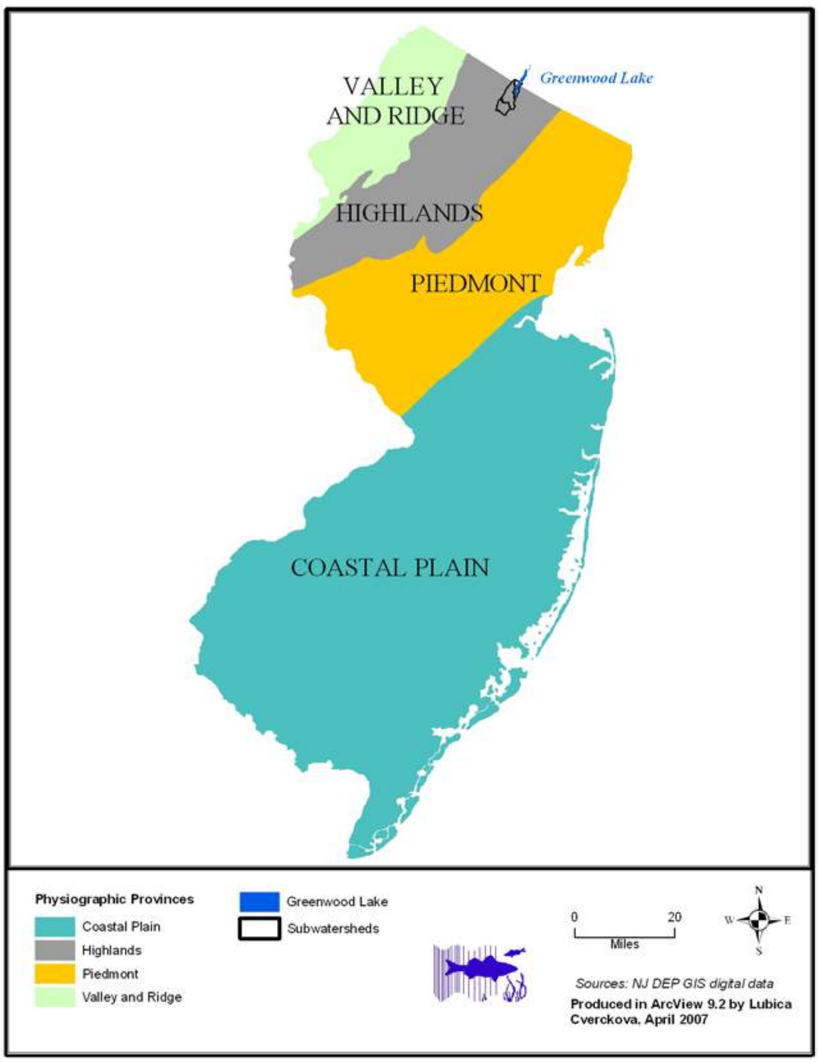
II. NATURAL RESOURCES OF THE GREENWOOD LAKE WATERSHED

A. LAND RESOURCES

Geologic History

The Greenwood Lake Watershed is located in the Highlands Physiographic Province, as shown in Figure II.A-1. The Highlands are underlain by the oldest rocks in New Jersey. These Precambrian igneous and metamorphic rocks were formed between 1.3 billion and 750 million years ago by the melting and recrystallization of sedimentary rocks that were deeply buried, subjected to high pressure and temperature, and intensely deformed.[1] The Precambrian rocks are interrupted by several elongate northeast-southwest trending belts of folded Paleozoic sedimentary rocks equivalent to the rocks of the Valley and Ridge Province.

Figure II.A-1 - Physiographic Provinces of New Jersey



[1] New Jersey Geological Survey, NJ Department of Environmental Protection. 1999. The Geology of New Jersey.

The Highlands ridges in New Jersey are a southward continuation of the Green or Taconic Mountains of Vermont and Massachusetts, the New England Upland of Connecticut, and the Hudson Highlands of New York.[2] The ridges continue through Pennsylvania to the vicinity of Reading. This Reading Prong of the New England Physiographic Province plunges beneath the surface of younger rocks for a distance of about fifty miles southwest of Reading and reappears where the northern end of the Blue Ridge Mountains begins to rise above the surrounding country. The Blue Ridge Mountains of the Virginia Appalachians, the mountains of New England, and the Highlands of New Jersey and New York all have a similar geologic history and character.

Topography

The granites and gneisses of the Highlands are resistant to erosion and create a hilly upland dissected by the deep, steep-sided valleys of major streams.[3] The Highlands can be characterized as broad high ridges composed of complex folded and faulted crystalline rocks and separated by deep narrow valleys.[4] The topography follows the northeast-southwest trend of the geologic structure and rock formations. Elevations across the area range from 600 to over 1,400 feet. The hills and valleys in the Greenwood Lake Watershed are depicted in Figure II.A-2.

The topography of the Greenwood Lake Watershed is varied. The low elevations at approximately 600-700 feet above sea level are associated with the basin of Belcher Creek that flows through the Pinecliff Lake and then into Greenwood Lake. The elevation rises with ridges and high plateaus of the Highlands to above 1,400 feet (Figure II.A-2). The area of Belcher Creek as it flows from the Pinecliff Lake into Greenwood Lake exhibits the lowest slope angles at about 3% (Figure II.A-3). Slope angles rise in the hilly uplands consisting of the Precambrian granites and gneisses which are resistant to erosion with average slope angles between 3 to 15%. The upland is in some parts dissected by the deep, steep-sided valleys of streams that exhibit steeper slope angles.[5] The Precambrian rocks are interrupted by several elongated northeast-southwest belts of folded Paleozoic sedimentary rocks equivalent to the rocks of Valley and Ridge province. The belts of erosion resistant sandstone and siltstone form long, parallel ridges with slopes above 25%, such as Bearfort Mountain. Easily eroded shale and limestone form valleys between ridges, such as Clinton Brook Valley.[6]

[2] Widmer, Kemble. 1964. *The Geology and Geography of New Jersey*. The New Jersey Historical Series, vol. 19, D. Van Nostrand Company, Inc., Princeton, NJ. Page 12.

[3] New Jersey Geological Survey, NJ Department of Environmental Protection. 1999. The Geology of New Jersey.

[4] Edwards and Kelcey, Inc. 1974. Natural Resource Inventory and Assessment, A Report to the Hopatcong Environmental Commission, Borough of Hopatcong, December 1974, page 30.

[5] http://www.state.nj.us/dep/njgs/enviroed/freedwn/psnjmap.pdf

[6] http://www.state.nj.us/dep/njgs/enviroed/freedwn/psnjmap.pdf

Figure II.A-2 – Land Elevations in the Greenwood Lake Watershed

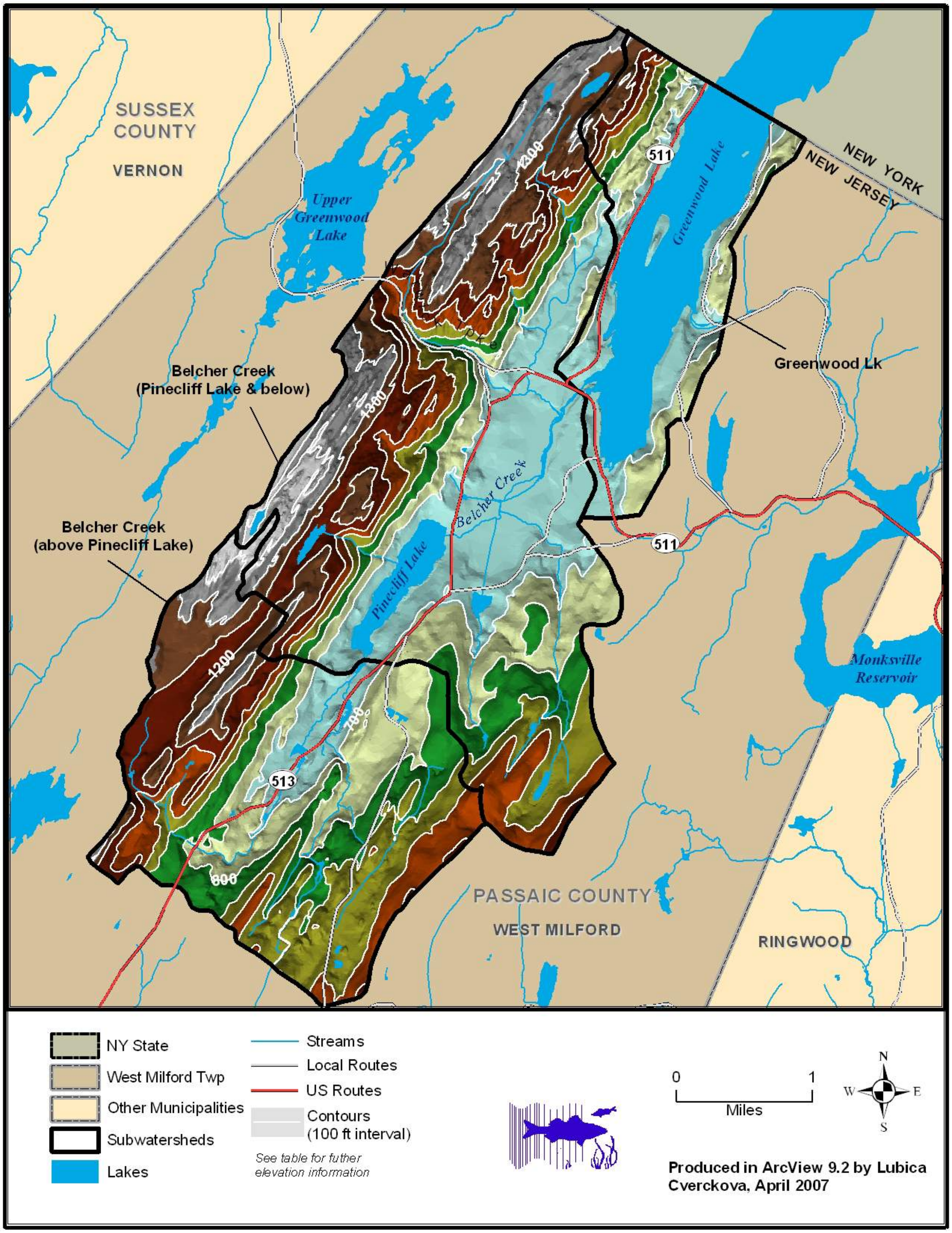
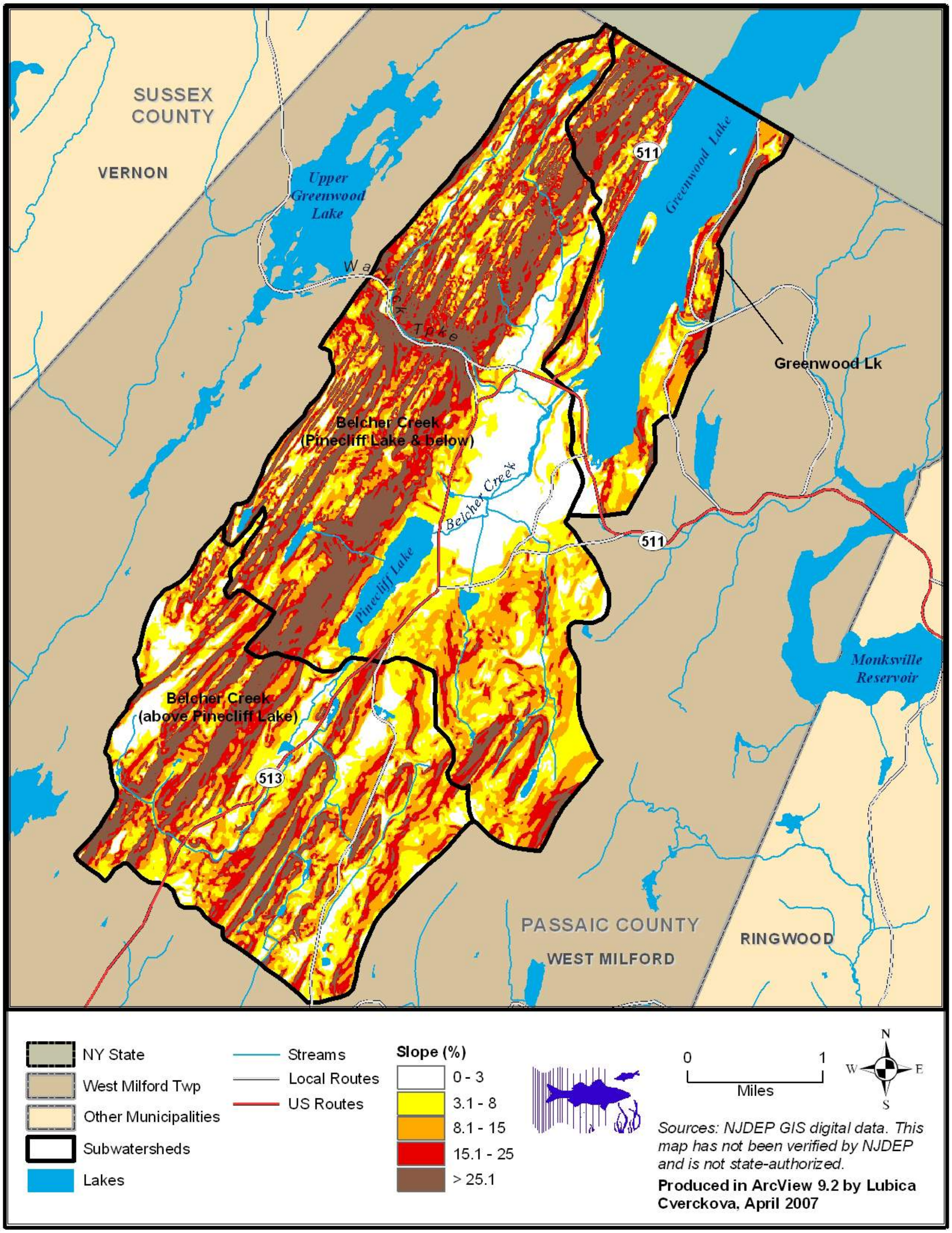


Figure II.A-3 – Slopes



Bedrock Geology

The geology of the Greenwood Lake Watershed is very complex. (See Figure II.A-4 and Table II.A-1.) The bedrock of the watershed is predominately of Precambrian age and erosion-resistant granite and gneiss. Subjected to high pressure and temperature deep within the Earth, these rocks, the oldest in New Jersey, were formed between 1.3 billion and 750 million years ago. These ancient rocks compose the basement beneath the younger, overlying strata of the Valley and Ridge Province, the sedimentary rocks of the Piedmont Province of Paleozoic time (570 to 345 million years old), and the sediments of the Coastal Plain from Cretaceous to Miocene times (135 to 5.3 million years old), called the Green Pond Outlier.[7, 8]

The bedrock of Greenwood Lake has been subjected to several stages of intense folding and faulting in a northeast-southwest direction, associated with the ancient collision of continental landmasses driven by plate tectonic forces. The Highlands Region has endured extensive periods of gradual uplift and erosion. As a result, ridges of the Greenwood Lake region are typically underlain by younger, Silurian and Devonian, sedimentary rocks such as sandstone, conglomerates and siltstone that are less susceptible to erosion. Stream valleys generally follow along fractured zones and faults, or along outcrop belts of rocks that weather and erode faster. These valleys are typically underlain by limestone, shale, or glacial sediments.[9, 10]

The mineral associations are consistent with the hornblende-granulite metamorphic facies. Depending upon the pre-existing rock type, the resulting granulite facies metamorphic rock would be quartzite (from relatively pure sandstone), or one of various types of gneiss (from shale or other pre-existing rocks of complex composition). Some of the different rocks encountered in the area are related to one another, such as the oligoclase-rich gneisses and granites of the Losee Metamorphic Suite.[11] In addition there are commonly encountered amphibolite, hypersthene-quartz-oligoclase gneiss, or metamorphic diorite bodies with unknown origins or affinities.[12]

From the Middle Proterozoic to the beginning of the Paleozoic Era there was considerable erosion. The deposition of the sands that would become the Cambrian Hardyston and Poughquag Quartzites was rather widespread over these rocks, indicating they were deposited over a surface that was worn somewhat flat. There is a conformable boundary (that is, one that does not indicate any period of erosion) between the Poughquag and the dolomite of the overlying Wappinger Group.[13]

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7 http://www.highlands.state.nj.us/njhighlands/master/rmp/draft/section_2.pdf

8 Herman, G.C. and J.P. Mitchell. 1991. Bedrock Geologic Map of the Green Pond Mountain Region from Dover to Greenwood Lake, New Jersey. 3 Plates. New Jersey Geological Survey. Geological Map Series 91-2.

9 Herman, G.C. and J.P. Mitchell. 1991. Bedrock Geologic Map of the Green Pond Mountain Region from Dover to Greenwood Lake, New Jersey. 3 Plates. New Jersey Geological Survey. Geological Map Series 91-2.

10 Princeton Hydro

11 Drake, A.A. Jr., R.A. Volkert, D.H. Monteverde, G.C. Herman, H.F. Houghton, R.A. Parker, and R.F. Dalton. 1996. Bedrock Geologic Map of Northern New Jersey. USGS Miscellaneous Investigations Series, Map I-2540-A.

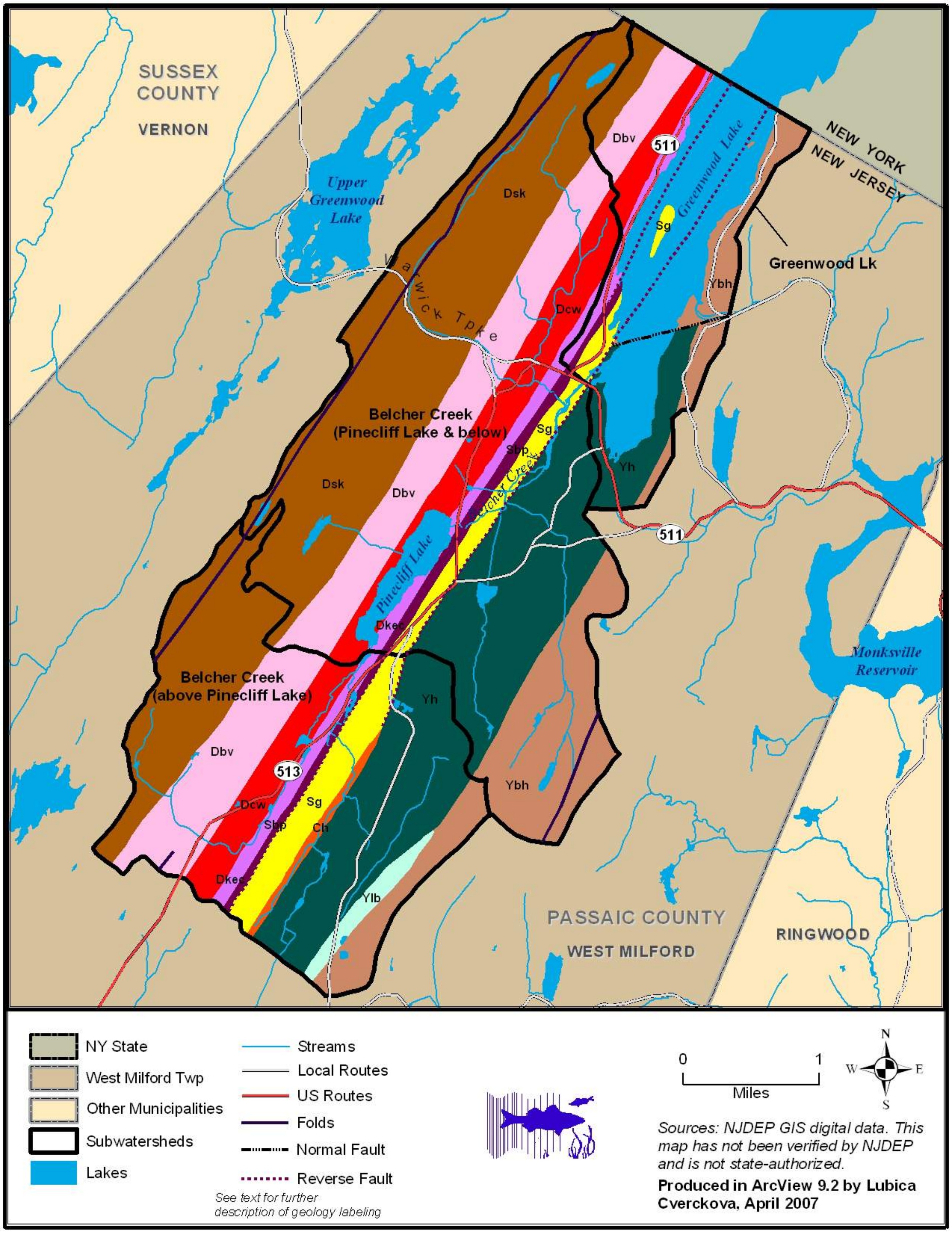
12 http://www.highlands.state.nj.us/njhighlands/master/rmp/draft/section_2.pdf

13 Fisher, D.W., Y.W. Isachsen, and L.V. Rickard 1970. (reprinted 1995). Geologic Map of New York. Lower Hudson Sheet. New York Geological Survey. University of the State of New York. The State Education Department.

Table II.A-1 – Bedrock Geology

Id	Name	Lithology
Dbv	Bellvale Sandstone	sandstone, siltstone, and shale
Dsk	Skunnemunk Conglomerate	conglomerate and sandstone
Dcw	Cornwall Shale	shale and siltstone
Dkec	Kanouse and Esopus Formations and Connelly Conglomerate	[Kanouse Sandstone: sandstone and pebbly conglomerate] [Esopus Formation: siltstone, mudstone, sandstone] [Connelly Conglomerate: quartz-pebble conglomerate]
Sbp	Berkshire Valley and Poxono Island Formations undivided	[Berkshire Valley Formation: limestone, calcareous siltstone, silty dolomite, dolomite conglomerate, and shale] [Poxono Island Formation: dolomite, calcareous sandstone, siltstone, and conglomerate, shale]
Sg	Green Pond Conglomerate	quartz-pebble to cobble conglomerate, quartzite, siltstone
Ybh	Hornblende Granite	granite, medium- to coarse-grained
Yh	Hypersthere-Quartz-Oligoclase Gneiss	gneiss, medium-grained
Ch	Hardyston Quartzite	conglomeratic sandstone, quartzite, and dolomitic sandstone
Ylb	Biotite-Quartz-Oligoclase Gneiss	gneiss, fine- to coarse-grained

Figure II.A-4 – Bedrock Geology



Glacial Sediments

During the Pleistocene Epoch of the Quaternary Period, the sea level fell as much as 300 feet due to the amassing of ice sheets in the Northern Hemisphere. The advance of ice caused the erosion of hills and the deposition of various stratified and unstratified deposits.[14] (See Figure II.A-5 and Table II.A-2.)

The largest glacial deposits with thicknesses up to 200 feet accumulated in the lowest portions of the watershed as continuous till. Although lacustrine fan, deltaic, and lake bottom deposits are found in the watershed, these are very limited in lateral extent, relative to sediments derived from comparable depositional environments in the Newark Basin.[15]

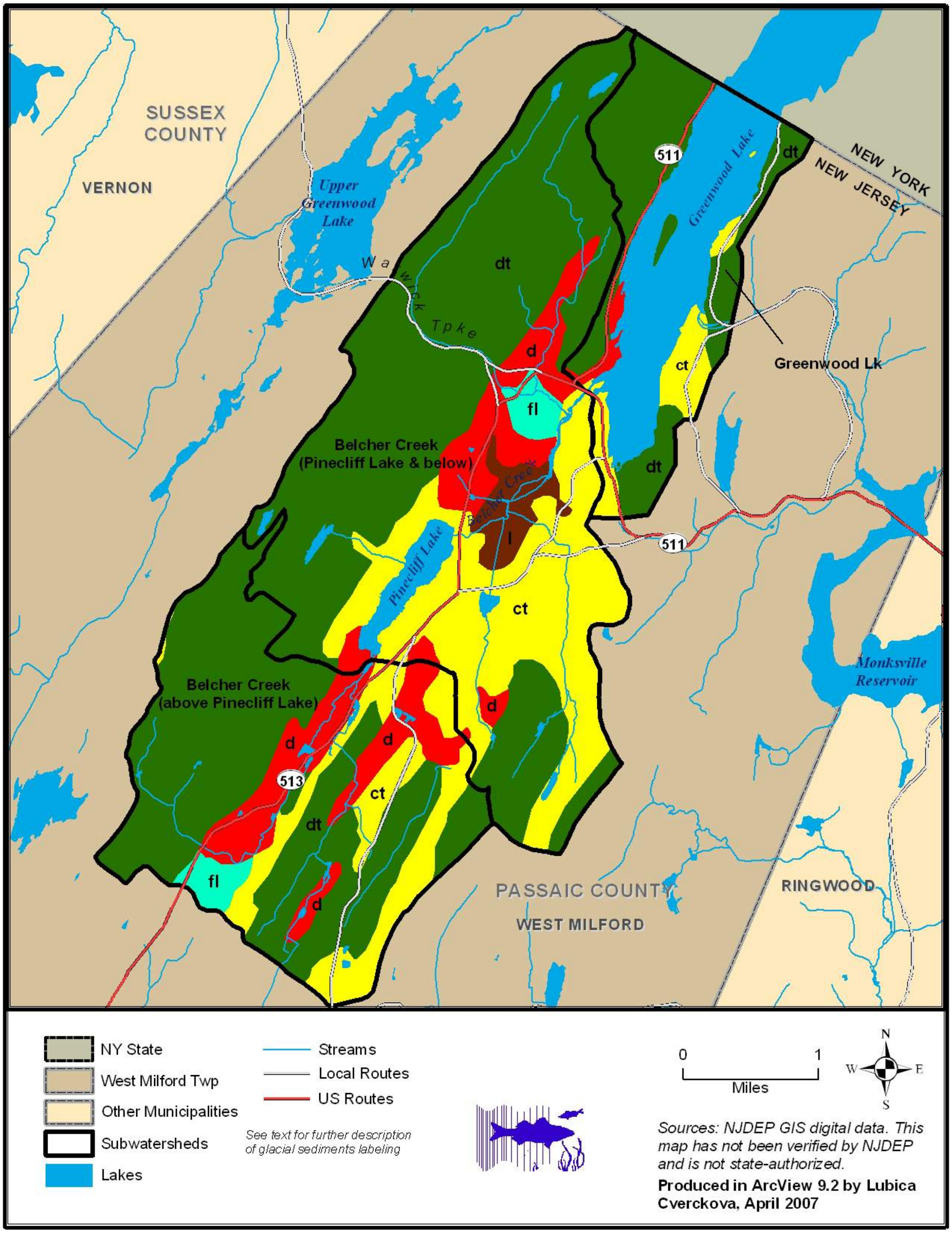
Table II.A-2 – Glacial Sediments

Id	*Name*	*Description*
dt	Thin Till and Rock Outcrop	Discontinuous till, generally less than 20 feet thick, numerous bedrock outcrops.
l	Lake-Bottom Deposits	Silt, clay, and fine sand deposited on the bottoms of glacial lakes, as much as 250 feet thick
ct	Continuous Till	Continuous till generally greater than 20 feet thick. May be as much as 200 feet thick. Grain size of matrix generally reflects underlying bedrock. Silty sand to sandy till forms on gneiss, sandstone, quartzite, and conglomerate; silty till forms of shale, carbonate, basalt and diabase; silty clay till forms locally on shale and on Cretaceous clay
d	Deltaic and Lacustrine-Fan Deposits	Sand and gravel deposited as deltas and fans in glacial lakes. May locally overlie lake-bottom sediment. As much as 200 feet thick.
fl	Fluvial over Lacustrine Deposits	Generally a three-part vertical sequence of fluvial sand and gravel overlying deltaic and lake-bottom fine sand, silt, and minor clay, in turn overlying lacustrine-fan sand and gravel. Entire section may be as much as 250 feet thick.

[14] Princeton Hydro (Princeton Hydro, LLC, has been a consultant for the Greenwood Lake Commission on a number of projects, and provided information to the Commission from which this information was obtained.)

[15] Princeton Hydro (footnote #14)

Figure II.A-5 – Glacial Sediments

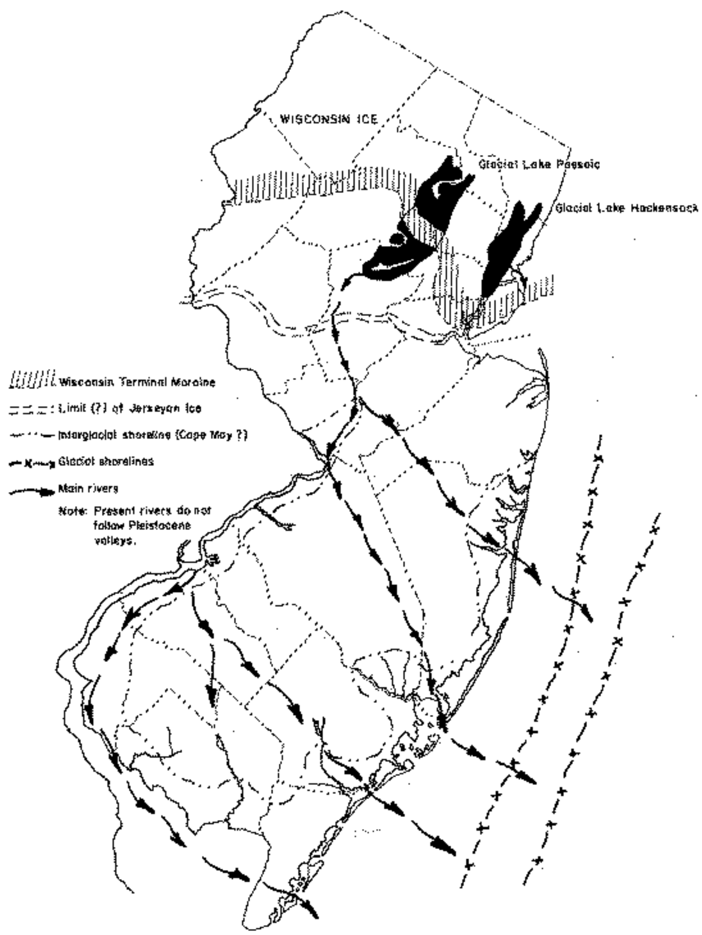


Soils

Over time soils have formed atop these bed rocks and sediments due to "the prolonged action of weathering processes combined with organic activity of plants and animals."[16] All land based plant and animal life is dependent for survival upon soils at the surface of the land. Thus, the soils in the Greenwood Lake Watershed are an important natural resource.

Formation of the Greenwood Lake Watershed soils has been dominated by glaciation. There have been three major glacial events in the past one million years, the pre-Illinoian, Illinoian, and Wisconsian events which occurred approximately 800,000 years ago, 150,000 years ago and 20,000 years ago, respectively. The former edge of the most recent glacier (Wisconsin ice sheet) is marked by a distinctive, ridge-like terminal moraine running approximately east-west along Interstate 80, which effectively marks the line between the glaciated and unglaciated sections.[17] Figure II.A-6 shows the approximate location of the terminal moraine.[18]

Figure II.A-6 - Area of New Jersey Covered by Wisconsin Glaciation about 18,000 Years Ago



ICE AGE (PLEISTOCENE) NEW JERSEY

16 Strahler, Arthur N. 1971. The Earth Sciences, Second Edition. Harper & Row, New York, NY. Page 576.
17 http://www.highlands.state.nj.us/njhighlands/master/rmp/draft/section_2.pdf
18 Widmer, Kemble. 1964. *The Geology and Geography of New Jersey.* The New Jersey Historical Series, vol. 19, D. Van Nostrand Company, Inc., Princeton, NJ. Page 116.

This most recent glaciation had the effect of creating soil features that differ in the northern section of the Highlands from those soils south of the moraine. North of the moraine, soils tend to be younger as the Wisconsin ice sheet obliterated the pre-existing soil associations, and reset the soil forming process. These northern soils are mostly formed in young glacial till and contain more unweathered material, including gravel, cobbles, stones, and boulders.[19]

The principal soils, in terms of area coverage are: (a) Soils that formed upon Wisconsinan age glacial till, including: Rockaway, Swartzwood, Hibernia, Ridgebury, Norwich; (b) Soils that formed upon Wisconsinan age outwash plains and terraces, including: Chenango, Preakness, Adrian Muck; and (c) Soils that formed upon glacial lakebed sediments, including: Parsippany, and Carlisle Muck.[20] The types of soils found in the Greenwood Lake Watershed are shown in Figure II.A-7 and identified in Table II.A-3.

It is extremely important to understand the hydrologic characteristics of the soils in the Greenwood Lake Watershed. The availability of recharge to underlying aquifers is strongly dependent upon the recharge capacity of the soils overlying the aquifer. Some soils are readily amenable to almost continuous recharge, whereas others are more given to retaining water above the water table or to producing surface runoff. For the purpose of watershed management, US Department of Agriculture (USDA) hydrologists and soils scientists have created a system of Hydrologic Soil Groups that rank the soils according to their recharge potential. Greenwood Lake watershed exhibits the following soil groups: A, C, D. There are also three dual group designations: A/D, B/D, and C/D, which indicate soils that in a natural condition would be assigned to Group D, but with some modification, would behave as would a soil belonging to one of the other groups.[21]

Hydrologic Soil Group A soils form on outwash sands and gravels. The most prominent Hydrologic Group A soils belong to the Chenango Series. The principal Hydrologic Soil Group C soils in the watershed are formed on glacial till. The Rockaway Series soils cover the most of the Group C soil. The Swartzwood Series soils, the Hibernia very stony loam, and the Ridgebury Series soils represent nearly all of the remainder of Group C soils in the watershed. Rock outcrop areas are often assigned to Hydrologic Soil Group D. The principal soils of Hydrologic Soil Group D in the watershed are the Norwich Series silt loams, formed on glacial till.[22]

Dual hydrologic groups, A/D, B/D and C/D, are given for criteria with soils that can be adequately drained. The first letter applies to the drained condition and the second to the undrained condition. Only soils that are rated D in their natural condition are assigned to dual groups.

The last hydrologic soil group in the watershed is the Udorthents series, which characterizes ground surfaces, which have been altered by cutting or filling. The slope ranges from steep cuts to nearly level fill. These soils include areas for construction of buildings and roads, residential and recreational areas, and refuse disposal. Where fill was used to level freshwater wetlands, floodplains, or salt marshes, there is an organic substratum. No Hydrologic Soil Group is assigned to these areas.

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[19] http://www.highlands.state.nj.us/njhighlands/master/rmp/draft/section_2.pdf
[20] Princeton Hydro (footnote #14)
[21] Princeton Hydro (footnote #14)
[22] Princeton Hydro (footnote #14)

Hydrologic soil groups found in the Greenwood Lake Watershed are shown in Figure II.A-8 and further described in Table II.A-5. Some of the types of soils are more fully described below.

Table II.A-4 – Soil Types

Color	*Soil Type*	*Soil Name*
	AdrAt	Adrian muck, 0 to 2 percent slopes, frequently flooded
	BrsA	Braceville gravelly silt loam, 0 to 3 percent slopes (SSURGO1)
	CarAt	Carlisle muck, 0 to 2 percent slopes, frequently flooded
	ChrB	Chenango silt loam, 3 to 15 percent slopes
	ChrC	Chenango silt loam, 8 to 15 percent slopes
	FNAT	Fluvaquents and udifluvents, 0 to 3 percent slopes, frequently flooded
	HhmCc	Hibernia loam, 0 to 15 percent slopes, extremely stony
	NowBc	Norwich silt loam, 0 to 8 percent slopes, extremely stony
	PHG	Pits, sand and gravel
	PbphAt	Parsippany silt loam, sandy loam substratum, 0 to 3 percent slopes, frequently flooded
	PrnAt	Preakness silt loam, 0 to 3 percent slopes, frequently flooded
	RkgBc	Ridgebury loam, 0 to 8 percent slopes, extremely stony
	RNRE	Rock outcrop-Rockaway complex, 15 to 45 percent slopes
	RNTE	Rock outcrop-Swartswood complex, 15 to 45 percent slopes
	RobCc	Rockaway sandy loam, 8 to 15 percent slopes, extremely stony
	RobDc	Rockaway sandy loam, 15 to 25 percent slopes, extremely stony
	RomC	Rockaway-Rock outcrop complex, 8 to 15 percent slopes
	SweBb	Swartswood fine sandy loam, 0 to 8 percent slopes, very stony
	SweBc	Swartswood fine sandy loam, 0 to 8 percent slopes, extremely stony
	SweCb	Swartswood fine sandy loam, 8 to 15 percent slopes, very stony
	SweCc	Swartswood fine sandy loam, 8 to 15 percent slopes, extremely stony
	SweDc	Swartswood fine sandy loam, 15 to 25 percent slopes, extremely stony
	SwhC	Swartswood-Rock outcrop complex, 3 to 15 percent slopes
	UdrB	Udorthents, refuse substratum, 0 to 8 percent slopes
	USROCC	Urban land-Rockaway complex, 3 to 15 percent slopes
	WhphA	Whippany silt loam, sandy loam substratum, 0 to 3 percent slopes
	WuoBc	Wurtsboro silt loam, 0 to 8 percent slopes, extremely stony
	WuoCc	Wurtsboro silt loam, 8 to 15 percent slopes, extremely stony

Soil Descriptions:

Adrian Muck (AdrAt) - Very deep, nearly level, very poorly drained soil formed in herbaceous organic material and in the underlying sandy deposits on outwash plains, lake plains and terraces, flood plains, moraines, and till plains. Permeability is moderately slow to moderately rapid in the organic material and rapid in the sandy material. The soil is hydric and in its natural condition, would be assigned to Hydrologic Soil Group D. When drained, it can be assigned to Group A.

Carlisle Muck (CarAt) - Deep, very poorly drained to poorly drained peat and silt loam in former glacial lake bottom sediments. This soil belongs to Hydrologic Soil Group D in the natural undrained state and is hydric. If drained, it may be assigned to Hydrologic Soil Group A.

Figure II.A-7 – Soil Types

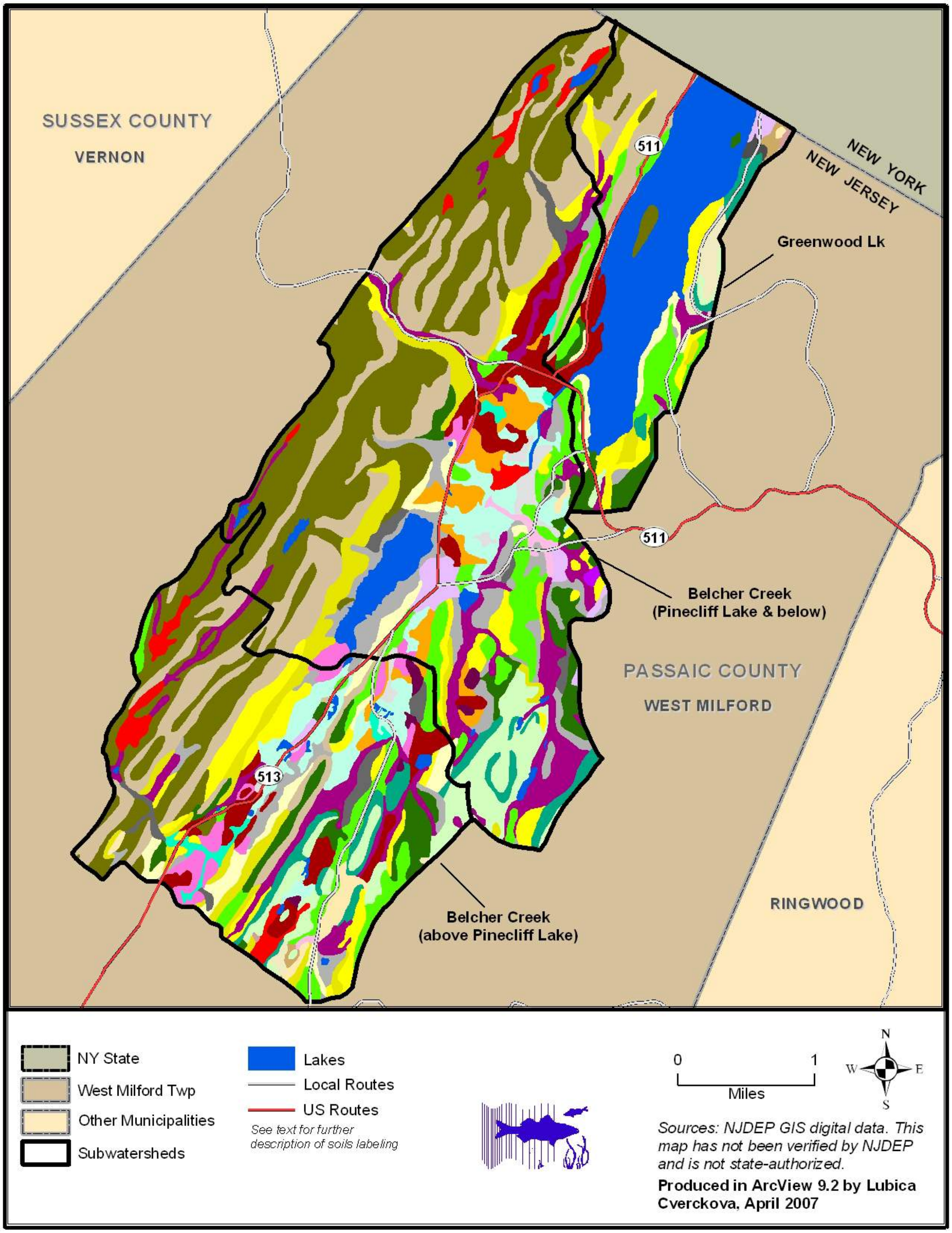


Table II.A-5 – Hydrologic Soil Groups

Color	*Soil Group*	*Description*
	A	Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well-drained to excessively drained sands or gravels. These soils have a high rate of water transmission, and low runoff potential.
	C	Soils having slow infiltration rates when thoroughly wetted, consisting chiefly of soils with a layer that impedes the downward movement of water, or soils with moderately fine or fine textures and slow infiltration rate. These soils have a slow rate of water transmission.
	D	Soils having very slow infiltration rates when thoroughly wetted, consisting chiefly of (1) clayey soils with high swelling capacity or potential, (2) soils with a high permanent water table, (3) soils with a clay pan or clay layer at or near the surface, and (4) shallow soils over nearly impervious materials. These soils have a very slow rate of water transmission, and high runoff potential.
	A/D	The Carlisle muck is the main representative of Group A/D soils. Most of the remaining area shown as Hydrologic Soil Group A/D is Adrian muck.
	B/D	Most of the area indicating Hydrologic Soil Group B/D belongs to the Preakness sandy loam, which forms on outwash.
	C/D	The area indicating Hydrologic Soil Group C/D is represented by the Parsippany silt loam.
		Udorthents

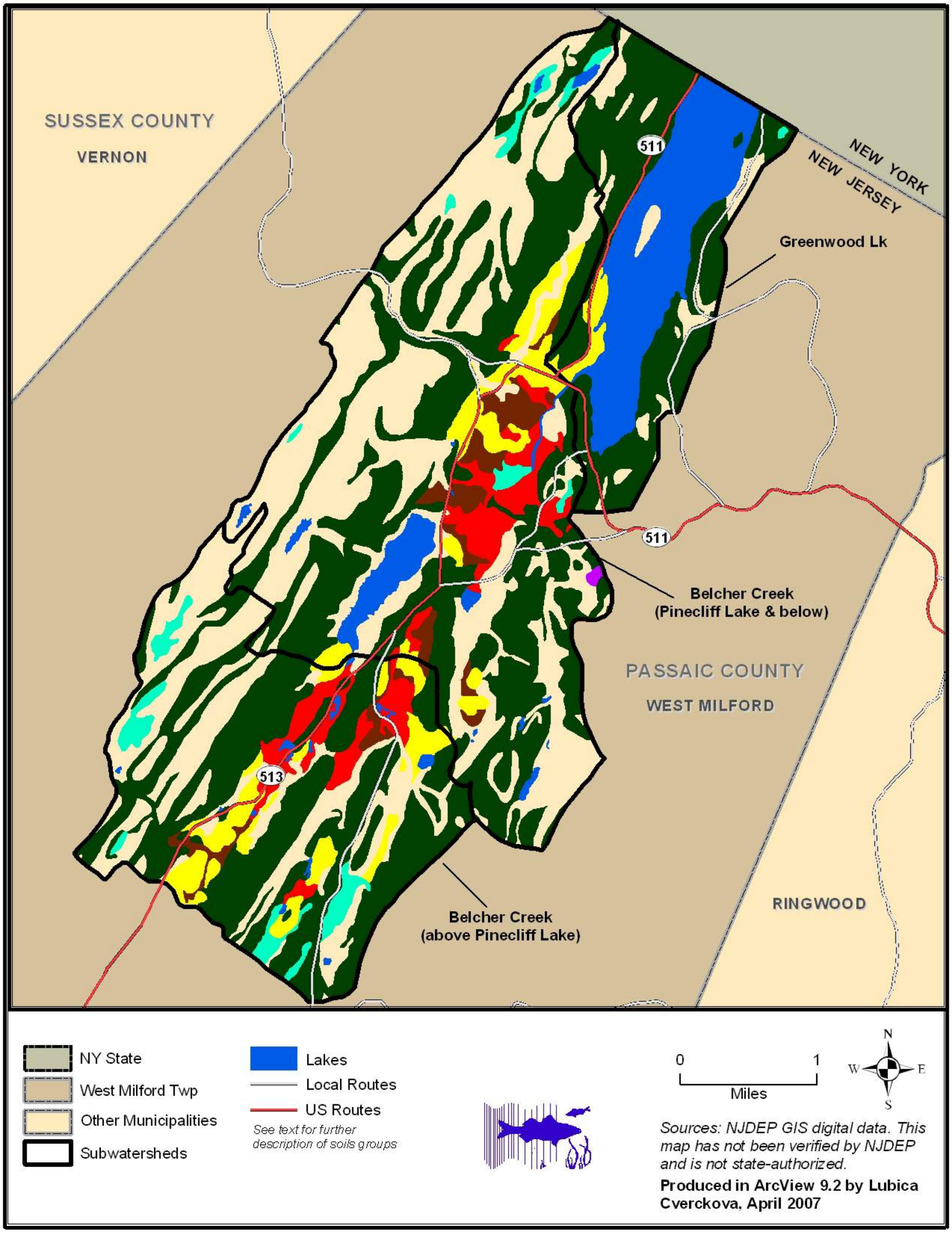
Chenango Series Soils (ChrC) **-** Very deep, nearly level to very steep, well and somewhat excessively drained soils formed in water-sorted gravelly and loamy drift on outwash plains, kames, eskers, terraces, and alluvial fans. The parent material is derived from gray sandstone, shale, and siltstone and lesser amounts of material from limestone and igneous rocks. The potential for surface runoff ranges from low to high. Permeability is moderate to moderately rapid in the solum and rapid in the substratum. These soils are assigned to Hydrologic Soil Group A.

Hibernia Very Stony Loam (HhmCc) - Deep, gently sloping to steep, somewhat poorly drained gravelly loam with a fragipan and surface stones formed in glacial till in the Highlands and colluvium derived from such deposits. These soils are found in depressions, in watercourses, and at the base of steep slopes. They are assigned to Hydrologic Soil Group C.

Norwich Series Silt Loam (NowBc) - Deep, nearly level to sloping, poorly and very poorly drained soils formed in glacial till. They are also in depressions and in wetlands in areas covered by glacial till rich in reddish sandstone, siltstone, and shale. Runoff is slow to temporarily ponded. Internal drainage is slow. Permeability is slow to very slow. These soils are assigned to Hydrologic Soil Group D.

Parsippany Silt Loam (PbphAt) - Deep, nearly level, poorly drained silt loam with moderately fine textured subsoil formed in stratified sediment of glaciolacustrine origin. These soils are found on the nearly level bottom of the basin formerly occupied by former Glacial Lake Passaic. These soils belong to Hydrologic Soil Group D in the natural, undrained state. If drained they can be assigned to Hydrologic Soil Group C.

Figure II.A-8 – Hydrologic Soil Groups



Preakness Sandy Loam (PrnAt) - Deep, nearly level, poorly drained sandy loam that formed in glacial outwash material composed primarily of granitic material. It is found in low areas that frequently receive runoff from adjacent areas. The water table is seasonally at the ground surface. The permeability is moderate in the surface and increases with depth to rapid in the substratum. In its natural state it is assigned to Hydrologic Soil Group D. When drained, it can be reassigned to Hydrologic Soil Group B.

Rockaway Series Soils (Ro) - Gravelly sandy loam and very stony and extremely stony sandy loam. Deep, gently sloping to very steep, well drained and moderately well drained sandy loam with a moderately developed fragipan and subsurface mottles formed in sandy loam glacial till. These soils are found on uplands and make up the majority of the Hydrologic Soil Group C.

Rock Outcrop (RN) - Areas of exposed crystalline bedrock. They are assigned to Hydrologic Soil Group D.

Swartswood Series Soils (Swe) **-** Deep and very deep, nearly level to very steep, well drained and moderately well drained soils formed in till derived primarily from gray and brown quartzite, conglomerate, and sandstone. Stones and boulders are common surface features in wooded areas of these soils. Permeability is moderately rapid to moderately slow above the fragipan and moderately slow or slow in the fragipan. Surface runoff is slow to rapid. These soils are assigned to Hydrologic Soil Group C. They are associated with the Wurtsboro soils.

Urban Land (US) **-** Gently sloping to nearly level areas where more than 80 percent of the land surface has been covered by impervious surfaces such as concrete, asphalt, and buildings. Urban Land is generally not assigned to any Hydrologic Soil Group except in Bergen County where it is assigned to Group D. The mapped units for the various soils may include some Urban Land in a "soil **–** Urban Land Complex," typically containing 25 to 40 percent Urban Land.

Soil Properties:

Soils contain different properties which affect their use for various purposes. The Natural Resources Conservation Service in the US Department of Agriculture provides information on the internet.[23] Of particular concern in the Greenwood Lake Watershed are the following factors: slope, soil erosion potential, and soil drainage.

Slope: One of the concerns for the Greenwood Lake Watershed is development on steeply sloping land. The topography of the watershed is shown on Figure II.A-2. Figure II.A-3 shows the slopes. The slope percentage refers to the number of feet that a slope increases or decreases within l00 feet of horizontal distance. Thus, the surface of a 10% slope would be 10 feet higher or lower for each 100 feet of slope length. The Natural Resources Conservation Service of the US Department of Agriculture states that a slope over 15% would present severe problems for most development uses because of the erosion potential. Inappropriate development on slopes of less than 15% should also be a concern because of the potential for erosion and the wash-off of sediment. Ian McHarg, a pioneer in the concept of environmental planning, has stated that all slopes of greater than 25% should be covered with forest, and development prohibited.

Soil Erosion Potential: The degree and length of slope partially indicate the likelihood of soil erosion. Other properties that affect erosion are soil texture, structure, permeability, and amount

[23] Natural Resources Conservation Service, United States Department of Agriculture. 2009. Soil Data Mart, NJ031 – Passaic County, New Jersey. Website: <http://soildatamart.nrcs.usda.gov/>

of stones and pebbles. Natural vegetation inhibits water and wind erosion, but when trees, bushes, leaves, and grass are removed, erosion occurs. The eroded soil, usually carried by water, clogs storm drains and silts ponds and streams. Erosion damage causes multiple losses: fertile top soil that took hundreds of years to develop is lost, silted pipes and waterways must be cleaned at public expense, and aquatic habitat and life are severely impaired. Soil properties that influence rainfall erosion are (1) those that affect infiltration rate, movement of water through the soil, and water storage capacity, and (2) those that affect dispersion, detachability, abrasion, and mobility of soil particles by rainfall and runoff. The Universal Soil Loss Equation (USLE) has been developed to predict the long term average soil loss from rainfall.[24] This equation follows:[25]

$$\mathbf{A = R * Kw * L * S * C * P}$$

A = estimated average soil loss in tons per acre per year
R = rainfall-runoff erosivity factor
Kw = soil erodibility factor
L = slope length factor
S = slope steepness factor
C = cover-management factor
P = support practice factor

The Natural Resources Conservation Service in the US Department of Agriculture lists an assigned Kw erodibility factor for each soil type to be used in the Universal Soil Loss Equation (USLE).

Soil Drainage: Where soil drainage is poor because the soil has a low permeability and water can't soak in readily or because the soil is already saturated with water, then rain runs off rapidly and causes flooding. This water is not stored in the ground to be used later as ground water or base flow in a nearby stream. Extreme caution is needed in development on poorly drained soils. Some of these soils occur in wetlands where development is prohibited under provisions of the Freshwater Wetlands Protection Act. Most of the precipitation on well drained soils, such as the Rockaway series, if they are also well vegetated, will either evaporate or soak into the ground, so that runoff is minimal. Development on these soils decreases permeability and increases runoff. Good storm water management is essential for protecting both the land and water resources of the Greenwood Lake Watershed.

[24] Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. 2004. Soil Properties and Qualities, NSSH Part 618 (42-55), Soil Erodibility Factors, USLE, RUSLE (618.55). Website: <http://soils.usda.gov/technical/handbook/contents>

[25] Institute of Water Research, Michigan State University. 2002. RUSLE, On Line Soil Erosion Assessment Tool, RUSLE Factors. Website: <http://www.iwr.msu.edu/rusle/>

B. AIR RESOURCES

Climate

The climate of the Greenwood Lake watershed is classified as continental climate due to the prevalence of westerly winds from the continental interior. The region experiences moderately cold winters and hot wet summers. Snow can be expected between November and April. The first frost usually falls in late September or early October and the last frost in early May.[26]

Two temperature monitoring stations are located close to the Greenwood Lake Watershed at the Charlotteburg Reservoir and at the Wanaque Raymond Dam. Temperature data from these stations are reported in Table II.B-1. Average winter temperatures are in the high twenties and low thirties on the Fahrenheit scale. Average summer temperatures are in the low seventies. Midsummer weather is characterized by high humidity and frequent thunderstorms. Prevailing wind directions are from the northwest from October to April and from the southwest during the rest of the year.

Average annual rainfall for the watershed for the 1971-2000 period is 53.31 inches. Data on the average monthly precipitation are presented in Table II.B-2 and Figure II.B-1.[27]

Table II.B-1 -- Normal Temperature Data (°F)

STATION NAME	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Charlotteburg Reservoir													
Minimum	15.0	16.5	25.3	35.0	44.8	53.6	58.6	56.6	48.7	37.4	30.2	20.9	**36.9**
Maximum	36.3	39.1	48.4	59.6	70.8	78.9	84.1	82.5	75.1	64.3	52.5	41.1	**61.1**
Average	25.7	27.8	36.9	47.3	57.8	66.3	71.4	69.6	61.9	50.9	41.4	31.0	**49.0**
Wanaque Raymond Dam													
Minimum	18.4	19.5	28.7	38.5	48.5	57.8	63.1	61.4	53.7	41.1	33.4	24.8	**40.7**
Maximum	35.6	38.6	47.5	59.1	70.1	78.7	84.1	81.6	73.7	62.6	51.6	40.8	**60.3**
Average	27.0	29.1	38.1	48.8	59.3	68.3	73.6	71.5	63.7	51.9	42.5	32.8	**50.6**

Data Source: Princeton Hydro

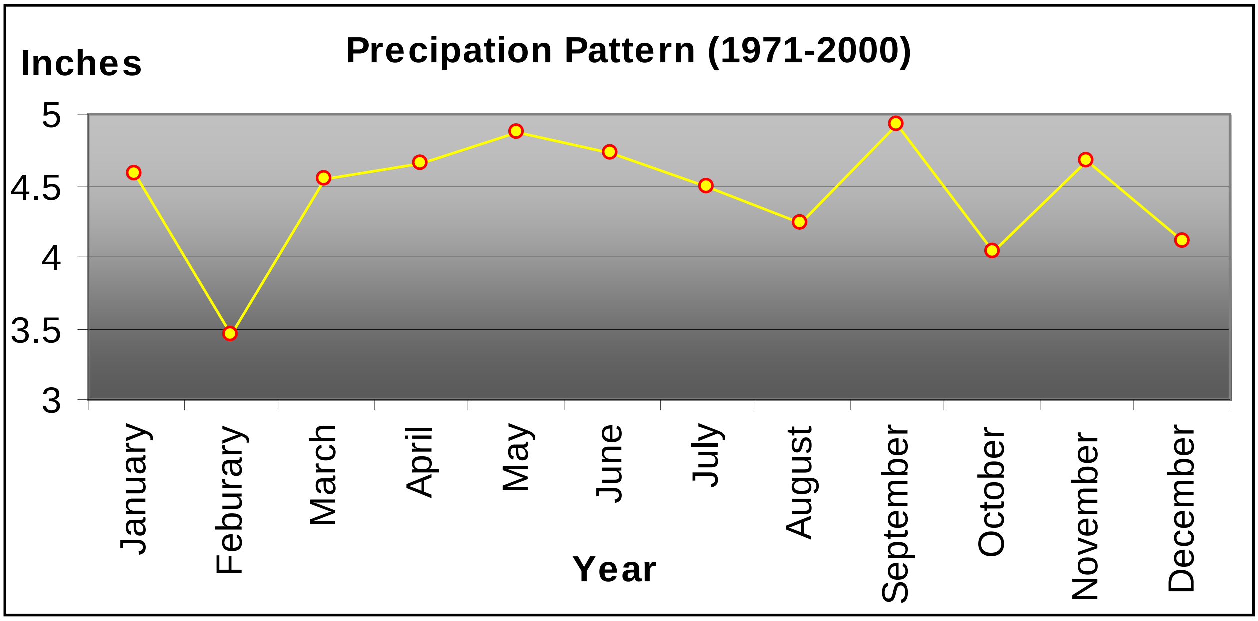
Table II.B-2 -- Normal Precipitation Data (inches)

STATION NAME	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Greenwood Lake	4.58	3.46	4.54	4.66	4.88	4.72	4.50	4.23	4.92	4.03	4.68	4.11	**53.31**

Data Source: New Jersey State Climatologist at Rutgers University, Data from 1971-2000

[26] Princeton Hydro (footnote #14)
[27] New Jersey State Climatologist at Rutgers University

Figure II.B-1 – Precipitation Pattern in Northern New Jersey



Data Source: New Jersey State Climatologist at Rutgers University, Data from 1971-2000

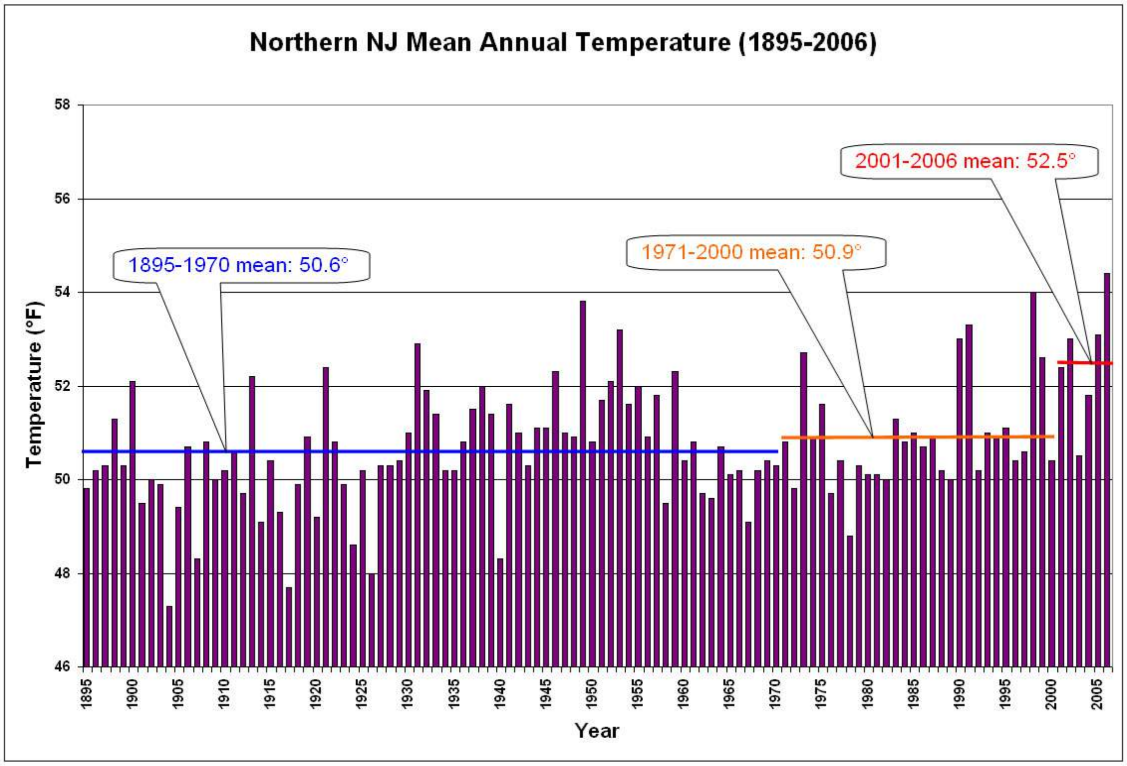
The Office of the New Jersey State Climatologist utilized data from 1971 through 2000 to represent "normal" mean values for monthly and annual temperature and precipitation. Long-term climatic data is available for individual stations and also for the three climatic regions or "Divisions" of the state. The Passaic River Basin in New Jersey is included in Division 1, which includes Bergen, Essex, Hudson, Hunterdon, Morris, Passaic, Somerset, Sussex, Union and Warren counties and covers 37% of New Jersey.

Temperature data for Division 1 is presented in the chart in Figure II.B-2. It shows annual mean temperatures during the 1895 to 2007 period. From the graph we can identify how the mean temperature for the area has been rising. The mean temperature during the period 1895 to 1970 was about 50.6ºF. It increased slightly by 0.3ºF during the next 30 years. Then during the 2001 to 2006 time span it increased to 52.5 ºF. [28]

Interestingly, the mean precipitation values for Division 1 for the period 1895 to 2007, as presented in Figure II.B-3, kept increasing as well. Through 1895 to 1970 the precipitation was about 44.57 inches. During this period there was the precipitation deficit in the 1960's drought that exceeded 15 inches per year in 1963 and 1964 and 19 inches in 1965. The average annual precipitation deficit from 1959 through 1970 was 8.6 inches. The mean rainfall roughly increased for the next 30 years by more than 5 inches. Throughout 2001 to 2006 it again increased to an average of 51.10 inches per year.[29]

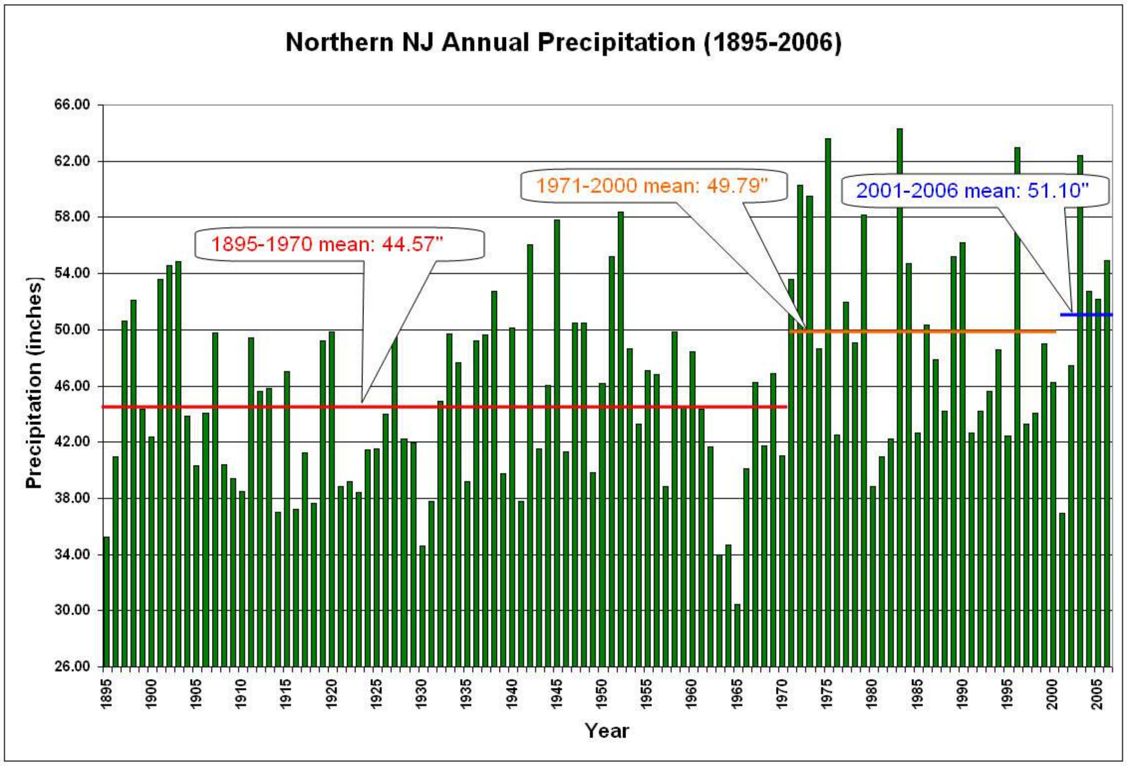
[28] New Jersey State Climatologist at Rutgers University, Data from 1971-2000, and 1895-2006
[29] New Jersey State Climatologist at Rutgers University, Data from 1895-2006

Figure II.B-2 – Mean Annual Temperatures in Northern New Jersey



Data Source: New Jersey State Climatologist at Rutgers University, Data from 1895-2006

Figure II.B-3 – Mean Annual Precipitation in Northern New Jersey



Data Source: New Jersey State Climatologist at Rutgers University, Data from 1895-2006

The 1960's drought remains the drought of record for the Passaic River Basin. However the droughts experienced in recent years, including the recent drought of 2001-2002, have served as reminders of the importance of protecting water resources for sustaining the ecological system and for water supply. Annual rainfall deficits in the last five years have affected not only surface water, as evidenced by low levels in reservoirs and low base flows in streams for several consecutive months, but also recharge of groundwater, as evidenced by numerous reports of wells going dry or static levels dropping, particularly in the Highlands area of the Passaic River Basin.

Air Quality

The Federal Clean Air Act (CAA) of 1970 and the Federal Clean Air Act Amendments (CAAA) of 1990, provide the legal jurisdiction for the States to address air quality. Under the CAA, the United States Environmental Protection Agency (USEPA) is required to set National Ambient Air Quality Standards (NAAQS) for pollutants that are harmful to public health and the environment. The USEPA has set NAAQS for six criteria pollutants, which include ozone (O_3), particulate matter (PM), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxides (NO_x) and lead (Pb).[30] Of the six criteria pollutants, ozone, PM and SO_2 are pollutants of current concern in New Jersey. New Jersey currently attains the NAAQS for CO, nitrogen oxides (NO_x), and lead.

Currently, the entire State, including the seven counties that are part of the Highlands Region, is classified as non-attainment for the 8-hour ozone NAAQS. Four counties in the Highlands Region are designated non-attainment for the $PM_{2.5}$ standard based on their impacts on other counties with non-attainment monitors.[31]

Sources of air pollution in New Jersey are from point, area, and mobile sources. Point sources are stationary sources which include, but are not limited to, industrial sources and power plants. Area sources include consumer products and smaller stationary sources, such as dry cleaners. Mobile sources consist of onroad sources and nonroad sources. Onroad sources include cars and trucks. The Draft Regional Master Plan Transportation System Technical Report discusses the vehicular emissions analysis from the Highlands sub-regional transportation model. Nonroad sources include, but are not limited to, lawn mowers, construction equipment, trains and agriculture equipment.[32]

Nitrogen Oxide (NO_x): In all counties of the Highlands region, the onroad sources contributed the greatest amount of NO_x emissions in the region, as shown in Figure II.B-4.

Volatile Organic Compounds (VOCs): In Hunterdon, Morris, Passaic, Sussex, and Warren counties, area sources contributed the greatest amount of VOC emissions in the region. In Bergen and Somerset counties, onroad sources contributed the greatest amount of VOCs in the region. See Figure II.B-5.

[30] http://www.epa.gov/ttn/naaqs/
[31] http://www.highlands.state.nj.us/njhighlands/master/rmp/draft/section_2.pdf
[32] http://www.epa.gov/oar/oaqps/emissns.html#about

Figure II.B-4 -- NO_x Emissions in the Highlands Region by Source and County

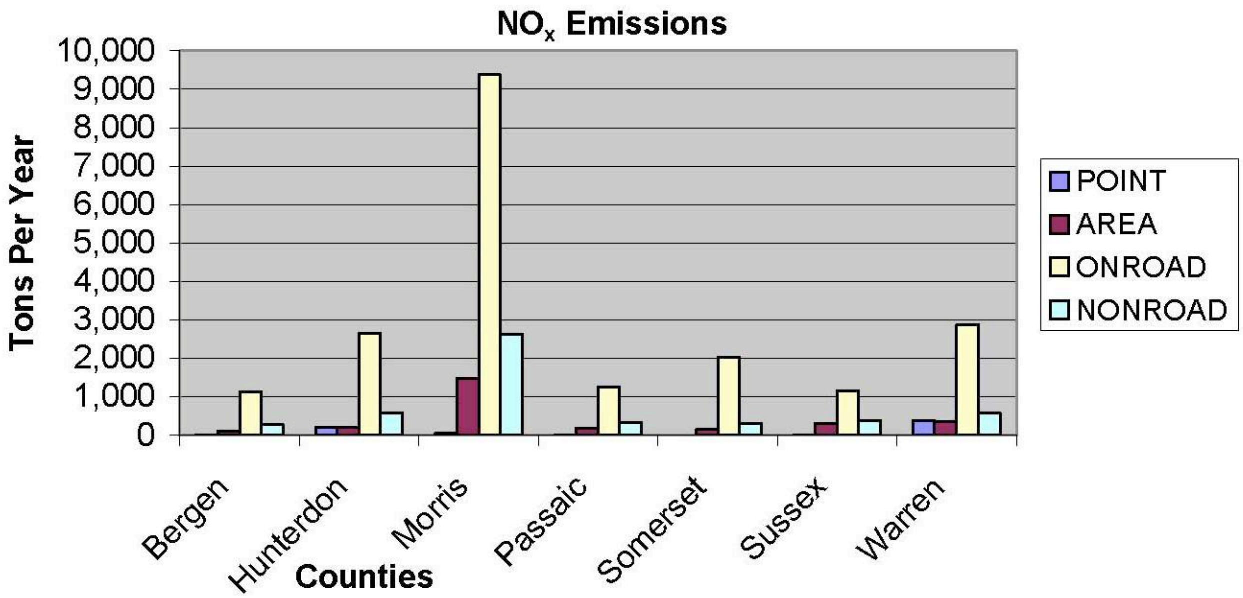
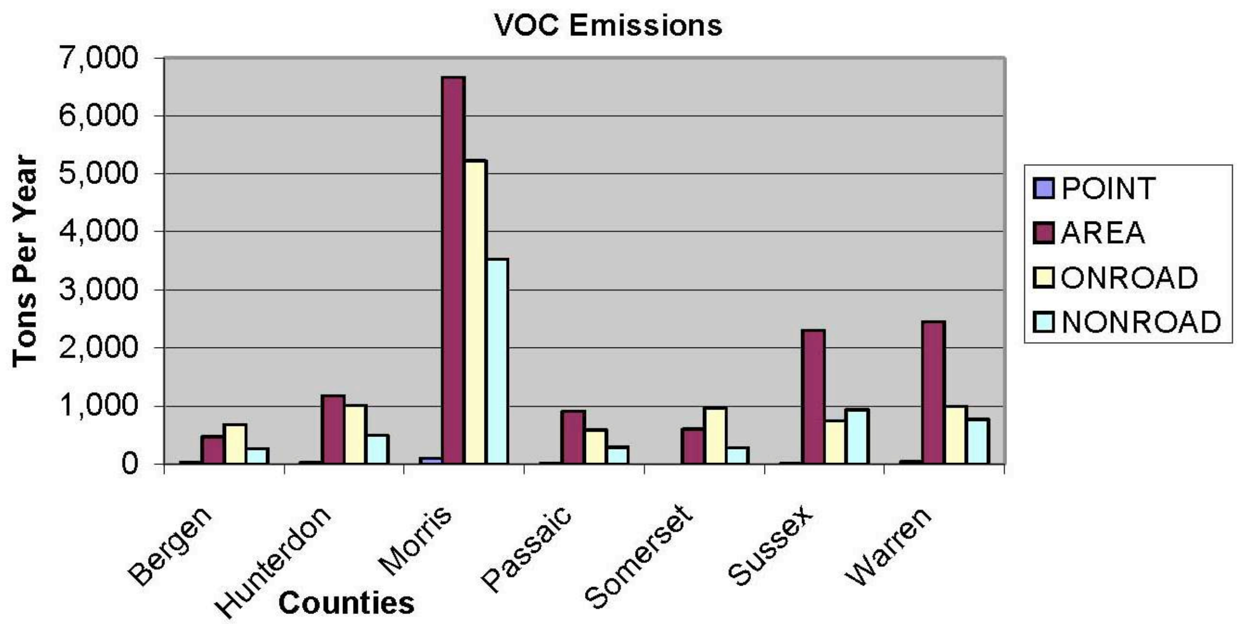


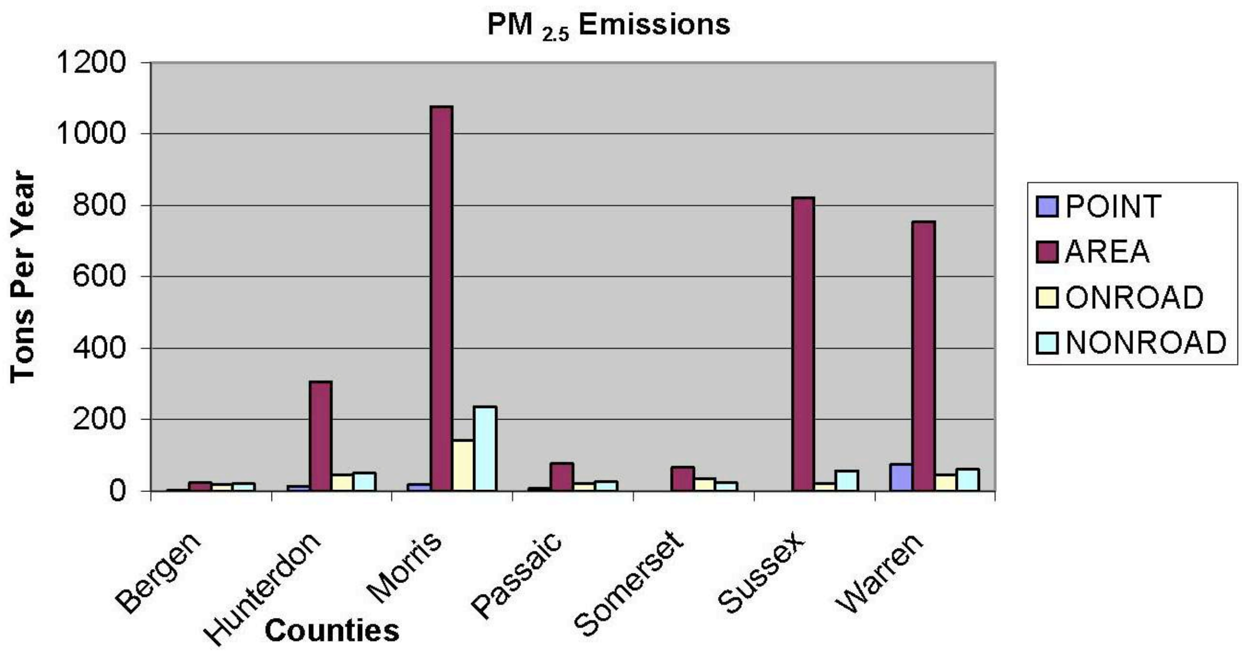
Figure II.B-5 -- VOC Emissions in the Highlands Region by Source and County



Particulate Matter: The USEPA has designated two non-attainment areas for $PM_{2.5}$ in New Jersey, the New York-New Jersey-Long Island-Connecticut Non-attainment Area and the Pennsylvania-New Jersey-Delaware Non-attainment Area. Four counties within the Highlands Region, Bergen, Passaic, Morris, and Somerset are designated non-attainment for $PM_{2.5}$ because of their predicted significant impacts on non-attainment monitoring in the New York-New Jersey-Long Island-Connecticut Non-attainment Area. The remaining counties in the Highlands

Region, Sussex, Warren, and Hunterdon are in attainment for $PM_{2.5.}$ The non-attainment area was designated for the $PM_{2.5}$ NAAQS annual standard of 15.0 micrograms per cubic meter.[33] In all counties of the Highlands Region, the area sources contributed the greatest amount of $PM_{2.5}$ emissions in the region (Figure II.B-5).

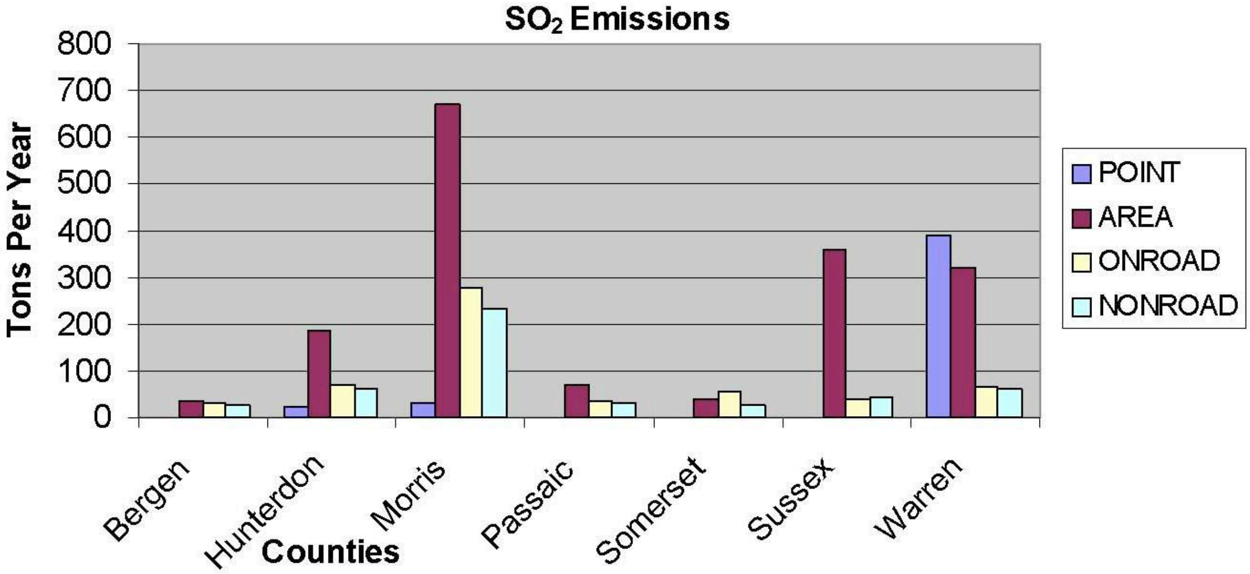
FigureII.B-6 -- $PM_{2.5}$ Emissions in the Highlands Region by Source and County



Sulfur Dioxide: SO_2 gases are formed when fuel containing sulfur (mainly coal and oil) is burned. Metal smelting and other industrial processes can also emit SO_2. The highest monitored concentrations of SO_2 have been recorded in the vicinity of large industrial facilities. Fuel combustion, largely from electricity generation, accounts for most of the total SO_2 emissions.[34] SO_2 emissions from upwind power plants can be transformed into particulate matter and accounts for about half of the fine particulates in New Jersey's air. The USEPA has designated a portion of Warren County as non-attainment for $SO_{2.}$ The remaining municipalities in Warren County and the remainder of the municipalities throughout the Highlands Region are in attainment for SO_2. See Figure II.B-6 for SO_2 in the Highlands Region. The SO_2 NAAQS includes an annual standard and a 24-hour standard. The annual standard is averaged over a three-year period and cannot exceed 0.03 parts per million (ppm) (80 micrograms per cubic meter). The 24-hour standard of 0.14 ppm (365 micrograms per cubic meter) is not to be exceeded more than once per year.

33 http://www.epa.gov/air/airtrends/sulfur2.htm
34 http://www.epa.gov/oar/visibility/what.html

Figure II.B-7 -- SO_2 Emissions in the Highlands Region by Source and County



Point Sources: The five largest point sources in the Highlands Region are Gilbert Generating Station; Hunterdon Cogeneration, Limited Partnership; Warren County District Landfill; DSM Nutritional Products, Inc.; and Covanta Warren Energy Resource Company, LP. Gilbert Generating Station and Hunterdon Cogeneration are located in Hunterdon County, and the remaining facilities are located in Warren County. Table 1 includes the NO_x, VOC, $PM_{2.5}$ and SO_2 emissions from 2004 for the five facilities reported in tons per year (tpy).[35] This information was obtained from New Jersey's Emissions Statement Program.[36]

Table II.B-3 – Emissions from Major Points Sources in Highlands Region

Facility Name	NO_x (tpy)	$PM_{2.5}$ (tpy)	SO2 (tpy)	VOC (tpy)
Gilbert Generating Station	88.5	4.37	10.4	1.45
Warren County District Landfill	8.36	3.99	369.4	1.34
DSM Nutritional Products	78.0	46.4	6.61	20.9
Hunterdon Cogeneration	35.0	1.57	6.32	.340
Covanta Warren Energy Resources	242	3.76	3.31	.370

Source: NJDEP Emissions Statement Program, August 2006

Air Quality Trends in the Highlands Region

The New Jersey Department of Environmental Protection (NJDEP) currently operates five permanent air-monitoring sites in the Highlands Region. The parameters monitored at each site are shown in Table II.B-4.

35 http://www.nj.gov/dep/opra/online.html
36 http://www.state.nj.us/dep/aqm/es/emission.htm

Table II.B-4 – Air Monitoring Sites in the Highlands Region

Location	*Pollutants Monitored*
Chester	Ozone, NOx, PM2.5 (including composition analysis), Toxics
Phillipsburg	PM2.5
Morristown (11 Washington Street)	CO, Smoke Shade (Particulates)
Morristown (Ambulance Squad, 16 Early Street)	PM2.5
Ramapo	Ozone

Source: NJDEP Air Monitoring Program, August 2006

In general, the air monitoring conducted in the Highlands Region shows lower levels of pollution than are recorded in more urbanized parts of the state. However, there are still air quality issues in this area. Some of these, such as ozone and fine particle pollution, are primarily the result of pollution that is transported into the area on prevailing winds, and much of it originates out of state. Other problems are related to specific sources, some in New Jersey and some in other states as well. Like all of the ozone monitoring sites in New Jersey, the sites in Chester and Ramapo regularly record exceedances of the health standard for ozone during the summer months. The number of days in excess of the ozone standard recorded at these sites is shown in Figure II.B-8. Note that the Ramapo site was not established until 1998. More detailed information on historical ozone levels at all the New Jersey monitoring sties can be found on the NJDEP web site at www.state.nj.us/dep/airmon.

Another pollutant of concern in most of New Jersey is $PM_{2.5}$. The state monitors for $PM_{2.5}$ at two sites in the Highlands Region, Phillipsburg and Morristown. While levels of $PM_{2.5}$ at these sites are not as high as at some other sites in more urbanized areas, they do record levels considered to be "unhealthy for sensitive groups" (USG) several times a year.

Air toxics are also measured in the Highlands Region. The state operated site in Chester and one of the special study sites in Belvidere in Warren County measured a number of common VOCs. Levels of some of the more common compounds, those primarily associated with gasoline, are shown in the graph in Figure II.B-9. Again, the lower concentrations of air toxics reflect the less urbanized nature of the areas around the monitoring sites. High levels of air toxics that might occur as the result of emissions from specific industrial sources would be controlled through the NJDEP's air pollution permitting program. This program requires an assessment of air toxics emissions from potentially significant sources.

Figure II.B-8 – Exceedances of Ozone Standard in the New Jersey Highlands (1986-2006)

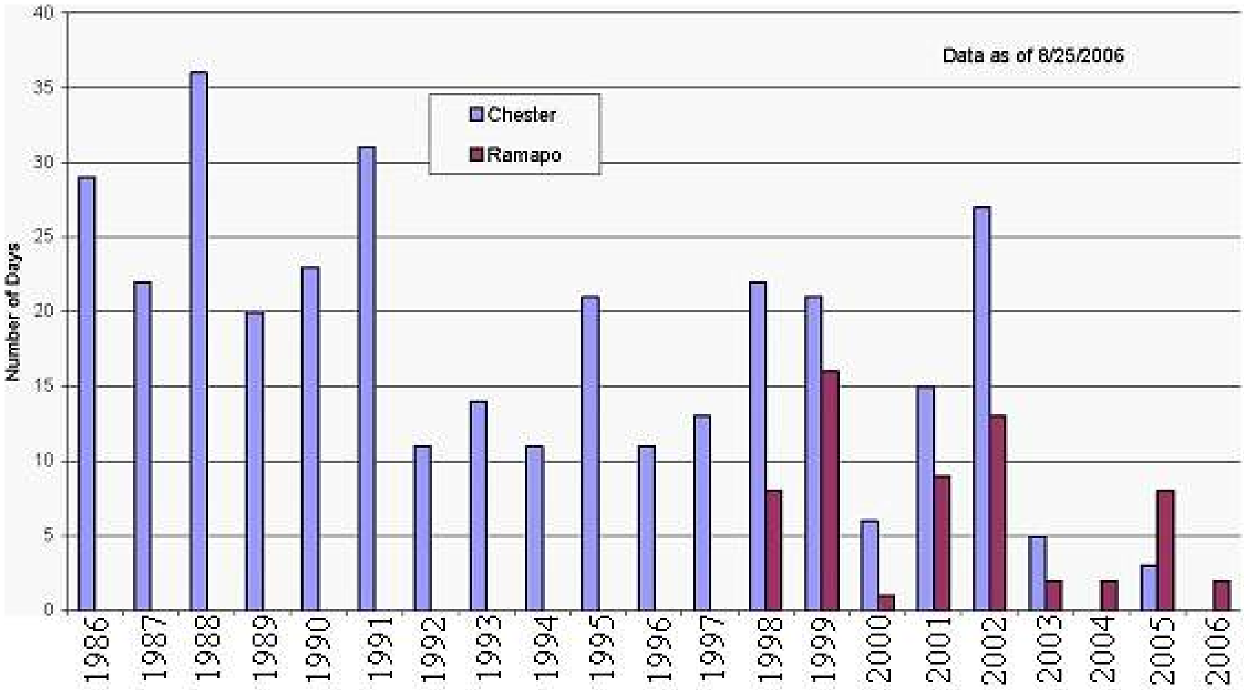
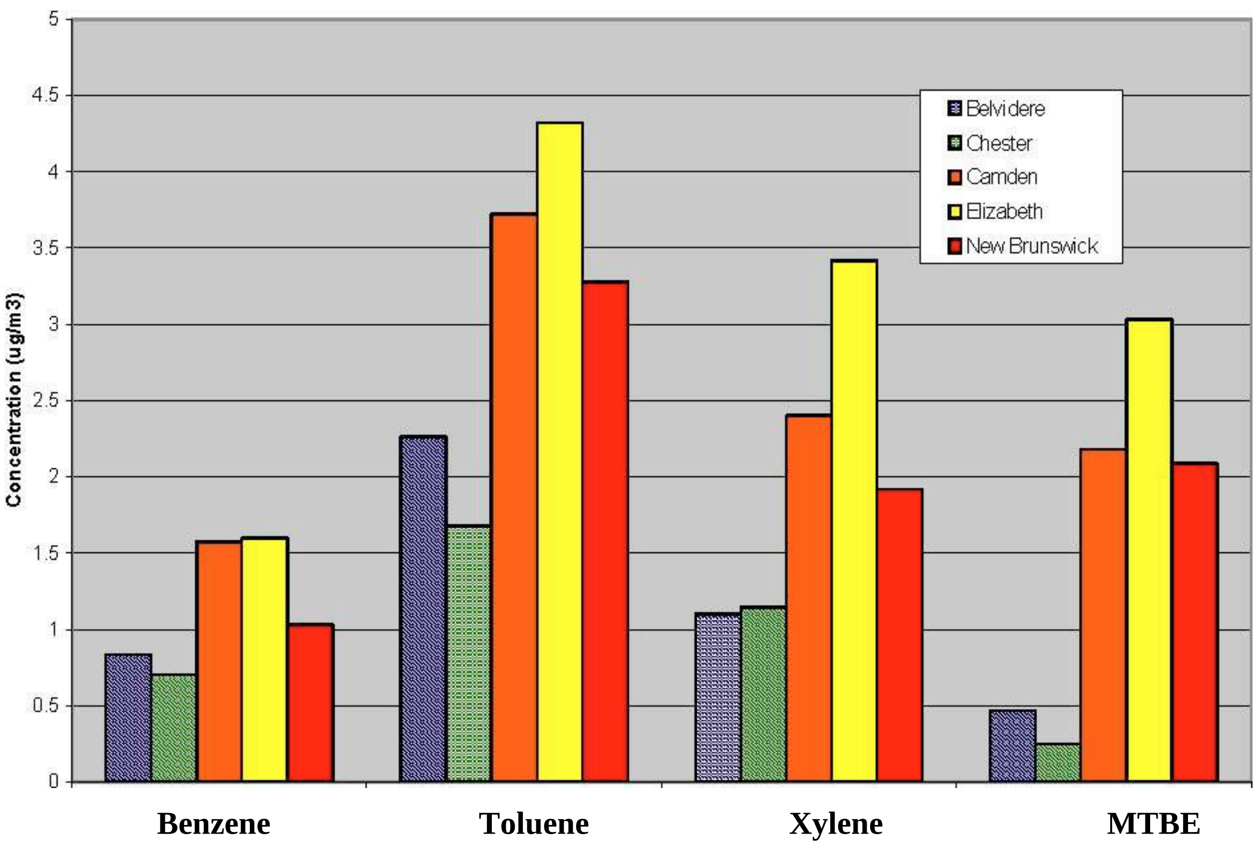


Figure II.B-9 -- Gasoline Related Air Pollutant Concentrations in New Jersey Air (October 2002 – April 2006)



C. LIVING RESOURCES

Upland Vegetation

The biota of Greenwood Lake and its accompanying watershed area are very rich in species diversity. The watershed which encompasses Greenwood Lake has five major vegetative habitats that can be divided into two categories, uplands and wetlands. These are vital habitats for many plants and animals.

Uplands consist of upland forests, and steep slopes and ridges.[37] The upland forests are defined as a well drained forested area of varying topography ranging from gentle slopes, hilltops, valleys, and ravines to flat lands. These areas have no standing water for long periods of time; however, the soils retain a good supply of water for use by plants.[38] The upland forests are subdivided into four different habitat types. The habitat types of upland forests around Greenwood Lake are North Jersey Mixed Oak, Sugar Maple Hardwood, Hemlock Hardwood, and Plantations.[39]

The North Jersey Mixed Oak Forest is the most common type in the Highlands. The red oak is the dominant species; however, it also contains black oak, white oak, scarlet oak, and chestnut oak. Other types of trees include maple, hickory, beech, and birch. The shrub layer has common dogwoods, including hazel and viburnum. Common groundcover species that occur include poison ivy, wintergreen, and partridgeberry. The Sugar Maple Hardwood Forest is quite similar to the Northern Jersey Mixed Oak Forest. It contains all the tree types of the Northern Jersey Mixed Oak, but in more evenly distributed numbers.[40]

The other two forest types are Hemlock Hardwood and Plantations. The Hemlock Hardwood forest is a remnant of the early post-glacial forest. This forest includes birch, beech, maple, and oak. Due to the dense forest and tannin containing needles there are little or no under story herbs and shrubs.[41] The Plantations were planted in the 1930's by the Civilian Conversation Corp to protect the watershed. Today they include red maple, black cherry, ash, and acid tolerant herbs.[42]

Wetlands and Flood Plains

Wetlands in the watershed include marshes, swamps and floodplains, and bogs. Marshlands are wetlands where standing water occurs most of the year, generally adjacent to lakes, ponds and rivers.[43] This habitat is typically dominated by grass-like plants, usually cattail, reed grass, or wild rice.[44] Typical vegetation found in marshlands is shown in Figure II.C-1.

37 West Milford Open Space Plan pg 48
38 West Milford Open Space Plan pg 48
39 West Milford Open Space Plan pg 51
40 West Milford Open Space Plan pg 51
41 West Milford Open Space Plan pg 51
42 West Milford Open Space Plan pg 52
43 West Milford Open Space Plan pg 48
44 West Milford Open Space Plan pg 49

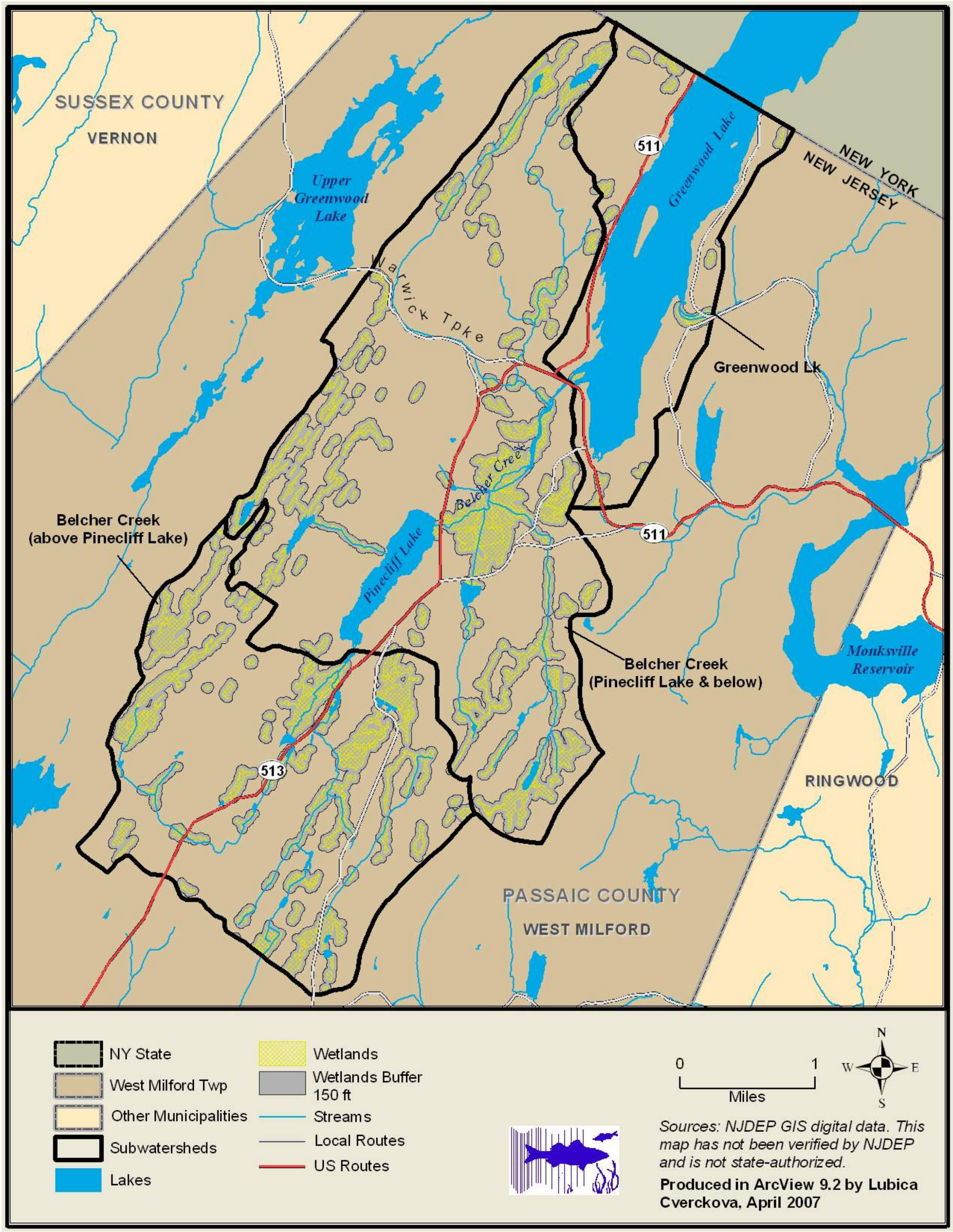
Swamps and floodplains are defined as wetlands where standing water is present part of the year, usually in spring and fall.[45] The habitat supports the growth of trees, including yellow and river birches, red maples, and willows. Shrub areas include pussy willow, alder, and skunk cabbage.[46]

Bogs are wet sites with very poor drainage in which peat accumulates to form a highly acidic environment of low fertility.[47] The habitat can be recognized by the presence of a thick mat of sphagnum moss. Several types of common vegetation can flourish, including azalea, low brush, cranberry, and sheep laurel. The bogs also contain insect eating plants such as pitcher plants, and several species of sundew.[48]

Figure II.C-1 – Cattails

[45] West Milford Open Space Plan pg 48
[46] West Milford Open Space Plan pg 49
[47] West Milford Open Space Plan pg 48
[48] West Milford Open Space Plan pg 49

Figure II.C-2 – Wetlands



Wetlands are valuable habitat for many wildlife and plant species. Wetland areas in the Greenwood Lake Watershed are shown on Figure II.C-2. The State of New Jersey prohibits development of wetlands under the Freshwater Wetlands Protection Act.[49] A potential developer must define the extent and character of the wetlands, and potential impact on the wetlands. This includes delineation of the wetlands based on soils, vegetation, and presence or absence of water. Although the map shown in Figure II.C-2 is useful for an overall view of where wetlands are present, an exact survey of an area must be made to determine compliance with the Freshwater Wetlands Protection Act.

Under the regulations developed pursuant to the Freshwater Wetlands Protection Act, freshwater wetlands in the watershed may be classified as intermediate, for which only a fifty foot transition or buffer area may be required. Nevertheless, wherever a 150 foot buffer that is naturally vegetated, which is required for exceptional wetlands, can be maintained or restored the natural functions of a wetland will be better protected. For more information on wetlands and how they are regulated see the New Jersey Department of Environmental Protection (NJDEP) website on the Freshwater Wetlands Program.[50]

Adjacent to the lakes, brooks, ponds, and rivers are flood plains. A flood plain is the relatively flat area adjoining the channel of the stream or river that is covered with water during periods of high flow. Flood plains were formed by the action of seasonal floodwaters over time. Flooding is exacerbated by increases in impervious cover and compacted soils, which change surface conditions and thereby increase the velocity and volume of surface runoff. Preserving flood plains in a natural state with trees and other vegetation is essential to reducing flooding problems. In New Jersey, the flood plain is regulated by the NJDEP under the Flood Hazard Area Control Act of 1979.[51] Flood Hazard Areas can be expected to flood at least once in a hundred years. Flood Hazard Areas are divided into the stream channel, the floodway, and flood fringe areas. Floodways flood frequently, at least once in ten years on average. Flood prone areas in the Greenwood Lake Watershed are shown on Figure II.C-3. The areas mapped in Figure II.C-3 are approximations of floodway and flood fringe areas based on mapping by the Federal Emergency Management Agency (FEMA). Many developments in Flood Hazard Areas require Stream Encroachment Permits. These requirements are described by the NJDEP on the Internet.[52] The Flood Hazard Area Control rules now have a 0% net-fill requirement that applies to all non-tidal flood hazard areas of the State.[53] For Category One waters, which include all the surface waters in the Greenwood Lake Watershed, near-stream vegetation in riparian zones that are 300 feet in width along each side of these surface waters must be protected. These riparian zones in the watershed are depicted on Figure II.C-4.

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[49] Freshwater Wetlands Protection Act, N.J.S.A. 13:9B-1 *et seq.* (P.L. 1987, c.156) and N.J.S.A. 58:10A-1 *et seq.* (N.J.A.C. 7:7A-1 *et seq.*).

[50] New Jersey Department of Environmental Protection. 2005. Land Use Regulation Program, Freshwater Wetlands Program. Website: <www.nj.gov/dep/landuse/fww>

[51] Flood Hazard Area Control Act, N.J.S.A. 58:16A-50 *et seq.* 1979. (N.J.A.C. 7:13 *et seq.*)

[52] N.J. Department of Environmental Protection, Division of Land Use Regulation. 2008. Flood Hazard Area Program. Website: <www.state.nj.us/dep/landuse/se.html>

[53] *Ibid.*

Figure II.C-3 – Flood Prone Areas

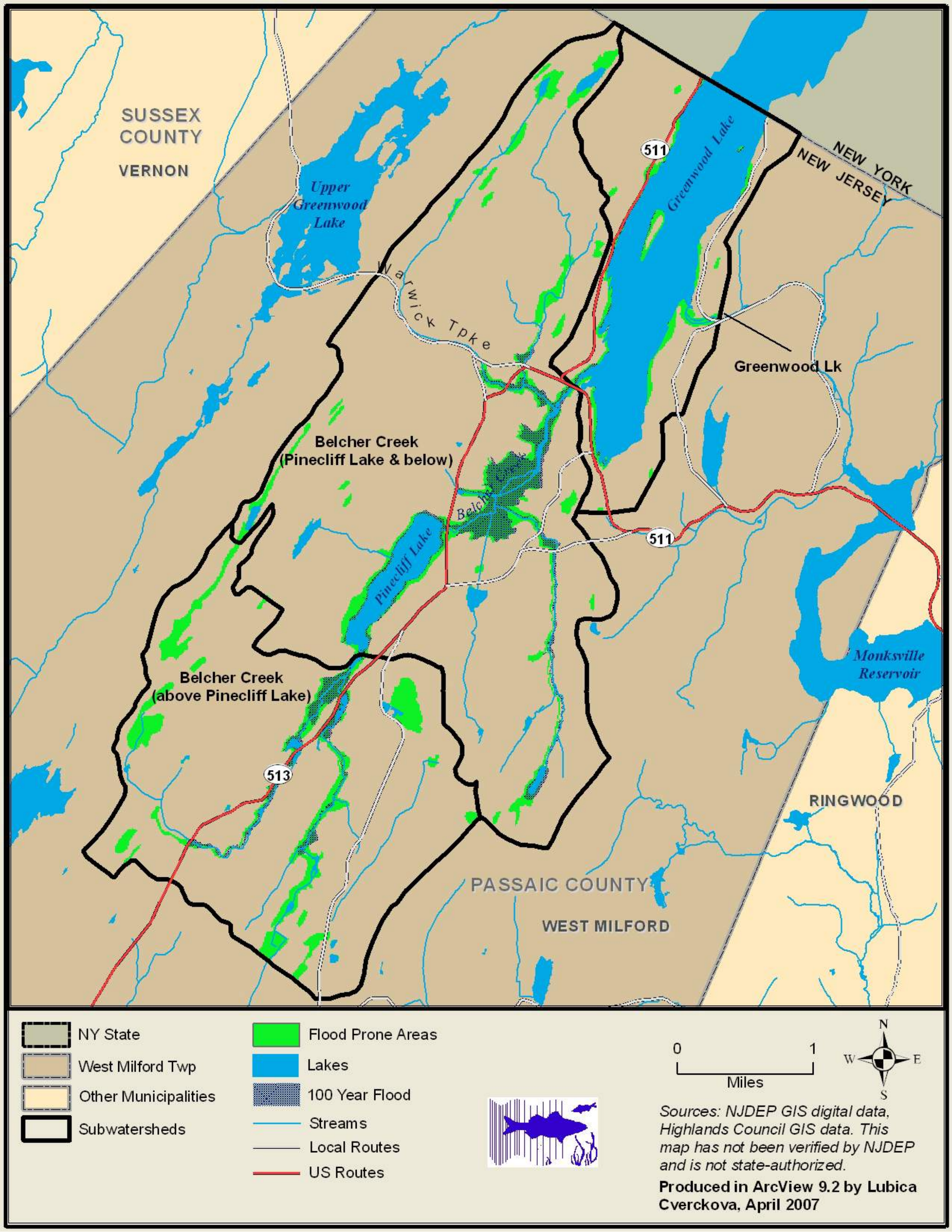
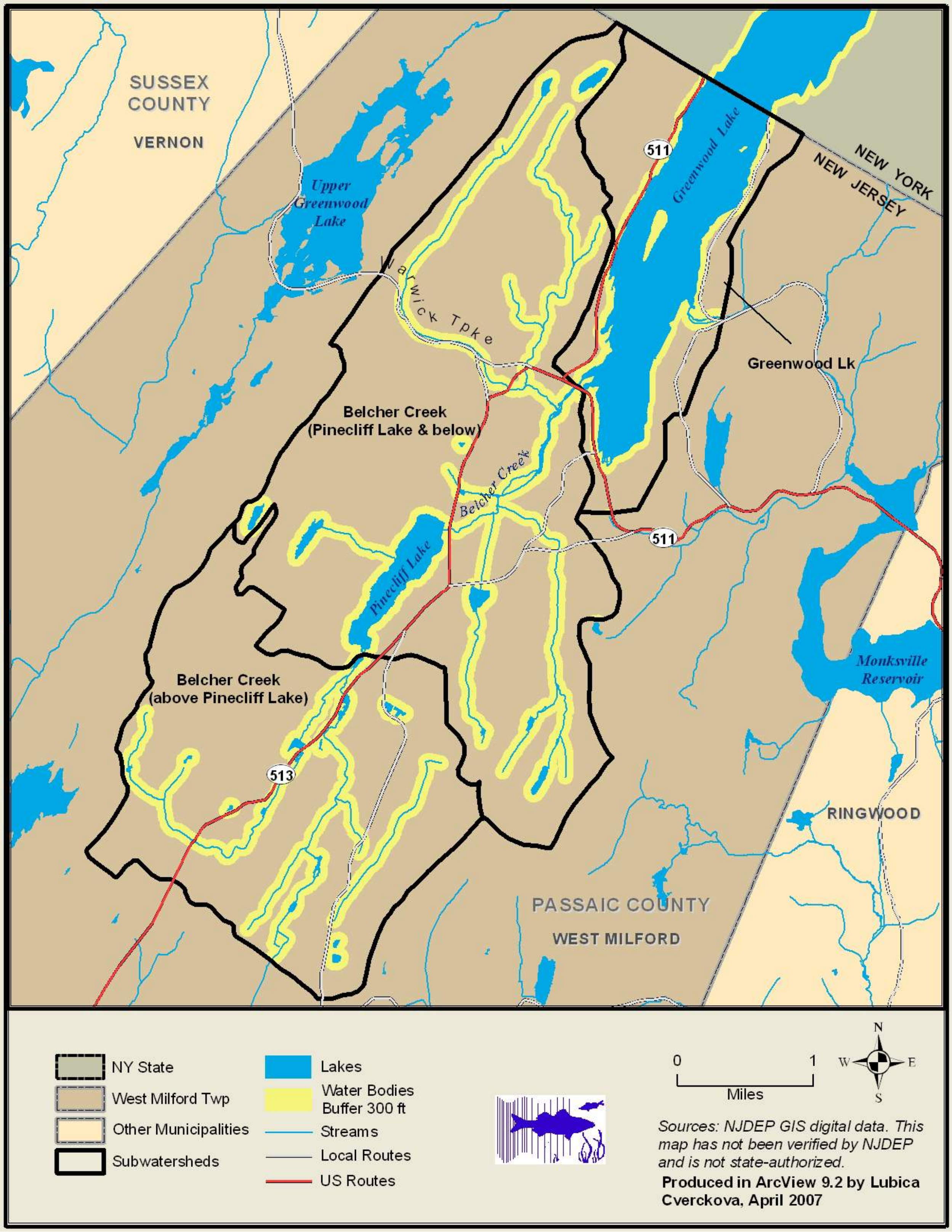


Figure II.C-4 – Flood Plains



Wildlife

The Greenwood Lake Watershed is an ecosystem of complex interactions. Each plant and animal has a place in the environment, and this area contains many threatened and endangered species that need protecting. It is these interactions that sustain the species richness of the watershed.

The Greenwood Lake Watershed has many ecologically interesting habitats. One of these habitats is Sterling Forest. The forest is home to species such as the barred owl, and the red-shouldered hawk. Other species include bats, timber rattlesnakes, and the rare golden-winged warbler.[54] The wetlands support many species of fish and wildlife, which is significant for seasonal waterfowl and water birds.[55] There are many species of wildlife that reside in this area. Species include wood turtles, timber rattlesnakes, red-shouldered hawks, barred owls, warblers and thrushes, black bears, bobcats, and native brook trout.[56]

The Greenwood Lake Watershed is home to many species of endangered and threatened plants and animals. The Eastern Hemlock forest is an area of concern. The government hasn't listed it as an endangered area; however, it is being watched as an area of concern. Some of the endangered animals include the Indiana Bat, Allegheny Woodrat, Timber Rattlesnake, and the Bog Turtle. The cottontail rabbit was being considered for the endangered species act, and the Wood Turtle is a threatened species.

In order to survive and flourish, wildlife needs significant areas of healthy, natural habitat. Because there are many different types of ecosystems, there are many different ways to assess ecosystem health. The Landscape Project, which was developed under the New Jersey Endangered and Nongame Species Program by the Division of Fish, Game and Wildlife in the New Jersey Department of Environmental Protection (NJDEP), has captured many of these aspects, and has produced maps of areas that should be conserved in order to protect wildlife habitat in New Jersey.[57] The purpose of the project is explained as follows:[58]

> Protecting large expanses of fields, forests and wetlands helps to ensure that rare species will remain a part of New Jersey's future. In addition to providing habitat for the conservation of rare species, the Landscape project will result in more open space for outdoor recreation. Recent surveys by the U.S. Fish and Wildlife Service show that more than 60 percent of Americans participate in some form of wildlife-related recreation. Open spaces provide places where people can escape the confines of urban and suburban living. Retaining habitats in their natural state provides other benefits such as reducing the threat of flooding, allowing for the biodegradation of environmental contaminants and recharging ground water reserves.

The Landscape Project has identified areas in the Greenwood Lake Watershed that should be protected for the wildlife habitat that they provide, including Forest Conservation Areas, Forested Wetland Conservation Areas, Emergent Wetland Conservation Areas, and Conservation Areas for Wood Turtles. These areas are depicted in Figure II.C-5.

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[54] WMA document – Critical Habitat Document pg 2

[55] WMA document – Critical Habitat Document pg 5

[56] WMA document – Critical Habitat Document pg 6

[57] Niles, Lawrence J., Jim Myers, Mike Valent. 2000. The Landscape Project. NJ Endangered and Nongame Species Program, Division of Fish, Game & Wildlife, NJ Department of Environmental Protection.

[58] Niles, Lawrence J., Jim Myers, Mike Valent. 2000. The Landscape Project. NJ Endangered and Nongame Species Program, Division of Fish, Game & Wildlife, NJ Department of Environmental Protection. Page 5.

Each conservation area was given a priority rank of 1 to 5. An area with a rank of 5 is most in need of protection. Factors which were used to assess whether or not an area should be considered a conservation area, and the priority ranking for conservation areas, included the following:

- Presence and number of endangered or threatened priority species;
- Size of contiguous areas undivided by major roads; and
- Identification of conserved areas that have some form of protection from development, either through ownership or regulation.

The rankings of the areas of land in the Greenwood Lake Watershed which the Landscape Project identifies as critical Forest Conservation Areas for the protection of wildlife are shown on Figure II.C-6. Figure II.C-7 shows rankings of areas of emergent wetlands. Efforts should be made to keep each of these areas in a natural condition so that wildlife can continue to thrive.

Aquatic Biota

Greenwood Lake itself is an important habitat for many aquatic plants and animals, and it is a major recreational locus. The increased visitor traffic and conversion of seasonal housing to full-year residences has produced an influx of excess nutrients leading to eutrophication of the lake. The excess nutrients, notably phosphorus, have caused an increase in invasive and nuisance species appearances, overgrowth of water-based weeds, and algal blooms, all of which detract from the lake's attractiveness as either habitat for native species or for human recreation and positive interaction with nature.

Dominant plant species found in Greenwood Lake over a long period of time (from macrophyte surveys conducted in the 1980s as well as in the present) include *Lyngbya latissma*, fern pondweed (*Potamogeton robbinsii*), Eurasian water milfoil (*Myriophyllum spicatum*), fanwort (*Cabomba caroliniana*), and bass weed (*Potamogeton amplifolius*).[59] Of these, *Lyngbya* is a blue-green algae that grows in long filaments, forming large, layered mats. Fern pondweed is a submerged plant with firm, narrow leaves arranged in ranks resembling fern fronds. Bass weed (also called large-leaf or broadleaf pondweed) is a perennial herb that produces broad, submerged leaves and occasional floating, surface leaves. Both fern pondweed and bass weed are native species. Eurasian water milfoil is a long-stemmed plant that forms thick canopies of surface vegetation, often blocking light for other plant species as well as becoming an obstacle to recreational boating and swimming. Fanwort is a submerged herb with long (up to 6 feet), slender stems covered with gelatinous slime, forming thick stands that crowd out other plants and can clog water channels. Eurasian water milfoil and fanwort are both classified as aggressive non-native (i.e., invasive) species.

The increase of invasive plant species has reduced the water quality for native fish. Invasive species out compete native aquatic plants like tape grass (*Vallisneria americana*) that offer preferred habitat for spawning. Denser stands of invasives can also restrict access to the Lake for human visitors, decreasing their recreational opportunities and even interfering with aesthetic appreciation of shoreline views. Eurasian water milfoil and fanwort have both been identified as dominant species in shallow areas of the Lake.[60]

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[59] PRC Report pg 9

[60] Princeton Hydro, LLC. 2007. Invasive Species Management Plan, Greenwood Lake, New York. Page 3.

Figure II.C-5 – Conservation Areas for the Protection of Wildlife Habitat

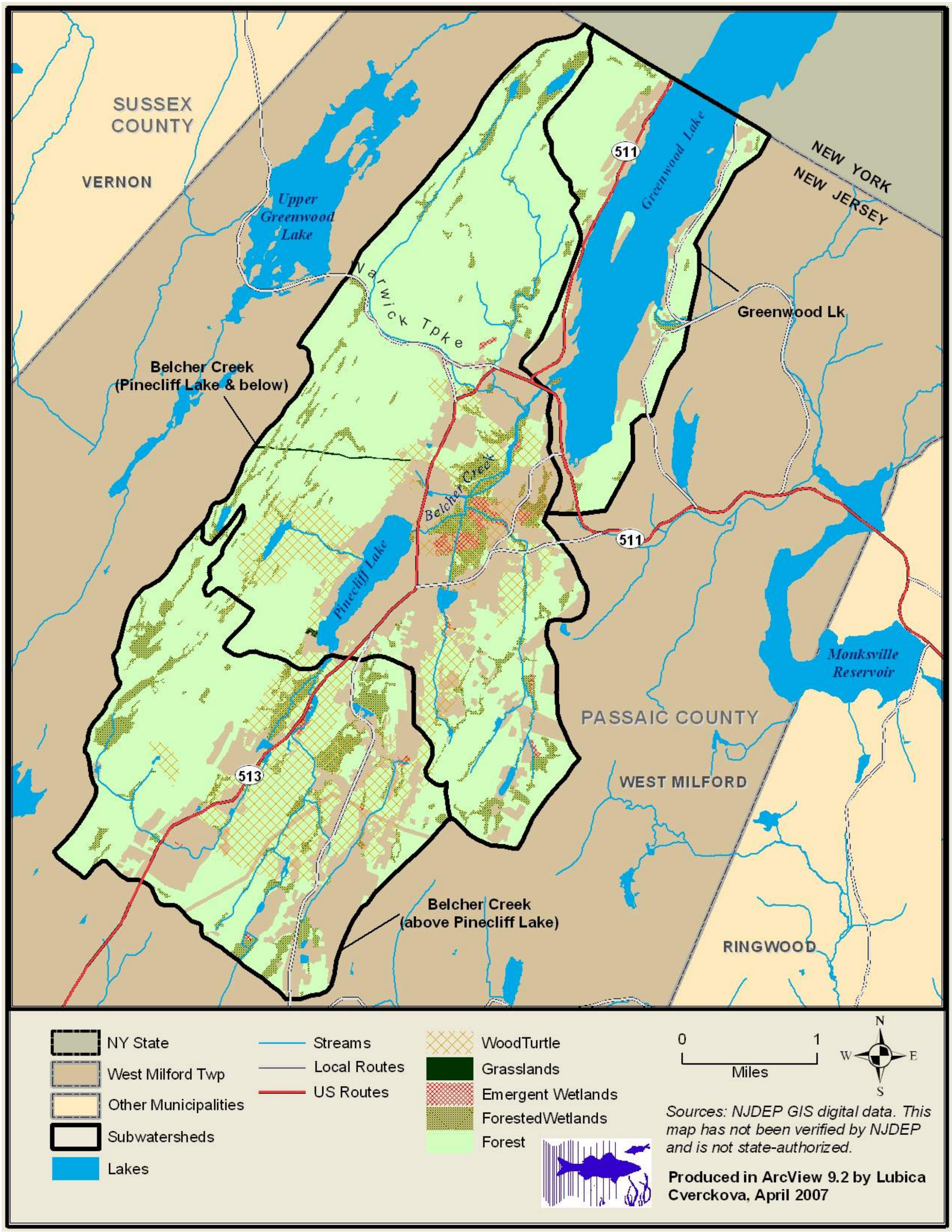


Figure II.C-6 – Rankings of Forest Conservation Areas

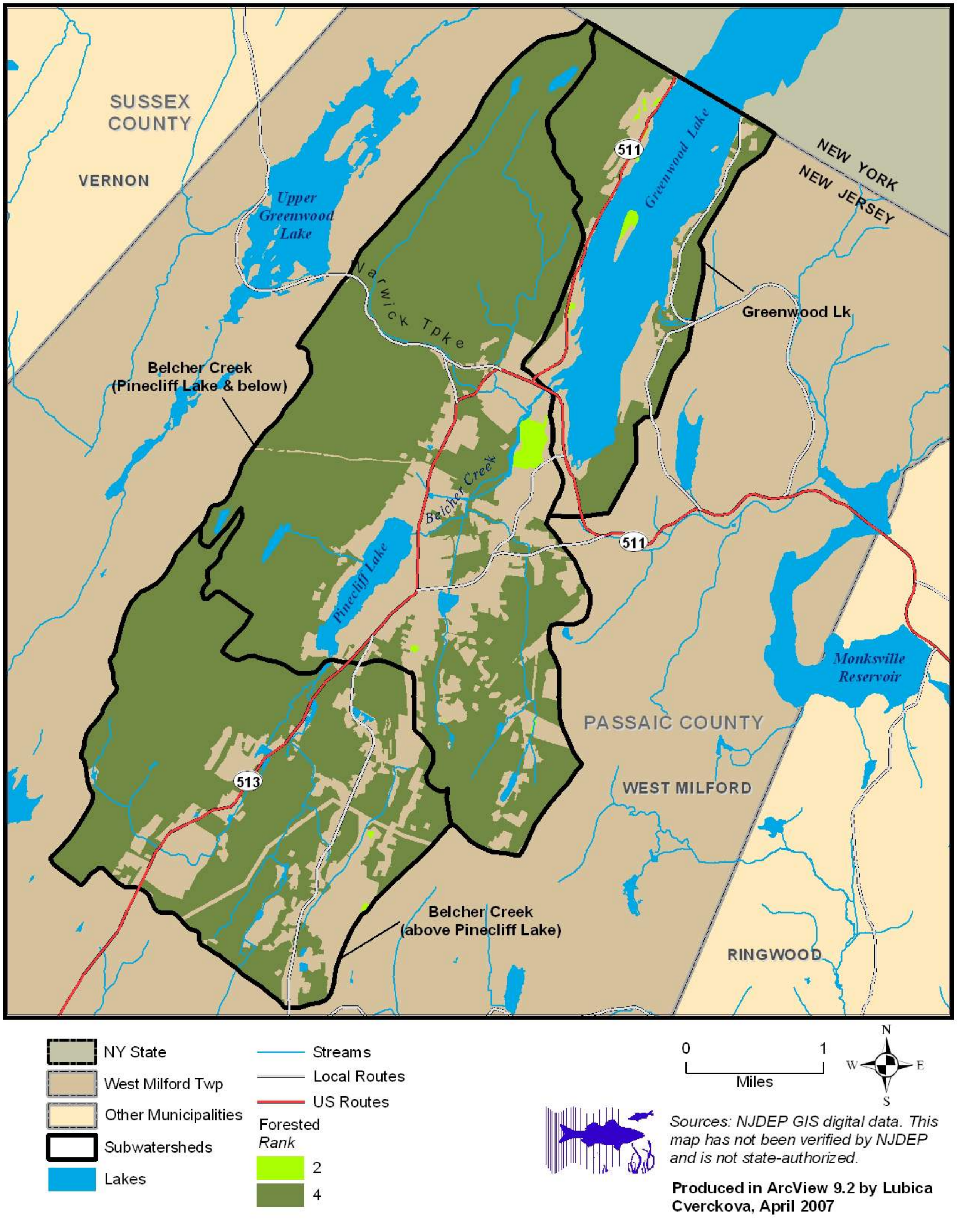
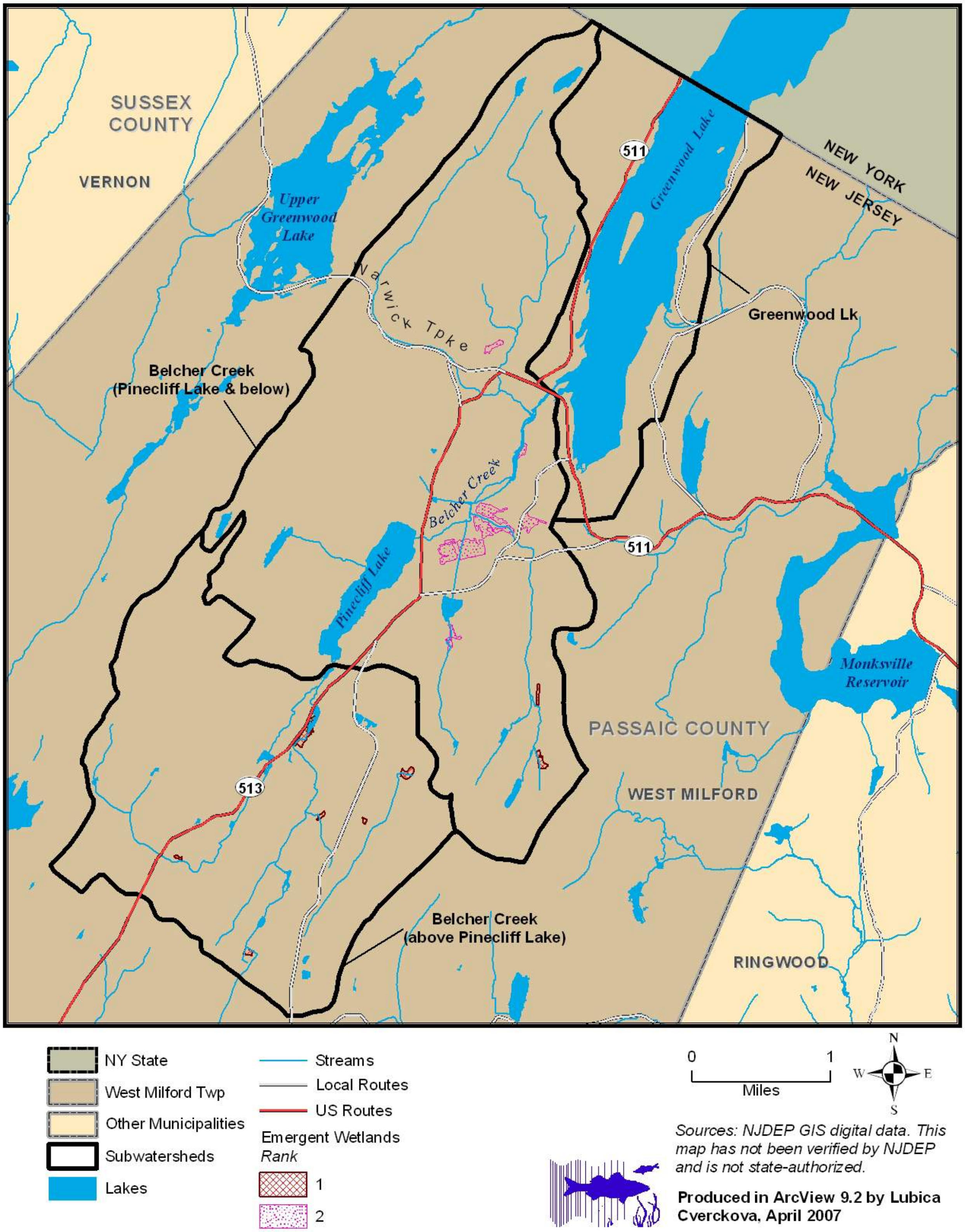


Figure II.C-7 – Rankings of Emergent Wetlands Areas



In addition to managing communities of live plants, Greenwood Lake is also challenged with control of stumps of hardwood trees left in the Lake when it was expanded in 1836 to provide water supply for the Morris Canal. The cold, oxygen-poor water has preserved the stumps, leaving them standing as hazards to boating and swimming. In addition, stumps and their root systems may be floated off the lake bottom through the buoyancy of trapped gasses from algal metabolic processes. These "floating islands," which may achieve sizes of up to several hundred yards, pose an additional threat, one which changes as water and weather conditions cause the floating islands to rise or sink.[61] A jellyfish seen in Belcher Creek is shown in Figure II.C-8.

Figure II.C-8 – Freshwater Jellyfish in Belcher Creek

[61] Greenwood Lake Commission. 2007. Stump Reduction Project, 2006-2007. Pages 1, 5-6.

D. WATER RESOURCES

Water Resources in the Greenwood Lake Watershed

In the Greenwood Lake Watershed the normal precipitation rate is over 53 inches of water per year based on data from the Greenwood Lake monitoring station for the years from 1971 to 2000.[62] About half of this water is returned to the atmosphere by evapotranspiration, which is evaporation and transpiration through trees and other biota. The remainder runs off into lakes, streams and rivers or recharges ground water. Ground water, like surface water, seeks a uniform level. But, because the ground impedes its movement, ground water usually cannot move fast enough to rise to its original level as it moves down slope. The water table tends to mimic the surface contours, or subsurface contours of a confining layer, but with much less relief.

A recharge area is a surface of the land that allows water to soak into the soil and reach an underlying aquifer, or seep into a stream. Ground water moves from higher recharge areas to lower discharge areas controlled by the force of gravity and the resistance of the rocks and sediments in the ground to that movement. In comparison with surface water, it moves slowly, with speeds ranging from a few feet a day to fractions of an inch per year.

When ground water meets the land surface, it discharges into surface water, springs, lakes, streams, wetlands, rivers, or the ocean. Ground water usually maintains the flow of water in streams and springs. Ground water discharge seeps through stream banks and stream beds, and is the base flow of these surface waters. Without ground water recharge, streams would run dry, and fish and other life in the stream would die. People in the Greenwood Lake Watershed rely on ground water for their water supplies. What happens to the rain that falls on the Greenwood Lake Watershed has profound impacts on the drinking water used in the Greenwood Lake Watershed, as well as many other parts of New Jersey. The Chief Hydrologist of the US Geological Survey (USGS) notes that "effective land and water management requires a clear understanding of the linkages between ground water and surface water as it applies to any given hydrologic setting."[63]

Storm water runoff and base flows in streams in the Greenwood Lake Watershed may flow into Greenwood Lake, and from there into the Wanaque River and eventually into the Passaic River. The Greenwood Lake Watershed is in the headwaters of the Passaic River Basin, as shown in Figure I-1 (page I-3). Waters from the Greenwood Lake Watershed are critical for replenishing water in the Monksville and Wanaque Reservoirs, seen in Figures I-1 and I-2 (page I-7). The Greenwood Lake Watershed in New Jersey is divided into the three subwatersheds shown in Figure II.D-1. The areas covered by these subwatersheds are listed in Table II.D.-1.

[62] Office of the NJ State Climatologist, Rutgers University. 2007. Website: <http://climate.rutgers.edu/stateclim_v1/norms/monthly/precip.htm>

[63] Hirsch, Robert M., Chief Hydrologist, US Geological Survey. 1998. Ground Water and Surface Water: A Single Resource. USGS Circular 1139. Website: <http://water.usgs.gov/ogw/gwsw.html>

Table II.D-1 – Subwatersheds of the Greenwood Lake Watershed

Subwatershed	*Hydrologic Unit Code (HUC)*	*Area (square miles)*
Belcher Creek (above Pinecliff Lake)	02030103070010	5.43
Belcher Creek (Pinecliff Lake and below)	02030103070020	9.03
Greenwood Lake (New Jersey, above gage at Awosting)	02030103070030?	3.20
Greenwood Lake (New York)	020301030700??	9.44
Greenwood Lake (New Jersey & New York to Awosting gage)	02030103[64]	27.10
Wanaque River (Awosting gage to above Monksville Gage)	02030103070030	11.42

Surface Water Flows

The ecology of the lakes and streams in the Greenwood Lake Watershed depends upon the flows of water through these systems. Also millions of people depend on reliable water supplies from the Monksville and Wanaque Reservoirs, which are replenished by water flowing over the Greenwood Lake dam into the Wanaque River. The outlet of Greenwood Lake is pictured in Figure II.D-2. Below this point, 700 feet downstream from the dam at the outlet of Greenwood Lake on the Wanaque River at Awosting, there is a gage to measure flow. The U.S. Geological Survey in cooperation with the North Jersey District Water Supply Commission reports daily mean values of discharges at this gage.[65] The annual mean flows for the years from 1920 through 2006 are shown in Figure II.D-3. The average flow for these years was 54.3 cubic feet per second (cfs), which translates to 35.1 million gallons per day (mgd). The watershed above the gage is 27.1 square miles, so the average surface water flow from the Greenwood Lake Watershed is about 1.3 mgd per square mile, or 27.3 inches per year. Precipitation at an average of 53 inches per year averages 2.5 mgd per square mile. This means that on average 1.2 mgd per square mile of precipitation is evapotranspired, and the remainder flows out of the watershed. The critical question is how much of this water is storm water runoff and how much is base flow. Since the drought of 1965, when the lowest annual mean flow of 21.0 cfs was recorded, the annual mean flow has been trending upward. This can be attributed to increased development in the watershed, which has increased storm water runoff and decreased recharge and base flow.

[64] U.S. Geological Survey. 1999. Passaic River Basin, 01383500 Wanaque River at Awosting NJ. Water Resources Data, New Jersey, Water Year 1999, Volume 1. Surface-Water Data, Water Data Report NJ-99-1, page73.

[65] U.S. Geological Survey. 2007. USGS Surface-Water Annual Statistics for the Nation, USGS 01383500 Wanaque River at Awosting NJ. Website: http://waterdata.usgs.gov/nwis/annual....

Figure II.D-1 – Subwatersheds in the Greenwood Lake Watershed in New Jersey

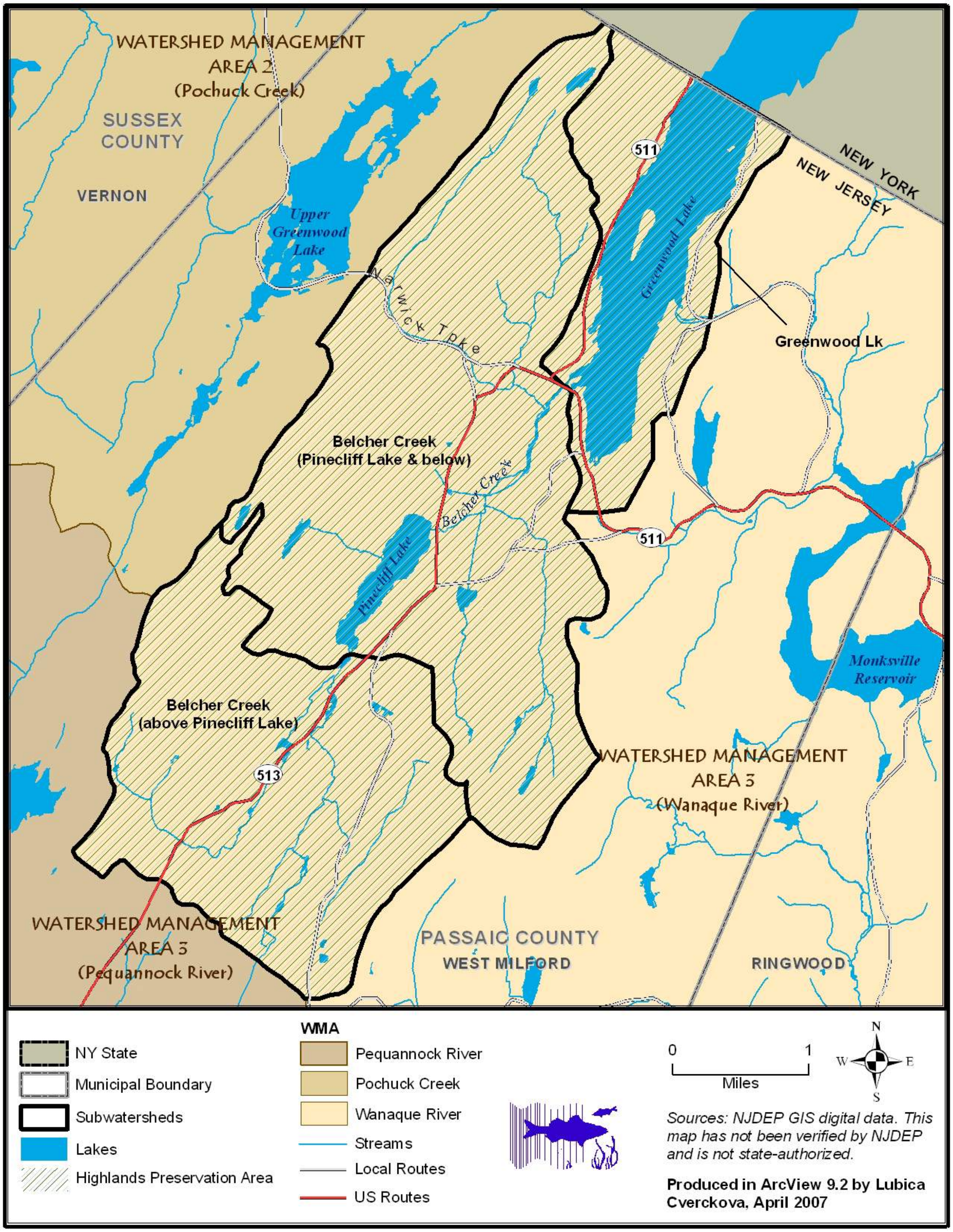
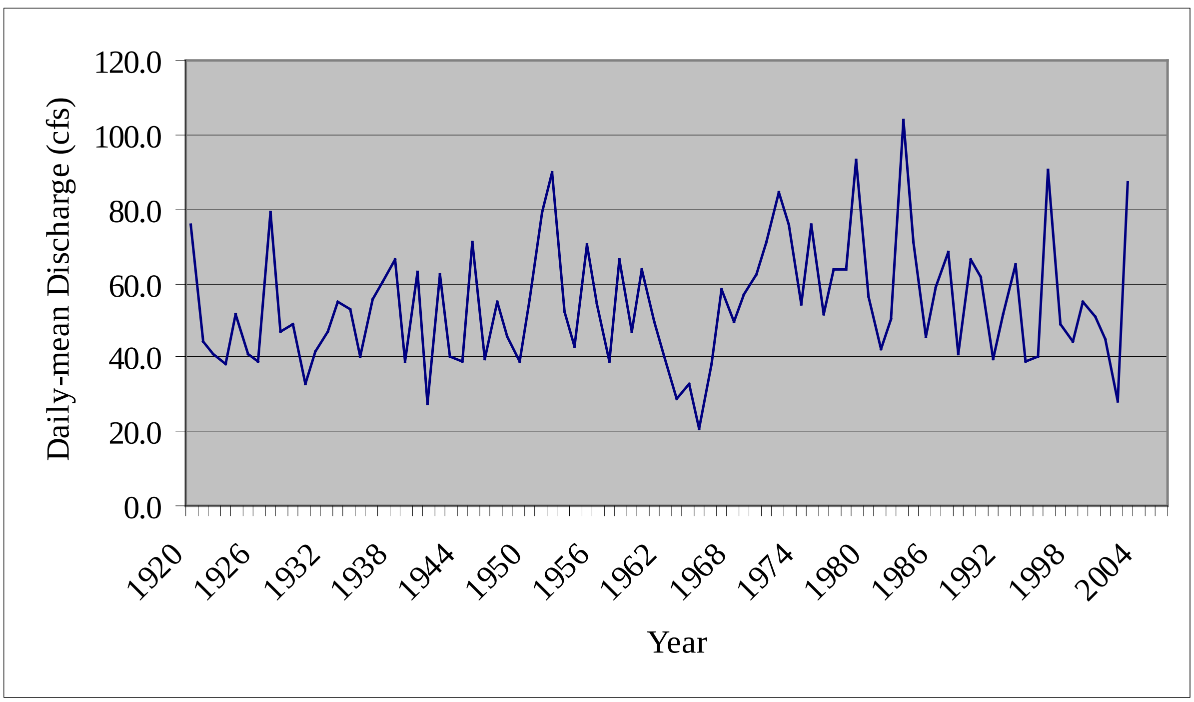


Figure II.D-2 – Outlet of Greenwood Lake at Awosting, NJ

Figure II.D-3 – Annual Mean Flows in Wanaque River at Awosting[66]



[66] U.S. Geological Survey. 2007. USGS Surface-Water Annual Statistics for the Nation, USGS 01383500 Wanaque River at Awosting NJ. Website: http://waterdata.usgs.gov/nwis/annual....

Recharge of Ground Water

What happens to the rain that falls on the Greenwood Lake Watershed has profound impacts on the drinking water used in the Greenwood Lake Watershed, as well as many other parts of New Jersey. The Passaic River Coalition describes these impacts in its Homeowner Guides advocating "Contain Your Rain, Soak It, Don't Send It, For Tomorrow You Drink It." Guide #1 describes why the recharge of ground water is so important.[67]

Ground water recharge begins with rain, snow and other forms of water that drop out of the clouds and onto the ground. Water that falls on the land may run off over the surface, return to the atmosphere through evaporation, or seep into the soil. Water in the soil is either taken up by plants in the upper layers, or infiltrates down into deeper layers. In the upper layers of soil, the pores or spaces between the soil particles often are filled with air so that water can trickle through. The deeper layers form a saturated zone where water is held, like a sponge, in all the spaces between the rock particles. The water table marks the top of this saturated zone. Water in the soil recharges ground water when it reaches the water table.

Ground water discharge occurs where the land's surface dips below the water table, allowing the water to flow out to the surface. Ground water exits the earth at discharge areas, coming to the surface to feed springs, streams and wetlands.

Base flow is the ground water discharge that keeps streams and wetlands soggy between rainfalls, even during times of drought. When recharge areas are covered with impervious or watertight, surfaces, rainwater can't replenish the ground water, base flow gets reduced, and streams run lower than usual during dry spells. Impervious surfaces also make flooding worse, because all the storm water runoff that would normally soak into the ground then gets added to flood-swollen streams.

Ground water recharge areas are land surfaces where the soil naturally allows rainwater to seep down to the water table. Ground water recharge areas function best when the land surface and the ground beneath it are permeable so water can infiltrate into, and flow through, the ground. Permeability is the relative ease with which water can move through soil or rock. For instance, beach sands are highly permeable, and the ocean water soaks into them readily, while dense clays have a very low permeability and rain runs off of them instead of soaking into the ground. Trees, bushes and grasses put down roots, helping to keep soil permeable. It is the combination of water permeable soils and vegetation that keep ground and surface water sources of drinking water clean and plentiful. When land is built upon, impervious surfaces, such as buildings, roads, and parking lots, seal up recharge areas and prevent rainwater from seeping into the ground. Even converting forest or meadow landscapes into lawn makes the soil less permeable, and the recharge less abundant.

Land use changes recharge. Land has been developed in various ways. Many of these changes in land use have added impervious surfaces and decreased the permeability of soils. Nowadays less water soaks into the ground to recharge ground water than it did before the natural landscape was altered. This means that there is less water stored in the ground that can later be used for drinking water. The graph in Figure II.D-4 compares the amounts of water that recharge ground water in an average year on the same type of soil found in large areas of the Greenwood Lake

[67] Passaic River Coalition. 2004. Contain Your Rain, Soak It, Don't Send It, For Tomorrow You Drink It! Homeowners Guide #1.

Watershed (Rockaway) with the same amount of rain and snow in the Greenwood Lake Watershed, but with different land uses.[68] A highly altered landscape, such as a shopping center, concentrates rain runoff, diverts it from recharge areas, and sends it into the nearest drainage pipe, brook or lake. In the Greenwood Lake Watershed large areas around Greenwood Lake have been developed with impervious surfaces. This means that much of the storm water precipitating on these areas flows into Greenwood Lake without pollutants being filtered out in the ground and without being available for pumpage from the ground to be used for water supplies or replenishment of water in Greenwood Lake in dry periods.

Increasing ground water recharge is possible by directing storm water into the ground instead of piping it to a stream. For more information on how you can contain your rain, please see the Passaic River Coalition's Homeowner Guides #2, #3, and #4.[69]

If the natural water resource base is to be maintained, wooded areas must be preserved. They have the highest recharge rates because the vegetation detains storm water and facilitates its percolation into the ground. The New Jersey Geological Survey (NJGS) has developed a method for evaluating ground water recharge in New Jersey.[70] The method relies on estimating a soil-water budget, where the following equation applies:

recharge = precipitation - surface runoff - evapotranspiration

The factors considered in estimating recharge include soil characteristics, impacts on permeability from various land uses, and average annual precipitation rates. Figure II.D-4 shows how land use on a Rockaway soil in the Greenwood Lake Watershed impacts recharge.[71] The recharge capabilities of the land in the Greenwood Lake Watershed are shown in Figure II.D-5. Note that the developed areas and wetlands in the Greenwood Lake Watershed have lower recharge capabilities than the well vegetated upland areas.

All ground water recharge in the Highlands is critical for maintaining or improving the availability of ground water and surface water supplies. In the Highlands Final Draft Regional Master Plan the Highlands Council focuses attention on "Prime Ground Water Recharge Areas", which are shown in Figure II.D-6.[72] These areas are "the most efficient recharge areas contributing 40% of the total recharge volume during a drought period."[73] The Highlands Council proposes that "protection of these lands and the quality and quantity of recharge from them has a high priority in the Regional Master Plan."[74]

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[68] Charles, E.G., C. Behroozi, J. Schooley, and J.L. Hoffman. 1993. A method for evaluating ground water recharge areas in New Jersey. New Jersey Geological Survey Report GSR-32. Division of Science and Research, New Jersey Department of Environmental Protection and Energy, Trenton, NJ.

[69] Passaic River Coalition. 2004. Contain Your Rain, Soak It, Don't Send It, For Tomorrow You Drink It! Homeowners Guides #2, #3, #4.

[70] Charles, E.G., C. Behroozi, J. Schooley, and J.L. Hoffman. 1993. A method for evaluating ground water recharge areas in New Jersey. New Jersey Geological Survey Report GSR-32. Division of Science and Research, New Jersey Department of Environmental Protection and Energy, Trenton, NJ.

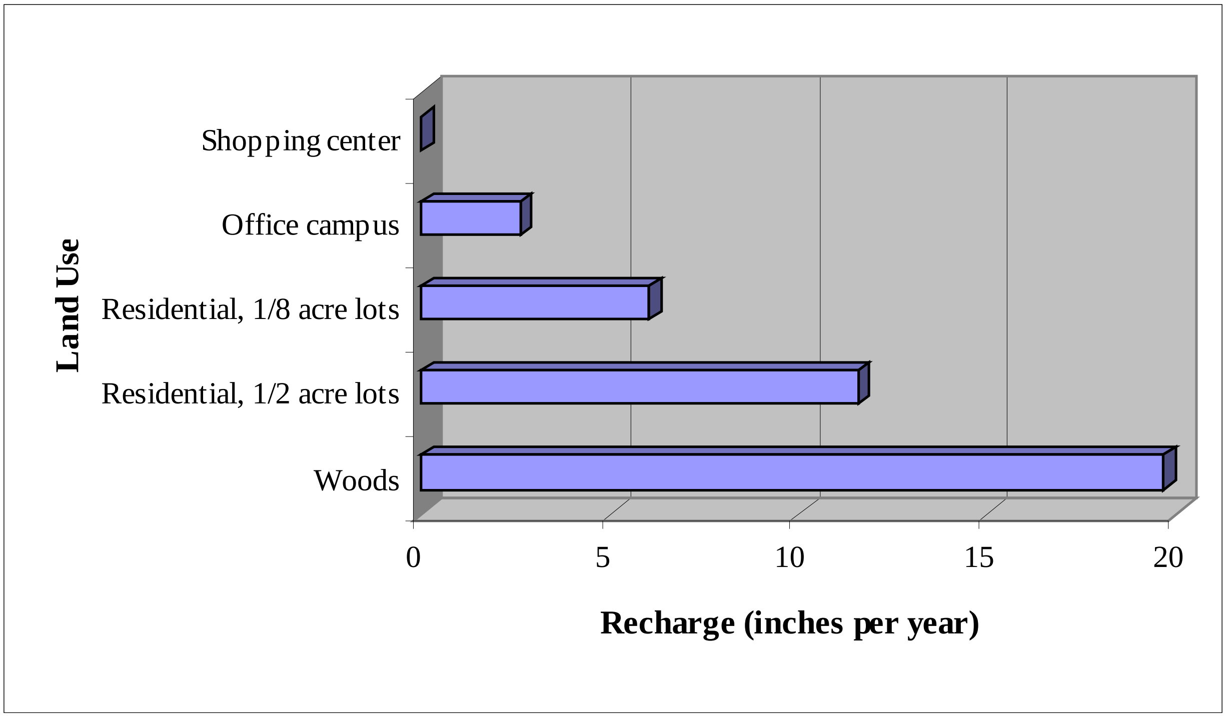
[71] *Ibid*.

[72] Highlands Water Protection and Planning Council. 2006. *Highlands Draft Regional Master Plan, November 2006.* Section III.C.1.b., pages 63-68. & Highlands Water Protection and Planning Council. 2007. Water Resources Technical Report, Volume II – Water Use and Availability (Draft), January 2007. Section 4.2.2, pages 19-21.

[73] Highlands Water Protection and Planning Council. 2006. *Highlands Draft Regional Master Plan, November 2006.* Section III.C.1.b., page 64.

[74] Highlands Water Protection and Planning Council. 2007. *Highlands Final Draft Regional Master Plan, November 2007*. Page 45.

Figure II.D-4 – Effects of Land Use on Recharge Capabilities of Rockaway Soils in the Greenwood Lake Watershed



Ground Water Storage

All the residents in and visitors to the Greenwood Lake Watershed rely on ground water for their water supplies. Therefore, sustaining ground water supplies is critical for the future of the region. In this watershed most of the ground water is stored in fractured bedrock aquifer systems. As shown in Figure II.A-5, the glacial sediments overlying much of the area are thin till with numerous bedrock outcrops. To the east of Bearfort Mountain there are areas of thicker glacial sediments. Studies of the yields from wells in these glacial deposits indicate that they are not very good aquifer systems in comparison to the yields from wells in the Buried Valley Aquifer Systems of the Passaic Valley.[75] Most of the wells in the watershed are drilled into the fractured bedrock. Data from these wells indicate that these aquifer systems are poor yielding and poorly transmissive.[76] There are not "any significant differences in yields between the Precambrian igneous and metamorphic rocks and the Devonian and Silurian rocks of the Green Pond Mountain Region."[77] Well yield and specific capacity data for public community water supply wells indicate that the bedrock and glacial aquifer systems "are not high yielding and that the aquifers have limited capacity to transmit groundwater."[78]

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[75] Mulhall, Matthew J., P.G., M^2 Associates Inc. 2003. Evaluation of Groundwater Resources of West Milford Township, Passaic County, New Jersey, November 26, 2003. Prepared for West Milford Township. Page 14.
[76] *Ibid.* Page 15.
[77] *Ibid.* Page 15.
[78] *Ibid.* Page 14.

Figure II.D-5 – Recharge Capabilities in Greenwood Lake Watershed

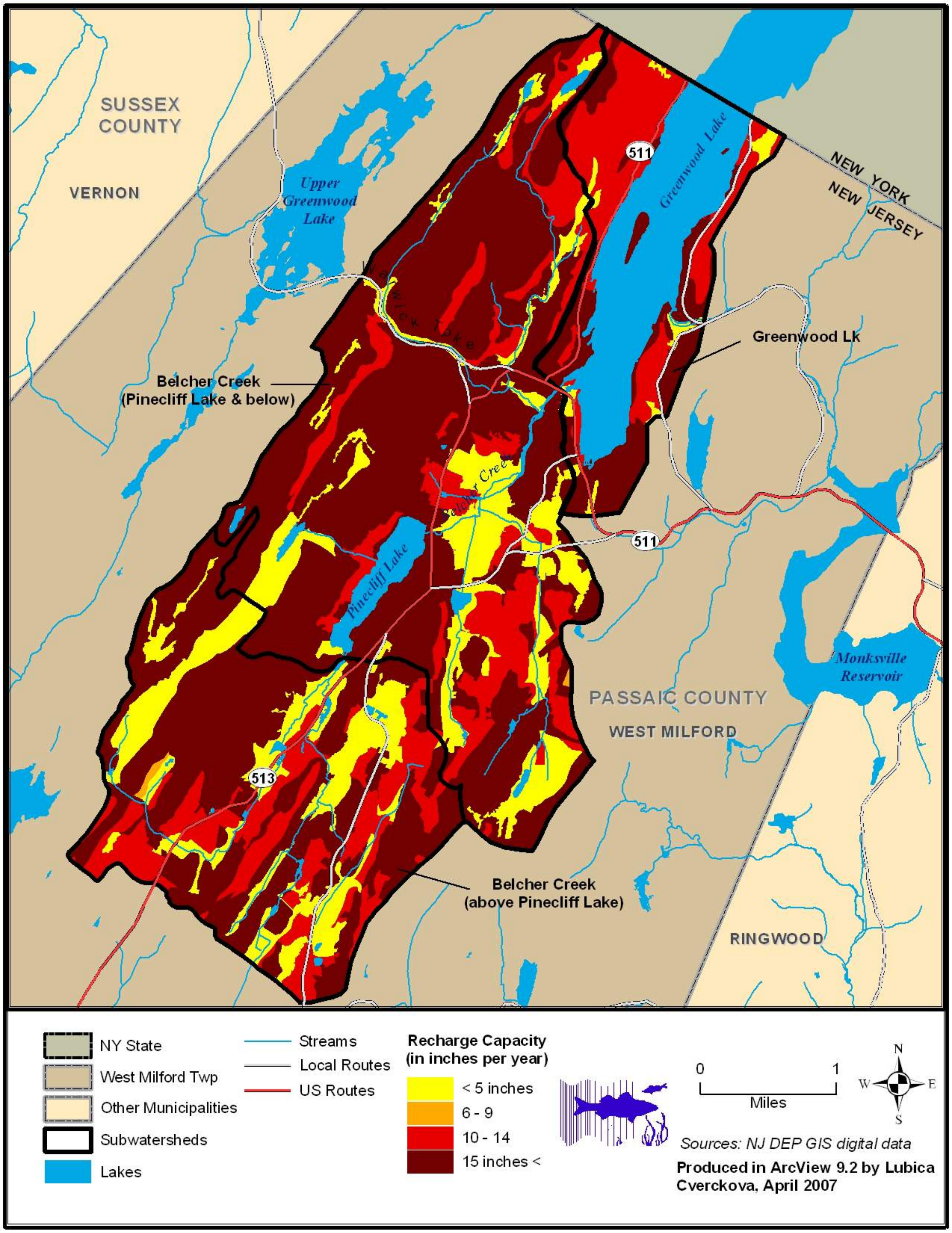
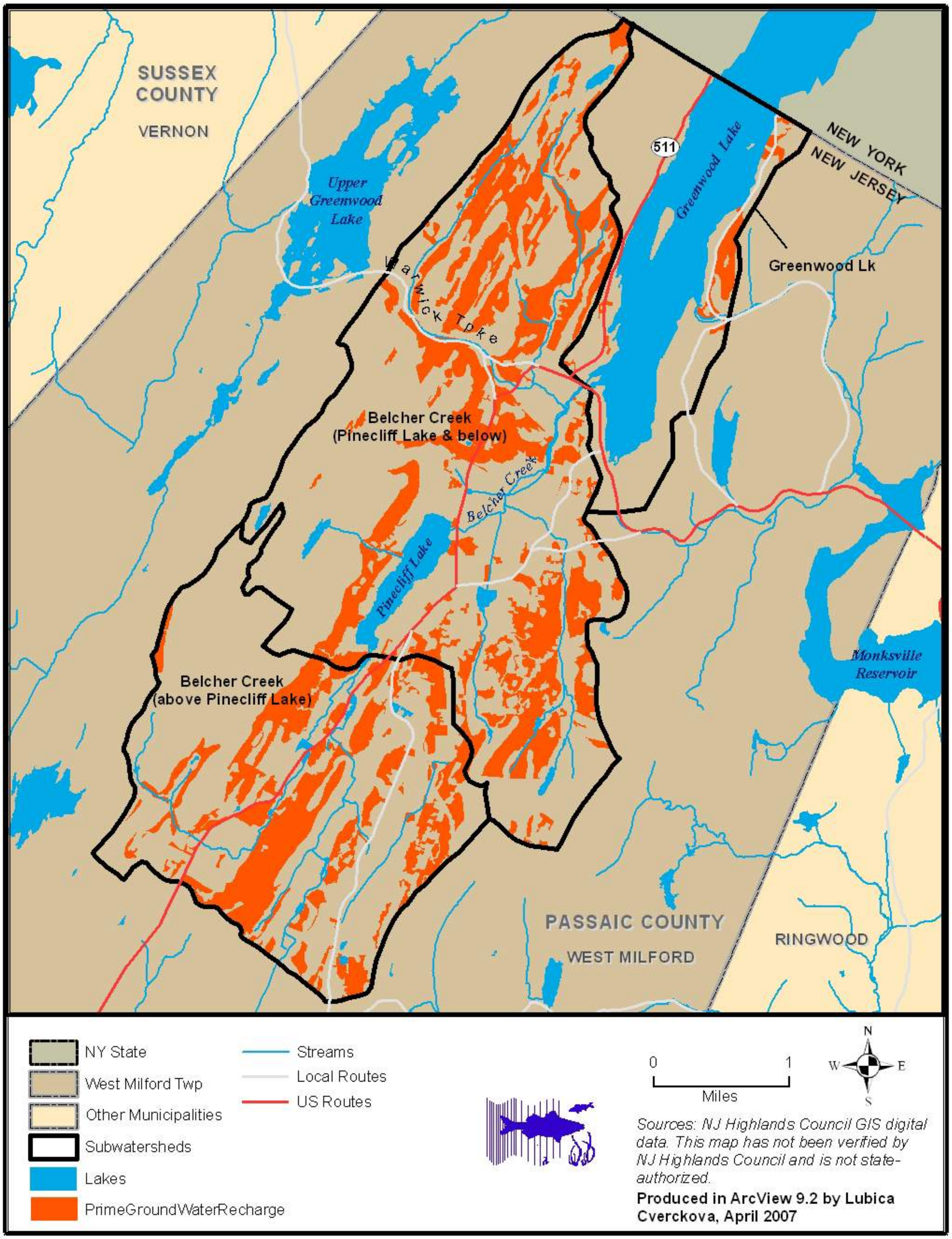


Figure II.D-6 – Prime Recharge Areas[79]



[79] State of New Jersey Highlands Water Protection and Planning Council. 2007. Highlands Final Draft Regional Master Plan, November 2007, Prime Recharge Areas, pages 43 & 45. & Water Resources Technical Report, Volume II – Water Use and Availability (Draft), January 2007, page 20.

The M^2 Associates Inc. evaluation of ground water resources discusses water balance studies in the Highlands.[80] The water balance is often described by the following equation:

$$P = GW + SW + ET$$

Estimated values for these parameters for the Greenwood Lake Watershed are as follows:

P = Precipitation = ~51.4 inches per year
ET = Evapotranspiration = ~24.7 inches per year
GW + SW = ~26.7 inches per year
SW = Surface Water Runoff = ~18.5 inches per year
GW = Ground Water Runoff = ~8.2 inches per year

Surface water runoff (SW) can account for much of the precipitation on poorly drained soils, along steep slopes, or in highly developed areas with impervious surfaces.[81] It also includes water that infiltrates soils to a shallow depth and then follows along a low permeability surface to a discharge point, such as a stream. Given the hydrogeologic conditions and the high elevations of the stream headwaters in the watershed, a surface water runoff rate (SW) of 18.5 inches per year is estimated. Ground water runoff (GW), which maintains stream base flow by storing water in wetlands, flood plains, and stream banks, as well as replenishing the bedrock aquifers, would then be 8.2 inches per year on average.

Availability of Ground Water for Water Supplies

In 1996 the New Jersey Department of Environmental Protection (NJDEP) estimated ground water availability for the New Jersey Statewide Water Supply Plan (NJSWSP). In the documentation for this plan the following is noted:[82]

> Estimating ground water availability is complex. In order to be precise, expensive and time-intensive geohydrologic investigations must be conducted. While such studies exist for some areas, uniform coverage is not available. Also, the assumptions of "acceptable impacts" vary among these studies or were not considered, so that some of these studies cannot be compared to one another. ... The NJDEP therefore developed and utilized a simplified methodology to estimate total available ground water for each of the 23 planning areas.

The method used by NJDEP was as follows:[83]

> The NJDEP estimated unconfined aquifer recharge for each of the planning areas using stream base flow separation analysis that employed a 30-year period of record ... The next step was to determine how much of the recharge could be used without harmful, regional impacts. In most regions (including the Passaic River Basin) the NJSWSP uses an assumption that twenty percent of natural recharge is available for human use without unacceptable regional impacts (although localized impacts are still possible) ... The resulting values are used as surrogate values for the true dependable yield.

The NJDEP was making the assumption that if twenty percent of natural recharge was allocated for withdrawal from the ground for use by people, then the negative impacts of such pumpage on people and other biota in the region would be acceptable to people.

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[80] *Ibid.* Pages 16-27.
[81] *Ibid.* Page 19.
[82] New Jersey Department of Environmental Protection. 1996. New Jersey Statewide Water Supply Plan. Page 31.
[83] *Ibid.* Page 32.

When water is pumped from the ground, some of it may be used and returned to the ground through septic systems. Uses of water in which the water is not returned to the ground are known as *consumptive* uses when water is returned to the air as evapotranspiration, or *depletive* uses when water is diverted either downstream in the watershed or to another watershed. Whether or not the method yields a "true" dependable yield depends upon one's view of the function of natural processes. For the Upper Passaic River watersheds, NJDEP estimated total recharge at a rate of 16 inches per year.[84] Twenty percent of this rate is 3.2 inches per year. If 3.2 inches of precipitation per year on this land can be used, then 0.15 million gallons per day (mgd) per square mile was estimated to be the dependable yield for wells in the watershed.

However, the total recharge rate of 16 inches per year was based on the New Jersey Geological Survey (NJGS) method for evaluating ground water recharge in New Jersey.[85] The NJGS states that this method is for determining "groundwater" recharge as opposed to "aquifer" recharge.[86] The M^2 Associates Inc. study suggests that the NJGS method estimates "soil" recharge rates. USGS stream flow data for the Wanaque River, Belcher Creek, and Morsetown Brook in the Greenwood Lake watershed indicate lower base flow rates than expected from the NJGS "soil" recharge rates.[87] Average "aquifer" recharge rates, which would replenish wells in the bedrock aquifers, are probably considerably less than the estimate for ground water runoff (GW) of 8.2 inches per year. In 1984 Posten evaluated stream flow data from West Brook, whose headwaters are in West Milford and which flows into the Pequannock River, and estimated that recharge rates in West Milford are about 280 gallons per day per acre, which is equivalent to 0.18 mgd per square mile or 3.8 inches per year.[88]

The NJDEP is currently revising the New Jersey Statewide Water Supply Plan, and will be revising its methods for estimating the availability of water supplies for human use. In 2004 the New Jersey Legislature adopted the "Highlands Water Protection and Planning Act", which created the Highlands Water Protection and Planning Council. The Highlands Council has been developing a Regional Master Plan. The Council recognizes that "human uses of water (both ground and surface) must take place within the context of ecological protection. Because every human use of water has the potential to affect ecological resources, methods to estimate the availability of water supplies for human use must address the acceptability of those impacts on Highlands ecological resources."[89] The Council retained the services of the US Geological Survey New Jersey Water Science Center and worked with the NJ Geological Survey to provide technical support in developing appropriate methods to assess "Ground Water Capacity" in the Highlands Region and its availability for human use.

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84 New Jersey Department of Environmental Protection. 1996. New Jersey Statewide Water Supply Plan. Page 20.

85 Charles, E.G., C. Behroozi, J. Schooley, and J.L. Hoffman. 1993. A method for evaluating ground water recharge areas in New Jersey. New Jersey Geological Survey Report GSR-32. Division of Science and Research, New Jersey Department of Environmental Protection and Energy, Trenton, NJ.

86 Mulhall, Matthew J., P.G., M^2 Associates Inc. 2003. Evaluation of Groundwater Resources of West Milford Township, Passaic County, New Jersey, November 26, 2003. Prepared for West Milford Township. Page 25.

87 *Ibid.* Page 26.

88 Mulhall, Matthew J., P.G., M^2 Associates Inc. 2003. Evaluation of Groundwater Resources of West Milford Township, Passaic County, New Jersey, November 26, 2003. Prepared for West Milford Township. Page 36.

89 New Jersey Highlands Water Protection and Planning Council. 2007. Water Resources Technical Report, Volume II-Water Use and Availability, January 2007. Page 34.

"Ground Water Capacity" is defined as "the natural ability of a subwatershed to support stream flow over time, during varied climatic conditions."[90] The method chosen for estimating the sustainability of water resources (Ground Water Capacity) calculates a Low Flow Margin of Safety (LFM) for each HUC14 subwatershed in the Highlands Region. The method estimates the median base flow for September, when base flows are usually lowest for the year, and subtracts the 7Q10 flow, which is the lowest flow over a seven day period that occurs about every ten years. The results of these analyses for the Greenwood Lake subwatersheds are reported in Table II.D-2. The Ground Water Capacity is about 3.0 inches of water per year, and the total capacity for the Greenwood Lake Watershed in New Jersey to Awosting is thus estimated at 2.53 mgd. If this amount of ground water were to be pumped out of the ground, and used consumptively or depletively, then the ground water levels in wells would go down, flows in Belcher Creek would go down or dry up, especially in late summer, and water levels during dry periods would go down in Greenwood Lake and the Monksville Reservoir. The question then becomes "how much of that capacity can be provided to human use without harm to other ground water users, the aquatic ecosystems or downstream water users."[91]

Table II.D-2 – Highlands Region Ground Water Capacities[92]

Subwatershed	*Hydrologic Unit Code (HUC)*	*Area (square miles)*	*Ground Water Capacity (mgd)*	*Ground Water Capacity (mgd per square mile)*	*Ground Water Capacity (inches per year)*
Belcher Creek (above Pinecliff Lake)	02030103070010	5.43	0.7595	0.140	2.94
Belcher Creek (Pinecliff Lake and below)	02030103070020	9.03	1.2982	0.144	3.02
Wanaque River/Greenwood Lake (New Jersey above Monksville gage)	02030103070030	14.62	2.1429	0.147	3.08

Ground Water Supplies for the Greenwood Lake Watershed

Water supplies for residents of the Greenwood Lake Watershed are pumped from domestic wells, noncommunity, or public community wells completed in fractured bedrock aquifers. The public community wells are listed in Table II.D-3, and their locations are shown on Figure II.D-7. Public community wells serve the areas shown in Figure II.D-8. A public community well provides piped, potable water to a regular consumer base of at least 25 individuals or 15 service connections throughout the year.[93]

[90] New Jersey Highlands Water Protection and Planning Council. 2007. Water Resources Technical Report, Volume II-Water Use and Availability, January 2007. Page 34.
[91] *Ibid.* Page 34.
[92] New Jersey Highlands Water Protection and Planning Council. 2007. Draft Technical Report Addenda, November 2007. Highlands Region Water Availability by HUC14 Subwatershed table following page 29.
[93] New Jersey Department of Environmental Protection and Energy. 1991. New Jersey Well Head Protection Program Plan, December 1991. New Jersey Department of Environmental Protection and Energy, CN 402, Trenton, NJ 08625. Page 3.

Most of these public community wells are owned by the West Milford Township Municipal Utilities Authority (MUA). Their water allocation permit issued in 2005 limits the diversion of ground water from 28 wells to no more than 175 million gallons per year.[94] Over all the Greenwood Lake Watershed this translates to approximately 0.026 mgd per square mile or 0.54 inches per year.

The Well Head Protection Areas for each of these wells, shown on Figure II.D-9, indicate the areas of land from which water seeps into the ground and then moves into the well within two years in Tier 1, within five years in Tier 2, and within 12 years in Tier 3. The yield capacity of all these wells in igneous and metamorphic rocks is low.

Also, many of these wells are clustered together, which means that the area providing recharge to these wells may not provide enough rainfall to sustain the withdrawal rates. The 2005 water allocation permit allowed the addition of one new well to the Awosting system because production of the existing wells had fallen off, even though there were no new service connections.[95] John Thonet notes that "declining well yields should send up a warning flag that the local aquifer in which the Awosting System is operating is probably being 'mined' and that drilling another well might not really provide a long-term solution to the problem."[96]

There are also 95 "noncommunity" wells in West Milford that provide drinking water to 25 or more people at least 60 days a year.[97] Many of these wells are in the Greenwood Lake Watershed. There are no estimates on the pumpage of water from these wells, nor from the more than 1,500 domestic wells. The critical issue that must be addressed is whether or not the water being withdrawn from the ground can be replenished by recharge on a sustainable basis, even under drought conditions. Evidence of declining water levels is unclear. The U.S. Geological Survey (USGS) does not monitor static ground water levels in the Greenwood Lake Watershed, nor does it monitor flows in Belcher Creek. Such monitoring is needed to determine whether or not ground water is being depleted in the watershed.

Replenishment of ground water is also needed "to maintain stream flows for aquatic ecology and downstream users".[98] Downstream users include millions of people in the Passaic River Basin, who have long-standing rights to this water. Consequently, the Highlands Council is recommending that only 5% of the ground water capacity calculated using the Low Flow Margin of Safety method be considered available for human use within each HUC14 subwatershed in a Protection Zone in the Highlands.[99] Thus, the "Ground Water Availability" within the Greenwood Lake Watershed in New Jersey should be limited to 5% of the "Ground Water Capacity". This is equivalent to about 7,000 gallons per day (gpd) per square mile, 11 gpd per acre, or 0.15 inches per year of rainfall. These estimated amounts are cited in Table II.D-4.

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[94] New Jersey Department of Environmental Protection, Bureau of Water Allocation. 2005. West Milford Township MUA, Water Allocation Permit - Modification. Program Interest ID: 5083.

[95] Thonet Associates Inc. 2004. Letter to Robin O'Hearn, Director, Skylands Clean, Inc., re West Milford MUA's Application for Modification of Water Allocation Permit No. 5083. Page 2.

[96] *Ibid.* Page 4.

[97] New Jersey Department of Environmental Protection. 2005. Noncommunity Source Water Assessment Report for West Milford Township, Passaic County. Website: <http://www.state.nj.us/dep/swap/>

[98] New Jersey Highlands Water Protection and Planning Council. 2007. Draft Technical Report Addenda, November 2007. Calculation of Net Water Availability, page 28.

[99] *Ibid.*

Table II.D-3 – Public Community Wells

ID	OWNER	PWSID #	SYSTEM	WELL NAME	WELL ADDRESS	WELL #
1	West Milford MUA	1615016	Olde Milford	Olde Milford Well 3	Rolling Ridge Rd	2216042
2	West Milford MUA	1615016	Olde Milford	Olde Milford Well 2	Eagle Rock Rd	4200038
3	West Milford MUA	1615016	Olde Milford	Olde Milford Well 1	Rolling Ridge Rd	2208312
4	West Milford MUA	1615014	Crescent	Well 2	Sussex St	2209496
5	West Milford MUA	1615014	Crescent	Well 1	Morris St	2208227
6	West Milford MUA	1615016	Olde Milford	Olde Milford Well 5	247 Ridge Rd	2230841
7	West Milford MUA	1615016	Olde Milford	Olde Milford Well 4	Ridge Rd	2226293
8	West Milford MUA	1615016	Olde Milford	Camelot Well 1	King Arthur Ct	2208899
9	West Milford MUA	1615018	Bald Eagle	Well 1	Concord Rd & Union Valley Rd	2221189
10	West Milford MUA	1615018	Bald Eagle	Well 2	Quincy Ln & Plymouth Alley	2222770
11	Reflection Lakes Apts	1615009		Well 1	Union Valley Rd	0000571
12	United Water NJ	1615020	West Milford	Well P2	Richmond Rd	2230019
13	United Water NJ	1615020	West Milford	Well E2	Cahill Rd	2227686
14	West Milford MUA	1615006	Parkway	Well 1	Maise Ln	2218282
15	United Water NJ	1615020	West Milford	Well I-2	Richmond Rd	2227685
16	United Water NJ	1615020	West Milford	Well T3	Lafayette St	2230283
17	United Water NJ	1615020	West Milford	Well A	Lafayette St	2224508
18	West Milford MUA	1615001	Birch Hill Park	Well 1A	Moore Rd & Marshall Hill Rd	2213427
19	West Milford MUA	1615001	Birch Hill Park	Well 1B	Moore Rd & Marshall Hill Rd	2209832
20	West Milford MUA	1615001	Birch Hill Park	Well 2	Marshall Hill Rd & Lincoln Ave	2238968
21	West Milford MUA	1615001	Birch Hill Park	Well 2A	Marshall Hill Rd & Lincoln Ave	2238969
22	West Milford MUA	1615002	Greenbrook	Well 3 (Pool Well)	GreenBrook Dr & Palmetto Ln	4200039
23	West Milford MUA	1615012	Awosting	Well 3A	Awosting Rd	2223740
24	West Milford MUA	1615002	Greenbrook	Well 2	Woodland Ave	2228061
25	West Milford MUA	1615012	Awosting	Well 3	Awosting Rd	2213327
26	West Milford MUA	1615002	Greenbrook	Well 1	Woodland Ave	2225674
27	West Milford MUA	1615012	Awosting	Well 1	Awosting Rd	4200015
28	West Milford MUA	1615012	Awosting	Well 4	Awosting Rd	2307160
29	West Milford MUA		Greenwood Lake	Greenwood Lake Beach	Lake Park Terrace	2301832

Figure II.D-7 – Public Community Wells

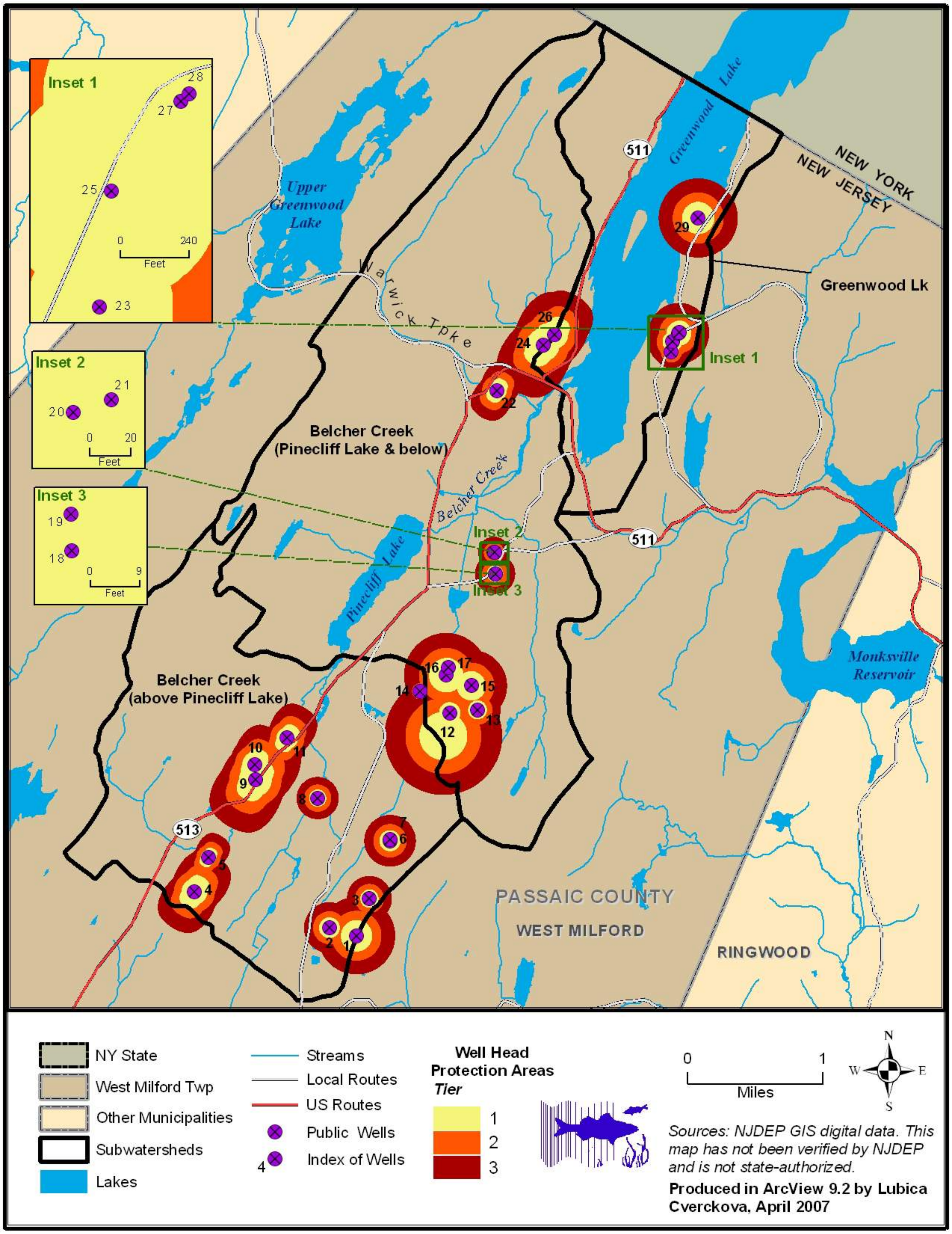
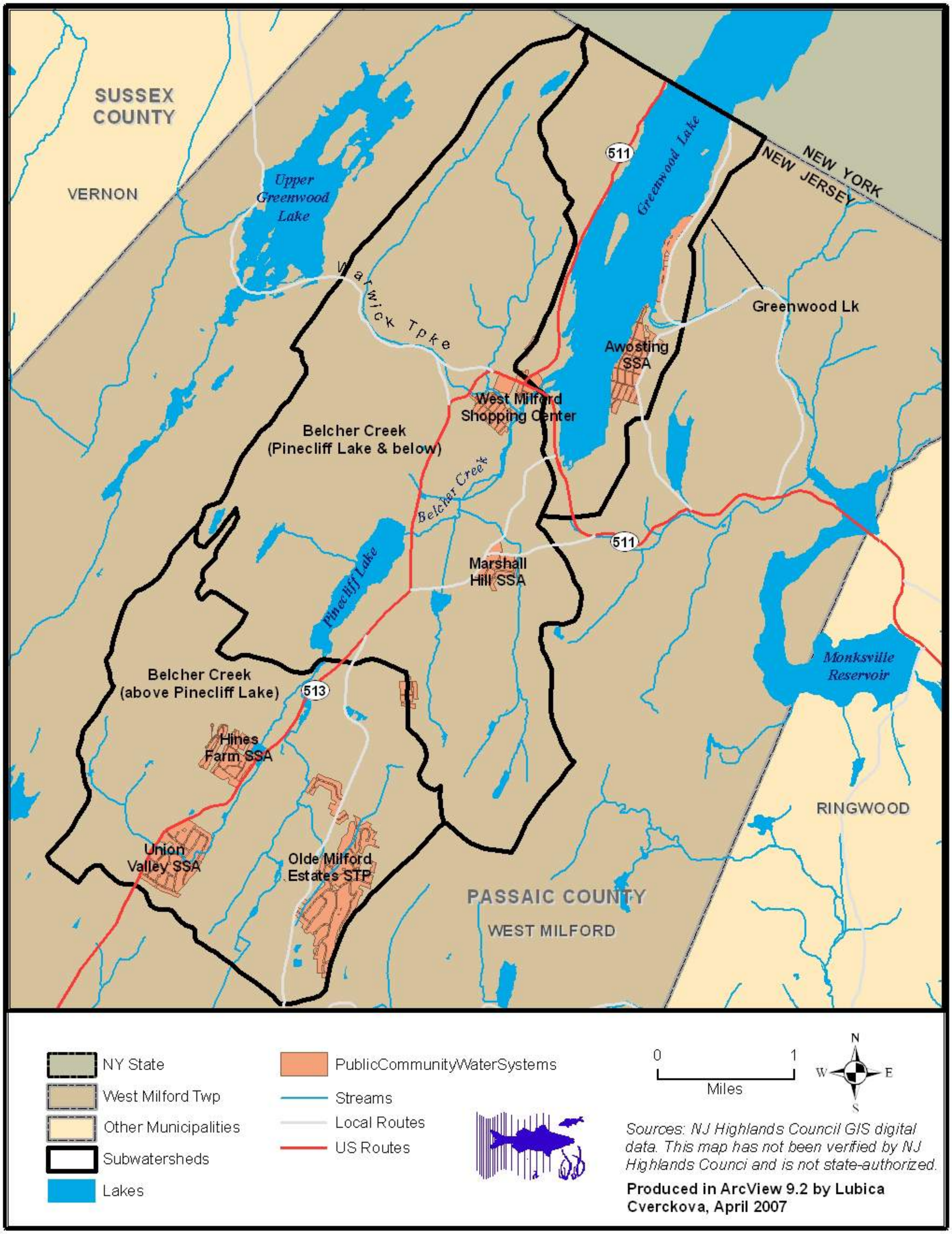


Figure II.D-8 – Service Areas for Public Community Wells



Staff of the Highlands Council has estimated existing consumptive/depletive uses using 2003 NJDEP permit data and estimates for domestic well and septic system use.[100] "Consumptive/depletive uses are those uses that are not returned to the subwatershed by a discharge back into the ground or a stream."[101] Septic systems are a major way of returning water to the ground, so discharges to septic systems are not consumptive/depletive uses. Sewer systems that discharge water into another subwatershed are depletive uses. Consumptive/depletive uses greatly exceed the Ground Water Availability in all three subwatersheds in the Greenwood Lake Watershed, as reported in Table II.D-4. The Net Water Availability is in serious deficit. Consumptive/depletive uses throughout the watershed are about 3.5 times the Ground Water Availability, and in the Belcher Creek above Pinecliff Lake subwatershed, they are over 5 times what should be used to sustain and restore the ecology of the watershed, and to supply clean water to users throughout the Passaic River Basin. Therefore, any increase in withdrawals of ground water in the Greenwood Lake Watershed should probably be avoided, and water conservation should be encouraged.

Table II.D-4 – Ground Water Availability and Consumptive/Depletive Use[102]

Subwatershed	*Area (square miles)*	*Ground Water Availability (mgd)*	*Total Consumptive/ Depletive Uses (mgd)*	*Net Water Availability (mgd)*
Belcher Creek (above Pinecliff Lake)	5.43	0.038	0.1965	(0.159)
Belcher Creek (Pinecliff Lake and below)	9.03	0.065	0.1780	(0.113)
Greenwood Lake (NJ, above Awosting gage)	3.20	0.024	0.0730	(0.049)
Greenwood Lake Watershed (NJ)	17.66	0.126	0.4475	(0.321)

Ground Water Quality

Some of the water that is being pumped out of these wells is being used for drinking water. How safe is it to drink? The New Jersey Department of Environmental Protection (NJDEP), with the aid of the US Geological Survey (USGS), has developed Source Water Assessment Reports for all the community and noncommunity public water systems in New Jersey. These reports are available on the Internet.[103] The Source Water Assessment Program developed susceptibility or vulnerability ratings for various types of potential contamination. The susceptibility ratings for the public community wells in the Greenwood Lake Watershed in New Jersey are summarized in Table II.D-5. All of these wells take water from unconfined aquifers in igneous and metamorphic rocks. These ratings do not reflect the presence or existence of contamination in these wells. The percentage of the susceptibility ratings found in unconfined ground water wells

[100] New Jersey Highlands Water Protection and Planning Council. 2007. Draft Calculation of Net Water Availability, October 31, 2007.
[101] *Ibid.*
[102] New Jersey Highlands Water Protection and Planning Council. 2007. Draft Technical Report Addenda, November 2007. Highlands Region Water Availability by HUC14 Subwatershed, table following page 29. Greenwood Lake (NJ, above Awosting gage) subwatershed values are estimated from values cited for Wanaque River/Greenwood Lake (above Monksville gage) subwatershed.
[103] New Jersey Department of Environmental Protection, Bureau of Safe Drinking Water. 2005. Source Water Assessment Program. Website: <http://www.state.nj.us/dep/swap/>

throughout New Jersey are compared with those for the wells in the Greenwood Lake Watershed in Table II.D-5.[104]

Table II.D-5 – Susceptibility Ratings for Community Wells in Greenwood Lake Watershed[105] Compared with Ratings for Unconfined Community Ground Water Wells in New Jersey[106]

Type of Potential Contamination	*High (Greenwood Lake)*	*High (New Jersey)*	*Medium (Greenwood Lake)*	*Medium (New Jersey)*	*Low (Greenwood Lake)*	*Low (New Jersey)*
Pathogens	7%	6%	27%	56%	67%	38%
Nutrients	37%	67%	43%	30%	20%	3%
Pesticides	0%	0%	0%	34%	100%	66%
Volatile Organic Compounds (VOCs)	7%	61%	0%	1%	93%	38%
Inorganics	0%	39%	47%	33%	53%	28%
Radionuclides	0%	50%	60%	47%	40%	3%
Radon (Rn)	**87%**	50%	13%	46%	0%	4%
Disinfection Byproducts (DBPs)	7%	26%	93%	74%	0%	0%

Radon is a radioactive gaseous element that occurs naturally in some of the bedrocks in the Highlands at higher levels than it occurs elsewhere in New Jersey. All the ratings for other potential pollutants may indicate a lower potential on average for contamination of these wells than for wells in other parts of New Jersey. Nevertheless, diligent care is needed to prevent contamination of ground water in this watershed.

Ground water from the public community wells is routinely monitored for over 80 drinking water contaminants in accordance with Federal and State laws. The Annual Drinking Water Quality Reports of the West Milford Township Municipal Utilities Authority (West Milford MUA) for 2005, 2006, and 2007 indicate that the water pumped from the Birch Hill, Crescent Park, and Olde Milford well systems did not contain any contaminants at levels above their recommended upper limits (RULs).[107] In the Greenbrook, Awosting, and Bald Eagle systems some manganese and iron were found at concentrations above their RULs. These elements are naturally occurring in ground water. They are essential nutrients and are not toxic in drinking water at the levels found. However, in 2005 lead was found in the Parkway well water at levels that violated the New Jersey standard, and which triggered a requirement for further treatment of the water. In 2006 and 2007 water from this well was in compliance with the standard for lead.

[104] New Jersey Department of Environmental Protection. 2005. Source Water Assessment Program, Source Water Assessments (Reports & Summaries), various reports and summaries for Passaic County, West Milford Township, and for New Jersey. Website: <http://www.state.nj.us/dep/swap/>

[105] 30 wells.

[106] 1,597 wells.

[107] West Milford Township Municipal Utilities Authority. 2008. Annual Drinking Water Quality Reports for 2005, 2006, 2007 for Birch Hill (PWSID #1615001), Greenbrook (PWSID #1615002), Parkway (PWSID #1615006), Awosting (PWSID #1615012), Crescent Park (PWSID #1615014), Olde Milford (PWSID #1615016), and Bald Eagle (PWSID #1615018) Systems.

United Water New Jersey reports that there were no violations of drinking water standards during 2006 in water from their five wells that serve the Bald Eagle Commons complex.[108]

There are also 95 public noncommunity wells in West Milford. The Source Water Assessment Program (SWAP) susceptibility ratings for these wells are compared with those of noncommunity ground water wells throughout New Jersey in Table II.D-6.[109] Contamination from radon or radionuclides is usually due to natural causes. Ground water contamination from volatile organic compounds (VOCs) or pathogens, such as fecal coliform, comes primarily from human sources.

Table II.D-6 – Susceptibility Ratings for Noncommunity Wells in West Milford[110] Compared with Noncommunity Ground Water Wells in New Jersey[111]

Type of Potential Contamination	*High (West Milford)*	*High (New Jersey)*	*Medium (West Milford)*	*Medium (New Jersey)*	*Low (West Milford)*	*Low (New Jersey)*
Pathogens	0%	2%	**37%**	18%	63%	80%
Nutrients	0%	0%	47%	66%	53%	34%
Pesticides	0%	0%	47%	66%	53%	34%
Volatile Organic Compounds (VOCs)	**57%**	32%	0%	0%	43%	68%
Inorganics	0%	19%	6%	42%	94%	39%
Radionuclides	7%	69%	**75%**	28%	18%	3%
Radon (Rn)	1%	17%	**99%**	72%	0%	11%
Disinfection Byproducts (DBPs)	0%	3%	100%	97%	0%	0%

Surface Water Quality

The New Jersey Department of Environmental Protection (NJDEP) has designated the uses surface waters should have, and what surface water quality standards these waters should meet in order to maintain these uses.[112] Surface water bodies in the Greenwood Lake Watershed were classified as indicated in Table II.D-7 in 2006.[113]

[108] United Water Mid-Atlantic. 2007. Consumer Confidence Report, United Water New Jersey/West Milford System (PWSID #1615020), 2006. Website: <www.UNITEDWATER.com>

[109] New Jersey Department of Environmental Protection, Bureau of Safe Drinking Water. 2005. Source Water Assessment Program. Noncommunity Source Water Assessment Report for West Milford Twp., Passaic County, April 2005. Website: <http://www.state.nj.us/dep/swap/>

[110] 95 wells.

[111] 3,480 wells.

[112] N.J. Department of Environmental Protection. 2006. Surface Water Quality Standards, N.J.A.C. 7:9B.

[113] N.J. Department of Environmental Protection. 2006. Surface Water Quality Standards, N.J.A.C. 7:9B-1.15(e), October 2006.

Table II.D-7 – Use Classifications of Surface Water Bodies

Water Body	*Subwatershed*	*Classification*
All surface water bodies within Abram S. Hewitt State Forest, including West Pond and upstream portions of Green Brook, and Surprise Lake and upstream portions of Cooley Brook	Belcher Creek (Pinecliff Lake & below)	FW1
Green Brook, downstream from Hewitt State Forest	"	FW2-TP (C1)
Cooley Brook, downstream from Hewitt State Forest	"	FW2-TP (C1)
Belcher Creek, entire length	"	FW2-NT
Belcher Creek, entire length	Belcher Creek (above Pinecliff Lake)	FW2-NT
Greenwood Lake	Greenwood Lake	FW2-TM
Wanaque River, Greenwood Lake outlet and below	Greenwood Lake	FW2-TM (C1)

FW stands for fresh water. The FW1 classification is reserved for waters that are "set aside for posterity to represent the natural aquatic environment and its associated biota".[114] They are also classified as "Outstanding National Resource Waters". The quality of these waters is to be maintained "in their natural state".[115]

The FW2 designation means that these waters are supposed to be clean enough to be used for the "maintenance, migration, and propagation of the natural and established biota," and for "primary and secondary contact recreation, industrial and agricultural water supply, and public potable water supply after conventional filtration treatment."[116] FW2 waters may be trout production waters (TP) which are used by trout "for spawning or nursery purposes during their first summer".[117] Trout maintenance waters (TM) should be able to support trout throughout the year. Nontrout waters (NT) are generally not suitable for trout, "but are suitable for a wide variety of other fish species".[118] There are trout production (TP), trout maintenance (TM), and nontrout (NT) waters in the Greenwood Lake Watershed, as illustrated in Figure II.D-9. Category One (C1) waters are to be protected "from measurable changes in water quality characteristics because of their … exceptional water supply significance, or exceptional fisheries resource(s)".[119]

NJDEP issued an "Integrated Water Quality Monitoring and Assessment Report" in 2006.[120] Their findings are reported in Table II.D-8.[121]

114 N.J. Department of Environmental Protection. 2006. Surface Water Quality Standards, N.J.A.C. 7:9B-1.12(a).
115 N.J. Department of Environmental Protection. 2006. Surface Water Quality Standards, N.J.A.C. 7:9B-1.14(a).
116 N.J. Department of Environmental Protection. 2006. Surface Water Quality Standards, N.J.A.C. 7:9B-1.12(c).
117 N.J. Department of Environmental Protection. 2006. Surface Water Quality Standards, N.J.A.C. 7:9B-1.4.
118 *Ibid.*
119 N.J. Department of Environmental Protection. 2006. Surface Water Quality Standards, N.J.A.C. 7:9B-1.4.
120 NJ Department of Environmental Protection, Water Monitoring and Standards. 2006. New Jersey Integrated Water Quality Monitoring and Assessment Report, 2006. Website: <http://www.state.nj.us/dep/wms/bwqsa/>
121 NJ Department of Environmental Protection, Water Monitoring and Standards. 2006. New Jersey Integrated Water Quality Monitoring and Assessment Report, 2006. Appendix B (New Jersey's 303(b) List of Impaired Waters) & Appendix C.

Figure II.D-9 – Trout Classifications

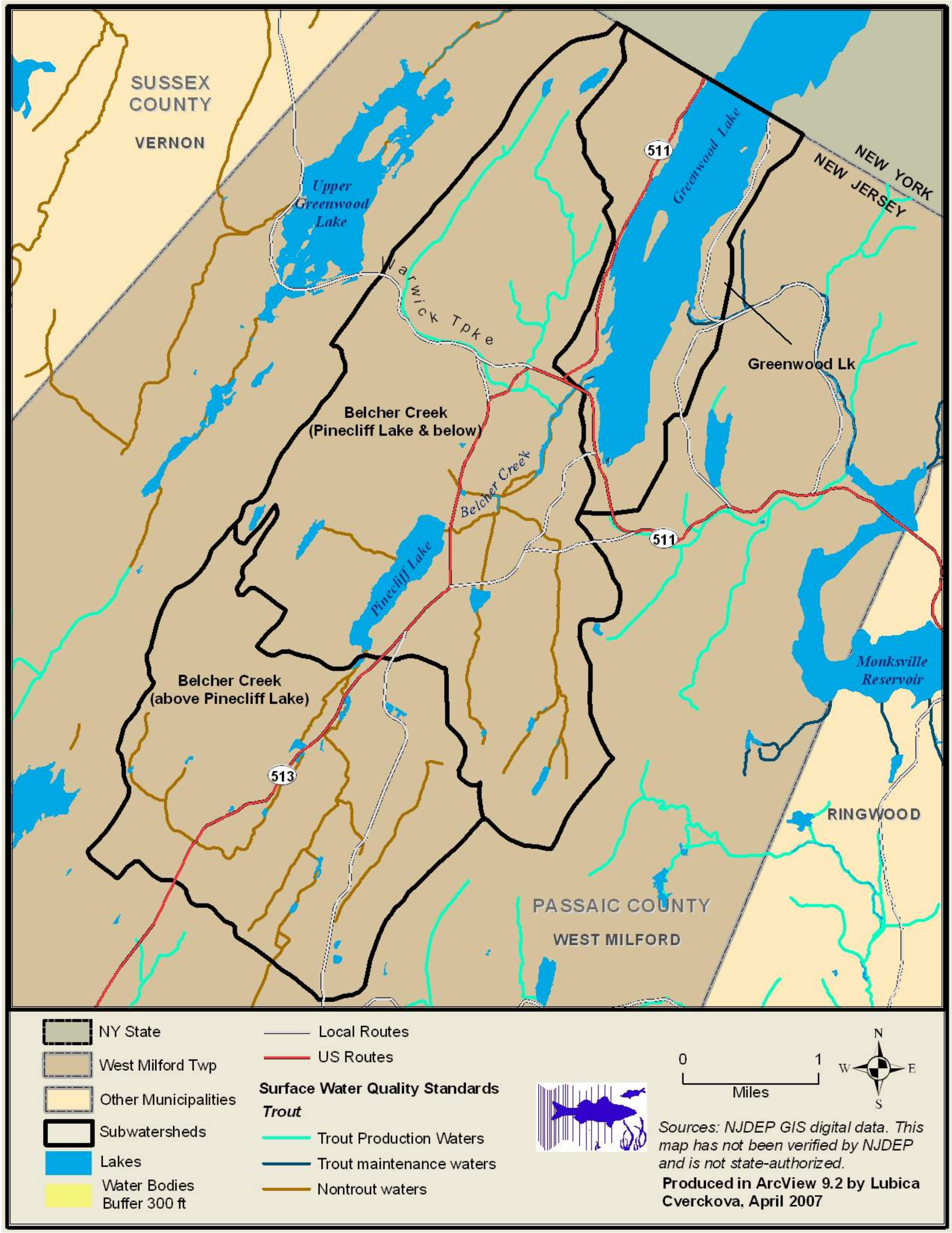


Table II.D-8 – 2006 Water Quality Assessments

Water Body Use	*Belcher Creek (above Pinecliff Lake)*	*Belcher Creek (Pinecliff Lake & below)*	*Wanaque River/ Greenwood Lake*	*Greenwood Lake*	*Pinecliff Lake*
Aquatic Life (general)	Sublist 3	Sublist 5	Sublist 1	Sublist 5	Sublist 3
Aquatic Life (trout)	N/A	Sublist 5	Sublist 1		
Primary Contact Recreation	Sublist 3	Sublist 3	Sublist 1	Sublist 2	Sublist 2
Secondary Contact Recreation	Sublist 3	Sublist 2	Sublist 1		
Recreation (Aesthetics)				Sublist 4A	Sublist 3
Drinking Water Supply	Sublist 3	Sublist 2	Sublist 1		
Agricultural Water Supply	Sublist 3	Sublist 2	Sublist 1		
Industrial Water Supply	Sublist 3	Sublist 2	Sublist 1		
Fish Consumption	Sublist 3	Sublist 3	Sublist 3	Sublist 5	Sublist 3

The reasons for the placement of a water body in a sublist category are described below:

1. Sublist 1 indicates that there is sufficient data to assess the designated uses for the water body, and that the water body is in full attainment of the standards for designated uses.
2. Sublist 2 designations indicate full attainment for the indicated use, but other designated uses are unassessed.
3. Sublist 3 indicates that there are insufficient data or no data to assess the designated use.
4. Sublist 4A means that the water body is impaired for the designated use, and that a TMDL has been adopted.
5. Sublist 5 means that the use assessment is complete, and indicates non-attainment of standards for the designated use.

The Wanaque River below the Greenwood Lake dam is on Sublist 1 for most uses because water quality monitoring has occurred. The waters in the Belcher Creek subwatershed above Pinecliff Lake and in Pinecliff Lake have not been adequately tested, as indicated by their Sublist 3 classifications, to assess their quality. Pinecliff Lake is clean enough for swimming (Sublist 2 for Primary Contact Recreation). Some data have been gathered regarding water quality in Belcher Creek before the Creek empties into Greenwood Lake. These data indicate that Aquatic Life is impaired in Belcher Creek below Pinecliff Lake. Greenwood Lake is impaired for Aquatic Life, Fish Consumption, and Recreation.

Greenwood Lake, into which Belcher Creek flows, is severely impaired by the excessive growth of algae and other nuisance plants. The NJDEP determined that Greenwood Lake is eutrophic, and impaired with regard to the Surface Water Quality Standards (SWQS) for phosphorus. In order to restore an impaired water body to a more healthy condition, the State creates a plan for the restoration of the waterway, called a “Total Maximum Daily Load” or “TDML” plan. The Total Maximum Daily Load (TMDL) for Phosphorus to Address Greenwood Lake in the Northeast Water Region, which was approved in September 2004, partially addresses this impairment. The TMDL requires an overall 37% reduction in loadings of total phosphorus for Greenwood Lake, and over 40% of these loadings come from the Belcher Creek Watershed.

Every two years, states must submit what is called an “impaired waters list” or “303(d)” list to the U.S. Environmental Protection Agency (EPA).[122] This list is mandated as part of the Clean Water Act. A waterway is determined to be “impaired” if its water quality does not meet the state's standards. The 2006 303(d) List of Impaired Waters (Sublist 5) includes the impairments listed in Table II.D-9.[123] These impairments and others, and how to address them are discussed at length in subsequent sections of this report.

Table II.D-9 – 303(d) List of Impaired Waters (Sublist 5)[124]

Assessment Unit Name/ Water Body	*2004 Impairment*	*2006 Impairment*	*Priority Ranking*
Greenwood Lake-03	Dissolved Oxygen	Dissolved Oxygen	Medium
Greenwood Lake-03	Sedimentation	Total Suspended Solids	Medium
Greenwood Lake-03		Mercury	Medium
Belcher Creek (Pinecliff Lake & below)	Benthic Macroinvertebrates	Temperature	Low

Potential Sources of Pollution in Ground and Surface Waters

In 2005 the New Jersey Department of Environmental Protection (NJDEP) reported that there were 20 Known Contaminated Sites in the Greenwood Lake Watershed at which cleanup was being actively pursued.[125] These sites are listed in Table II.D-10. The locations of these sites are shown on Figure II.D-10. NJDEP updated its list of Known Contaminated Sites in 2006, and three of these sites are no longer on the list, presumably because the sites have been cleaned up, or because “No Further Action” (NFA) is required by NJDEP at these sites.[126] At many of these sites, the contamination is caused by leaking underground storage tanks. At one of the sites, #16, the source of the contamination is unknown. Any of these cases could cause contaminants to leach into ground water, and well water might become contaminated.

The NJDEP has established a Classification Exception Area (CEA) at three of the sites (#11, #12, and #19). The extent of these CEAs is depicted in Figure II.D-10. CEAs are institutional controls in geographically defined areas within which the New Jersey Ground Water Quality Standards (NJGWQS) for specific contaminants have been exceeded. When a CEA is designated for an area, the constituent standards and designated aquifer uses are suspended for the term of the CEA. The CEA coverage was developed to provide information regarding the spatial extent of groundwater contamination within designated CEAs and Well Restriction Areas (WRAs). These data, in geographic format, are intended to provide information to the public regarding areas of contaminated groundwater, and to aid in new well placement and installation.[127]

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[122] Section 303(d) of the Federal Clean Water Act (33 U.S.C. 1313(d)).
[123] NJ Department of Environmental Protection, Water Monitoring and Standards. 2006. New Jersey Integrated Water Quality Monitoring and Assessment Report, 2006. Appendix B, New Jersey’s 303(d) List of Impaired Waters. & Appendix C, 2006 Integrated Report Delisting Document.
[124] *Ibid.*
[125] NJ Department of Environmental Protection, Site Remediation Program. 2005. Known Contaminated Sites in NJ. Website: <http://www.state.nj.us/dep/srp/kcs-nj/>
[126] NJ Department of Environmental Protection, Site Remediation Program. 2006. Known Contaminated Sites in NJ. Website: <http://www.state.nj.us/dep/srp/kcs-nj/passaic/>
[127] Website: <http://www.nj.gov/dep/gis/digidownload/metadata/statewide/cea.htm>

Table II.D-10 – Known Contaminated Sites

ID	*Name*	*Address*	*Status*
1	27 EAGLE ROCK ROAD	27 EAGLE ROCK RD	Active
2	CRESCENT PARK WATER STORAGE TANK	SUSSEX DR	NFA?
3	56 BRADRICK LANE	56 BRADRICK LN	NFA?
4	144 VREELAND RD	144 VREELAND RD	NFA?
5	7 MOUNT CIRCLE NORTH	7 MT CIR N	Active
6	498 RIDGE ROAD	498 RIDGE ROAD	Active
7	11 MAISIE LANE	11 MAISIE LN	Active
8	MOBIL 57215	1367 UNION VALLEY RD	CKE/ Active
9	TOWNE CENTER INCORPORATED	1463 UNION VALLEY RD	CKE/ Active
10	WEST MILFORD ANNEX	1477 UNION VALLEY RD	Active
11	WEST MILFORD EXXON #35139	2 MARSHALL HILL RD	CEA/ Active
12	WEST MILFORD DEPT OF PUBLIC WORKS MAIN GARAGE	30 MARHILL RD	CEA/ Active
13	89 LINCOLN AVE	89 LINCOLN AVE	Active
14	A TO Z AUTOMOTIVE REPAIR CENTER	1692 UNION VALLEY RD	CKE/ Active
15	4MZA INC	1891 GREENWOOD LAKE TPKE	Active
16	STAINSBY COURT GROUND WATER CONTAM	STAINSBY CT&LAKESIDE RD & GREENWOOD LAKE	Active
17	J & D CLEANERS @ 2019 GREENWOOD LAKE TPKE STR	2019 GREENWOOD LAKE TPKE	Active
18	WEST MILFORD SHOPPING PLAZA	1926 UNION VALLEY RD	Active
19	LAKESIDE AMOCO	2 LAKESIDE DR	CEA/ Active
20	MOBIL #57360	1910 UNION VALLEY RD	Active

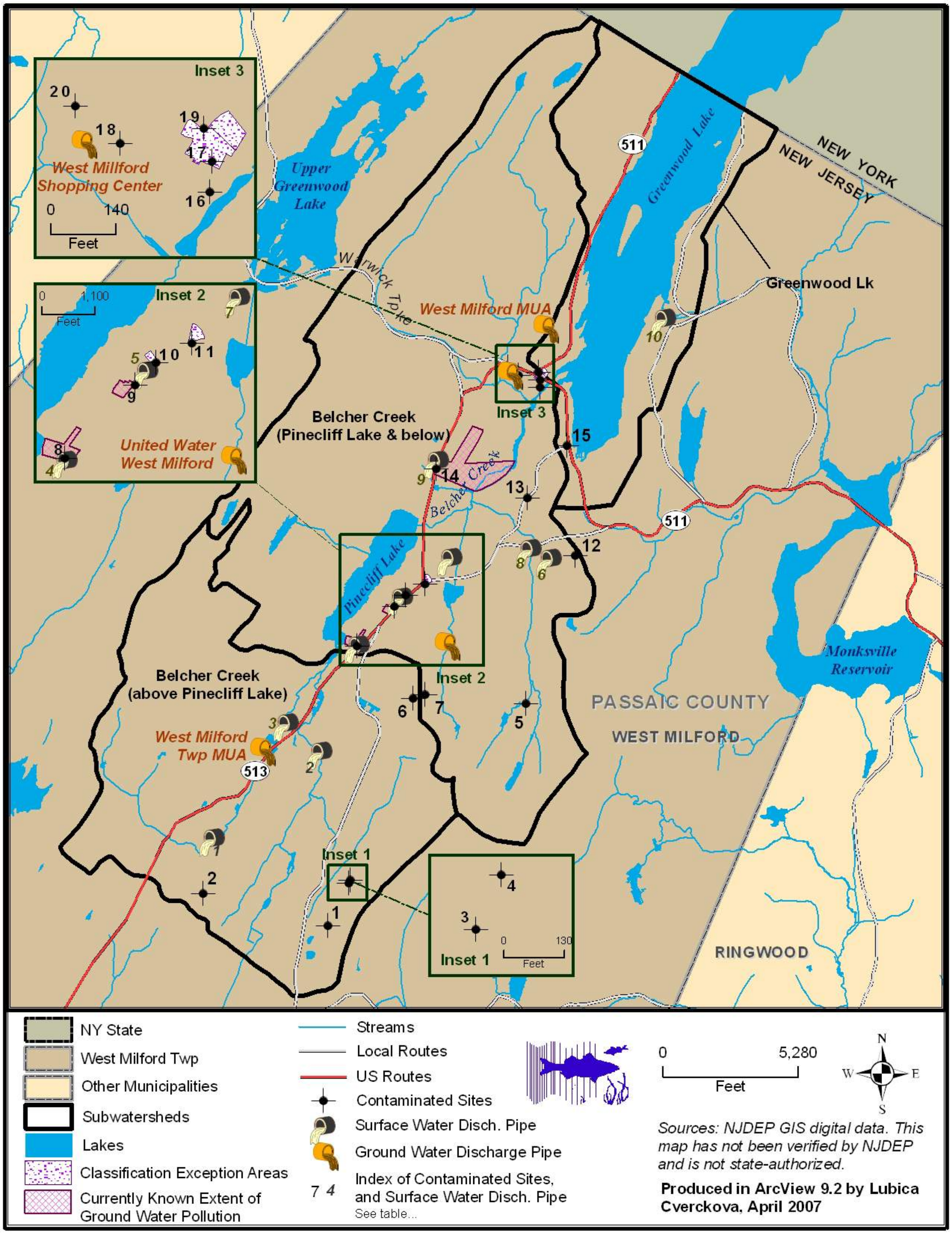
Table II.D-11 – Discharges to Surface Water

Name of Site	*NJPDES Permit #*	*Surface Water*	*ID*
West Milford Twp MUA, Crescent Park STP	NJ0026174	Belcher Creek	1
West Milford Twp MUA, Olde Milford	NJ0027677	Belcher Creek via unnamed tributary	2
Reflection Lake Garden Apartments	NJ0027201	Belcher Creek via unnamed tributary and ditch	3
Mobil S/S 15-BF2	NJG0076511	Pinecliff Lake (Belcher Cr) via storm sewer	4
Texaco Refining & Marketing	NJG0129488	Belcher Creek via storm sewer	5
West Milford Twp BOE - Marshall Hill		Morsetown Brook (Belcher Creek)	6
West Milford Shopping Center	NJ0024414	Belcher Creek via unnamed tributary	7
West Milford Twp MUA, Birch Hill	NJ0028541	Morsetown Brook (Belcher Creek)	8
A-Z Automotive	NJG0134660	Belcher Creek	9
West Milford Twp MUA, Awosting	NJ0027669	Wanaque River via ditch	10

Table II.D-12 – Discharges to Ground Water

Name of Site	*Address*	*NJPDES Permit #*	
West Milford MUA, Greenwood Townhouse Assoc.	22 Lakeside Road	NJ0065706	
West Milford Shopping Center	1926 Union Valley Road	NJ0087530	
United Water West Milford	Morsetown Road	NJ0081914	
West Milford Township MUA, Bald Eagle Village	1480 Union Valley Road	NJ0051098	

Figure II.D-10 – Known Contaminated Sites



At three of the sites (#8, #9, #14), as shown in Figure II.D-10, the Currently Known Extent (CKE) of ground water pollution has been identified. CKE areas are geographically defined areas within which the local ground water resources are known to be compromised because the water quality exceeds drinking water and ground water quality standards for specific contaminants. Historically, a number of the CKEs have also been identified as Well Restriction Areas (WRAs). Unless precautionary measures are taken to protect potable water users, well installation should be avoided.[128]

Surface Water Discharge Pipes are also shown on Figure II.D-10, and the sources of the water being discharged are listed in Table II.D-11. The locations of Ground Water Discharge Pipes are also shown on Figure II.D-10. These discharges are operated by the facilities listed in Table II.D-12.

Six of the discharges to surface water are treated sanitary wastewater from sewage treatment plants (STPs). The locations of these STPs are shown in Figure II.D-11. They are identified in Table II.D-13. The point source discharges from these STPs are regulated under New Jersey Pollutant Discharge Elimination System (NJPDES) permits. The areas served by these STPs are shown in Figure II.D-12. In all other areas of the Greenwood Lake Watershed waste water is usually treated in septic systems.

Table II.D-13 – Sewage Treatment Plants

NJPDES Permit Number	*Facility Name*	*Receiving Water*	*Maximum Allowable Flow (mgd)*[129]	*Surface Water Discharge Pipe ID #*
NJ0028541	West Milford MUA, Birch Hill Park STP	Morsetown Brook (Belcher Creek)	0.02	8
NJ0027677	West Milford MUA, Olde Milford Estates STP	Belcher Creek via unnamed tributary	0.172	2
NJ0027669	West Milford MUA, Awosting STP	Wanaque River		10
NJ0027201	Reflection Lakes Garden Apartments STP	Belcher Creek via unnamed tributary	0.005	3
NJ0026174	West Milford MUA, Crescent Park STP	Belcher Creek	0.064	1
NJ0024414	West Milford Shopping Center STP	Belcher Creek via unnamed tributary	0.02	7

[128] Website: <http://www.nj.gov/dep/gis/digidownload/metadata/statewide/cke.htm>

[129] New Jersey Department of Environmental Protection, Division of Watershed Management. 2004. Amendment to the Northeast Water Quality Management Plan, Total Maximum Daily Load for Phosphorus to Address Greenwood Lake in the Northeast Region. Proposed: June 7, 2004; approved: Sept. 2004. Table 2, page 11.

Figure II.D-11 – Sewage Treatment Plants

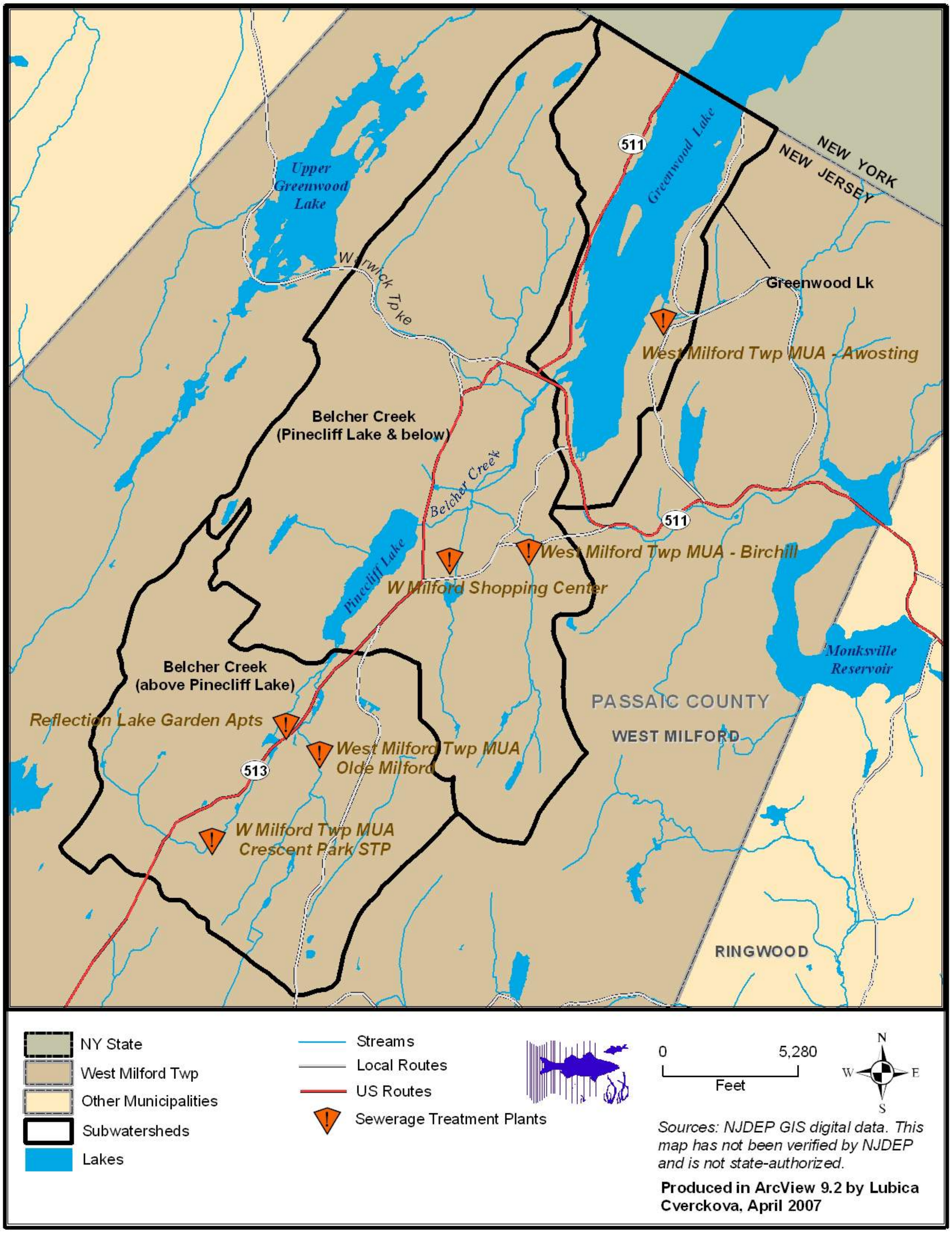
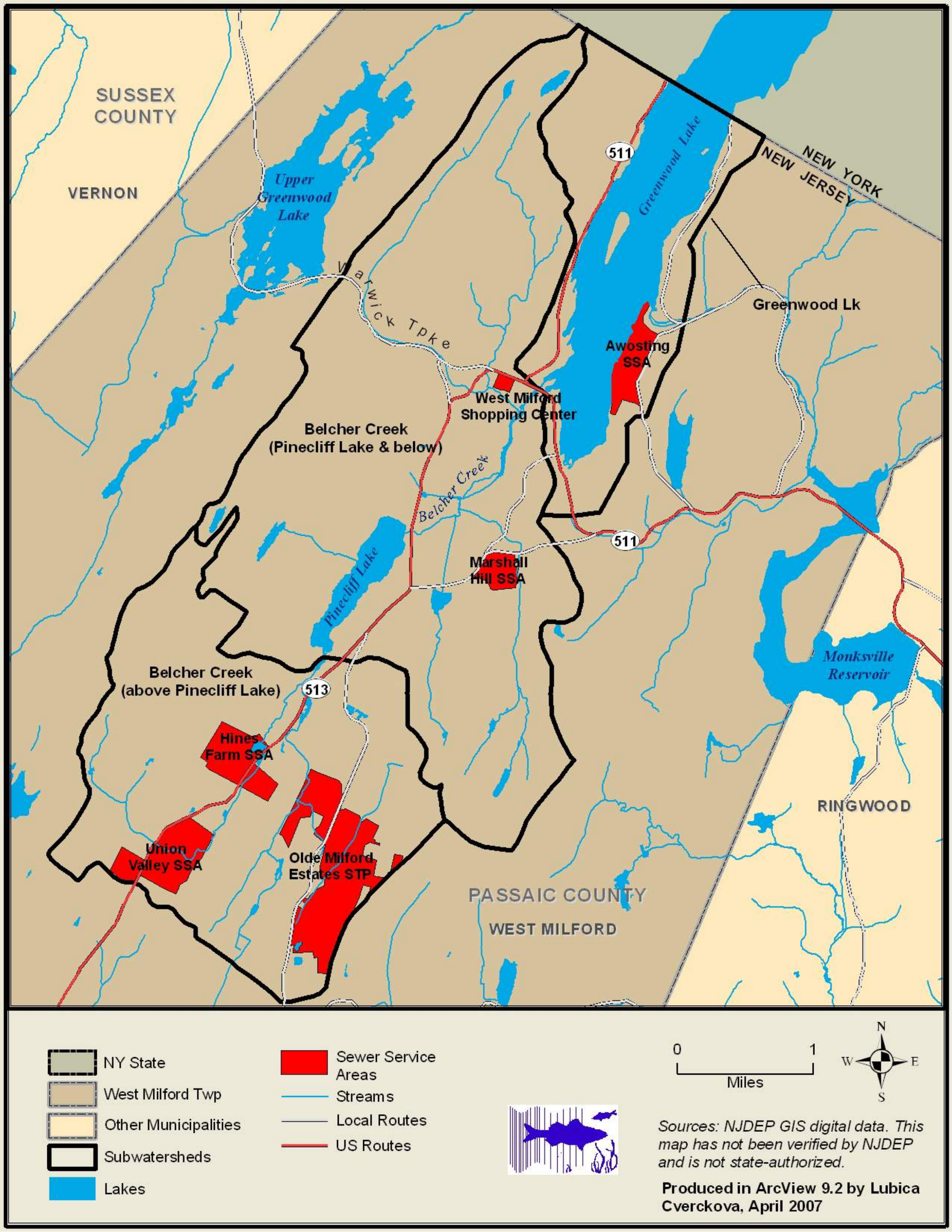


Figure II.D-12 –Sewer Service Areas



Septic systems, which are also called On-site Wastewater Treatment Systems (OWTS), are significant potential sources of ground water and surface water contamination in the watershed. There are about 2,392 homes within the New Jersey end of the Greenwood Lake Watershed.[130] Of these homes 86% are on private wells, and 92% have some type of OWTS.[131] Discharges from these OWTS are impacting water quality in the well water and in the surface waters.

Other potential sources of pollutants, primarily in surface waters, are nonpoint sources (NPS), such as storm water runoff and air deposition, and internal loading. Past and present uses of the natural resources of the Greenwood Lake Watershed and their impacts on water quality are discussed further in the following sections.

[130] Princeton Hydro, LLC. 2006. Request for 604(b) Funding for Greenwood Lake / Belchers Creek; A Proposal to Develop a On-site Wastewater Treatment System Management Plan; Township of West Milford, Passaic County, New Jersey, April 2006. Page 3.
[131] *Ibid.*