valley	**1,568**	**24,885.627**	**15.87**	**100.00%**
Agricultural	167	6,915.264	41.41	27.79%
Commercial	17	172.827	10.17	0.69%
Community Services	21	27.574	1.31	0.11%
Industrial	1	1.694	1.69	0.01%
Onondaga Nation	1	1,519.493	1519.49	6.11%
Public Services	10	105.069	10.51	0.42%
Recreation and Entertainment	5	276.638	55.33	1.11%
Residential	918	7,390.454	8.05	29.70%
Vacant Land	414	8,119.412	19.61	32.63%
Wild, Forested, Conservation Lands and Public Parks	14	357.201	25.51	1.44%
West Branch	**1,533**	**15,993.091**	**10.43**	**100.00%**
Agricultural	193	8,298.157	43.00	51.89%
Commercial	10	31.324	3.13	0.20%
Community Services	17	67.775	3.99	0.42%
Industrial	7	441.599	63.09	2.76%
Public Services	9	27.686	3.08	0.17%
Recreation and Entertainment	3	309.933	103.31	1.94%
Residential	1,036	5,017.701	4.84	31.37%
Vacant Land	258	1,798.917	6.97	11.25%

Table 1. Onondaga Creek subwatersheds information based on land use type.

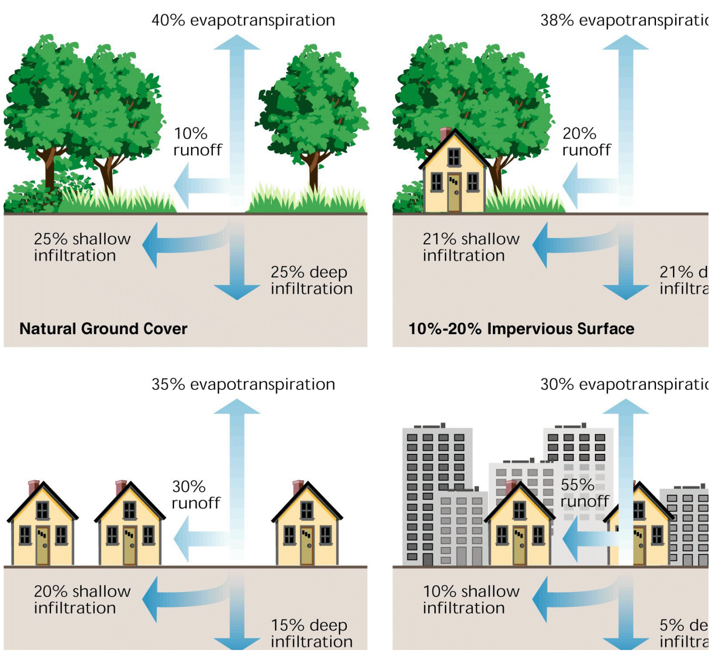
Monocultures of turf or crops reduce habitat diversity and the variety of wildlife that can be supported, which affects the riparian and aquatic food web[1]. Little or no buffer of natural vegetation in the riparian corridor allows runoff to carry pollutants and excess nutrients unimpeded to the creek.

Rural residential development in the upper watershed means adding houses, roads, driveways, wells, and septic systems to the environment. The impervious surfaces of roofs and roads reduce or prevent precipitation from percolating into the ground, and the impervious surfaces also dramatically increase the speed with which water can travel over the surface of the land in the form of runoff, eventually reaching surface waters. Both of these impacts of impervious surfaces eliminate the filtering effect of well-vegetated land cover. See Figure 4[2], which illustrates the effect of increasing impervious cover.

1 FISRWG, 1998, Stream Corridor Restoration: Principals, Processes, and Practices, p 3-14.
2 Ibid., p 3-22.

Figure 4. "Relationship between impervious cover and surface runoff. Impervious cover in a watershed results in increased surface runoff. As little as 10 percent impervious cover in a watershed can result in stream degradation."

(Image and caption: FISWRG, 1998, p. 3-23.)



Roads are impervious networks that act as non-point sources of rubber, oil, and petroleum from vehicles, and salt that is applied in the winter. Roads can have deleterious effects on surface waters.

Slope of the land influences how land use affects water quality. Vegetative land cover, even turf and crops, are better at slowing runoff, and provide better ground water recharge, than impervious surfaces such as roads and roofs. However, the slopes of the valley walls in the upper watershed are steep in comparison to the valley floor, and the urbanized areas of Syracuse are even flatter. The steep slopes in the upper watershed cause runoff to travel more quickly, which causes greater erosion and less opportunity for the water to percolate into the ground. The time needed for runoff to reach its discharge or collection point is called the *concentration time.* Short concentration time, as results from steep slopes and large amounts of impervious cover, results in a 'flashy' hydrograph where water levels in streams can rise quickly.

Steep slopes in the Tully Valley account for fast concentration times and therefore, it becomes important to minimize certain types and densities of land use in order to minimize the amount of impervious surfaces, and even more important to insure sufficient riparian buffer exists to slow and filter runoff before reaching the creek.

Land use mix and similar uses The range and pattern of human land uses is not random. Landform, geology, and location are important factors which determine land use. Soils, slope, surface water, and the distance to other related land uses are strong determinants of how a particular piece of land will be used. Since two adjacent parcels of land are more likely to share the same slope, soils, and other factors than two distant parcels of land, it stands to reason that adjacent parcels will likely be suitable for similar land uses. This is why land use patterns commonly show areas that are primarily residential, or that are primarily commercial, industrial, agricultural, and so on.[3]

3 The concept that human use among near parcels of land are more similar than that of distant parcels is refered to as *proximal homogeneity.*

Land use planning and zoning Land use planning is the purposeful application of the principal that parcels of land near each other are more likely to be similar, and suited for similar land use, than parcels that are far from each other. This principle is used to establish 'zones' of similar land use, or of an array of suitable or permissible land uses. It logically assumes that adjacent land will have similar suitability for use and a group of adjacent parcels can therefore be regulated as a district or 'zone'.

Wise land use planning takes into account the environmental conditions of soils, slope, water, geology and other natural factors; and the economic and social arrangement of related, dependent, or conflicting land uses; in order to determine the most suitable social use of the land while maintaining ecosystem health and function. If a narrow set of criteria is used in selecting a use for a land parcel then it can lead to a loss in one of the other unconsidered factors. Past land use decisions have often emphasized the economic criteria, with resultant environmental degradation and diminished ecological function. Later generations have had the burden of correcting, as best is possible, the poor land use decisions of the past. This is part of the legacy of Onondaga Creek today – land use decisions in the past, made with only economic and human centric criteria as a guide, have resulted in an impacted stream ecosystem.

Today we have a deeper understanding of the balance needed between mankind's use of the land and the requirements for sustainable natural ecological function within a watershed. In order to revitalize Onondaga Creek we will have to change the land use and the resultant land cover within the watershed, with particular emphasis on those areas closer to the creek, on steep slopes, or having a large degree of impervious cover.

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Flood Control

Onondaga Creek Fact Sheet

INTRODUCTION

Flood Hydrology Basics: What is a flood in a freshwater stream?

- A flood occurs when water escapes from the channel cut by the flow of water. Water level at the top edge of the stream bank is "bankfull." When the water flows above and beyond the bankfull level, it is in flood.
- The flood plain is the land area contacted by water that escaped the stream channel. Flood plains do not have to be flat!
- Natural stream flooding occurs every two to three years, unless limited by control measures to protect human activity.
- Wetlands may be inundated more frequently than then rest of a flood plain.
- Precipitation can be retained by soil and plants, or it can runoff.
- Soil's retention of water is the first step in "groundwater recharge."
- Evaporation of water coupled with its release by plants to the atmosphere is termed "evapotranspiration."
- Floods naturally occur when rain and/or snowmelt exceed the combined retention capacities of the system's soil, vegetation and stream channels.
- A "100-year flood" is not always a flood. The US Geological Survey computes the probable frequency of peak flows and their volumes. The estimated once-in-a-100-year peak flow is used to calculate the location of a flood plain. For example, the Onondaga Creek channel at Spencer Street has a greater capacity than the computed cubic feet per second of a peak flow that might occur only once in 100 years. The so-called "hundred-year flood," can occur in the creek at Spencer Street without the creek actually overflowing its constructed banks. This situation is reflected in the very narrow flood plain drawn by the Federal Emergency Management Agency (FEMA) for that location.

See also hydrology fact sheet

FINDINGS

Impairments due to the flood control measures

Human access was lost to urban parts of the creek through channelization, barriers, and related safety features. Diversity of activity was lost when channelization increased the velocity of water over long stretches. When slower water was lost, that eliminated in-stream fishing and wading areas, boat pull outs, and safety pullouts. Channelization also eliminated the mix of faster and slower water that is desirable for recreational kayaking. The reduction in flood plain through increased channel depth led to water levels unsafe for wading; e.g. creek water depth at Spencer Street typically ranges from 2 to 4 feet (USGS 1993-present). Smoothed channel sides lack boat pull-outs and are largely without handholds.

Continuity of activity along the length of the creek was physically lost at the Dorwin drop structure and the Onondaga Dam, which are barriers to canoes and kayaks.

Approach to the creek sides is blocked by fencing in the city. Fencing has reduced liability and the risk of accidents and drowning fatalities such as had occurred in the past when children fell into the fast water and were not rescued in time (hence the name "Killer Creek").

Fish habitat was lost. Habitat features needed by fish were eliminated by the smooth sides and bottoms of channels and culverts. Without an accumulation of organic debris in the creek bottom, there were fewer invertebrate creatures that are fish food. Without patches of gravel and sand, the fish lack spawning "substrate" in which to lay eggs. The channel's typically higher water velocity means fish experience metabolic stress, as there are fewer places to rest in the channel or the attached culverts. Long stretches occur in the channel without distinct pools and riffles for fish activity.

Water qualities were affected by channels and culverts. The reflective bottom surface of the channel has a thermal effect on water, making it too warm at times for some species. Fewer riffles are present to oxygenate water. With high precipitation or snowmelt, the culverts' outfalls contribute urban storm water that can be saltier, warmer or colder, and often more contaminated than natural runoff. Some of the storm water outfall pipes also add raw or partially treated human sewage to the creek during high runoff.

Fish migration going upstream is impeded or blocked at one to three locations, depending on conditions:

- The Onondaga Flood Control Dam's conduit is a 200 foot long pipe with a shallow slope of 0.25% [1] as it passes through the base of the dam. Over 31 years of daily monitoring (1967-1998), flow through the conduit ranged from lows around 40 cubic feet per second (cfs) up to about 750 cfs in a peak flow. Around 10% of the days monitored, the conduit was full of water that had backed up behind the dam, causing high velocity in the conduit. The conduit is a smooth pipe that does not have a fish ladder in its 200 foot traverse.

- The Dorwin Avenue drop structure includes a smooth sloped barrier that is approximately 7 feet high and roughly fifty feet in horizontal extent between the downstream and upstream edges,[2] which is too extended a length for many fish to ascend.

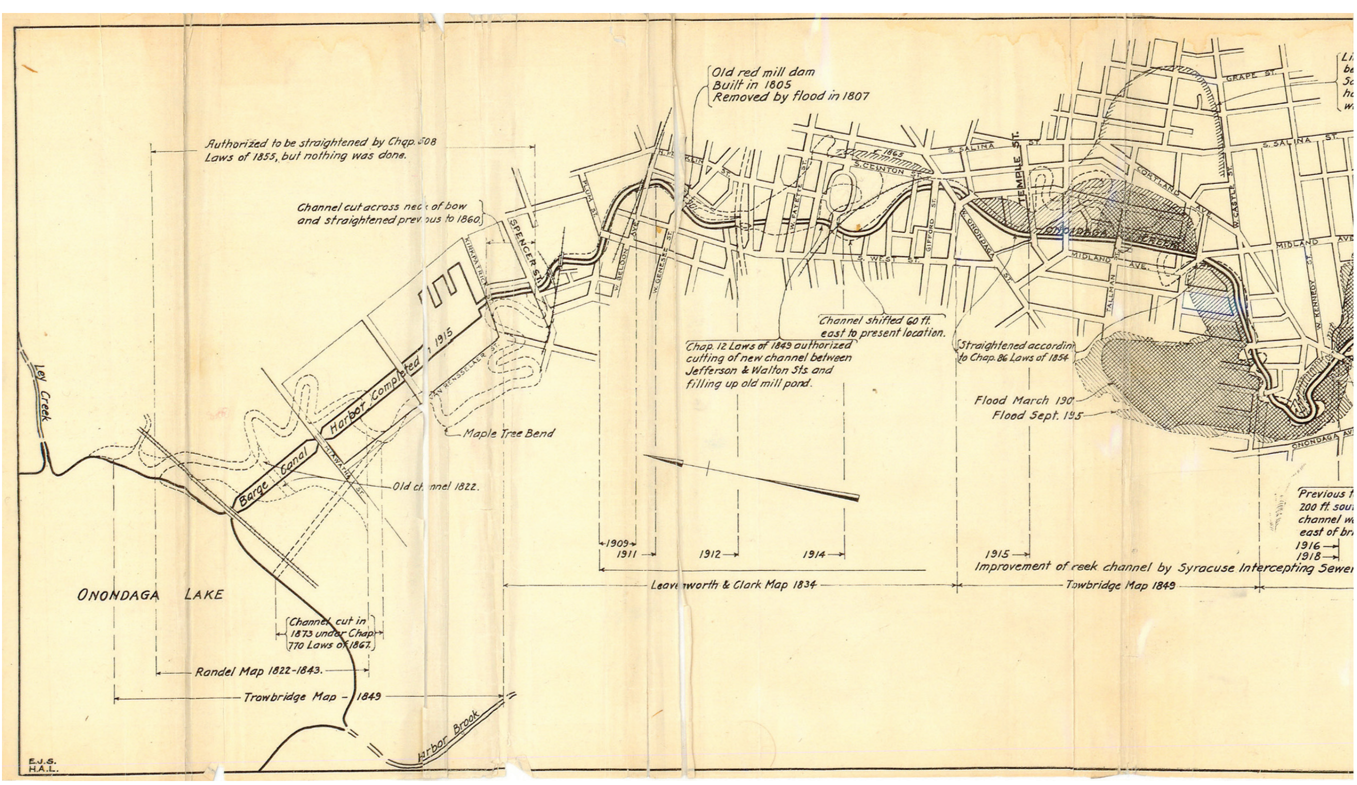
- A concrete sewer pipe crosses Onondaga Creek near Spencer Street. At high lake levels this pipe is covered by water that backs up into the creek, while at low water levels its edge is visible as a riffle or small waterfall, and may be a barrier to fish.

Less vegetation on the stream edges affects fish conditions. Stream bank trees can moderate the temperature of water,

1 USACE, U. S. A. Corps of Engineers, et al. (1949). Definite Project Report on Local Flood Protection, Onondaga Creek, Syracuse, New York. Buffalo, New York: I-II, A-C, 1-? Appendices, maps., Plate 4A.Onondaga Creek Conduit Rating Curve, and page 1.14 text.

2 Ibid. Plate, Onondaga Channel Improvement Details.

Figure 1. Syracuse Intercepting Sewer Board Map of Onondaga Creek (Holmes 1926). Peck Brook is now known as Cold Brook, and part of Atlantic Ave. is now known as Ballantyne Ave.



keeping stream water cooler in summer and acting as wind barrier in winter. When present, vegetation can shape shallows and wetlands in patterns that allow spawning and contribute organic material for the fishes' 'food chain.' However, vegetative debris can dam up the creek, so fallen trees are routinely removed from the urban sections of creek channel to avoid flooding in the city.

Human health and safety are affected both positively and negatively

The city center of Syracuse is protected from flooding, although it is located on the former natural flood plain of Onondaga Creek and several of its tributaries. The flood control measures accommodated more rapid transit of sewage overflows from the city through the main creek channel to the lake. Channelization contributed to the danger of deep fast flows with no hand holds; it proved difficult to retrieve children who fell in, earning the creek nickname, "Killer Creek."

Flood control planning: The closest thing to a plan

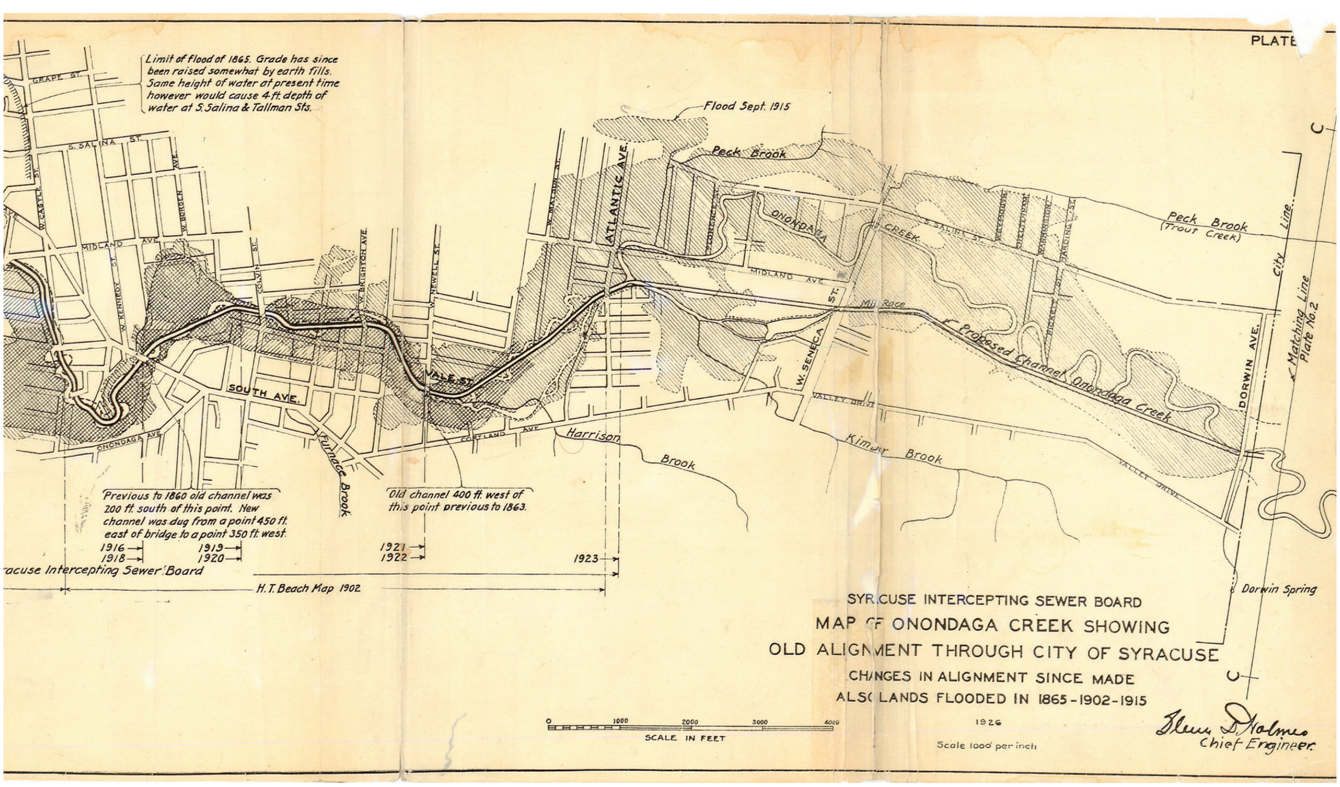
The City of Syracuse's 1927 report on flood-control was used throughout the 20th century by the City of Syracuse, State of New York and the Army Corps of Engineers to guide their policies and construction (Holmes 1927).

As the Chief City Engineer who coordinated the 1927 report, Holmes drew a map (see Figure 1) of three notable floods, with the occurrences spread over fifty-one years (1865, 1902, 1915), along with proposals to expand channelization and construct a flood control dam or dams, to be located upstream of the city.

The three floods emphasized by Holmes and the Intercepting Sewer Board had all occurred during a period of deforestation in the county. A major flood in the city in 1920 was not mapped by Holmes, but the public sentiment that resulted from that flood had favored immediate measures to protect from further floods. The 1927 designs for channels and a dam or dams were implemented over twenty years later in post World War II projects by U.S. Army Corps of Engineers, under an Act of Congress passed before the war.

The 1927 report had dismissed reforestation as a control measure at a time when the watershed was largely devoted

*map continued from previous page.



to agriculture. In 1930, only 8% of Onondaga County had been forested (Nyland, Zipperer et al. 1986). That era was followed by decades of reforestation efforts in the county and across New York State (NYSDEC 2006). By 1997, the Onondaga Creek sub-watershed was 53% forested, the highest percentage of forest cover among the sub-watersheds of Onondaga Lake (Coyle 2002). The Onondaga Flood Control Dam, completed in 1949, has yet to be exposed to the maximum water volumes for which it was designed.

Flooding has occurred, though more rarely, since the 1927 designs were implemented by the dam construction in 1949 and the last channelization in 1963.

Types of flood control measures in place

Engineering objectives

- *Water removal*
  - Channelization design controlled the main channel's volume capacity, by widening the channel, smoothing an artificial creek bottom, incising the channel deeper than its natural elevation, and armoring the lining of the channel with rock. These measures while intended primarily to increase volume, also served to fix the location of the creek channel relative to valuable properties.
  - Similarly, tributaries were merged into the urban drainage system either by complete co-option into the sewer system or by partially covered stretches, such as Furnace Brook and Cold Brook (Peck Brook).
  - Greater speed of removal was approached by straightening of channel sections to reduced transit time, and by grading the channel's bottom to a more consistent slope. The Dorwin Drop Structure is a junction between a shallower upper channel and a deeper stream bed elevation. A more consistent grade (slope) of creek bottom shunted potentially catastrophic flood events more quickly through the city, as there was typically little time to prepare for evacuation when flooding was imminent.
- *Water retention or delay* The Onondaga Dam is the largest constructed retention area in the main channel. The flume at Ballantyne is also a form of retention.
- *Shunting of some runoff to the lake via Metro* Combined storm and sanitary sewers (CSOs) route some of the urban storm water to Metro Sewage Treatment Plant, and in heavy rain, release storm water to Onondaga Creek along with sanitary waste

Reduced flood plain area - Storm sewers routinely drain city locations, and their outfall drops into the lowered channel of the creek.

Policy

- Debris removal from the urban creek channel avoids damming up of water.
- Rural Best Management Practices (BMP)

STRUCTURE:	Onondaga Flood Control Structure (Dam) [1949]	Nedrow Channel [1963]	Dorwin Drop Structure [1950]	Channel from Dorwin Ave. to Ballantyne Rd. [1950]	Channel Sections from Ballantyne to Onondaga Lake
DESIGN	City of Syracuse, Chief Engineer Glenn D Holmes, and US Army Corps of Engineers (USACE)				City of Syracuse
CONSTRUCT	Subcontractors				City of Syracuse
WATER LEVEL MONITOR	USGS, NYS DEC		USGS		USGS
MAINTAIN	NYS DEC	NYS DEC	NYS DEC		City of Syracuse
JURISDICTION	Onondaga Nation	New York	New York	Syracuse	Syracuse

Table 1. Management history of the flood control structures

Current effectiveness of flood control measures

Specific flood control structures built by 1963 are presumed structurally sound at this time although an engineer's report of the whole has not been found to date. The effectiveness of each component is related to the hydrology of the whole system.

Valley Area and Nedrow Floods in the 1950s occurred after some of the structures were in place. The Onondaga Creek Dam (1949) followed by the Dorwin drop structure (1950) and the straightened channel from Dorwin Ave. to Ballantyne Rd. (1950) were built to reduce floods in the more densely populated sections of city of Syracuse, further downstream. The Dorwin Avenue drop structure connected a shallower natural section of the creek upstream to the deeper dredged-out channel from Dorwin Avenue to Ballantyne Road (Pollard, 1960). The Dorwin section can carry water at 6000 cubic feet per second, an increased in-channel flow capacity, while it reduces the storage of water in the flood plain. Ironically, the channel's presence combined with the dam to prompt homebuyers and developers in the 1950s to feel safe to occupy the flood plain. Between 1950 and 1960, eighteen floods occurred in the recently-built residential areas near the creek in Nedrow and Syracuse's Valley section (Pollard, 1960). In 1963, the construction of a newer Nedrow section of channel upstream of Dorwin Ave. to the border of the Onondaga Nation further reduced flood plain holding capacity, while increasing in-channel flow capacity. Data on more recent flooding in the Nedrow and Valley areas has not been located to date.

Syracuse Neighborhood Flood in 1974. Heavy thunderstorms fell on the region in early July 1974; the creek channel near Kirk Park overflowed into a residential neighborhood. Factors involved were rapid urban runoff and very heavy rain that combined to be in excess of the design capacity. Urban rain runoff typically reaches the creek quickly (as shown in flashy hydrograph patterns). Although the dam upstream delays flow from the upper watershed, it had no effect on rain that fell directly on the city. The 1970s were a period of heavier precipitation and saturated soil conditions in the region. Those factors combined with a heavy multi-day rainfall to produce localized flooding, even though control measures were in place.

Tributary Floods in 1996. In 1996, also after heavy rain, sections of the creek's two main branches, both upstream of the dam, overflowed into occupied areas previously identified as flood plain. This is a further indication that population has spread into more flood-prone areas, in ways that were not fully anticipated in 1927 plans or the latest 1963 construction.

Current policies affect flood control. The City of Syracuse conducts debris removal from the urban channel, and has been proceeding with construction of catchment areas, including Kimber Brook and Valley Drive area. Two other policies positively affect flood control, but are not specifically identified for this purpose. The Onondaga County Soil and Water Conservation District promotes agricultural Best Management Practices (BMP) upstream of the dam, including management of runoff. The New York State Department of Environmental Conservation (NYSDEC) has a multi-decade reforestation policy which has supported the great recovery of the Onondaga Creek watershed from a mere 8% forest cover in 1930 to 53% forest cover in 1997.

Whole system effectiveness Few episodes of flooding have occurred in the past four decades that followed the last channelization construction in 1963. An unpublished thesis on the hydrology of the dam has shown that the dam is essential to flood control in the current hydrologic system, although alternate measures could be developed to maintain effectiveness if the dam were to be removed (Higgins, 2005).

IMPLICATIONS

Shifting factors are a consideration in looking to the future

- Heavy precipitation pattern occurred in the 1970s and may occur again.
- Population spread, or "suburbanization," continues to occur in flood-prone areas above and below the dam.
- The constructed components in the system are ageing.
- Forest protection is voluntary at this time so the conservation of a forested watershed is uncertain.

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The Onondaga Lake Partnership (OLP) sponsors the Onondaga Creek Revitalization Plan project with funds from the U.S. Environmental Protection Agency. Visit www.onlakepartners.org for more information about the OLP.

This fact sheet and additional information about the Onondaga Creek Revitalization Plan project can be found on the World Wide Web at www.esf.edu/onondagacreek/.

Fish

Onondaga Creek Fact Sheet

INTRODUCTION

What is the relationship between an aquatic "ecosystem" and a fish "community"? An aquatic ecosystem is made up of the interactions between all of the animals and plants, and their physical and chemical surroundings (e.g., physical habitat, nutrients, oxygen, temperature), in a specific place. A fish community is one part of the ecosystem, including only fish and their interactions with each other. The physical and chemical surroundings usually determine the character of the fish community, and can vary between places and change over time (e.g., due to seasons or human influences). Fish communities are likely to reflect those environmental differences. Common ways to group fish are described in Text Box 1.

How are ecosystems and fish communities delineated? Ecosystem or fish community boundaries are arbitrary, but are usually defined by natural patterns in environmental features. For example, lakes or ponds are commonly identified as distinct ecosystems. Watershed divides are frequently used as boundaries between lotic ecosystems. Boundaries within natural rivers and creeks can be more difficult to define because the character of the system changes, sometimes gradually, along its length. However, obstructions to water or fish movement sometimes provide clear boundaries between fish communities. These include natural barriers such as waterfalls, and man-made barriers like dams or extensive reaches of degraded habitat.

What are fish communities like in undisturbed streams? Fish communities vary between headwaters and mouth of a creek. In undisturbed streams, fish communities near headwaters are typically comprised of a few cold water species, gradually transitioning to cool or warm water communities at the mouth, with the greatest diversity in between. This transition in species composition reflects changes in topographic, aquatic and riparian habitats, water quality, and food types along the length of a stream. Migratory and transient species may use parts of the creek seasonally for feeding, reproduction, or refuge, temporarily increasing diversity.

How are fish communities studied in streams? Fish surveys investigate species, number, size, sex, reproductive status, and health of fish using a number of field techniques. A common sampling technique for fish surveys in wadeable streams is electroshocking. Various types of nets can be used in deeper waters. Repeated sampling in an area enclosed with nets can be used to calculate the total number of fish at a location. Fish density (number / area) is the total abundance divided by the estimated stream area. The aquatic environment in

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Text Box 1

How do ecologists refer to groups of fish?

Ecologists frequently group fish into broad categories based on the behavior of the fish, their preferred environment, or human use. A single fish species may belong in several of the following groups:

By temperature preference:
- Cold water (e.g., trout, salmon, whitefish)
- Cool water (e.g., walleye, muskellunge)
- Warm water (e.g., carp, bluegill, largemouth bass)

By movement pattern:
- resident (e.g., brook trout, minnows)
- migratory (e.g., salmon, eel)
- transient (e.g., large predatory fish)

By location within the ecosystem or type of ecosystem:
- Lotic – flowing water
- Lentic – still water
- Benthic – bottom-dwelling
- Littoral – near shore
- Pelagic – open water

By the food they eat:
- Herbivore – aquatic vegetation
- Planktivore – free-floating plankton (usually zooplankton)
- Benthivore – benthic macroinvertebrates (e.g., insect larvae, mussels, or worms), periphyton (small attached algae and microbes)
- Piscivore – fish
- Omnivore – plant and animal

By response to pollution:
- Tolerant
- Intolerant

By human use:
- Sport fish
- Pan fish
- Commercial fish

Onondaga Creek changes along its length and seasonally. During a particular fish survey, species composition at that time is affected by a number of environmental and circumstantial factors. Multiple samples conducted at intervals along a creek and its tributaries, and at multiple times, can give an overall picture of local fish communities and their spatial relationships to natural and man-made conditions.

FINDINGS

What factors affect fish distribution in Onondaga Creek? Habitat and water quality, angling, and stocking regimes affect fish communities in Onondaga Creek. Habitat and water quality change dramatically from the headwaters and tributaries to its mouth at Onondaga Lake (see Aquatic Habitat and Water Quality Fact Sheets), so we would expect changes in the fish community along the creek length. However, the natural gradient has been altered by several impoundments and barriers to natural fish movement, channelization, reduction in riparian wetland and floodplain habitats, among other impacts, which affect local fish communities and impede upstream movement.

What kinds of fish are in Onondaga Creek? Thirty-four species have been identified in the Onondaga Creek fish surveys, divided into fairly distinct coldwater and warmwater fish communities (Figure 1).[1] The cold water of the Tully Valley and headwaters segment, and the West Branch segment, support a distinct and persistent assemblage of brown trout, sculpins (slimy and mottled), dace (longnose and blacknose), creek chub, and white sucker.[2] Wild brook trout were reported in very small headwaters tributaries, and locally in the upper main stem. All but the brown trout are native to New York State. In 2003 and 2005, stocked Atlantic salmon have also been reported in the upper main stem. Relatively few warm water fish have been reported in the upper main stem and West Branch, most likely washed down from impoundments upstream or transients occasionally introduced by anglers. No formal survey data were located for the Onondaga Nation territory. Hemlock and Kennedy Creeks above the Nation supported the same cold water assemblage in the early 1990's. As of 1989, both brook and brown trout were reported in Upper Furnace Brook, which empties into the urban segment of Onondaga Creek. The greatest number of species was reported in the urban main stem, due to encroachment of lake species up to the Dorwin Ave. drop structure barrier.

Since 1989, 28 fish species have been recorded in surveys of the urban main stem. Most of these species are transient warm-water species, but brown trout, longnose dace, Atlantic salmon, mottled sculpin, and white sucker from the cold water assemblage were also observed in the city. Creek chub, trout, and suckers were reported among dead fish found at the Seneca Turnpike (below the Dorwin drop structure) that were killed after a brine leak in 1984 from the Allied Chemical Company's pipeline which transported brine from solution mines in the Tully Valley to Syracuse (Linhorst, 1984). White suckers comprised 90% of the fish kill (Kelly, 1984). Blacknose dace and slimy sculpin were never reported in the urban main stem, suggesting that these species may be indicative of the Onondaga Creek cold

Text Box 2

Fish surveys in Onondaga Creek.

Between 1982 and 2005, at least 15 fish surveys of varying scope were conducted in the Onondaga Creek watershed by academic or government researchers. Most of the information in this report was obtained from those surveys and accompanying reports. Surveys included:

Dr. Neil Ringler and students, State University of New York, College of Environmental Science and Forestry (SUNY ESF)
- 1982 - Furnace Brook (student E. Bannon)
- 1991, '92, '93, '94 - main stem and tributaries in the Tully Valley and tributary headwaters above the Onondaga Nation (student R. Danehy)
- 2003 (July and September) - main stem from headwaters to urban (student S. Coghlan)

NYS Department of Environmental Conservation (NYSDEC)
- 1989 - Tully Valley and urban main stem, Furnace Brook
- 1992 - small tributary headwaters
- 1998 - headwaters and Tully Valley main stem
- 2001 - West Branch
- 2002 - tributary in Tully Valley
- 2003 - urban main stem

U.S. Geological Survey (USGS)
- 1998 - Tully Valley main stem

Dr. Karin Limburg and students, SUNY ESF
- 2005 - headwaters and Tully Valley main stem

1 Fish community spatial delineations are approximate, based on the nearest and most recent available fish survey data.
2 The white sucker is not typically considered a "coldwater" fish, but is included in the coldwater assemblage simply because it was consistently found with coldwater fish in available surveys.

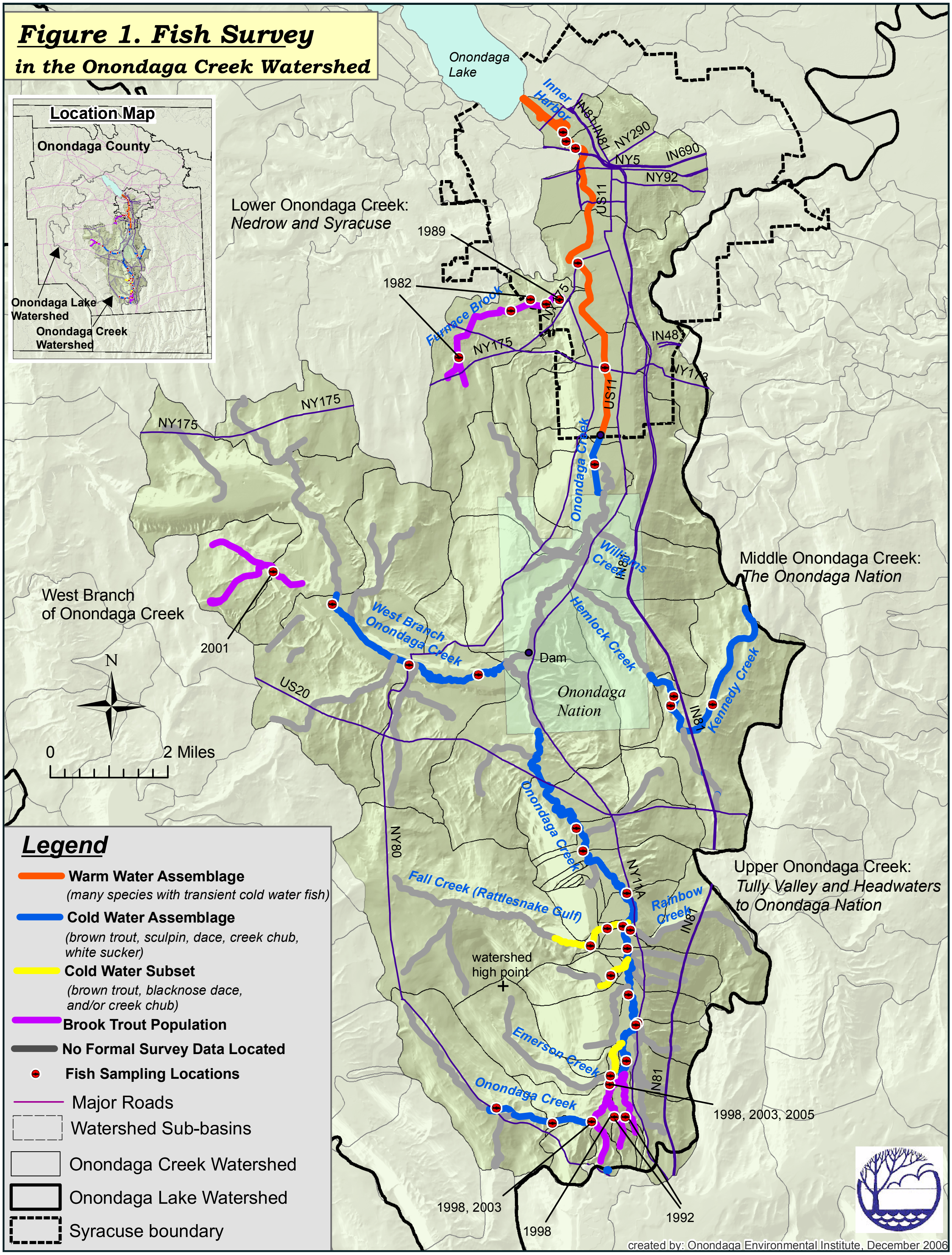


Figure 1. Fish Survey in the Onondaga Creek Watershed

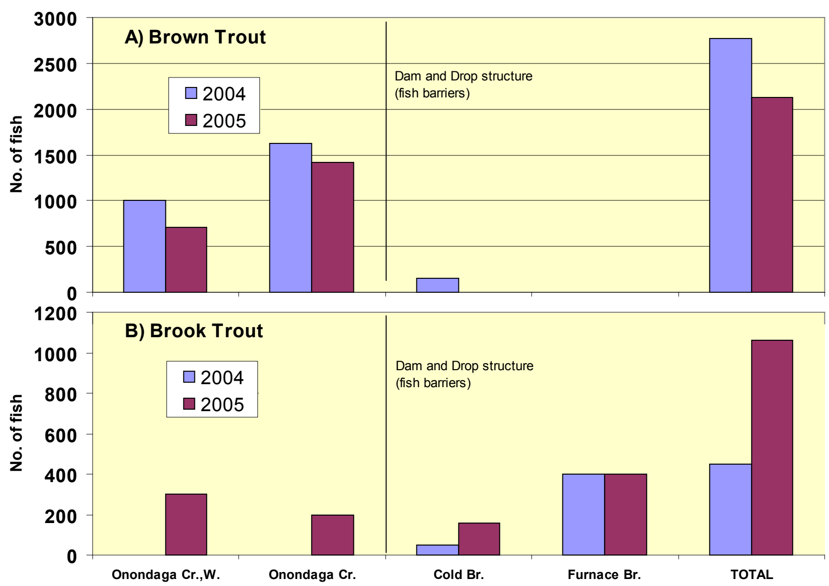
water fish community. A low barrier upstream of the Kirkpatrick Street bridge may be impassable to certain species from the lake.

Has the fish community changed? The cold and warm water fish communities have changed little between 1989 and 2005. A number of surveys (Text Box 2) show a remarkable persistence in the watershed's cold water fish assemblage. In the lower main stem, the most consistent observations include brown trout, white sucker, bluegill, and largemouth bass, all of which are also common in the lake. No detailed survey information was located for periods prior to 1982, but Dr. Neil Ringler (SUNY ESF) and collaborators reported in 1996 that little change in the lower creek fish community had been seen between an earlier 1928 survey and 1991 (Ringler et. al. 1996). Several species that had been eliminated from the system were not reported in formal surveys since 1928, and therefore are candidates for eventual restoration. Beauchamp (1908) documents an anecdote from a prominent Syracusan, Thurlow Weed. Mr. Weed remembered catching salmon in Onondaga Creek in the spring of 1810, with help from members of the Onondaga Nation. Earlier records and the oral history of the Onondaga Nation indicated that eel, also a migratory species that lives part of its life cycle in the Great Lakes or ocean, were once common in the creek (Smardon Affadavit, 1998). Restoration of local populations of large migratory species, such as salmon and eel, is a challenging and ecologically complex problem (see below).

Is the cold water fishery naturally sustainable at present? The current cold water fishery may not be sustainable under persistent angling pressure, without a supplemental stocking program. Onondaga Creek is not a large flowing system, and much of the system is severely degraded. Onondaga County currently stocks significant numbers of brown trout and brook trout each spring in the upper Onondaga Creek watershed to support angling (Figure 2); NYSDEC does not stock fish in the Onondaga Creek watershed (D. Lemon, pers. comm.). Brown trout have been stocked in the creek at least since 1928. Significant densities of wild brook trout are found only in small tributaries to the upper main stem in which the water is too cold for brown trout. The USGS reported high densities of brook trout (up to 9,800 to 37,000 fish/acre stream bed) at unreported locations in these tributaries based on NYSDEC data (McKenna et al. 1999), yet total numbers of fish may not be high due to narrow tributaries. Few brook trout are in the main stem, despite persistent stocking. The USGS suggested this is due to competition between the trout species, favoring brown trout. Brown trout biomass is at least seven times greater than brook trout biomass in the creek's main stem (McKenna et al. 1999). Atlantic salmon, a migratory species that spawns in headwaters and grows to adulthood in very large open waters, was stocked in Onondaga Creek in 1994 by the NYSDEC, and at six locations in 2002 and 2003 by SUNY ESF researchers (Coghlan, 2004). No adult salmon have been captured in any formal surveys, although juvenile fish were captured upstream in 2003 and 2005, and in the lower creek in 2003.

Figure 2. Trout stocking by Onondaga County in the Onondaga Creek watershed, 2004 and 2005.

Please note scale difference between graphs. A small, unreported number of fish were placed downstream of the drop structure at Dorwin Ave.



Are the fish contaminated? Significant levels of DDT, PCBs, and mercury were found in a 1989 analysis of Onondaga Creek fish (Table 1); many of the sampled fish were inedible according to US Environmental Protection Agency (EPA) Fish Consumption Limits. No additional fish contaminant data were located, and it is uncertain why further studies were not performed. The available data indicate that fillet samples were composited from several fish, representing a mean rather than the full range of concentrations. Mean contaminant concentrations in fillets exceeded EPA consumption limits in a number of samples (Table 1). Mercury, PCBs, and DDT and derivatives were detected in three composite white sucker samples collected along the main stem at Spencer Street. A few white perch samples collected at that site also contained detectable amounts of heavy metals. In white suckers sampled at Spencer St., mean mercury concentrations ranged between 0.13 and 0.64 ppm, mean PCBs from 0.15 to 0.41 ppm, and mean DDT levels were low, ranging between 0.01 and 0.03 ppm. White perch sampled at Spencer Street contained mean mercury concentrations up to 1.9 ppm, and PCBs up to 6.1 ppm. Fish collected from the main stem at Webster Rd. in the Tully Valley were also evaluated for contaminants. In white sucker fillets, mean mercury concentration ranged from 0.05 to 0.11 ppm; in brown trout from 0.04 to 3.9 ppm. Total PCBs ranged from 0.46 to 0.64 ppm in white sucker and 0.52 to 3.2 ppm in brown trout. Heavy metals including zinc, copper, nickel, chromium, and manganese were also detected at significant levels in white suckers at Webster Rd. Significantly higher mean mercury concentrations were seen in white suckers at Spencer St. than at Webster Rd., suggesting that the upper and lower creek white suckers belong to separate subpopulations. No further data on contaminants in Onondaga Creek fish were located.

Table 1. Fish contaminant data from 1989 Onondaga Creek sampling[1].
(Data reliability is under review)

Sample location	Sample date	Species	Number of fish in sample	Average length (in)	Mercury (ppm)	Total DDT (ppm)	Total PCB (ppm)
EPA Fish Consumption Limits[2] - 1 meal/month (ppm)					0.48 - 0.97	0.14 - 0.28	0.023 - 0.047
EPA Fish Consumption Limits - 4 meals/month (ppm)					0.12 - 0.24	0.035 - 0.069	0.0059 - 0.012
Spencer St., Syracuse	8-Jun-89	White perch	14	8.0	1.8		
	8-Jun-89	White perch	16	7.0	1.9		0.63
	15-Aug-89	White perch	14	8.0	1.8	0.34	6.1
	6-Sep-89	White perch	13	7.0	1.9		
	8-Jun-89	White sucker	11	13.6	0.43	0.02	0.18
	8-Jun-89	White sucker	3	10.0	0.13	0.03	0.15
	8-Jun-89	White sucker	9	16.3	0.64	0.03	0.41
Webster Rd., LaFayette	15-Aug-89	Brown trout	11	8.4	0.05	0.05	0.92
	15-Aug-89	Brown trout [3]	1	13.8	3.9	0.1	3.2
	15-Aug-89	Brown trout	9	9.5	0.04	0.05	0.52
	15-Aug-89	Brown trout	9	9.5	0.04		
	8-Jun-89	White sucker [3]	11	13.6	0.11		
	15-Aug-89	White sucker	17	7.8	0.11	0.06	0.64
	15-Aug-89	White sucker	4	9.7	0.05	0.02	0.46
	15-Aug-89	White sucker	4	9.3	0.05		

1. Highlighted data are exceedences of risk-based EPA Fish Consumption limits. Blank cells indicate that the substance was either below the detection limit or not analyzed (Source: NYSDEC 2005 (database)).

2. EPA Consumption limits based on cancer risk assessments (more protective than non-cancer values) with the exception of mercury for which only non-cancer values were developed. Meal size was assumed to be 8 oz. of fillet. Information Source: USEPA. 2000. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories. Volume 2. Risk Assessment and Fish Consumption Limts (3rd ed.). Office of Water, November 2000. EPA Document No. EPA 823-B-00-008.

3. Data were combined from separate database records of metals and organics concentrations, based on similarities in sample identification data (e.g., sample date, species, number of fish in sample, and/or average length); confirmation is pending examination of original hardcopy data reports.

IMPLICATIONS

How do we interpret absence versus presence in fish surveys? Fish presence/absence data from surveys should be interpreted carefully, and should consider other relevant information about fish biology. Fish are mobile in the creek. They follow changes in water conditions, food availability, and density of competitors and predators. Population densities are variable. Thus, the presence or absence of a particular fish species can be interpreted as significant only if consistent over long periods, which underscores the importance of long-term monitoring in Onondaga Creek. For instance, the creek chub has never been caught in urban creek surveys, suggesting that conditions may be unsuitable for chub in the city. However, it is not always true that fish absent in surveys are actually absent in the creek. The common carp has been reported in the creek surveys only once, in 2005, at Kirkpatrick Street (near the mouth) and never upstream of there. But anecdotal accounts relate large numbers at the Dorwin Ave. drop structure. Similarly, occasional presence does not necessarily indicate conditions are suitable for local persistence. Small fish could be washed downstream or only use a reach to traverse between more suitable locations. The frequency of capture, number and size of fish, and habitat requirements provide clues to whether a species is resident or transient in a particular creek segment.

Barriers to movement – good or bad? There is a balance between desired fish community outcomes when considering establishing or removing barriers to fish movement. For example, removal of the Dorwin St. drop structure or the low barrier near Spencer St. may enhance the likelihood of establishing a reproducing salmon population[3], but it would also likely result in the upstream spread of warm and cool water species from the lower creek and lake that are likely to be contaminated.

Brook Trout (Salvelinus fontinalis)

Fish images by E. Edmonson, courtesy of NYSDEC.

Contamination in creek fish – local sources, fish movement, or angler "assistance"? The source of contamination in creek fish is unknown. Mean concentrations of toxic chemicals in fish fillets exceeded EPA consumption limits in a number of cases (Table 1). Since the analyzed samples were mean values, higher concentrations must have been present in individual fish. A high level of contaminants in a single brown trout, and significant levels of contaminants in other species, begs the question of the source of contamination. Brown trout data were available only from the Webster Road site in the Tully Valley; no data on brown trout from the urban segment of the creek were located for comparison.

A brown trout with the highest levels of contamination weighed about 400 g (0.9 lb), while the less contaminated fish averaged between 96 and 138 g. One possible explanation is that there is an unrecognized source of contaminants in the upper creek. Larger fish typically accumulate contaminants such as PCBs and mercury to higher concentrations than smaller fish, so a local source is plausible. In 1989 at Webster Road, various metals, including mercury (0.28 ppm, dry wt), chromium (12 ppm), titanium (12 ppm), zinc (100 ppm), and aluminum (1020 ppm) were detected in caddis fly larvae, a significant component of the upper creek food web (NYSDOH, 1989). Caddis fly larvae do not travel upstream, so the source of the metals in the larvae must have been near, or upstream of, the Webster Road site. It is conceivable that the individual brown trout with elevated mercury at Webster Road accumulated a significant amount of its mercury through the local food web. However, this seems unlikely because several composite brown trout samples and all of the white sucker composite samples from that site did not show elevated mercury levels. Another possibility is that the fish was "stocked" by an angler after having caught it from the lake or the lower creek. It is also conceivable that the brown trout swam upstream from the lake, although the drop structure at Dorwin Ave. is regarded by some as an effective barrier to almost all upstream fish movement, with the possible exception of eels (e.g., D. Lemon pers. comm.). No formal studies concerning the extent of fish movement within the creek or between the creek and lake were located for the Onondaga Creek watershed, so this remains an open question. Finally, the original lab reports for the fish data were not located; it is also possible that the high tissue mercury in the individual fish at Webster Road was represented incorrectly in the electronic database (NYSDEC 2005).

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3 Barrier removal is only one important factor among many in the complex issue of re-establishing local populations of naturally reproducing salmon populations.

Although PCBs were found to be elevated in all fish samples collected at Webster Road (in contrast to mercury), PCBs, pesticides, and other toxic organic chemicals were not detected in crayfish at Webster Road using laboratory analytical methods available at the time. Thus, the source of PCB contamination in fish captured at Webster Road crossing in 1989 was likely not at, or just above, Webster Road.

Fish community restoration - what are the possibilities and implications? Restoration is conceivable for formerly abundant species but will likely require a long-term plan with a regional geographic scope in order to successfully reintroduce wide-ranging species. Depending on the species, successful restoration may depend on a combination of improving specific aspects of habitat (see Habitat Fact Sheet), angling management, and stocking programs. It is conceivable that the fish community in Onondaga Creek upstream of the city could be restored to dominance by native species. Brown trout is the dominant fish species in the cold water assemblage. It is the only species in the Onondaga Creek cold water assemblage that is not native to New York State, and is more heavily stocked in the upper creek than native brook trout (Figure 2). If brown trout stocking were to cease, and brook trout stocking increase, then their relative dominance in the system could shift from brown trout to brook trout over time. Brook trout caught in small tributaries in the Tully Valley were characterized as "wild" by the NYSDEC in 1992, suggesting that a sustainable brook trout population is possible given appropriate adjustments to angling and stocking. Insufficient information was located to assess whether free movement of brown trout from the lake to the headwaters might interfere with this type of restoration. Brook trout have re-colonized other streams in the region after being absent (D. Lemon, pers. comm.), likely due to improvements in water quality (N. Ringler, pers. comm.).

It is possible that alternative goals for native cold water assemblages or species might compete with each other. For instance, successful reintroduction of historically abundant eel and salmon, both top predators, in the system may significantly affect the cold water fish assemblage. Atlantic salmon, which were historically abundant in the system but is no longer a naturally sustained population, were experimentally stocked in 2002 and 2003 at six locations in the creek (Coghlan, 2004). Sixteen salmon were recaptured in the upper creek in 2005.

There are active international interest, research, and field implementations toward restoring Atlantic salmon, American eel, and other extirpated species in the Great Lakes system. The NYSDEC's Comprehensive Wildlife Conservation Strategy for New York state (NYSDEC, 2006) addresses restoration of these species. The NYSDEC's (Region 7) current position is that, without a successful regional reintroduction, Atlantic salmon stocking is likely not to be successful ultimately because of a lack of the habitat necessary to complete their migratory life cycle within the Onondaga watershed (D. Lemon, pers. comm.). Similarly, American eel restoration is of interest to the NYSDEC and Onondaga Creek would provide habitat for eels, but successful reintroduction in the Onondaga Creek/Onondaga Lake system is likely to be tied to the Lake Ontario basin-wide population status, which has been in dramatic decline (D. Lemon, pers. comm.). In addition to a stocking program, salmon and eel restoration might require significant improvements in the corridor from the creek to Lake Ontario, including Onondaga Lake. NYSDEC (Region 7) has identified lake sturgeon as a candidate for future reintroduction to the Onondaga Lake system because the lake has potential to support sturgeon (D. Lemon, pers. comm.); presumably, successful re-establishment in the lake would increase usage of Onondaga Creek.

Life History Sketches of Candidate Species for Restoration

The fish illustrated below were historically documented in Onondaga Lake watershed, but now naturally reproducing populations are absent. All three species are of interest for Onondaga Creek restoration. These fish spend part of their lives in streams like Onondaga Creek. Excerpts about their life history are quoted from The Inland Fishes of New York State by C. Lavett Smith, published in 1985 by the New York State Department of Environmental Conservation. More information about species restoration is above. See also the Habitat Fact Sheet.

American Eel - Habitat, Diet and Distribution

American Eel (Anguilla rostrata)

"Because of their migratory habits, eels are found from the ocean to small headwater creeks far inland. They are adept at working their way upstream over or around low falls and dams and sometimes travel overland, presumably on rainy nights….Eels spend much of their time buried in gravel or mud bottoms or under rocks.

Ogden (1970) studied the food habits of eels in eight New Jersey streams. The size of the food items increased with the size of the eels; the smallest had fed on insects and the larger eels had eaten fish and crustaceans.

In New York, the eel is extremely abundant in the Lower Hudson and it also occurs inland in the St. Lawrence, the Great Lakes and their tributary streams, including the Finger Lakes."[1]

Atlantic Salmon - Habitat, Diet and Distribution

"The salmon is an anadromous fish that moves into streams to spawn. Some populations are landlocked and able to complete their life cycle in fresh water.

Landlocked salmon move into the streams in early fall...After spawning, the female moves upstream and fans more gravel which is carried downstream by the current and covers the eggs...The eggs hatch in April and the young salmon spend 2 or 3 years in streams before moving into big waters until they mature.

In the streams, the young salmon feed mostly on aquatic insects, with terrestrial insects contributing to the diet, especially in late summer and fall.

They were native to Lakes Ontario and Champlain but apparently did not survive the environmental changes and overfishing. In 1810, when DeWitt Clinton visited the western part of the state there were populations in Lakes Seneca, Cayuga, Onondaga and Oneida.

Salmon of Lake Ontario began to decline in the early 1800s...Mill dams and other manmade obstructions prevented them from reaching their spawning grounds and deforestation, leading to increased temperatures and silting, overfishing and pollution were contributing causes."[2]

Atlantic Salmon (Salmo salar)

Lake Sturgeon - Habitat, Diet and Distribution

"Lake sturgeons are confined to larger lakes and rivers where they show a marked preference for clean sand, gravel, or rock bottom where food is abundant and they tend to avoid muddy areas. They move into smaller streams during spawning runs… The lake sturgeon spawns in the spring not long after the ice disappears and sometimes even under the ice. Spawning takes place along windswept shores of rock islands or the fish move into streams to spawn in the rapids.

The lake sturgeon feeds on insects, especially mayflies and midge larvae, and other benthic invertebrates including snails, clams, amphipods, and crayfish. It also feeds on fish...

The lake sturgeon occurs throughout most of the Northeast...It ranges through the Great Lakes and down the St. Lawrence...In New York, it has been recorded from Lakes Ontario and Champlain and it was once an important commercial fish in Lake Erie.

1 from (Smith, 1985) *The Inland Fishes of New York State*, p 61
2 *ibid.*, pp 229, 230

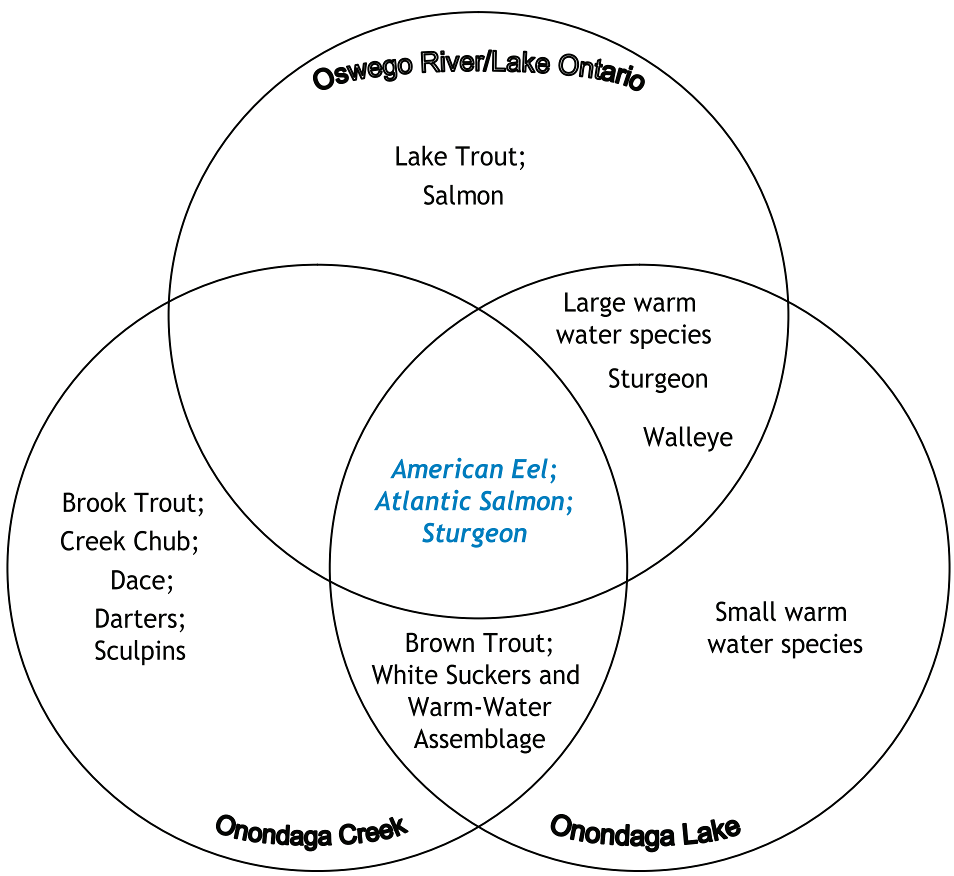
Lake Sturgeon (Acipenser fulvescens)

Sturgeon were formerly so abundant that they were considered trash fish. Their long generation time and slow growth, however, has led to their decline throughout most of their range."[1]

Fish Movement - Conceptual Model

Certain fish species move between habitats in different waterbodies during their life cycles. In the diagram below, local waterbodies are represented as interconnected circles; Onondaga Creek flows into Onondaga Lake, the outlet of Onondaga Lake flows into the Oswego River/Lake Ontario system via the Seneca River. Current fish movement between waterbodies for selected species is illustrated in the diagram in black print; likely former migrations are represented in blue (bold, italics). For example, since Brown Trout can move back and forth from Onondaga Lake to lower Onondaga Creek, they are listed at the intersection of Onondaga Creek and Onondaga Lake. If unobstructed, some species may migrate a greater distance. Atlantic Salmon formerly migrated from Lake Ontario to Onondaga Creek to spawn. American Eel live part of their lives in streams (Onondaga Creek was one such stream), but migrate to the Atlantic Ocean to reproduce, via Lake Ontario and the St. Lawrence River. Other species spend their lives in one waterbody. For example, the smaller cold-water assemblage fish found in Onondaga Creek, like Creek Chub, will remain in Onondaga Creek.

1 *ibid.*, p 46



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The Onondaga Lake Partnership (OLP) sponsors the Onondaga Creek Revitalization Plan project with funds from the U.S. Environmental Protection Agency. Visit www.onlakepartners.org for more information about the OLP.

This fact sheet and additional information about the Onondaga Creek Revitalization Plan project can be found on the World Wide Web at www.esf.edu/onondagacreek/.

Aquatic Habitat

Onondaga Creek Fact Sheet

INTRODUCTION

The term 'habitat' is usually used with respect to a specific group of organisms, most frequently a species. This section introduces methods broadly applied in the Onondaga Creek watershed for assessing habitat degradation in general terms that are relevant to biological communities rather than individual species. Species-specific methods may be important if either conservation or reintroduction of individual species is an eventual goal for Onondaga Creek. Scores from habitat and biological surveys are usually interpreted in comparison to a reference system. A generalized stream habitat continuum concept is described to illustrate expected conditions in an unimpacted system.

What is the relationship between an aquatic "ecosystem" and "habitat"? An aquatic ecosystem is made up of the interactions between all of the animals and plants, and their physical and chemical surroundings (e.g., physical habitat, nutrients, oxygen, temperature), in a specific place. The term "habitat" may be broadly defined as the subset of ecosystem components that directly relate to the biological requirements and preferences of a particular group of organisms (see Text Box 1). Typically, habitat is thought of in relation to a particular species, but can also apply to a larger group such as coldwater fish, or a subset of individuals within a species, such as early life stages. Habitat for a species may include other organisms as part of their surroundings. For instance, some fish prefer the presence of rooted aquatic plants, which in turn have their own habitat requirements. A species' habitat can differ between life stages and between seasons for adults.

How are habitat assessments and restoration goals related? Habitat assessments cannot by themselves lead to restoration planning goals. The field of ecological restoration draws a clear distinction between value-based goals themselves, and the knowledge that can be used to formulate the value-based goals (Davis and Slobodkin 2004; Lancaster 2000). The knowledge obtained from habitat assessments could be used in prioritizing steps toward achieving goals.

Text Box 1

Examples of factors that are used to describe stream habitat:

Water quality
- temperature
- nutrients (phosphorus, nitrogen)
- dissolved oxygen
- pH
- turbidity

Hydrology
- water flow (volume / time)
- water velocity
- water level relative to bank full
- channel shape
- steepness of grade

Physical structure
- shading
- substrate composition
- cover from predation
- riffle/pool alternation
- stream bed shape
- size and shape of riparian wetlands and floodplains
- sinuousity (degree of stream meandering)

Biological structure
- aquatic plants
- riparian wetland plants
- floodplain plants

Relative importance among these factors depends on:
- Species - size, resource requirements, and tolerance ranges
- Annual cycles – some fish spawn under one set of conditions, but live the rest of the year under other conditions, such as migratory species that live only part of their lives in streams
- Life stage - preferred habitat for adults and early life stages may differ significantly

What would habitat look like in an undisturbed creek? Habitat typically changes dramatically from headwaters to the mouth of the main stem of a stream. A classical paradigm of changes in flowing water systems from headwaters to mouth is called the River Continuum Concept (Text Box 2). The unimpacted continuum of conditions can be disrupted by changes to hydrology (due to damming, loss of riparian wetlands and floodplains, and channelization), and pollution (nutrients, suspended solids, and toxics). Unaltered streams in temperate climates can flood during seasons of high precipitation or during snowmelt. The transitional zone between adjacent aquatic and terrestrial ecosystems is called the "riparian zone" (Mitsch and Gosselink 2000). It is the area where the soil can become saturated due to the influence of surface water. Riparian wetlands are closely linked to aquatic habitats, providing important habitat for birds, insects, fish, and animals. They provide an infusion of food material during spring floods that support the food web of early life stages of many fish species. Riparian zone vegetation is important for shading the water, providing cover during flood periods, and contributing vegetative detritus that is the base of the food web in headwaters areas. If riparian vegetation is sufficiently dense, and/or its width is sufficient, then it may serve as a buffer to intercept nutrients or sediments in surface runoff from open areas such as pastures, crop fields, suburban lawns, and urban open areas.

Text Box 2

The River Continuum Concept (RCC)

The river continuum concept (RCC) is a classic paradigm in stream and river ecology (Vannote et al. 1980). It proposes that an unimpacted stream will exhibit somewhat predictable physical and chemical changes from the headwaters to its outlet. Additionally, these changes are reflected in changes in the plant and animal life, or biota, in the stream. In the classic model, the water in the upper reaches of a stream are fast-moving due to relatively steep topography, shallow, cold due to groundwater springs and forest shading, well-oxygenated, clear, and relatively nutrient-poor. The food web near the headwaters is based primarily on energy sources from outside of the system (allochthonous sources), such as leaf fall, because relatively little photosynthesis occurs in the swift-flowing, nutrient-poor, shaded waters. Species richness (number of species) and biomass (total weight) are relatively low near the headwaters compared to downstream areas of the system. Near the outlet of an unimpacted stream, the topography has flattened out, the waters are slower, deeper, wider, and more turbid, less oxygenated, less shaded, and relatively nutrient-rich. A greater fraction of the energy entering the food web is captured within the system (autochthonous sources) by photosynthetic algae and macrophytes, and both species richness and overall biomass are greater than at the headwaters. Between these extremes is a continuum of habitat conditions for biota. According to the RCC paradigm, both autochthony and species richness are greatest in middle reaches of the stream system, where biota from both upstream and downstream converge, and the waters are still clear enough to support high levels of photosynthesis.

FINDINGS

Who has been monitoring Onondaga Creek habitat? Between 1981 and 2005, various habitat assessment methods were applied in an assortment of reaches in the Onondaga Creek watershed by regulatory agencies (NYS Department of Environmental Conservation (NYSDEC), US Environmental Protection Agency (USEPA)), academic researchers (State University of New York, College of Environmental Science and Forestry (SUNY ESF]- students of Dr. Neil Ringler and Dr. Karin Limburg), and an environmental consultant to Onondaga County (EcoLogic) (see Text Box 3).

How can information from different studies be interpreted? The variety of approaches to assessing aquatic habitat in Onondaga Creek yielded results that were not readily integrated into consensus habitat quality scores. Three general types of formal surveys on Onondaga Creek habitat were located (Text Box 3). Academic studies investigated the relationship between several specific habitat variables and certain aspects of creek biology, usually having to do with particular fish species or communities. In other studies, benthic invertebrate surveys (referring to streambed organisms, like insect larvae, crayfish, and mussels) in a limited number of locations were used to infer water and substrate quality, which in turn could be used as an index of overall creek degradation. The third type of survey assessed a number of physical and biological variables, and integrated them into a single, overall index, ultimately represented in verbal terms such as "poor" or "good". Six different benthic community or biological index surveys were conducted, each with a different set of variables measured, and different ways of combining those data into final habitat scores. Additional data are occasionally collected by students from regional colleges for fulfilling thesis or class requirements, by high school students involved in educational programs such as Project Watershed, or during the course of community educational events, such as SUNY ESF's Bioblitz. Such information collected for educational purposes was generally of limited geographic scope (relative to the entire watershed), and/or did not utilize nationally recognized and accepted methodologies, so they were not incorporated into this watershed-wide aquatic habitat summary at this time. These data may be reviewed during the course of developing specific recommendations for habitat improvements in specific reaches.

It is beyond the scope of this fact sheet to develop a rigorous method for combining the various study results into a defensible integrated score. However, the compiled information showed encouraging qualitative corroboration between the studies. Survey data from EcoLogic (2001, 2003) were selected as the basis for comparing relative habitat quality and causes of degradation over the length of the main stem, for several reasons: (1) they were geographically the most extensive and used the largest number of sites among all of the studies; (2) they surveyed sections of the creek not covered in any other study (e.g., above the Vesper impoundment, and on the Onondaga Nation territory); (3) they used a consistent method of scoring (Stream Visual Assessment Protocol), developed by the US Department of Agriculture (USDA), in two separate years; (4) habitat quality descriptions, at the most frequently sampled locations (Spencer Street, Dorwin Avenue, Webster Road, and Tully Farms Road), were qualitatively similar across studies with different methods, providing a degree of corroboration of the EcoLogic results; (5) the EcoLogic reports identify potential causes of the observed habitat degradation at each sampling point, which will assist in decisions of how to prioritize remediation along reaches. The following section presents the habitat assessment findings for Onondaga Creek in qualitative terms.

Text Box 3

Habitat assessments conducted in Onondaga Creek, 1982–2005.

Classical Habitat Surveys (SUNY ESF – Bannon/Ringler: 1982; Danehy/Ringler: 1991-94; Coghlin/Ringler: 2002-03). SUNY ESF researchers surveyed locations in the watershed for a number of attributes, including:

- Creek bed substrate
- Water velocity
- Riperian vegetation
- Discharge
- Creek bed and bank stability
- Water surface slope
- Water quality

Stream Visual Assessment Protocol (SVAP) (EcoLogic: 2000, 2002; entire watershed). Developed by the Natural Resources Conservation Service, USDA. The SVAP was developed for landowners to score overall habitat quality using a composite score of 15 habitat factors, each scored between 1 and 10, that could be assessed visually - mostly physical conditions.

Family Level Biotic Index (EcoLogic: 2000, 2002; entire watershed). This index is based on a well-known survey method (Hilsenhoff 1982, 1987,1988) used to score the general status of organic pollution and habitat on a scale between 0 and 10 based on the composition of the macroinvertebrate community.

Bioassessment Profile Score (NYSDEC: 1994; EcoLogic: 2000). This methodology was developed at the NYSDEC Department of Water. The overall BAP score is the mean of four indices (species richness, Hilsenoff Biotic Index, EPT index, and percent model affinity) whose scores have been scaled to between 0 and 10, and interpreted as follows: severe impact (0-2.5), moderate impact (>2.5-5), slight impact (>5-7.5), no impact (>7.5-10).

Habitat Assessment Score (USEPA: 1993). This index is a complex combination of 12 component indices in an adaptation of EPA's Rapid Bioassessment Protocol, which normalized each index to a score of 0, 2, 4, or 6, and then summed all scores for an overall assessment score, with possible values ranging between 0 (no impact) to 72 (severe impact).

Biotic Index (SUNY ESF - Coghlin/Ringler: 2002-03). This index is a variation on the BAP that relies on only one of the four component indices, the Hilsenhoff Index, scaled from 0-10.

Index of Biotic Integrity (SUNY ESF – Limburg et al.: 2005). The fish IBI, based on a classic assessment method (Karr et al. 1986), is used to score fish communities relative to a reference community and rank the degree of impact between multiple sites.

Where are the most and least degraded aquatic habitats? What parts of Onondaga Creek haven't been surveyed? Refer to Figure 1 for a creek watershed map that shows the following information.

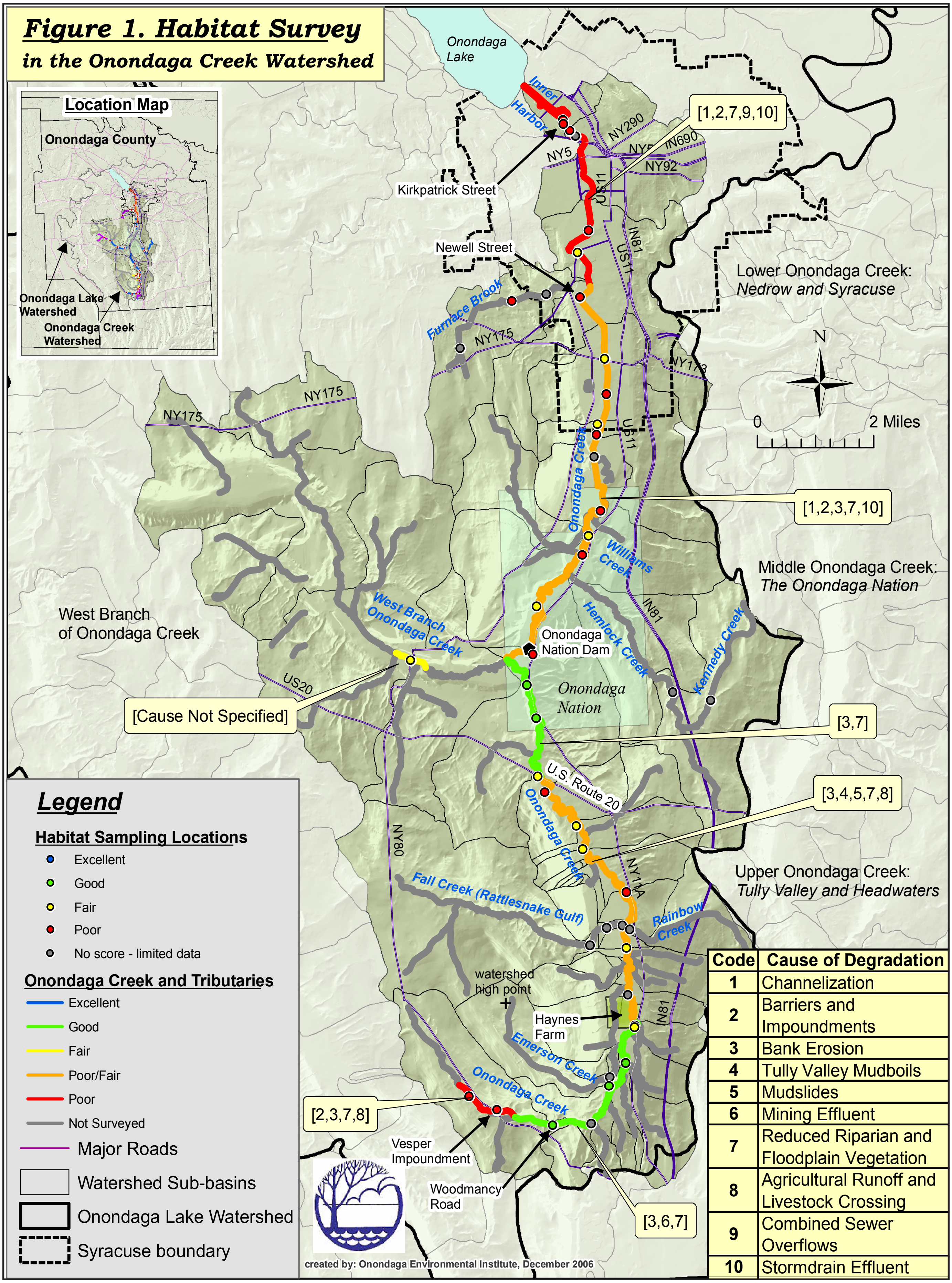

Figure 1. Habitat Survey in the Onondaga Creek Watershed

Code	Cause of Degradation
1	Channelization
2	Barriers and Impoundments
3	Bank Erosion
4	Tully Valley Mudboils
5	Mudslides
6	Mining Effluent
7	Reduced Riparian and Floodplain Vegetation
8	Agricultural Runoff and Livestock Crossing
9	Combined Sewer Overflows
10	Stormdrain Effluent

Onondaga Creek reaches having the *worst* habitat or biological community survey scores (most degraded conditions) were located in:

- Vesper near the old mill impoundment on NY Route 80; and
- Syracuse below Newell Street (see Figure 1).
  These areas are shaded red for "poor" on Figure 1.

The best survey scores (least degraded conditions) were in:

- The main stem of Onondaga Creek in the reach above the mudboils in the Tully Valley to Woodmancy Road (shaded green for "good" on Figure 1)

The next best scores were obtained:

- Between the dam on the Onondaga Nation territory and US Route 20 (shaded green on Figure 1).

Reaches of Onondaga Creek not surveyed intensively or not surveyed at all were shaded grey on Figure 1 map:

- West Branch of Onondaga Creek;
- Tributaries of the main stem of Onondaga Creek, including Furnace Brook, Williams Creek, Hemlock Creek, Kennedy Creek, Fall Creek, Rainbow Creek, Emerson Creek, and many smaller, unnamed tributaries.
  Grey-shaded survey points on Figure 1 represent sites studied by researchers, but resulting data can not be readily interpreted using a "good/poor" scale.

Interestingly, fish community structure upstream of the urbanized areas was a fairly consistent cold water assemblage (see Fish Fact Sheet), despite a wide range of habitat assessment scores, although fish densities varied with reach. Other tributary reaches off the main stem and areas of the West Branch sub-watershed that were not intensively surveyed may also be relatively intact. High densities of brook trout were observed in the upper reaches of tributaries in NYSDEC fish surveys that did not also score habitat.

What are the primary causes of habitat degradation in Onondaga Creek? A number of causes of aquatic habitat degradation were identified in surveys conducted along the main stem of Onondaga Creek (numbers below correspond to Figure 1 and Table 1), but limited information is available elsewhere in the watershed. Results of a number of habitat and biological community surveys are generally in agreement as to the nature and principal causes of degradation in the Onondaga Creek watershed. The following factors were repeatedly identified as important impacts (Table 1 describes biological implications for each cause of habitat degradation):

1. Channelization is associated with flood control in Syracuse, drainage in agricultural areas, and flow control around and through structures such as bridges and the dam on the Onondaga Nation territory. Habitat surveys have identified channelized reaches throughout the urban lower creek (Figure 2), much of which is further degraded by a concrete liner. Unlined channels in agricultural areas are associated with bank erosion and turbidity. By design, channels eliminate the hydrological connection to floodplains, and can also severely reduce or eliminate riparian zone vegetation.

2. Barriers and impoundments are flow control devices (see Flood Control Fact Sheet). A 'drop structure' is located at Dorwin Avenue in the city, a dam is located on the Onondaga Nation, and a former mill pond is located near the headwaters in Vesper. The Dorwin Avenue drop structure and the Vesper impoundment create a terraced slope, slowing the flow of water, which allows the water to warm and siltation to occur behind the barrier. The dam on the Onondaga Nation is primarily for flood control; a culvert under the dam channelizes water flow and limits water flow-

Figure 2. Urban Reach of Onondaga Creek (Courtesy of Atlantic States Legal Foundation)

through during high flow periods. There is an additional low barrier just south of Spencer Street in the city.

3. Bank Erosion occurs where riparian vegetation has been severely reduced, at road or cattle crossings, on the outer banks of stream bends, and in areas that were channelized but not lined with concrete, such as short reaches in agricultural areas. In addition to the habitat surveys (Text Box 3), the Onondaga County Soil and Water Conservation District (OCSWCD) has conducted bank stability and erosion surveys in the watershed and identified areas most in need of improvement (Blatchley, 2000).

4. Tully Valley Mudboils are a continuous source of suspended sediment and salinity to the creek (see Tully Valley Mudboils Fact Sheet). Various researchers have identified the mudboils as a critical source of degradation, principally including severe turbidity in the water column and fine sediment loading to the substrate.

5. Mudslides have occurred near Onondaga Creek tributaries due to slumping after heavy rain or snowmelt, or from streambank "toe-cutting" by surface water. They are a relatively continuous source of suspended particles to the water column, with pulsed heavier contributions associated with heavy rain or snowmelt (see Geology Fact Sheet).

6. Mining effluent from the gravel mine on the Tully Valley terminal moraine, ½ mile south of Solvay Road, makes the downstream tributary turbid after significant precipitation. The settling pond also likely warms the surface water. The impact to a wild brook trout population identified in the moraine tributaries by the NYSDEC in 1992 has not been formally assessed. This contributor to creek habitat degradation was not identified in the EcoLogic reports, but was mentioned in other studies.

7. Reduced riparian and floodplain vegetation occurs along almost the entire main stem of Onondaga Creek. In some channelized urban areas and in heavily agricultural areas in the upper creek there is reduced shading from riparian vegetation, which increases water temperature and reduces leaf fall and vegetation litter, a source of habitat and nutrients to life in the creek. Trees and plants in riparian zones provide a buffer to the creek, filtering runoff and stabilizing streambanks with their roots.

8, 9, 10. Pollution occurs throughout the watershed, but is most evident in heavily urbanized and heavily agricultural reaches of the main stem. Non-point nutrient loadings from fertilizers and manure in the upper creek and CSOs in the city can promote algae growth. Toxic chemicals have been reported in Onondaga Creek fish at levels unsafe for consumption (see Fish Fact Sheet).

Is anyone taking measures to improve habitat?

- The Onondaga Creek Working Group, a volunteer group of citizens who live or work in the Onondaga Creek watershed, will develop a revitalization plan for the Onondaga Creek corridor, based on technical information and public input. The Working Group will identify goals for the corridor as they develop the revitalization plan. The goals will help define recommendations for specific habitat improvements.
- In the mean time, stream bank stabilization and non-point source pollution reduction projects (funded under the Onondaga Lake Partnership (OLP) and implemented by Onondaga County Soil and Water Conservation District (OCSWCD)) are on-going in the rural regions of the watershed. Some of the bank stabilization projects, particularly between Nichols and Tully Farms Roads in Tully Valley, include measures to reconstruct riffle-pool alternating reaches in Onondaga Creek, direct water flow, and improve trout breeding habitat.
- The US Geological Survey (also under OLP auspices) has been conducting mudboil remediation measures in the Tully Valley for many years, and has greatly reduced sediment loadings to the middle creek reaches.
- The Combined Sewer Overflow (CSO) treatment projects that are being implemented by Onondaga County in the city are designed to remove large solids and treat for bacteria, but are not designed to reduce nutrient loadings or suspended solid loadings to the lower creek from CSOs, and are likely to discharge chemical byproducts of the chlorination-dechlorination process into the lower creek.
- Additional habitat improvement studies are underway by SUNY ESF researchers.

IMPLICATIONS

This section describes reaches of the creek with similar degrees of degradation, identifies the nature and principal causes of degradation in those reaches, interprets the observed degradation in terms of biological impacts (Table 1), and provides a general assessment of the usefulness of the aquatic habitat surveys for prioritizing improvements.

What is the geographic distribution of impacts to Onondaga Creek habitat? The entire creek main stem is impacted to varying degrees, but reaches of relatively similar quality and causes of degradation were identifiable (Figure 1). Few of the tributaries were surveyed for habitat quality, and sites in tributaries that were sampled are very near the main stem. The two most thoroughly studied segments of the creek are the Tully Valley and Headwaters, and the Lower Creek in the city. The following summary describes habitat conditions along the main stem from the Vesper headwaters to Onondaga Lake, as described in habitat surveys found in the available literature. Biological implications are described in Table 1. The following discussion corresponds to the Onondaga Creek habitat map (Figure 1).

Tully Valley and Headwaters

Above the Vesper impoundment at NY Route 80. *Rating: Poor.* Some of the lowest habitat scores observed in the watershed in 2000 and 2002 (EcoLogic). Impacts and likely causes include:

- Increased water temperature due to inadequate shading from riparian vegetation
- Non-point nutrient loading due to sparse riparian buffer vegetation between the creek and crop fields
- Sediment loads from direct bed and bank disturbance from livestock and dirt road crossings

Vesper impoundment and immediately downstream. *Rating: Poor.* Likely impoundment impacts that affected habitat scores in 2005 (SUNY ESF – Limburg) include:

- Increased temperature immediately downstream due to pooling of water
- Possible excessive nutrients reflected in algae and macrophyte growth. Aquatic plants larger than algae are called macrophytes.
- Occasional introduction of warmwater fish species washed downstream during high flow events

Just above Woodmancy Road to just above the Haynes Farm[1] on NY Route 11A. *Rating: Good.* This segment has the best habitat scores in the watershed based on surveys in 2000 and 2002 (EcoLogic), and 2005 (SUNY ESF – Limburg). The segment was likely affected by sediment loading due to bank erosion; some remediation of these problems in ongoing by OCSWCD.

Haynes Farm to US Route 20. *Rating: Poor/Fair.* Habitat scores are either fair or poor throughout this segment, based on surveys conducted by EcoLogic (2000, 2002), NYSDEC (1989, '90, '95, 2001), SUNY ESF – Coghlin/Ringler (2002, '03), and SUNY ESF – Limburg (2005). Some of the issues are currently being addressed by the OCSWCD. Principal impacts and likely causes include:

- Increased turbidity and benthic degradation principally from mudboil discharge
- Additional sediment loadings due to bank erosion from occasional unlined channelization, cattle crossings, dirt road crossings, unstable stream bed due to dredging, and crop field runoff
- Possible non-point nutrient loadings from manure and fertilizer applications, due to reduced riparian buffer zone, resulting in observed algae growth at Nichols and Turner Road crossings
- Webster Rd. was surveyed most frequently in this segment, with ratings as follows:
    - "slightly impacted" in 1989, 1990, and 1995 (NYSDEC)
    - "moderately impacted" in 2001 (NYSDEC)
    - "fair" overall habitat score in 2000 and 2002 (EcoLogic)

US Route 20 to just upstream of the Onondaga Nation dam. *Rating: Good.* This segment had the second best set of habitat scores, but was only evaluated once in 2000 (EcoLogic). Some turbidity and algae were observed, likely due to local bank erosion, unstable creek bed from dredging, and upstream inputs. Thin riparian cover was also noted.

West Branch of Onondaga Creek

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1 The term "Haynes Farm" is simply a place label (there is no nearby road crossing), and is not used here to imply any causal connection to habitat condition.

Table 1. Relationships between degraded states in Onondaga Creek, and their causes and potential biological effects.

Cause(s) (per Figure 1 map)	Degraded State	Potential Biological Implications
1. Channelization	• Bed scouring from increased water velocity during high flow periods reduces, or eliminates, diverse substrate (e.g. sand, gravel, etc.) and cover (protected places for fish, other organisms) • Elimination of meanders • Elimination of alternating shallow and deep habitats (riffle/pool) • Few large rocks and boulders • Virtual elimination of riparian wetlands, floodplain connection in lined urban channels	• Food Web. Reduced aquatic vegetation abundance leads to decreased macroinvertebrate (small aquatic animals, visible to the naked eye) and periphyton (attached algae) abundance and/or diversity, hence possibly reduced fish species abundance or richness (number of species). • Fish Cover, Spawning and Nursery Habitat. Riparian and floodplain wetlands provide vegetative structure, as cover, and an infusion of food material during early development of some fish species, and cover for young of the year (less than one year old), juvenile, and small adult fish. Reduction in riparian and floodplain vegetation may significantly reduce fish diversity and recruitment to adulthood (reproductive age). • Fish and Benthic (stream bottom) Communities. Virtual elimination of variety in the stream's aquatic vegetation, physical shape, and natural means to dissipate water energy (e.g., flood plains, riparian vegetation, obstructive boulders and rocks, meanders and pools) combine to limit the number of resident species that can both survive and reproduce within the channelized reaches.
2. Barriers and Impoundments /	• Reduced water velocity, likely resulting in: ◦ Increased water temperature ◦ Reduced oxygen ◦ Sediment accumulation • Increased turbidity (cloudiness) downstream during high flow events from re-suspended sediments • Reduced fish movement	• Fish Health. Water that is slowed and warmed at dams and impoundments carries less oxygen, yet increases the physiologic requirement for oxygen. Fish that are adapted to clear water expend more energy foraging for food in turbid water. High levels of suspended solids could interfere with respiration (breathing water), especially in early life stages, small fish species, and macroinvertebrates. These impacts may lead to severely impacted energy balance that can reduce growth, reproductive success, and survival rate. • Benthic Community. A heavy accumulation of sediment in the stream bed reduces substrate diversity for benthic invertebrates and is more readily disturbed than rock substrate. This severely reduces benthic invertebrate abundance and/or diversity, which in turn affects fish communities – benthic macroinvertebrates are an important food source for fish. • Fish Spawning. Many species require specific substrate conditions for successful spawning. Heavy accumulation of fine particles in the creek bed can interfere with spawning, especially in some cold water species that require gravel or cobble.
3. Bank Erosion **4. Tully Valley Mudboils** **5. Erosion of Mudslide Soils** **6. Mining Effluent**	Increased sediment loading (input) to creek, usually associated with high flow from precipitation or snow melt (except for mudboils, which are relatively continuous), resulting in: • Increased turbidity, sometimes very high • Sediment accumulation • Likely increased temperature (from mining impoundment)	• Fish Health. Fish that are adapted to clear water expend more energy foraging for food in turbid water. High levels of suspended solids could interfere with respiration, especially in small fish and invertebrates. These impacts may lead to severely impacted energy balance that can reduce growth, reproductive success, and survival rate. • Benthic Community (see discussion under 2. Barriers and Impoundments). • Fish Spawning (see discussion under 2. Barriers and Impoundments).
7. Reduced Riparian and Floodplain Vegetation	• Reduced shading, resulting in: • Increased water temperature • Reduced oxygen • Reduced cover (protected places for fish, other organisms) • Reduced input of vegetation litter	• Food Web. Near headwaters, vegetation litter forms the foundation of the nutrient poor headwaters food web, and diversifies substrate for benthic macroinvertebrates. Reduced litter may reduce abundance and/or diversity. • Fish Health. Unshaded water warms and carries less oxygen, yet increases the physiologic requirement for oxygen. Severely impacted energy balance can reduce growth, reproductive success, and survival rate. • Fish Reproduction. Riparian and floodplain wetlands provide vegetative structure as cover and a temporary infusion of food material during spring floods that support the food web of early life stages of many fish species. The abundance and sustainability of fish populations are highly dependent on their ability to successfully reproduce and recruit the next generation of fish to reproductive age.
8. Agricultural Runoff and Cattle Crossings	Runoff is closely related to precipitation and spring melt, while disturbances at cattle crossings are not. Both are related to inadequate riparian zone vegetation buffer (protective filter). The resulting degradation includes: • Nutrient and bacteria loading • Increased turbidity • Sediment accumulation • Pesticide loading	• Ecosystem. Excessive nutrients promote algae growth in reaches with low enough turbidity to allow photosynthesis (capture of the sun's energy by plants). Thick beds of attached algae can reduce local benthic (stream bottom) diversity, and reduce oxygen in the downstream water during decomposition. Increased phytoplankton production can affect turbidity (phytoplankton are microscopic free-floating plants). • Human Health. The extent and persistence of bacteria in the creek are discussed in the Pathogens Fact Sheet • Fish Health. Fish that are adapted to clear water expend more energy foraging for food in turbid water. High levels of suspended solids could interfere with respiration, especially in small fish and invertebrates. These impacts may lead to severely impacted energy balance that can reduce growth, reproductive success, and survival rate. • Benthic Community (see discussion under 2. Barriers and Impoundments). • Fish Spawning (see discussion under 2. Barriers and Impoundments).
9. Combined Sewer Overflows	• Nutrient and bacteria loading • Increased turbidity • Sediment accumulation • Toxics	• Ecosystem (see discussion under 8. Agricultural Runoff and cattle Crossings) • Human Health (see Pathogens Fact Sheet) • Fish Health (see discussion under 8. Agricultural Runoff and cattle Crossings) • Benthic Community (see discussion under 2. Barriers and Impoundments) • Fish Spawning (see discussion under 2. Barriers and Impoundments) • Toxic Effects. Certain impacts to benthic invertebrate communities may be consistent with generalized toxic chemical exposures, but the habitat surveys provided little specific information on potential for human health or ecological toxic effects from treated or untreated CSO effluent.
10. Storm Drain Effluent	• Increased turbidity • Increased water velocity	• Fish Health. (see discussion under 8. Agricultural Runoff and cattle Crossings)

Rating: Fair. This entire segment was assessed only once at a single location in 2001 by the NYSDEC at the NY Route 80 crossing, where water quality was scored as "slightly impacted" based on a biological survey, but the likely cause of degradation was not discussed.

Onondaga Nation

Rating: Poor/Fair. Only one formal survey was located, conducted by EcoLogic in 2000, which included four sites on the Onondaga Nation territory. Scores were fair and poor throughout this segment; the principal impact was high turbidity, likely from upstream contributions, as well as local bank erosion, thin riparian buffer, and some channelization and dredging. Poor riparian cover was noted just above the flood control dam, and at other locations.

Lower Creek (Nedrow and Syracuse)

Onondaga Nation to Newell Street. *Rating: Poor/Fair*. This segment was surveyed in 1999, 2000, and 2002 (EcoLogic) and in 2005 (SUNY ESF – Limburg). The most frequently sampled location was Dorwin Ave., which was rated as "slightly impacted" in 1999 and 2000 (EcoLogic), and "poor' in 2002 (EcoLogic). Survey scores were mostly 'poor,' due to effects from channelization and poor riparian zone vegetation.

Newell Street to Kirkpatrick Street. *Rating: Poor*. Various sites within this segment were sampled during numerous surveys conducted between 1989 and 2005. This is the largest severely impacted segment of the main stem, with ratings of 'poor' in nearly all cases, interspersed with occasional 'fair' and 'severe impact' scores. There is no evidence in the available survey data that conditions changed during that time. Degradation includes: no floodplain; channelization essentially throughout this segment; bacteria and loading of solids from CSO effluent; algal growth from CSO nutrient loadings; garbage and stormdrain effluent; and poor riparian zone and benthic substrate.

Are existing survey data adequate for prioritizing habitat improvements? It depends on the goals for the biological communities. If conservation of a general community type – such as a cold water fish community - is the goal, then the existing surveys likely provide sufficient information for prioritizing the most obvious improvements in the main stem of the creek. Habitat information is generally more sparse in tributaries, and may need to be supplemented. Remediation of obvious sources of degradation, such as mudboils and bank erosion, is

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Tully Valley Mudboils

Onondaga Creek Fact Sheet

INTRODUCTION

Tully Valley mudboils are "muddy springs" composed of water, liquefied sediments, and dissolved mineral salts which are discharged through surface vents via subsidence fractures caused by persistent artesian groundwater pressure (see Figures 3 & 4). Associated land subsidence (sinking) results from erosion underneath the land surface, as water removes deeply buried glacial-lake deposits.

Basic Facts about Tully Valley Mudboils

Occurrences have been documented from 1899 to the present day. Activity may predate the 20th century, but phenomena have been continuous since 1987. Mudboil flow occurs year round due to persistent artesian ground water pressure with "head" in the valley walls that is higher than the valley floor.

Location is near Onondaga Creek, south of Otisco Rd., Lafayette, NY. The area of concentrated mudboils where land subsidence has occurred is known as the Mudboil Depression Area (MDA) (see Figures 1 & 2).

Number of surface vents varies. From the 1980s to present, typically 3 to 7 mud boils discharge at any given time in the MDA, with one or more in a 'rogue' area.

Duration A vent cone can form within few days and then stop, while others discharge for years. One has been monitored for a decade. New vents are more likely to develop near recently active mudboils, due to the subsurface fracturing.

Flow intensity fluctuates with groundwater level, which is typically highest in Spring, with a secondary peak in late Fall-early Winter.

Rare Phenomenon. Other recorded mudboils occur under contrasting conditions (earthquake, freeze/thaw conditions, or tectonic weight on sediments). Most were temporary phenomena that formed in response to earthquakes in California and Alaska. In general, sand springs are more common than mudboils.

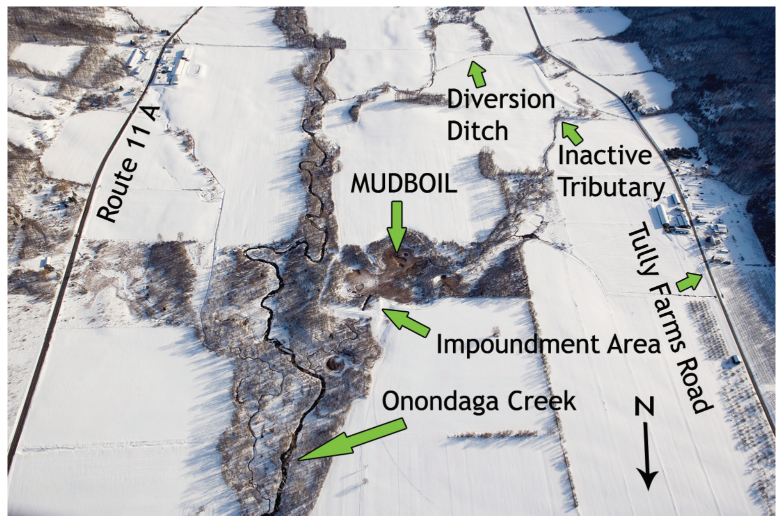

Figure 1. Aerial view from the north of the Tully Valley Mudboils. Photography by William S. Hecht, 2005.

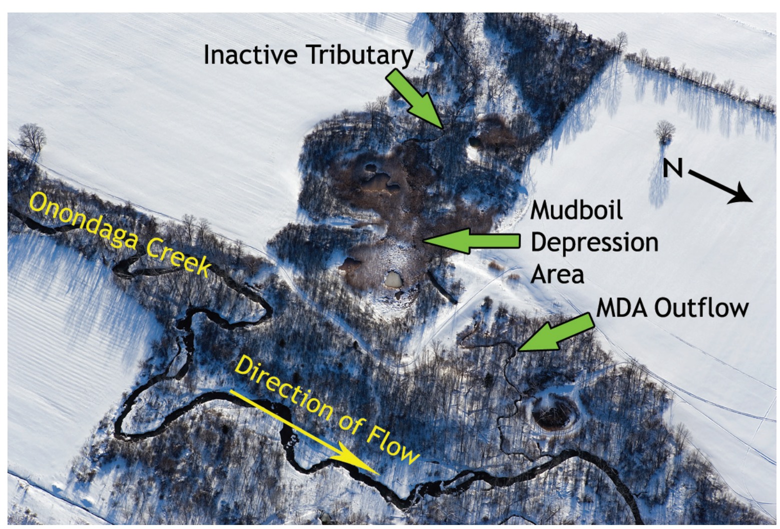

Figure 2. Aerial view from above mudboil area, south-southwest is left, west is at top. Photography by William S. Hecht, 2005

onondaga creek
CONCEPTUAL REVITALIZATION PLAN

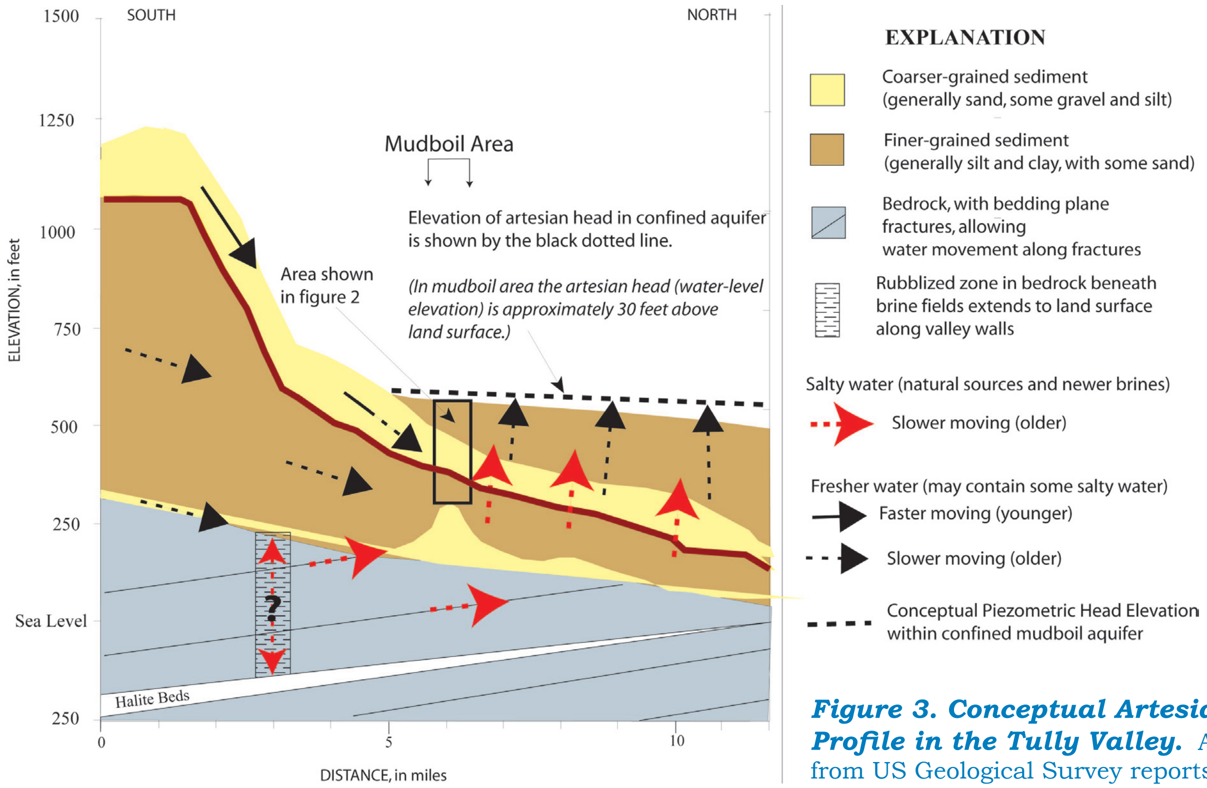

Figure 3. Conceptual Artesian Head Profile in the Tully Valley. Adapted from US Geological Survey reports.

Sediments discharge from vents in a range of particle sizes:

- Fine sand accumulates to form a 'volcano' cone around each mudboil vent.
- Silt-size particles settle behind a dam (see remedial measures).
- Finer silt and clay-sized particles flow to Onondaga Creek, turning it a turbid (cloudy) brown color.

Dissolved ions discharge from deep aquifer zones through the mudboils, contributing salty or brackish water to Onondaga Creek.

- Fresh water mudboils, once common in 1977, are harder to find today.
  - High suspended solids (turbid, brown water).
  - Low dissolved solids, not salty.
- Brackish to saline mudboils are the most common type occurring today.
  - High suspended solids (turbid, muddy water).
  - Higher dissolved solids: Brackish/ slightly saline to very saline (sea-water quality.
  - Typical dissolved ions: Sodium, Magnesium, Calcium, Chloride, Sulfate

Three kinds of aquifers provide artesian pressure which erodes and discharges unconsolidated subsurface material to the land surface. Figure 3 shows groundwater directional flow along the south to the north cross-section of the Onondaga Valley (Kappel 2000).

- *Brackish water* aquifer deep under the valley floor at 250 to 400 ft. depth. Source waters originate in:
  - Deep regional bedrock flow.
  - Interconnected bedrock aquifers in the solution-mining collapse areas.
  - Tully Moraine - southern end of the Tully Valley.
- *Fresher water* aquifer located under the valley floor at an approximate 60 to 120 ft. depth.
- *Fresh water,* near-surface recharge from alluvial fans of tributaries from the side walls of the Tully Valley.

Remedial measures were implemented and are maintained to date by the U.S. Geological Survey to reduce mudboil sediment discharges from the MDA to Onondaga Creek.

- *Depressurizing wells* were installed in the early to mid 1990s to lower artesian pressure.
- *A diversion channel* was installed in June 1992 to reroute an unnamed tributary away from the MDA.
- *A dam* was constructed in July 1993 creating a settling impoundment where detained water also maintains hydraulic pressure over the mudboils.

Mudboil loading (as measured in outflow) is now largely driven by the artesian pressure in the aquifers (Kappel, Sherwood *et al*. 1996).

- In early 1992 prior to tributary diversion, the annual mean daily discharge (outflow) from the MDA was 2.2 cubic feet per second (cfs), combining surface water with mudboil "spring" water.
- After 1993 improvements, the average annual

mean daily discharge dropped to 1.02 cfs (Kappel *et al*., p42)
- Since 1993, average annual mean daily discharge ranged from 0.71 cfs to 1.04 cfs outflow from the MDA, which reflects the continuing dominant role of aquifer discharge.

Sediment reduction from the MDA.
- Before remediation: 29.7 tons per day (measured 1992 water year, Oct. 1991 –Sept. 1992).
- After remediation: 0.7 tons per day (measured 2005 water year, Oct. 2004- Sept. 2005).
- Landslides in two creek tributaries contribute sediment to the creek downstream of the mudboils
    - Rainbow Creek (2004)
    - Rattlesnake Gulf (2005)

Land subsidence deforms the surface terrain.
- MDA is approximately 5 acres in extent in 2006.
- Maximum subsidence depth is approximately 15 ft. in 2006.

If the remedial measures cannot be maintained, site restoration (closure) must be conducted. Without funding for continuous maintenance of the wells, impoundment dam, and diversion ditch, the property would have to be restored as much as possible to the condition before the measures were implemented.
- The depressurizing wells would be closed down.
- The impoundment border would be graded to remove the dam.
- The diversion ditch would not be maintained, thus permitting the tributary to resume passing through mudboils.

Property ownership
- Honeywell International owns the surface in which mudboils are active, including the locations of the impoundment dam and depressurizing wells; the Onondaga County tax assessor lists Allied Chemical Corp. as owner. Allied Chemical is the corporate name prior to a merger with Honeywell.
- The diversion ditch passes though the property of John Snavlin and Richard Snavlin.
- Onondaga County holds an easement for the ditch.

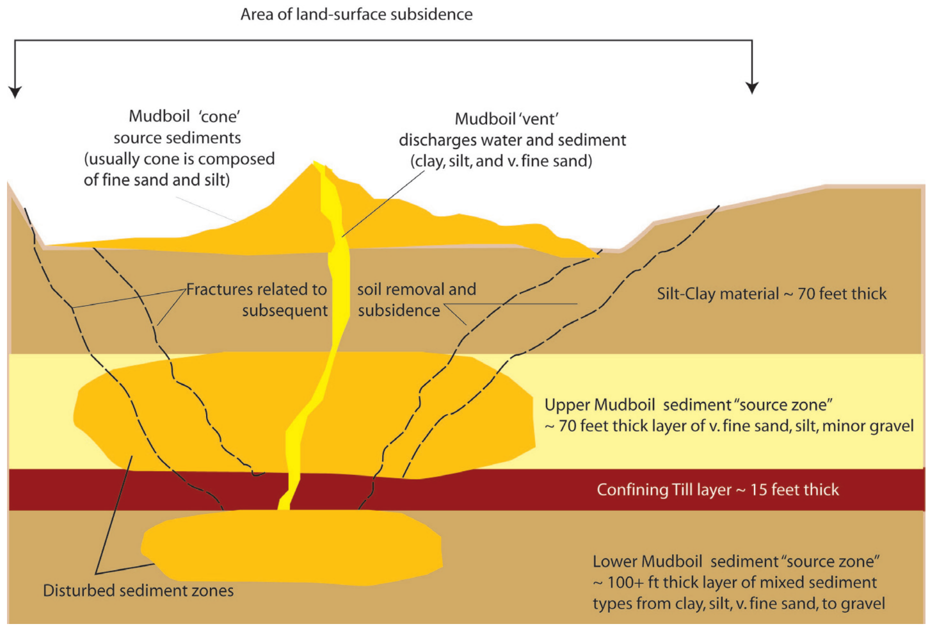

Figure 4. Typical mudboil layers, adapted from US Geological Survey data. Not to scale.

Anthropogenic influence

Solution mining in the Tully Valley led to increased artesian groundwater pressure in deep aquifers (over pre-existing natural conditions.) Rain and snow melt in the porous Tully brine field can penetrate fractured rock and disturbed sediment layers, thereby increasing the volume and depth of groundwater.

During mine operation, brine was continuously withdrawn from deep in the hydraulic system. This withdrawal generally lowered groundwater table and reduced artesian pressure in the brine field. When brine mining ceased, the groundwater level rose and artesian pressure increased, thereby exacerbating mudboil conditions.

The added groundwater recharges two aquifers in the valley floor that affect the mudboils. Under pre-mining conditions, ground water flow was more likely retained in shallow aquifers or surface water, without recharging deeper aquifers.

FINDINGS

- The flow of artesian-pressured water causes mudboils.
- Hydraulic pressure exceeds the capacity of wells to prevent further mudboil eruptions (Hayes 1998)
- Depressurizing wells bring fresh to mostly brackish water to the surface from the deeper aquifer.
- Subterranean solid material is exceptionally vulnerable to erosion and will continue to be brought to the surface.
    - Fractures in unconsolidated sediment layers connect aquifers to the land surface.

- Water erodes unconsolidated material as very fine sand, silt, and clay, discharged at land surface.
- Location and timing of new mudboils is not predictable.
- Land subsidence is expected to continue, although at a reduced rate from that measured in the early 1990's.
- Should new mudboil discharges be eliminated, currently existing mudboil sediment deposits on the creek bottom will continue to impact water quality for several decades.
- The brine-mining subsidence area in the southern part of the Tully Valley allows formerly separate bedrock aquifers to interconnect and thereby provide greater artesian pressure and greater volumes of brackish water that discharge from the mudboils.
- Dissolved halite (sodium chloride) from the Tully Valley brine field probably moves northward to the mudboils.
- Most of the dissolved ions in the mudboils are from the deep brackish water aquifer.
- Clay and fine silt from mudboils can remain suspended as turbid water in Onondaga Creek and affect water quality.
- Dissolved ions (salts) from mudboils continue to affect water quality in Onondaga Creek.

IMPLICATIONS

Mudboil management will require intermittent maintenance activities:

- Reshape the impoundment area where subsidence has occurred or where a new mudboil has formed.
- Maintain tributary diversion channel.
- Redevelop depressurizing wells and (or) replace with new wells as older wells lose their ability to discharge water due to sediment fouling within the mudboil aquifer

Mudboil management has persistent regular activities:

- Dredge sediments from the impoundment area before it fills.
- Monitor water quality and detect new eruptions.

Mudboil conditions could limit water quality improvements.

- Suspended sediments of clay and silt intermittently cloud the creek.
- Brackish water reaches the creek from mudboils and landslide areas further to the north.
- Multiple aquifer sources limit options to reduce mudboil activity.
- Management practices are not presently financially self-sustaining.

Land uses in the area are at risk.

- Subsidence and loss of land occurs in adjacent agricultural fields.
- New mudboil eruptions are not predictable in time or location but will probably occur within and near the historic mudboil 'corridor' upstream of Otisco Road and on the main mudboil tributary channel leading to the MDA.
- Channel instability (landslides) occurs in nearby tributaries (Rattlesnake Gulf and Rainbow Creek).
- Mudboil material
    - Is a quicksand that is not safe for walking.
    - Has highly astringent properties, removes soil, leaving skin dry upon contact, similar to a 'facial.'

SUMMARY

Mudboils are a persistent natural phenomenon that appears to have been exacerbated by solution-mining activities south of the mudboil area. Dynamic and unpredictable mudboil activity will require regular monitoring and innovative management solutions. Brackish water and suspended fine sediment will continue to reach Onondaga Creek, even with careful and continuous management.

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Landslides, Subsidence & Fractures

Onondaga Creek Fact Sheet

TULLY VALLEY LANDSLIDES

Numerous Landslides have occurred in the Tully Valley over a 15 year interval, April 1993 to present.

Land slumping on a valley wall occurred at the foot of Bare Mountain on April 27, 1993, when 1.3 million cubic yards of land slid across Tully Farms Road towards Onondaga Creek. (Fig.1) Research by the US Geological Survey (USGS) of other sites along the foot of Bare Mountain found evidence of previous landslide occurrences that ranged from 7,000 to 10,000 years ago.

A shale ledge failure released glacial sediments into Rainbow Creek. Some time in the early 1970's a shale ledge (waterfall) failed (Fig. 2a) along Rainbow Creek between I-81 and State Route 11A. This lead to the presently-ongoing landslide which has carried large volumes of sediment down to the valley floor, filling culverts under State Route 11A with substrates ranging in size from boulders to cobbles, down to silt and clay which add turbidity to Onondaga Creek. (Fig. 2b) The landslides along Rainbow Creek are due to rapid erosion of the creek bed behind the former shale ledge and subsequent toe-cutting[1] of steep slopes on either side of the creek.

Stream toe-cutting into glacial sediments along Rattlesnake Gulf. Ongoing landsliding in Rattlesnake Gulf has also cut away at the base of a massive bluff consisting of clay soil on the south side of this steep stream channel. The face of the bluff continues to slide into the stream, further exposing the bluff to rapid erosion and partly blocking the channel under the bridge at Tully Farms Road and also adding turbidity to Onondaga Creek. This landslide area was apparently active before the late 1930s (when the first aerial photography of the region was collected) and continues to erode into the steep hillside today (2008). Previous

1 The toe is synonymous with the base of the slope forming a stream bank.

Figure 1: Oblique aerial view of the Tully valley landslide taken April 30, 1993, three days after the slide. Debris moved toward the viewer, in the process covering Tully Farms Road (dashed line) with up to fifteen feet of reddish remolded clay. Three people were rescued by helicpoter behind the white house (lower left) from the rapidly advancing landslide. Springs are located between the red arrows.

source: http://pubs.usgs.gov/fs/fs13-98

Figure 2a

source: USGS William M. Kappel presentation to US EPA, April 7, 2008, slide 42

Figure 2b
Source: USGS William M. Kappel, presentation to US EPA April 7, 2008, Slide 44

Figure 3
Source: USGS photo of Rattlesnake Gulf, Tully Valley, New York

landslides along Rattlesnake Gulf are attributed either to bedrock failure or sediment-slope failure, both related to stream toe-cutting. (Fig. 3)

TULLY VALLEY SUBSIDENCE

Cracking and subsidence of bedrock along the east and west valley walls has occurred in the former brine field areas at the southern end of the Tully Valley due to the removal of halite (rock salt), at a depth of 1,200 feet below land surface. For a century (1880s to 1980s) the halite was solution-mined for the production of soda ash in Syracuse (Solvay Process Company – Allied Chemical Corporation).

Deformation of rock is visible in the broken and tilted rock layers at Emerson Gulf (Fig. 4).

Collapse of rock into voids left by brine mining occurred where wells drilled to depths of 1,100 to 1,300 feet had removed layers of halite that were over 150 feet thick. The overlying bedrock collapsed, which is expressed as land-surface displacement along the edges of the valley in this area.

Subsidence of the land surface in the former brine fields is visible on the east and west sides of the valley floor, above the subsurface rock-collapse zones (Figure 5a, sinkhole). The subsidence extends across the valley floor between the east and west brine fields (Fig.5b, map).

Subsidence also occurs at the mudboils several miles north of the brine fields, and is due to the discharge of unconsolidated very-fine sand, silt, and clay, which is carried by water under artesian pressure. (See Mudboil Fact Sheet)

TULLY VALLEY FRACTURES

Vertical to horizontal cracks (joints) extend hundreds of feet through the bedrock due to tectonic forces that formed the Earth's continents over many millions of years. These joints have been identified regionally through mapping of bedrock joints and fractures in stream channels and other bedrock exposures.

Multiple new bedrock fractures have opened along these joint surfaces in the east and west valley walls (Fig. 6), upslope of the brine field subsidence. These fissures have opened at a rate which can be identified by tree roots that straddle a fissure (Fig. 7). Hydraulic connections may have developed within these 'enhanced' fracture zones and the unconsolidated mudboil aquifer.

Figure 4
Source: USGS William M. Kappel presentation to US EPA, April 7, 2008, slide 31

Figure 5a
Source: USGS William Kappel presentation to US EPA April 7, 2008, slide 33

Figure 5b
Source Figure 13 in Kappel, W.M., D. A. Sherwood, and W.H. Johnston. 1996. Hydrogeology of the Tully valley and characterization of mudboil activity, Onondaga County, New York. WRIR96-4043. U.S.Dept. of the Interior U.S. Geological Survey; Branch of Information Services distributor, Ithaca, N.Y., Denver, C.O.

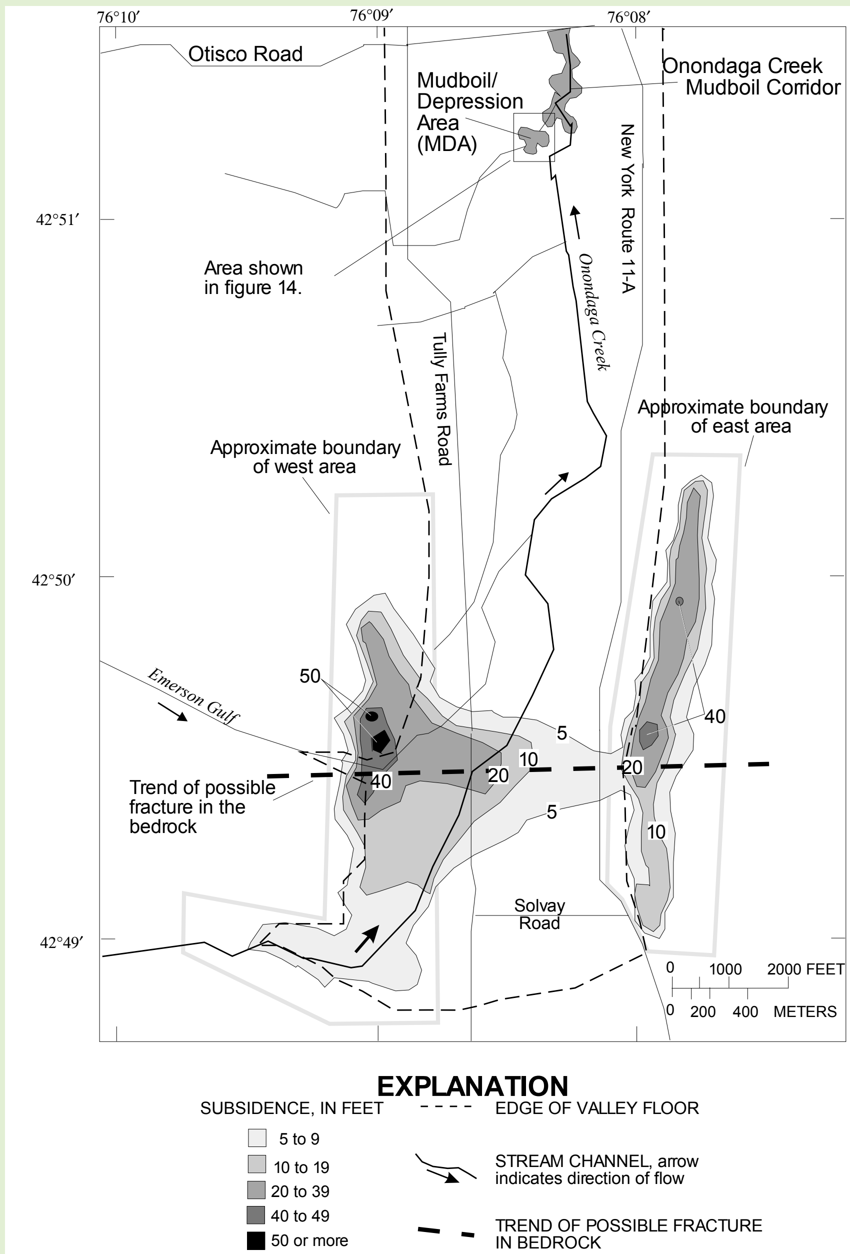

Figure 6
Source: USGS William M. Kappel presentation to US EPA, April 7, 2008, slide 32

Figure 7
Source: USGS William M. Kappel (2008)

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The Onondaga Lake Partnership (OLP) sponsors the Onondaga Creek Revitalization Plan project with funds from the U.S. Environmental Protection Agency. Visit www.onlakepartners.org for more information about the OLP.

This fact sheet and additional information about the Onondaga Creek Revitalization Plan project can be found on the World Wide Web at www.esf.edu/onondagacreek/.