Section 5 – Watershed Description and Characterization

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5. Watershed Description and Characterization

5.1 Regional Setting

The West Branch of the Delaware River drains the central portion of Delaware County, NY (**Figure 5.1**). The river flows southwest into the Cannonsville Reservoir, the western most impoundment in the Catskill/Delaware water supply system for the City of New York. The *watershed* includes the river and its tributaries to the headwaters of the riverine system (its upper headwaters extend into Utsayantha Lake in Schoharie County).

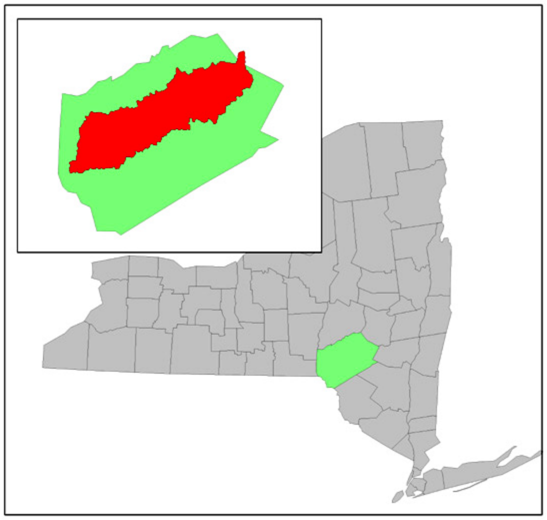

Figure 5.1 Cannonsville Watershed regional setting

As shown in **Map 5.1**, seven towns are largely within the project area: Walton, Hamden, Delhi, Kortright, Stamford, Harpersfield, and Bovina. These are all contiguous to the main stem of the West Branch of the Delaware River with the exception of the Town of Bovina, which is contiguous to the Little Delaware River, the largest *tributary* in the project area. Parts of the Towns of Meredith, Franklin, Andes, Roxbury and Sidney are located in tributary headwaters areas. The incorporated villages of Walton, Delhi, Hobart, and Stamford plus the five recognized hamlets of Hamden, Delancey, Bloomville, South Kortright, and Bovina Center are also included.

Due to its proximity to downstate population centers, the area has been popular for tourists and for development of seasonal homes for over a century. The watershed is largely rural, yet metropolitan New York and upper New Jersey are about a 3 hour drive and the Albany/Capitol District about a 1½ hour drive from the center of the watershed. New York State Route 10 parallels the West Branch and is the only east-west access through the area, Interstate 88 lies parallel and to the north, and the Route 17 "quick-way" is to the south.

Looking down the West Branch valley from atop Utsayantha Mountain near Stamford

5.2 Physiography

Physiography refers to the physical features of the earth's surface, including landforms, climate, currents of the atmosphere and ocean, and distribution of flora and fauna or the general "look" of the land. A physiographic province is a region in which all parts have similar geologic structure and climate, a unified geomorphic history and pattern of relief features or landforms that differ significantly from adjacent regions.

The watershed is located in the eastern portion of the Allegheny Plateau physiographic province, which is the northern part of the Appalachian Plateaus that extend from southern New York to central Alabama (**Figure 5.2**). Locally, the Allegheny Plateau extends throughout southern New York and includes the Catskill Mountains and southern sections of the Mohawk River basin (Isachsen, et al., 1991). Rivers and their tributaries have cut the originally level plateau into hilly uplands. The plateau surface is evident in the pattern of hilltops all tending to reach the same elevations in their respective locations in the watershed, creating a dissected plane that slopes gradually upward from northwest to southeast

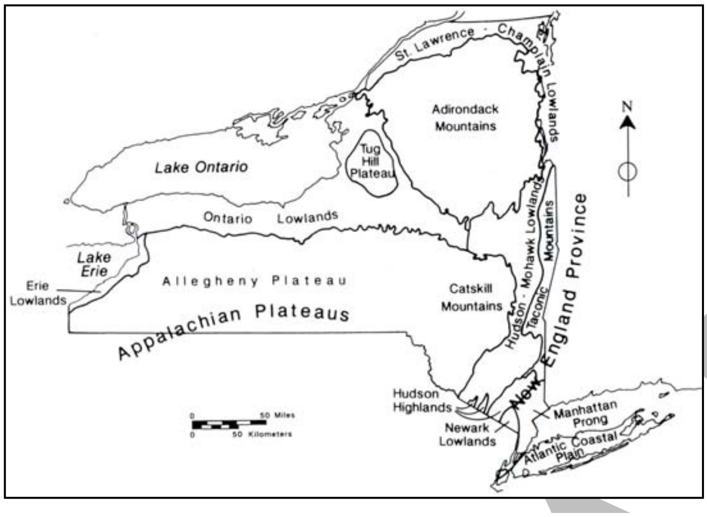

Figure 5.2 Physiographic regions in NY State

The West Branch of the Delaware River is the principal drainage channel for the basin and it delivers flows form northeast to southwest through a relatively narrow, flat floored valley. At its maximum, in the Village of Walton, the valley is about 1 mile across. Hillsides along the West Branch valley tend to be asymmetric, with steeper slopes facing north and gentler slopes facing south. Tributary streams typically occupy very narrow valleys, or "hollows", that generally intersect the West Branch at right angles.

5.3 Morphometry

Morphometry refers to the techniques used to measure the shape and form of something, in this case the watershed and its stream network. Such measurements form the foundation for understanding the current state of the river corridor in quantitative terms. This allows the design of practices that fit naturally within the watershed. Much of the remainder of this section of the stream corridor management plan describes information from scientific disciplines related to basin morphometry. A discussion of how this information is used in geomorphic stream design is given in **Section 5.9.2**.

The West Branch of the Delaware River drainage encompasses an area of 353.5 square miles. It contains 662.4 miles of streams, from the high-water mark of the Cannonsville Reservoir to the source of the West Branch. The minor portion of headwaters located in Schoharie County is not included in this management plan area, but does contribute to the overall watershed drainage area. **Map 5.2** shows the 20 major sub-basins delineated for the purpose of this plan. **Table 5.1** shows the drainage areas and stream lengths for each of these identified sub-basins.

Table 5.1 West Branch Delaware River sub-basins, drainage areas and stream lengths

Sub-basin (alphabetical)	**Watershed Area** (sq. mi.)	**Stream Miles**
Bagley Brook	15.64	25.60
Beers Brook	6.79	11.30
Betty Brook	9.14	15.20
East Brook	24.94	48.60
Elk Creek	14.50	27.10
Falls Creek	7.77	13.40
Kidd Brook	5.20	10.00
Lake Brook	6.91	13.40
Little Delaware River	52.26	97.50
Peak's Brook	7.80	13.20
Pines Brook	5.23	10.60
Platner Brook	13.99	26.40
Rose Brook	14.86	27.70
Steele Brook	6.73	10.80
Third Brook	5.52	9.20
Town Brook	16.08	27.00
West Branch Headwaters	15.64	26.30
West Brook	22.45	42.00
Wright Brook	12.03	22.40
Subtotal	**263.48**	**477.70**
West Branch Main Stem Basin	90.04	184.70
Total	**353.52**	**662.40**

From the outlet of Utsayantha Lake (1875 feet elevation above mean sea level), the West Branch of the Delaware River flows approximately 51 miles to the Cannonsville Reservoir (elevation of high-water mark 1150 feet). The river itself has an average slope of 0.58 %, while the average valley slope is 0.66%.

The West Branch watershed includes numerous ridges and peaks with elevations greater than 2000 feet. The highest elevations occur along the eastern edge of the basin, where the summit of Mount Pisgah reaches 3345 feet and Plattekill Mountain in the Little Delaware River sub-basin rises to over 3340 feet. Ridgetop elevations are slightly lower in the southwestern portion of the watershed, reaching just above 2500 feet along the southern divide between the West Branch main stem basin and the Beers Brook sub-basin. Ridgetop elevations in the northern portion of the watershed generally range from 2200 to 2300 feet, rising to over 2500 feet in the Wright Brook, Betty Brook and Lake Brook sub-basins, with the highest elevation of 2560 feet in the Wright Brook sub-basin. The sub-basins are generally drained by low to moderately steep tributaries that flow along U-shaped valleys. Tributary streams entering the West Branch main stem valley from the north and south have, in many places, truncated previously existing landforms and added their own *bedload* to form alluvial fan deposits (Day and Weidenbach, 1990).

5.4 Climate

5.4.1 General

The climate of Delaware County is humid continental. Cool, dry air masses move generally eastward throughout the year, and warm, humid maritime air masses from the south move northeastward during the summer (Lumia, 1991). The summers are cool, with relatively few hot days. Cold winter temperatures prevail whenever Arctic air masses flow southward from central Canada. Mean daily temperatures range from the low 20's in winter to the upper 60's in summer. Rainfall is usually adequate during the growing season (May – September) but deficiencies of precipitation may occur from time to time.[1] Mean annual precipitation ranges from 46.69 inches in Walton to 41.40 inches in Stamford. **Map 5.3** shows the average annual rainfall distribution in the basin. Average snowfall in the valleys is near 65", with higher terrains receiving slightly more. **Table 5.2** shows the monthly averages for precipitation and temperature for the period of 1971 through 2000 (NOAA, 2002). Solar aspect, the orientation of a slope to the sun, also affects the local microclimatic conditions. South facing slopes are warmer and drier than the cool, often moist north facing slopes of the valley. A dramatic example of the effect of aspect on the watershed hydrology occurred during the January 19, 1996 flood event (see **Section 5.8.3**). Warm winds blowing against the south facing slopes of the watershed rapidly melted the 20 - 30 inch snow pack which contributed an estimated 3 inches of equivalent rainfall to approximately 2 ½ inches (average) of actual rainfall (Lumia, 1998, pages 8-13).

Table 5.2 Monthly average precipitation and temperature in the West Branch of the Delaware River basin.

	Precipitation Normals (Inches)*												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Walton	3.29	2.83	3.72	3.98	4.34	4.28	4.31	4.13	4.07	3.91	4.26	3.57	46.69
Delhi	2.95	2.35	3.39	3.90	4.26	4.47	3.86	3.29	3.97	3.70	3.87	3.19	43.20
Stamford	2.82	2.28	3.14	3.61	4.26	3.91	4.01	3.72	3.73	3.43	3.65	2.84	41.40
Average Snowfall (Inches)													
Delhi	17.1	10.9	11.9	4.3	0.0	0.0	0.0	0.0	0.0	0.4	4.8	13.7	63.1
Temperature Normals (Degrees Fahrenheit)													
Max	31.2	34.1	43.3	55.6	68.2	75.9	80.2	78.5	70.4	59.7	46.7	35.5	56.6
Mean	21.5	23.6	32.9	44.0	55.3	63.5	67.6	66.3	58.8	47.9	37.8	26.9	45.5
Min	11.7	13.1	22.4	32.2	42.3	50.9	55.0	54.1	47.1	36.0	28.8	18.3	34.3
	*Data from Climatography of the United States Nos. 20 & 81, 1971-2000, National Oceanic & Atmospheric Administration National Climatic Data Center												

5.4.2 Effects of Physiography on the Local Economy

Dairy farming and forestry are the most common and extensive land uses in the basin. Precipitation and temperature favor the growth of alfalfa and grasses for hay and corn for silage,

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[1] The Climate of New York, Cornell University Website: http://nysc.eas.cornell.edu/climate_of_ny.html (Verified 7-27-04)

except where limitations are imposed by soils and topography. Stands of sugar maple (*Acer saccharum*) are widely used for syrup production. Timber management is especially prevalent in the lower portion of the watershed where soils and slopes are less suitable for agriculture. Generally abundant snowfall supports snowmobiling for winter recreation. Spring and early summer flows provide a venue for water recreation by kayakers and canoers on the West Branch main stem. Combined with the local geology, the climate has resulted in the large number of springs that commonly occur near the base of hills. These cold water inputs to the river provide excellent fish habitat which attracts numerous anglers from the local community and the New York City metropolitan area. Spring water is also an important source of drinking water for some individual homes and some municipal water supplies.

5.5 Geology

5.5.1 Introduction

In landscapes unchanged by human activities, streams reflect the regional climate, biology and geology. Climate was discussed in the preceding section, while biology, especially streamside vegetation, will be discussed in **Section 5.10**. The following section describes the basic geology of Delaware County and the West Branch basin, how this affects the stream channel form or fluvial *morphology*, and water quality of the basin.

5.5.2 Bedrock Geology

The bedrock underlying all of Delaware County is of sedimentary origin. The *sediments* resulted from the *erosion* of a large mountain range that once existed to the east during the upper Devonian Period, some 370 million years ago. Westward flowing rivers deposited layers of *sand*, *silt* and *clay*, which eventually became the beds of sandstone, siltstone and shale rocks of today.

The regional dip of these otherwise flat lying rock layers is towards the south-southwest at angles less than 10 degrees, although steeply inclined, coarse crossbedding within individual rock units also occurs. Rock colors are shades of red or bluish gray due to deposition in environments of high oxygen (terrestrial) or low oxygen (tidal or alluvial plain), respectively. Fossils are typically few, poorly preserved plant fragments, trace fossils, and some marine fauna; the dominance and abundance of each varies between locations and individual beds. Studies of bedrock types, layer sequences and fossil records indicate ancient delta-like and shallow marine environments within a tropical climate that was alternately wet and dry.

Eventually, long periods of pressure from overlying sediments and cementation by mineral-carrying waters lithified sands into sandstones (or conglomerate, if gravelly) silts into siltstone and silty clays into shale. The thickest and most uniform beds of certain sandstones are now valuable for local "bluestone" quarries. As one travels from north to south across Delaware County, bedrock outcrops tend to expose progressively younger rocks. **Map 5.4** shows the occurrence of bedrock types in the watershed.

Important rock Groups and some of their component rock formations are, from oldest to youngest: the Genesee Group, which includes the Unadilla and Oneonta formations; the Sonyea

Group, which includes the Lower Walton formation; and the West Falls Group, which includes the Slide Mountain and Upper Walton formations. None of these formations contain beds of limestone, but rather contain much silica; they are therefore considered to be "acidic" rocks, and spring water arising from bedrock cracks and fissures tends to be low in calcium and magnesium carbonates (“soft” water).

As mountain-building forces raised the Appalachian mountain chain to the south, this also created a smaller uplift of the Catskill region. As this occurred, long periods of erosion created the stream valleys of today, which probably originated along joints or fractures in the bedrock layers. Thus, the Catskill Mountains were created more by forces of erosion than those that build mountains upward. However, the shapes of the landscape have also been significantly remolded by glacial events, as described below (Isachsen, et al., 1991).

5.5.3 Glacial Geology

A number of major glaciations have occurred in North America. Geologic age dating techniques imply that the most recent glaciation to leave this area (the Wisconsin glaciation) did so only some 10 to 12 thousand years ago. At its furthest advance, glaciers covered the county with moving ice nearly one mile thick, extending hundreds of miles northward. This caused tremendous amounts of erosion by abrasion and bedrock "plucking", pressure melting and refreezing of the ice as it moved over hills. The generally rounded and smoothed profile of hills and the U-shaped cross section of larger valleys resulted. The processes of glacial erosion crushed and fragmented rocks into a slurry of *boulders*, angular stones and *gravel*, sand, silt and clay. This mixture was transported beneath, within and on top of the glacier, sometimes for many miles before being deposited by the ice or its meltwaters. When deposited in this form, i.e. a random mixture of particle sizes, this material is called glacial till, and most uplands are covered with till (**Map 5.5**)[2]. Because layers of sandstone and siltstone were continuously ripped up and incorporated into the till, upland soils are commonly stony (or very stony) throughout their depth. Till was deposited as a relatively thin layer (less than 40 inches thick) on many hilltops and north facing slopes, and in thicker layers over other areas. Certain south facing hillsides received unusually thick accumulations of till (over 50 feet thick) where they were on the lee side of hills that obstructed the flow of advancing ice.

After long periods of glaciation, the climate warmed again and the glaciers melted back northward faster than they were flowing southward. This melting created tremendous amounts of sediment-laden water in rivers and lakes. However, tongues or flows of ice tended to remain in the larger valleys long after the uplands were relatively ice-free. Eventually these valley ice masses stopped flowing and melted away, creating landforms and deposits that are distinctly different from those in the uplands. Large amounts of meltwater flowed along the sides of and beneath the stagnant valley ice masses, washing through the rocky and muddy debris. This tended to separate and remove the finer silt and clay from sand and gravel. In locations where washed and sorted debris was deposited, usually the margins of major valleys such as the West and East Branches of the Delaware River, gravelly terraces and kame deposits occur (**Map 5.5**).

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[2] Isachsen and others (1991, pgs. 161-193) discuss the glacial epoch and its effects on NY landscapes. Titus (1996) and Rich (1935) give more in-depth descriptions of glacial landforms in the Catskills Region than the summary provided here. Map 3.5 is based in part on the work of Rich and others.

This gave these parts of the landscape a somewhat lumpy and bumpy appearance. Such deposits are often valuable sources of sand and gravel, although they typically contain more silt and clay than are desirable.

The stagnating remains of the valley glaciers blocked off the outlets of some meltwater streams, creating lakes until the dams of ice could melt, which took many years. In the quiet waters of deeper lakes, silts and clays settled out and accumulated while in shallower, more agitated lakes fine sand and silt was deposited. The finest-textured (clayey) sediments formed relatively small deposits (commonly a few acres each), as have been observed in excavations north and south of Walton (personal communication, Laurence Day, DCSWCD, 12/15/04). Coarser lake-laid deposits occur in the West Branch and other valleys, although more recent *floodplain* deposits often overlie them. The river itself winds through the relatively flat surface of accumulated sediments over the much deeper valley carved into the bedrock. Rich (1935) reported about 60 feet of sediment filling the valley floor at Bovina Center, and Day and Weidenbach (1990) reported numerous test wells in the Village of Walton were drilled more than 130 feet before bedrock was encountered.

Where relatively fast-flowing tributary streams enter major valleys, water *velocity* slows as they flow across the flatter river floodplain. The abrupt slowing of the stream's velocity causes it to drop its bedload of sand and gravel on the floodplains as a subtle fan or delta-shaped alluvial fan deposit. This process has been continuing since the waning stages of glaciation, and alluvial fans are commonplace in larger valleys. Because these deposits are fairly level and well drained, they make good farmland and building sites; the center of many villages and hamlets, including Walton and Delhi, are on alluvial fan landforms.

The glacial deposits described above are the parent materials in which the soils of today have developed. In terms of geology and soil formation, the Epoch since the glaciers left their deposits on the Delaware County landscape is a short period of time. Processes of erosion and sediment accumulation continue to affect the landscape, although their rates can be greatly accelerated by man's activities.

5.5.4 Applied Geology

An understanding of geology can be useful background to stream corridor management because bedrock and glacial deposits (see **Map 5.5**) influence the stream system within its drainage basin. Dendritic stream patterns, such as in this watershed, tend to develop where horizontally bedded, sedimentary bedrock had a gently sloping regional dip at the time the initial drainage channels began forming[3]. The bedrock jointing pattern (intersections of deep fractures) also influence stream pattern formation. Rates of stream channel downcutting, bank *stability* and lateral migration are dramatically reduced wherever the stream channel contacts bedrock instead of stream deposits. One example where the stream has cut down to bedrock is in Town Brook near the intersection of Clove Rd.

Thin soils typically cover fractured bedrock on the hilltops, while thicker deposits of glacial till occur at some distance downslope. As a result, precipitation infiltrates bedrock fractures on

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[3] Ritter, 1978, p. 171.

hilltops, creating and recharging the bedrock aquifer that is relied on for individual drinking water wells and springs. Small springs are quite common throughout the basin, and often are the places where tributary streams originate. Springs and other groundwater sources comprise the majority of stream base flow in drier, summer months. In general, the quality of this groundwater is soft (since the bedrock is low in limestone and other carbonate rocks), low in dissolved solids and chloride, but commonly contains considerable iron.[4]

The extensive areas of glacial till in the basin have developed permeable, upper soil layers, often 1 to 3 feet thick, that overlie relatively dense and slowly permeable subsoils. Abrupt changes in permeability create saturated zones (perched water tables) at the contact between the two materials. On lower portions of hillslopes, the upper soil layers often become saturated to the surface from the shallow throughflow. This in turn influences where erosive rills begin to form on a slope, and where new stream channels eventually begin to form.

The glacial till deposits tend to be relatively coarse textured, often including a substantial amount (15 to 35% by volume) of gravel- to boulder-sized rock fragments. This reduces soil erodibility by providing a sort of "armoring" effect[5], and physical stability of stream beds and banks may similarly be increased, especially where the rock fragments are firmly held within firm till deposits. The pervasive sandstone layers in local bedrock tend to form relatively flat clasts (rock fragments) in the till. In stream deposits, such as gravel bars, point bars and alluvial fans, flowing water often arranges these flat stones into a shingled or imbricate form, where one clast rests on a slight angle on top of another. Imbricated streambeds require a larger flow to move the bed material than do non-imbricated beds.

The main stem of the West Branch Delaware River flows mostly through alluvial soils (shown as "recent alluvium" on **Map 5.5**). Wherever eroding streambanks include deposits of relatively loose (non-cohesive) soil materials containing considerable fines, much sediment can be suspended in the water downstream. Such materials can include the "kame", "kame moraine" or "till moraine" deposits of **Map 5.5**, as well as recent alluvium. The tributaries of the main stem are more likely to contact the more cohesive glacial "till" in the uplands. Soils

Agriculture is a major land use in the West Branch watershed, and it is linked to the land use changes that may be needed in the future to enable successful stream corridor management. Many practices that limit the loss of excess *nutrients* and eroded sediments from farmland, and keep them from entering surface water, involve the consideration of soil type. While it is important to at least introduce the subject of soils, because the preceding section described glacial deposits in some detail, and since soils and the glacial deposits they develop in are closely linked, discussion about soils in the study area can be kept on a generalized level.

5.6 Soils

The character of soils reflects the various forces that have been weathering a geologic deposit over time. As described in the glacial history section, the most extensive geologic deposits in the watershed are the broad areas of glacial till in uplands, while sandy or gravelly materials are

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[4] Soren, 1963.

[5] McCormack, et al., 1984.

limited to relatively narrow floors and margins of valleys. The dominant soil types in these upland and valley settings strongly reflect the geologic deposit or "parent material" in which they are forming. Hence, the large proportion of angular-shaped stones incorporated into the till has produced the stony soils we see exposed in upland crop fields, and gravelly loam soils are common where villages have been built in the valleys, for example.

The USDA-Natural Resources Conservation Service has mapped soils in Delaware County through their soil survey program. **Map 5.6** shows a generalized view of soils mapping in the study area, using only four map units instead of the 129 recognized in the detailed soil survey. Reddish brown soils that occur in upland glacial tills are Lackawanna-Wellsboro (which occur at elevations below 1750 feet), and Willowemoc-Lewbeach-Onteora (similar soils but with a shorter growing season, mapped above 1750 ft). The more sandy and gravelly soils of the valleys (below 1750 ft.) comprise the Tunkhannock-Maplecrest-Barbour map unit. The West Branch main stem flows largely within this soil map unit. A small area of Mongaup-Willdin soils, which are brown-colored and occur above 1750 ft., occur in the northwest part of the study area. As illustrated, a distinct soil group trend occurs from lowland areas to the surrounding uplands. For readers that are interested, these soil groups are further described below, from lowest to highest elevations in the basin.[6]

The *Tunkhannock-Maplecrest-Barbour* soil group is found along the West Branch main stem and adjacent valley lowland areas from the Cannonsville Reservoir upstream nearly to the Schoharie County line. This soil group covers slightly less than 11% of the basin and is the predominant soil group in the stream corridor of the West Branch of the Delaware River. General characteristics include: very deep, more than 60 inches to bedrock; somewhat excessively drained (Tunkhannock) to well drained (Maplecrest and Barbour); medium to moderately coarse textured; found on nearly level to steep slopes in valleys, on valley sides, on terraces in mid-valley positions, and on low terraces and floodplains along streams.

The *Lackawanna-Wellsboro* soil group is adjacent to the Tunkhannock-Maplecrest-Barbour soil group in approximately the lower one-half of the basin, and extends substantially upstream into the Pines Brook, Third Brook, West Brook, East Brook, Platner Brook, Peaks Brook, and Steele Brook sub-basins. This soil group also encompasses significant portions of the main stem areas of Bagley Brook and Little Delaware River, and is present in the upper headwaters area. This soil group covers approximately 19.3% of the basin. General characteristics include: very deep, more than 60 inches to bedrock; well drained (Lackawanna) to moderately drained (Wellsboro); medium textured, with relatively dense subsoils; found on gently sloping to very steep hilltops and hillsides.

The *Willowemoc-Lewbeach-Onteora* soil group is found at the next general elevation level and is the predominant soil group, covering approximately 69.6% of the basin. General characteristics include: very deep, more than 60 inches to bedrock; moderately well drained (Willowemoc) to well drained (Lewbeach) to somewhat poorly drained (Onteora); medium textured, with relatively dense subsoils; found on nearly level to very steep hillsides and hilltops and along small drainageways.

The *Mongaup-Willdin* soil group is found in only a small area in the northwesterly portion of the West Brook sub-basin, covering less than 1% of the basin, and is primarily found in sub-basins outside of the project area. General characteristics include: moderately to very deep; moderately well drained (Willdin) to well drained (Mongaup); medium textured; found on gently sloping to very steep hillsides and broad hilltops. Willdin soils are found on gently sloping to moderately steep hillsides, have relatively dense subsoils and are more than 60 inches in depth to bedrock. Mongaup soils are found on the upper parts of hillsides and on bedrock-controlled hilltops and are 20 to 40 inches to bedrock.

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[6] USDA-NRCS, unpublished soil survey data, Delaware County, New York, 1998. *General Soil Map Units,* 16 pages.

Silty clay deposits are very few and of small size across the basin. Represented on the map by black dots, these are areas of less than 5 acres that have notably finer texture than the surrounding soil types and were noted when the soil survey was being performed in Delaware County.

In New York State, soils have been classified into four hydrologic soil groups based on *runoff* potential and infiltration rates. **Map 5.7** shows this information in the project area, which is useful for determining runoff characteristics in the basin. These four runoff groups are defined as follows:[7]

> Group A soils exhibit low runoff and high infiltration even when thoroughly wetted. They are chiefly sands and gravels that are deep and well drained to excessively well drained. Group A soils are found in 3.9% of the basin, generally occurring along the West Branch main stem and the main stems of larger tributaries.
>
> Group B soils exhibit moderate infiltration when thoroughly wetted. They are moderately deep to deep, moderately drained to well drained, and are moderately fine to coarse textured. Group B soils are found in 5.1% of the basin, again generally occurring along the West Branch main stem and the main stems of larger tributaries.
>
> Group C soils exhibit low infiltration rates when thoroughly wetted. They have a layer that impedes downward movement of water, such as hardpan subsoils or bedrock at 20 to 40 inch depths, and are moderately-fine to fine textured. This is the predominant hydrologic soil group, covering 68.2% of the basin. These soils can contribute substantially to runoff.
>
> Group D soils exhibit high runoff and very low infiltration when thoroughly wetted. They are chiefly clay soils with a permanent high water table, have a clay layer at or near the surface, and are shallow over nearly impervious material. Group D soils are found in less than 1% of the basin.
>
> In many areas of the basin, dual hydrologic groups exist. These are Group A/D and Group C/D and are soils that can be adequately drained. The first letter applies to the drained condition and the second to the undrained condition. Group C/D soils are generally found where bedrock is close to the surface. If the bedrock is not fractured, the soils exhibit Group D characteristics. Where the bedrock is fractured, the soils exhibit Group C characteristics.[8] Group C/D soils are found in approximately 20.1% of the basin, generally in the higher upland areas. In Delaware County, Group A/D soils are quite permeable but are generally saturated, therefore exhibiting Group D characteristics. Group A/D soils are found in less than 0.1% of the basin

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[7] National Engineer Handbook 649.00, United States Department of Agriculture Natural Resources Conservation Service. Chapter 2, page 2-2.

[8] Personal communication with Laurence Day, Soil and Groundwater Specialist, Delaware County Soil & Water Conservation District.

Two other soil types identified not previously mentioned are Fluvaquents and Udorthents. Fluvaquents are composed of many soils of varying textures along narrow stream channels. These soils flood frequently, resulting in both erosion and deposition. These soils are found in 1.4% of the basin, sporadically located along watercourses throughout the watershed. Udorthents consist of very shallow to deep, excessively drained to moderately well drained soils that have been altered for construction operations. They can also be found at landfill sites or may be former sand and gravel pits. Udorthents appear sporadically in developed areas and areas of excavation and/or filling and cover approximately 0.1% of the basin.

"Urban land" was mapped where 80% or more of the surface is covered with asphalt, concrete, other impervious materials or roofed buildings.[9] These impervious surfaces shed water very quickly, which can produce localized flash flooding. Less than 0.1% of the basin is mapped as urban land. Bodies of open water, which include larger streams, ponds, lakes and reservoirs, account for about 0.4% of the basin.

5.7 Land Use/Land Cover

Map 5.8 shows vegetative cover in the watershed as interpreted by remote sensing techniques. The dominant cover type throughout the basin is deciduous tree forest, with some north facing hill-slopes dominated by coniferous species. Deciduous tree species include maples, beech, birch, oaks, ash and cherry. Eastern hemlock (*Tsuga candensis*) is the predominant conifer; some eastern white pine (*Pinus strobus*) stands exist, as well as many fields that have been planted to various spruce and pine species. These forests encompass the majority of the upland area and the timber is frequently harvested. Along watercourses and the adjacent hillsides, cover types range from grass to a mix of grass and shrub, grass, corn and alfalfa. These cover types are indicative of the agricultural character of the basin. The grass and shrub component represents success ional land composed of grasses, forbs and woody plants, with hawthorns being common. The grass component includes turf, pasture and hayland. Tree species along the West Branch main stem include the species listed above, as well as sycamore, butternut and willows. Urban areas appear to cover less than 0.1% of the basin.

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[9] Soil Survey Data, Delaware County, New York, 1998. *Non-Technical Descriptions*, USDA-NRCS, pages 7 and 27 of 34.

5.8 Hydrology

5.8.1 Introduction

> **"Between earth and earth's atmosphere, the amount of water remains constant; there is never a drop more, never a drop less. This is a story of circular infinity, of birthing itself."** **Linda Hogan**

Understanding the hydrology of a drainage basin is important to stream management because *stream flow* patterns affect *aquatic habitat*, flood behavior, recreational use, and water supply and quality. Although it may not be obvious, the water flowing through the West Branch drainage system reflects the integrated net effect of all the watershed characteristics that influence the hydrologic cycle (**Figure 5.3**). These characteristics include the climate of the drainage basin (type and distribution patterns of precipitation and temperature regime), geology and land use/land cover (permeable vs. impermeable surfaces, materials affecting the timing and amount of runoff, constructed drainage systems), and vegetation (uptake of water by plants, protection against erosion, and influence on infiltration rates). These factors affect timing and amount of stream flow, referred to as the stream's hydrologic regime.

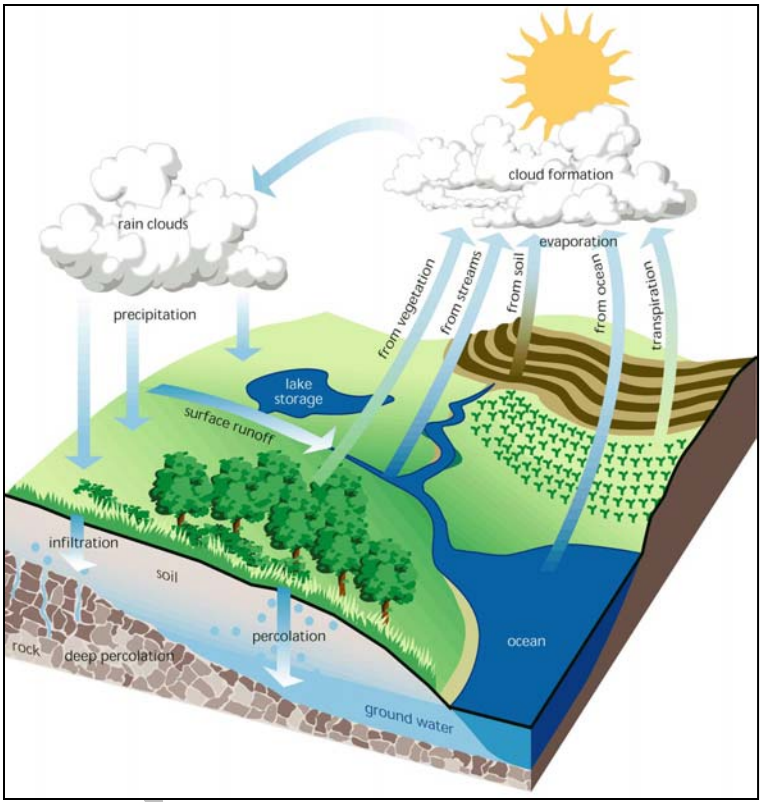

Figure 5.3 The Hydrologic Cycle

Streams in the West Branch watershed are primarily perennial streams—they flow year round except in smaller headwater streams or in extreme drought conditions. The drainage pattern is generally dendritic (a branching, tree-like form), which is typical of watersheds in the Catskill Mountain region uncontrolled geology (see **Map 5.2** for West Branch stream system).

Streams in the West Branch basin form a connected system that can be classified by "stream order". Stream order identifies the position in a hierarchy of tributaries occupied

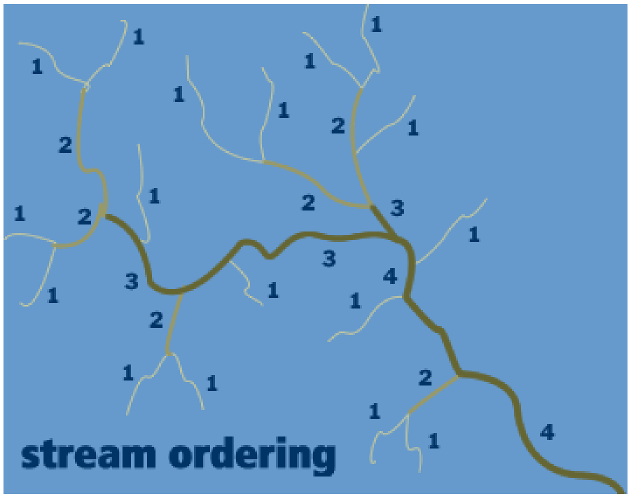

Figure 5.4 Stream Ordering (NRCS)

by a stream segment. As described by Strahler (1964) and shown in **Figure 5.4**, above, any clearly defined (ephemeral) channel without tributaries is designated as a 1st order channel; where two 1st order channels join they form a 2nd order channel; where two 2nd order channels join they form a 3rd order channel, and so on. Tributary headwater streams are 1st and 2nd order streams. The lower main stems of the majority of the identified sub-basin tributaries are 3rd order streams. Using this system, the lower main stems of the Little Delaware River, Wright Brook, Platner Brook, East Brook and West Brook sub-basins are 4th order streams. The West Branch main stem is a 3rd order stream at the outlet of Utsayantha Lake. This information was not used in the research and analyses done for this management plan. It is described to show the reader that streams generally increase in size as smaller streams converge to form larger channel.

5.8.2 Stream flow

Streams flow at many different levels during the course of a year, ranging from a small trickle during a dry summer to a raging torrent during rapid thaw of a thick snow pack. Stream flow varies on several temporal scales. Throughout the course of a year we see a stream swell and shrink with seasons, or over the course of a single summer storm (hours to days) or a spring thaw (days to weeks) we can also watch a stream swell and subside.

There are essentially two basic types of stream flow: storm flow and base flow. Storm flow appears in the channel in direct response to precipitation and/or snowmelt, whereas base flow sustains stream flow during inter-storm (between storms), subfreezing or drought periods. Storm flow reaches a stream channel as channel interception, overland flow, or subsurface storm flow. Channel interception is simply the precipitation that falls directly into the water that is already in a stream channel; it enters the stream directly and its effect disappears as soon as the event is over. In the West Branch watershed it is a minor component of the stream flow.

Overland flow is one portion of storm flow that occurs over and slightly below the soil surface during a rain or snowmelt event. This surface runoff appears in a stream relatively quickly and recedes soon after the event. The role of overland flow in the West Branch watershed is variable and depends on the time of year, location, severity of storms, and soil conditions. Relatively impermeable areas (exposed bedrock, frozen ground, clayey soils) will generate more surface runoff to the stream than will relatively permeable areas (deep, coarse soils) or well-vegetated areas. Saturated well-drained soils can also contribute to increased runoff (in effect, they are already "full" and don't allow additional infiltration). Generally, higher stream flows are more common during spring rains and snowmelt events, and during the fall hurricane season. During summer months, actively growing vegetation draws significant amounts of water from the soil. This demand for groundwater by vegetation can significantly delay and reduce the amount of runoff reaching streams during a rainstorm. During winter months, precipitation is held in the landscape as snow and ice so precipitation events do not generally result in significant runoff to streams. However, frozen ground may increase the amount of overland flow resulting from a rainstorm, especially in the absence of snow, which can absorb a certain amount of water.

In the northeastern US, shallow soils (less than 3 ft. deep to a restrictive layer) on sloping hillsides often have infiltration rates that are seldom exceeded by the rainfall rate (Goehring, et al., 2002). Instead, subsurface storm flow, or interflow, develops from rain or snowmelt after it has infiltrated the soil. It flows rapidly through permeable portions of the soil above restrictive layers until it reaches the soil surface, usually in saturated areas such as surface depressions or in the lower, concave sections of hillslopes. Nearly saturated soils can experience interflow during precipitation even before overland flow begins. Subsurface storm flow can also contribute to stream flow after the overland flow component has passed and as the stream recedes to base flow conditions. Interflow is becoming recognized as a transport mechanism for dissolved phosphorus compounds, which degrade water quality after entering streams and reservoirs (Akhtar, et al., 2003).

Base flow is water that drains slowly from the land, sustaining stream flow during dry periods and between storm events. The source of base flow is groundwater that has passed through the soil and entered deeper cracks or layers in bedrock, eventually being *discharge*d adjacent to or beneath a stream.

The distinction between base flow and subsurface storm flow is transitional – that is, there is no specific time period or exact flow magnitude at which a stream is clearly at storm flow or base flow *stage*. To get some idea of what might constitute base flow, hydrologists commonly utilize a graphical representation of the stream flow over some period of time, the hydrograph, which is created from data obtained from a stream gaging stations. The United States Geological Survey (USGS) maintains eight *continuous-recording stream gages* in the West Branch watershed (see **Map 5.9** and **Table 5.3**).

Table 5.3 Continuous Recording USGS Stream Gaging Stations in the West Branch of the Delaware River basin.

Station ID	Station Name	Drainage Area (Mi^2)	Period of Record
1421610	West Branch Delaware River at Hobart	15.50	Aug 2000 - present
1421614	Town Brook Tributary SE of Hobart	0.76	Oct 1998 - present
1421618	Town Brook SE of Hobart	14.30	Oct 1997 - present
1421900	West Branch Delaware River US of Delhi	134.00	Feb 1937 - Sept 1970, Dec 1996 - present
1422389	Coulter Brook Near Bovina Center	0.76	Oct 1997 - present
1422500	Little Delaware River Near Delhi	49.70	Oct 1937 - Sept 1970, Jan 1997 - present
1422747	East Brook East of Walton	24.70	Oct 1998 - present
1423000	West Branch Delaware River at Walton	332.00	Oct 1950 - present

These gages measure the stage, or height, of the water surface at a specific location, updating the measurement every 15 minutes. By knowing the stage, we can calculate the discharge (the volume of water flowing by that point every second) using a rating curve relationship developed by USGS. In this way, the discharge can be predicted for any stage of interest. We can also use the historic record of constantly changing stage values to evaluate stream response to rain storms, snow melt, extended periods of drought, to analyze seasonal patterns or flood characteristics.

The gages in the West Branch basin have long enough periods of record to prepare hydrographs for their individual streams. **Figure 5.5** is an annual hydrograph for the gage upstream from Delhi, showing the peaks and lows of stream flow over the course of the year. The rise and fall of the peaks are generally associated with storm flows, while minimum values are related to average annual base flow conditions. A review of the hydrograph reveals that the winter of 1998/1999 was a wet period that followed a dry fall, and that late spring/early summer was also dry. The smaller graph inserted within **Figure 5.5** is a close-up of the July 4, 1999 storm event. At the end of June, a small rainfall event brought the stream flow up slightly. Storm flow receded prior to the July 4, 1999 rainstorm. The response to this storm was rapid, presumably due to preceding conditions from the previous rainfall. Minor rainstorms followed, but eventually the landscape drained and the stream flow returned to lower base flow conditions.

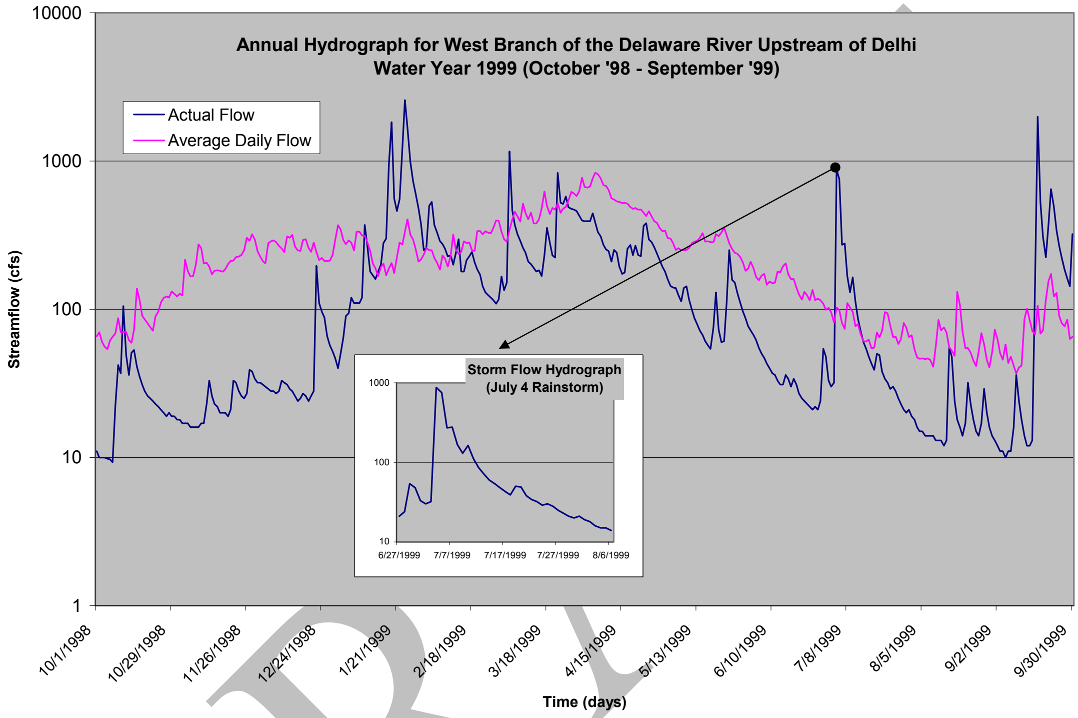

Figure 5.5 Annual Hydrograph for West Branch of the Delaware River upstream of Delhi for water year 1999.

We can also analyze longer time periods to see seasonal trends or long-term averages for any given period when the gage was in service. The record for the gage upstream from Delhi (**Figure 5.6**, below) shows higher flows in fall (hurricane season) compared to winter (when water is held in ice and snow), and higher flows in spring (snow and ice melt) compared to summer (drier conditions, with vegetation removing a lot of water). The highest flows of the year are generally associated with spring snowmelt. A spike from the July 4, 1999 storm is also noticeable.

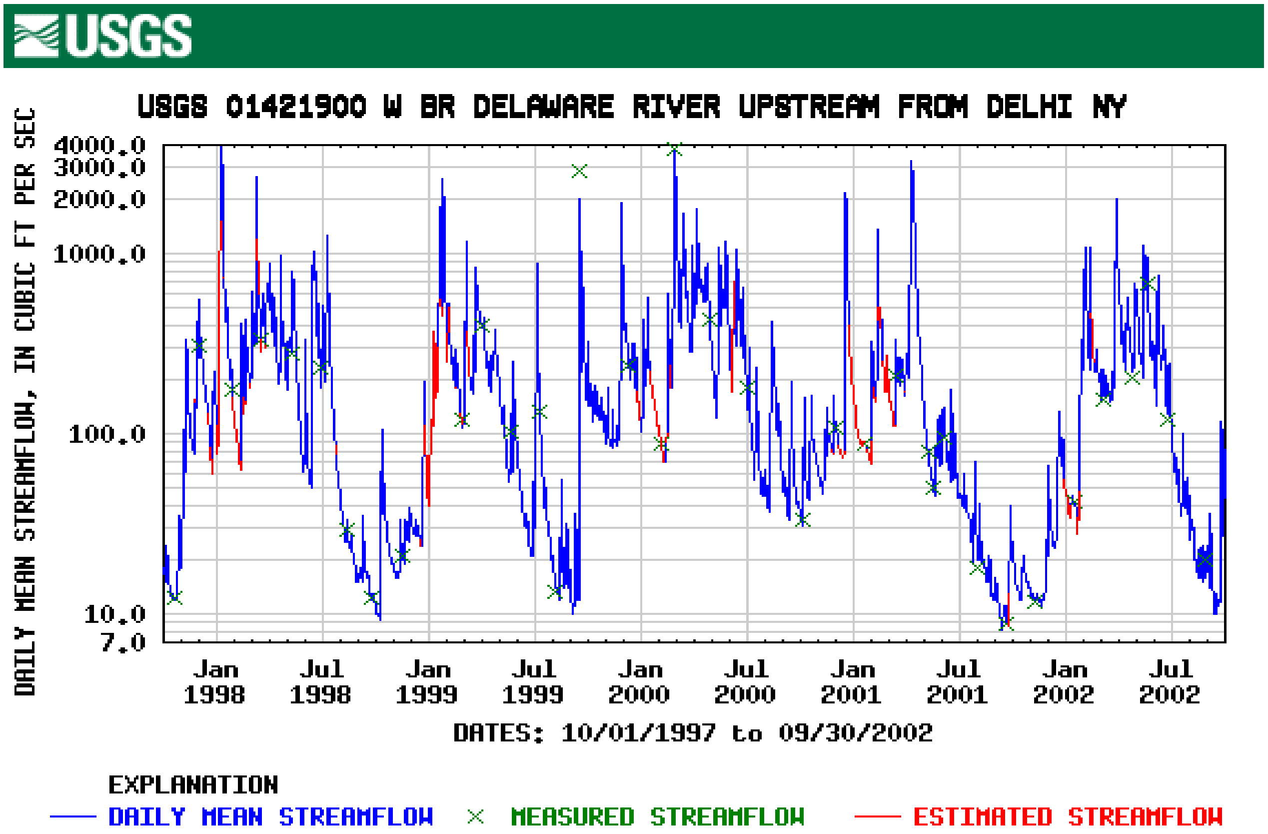

Figure 5.6 Hydrograph for a five-year period from the USGS Station upstream from Delhi, water years 1998 through 2002.

5.8.3 Flood History

Floods are events that occur whenever and wherever a defined stream stage is reached. In the West Branch basin, stream flows generally exceed channel capacity at the flood stage and flow over their banks (however, highly *entrenched* streams may reach a defined flood stage long before channel capacity is reached). They may range in size from minor overbank events to the raging torrents that destroy bridges and carve new channels. Floods can result from runoff associated with spring snowmelt, summer thunderstorms, fall hurricanes, and winter rain-on-snow events.

Examining the USGS records can help us evaluate the flooding history of a basin. The USGS publishes annual peak flow data for all stream gaging stations and calculates discharges (in cubic feet per second or cfs) for periodic flows at continuous record gaging stations (or peak flow only stations) with ten or more years of record. Annual peak stream flow is the highest stream flow recorded for a particular 12-month period (usually from October 1 through September 20 – the "hydrologic water year" as defined by USGS). A flood frequency distribution shows flood magnitudes for various degrees of probability (likelihood). These values are most often converted to a number of years, the "recurrence interval" or "return period". For example, the flood with 20% chance of occurring or being exceeded in any single year corresponds to what is commonly referred to as a "5 year flood" (1 divided by % probability equals the recurrence interval in years). This simply means that on average, for the period of record, this magnitude of flood will occur approximately once every 5 years. This probability is purely statistical; the probability remains the same from year to year over time for a particular size flood. Many years may go by without one or it may occur several times in one year. The calculated flows most often referred to by stream managers include the 1, 1.2, 2, 5, 10, 25, 50, 100, 200 and 500-year storms. Also, the greatest flow in any single year is not always a significant event, such as those recorded in the drought years of 1940, 1966, and 2002.

Table 5.4, below, shows the dates and flows for events greater than a 5-year recurrence interval for the three stream gaging stations in the watershed with ten or more years of record. The gage in the Village of Walton has the greatest number of years of record, the greatest number of events exceeding the five-year recurrence interval, and is also the downstream-most gage in the system.

Table 5.4 Flood flows exceeding the five-year recurrence interval at three stream stations

West Branch of the Delaware River at Walton			
Date	**Flood Discharge (cfs)**	**Recurrence Interval (Years)**	**Flow (cfs)**
12/11/1952	14,300	5	14,090
8/19/1955	15,100	10	17,210
1/22/1959	15,700	25	21,200
3/5/1964	15,800	50	24,190
6/29/1973	14,500	100	27,210
12/21/1973	14,700	200	34,350
3/14/1977	17,400		
1/9/1978	15,400		
2/11/1981	17,900		
3/15/1986	19,500		
4/5/1987	14,800		
1/19/1996	25,000		
11/9/1996	18,200		
9/18/2004	15,200		
West Branch of the Delaware River upstream from Delhi			
Date	**Flood Discharge (cfs)**	**Recurrence Interval (Years)**	**Flow (cfs)**
9/21/1938	8,940	5	5,551
3/31/1940	6,430	10	6,673
3/9/1942	6,090	25	8,126
11/26/1950	6,700	50	9,232
1/22/1959	5,500	100	10,360
3/5/1964	6,330	200	11,510
12/21/1973	6,070		
1/19/1996	13,000*		
11/9/1996	7,000*		
Little Delaware River near Delhi			
Date	**Flood Discharge (cfs)**	**Recurrence Interval (Years)**	**Flow (cfs)**
9/21/1938	3,280	5	3,051
8/13/1953	4,530	10	3,688
1/22/1959	3,120	25	4,499
7/30/1974	3,260	50	5,105
1/19/1996	6,100*	100	5,713
11/9/1996	4,540	200	6,326
9/18/2004	3,210		
* Estimated flow	Highlighted cells indicate same flood event.		

Considering the flood events in **Table 5.4**, the largest recorded flood in the basin was a wintertime rain-on-snow event that occurred on January 19, 1996 and which has been well documented. Conditions preceding this event were as follows:

Figure 5.7 Washout on Chase Brook Road over Chase Brook near Cannonsville Reservoir, January 19, 1996

The fall of 1995 was wet and stream flows were above normal. Below normal temperatures from mid-December through mid-January reduced stream flows to much below normal during the period. Snowstorms in early to mid-January left up to two feet of snow on the ground. The first half of January was colder than normal; therefore, the snow pack lost little moisture and the ground was mostly frozen. Unseasonably warm air preceded the storm on January 18-19, with temperatures reaching the 60° F range. On January 19th, 2 to 2 ½ inches of rain fell on 20-30” of snow in the watershed (Lumia, 1998; The Reporter Company, 1996). The ensuing flood claimed six lives and was the worst flood since 1935 according to local residents (The Reporter Company, 1996). Delaware County damages were $30,000,000. This flow was generally either the flood of record (largest flood on record) or greater than the 100-year flood flow throughout the watershed, although the flow recorded at the Walton gaging station was closer to a 70-year recurrence interval event (Lumia, 1998).

The remainder of 1996 continued to be wet. Heavy rains falling on nearly saturated soils caused a smaller flood event on November 9, 1996 that exceeded the 10-year recurrence interval flow at all three gaging stations, as shown in **Table 5.4**.

The flood of July 1935 was the result of heavy rains and caused nearly $1,500,000 in damages throughout the county.[10] No gaging station records exist for this time period. **Figure 5.8** shows a view of Walton at that time.

The flood of September 1938 was also the result of heavy rains.[11] The hydrograph at the Delhi gaging station recorded a particularly wet year with several storm events throughout the spring and summer. A minor event just prior to the storm on September 21, which would have saturated the ground, created a rapid rise in the river.

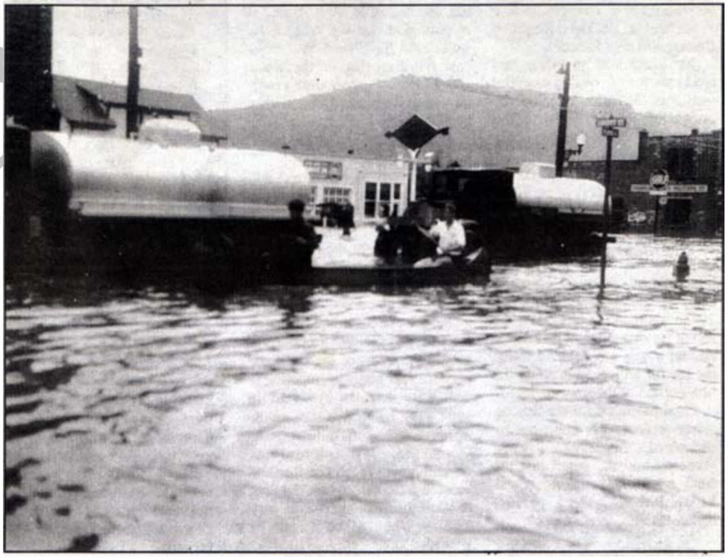

Figure 5.8 Scene from 1935 flood in Walton

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[10] The Walton Reporter (weekly newspaper), Friday, July 12, 1935 and Friday, July 19, 1935.

[11] The Walton Reporter (weekly newspaper), Friday, September 23, 1938.

Figure 5.9 West Branch of the Delaware River looking upstream from County Bridge on County Route 2 in Delancey, January 1996

The March events in 1940 and 1942 are presumably associated with major snow melt events from either spring thaw or rain-on-snow events. 1942 was unusually wet during January and February.

The event of November 26, 1950 is presumably the result of a wet November. This event exceeded the 5-year recurrence interval at the Delhi station, but not at the Walton station (see **Table 5.4**), which may have been due to localized storm cells in certain parts of the watershed, or damping effects of the larger drainage area at Walton.

The hydrographs at the Delhi and Walton stations show two storm events close together, which caused the river to peak in Delhi on August 18, 1955 and a day later in Walton. The January 1959 event is presumably a rain-on-snow event, after a smaller preceding storm, following a wet fall with the river returning to winter base flow in late December. The March 1964 event is presumably a spring runoff event following a wet January and return to winter base flow near the end of February.

The June 29, 1973 event was the result above average flows following a wet May. Before the arrival of hurricane Alice (July 2-6, 1973) low-pressure systems existed in the eastern United States[12] that spawned preceding storms, resulting in the river system being unable to contain this storm. The December 21, 1973 flow is presumably a rain or rain-on-snow event following below-average flows in October and November, two storms in early December, followed by a return to approximate normal flow just prior to the recorded storm event.

In early March 1977, melting snows due to above average temperatures for several days placed stream levels above normal. A steady rain fell for more than a day with considerable snow still present at higher elevations[13], which resulted in an event slightly greater than the 10-year recurrence interval at the Walton station.

In January 1978 temperatures in the high 50's and heavy rains[14] following a wet November and December caused the flood flow of January 9, 1978. Another flow of nearly the same magnitude peaked on January 26, 1978 at the Walton station.

The event of February 11, 1981 is presumably a rain-on-snow event that following below average flows from mid-December through January. A storm in early February had not fully subsided when a second storm sent the West Branch to its second event exceeding the 10-year

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[12] National Oceanic and Atmospheric Administration National Hurricane Center Website: ftp://ftp.nhc.noaa.gov/pub/storm_archives/atlantic/prelimat/atl1973/alice/ (Verified 12-22-04)

[13] The Walton Reporter (weekly newspaper), Wednesday, March 16, 1977.
[14] The Walton Reporter (weekly newspaper), Wednesday, January 11, 1978.

recurrence interval at the Walton station in four years (recurrence interval approximately 12.5 years).

Heavy rains and snow melt[15] following storm events in late January and late February resulted in heavy flooding on March 15, 1986. This is the second highest flow recorded at the Walton station, which significantly exceeded the 10-year recurrence interval (approximately an 18.5 year recurrence interval). The event of April 5, 1987 is a spring runoff event following a wet February and March with flows remaining above normal for that period. It is presumably the result of heavy rain.

A recent event on September 18, 2004 was the result of greater than 5 inches of rainfall (a 25 year rainfall event) throughout much of the West Branch basin. With soils saturated and most flows significantly greater than the annual mean daily flow for that time period, many streams significantly exceeded the 5-year recurrence interval flood. Of particular note was the flow in the Town Brook sub-basin, which is estimated to have been at or near the 25-year recurrence interval flow (The Town Brook station currently has 7 years of record. Therefore recurrence interval flows are estimated).

Over the last 67 years of record on the West Branch of the Delaware River there have been 18 events that have exceeded the 5-year recurrence interval flood. (Many other events exceeded *bankfull* discharge, but were less than the 5-year flood.) Approximately 33% of these 18 events have occurred in the winter and spring equally, 12% occurred in the summer and 20% in the fall. Of these 18 events, 6 have exceeded the 10-year recurrence interval flood. Although not evenly spaced within the 67 year period, one would expect the 10-year event to occur approximately 6 times during this period. In actuality, the record used to generate the flood frequency distribution would expect to closely show this pattern.

From the review of available stream gage data, it is apparent that most events at the bankfull stage and greater occur in late winter/early spring as the result of thaws and/or major rain-on-snow events. This is in large part due to the storage of available water as snow on the landscape, reduced infiltration capacity (if the ground is frozen) and the lack of evapotranspiration from vegetation during the dormant period.

Storm events can be unevenly spatially distributed across the basin. For example, an event exceeding the 5-year recurrence interval occurred in August 1953 at the Little Delaware River station (perhaps from an isolated thunderstorm) while all flows that year stayed within the streambanks at the Walton station. The July 4, 1999 storm, when over 6 inches of rain fell in a few hours, was estimated to be of “Biblical proportions” (as reported by a local farmer with respect to his conversation with USGS personnel during a mutual visit to the stream gaging station) on Town Brook near Hobart—yet this flow again stayed well within the banks at both the Delhi and Walton stations. During such storms, localized flash flooding may occur due to a sustained storm cell within isolated sub-basins of the West Branch; meanwhile, steady but light rainfall near the storm margins created only a moderate increase in stream flow elsewhere in the system.

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[15] The Walton Reporter (weekly newspaper), Wednesday, March 19, 1986

Occasionally, a widespread storm/snow melt event results in a flow with a higher recurrence interval flood at upstream gaging stations than at the Walton station, such as happened in January 1996. This is probably due to flows from downstream tributaries, peaking and flushing through the system before water from upstream sources reaches the Walton station.

Figure 5.10 East Brook near the former Pierce farm, January 19, 1996

The recent years between 1998 and 2003 (not including 2003) were generally droughty with intervening wet conditions. Recorded high water events have been at or slightly above bankfull, although 2003 and 2004 were particularly wet and characterized with more than one such event on many streams. During these two years, USGS station records show that flows generally remained above the average base flows for a significant portion of each year.

5.9 Introduction to Stream Processes

5.9.1 Introductory Overview

"You cannot step twice into the same river; for other waters are ever flowing on to you."
- Heraclitus of Ephesus, 500 B.C.

Pettis Brook tributary just above NYS Route 10, near Delancey.

Ask anyone who lives streamside, and they'll tell you that living near a stream carries both benefits and risks; to enjoy the benefits we accept the risks. The pleasures and dangers of living near streams is part of their ever-changing nature. Icy spring flood-flows are exciting and beautiful as long as they don't creep up over their banks and run across your yard into the basement window, or suddenly tear out a streambank and begin flowing down the only access road to your house. For many reasons, the relatively flat land in the floodplain of a stream may be an inviting place to build a home or road — in fact it may be the only place — but as long-time residents of floodplains know only too well, it's not a matter of *if* they will see floodwaters, but of *when*.

As changeable as streams are, there remains something consistent about how they change through the seasons — or even through an individual storm. As unpredictable as streams can be, they are also predictable in many ways. If we take the time to observe them carefully, we begin to understand the patterns of stream behavior, what we might do in our individual roles as stream stewards and managers to increase their benefits to us, and to reduce the risks they pose.

This section of the management plan is provided to offer the reader a basic explanation of what stream scientists know about how streams "make themselves": why they take different forms in different settings, what makes them evolve, and how we can effectively manage them.

It's obvious that streams drain water off the landscape, but they also have to carry *bedload* - gravel, *cobble*, and even boulders - eroded from streambeds and banks upstream.

Town Brook reference reach.

If you stand near the bank of a mountain stream during a large flood event, you can feel the ground beneath your feet vibrate as gravel, cobbles and boulders tumble against each other as the force of the floodwaters pushes them down the streambed. As the water begins to rise in the channel during a major storm, at some point the force of the water begins to move the channel bottom material. As the stormwaters recede, the force falls and the gravel and cobbles stop moving. The amount of water moving through the channel determines the amount of *bedload* moving through it as well.

To effectively manage the stream, managers first need to understand how much water is delivered from the landscape to the stream at any particular point in the system. The amount of water any stream will carry off the landscape is primarily determined by four characteristics of the region:

- climate, specifically the amount of rainfall and the temperatures the region typically sees throughout the course of a year;
- topography;
- soils and bedrock geology; and
- type of vegetation (or other land cover like roads and buildings) and its distribution across the landscape.

These characteristics also play key roles in determining the type and frequency of flood hazards in the region, the quality of the water, and the health of stream and floodplain ecosystems.

The shape and size of a stream channel adapts itself to the amount of water and bedload it needs to carry. Within certain limits, the form, or *morphology*, of a stream is self-adjusting, self-stabilizing, self-sustaining. If stream managers exceed those limits, however, the stream may remain unstable for a long time.

Over the period since the last glaciers retreated some 12,000 years ago, Catskills streams have adapted their size and shape to these regional conditions. Because the climate, topography, geology and vegetation of a region usually change very slowly over time, the amount of water moving through a stream from year to year, or stream flow regime, is fairly consistent at any given location.[16] This stream flow regime, in turn, defines when and how much bedload will move through the stream channel from year to year. Together, the movement of water and bedload carve the form of the stream channel into the landscape. Because the stream flow regime is fairly consistent year after year, the form of the stream channel changes relatively slowly, at least in the absence of human influence. Over the 120 centuries since glaciers covered the region, the stream and the landscape conditions have evolved into a dynamic balance.

However, as we made our mark on the landscape — clearing forests for pastures and cropland, or straightening a stream channel to accommodate agriculture and/or development — we unintentionally changed that balance between the stream and its landscape. We may notice that some parts of a stream seem to change very quickly, while others remain much the same year after year, even after great floods. Why is this? Streams that are in dynamic balance with their landscape adapt a form that can pass the water and bedload associated with both small and large floods, regaining their previous form after the flood passes. This is the definition of stability. In many situations, however, stream *reaches* become *unstable* when some management activity has upset that balance, altering the stream's ability to move its water and bedload effectively.

The amount of potential force that water has to move its bedload is determined by (1) slope — steeper slopes create more force; and (2) depth — deeper streams create more force. For example, if changes made to a *stable* reach of stream reduce its slope or depth, the stream may not be able to effectively move the bedload from an upstream supply. The likely result is the material will be deposited in that section, and the streambed will start building up, or *aggrading*.

On the other hand, when a stream is straightened, it becomes shorter in length; this means its slope is increased along with its potential force to move its bedload. Especially in the Catskill region, with its narrow and winding valleys, roads are commonly located close to streams. Road encroachment has narrowed and deepened many streams, with the same result: too much force, causing the bed of the stream to *degrade* and, ultimately, to become *incised,* like a gully in its valley. Both situations, aggrading and *degrading*, mean that the stream reach has become unstable, and both can lead to rapid bank erosion as well as impairment of water quality and stream health. Worse yet, these local changes can spread upstream and downstream, causing great lengths of stream to become unstable.

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[16] One exception is when the vegetation changes quickly, such as can happen during forest fires, catastrophic geologic events, or rapid commercial or residential development.

The lay of the land determines the pattern and grade of the stream, but the stream also shapes the lay of the land. The stable form for a particular stream depends on the larger form of the valley it flows through.

The stream pattern we now see throughout the Catskills is the result of millions of years of landscape evolution as previously discussed in **Section 5.5.4**.

As our climate warmed following the glacial period, grasses and then trees re-colonized the evolving valley floor. As vegetation returned to the floodplains, the conditions that determine the balance between stream shape and the landscape changed once again. Streambanks that have a dense network of tree and shrub roots adding strength to the soil can better resist the erosive power of flood flows, and consequently a new stable stream form emerges; a new balance is struck between resistive and erosive forces. A dense mat of woody roots is essential if we want to maintain a stable streambank. If streamside trees and shrubs are removed, we can expect the bank to soon begin eroding.

In the Catskills, a naturally stable stream will have trees and shrubs all along the streambank to help hold the soil together. If you remove the trees and shrubs, and mow right down to the edge of the stream, you may be risking big-time erosion problems.

The stable form that a stream takes where it is in balance with steep mountain notches will be different from the form it takes in medium-gradient valleys, and this will be different still from the stable form in a gently-sloping, broad floodplain like the West Branch of the Delaware. Stable streams are less likely to experience bank erosion, water quality and habitat problems. Since we want to maintain "healthy" and stable streams, we need to maintain a stable stream *morphology* and vigorous *riparian* (streamside) vegetation. The management developed by the Delaware County Stream Corridor Management Program (SCMPr) generally describes the current condition of the stream form and streamside vegetation throughout the watershed. The Stream Corridor Management Plan contains recommendations for protecting healthy sections and for restoration of sections at risk.

5.9.2 Stream Morphology and Classification

"The river is the carpenter of its own edifice" - Luna Leopold, 1994

For those interested, this section provides technical information about the relationship between stream *form* (or *morphology*) and physical stream *function* (e.g., flood behavior, sediment transport).

The last section described how a stream's form (slope and depth) determine its function — how much potential force the stream has to move the silt, sand, gravel, cobble and boulders that make up its *bedload*. Slope and depth were emphasized because they are often changed, intentionally or unintentionally, by stream managers. There are, however, many characteristics that come together to influence how a stream "makes itself", and whether it is stable or unstable in a given valley. These characteristics[17] include:

Stream flow (Q)

Usually represented as cubic feet or cubic meters per second, stream flow is also called stream *discharge*. Stream flow changes from hour to hour, from day to day, from season to season, and from year to year.

The typical pattern of stream flow over the course of a year is called the stream flow regime. Some stream flows play a more significant role than others in determining the shape of the stream. The "*bankfull flow*" is considered most responsible for defining the stream form. For this reason, bankfull flow is also sometimes called the *channel-forming flow*. This flow typically recurs every 1-2 years. It may seem surprising that very large floods aren't more important in forming the channel. While they may induce catastrophic changes in a stream—severely eroding banks and washing countless trees into the channel—these major floods are rarer, occurring on the average every decade or so. The flows that have the most effect on channel shape are those that come more frequently, but which are still powerful enough to mobilize the gravel and cobble on the streambed: the smaller, bankfull flows.

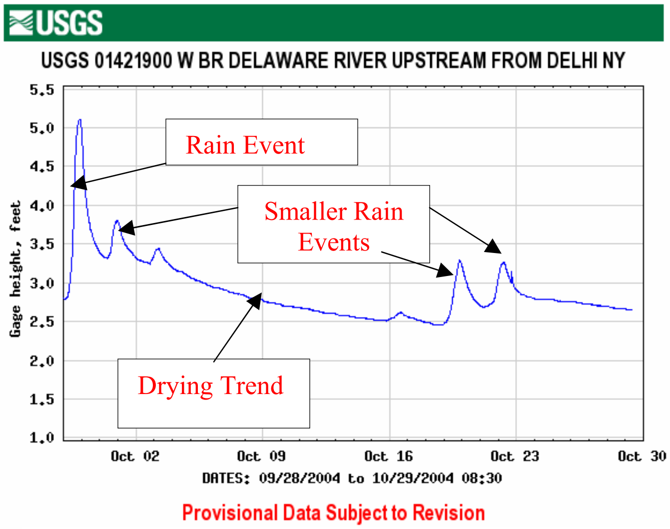

Figure 5.11 Hydrograph for one-month period showing storm events at the USGS station near Delhi

The height of the water in the channel is called the *stage*. When a stream overtops its banks, it is in *floodstage*. *Bankfull stage* — when the stream is just about to top its banks — is used as a benchmark for measuring stream dimensions for classifying different *stream types* (see *Rosgen Classification System*, below).

Slope (S)

Slope was already mentioned as one of the two main determinants of a stream's potential force for erosion of the streambed and banks. The slope of a stream usually refers to the average slope of the water surface when the stream is running at bankfull flow, though can be measured as a low flow water surface slope for use in stream classification.

Channel average depth (d)

Depth is the other primary determinant of potential force, and is measured from the streambed to the water's surface at the bankfull stage elevation. Again, this will depend on the level of the stream flow. When used to compare one stream reach to another in *stream classification systems*

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[17] Each characteristic is followed (in parentheses) by the symbol commonly used to represent it in hydrology equations.

(see below), the average depth of the stream during a bankfull flow is used.

Channel width (W)

Together with average depth, channel *width* determines the *cross-sectional area* (Area (A) = width x depth). Channel width is measured from bank to bank at the bankfull elevation. One principle important to understanding stream morphology is that whenever outside influences change a stream's channel dimensions, the stream usually adjusts itself to maintain a cross-sectional area that will pass normal bankfull flows.

Channel roughness (n)

Although flowing water develops potential to erode streambeds and banks, other stream characteristics combine to slow the water down. One of these is the channel *roughness*: there is more resistance to flow where a stream reach contains boulders and cobbles than through a reach with a smooth, silt-bottomed bed and no obstructions. Similarly, water flows more slowly across a floodplain filled with trees and dense brush, and so is less likely to cause erosion, than it does across a smooth, newly mown lawn or parking lot. This characteristic is also referred to as *bed roughness*.

Sinuosity (k)

A different kind of roughness that slows water flow has to do with whether the channel runs straight, or curves. The flow of a stream is slowed as it moves around a bend as a result of *form roughness*. The overall "curviness" of a stream is called its *sinuosity*, and is measured as the stream length divided by the valley length. That is, if a stream runs completely straight down a mile long valley, both the valley and the stream are the same length, or 1 mile ÷ 1 mile = a sinuosity of 1. If the stream snakes, or *meanders*, down the same valley, it might be two miles long, or 2 miles / 1 mile = a sinuosity of 2. In natural channels we find that, as a rule of thumb, lower slopes produce more sinuous streams.

Radius of curvature (Rc*)*

Radius of curvature describes the “curviness” of the stream at a single curve, and is measured as shown in **Figure 5.12**.

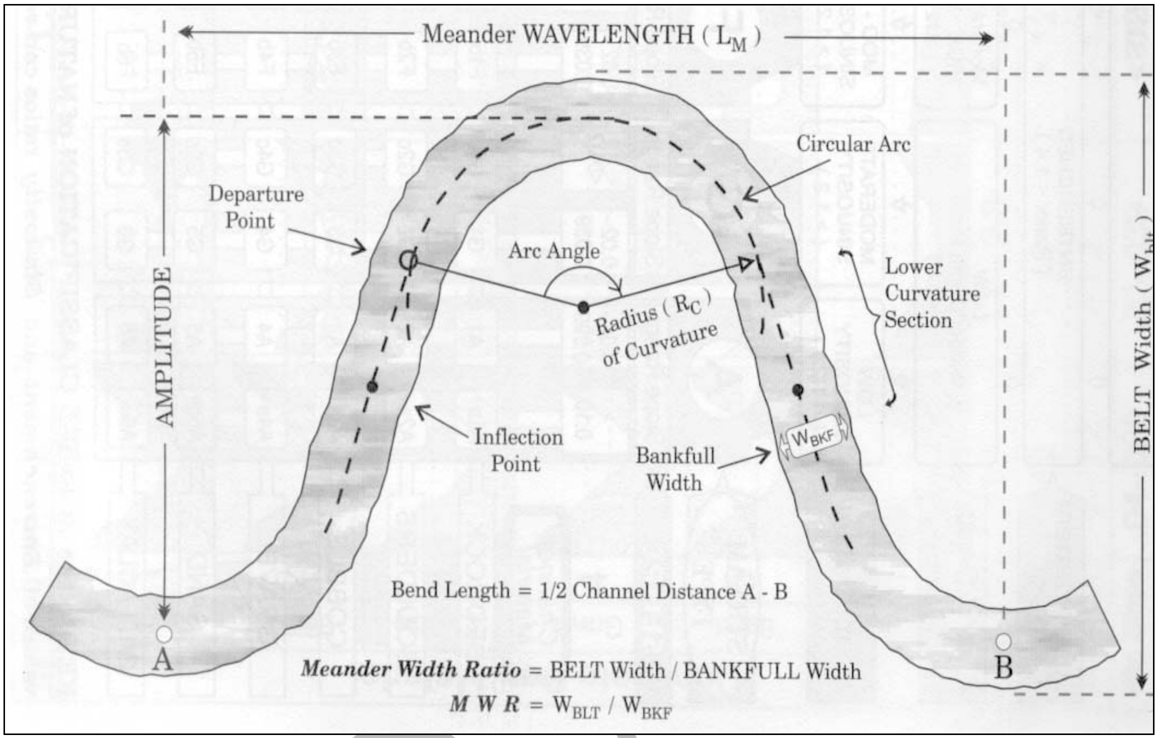


Figure 5.12 Radius of Curvature (Adapted from The Reference Reach Field Book, D. Rosgen.)

Sediment size (D_{50})

Name	Particle Size	
Silt	< 0.062mm	< 0.002 in
Sand	0.062mm - 2mm	0.002 in - 0.08 in
Gravel	2mm - 64mm	0.08 in - 2.52 in
Cobble	64mm - 256 mm	2.25 in - 10.08 in
Boulder	256mm - 2048 mm	10.08 in - 80.63 in

It takes more force for a stream to move material on the streambed if it consists of large cobbles than if it is sand or silt; the smaller the particles, the more easily they will be moved. To characterize the sediment in a stream reach, 100-300 particles are randomly selected and measured, and the median size particle determined. Although a time-consuming task, this procedure determines the *D_{50}* of the reach: meaning that 50% of the particles in the stream are smaller, and 50% are larger.

Bed and Bank Cohesiveness

Due to the glacial history of the region, soils in the Catskills are extremely variable from place to place, and some soil types hold together better than others, or are more *cohesive*. Some streambeds have their gravel and cobbles bound together in a *matrix* of finer material that resists movement by stream flow; those that do not can erode more easily. The roots of trees and shrubs can reach deep into streambanks, and the web of fine root fibers can add much strength to otherwise erosive soils.

Over time, streams tend to develop a balance between the erosive forces of floodwaters, and the strength of the bed and banks to resist that erosive power. This balance develops because streams will keep eroding their banks until the lengthening of their meanders reduces stream slope, or the stream is widened and depth is decreased sufficiently, such that soil cohesion plus vegetative reinforcement equal the erosive potential of floodwaters. When changes in streambank vegetation change soil erosivity, stream morphology will change in response, until a new *equilibrium* is reached. Also, if a streambank gradually migrates into an area with less cohesive soil, it may suddenly begin to erode this new area quite quickly.

Sediment discharge (Qs)

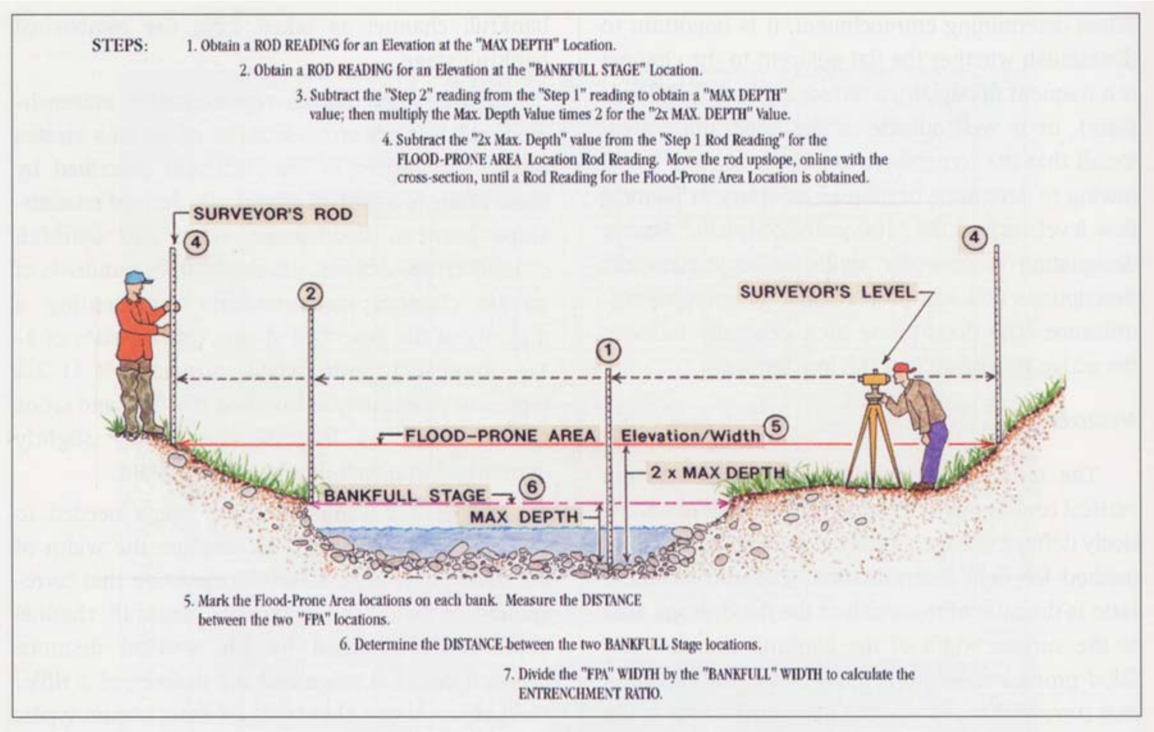
In general, the term “sediment” is used to describe the silt, sand, gravel, cobbles and even boulders that are moved by stream flow. *Sediment discharge* is the amount of sediment moving past a particular point over some interval of time, usually measured in tons per year. *Bedload* is sediment that moves along the bottom of the channel, while *washload* is sediment that is suspended within the water. Measuring sediment discharge helps determine if a stream reach is stable. If the amount of sediment entering a reach doesn’t roughly equal the amount leaving it, the form of the reach is changing or unstable.

Entrenchment

When a reach of stream is either straightened or narrowed, the power of the stream flow is increased. The stream may then cut down into its bed, so that flood flows are less likely to spill out into the floodplain. When this happens, we say that the reach has incised, and that the channel has become *entrenched*, which can occur to varying degrees of severity. When large flood flows are confined to the narrow channel of an incised stream, the water becomes very deep and erosive; the stream may gully down even deeper into its bed. Eventually the banks may become so high and steep that they erode away on one or both sides, widening the channel. This in turn can change previously stable areas downstream, having a significant impact on our road and bridge infrastructure.

Entrenchment also occurs from *berms* built to prevent the stream from using its natural floodplain during large flows, and when the amount of water that the stream carries is increased significantly due added storm drainage associated with land development.

One method of measuring entrenchment was developed by hydrologist Dave Rosgen. His *Entrenchment Ratio* compares a stream’s width at bankfull flow with its width at twice the maximum depth at bankfull flow: (The entrenchment ratio is a measure of stream incision).


STEPS: 1. Obtain a ROD READING for an Elevation at the "MAX DEPTH" Location.

2. Obtain a ROD READING for an Elevation at the "BANKFULL STAGE" Location.

3. Subtract the "Step 2" reading from the "Step 1" reading to obtain a "MAX DEPTH" value; then multiply the Max. Depth Value times 2 for the "2x MAX. DEPTH" Value.

4. Subtract the "2x Max. Depth" value from the "Step 1 Rod Reading" for the FLOOD-PRONE AREA Location Rod Reading. Move the rod upslope, online with the cross-section, until a Rod Reading for the Flood-Prone Area Location is obtained.

5. Mark the Flood-Prone Area locations on each bank. Measure the DISTANCE between the two "FPA" locations.

6. Determine the DISTANCE between the two BANKFULL Stage locations.

7. Divide the "FPA" WIDTH by the "BANKFULL" WIDTH to calculate the ENTRENCHMENT RATIO.

Figure 5.13 Rosgen method to measure stream entrenchment (Rosgen, 1996).

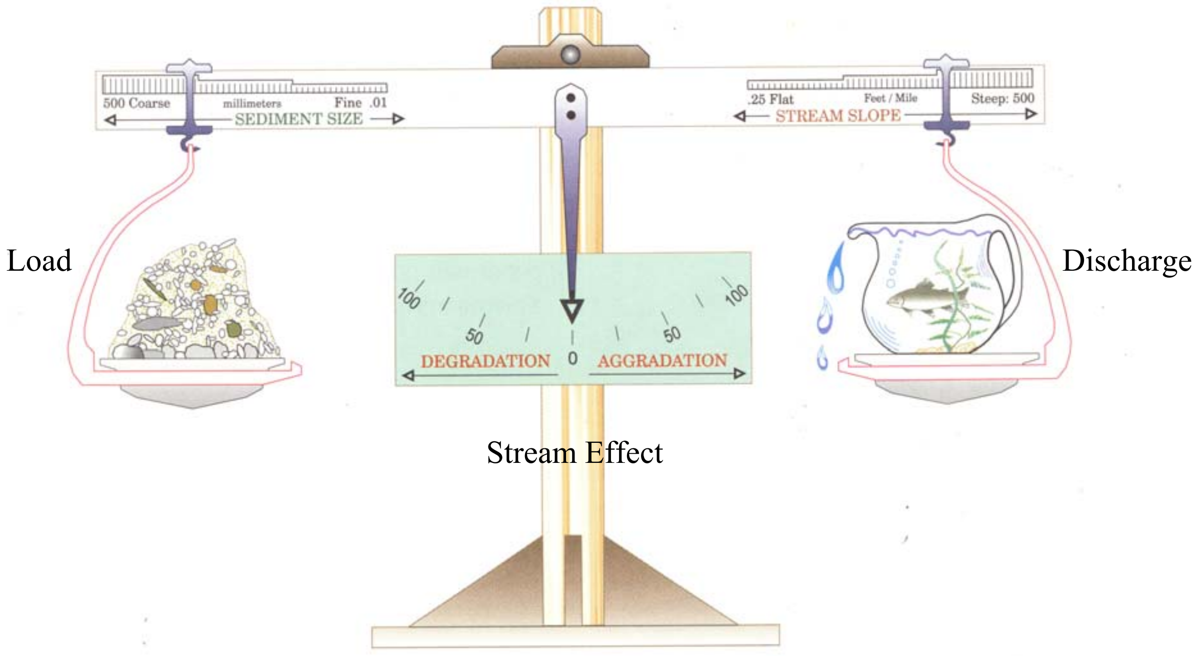
Sediment Balance

It must be emphasized that maintaining a sediment balance is essential to maintaining a stable stream. The following paragraph sums up the importance of sediment transport in the formation of rivers:

"Sediment transport processes have a major control on channel morphology since rivers can only develop if sediment is eroded and transported. Not only are the overall dimensions of the river influenced by sediment transport, but local temporal and spatial variations in transport capacity within a reach result in the formation and maintenance of *pools*, *riffles* and bar forms which are so characteristic of alluvial channels." (R. D. Hey, 2003).

It is the movement of bedload material that determines the characteristics of the stream channel. In the Catskills, the channel bottom is commonly made up of gravel or cobbles, though can include sands, silts, clays and boulders in varying concentrations. When we speak of sediment transport we are typically referring to movement of small and medium sized rocks, though in some instances, we may refer to sediment transport of fine material in a habitat or water quality context.

Sediment discharge has long been recognized as one of the primary variables that determine the characteristics of a stream. **Figure 5.14** below symbolically illustrates the inversely proportional relationship between a set of four primary physical variables (sediment size, sediment load, stream discharge and stream slope) and two opposing processes (stream bed aggradation and *degradation*) that determine stream sediment and channel characteristics and balance. The figure suggests that a change in one of four physical variables will trigger a response in the two process variables. This in turn creates changes in river characteristics.



(Sediment LOAD) x (Sediment SIZE) is proportional to (Stream SLOPE) x (Stream DISCHARGE)

Figure 5. 14 Sediment balance illustrative diagram (Rosgen, 1996).

If the supply of sediment decreases (for example, an impoundment leading to reduced sediment load downstream) or the supply of water increases (for example, increase in impervious area or decrease in vegetative cover in the watershed leading to increased runoff), the stream will begin to erode downward or *degrade*. The most noticeable manifestations of this will be incision (the stream depth will increase), and the stream slope will become less steep. Incision could lead to undermining of the streambanks as they become over-steepened and bank height ratio increases. As banks fail, this feedback mechanism provides additional sediment and results in a widening of the stream channel, bringing sediment transport capacity and sediment supply back into equilibrium. An increase in sediment transport capacity by increasing slope or decreasing width will have similar effects as increasing discharge or decreasing sediment supply (**Figure 5.14**).

Conversely, if the supply of sediment increases (for example, due to removal of bank vegetation causing increased erosion) or the supply of water decreases (for example due to water diversions or increasing vegetation on floodplain or watershed areas), the stream will begin to *aggrade* or fill in. Noticeable manifestations of this include a localized increase in stream slope and a reduction in stream depth often followed by further increase in stream width. Frequently the supply of sediment increases while the supply of water remains constant. This leads to a stream becoming too shallow from increased deposition, which can cause greater frequency of flooding due to a lack of channel capacity for its available water. Alternatively, the stream may erode its banks to become wider and achieve the necessary cross-sectional area to transport its available water. This process is temporary, because the increase in width encourages additional deposition. Eventually, the stream channel will develop a flow concentration between deposits, and a new channel will develop within the over-widened channel.

Channel Disturbance and Evolution

Channels that have been disturbed by dredging, incision, or channelization follow a systematic path to recovery. This process has been documented by Simon and Hupp (1992), and is illustrated in **Figure 5.15**.

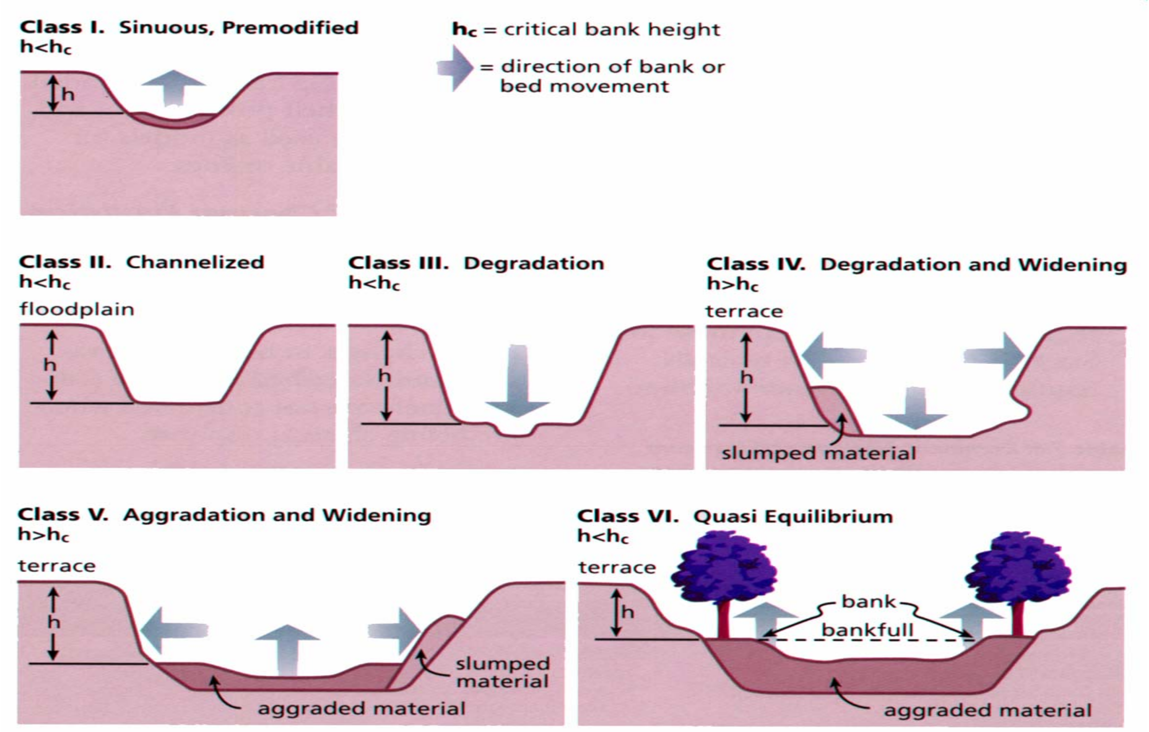


Figure 5.15 Channel evolution sequence in cross sectional view (Simon and Hupp, 1992).

- Class I, is the channel in its natural pre-disturbed state.
- Class II, is the channel immediately after being disturbed (in this case, channelized, presumably straightened and steepened in addition to over-widened).
- Class III, is the channel eroding down (degrading) due to the flood waters being confined because channel is lower and out of contact with the former floodplain.
- Class IV, the channel continues to degrade, the banks become unstable, and the channel erodes laterally.
- Class V, the channel begins to deposit eroded material in the over-wide channel, and the

newly developing floodplain continues to widen.

- Class VI, and a new channel is established and becomes relatively stable. A new floodplain is established within the original channel, and the former floodplain becomes a *terrace* (abandoned or inactive floodplain).

The six classes would temporarily occur at a single cross-section, but they can be seen to occur spatially as well when viewed along the stream profile, most typically in the downstream direction from Class I at the headwaters to Class VI at the mouth.

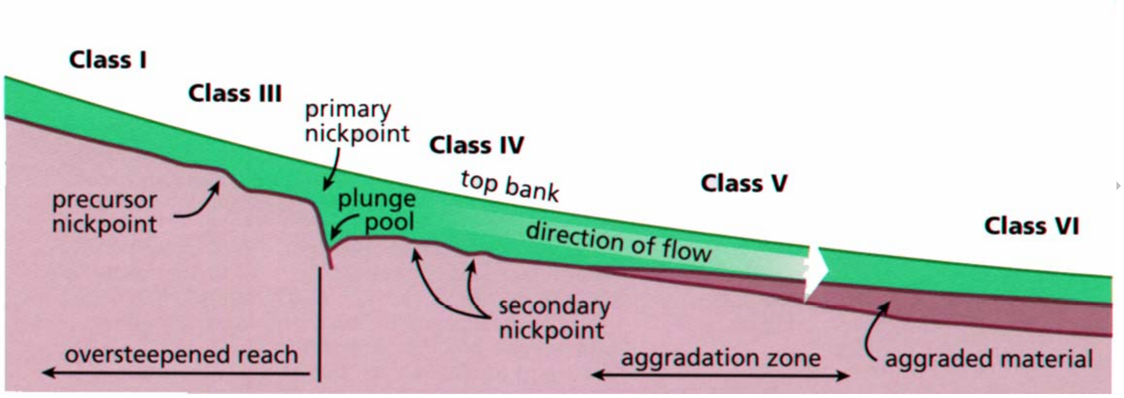


Figure 5.16 Channel evolution sequence in profile view (Simon and Hupp, 1992).

Figure 5.16 shows this process occurring along the stream profile. The profile view illustrates the changes a stream goes through in adjustment to disturbance or to natural stream processes over geologic time. Bank erosion is a symptom of change within the watershed. Focusing on stabilizing short reaches of eroding bank (*rip rap*) does not address the issue of change within the watershed. It ignores the effect that excess sediment form upstream will be deposited, and that this in turn triggers rapid channel migration and additional bank erosion. The causes of erosion must be addressed and this requires looking at the watershed as a whole.

Dave Rosgen (2001) has described nine evolutionary scenarios using his stream types which are illustrated below in **Figure 5.17**. These are not theoretical evolutionary scenarios; each has been observed by Rosgen in the field. A common evolutionary sequence in this region is number nine. A C type stream degrades to a G, then widens to an F. Eventually a new C is formed inside the wide F channel. Note that in this case a new floodplain has been created. The old floodplain is at a higher elevation relative to the streambed, and becomes a terrace.

The evolutionary sequence can be used on any particular stream to tell scientists, engineers, or hydrologists something about the stream's former and present state, or to determine what the stream's former condition (type) and what it should be to be in balance with the current setting.

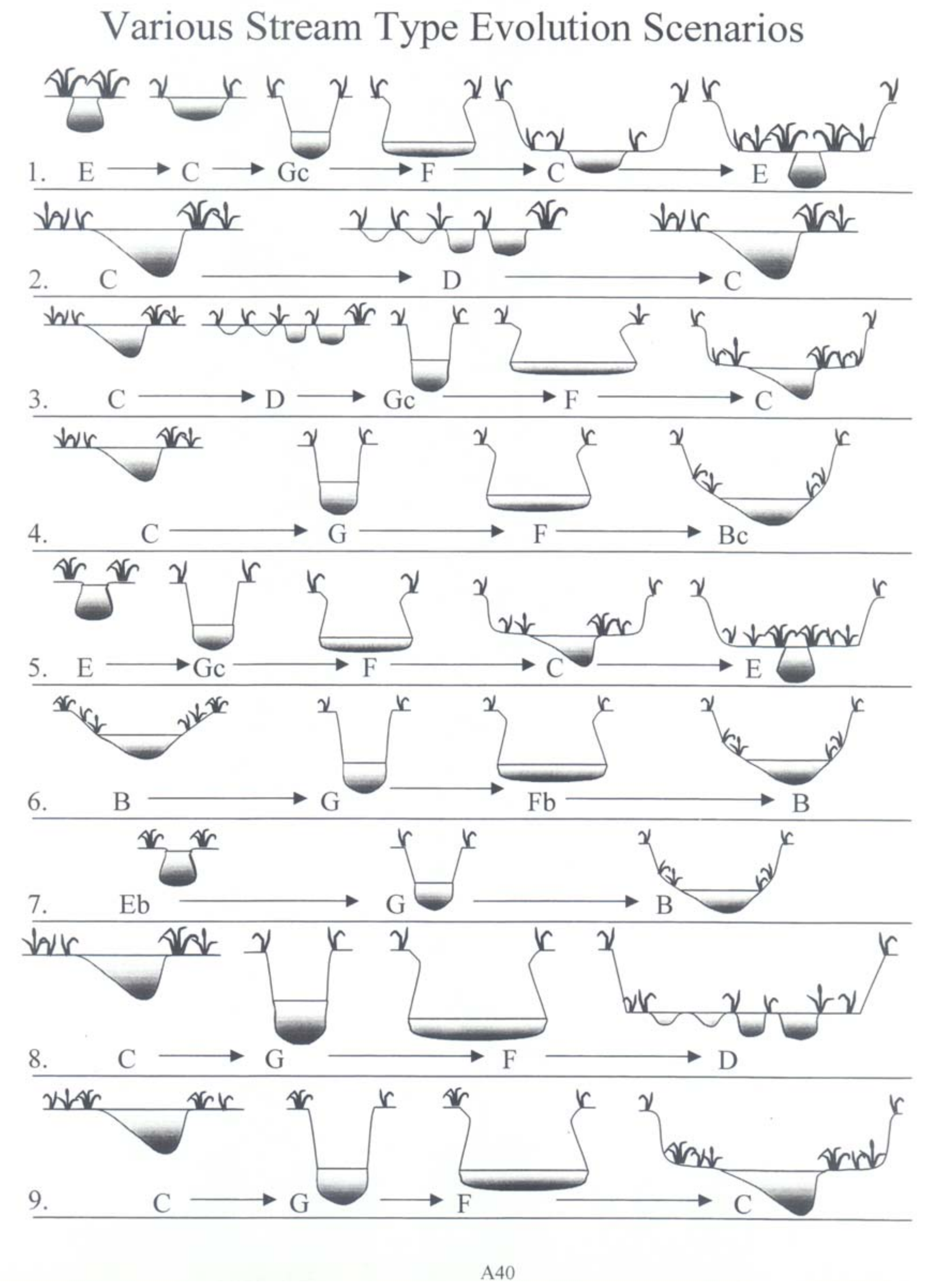
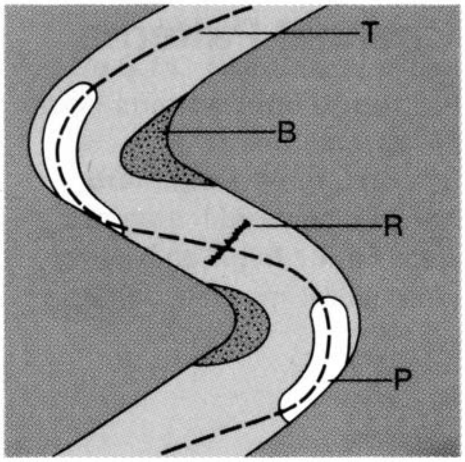


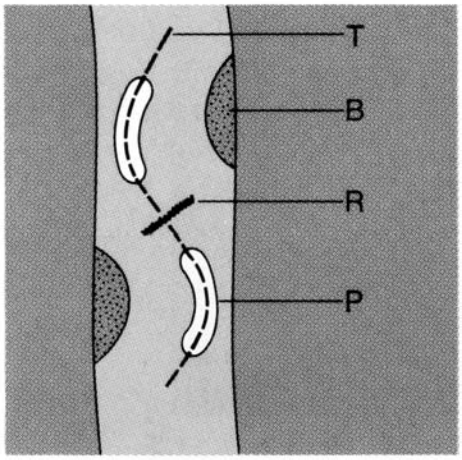
Figure 5.17 Stream Evolutionary Sequence from River Restoration and Channel Design (Rosgen, 2001)

Riffle-pool sequences

The channel form most commonly associated with rivers is that of a meandering channel. The figure below (Ritter 1978) shows the location of the principal features of a meandering channel where T is the *thalweg*, B is a point bar, R is the riffle section, and P is pools.



The following figure (Ritter 1978) shows these same features in a straight channel. The pool-pool spacing of a straight channel approximates the pool-pool spacing of a meandering channel.



Applying the Science of Stream Form and Function to Stream Management

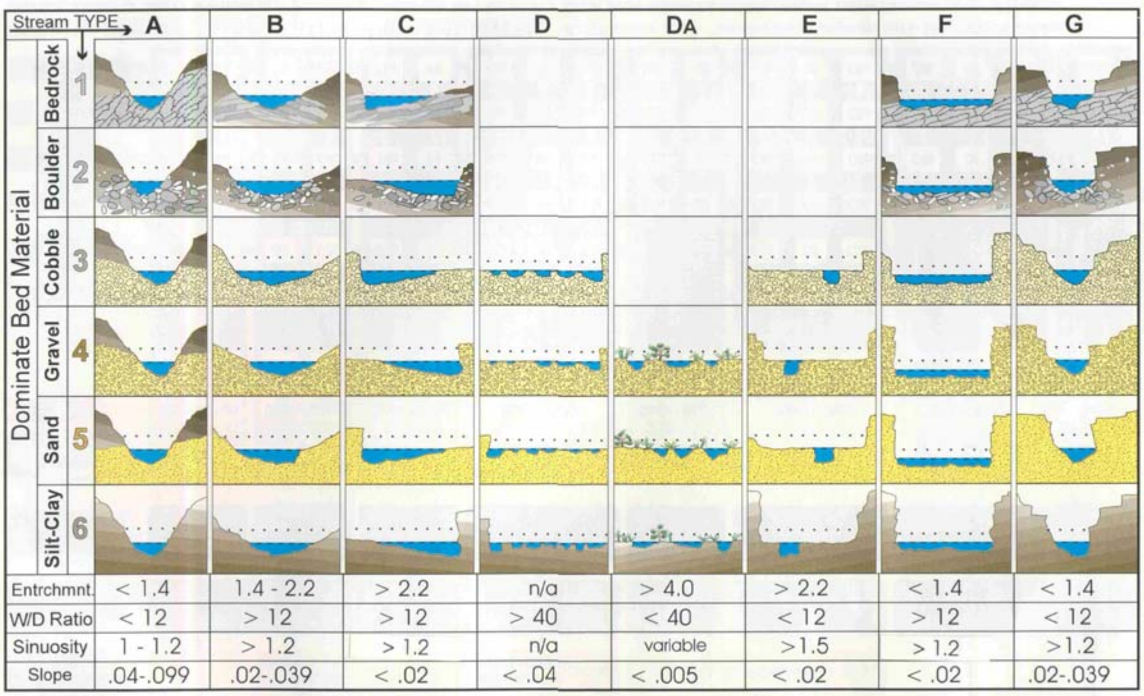
By carefully measuring the characteristics of stream form described above, stream managers can get a fairly good idea about the relative stability of a stream, reach by reach, over its whole length. By understanding the relationship between form and function, managers can prioritize severely unstable stream reaches for treatment, and can apply different management strategies appropriately and more cost effectively. Analysis of stream morphology can improve the success of stream restoration projects; designers identify and survey stable stream reaches *(reference reach*), and then use stable form characteristics as a design template for restoration projects.

Classifying Streams by their Form

One useful tool for stream managers, also developed by Dave Rosgen (1996), is a system for classification of different stream reaches based on their form. Rosgen's system gives letter and number designations to different stream types, depending on their combination of five bankfull channel characteristics:

1) Entrenchment ratio
2) Ratio of width to depth
3) Slope
4) Sinuosity
5) Bed material size (D_{50})

Different combinations of these characteristics result in a great number of different stream types, from A1 through G6 (see **Figure 5.18**; read letter designation across the top, particle size number down the left side). These letter/number designations provide a sort of shorthand for summing up the form of a stream reach.



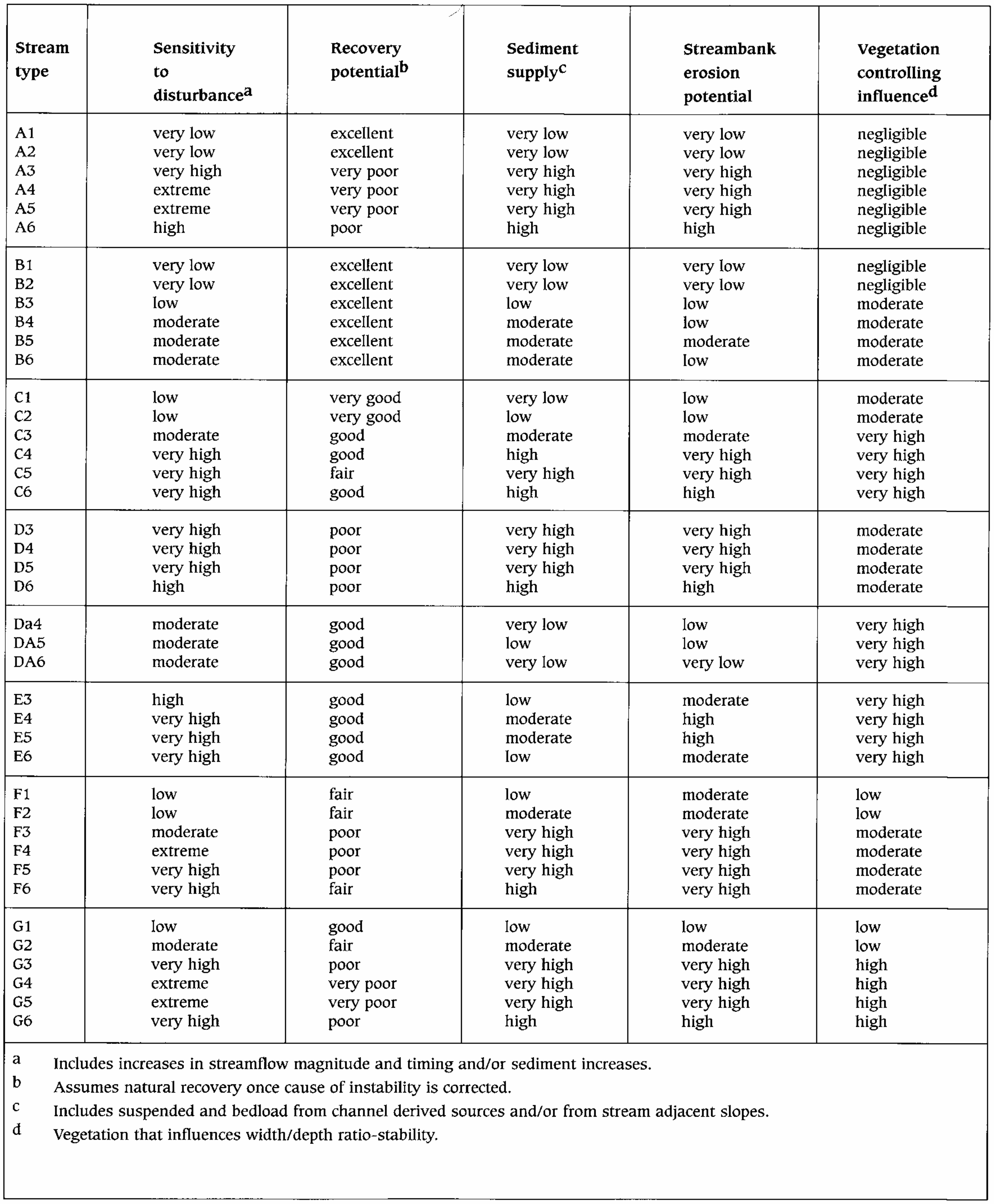
Stream TYPE	A	B	C	D	DA	E	F	G
Entrchmnt.	< 1.4	1.4 - 2.2	> 2.2	n/a	> 4.0	> 2.2	< 1.4	< 1.4
W/D Ratio	< 12	> 12	> 12	> 40	< 40	< 12	> 12	< 12
Sinuosity	1 - 1.2	> 1.2	> 1.2	n/a	variable	>1.5	> 1.2	>1.2
Slope	.04-.099	.02-.039	< .02	< .04	< .005	< .02	< .02	.02-.039

Figure 5.18 Stream type delineative criteria, from Rosgen, 1996.

So, for example, a B3 stream type has a cobble dominated bed, has a moderate amount of accessible floodplain, is more than 12 times as wide as it is deep, is moderately sinuous, and drops between 2 and 4 feet for every 100 feet of stream length. How does a B3 differ from an F3? An F3 is more entrenched, so it can't spill out onto its floodplain during storm flows, and it's also less steep, dropping less than 2 feet for every 100 feet of stream length. How is a B3 different from a G4? Not only is the G4 more entrenched, like the F3, but also has a smaller width-to-depth ratio than a B3, and a finer, gravel-dominated bed.

As discussed above, each form functions a little differently from the next, especially with regard to the stream's ability to transport its sediment effectively. By classifying the different stream types in a watershed, then, different management strategies can be targeted to each section of stream. In **Table 5.5**, Rosgen (1996) has suggested how different stream forms can be interpreted with regard to various management issues.

Table 5.5 Management Interpretations of various stream types (Rosgen, 1996)



Stream type	Sensitivity to disturbance[a]	Recovery potential[b]	Sediment supply[c]	Streambank erosion potential	Vegetation controlling influence[d]
A1	very low	excellent	very low	very low	negligible
A2	very low	excellent	very low	very low	negligible
A3	very high	very poor	very high	very high	negligible
A4	extreme	very poor	very high	very high	negligible
A5	extreme	very poor	very high	very high	negligible
A6	high	poor	high	high	negligible
B1	very low	excellent	very low	very low	negligible
B2	very low	excellent	very low	very low	negligible
B3	low	excellent	low	low	moderate
B4	moderate	excellent	moderate	low	moderate
B5	moderate	excellent	moderate	moderate	moderate
B6	moderate	excellent	moderate	low	moderate
C1	low	very good	very low	low	moderate
C2	low	very good	low	low	moderate
C3	moderate	good	moderate	moderate	very high
C4	very high	good	high	very high	very high
C5	very high	fair	very high	very high	very high
C6	very high	good	high	high	very high
D3	very high	poor	very high	very high	moderate
D4	very high	poor	very high	very high	moderate
D5	very high	poor	very high	very high	moderate
D6	high	poor	high	high	moderate
Da4	moderate	good	very low	low	very high
DA5	moderate	good	low	low	very high
DA6	moderate	good	very low	very low	very high
E3	high	good	low	moderate	very high
E4	very high	good	moderate	high	very high
E5	very high	good	moderate	high	very high
E6	very high	good	low	moderate	very high
F1	low	fair	low	moderate	low
F2	low	fair	moderate	moderate	low
F3	moderate	poor	very high	very high	moderate
F4	extreme	poor	very high	very high	moderate
F5	very high	poor	very high	very high	moderate
F6	very high	fair	high	very high	moderate
G1	low	good	low	low	low
G2	moderate	fair	moderate	moderate	low
G3	very high	poor	very high	very high	high
G4	extreme	very poor	very high	very high	high
G5	extreme	very poor	very high	very high	high
G6	very high	poor	high	high	high

[a] Includes increases in streamflow magnitude and timing and/or sediment increases.

[b] Assumes natural recovery once cause of instability is corrected.

[c] Includes suspended and bedload from channel derived sources and/or from stream adjacent slopes.

[d] Vegetation that influences width/depth ratio-stability.

Throughout this management plan there are references to these stream types. It is important to emphasize that the above are only general management interpretations, and that stream types are used as a convenient "shorthand" summary of the morphology of a reach. To predict how a stream reach is likely to behave in the future, the surveyed conditions at each reach must be considered along with conditions of adjoining reaches upstream and downstream, historical information taken from aerial photography, field studies of soils, vegetation (adequate streamside vegetation of the proper specie mix is important to stream function) and watershed land use.

5.10 Riparian Vegetation Issues in Stream Management

5.10.1 General Concepts of Riparian Vegetation Ecology

Streamside vegetation provides numerous benefits to water quality, aquatic and terrestrial plants and animals, and local landowners. Vegetated *riparian zones* facilitate stream stability and function by providing rooted structure to protect against bank erosion and flood damage. Riparian buffers offer protection against pollution and the adverse impacts of human activities. Streamside forests also reduce nutrient and sediment runoff, provide food and shelter, and moderate fluctuations in stream temperature. Streamside vegetation also improves the aesthetic quality of the stream community.

Figure 5.19 A healthy riparian community is densely vegetated, has a diverse age structure and is composed of plants that can resist disturbance. View of Town Brook Reference Reach.

The extent of benefits is proportional to the width of the riparian zone and its species diversity. For example, a narrow 25 foot buffer zone may offer only bank stabilization as a benefit while a buffer over 200 feet wide includes a diverse range of water quality and ecological benefits. A buffer containing a variety of species and types (trees, shrubs, grasses and forbs) offers the best protection **(Figure 5.19)**. An area with a diverse mix of native species of different ages and good regeneration will function more appropriately than a simpler community if disease or pests eliminated one or more species. Different types and species of plants also provide a variety of root depths and strength to help stabilize streambanks in both shallow and deep soils. Native plants in the riparian zone have the ability to resist or recover from disturbance, mainly from repeated inundation by floodwaters.

The riparian forest community can be more extensive where a floodplain exists and valley walls are gently sloping. Where valley side slopes are steeper, the riparian community may occupy only a narrow corridor along a stream and transition to an upland forest community. Soils, ground water and solar aspect may create conditions allowing the riparian forest species to occupy steeper slopes along a stream, as in the case where Eastern hemlock (*Tsuga canadensis*) inhabits steep, north facing slopes along a watercourse.

5.10.2 Natural Disturbance and its Effects on Riparian Vegetation

Natural disturbances can greatly affect the vigor of streamside vegetation. These disturbances include floods, ice or debris floes, and to a lesser extent, high winds, pest and disease epidemics, drought and fire. Deer herds can also alter the composition and structure of vegetation due to their specific browse preferences.

The effect of flooding on healthy streamside vegetation is generally short term and the recovery/ disturbance regime can be cyclical. Following a large flood, the channel and adjacent floodplains can be littered with everything from woody debris to downed live trees. In following years, much of the vegetation recovers. Trees and shrubs flattened by floodwaters re-establish their form. In stable streams, gravel bars and sites disturbed in previous flood events become seedbeds for natural regeneration of grasses and forbs. However, if significant flood or ice floe events occur too frequently to allow adequate vegetation re-establishment, large trees do not have the opportunity to establish.

Figure 5.20 A channel-wide debris jam.

Springtime ice break-up, like floods, can damage established vegetation along streambanks and increase mortality of young tree and shrub regeneration. Ice floes can also cause channel blockages **(Figure 5.20)**, which result in erosion and scour associated with high flow channels and over-bank flow. This type of disturbance generally has a short recovery period.

When stream managers seek to expedite or augment the recovery process, the following local geology and stream morphology factors are important to consider before attempting restoration: hydraulics of flowing water, morphological evolution of the stream channel, geology of the streambank, and the requirements and growth capabilities of vegetation.

Pests and diseases that attack vegetation also impact the riparian area. In portions of the eastern United States, the hemlock wooly adelgid (*Adelges tsugae*) attacks eastern hemlock and can affect entire stands[18]. Currently, the adelgid is confined to the warmer southeastern section of New York State with no known infestations in the West Branch basin, although natural resource managers are aware of its potential to expand its impacted range. Hemlock stands have been delineated in the West Branch watershed to assist in future efforts to conserve this species.

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[18] U.S. Forest Service, Morgantown office website: www.fs.fed.us/na/morgantown/fhp/hwa/hwasite.html (Verified 11-03-04)

5.10.3 Human Disturbance and its Effects on Riparian Vegetation

"When we try to pick out anything by itself, we find it hitched to everything else in the universe." - John Muir

The distinction between natural and human disturbances is important to understand. The effects of floods, ice floes, pests and disease can cause widespread damage to riparian vegetation but these effects are usually temporary. However, human activities often significantly alter natural conditions and can have a longer lasting impact on the capability of riparian vegetation to survive and function. These disturbances can include livestock overgrazing, cropping practices, construction and maintenance of highway infrastructure, real estate development and introduction of non-native species in the riparian zone.

Agriculture Influence

Figure 5.21 View of streambank significantly impacted by cattle activity.

Continuous access to streams by livestock has a significant impact on the vigor, mortality and diversity of riparian vegetation. Grazing can reach an intensity that keeps grasses and forbs at a height too low to effectively uptake nutrients and impede storm runoff, which increases environmental contamination and streambank erosion. Intensive riparian grazing also inhibits the growth, establishment and/or regeneration of shrubs and trees while hoof shear (cattle-eroded stream access points) on streambanks exacerbates erosion. Cultivating row crops and mowing haylands to the stream's edge or the top of the streambank also result in decreased species diversity and riparian buffer width. These practices significantly increase runoff and associated nutrient contamination and erosion.

The United States Department of Agriculture's (USDA) Conservation Reserve Enhancement Program (CREP) is a voluntary program that protects environmentally sensitive agriculture land with vegetative riparian buffers often associated with exclusionary livestock fencing. This program provides numerous environmental benefits and has met with great success in the West Branch of the Delaware River watershed. More information on CREP is included in **Section 6.3.2**.

Highway/Public Utility Infrastructure Influence

Use and maintenance of state and local highways also impacts the vigor of riparian vegetation where narrow buffers exist between roads and streams. These areas receive runoff containing sediment and road chemicals that stunt vegetative growth or increase stress and mortality. Accelerated storm runoff from these highways also contributes to increased streambank erosion.

Highway maintenance activities that regularly disturb the soil along shoulders and cut banks can welcome undesirable *invasive plants*. In areas where public utility lines parallel or cross streams, riparian areas are disturbed by the practice of keeping vegetation trimmed to near ground level. This is another contributor to accelerated runoff and increased streambank erosion.

Residential Development Influence

Residential land use and development of new homes can have a significant impact on the watershed and ecology of the riparian area. Houses require access roads and utility lines that often have to cross streams. Homeowners who enjoy their stream and desire to be close to it may clear all the trees and shrubs along it to provide access and views. They may replace natural conditions with an un-natural mowed lawn that provides little benefit to stream health or local wildlife. These practices can lead to new streambank erosion or increase existing erosion.

Many people live close to a stream and have access to the water without destabilizing the bank. Careful selection of a route to the stream and locating access where the water's force on the bank is lower, a landowner can minimize disturbance to riparian vegetation and the streambank. Minimizing disturbance in the flood prone area and promoting a dense natural buffer provide property protection, aesthetic value and wildlife habitat. Riparian gardeners must know which riparian species are appropriate for planting. A list of native trees and shrubs is included in **Appendix 2.** More information can be obtained by contacting the Delaware County Soil & Water Conservation District, 44 West Street, Suite 1, Walton, New York, 13856, (607) 865-7162. The following websites also offer information on riparian buffers:

USDA Natural Resources Conservation Service backyard tree planting -
http://www.nrcs.usda.gov/feature/backyard/TreePtg.html (Verified 11-05-04)

USDA Natural Resources Conservation Service wildlife habitat -
http://www.nrcs.usda.gov/feature/backyard/WildHab.html (Verified 11-05-04)

Connecticut River Joint Commission, Inc. - http://www.crjc.org/riparianbuffers.htm
(Verified 11-05-04)

The National Wildlife Federation - http://www.nwf.org/backyardwildlifehabitat/ (Verified 11-05-04)

5.10.4 Invasive Plants and Riparian Vegetation

Sometimes attempts to beautify a property with new and different plants will introduce a plant that spreads out of control and "invades" the native plant community. Invasive plants present a threat when they alter the ecology of the native plant community. This impact may extend to an alteration of the landscape should the invasive plant destabilize the geomorphology of the watershed (Malanson, 1993). *Japanese knotweed* (*Fallopia japonica*), an invasive plant gaining a foothold in the West Branch basin, is an example of a plant capable of causing such a disruption.

Japanese knotweed, (*Fallopia japonica*), an invader of the Catskills

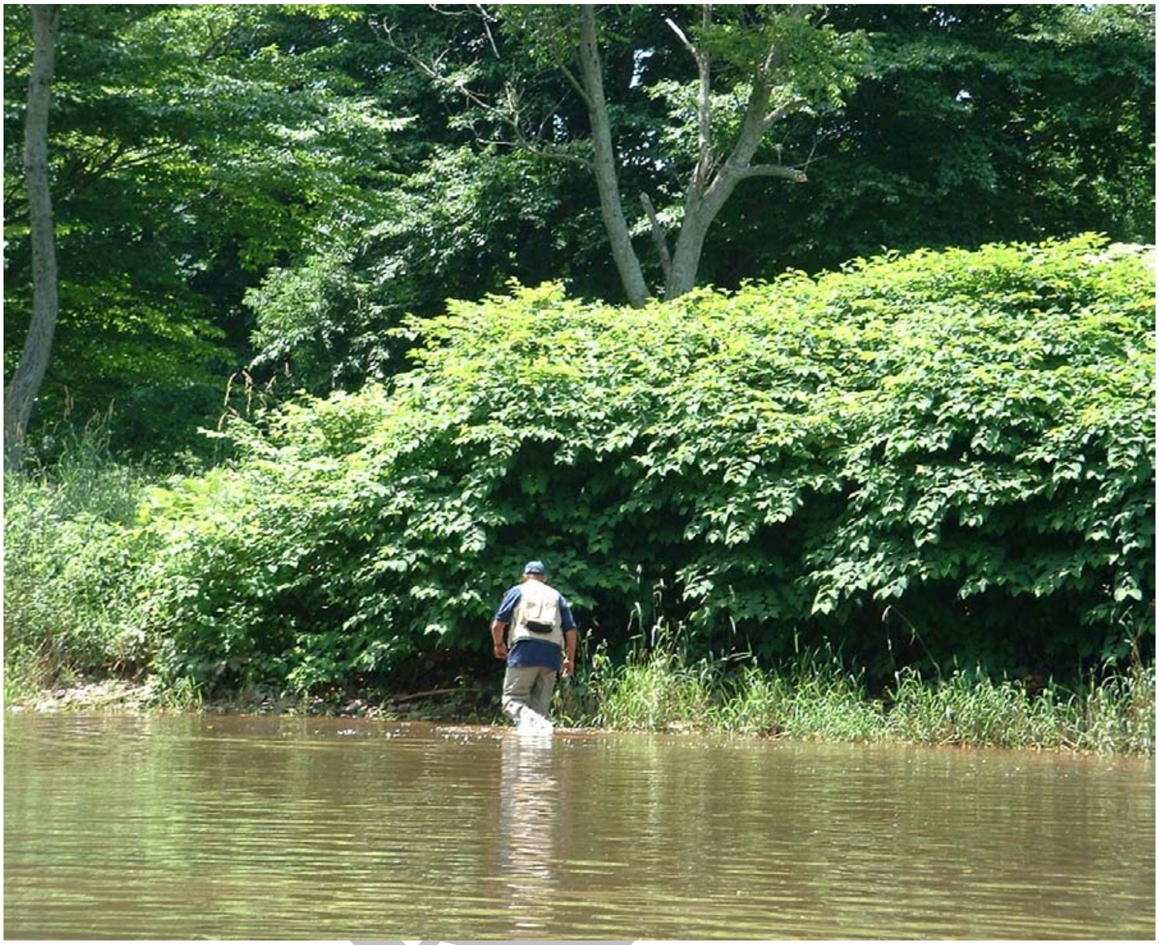

Figure 5.22 Japanese knotweed along the West Branch of the Delaware, summer 2003

A plant whose presence within the Catskill region has become much more prevalent in the last few years, Japanese knotweed, is an invasive plant is often referred to by Catskill residents as bamboo or Japanese bamboo. Although bamboo and Japanese knotweed are two different plants, they do have a couple of similarities. Both have tall, hollow stems, but more importantly, neither belong in the United States. As implied by its name, Japanese knotweed originates from Asia. This categorizes knotweed as an *exotic* plant, one that evolved in another area of the world with different plants and animals.

Because exotic species are often transported without the associated plants and animals that normally keep them in check, exotic species can become *invasive* species. Invasive species earn this categorization by out-competing local, native species and may alter the ecosystem and its functions. Invasive plants can often survive under less than perfect conditions – from high and low soil pH levels to full or no shade to wet or dry conditions. The following section describes Japanese knotweed, its traits as an invasive species, what people can do about it and resources for additional information.

Characteristics of Japanese knotweed

Fortunately, Japanese knotweed is quite recognizable throughout the year. The photographs to the left illustrate different stages of Japanese knotweed's growth throughout each season. This herbaceous, or non-woody, perennial goes through these cycles every year.

In the spring (generally late April, early May), new red, asparagus-like shoots sprout from last year's crown or from underground roots (*rhizomes*).

By July individual stems may reach as tall as 11 feet. Many thick, hollow stems are based at a crown. The upper areas of the stems form a few branches that reach out like an umbrella from the crown. Each main stem and branch holds several large, nearly-triangular leaves that shade out most of summer's sunlight.

In August knotweed dons abundant clusters of small, white flowers that attract several pollinators, such as bees, wasps and Japanese beetles.

The numerous flowers turn into buckwheat-like seeds by late September, early October. Although some seeds may create small seedlings, knotweed spreads more by their *rhizomes*.

Cold weather halts the growth of knotweed; once frost covers the land, knotweed drops its leaves and turns an auburn hue. These dead stems often remain standing for one or two years and then cover the ground, decaying slowly.

Problems associated with Japanese knotweed

As previously mentioned knotweed is an exotic, invasive species. Some texts explain that knotweed was brought to Great Britain as early as 1825 where it won accolades as an ornamental plant. By the late 1800s immigrants to the U.S. brought their prized garden plant. Knotweed has escaped personal gardens and spread into lawns, farm fields (**Figure 5.23**), along roadsides and railroads, along streambanks and onto floodplains. It is found in five Canadian provinces and all but ten states in the US.

Figure 5.23 A farmer in the Batavia Kill valley explained how a tractor barely caught a knotweed stem and pulled it into his cornfield and now it's growing amongst the corn.

Knotweed spreads vegetatively from portions of the roots or shoots. This vegetative propagation characteristic explains how it has expanded into such a wide variety of environments. The rhizomes begin new colonies of knotweed by spreading up to 20 feet from an existing plant. For this reason people may transport knotweed unknowingly by digging up rhizome-contaminated soils and dumping them elsewhere. Even a very small piece of this rhizome can sprout a new plant.

When kept moist, other plant parts, such as the stem, can also sprout new plants. Stems and rhizomes float downstream after breaking off from floods (knotweed is actually a very brittle plant and breaks easily) or from beaver damage. These fragments then come into contact with disturbed or eroded soils lacking vegetation and begin more new colonies. This is why streams host such dense stands of knotweed.

Knotweed can also be unwittingly introduced to new areas by highway departments and contractors through soil transported from gravel and sand pits contaminated with knotweed. *Stream assessment* teams have noted several instances where knotweed stands have developed in the new soil where a *culvert* or bridge has been renovated. Once established near the waterway, the knotweed is able to spread downstream after disturbance associated with a storm event.

Figure 5.24 From left to right: knotweed flattened by high flow event in Greene County, a stream bank *slump* where only grass and knotweed bordered streambank, and the shade created by dense canopy of broad knotweed leaves.

Why is this rapid invasion such a concern? Knotweed's traits pose a broad array of concerns. Some of these concerns include:

- Knotweed appears to be less effective at stabilizing streambanks than deeper-rooted shrubs and trees, possibly resulting in more rapid bank erosion (**Figure 5.24**).
- The shade of its broad leaves and the cover by its dead litter limit the growth of native plants that provide food and shelter for associated native animals (**Figure 5.24**).
- Dead knotweed leaves (*detritus*) may alter food webs and impact the food supply for terrestrial and aquatic life.
- Large stands of knotweed impede access to waterways for fishing.

Knotweed on the West Branch of the Delaware River

As part of the stream assessment for this plan, the field team used GPS to map the location of Japanese knotweed colonies along the river. This mapping effort began in 2003 and was completed in 2004. The mapping effort began within the Town of Delhi because, despite its presence, knotweed was not identified as a major component of the riparian vegetation in the upper portion of the watershed. The team mapped colonies that could be observed from within the stream channel, therefore the resulting mapping effort may not have captured colonies that are distant from the channel (but may be within the floodplain or flood fringe). Colonies were mapped as isolated points, or as a line with the beginning and end of a continuous stretch of colony identified along a bank.

The resulting map of colony locations (**Figure 5.25**, page 47, below) shows that the plant has extensively colonized the banks of the river from above Delhi to the Cannonsville Reservoir. Of the 26.8 miles of river within the mapping area, Japanese knotweed had colonized approximately

13.5 miles of streambank. Over 300 colonies were identified and the longest single colony stretched over 2400 feet along one stream bank. The median size colony was 61 feet long. The small median size relative to an average of over 200 feet suggests that a number of the colonies may be small and capable of being controlled.

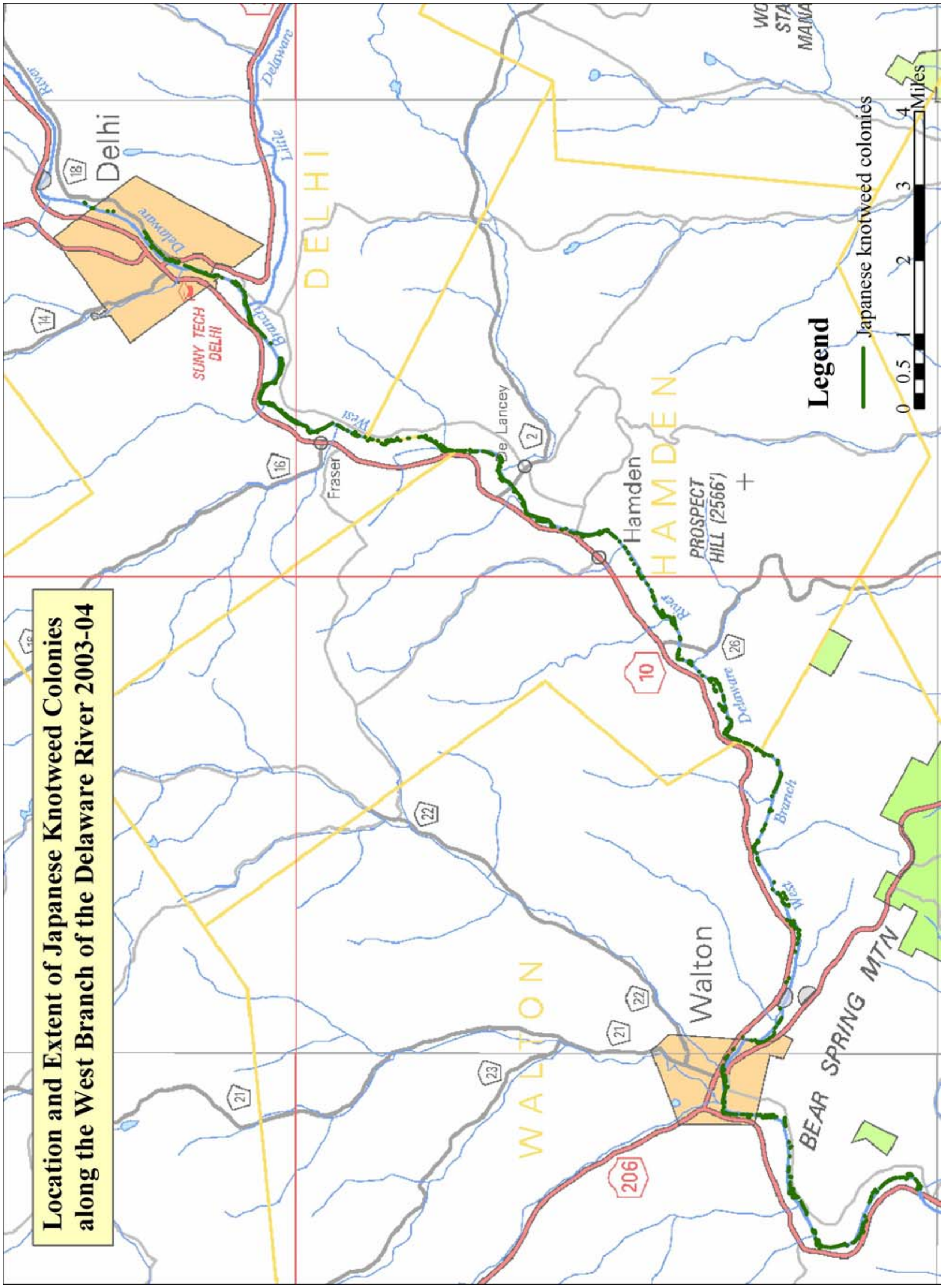

Figure 5.25 Japanese knotweed colonies along the West Branch from Delhi to Beerston

What to know before treating knotweed

Besides understanding key characteristics about knotweed (e.g. how it spreads, what environments it prefers), it is also essential to recognize a few key concepts that actually apply to most invasive species.

First and foremost,

Prevention is the best policy

No knotweed is the best knotweed

Preventing its spread is the best, most cost effective and time efficient approach to take.

Prevention may be in the form of:

1). Telling others about knotweed and warning them of its associated problems,
2). Keeping stream banks stable by allowing native trees and shrubs to grow and mature, and
3). Testing transported soil and sources for any knotweed colonies and plant fragments.

Unfortunately, the West Branch of the Delaware River has a knotweed problem and some level of treatment is necessary. It is critical to recognize that knotweed grows under diverse conditions and in varying locations, so there are different ways to approach its control. Before simply mowing down all the knotweed or spraying herbicides everywhere, one should first ask:

- How large is the stand of knotweed?
- Is it located near a waterway?
- What native plants exist nearby?

With answers to the above questions, a customized approach may be taken, saving time and money by applying the most appropriate techniques.

Finally, someone wanting to control knotweed should understand that:

- A disposal plan for all knotweed material is a must; otherwise a new colony will just sprout somewhere else. This might include burning the material, burying it more than 6 ft. deep or letting it completely dry out.
- Most treatments require multiple applications. A one-time cutting or mowing of knotweed will not do anything except stunt it temporarily and cause the rhizomes to extend underground faster towards more nutrients, possibly causing a higher rate of spread. Be prepared to make follow-up visits to past treatment sites to ensure complete control of knotweed.
- Re-vegetation with native species after treatment is necessary. Leaving bare ground only promotes the reinvasion of knotweed. Rapid-growing, native trees and shrubs must be planted soon after removing knotweed in order to affect the most beneficial change.

What to do about knotweed

Getting involved is as simple as 1, 2, 3:

1. Check your property. Locate any knotweed or areas of bare soil to know where you may need to remove knotweed or add more native trees or shrubs.
2. Become informed & spread the word. Since knotweed can travel anywhere, via stream or dump truck, let your neighbors know about it. *Spread the word, not the weed.*
3. Ask for help. Contact the Delaware County Soil & Water Conservation District for assistance with assessment or control.

Below are various treatment prescriptions depending on size of the knotweed stand, its proximity to a waterway, and amount of surrounding vegetation. Please note that where bare ground exists after removing knotweed stems and roots, it is essential to re-vegetate the area with competitive (fast-growing) native trees and shrubs. This is especially critical if surrounding vegetation is limited or nonexistent. Otherwise, reestablishment of knotweed is likely and control efforts may be futile.

For *small* stands (less than 3ft^2):
Cover with dark plastic.
Frequent cutting, grubbing or pulling with safe disposal of knotweed stems.
Herbicide injection of stems. **PLEASE READ CAUTION BELOW**.

For *medium* stands (3ft^2 to 25ft^2):
Frequent mowing (do not allow cut material to leave site).

For *large* stands (25ft^2+):
In some cases, the extent of a knotweed colony is so extensive that more harm (e.g. damage to soils) would be done in trying to eliminate the entire stand. For this reason control of expansion is the appropriate action.
Frequent mowing around edges of stand (do not allow cut material to leave site).
Herbicide injection of stems in edges of stand. **PLEASE READ CAUTION BELOW**.

Herbicide Caution: Glyphosate (e.g. Rodeo, Roundup, Aquamaster) is the recommended active agent. When used with care and according to product labels, this herbicide does NOT negatively affect *un*touched plants and animals. Using an injection method is highly recommended, because knotweed material is not cut therefore requiring no disposal. Also this method eliminates drift and targets only injected stems. Only certain herbicides, such as Rodeo and Aquamaster, can be safely used near a waterway.

Please take care to wear appropriate protective equipment. Check with Cornell Cooperative Extension of Delaware County at (607) 865-6531 for information about the proper, safe and legal use of herbicides.

Current research

Batavia Kill, Greene County

In summer 2003, Hudsonia, DEP SMP and the Greene County Soil & Water Conservation District (GCSWCD) established a number of permanent plots for long-term research. These included *monitoring* plots, which measure the rate of spread of Japanese knotweed under various conditions, and treatment plots, which will provide the setting for testing various management techniques. While setting up the different plots, the research partners gathered baseline data about knotweed, including average height and diameter of individual stems, percent canopy & litter cover and associated vegetation. Another element of last year's research included mapping Japanese knotweed and general vegetation categories along the main stem of the Batavia Kill. GCSWCD and Hudsonia hope to expand this research effort to increase community involvement in the management of Japanese knotweed. In addition to continuing to monitor the established research plots, the knotweed management team will focus on education and outreach about the prevention of knotweed expansion and its proper management and disposal. In the near future GCSWCD will be posting a literature review conducted by Hudsonia in 2002 on its website (see **Table 5.6** below)

Stony Clove, Greene & Ulster Counties

In conjunction with the Stony Clove Stream Management Plan, developed by GCSWCD and NYCDEP Stream Management Program, the partners developed the Stony Clove Planting Project to address the vegetation of private properties adjacent to over-widened sections of the creek. GCSWCD received a grant from the Watershed Agricultural Program (WAC) Forestry to treat eight sites. This money enabled contracting with Munro Ecological Services (MES), a consultant specializing in ecological restoration of floodplains, to produce designs and installation specifications. These designs included recommendations for the eradication of Japanese knotweed that exists on a couple properties. Implementation of MES recommendations is scheduled for the growing season of 2005.

Delaware River, Delaware & Sullivan Counties

The Delaware River Invasive Plant Partnership (DRIPP) was formed to increase public awareness and understanding of invasive plants and their impacts, facilitate the exchange of information regarding invasive plant management, and help coordinate public and private efforts to control these weeds in the Delaware River watershed. Recently the director of DRIPP, in partnership with the National Park Service, established a Knotweed Initiative working group that meets periodically to coordinate efforts to address knotweed management.

Catskill Region, Delaware, Greene, Sullivan & Ulster Counties

Through matching funds from WAC Forestry, The Nature Conservancy's Catskill Mountain Chapter began a study in summer 2004 of the distribution of nine exotic, invasive species, including Japanese knotweed, in seven forest matrix blocks in the Catskills – Beaverkill, Cannonsville, Panther Mountain, Sugarloaf, Catskill Escarpment, Westkill and Bear Pen Vly.

Resources for more information

While scientists and resource managers throughout the U.S. and the United Kingdom are conducting useful research and experiments on knotweed, various agencies within the Catskill region are making their own efforts to address this problem plant. Learning from the experience of others has greatly informed the above text and will continue to inform future practices. **Table 5.6** below shows summaries of these local efforts, including contact information.

Table 5.6 Regional agencies and organizations for Japanese knotweed information

Regional Agencies & Organizations		
NYCDEP Stream Management Program	845-340-7515	http://www.ci.nyc.ny.us/html/dep/watershed/html/streams.html
Greene County Soil & Water Conservation District	518-622-3620	www.gcswcd.com
Hudsonia, Ltd.	845-758-7053	www.hudsonia.org
Delaware River Invasive Plant Partnership (DRIPP)	570-643-7922 x12	http://www.upenn.edu/paflora/DRIPP%20mission%20statement.htm
Adirondack Park Invasive Plant Partnership (APIPP)	518-576-2082 x 131	http://www.adkinvasives.com/terrestrial/Program/Program.html
The Nature Conservancy-Catskill Mountain Program	845-586-1002	
National Park Service-Upper Delaware Scenic & Recreational River	570-729-7842	
Other Japanese Knotweed resources		
The Nature Conservancy-UC Davis		http://tncweeds.ucdavis.edu/esadocs/polycusp.html
The Nature Conservancy-Oregon	503-230-1221	http://tncweeds.ucdavis.edu/success/or002.html
The Knotweed Page		http://www.knottybits.com/Knotweed/
Japanese Knotweed Control Forum of Cornwall		http://www.ex.ac.uk/knotweed
The Invasive Plant Council of New York State	518-271-0346	http://www.ipcnys.org/

5.10.5 Forest History and Composition in the West Branch Delaware River Basin

Catskill region forests evolved since the last ice age, reflecting changes in climate, competition and human land use. As ice melted, plants adapted to warmer temperatures and migrated north, replacing species with a colder climate preference. The forests of the West Branch basin gradually re-established and evolved from boreal spruce-fir dominated forests (examples of which can presently be found in Canada) to maple-beech-birch forests (typical northern hardwood forests of the Adirondacks and northern New England) with a final transition in some areas to oak-hickory-ash dominated southern hardwood forests typical of the northern Appalachians (Kudish, 2000). The forests of the western Catskills and West Branch of the Delaware River basin are the eastern most extension of the Allegany Highlands forests, a broadleaf, temperate, mixed forest ecozone. The pre-settlement forests in this ecozone consisted largely of American beech (*Fagus grandifolia*) and hemlock. Sugar maple (*Acer saccharum*) later replaced hemlock as a major component of the forest on drier sites as fire controlled hemlock. Red maple (*Acer rubrum*), white ash (*Fraxinus americana*), black cherry (*Prunus serotina*), yellow birch (*Betula alleghaniensis*) and black birch (*Betula lenta*) were and continue to be associates of the beech-maple and beech-hemlock forests. Eastern white pine (*Pinus strobus*) established nearly pure stands after fire or wind impacted the previous stands[19]. One of the earliest recorded natural disturbances was the March 20th blowdown in 1797. Regional high winds felled trees around Delaware and surrounding counties (Kudish, 2000). There have also been several significant floods that have altered the landscape over the years. Hemlock has remained an important species in riparian forests along the north facing slopes of the West Branch of the Delaware River. Because of its dense overstory and allelopahtic characteristics, hemlock may have been able to preserve its dominance by regulating the diversity and abundance of ground cover vegetation in riparian zones (Williams and Moriarity, 1999).

Human activities have affected forests through manipulation of regeneration for desirable species maintenance, exploitation for wood and wood products and through clearing for development. Native American land management practices included the use of prescribed burning as a means of enabling nut bearing oaks to remain dominant in the forest. In response to a rising industrial economy, European settlers altered the landscape and forest cover through land clearing for agriculture, harvesting for construction materials, and hemlock bark harvesting for tannin extraction. These activities may have allowed the migration of some southern hardwood species (e.g. sycamore and shagbark hickory). Land cover in the basin began to revert back to forest with the local collapse of these economies in the 20th century (Kudish, 2000).

5.10.6 Summary

Changes in the composition, vigor and density of riparian vegetation produce corresponding changes in rooting depth and density, shading, water temperature, physical protection from bank erosion processes, terrestrial insect habitat and contribution of detritus to the channel. Adverse changes in riparian vegetation generally sets in motion a series of channel adjustments seen as increased sediment deposition, bank erosion, sediment supply, channel slope, and degradation of

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[19] 2001, World Wildlife website: http://.www.worldwildlife.org/wildworld/profiles/terrestrial/na/na0401_full.html (Verified 12-22-04)

aquatic habitat. Eventually stream alignment may change and begin to cause stream migration affecting downstream landowners. Streambanks in this region require a mix of vegetation having a range of rooting depths. Grasses alone are insufficient to maintain bank stability in most cases (Rosgen, 1996).

5.11 Fisheries and Wildlife

5.11.1 Fisheries Management[20]

Management of the fisheries of the West Branch of the Delaware River above the Cannonsville Reservoir, and all waters of the state, is the responsibility of the Division of Fish, Wildlife and Marine Resources of the New York State Department of Environmental Conservation (NYSDEC). (Note: NYSDEC internally designates this portion of the river as the Upper West Branch for management purposes; this is the same basin delineation used for this management plan). Delaware County and the entire Upper West Branch basin are located in DEC Region IV. Fittingly the NYSDEC Region IV Fisheries Unit is located in Stamford DEC Sub-Office, only several hundred yards from the West Branch main stem.

The majority of the fisheries management activities associated with the West Branch fishery include provisions for public use, management of fish species and fish habitat protection.

Fishery Designations and Habitat Components

The designations cold-water fishery, cool-water fishery and warm-water fishery are arbitrarily given relative to the types of fish that a water body supports. While it is true that trout, representative of a cold-water fishery, can be found to live in most any water during the winter, they will not be able to survive water temperatures that support a healthy bass population during the summer months. Generally, cold-water rivers have trout of varying ages and warm-water rivers have warm-water species of varying ages. Chain pickerel (*Esox niger*) and yellow perch (*Perca flavescens*) are representatives of cool-water species.

Components of fish habitat that are essential to maximize fish population size are water of temperatures at which the fish best function, cover where fish may go to escape detection, predation or to avoid the current, and places to spawn having the necessary substrate. Additionally, habitat for food species is necessary for fish growth and reproduction. Attempts at riverine fish habitat alteration have addressed all of the above except water temperatures as influenced by spring seeps. Physical structures have been placed and continue to be located without regard to ground water influences.

Management of Fish Species

The Upper West Branch is a cold-water stream managed as a trout fishery. It is home to wild trout spawned in the stream and tributaries whose numbers are supplemented with trout raised in New York State fish hatcheries. In 1993 D.K. Sanford updated the trout stocking policy for the

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[20] This section has been contributed by Walt Keller, a local resident and avid fisherman who retired in 1999 as the Regional Fisheries Manager for NYSDEC Region IV.

Upper West Branch. The trout stocking objectives for the basin are catch-rate-based, with trout stocked in numbers adequate to provide an average catch rate of one trout for every two hours fished and an average creel rate of one pound of trout (the equivalent weight of a two-year old hatchery brown trout (*Salmo trutta*) at stocking) for every ten hours fished. The number of trout stocked to achieve those rates is based on estimates of fishing pressure, wild trout biomass, angler accessibility to the fishery and the abundance of trout forage and aquatic competitors of trout.

The Upper West Branch is usually stocked with brown trout in mid-April, and again in mid-May with about 50 percent of the brown trout stocked in each increment. As with most other DEC Region IV streams, only brown trout are included in the trout stocking policy. The 1993 stocking policy considered only spring yearling trout, but this has been modified in recent years to make use of two-year old fish to supplement the yearling brown trout. Two-year old hatchery brown trout average about 13.5 inches, weigh about a pound each and are equivalent to four yearling hatchery brown trout. The NYSDEC fish hatchery diet includes supplements that enhance the color of trout, particularly the two-year olds, to more closely match that of their wild, stream grown counterparts. During 2004, about 17,570 brown trout were stocked in the Upper West Branch above the Cannonsville Reservoir, including 3,340 two year old fish with a total weight of approximately 6,900 pounds. The number of trout stocked each year may vary due to fish hatchery shortfalls. Any shortfall in hatchery production is shared across the state. At the time the two-year old fish stocking program was initiated New York State, hatchery brown trout cost about four dollars per pound.

Figure 5.26 Brown trout (*Salmo trutta*)

Sanford (1989) reported that Upper West Branch wild brown trout at age 4 and older were about 15 inches long (**Figure 5.26**). Consider the fact that anglers who know the river are able to catch wild brown trout in excess of 20 inches on a fairly regular basis (colorful, riverine brown trout, unlike those that migrate up from Cannonsville Reservoir to spawn). If so, the river clearly contains trout habitat even through years when flows are low ─ and ambient water temperatures are too warm ─ for trout to otherwise survive. In fact, one wild Upper West Branch riverine brown trout, caught on a recent April 1st, that weighed over seven pounds was pictured in the Oneonta Daily Star (a local daily newspaper). An abundance of cool ground water entering the streambed is necessary to keep such fish alive and healthy long enough to attain the ages and sizes that they do. Because the Upper West Branch can produce and hold large trout, special fishing regulations require that trout be at least nine inches long before they are harvested. Also, the trout fishing season is closed from October 1st ─ April 1st to protect resident brown trout, plus those migrating up from Cannonsville Reservoir, during their spawning season.

In addition to brown trout, wild brook trout (*Salvelinus fontinalis*) also contribute to anglers' catches from the Upper West Branch and its tributaries. Brook trout, however, are neither as abundant nor do they grow as large as the brown trout in the basin. Warm water and cool water game fish in the Upper West Branch, including chain pickerel and largemouth and smallmouth bass (*Micropterus salmoides* and *M. dolomieu*), are managed with statewide fishing regulations. No non-trout species are stocked in the river.

There is nothing unique about the fish fauna of the Upper West Branch relative to that of other Catskill waters. Its fishes comprise nine families, including fish that are native and introduced. More species of minnows are present than fishes in any other family. Minnows include common carp (*Cyprinus carpio*) ─ the largest fish found in the Upper West Branch; gold fish (*Carassius auratus*) and rudd (*Scardinius erytrophthalmus*), bothexotic species; native minnows, including fallfish (*Semotilus corporalis*), creek chub (*Semotilus atromaculatus*), blacknose dace (*Rhinichthys atratulus*), longnose dace (*Rhinichthys cataractae*), common shiner (*Luxilus cornutus*), and golden shiner (*Notemigonus crysoleucas*). White suckers (*Catostomus commersoni*), closely related to minnows, are also present. The catfish family is represented by the brown bullhead (*Ameiurus nebulosus*). Chain pickerel are the lone member of the pike family present in the Upper West Branch. Slimy sculpins (*Cottus cognatus*), primitive looking but nevertheless highly evolved, are the lone sculpin species present in the watershed. Yellow perch and the tessellated darter (*Etheostoma olmstedi*) are the two members of the perch family inhabiting the Upper West Branch. Members of the sunfish family include largemouth and smallmouth bass, black crappie (*Pomoxis nigromaculatus*), pumpkinseed (*Lepomis gibbosus*), bluegill (*Lepomis macrochrius*) and rock bass (*Ambloplites rupestris*), all of which are more likely to be found in impoundments, but nevertheless are in the river. The alewife (*Alosa pseudoharengus*), a herring native to the lower main-stem Delaware and its tributaries, was introduced into the Cannonsville Reservoir by bait pail. Finally, brook trout and brown trout both occur in the watershed, but only brook trout are native to the system.

This list is probably not exhaustive, as one never knows whether all the species present have been collected or noted, and additional species become introduced into the watershed, such as the rudd most recently. Noticeably absent from the list is the American eel (*Anguilla rostrata*), whose migratory passage upriver was impeded by the Cannonsville Reservoir, particularly the dam. Eels do inhabit the West Branch of the Delaware River downstream of the reservoir, as do sea lamprey (*Petromyzon marinus*).

Public Use

Twenty-two equivalent miles (44 bank miles) of Public Fishing Rights (PFR) have been purchased by the NYSDEC on about 95 proposals along the 51 miles of the Upper West Branch in Delaware County. (A small portion of the West Branch, the very headwater portion, is located in Schoharie County.)

The purchase of PFR is ongoing and property owners on the Upper West Branch are currently being paid $16,800 per two miles of streambank. Sale of PFR easements is for perpetuity and is recorded on property deeds, but only obligates the landowner to allow fishermen access to fish. In years past PFR was one chain (66 feet) wide, but in

PUBLIC FISHING STREAM

PUBLIC FISHING RIGHTS ARE RESTRICTED TO THE STREAM AND BANKS DESIGNATED BY THESE SIGNS. ACCESS AT DESGINATED POINTS. ACTIVITIES OTHER THAN FISHING ARE UNLAWFUL. AVOID TRESPASS ON OTHER LANDS. RIGHTS PROVIDED UNDER EASEMENTS SECURED FROM LANDOWNERS.

RESPECT THEIR PROPERTY

N.Y.S. DEPARTMENT OF ENVIRONMENTAL CONSERVATION recent years it is two rods (33 feet) wide along the streambank. Purchase of PFR on the Upper West Branch began around 1948. PFR is marked with signs printed with dark lettering on a yellow background and posted on trees facing the stream from the bank. Additional, non-formal access to the river is allowed by the generosity of some landowners who have chosen not to sell PFR but have no problem allowing fishermen to fish from their property.

PFR is mapped, by proposal, on letter-sized paper in a format and at a scale that does not currently lend itself to public use. These maps reside in the NYSDEC Regional Fisheries Office in Stamford and in the NYSDEC Central Office in Albany. A *Global Positioning System* (GPS) mapping project of PFR is nearly complete in NYSDEC Region IV and those maps should be available on the NYSDEC web site in the near future.

Five formal Fisherman-Parking Areas (FPAs), also purchased by the NYSDEC with public funds, have been developed and are maintained along the river. Four are situated between New York State Route 10 and the river. From upstream the locations of those five are: at McMurdy Brook, 0.5 miles upstream of South Kortright; immediately downstream of Bloomville; upstream of Delhi across from Falls Mills Road; and downstream of Delhi on Sherwood Road. FPAs are identified roadside by large, brown stained wooden signs lettered in yellow, and suspended from similarly stained, rustic standards. Originally, the parking areas were bounded with log barriers, but those are being or have been replaced with large rocks as barriers. During the summer, a NYSDEC field crew mows the grassed areas, maintains the signs, standards and barriers, and picks up trash at each of the sites. Some of the FPAs are removed from the road on the stream and are linked to the stream by either a fisherman footpath or a gravel road, which also require maintenance. Each FPA has a small birdhouse backing board on a small standard, displaying rules and regulations regarding use of the FPA. More parking is available at pull-offs along NYS Route 10 and other roads paralleling the river.

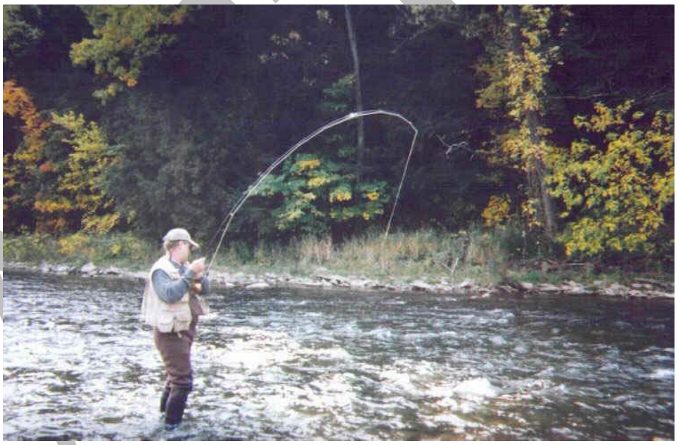
Fish Habitat Protection

Laws are currently in effect that provide some protection to the bed and banks of the Upper West Branch, and also to its water quality. Permits are required for any work on the banks or in the bed of the stream, and for any discharge from a point source (see Section 3.13). Those laws do not change the fact that many years of abuse have altered the physical form of the river, and accidents do occasionally happen that result in fish kills. Despite this, the aquatic community of the Upper West Branch appears to be in good shape. A quote from a report of a 2000 biological assessment of the Upper West Branch (Bode, et al, 2001) reads, “Overall, the West Branch Delaware River appears heavily enriched by nutrients, but still supportive of a healthy, productive invertebrate fauna.”

That the Upper West Branch runs reddish brown during and after rainstorms is also indicative of the serious erosion that occurs in the watershed. That erosion is not all mineral and contributes heavily to the enrichment mentioned in the above quoted report.

Two major fish habitat issues need to be addressed. They are the continuation of riparian buffer planting and ground water protection. Riparian vegetation provides shading of the stream which results in more optimal water temperatures for trout and cover for both aquatic and upland species. Riparian buffer planting is actively progressing and appears to be a widely accepted practice along the Upper West Branch stream corridor (see **Section 6.3.2**). Although ground water is recognized as important to keep the fishery in great condition, protection efforts are only starting to be discussed. Studies on spring seeps have been conducted by researchers at the State University of New York College of Environmental Science and Forestry in Syracuse, New York, and Cornell University in Ithaca, New York. Studies treating groundwater on a much larger scale, relating groundwater to landforms have been proposed. The determination of the location of spring seeps prior to stream re-alignment can be as indicated by localized water temperature changes and the presence of blue-green algae. Protection of groundwater inputs, especially on the inside of meander bends is critical to the maintenance of trout habitat.

The trout fishery of the Upper West Branch of the Delaware River, My Opinion, by Walt Keller.



The trout fishery of the Upper West Branch is outstanding for many reasons. It is easily accessible for most of its length. It grows very large stream brown trout and gets stocked with brown trout that provide instant gratification to anglers of all ages and levels of skill for short periods of time in the spring. Its cool ground water keeps trout spread out during times of drought and warm ambient stream temperatures, precluding easy predation on them and reducing the risk of disease that can result from crowding. The stream has an abundance of trout forage for fish of all sizes, including insects, fish and crayfish for the larger trout. The only limitation is that the stream gets un-fishable during and just after rainstorms due to rapidly rising water levels and serious *turbidity*, as do many streams in agricultural watersheds and watersheds with fine or exposed soil. My recommendations for fisheries management of the UWB include that groundwater impacts are a design consideration for projects, riparian buffer planting be encouraged and continued, and useable maps of PFR be made available to the angling public.

5.11.2 Wildlife

Riparian corridors in the West Branch basin support a diverse community of wildlife species. Species mix ranges from predator to prey and commonly includes: white-tailed deer (*Odocoileus virginanus*), eastern wild turkey (*Meleagris gallopavo*), ruffed grouse (*Bonasa unbellus*), eastern coyote (*Canis latrans*), red and gray foxes (*Vulpes vulpes* and *Urocyon cinereoargenteus*), eastern cottontailed rabbit (*Sylvilagus floridanus*), muskrat (*Ondatra zibethicus*), beaver (*Castor canadensis*), porcupine (*Erethizon dorsatum*), mink (*Mustela vison*), striped skunk (*Mephitis mephitis*), raccoon (*Procyon lotor*), Great blue heron (*Ardea herodias*), turkey vulture (*Cathartes aura*), American crow (*Corvus brachyrhynchos*), Canada goose (*Branta canadensis*), and various ducks, songbirds, hawks, owls, gulls, snakes, frogs, toads, salamanders, turtles, squirrels, chipmunks, mice, voles, bats, weasels, shrews, woodchucks, and an occasional black bear (*Ursus americanus*), bald eagle (*Haliaeetus leucocephalus*) (**Figure 5.27**), bobcat (*Lynx rufus*).

All these species depend on the stream and/or the floodplain and adjacent uplands for food, cover and shelter. Many of these species are managed as game species under jurisdiction of the NYSDEC Division of Fish, Wildlife and Marine Resources, while others are permanently protected by state and federal legislation (migratory birds that are game species are additionally managed through the federal Migratory Bird Treaty Act).

Figure 5.27 Bald Eagle
(Photo by Joel Fisk, DCSWCD)

5.12 Water Quality

There are numerous approaches for evaluating the quality of water bodies. The preferred method for any study depends upon the time and funds available and on the research focus (chemistry, biology, etc.). Because the Cannonsville Reservoir is important as a drinking water source, there have been many water quality studies of the reservoir, and there are ongoing studies along the West Branch. These studies tend to be complex, but only a summary of representative information is appropriate for this report.

All waters in the State of New York are assigned a letter classification by the NYS-DEC that denotes their "best usages". These are: AA and A – source of drinking water, culinary or food processing purposes (reservoirs, direct tributaries to reservoirs); B – swimming and other contact recreation and fishing (ponds, lakes and some streams); C – waters supporting fisheries and fish propagation; D – waters supporting fishing but not fish propagation. Waters may also have a standard designation or specification. These are: (T) – supports a trout population or (TS) – supports trout spawning.[21] For example, the Lake Brook tributary to the West Branch of the Delaware River is designated C (TS) indicating it supports fisheries and fish propagation, and is a designated trout spawning stream.

The West Branch main stem is predominantly a C (T) stream with the section between the southerly bounds of the Village of Walton to the Cannonsville Reservoir being designated B (T). Most tributary streams are classified as C, with some classified as A or AA (most of which are local water supplies and are also protected by rules and regulations approved by the NYS Department of Health) and a few classified as B. Most tributary streams also carry a (T) or (TS) designation.[22] Primarily, the West Branch river system is trout habitat.

One method to assess the overall biological health of water, in addition to evaluating fish populations as mentioned previously, is to sample and evaluate smaller life forms — macroinvertebrates and diatoms. The NYSDEC's Stream Biomonitoring Unit performed this

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[21] Official Compilation of Codes, Rules and Regulations of the State of New York, Title 6, Chapter X, Parts 701, 703 and 815 (6 NYCRR Parts 701, 703 and 815)

[22] 6 NYCRR Part 815.

kind of study at selected locations along the West Branch in September, 2000 (Bode, et al., 2001). Their results and conclusions included the following:

> “Water quality in the West Branch Delaware River was assessed as non-impacted at Stamford, and slightly impacted for the remaining 43 miles from Hobart to Beerston, based on combined assessments of macroinvertebrate and diatom communities. Nonpoint nutrient enrichment was likely the major source of impact.”
>
> “Overall, the West Branch Delaware River is considered heavily enriched by nutrients, but still supportive of a healthy, productive invertebrate fauna. Water quality in this reach may be vulnerable to added sources of enrichment, so that seemingly minor nonpoint source discharges could result in substantial changes is the ecosystem.”
>
> Based on diatom assessments alone, which are considered a sensitive indicator of nonpoint runoff, a moderate impact was noticed between Hobart and Beerston, with “a sharp decline in water quality between Stamford and Hobart”.

Annual macroinvertebrate studies in the West Branch main stem, beside the county Solid Waste Management Center in Walton during 1998-2002 (also performed by R. Bode), found similar results. Water quality was generally nonimpacted, with slight impacts noted in some parameters during 2000 and 2002 (personal communication, S. McIntyre, Delaware Co. DPW, 12/1/04).

Water quality in the West Branch has been routinely monitored for a number of years as part of the NYCDEP watershed monitoring program at nine sampling locations within the watershed. There are three on the West Branch main stem (above Hobart, near Delhi and at the NYS Route 10 bridge just above the Cannonsville Reservoir) and two each on three tributaries (Town Brook, Little Delaware River and East Brook, one each in the headwaters and near their *confluences* with the West Branch)[23]. Analytes chosen to be the most important for the City water supply for streams are turbidity, coliform bacteria[24] and total phosphorus.

Although streams in the basin are turbid during significant storm events (which implies erosion and suspension of sediments), average turbidity levels for 2003 were generally near normal values and below the maximum accepted water quality value. Coliform levels remained well below the maximum accepted water quality value. Phosphorus levels tend to be greater than desirable but have been decreasing; the Cannonsville Reservoir has remained off the list of phosphorus-restricted water bodies for the third consecutive year[25]. (When negotiations first began to develop this management plan, the Cannonsville was classified as a phosphorus-restricted basin. Hence, the West Branch received top priority for creating a SCMP).

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[23] New York City Department of Environmental Protection, *Integrated Monitoring Report*, October 2003, Section 2, pages 9-17.

[24] New York City Department of Environmental Protection, *2003 Watershed Water Quality Annual Report*, July 2004, Section 3, pages 29-40.

[25] Ibid.

The Delaware County Action Plan (DCAP) was formulated in 1999 by a contingent of county departments and agencies to address water quality issues in the New York City watershed. Current components of DCAP include management programs for stormwater, highway runoff, on-site septic systems, precision livestock feeding, stream corridors and monitoring and modeling of best management practices to assess phosphorus reduction. More detailed information regarding DCAP is included in **Section 4.6**.

5.13 Permitting Requirements for Stream Related Activities

5.13.1 NYSDEC Permit Requirements

The NYSDEC regulates activities in and around the water resources of New York State pursuant to the Environmental Conservation Law (ECL) Article 15, Title 5, Protection of Waters Program. This is known as an Article 15 Permit, and is issued to applicants at no charge.

A Protection of Waters Permit is required for temporary or permanent disturbances to the bed or banks of a stream with a classification and standard of C(T) or higher. Examples of activities requiring this permit are:

- Placement of structures in or across a stream (i.e., bridges, culverts or pipelines);
- Fill placement for bank stabilization or to isolate a work area (i.e., riprap or other forms of *revetment*);
- Excavations for gravel removal or as part of a construction activity;
- Lowering streambanks to establish a stream crossing;
- Use of heavy equipment in a stream to remove debris or to assist in-stream construction.

Some stream disturbance activities are exempt from the requirements of an Article 15 Permit. The most common of these are:

- Disturbance of a protected stream by a town or county government that enters into a written agreement with NYSDEC for specified categories of work, undertaken in compliance with performance criteria that are protective of stream resources.
- Agricultural activities involving the crossing and re-crossing of a stream by livestock or farm equipment at an established crossing.
- Removal of fallen tree limbs or tree trunks where material can be cabled and pulled from the stream without disruption of the streambed or banks, utilizing equipment placed on or above the streambank.

Projects are classified as minor or major for the purposes of review by NYSDEC. Maximum allowable review periods are different for “minor” and “major” projects under the Uniform Procedures Act requirements (6 New York Code of Rules and Regulation (NYCRR) Part 621). Minor projects include: 1) repair or in-kind replacement of existing structures; and 2) disturbances of less than 50 linear feet along any 1,000 feet of watercourse. All other activities are considered major projects for the purposes of review and public notice, as required by the Uniform Procedures Act. For minor projects, NYSDEC must make a permit decision within 45 days of determining the application complete. For major projects: 1) if no hearing is held, NYSDEC makes its final decision on the application within 90 days of its determination that the application is complete; and 2) if a hearing is held, NYSDEC notifies the applicant and the public of a hearing within 60 days of the completeness of determination. The hearing must commence within 90 days of the completeness determination. Once the hearing ends, NYSDEC must issue a final decision on the application within 60 days after receiving the final hearing record.

For permit applications and any questions regarding the permit process contact the Deputy Regional Permit Administrator at:

NYS Department of Environmental Conservation
Division of Environmental Permits, Region 4
65561 State Highway 10, Suite 1
Stamford, NY 12167-9503
(607) 652-7141

Protection of Waters permit information is also available on the NYSDEC website: http://www.dec.state.ny.us/website/dcs/streamprotection/protwater05.html (verified 11-17-04).

5.13.2 U. S. Army Corps of Engineers Permit Requirements

Under Section 404 of the Clean Water Act, any activities where placing fill or undertaking activities resulting in a discharge to waters of the United States[26] also require
a Nationwide permit from the U. S. Army Corps of Engineers (USACOE). Minor projects include those projects that will not exceed the minor project thresholds for NYSDEC Article 15 permits, and which do not involve the approval of construction and operation of hydroelectric generating facilities. All other projects are major projects and require USACOE review.

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[26] The term **"waters of the United States"** means

1. All waters which are currently used, or were used in the past, or may be susceptible to use in interstate or foreign commerce, including all waters which are subject to the ebb and flow of the tide;
2. All interstate waters including interstate wetlands;
3. All other waters such as intrastate lakes, rivers, streams (including intermittent streams), mudflats, sandflats, wetlands, sloughs, prairie potholes, wet meadows, playa lakes, or natural ponds, the use, degradation or destruction of which could affect interstate or foreign commerce including any such waters:
    - **i.** Which are or could be used by interstate or foreign travelers for recreational or other purposes; or
    - **ii.** From which fish or shellfish are or could be taken and sold in interstate or foreign commerce; or
    - iii. Which are used or could be used for industrial purpose by industries in interstate commerce;
4. All impoundments of waters otherwise defined as waters of the United States under the definition;
5. Tributaries of waters identified in paragraphs (1)-(4) of this definition;
6. The territorial seas;
7. Wetlands adjacent to waters (other than waters that are themselves wetlands) identified in paragraphs (1)-(6) of this section.

Currently, applications are a one form joint application available from the NYSDEC, which forwards a copy of the application package to the regional USACOE office. USACE will contact the applicant if additional information is required. Information is also available from the regional USACE office at:

Department of the Army
New York District, Corps of Engineers
Albany Field Office
1 Bond Street
Troy, NY 12180
(518) 270-0588

5.13.3 Erosion and Sediment Control

Stormwater Pollution Prevention Plan

A Stormwater Pollution Prevention Plan (SPPP) documents how erosion will be controlled during construction, and the project's likely effects on the rate and quality of stormwater leaving the site. An SPPP consists of a narrative report, plans, details and specifications.

NYSDEC Requirements

Generally, construction activities in the West Branch watershed that involve one acre or more of land disturbance must obtain a State Pollutant Discharge Elimination System (SPDES) permit, which includes the development of an Erosion and Sediment Control Plan and an SPPP. Operators of potential construction activities should contact the local NYSDEC office in Stamford (see **Section 5.13.1**) for a determination whether or not a SPDES permit is required. Additional information is available from the NYSDEC website: http://www.dec.state.ny.us/website/dow/mainpage.htm (Verified 11-18-04).

Implementation of certain agricultural Best Management Practices are exempt from SPDES permitting requirements pursuant to a Memorandum of Understanding (MOU) between the NYSDEC, NYS Department of Agriculture and Markets and the NYS Soil and Water Conservation Committee dated March 25, 2004. A copy of this MOU is included in **Appendix 3.**

New York City Requirements

The New York City Department of Environmental Protection (NYCDEP) requires an SPPP to be submitted and approved prior to implementation of any of the following activities:

- Development or sale of land that will result in the disturbance of five or more acres of land.
- Construction of a subdivision.
- Construction of a new industrial, municipal, commercial or multi-family residential project that will result in creation of an impervious surface totaling over 40,000 square feet in size.

- A land clearing or land grading project, involving two or more acres, located at least in part within the limiting distance of 100 feet of a watercourse or *wetland*, or within the limiting distance of 300 feet of a reservoir, reservoir stem or controlled lake or on a slope exceeding 15%.
- Construction or alteration of a solid waste management facility within 300 feet of a watercourse or wetland or within 500 feet of a reservoir, reservoir stem or controlled lake.
- Construction of a gasoline station.
- Construction of an impervious surface for a new road within certain limiting distances from various watercourses.
- Construction of an impervious surface within a village, hamlet, village extension or area zoned for commercial or industrial uses.
- Up to a 25% expansion of an existing impervious surface at an existing commercial or industrial facility which is within the limiting distance of 100 feet of a watercourse or wetland.

Generally, installation of culverts, stream diversions and bridges or stream crossings within 100 feet of a stream or wetland, or within 300 feet of a reservoir , reservoir stem or controlled lake also require NYCDEP approval. For applications and any questions regarding this process contact the Deputy Chief, Engineering Section at:

NYCDEP
71 Smith Avenue
Kingston, NY 12401
(845) 657-2390

5.14 Flood Protection and Recovery

As protection is a principal function of government, and floods and the potential resulting loss of life and property are a serious threat to those living along the West Branch of the Delaware River, it is the role of all levels of government to assist the public in securing itself from the threats associated with flooding. Policy for protecting the public from flooding and programs for assisting the public in the event of a flood, flow from the federal level to the state and local levels of government. The Federal Emergency Management Agency (FEMA) within the Department of Homeland Security, establishes flood programs enabling communities to plan and respond to flood events, minimize or mitigate against flood hazards, and recover from flood disasters. The State Emergency Management Office (SEMO) generally mirrors FEMA policies and programs and helps to administer flood planning, mitigation and coordinate state resources for recovery efforts. Within Delaware County, the Director of Emergency Services coordinates emergency response and recovery, while efforts to plan for mitigating against flood hazards is shared across county agencies such as the Department of Public Works and Planning Department. As a tool for individuals and communities living along the river, this Stream Corridor Management Plan provides a general background on the programs and policies that will enable the community to avoid, mitigate against, or recover from a flood. This section is written for home owners, local leaders and the general public to help increase their knowledge of steps they can take to reduce flood losses and facilitate disaster recovery.

5.14.1 Avoiding Flood Losses

Flood waters are very destructive and while losses in terms of property or life cannot be totally avoided, with good information and wise decisions, individuals and communities can reduce their losses. Information is the most important tool available. Local knowledge, timely communications and accurate maps of where flood waters are likely to have their greatest impact are only some of the information that can help the community with decisions as they seek to avoid flood losses.

Communicating with local experts is critical to avoiding flood losses. A very important and often overlooked individual is the local *floodplain manager* or floodplain regulation enforcement officer. Many municipalities employ a person in this position to inform the public about floodplain regulations and help landowners make wise decisions about their development projects. The floodplain manager develops an understanding of the regulations, the best practices and the location of floodprone areas for their community. Making use of their knowledge can save time and money by avoiding red tape and otherwise avoidable flood damages. Often, the floodplain manager is also the building code enforcement officer, so it is likely to meet this person in more than one capacity when a construction project be undertaken in or around a floodplain. Training courses are available through NYSDEC and FEMA to keep the local floodplain manager current with the latest best management practices and regulations.

Flood Insurance Rate Maps (FIRMs) are available for most communities in the United States and provide a guide to where flood waters of larger floods are likely to inundate the lands surrounding a water body. Before buying or building a house or buying property near a body of water, whether stream, river, lake or wetland[27], an individual should consult their floodplain map or FIRM "community panel" to find out where the waters will be likely to rise during a major storm event. The FIRMs are produced and are maintained in support of the National Flood Insurance Program (NFIP) which provides low cost flood insurance to home owners and businesses living in areas likely to be flooded during a flood event. The most recently updated FIRMs for Delaware County were created through engineering studies which based the estimated extent of the floodplain on local topography, channel shape and slope, hydrology and hydraulic conditions for a range of flood return probabilities. Typically, the maps show the one percent annual chance flood (also called the base flood or 100 year flood) extent or the Special Flood Hazard Area. An example of this generation of maps includes the Village of Walton, Delhi and Stamford. These maps are of reasonable accuracy but could be improved with current mapping technologies. Older maps, such as the FIRM map for the Town of Hamden, created in the late 1960's at the start of the NFIP, only show the "flood hazard boundary" based on approximate studies of the floodprone area for the 100 year flood event. Care should be exercised in using these maps if one is considering a development anywhere near this map zone. When an area is suspected as being within the floodplain, but the limits and depth of the base flood are not known for a location, a flood study should be required of the applicant by the local code officer or planning board.

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[27] The National Wetland Inventory (NWI) maps produced by the U.S. Fish and Wildlife Service provide a good reference for the location of wetlands. These maps are available for inspection through the local planning board, the Delaware County Planning Department or the DCSWCD.

Should an older map be of questionable accuracy, the individual should obtain an engineer's estimate of the floodprone area or the *Base Flood Elevation* (BFE) for the development site prior to any construction. Before securing financing to purchase or build a home within a known floodprone area with an established Base Flood Elevation (BFE) a lender will require the purchase of flood insurance and have a surveyor define the elevation of the structure's first floor for use in estimating your flood insurance premium. Building in a floodplain can result in thousands of dollars of losses, especially if the construction does not meet NFIP code. Not only does the individual risk personal losses, but building within the floodplain or floodway can seriously impact the neighboring property owners by causing flood elevations to rise or flood routes and velocities to change. The local Code Enforcement Officer can inform individual of the requirements before they begin planning a project. Individuals that are buying land with the intent to build should avoid floodprone areas. FIRM maps are available for inspection through the Delaware County Planning Department and should be available for viewing at the Town or Village Hall. Copies of the maps can also be purchased from FEMA through their web site or by mail.

Recent advances in remote sensing, hydraulic modeling and computer mapping technology have greatly improved the ability of engineers to accurately estimate the flood extent and elevation for a range of floods. FEMA, together with the NYSDEC have established procedures for revising the current **flood studies** around New York State. NYSDEC and Schoharie County are in the process of completing a new flood study and set of revised paper floodplain maps and Digital FIRMs (DFIRMs) for the entire county. Similar efforts in Delaware County could improve the information available to landowners about the development potential of their property, their risk of flood losses, and help prevent future threats to life and property throughout the area. This information could also improve the community's rating and minimize the need for individuals to bear the expense of site specific flood studies.

NFIP was established by Congress in 1968 to reduce the cost of taxpayer funded disaster relief. The Mitigation Division, within FEMA, manages the NFIP, and oversees the floodplain management and mapping components of the Program.

Nearly 20,000 communities across the United States, (including all municipalities within Delaware County), participate in the NFIP by adopting and enforcing floodplain management ordinances to reduce future flood damage. In exchange, the NFIP makes Federally backed flood insurance available to homeowners, renters, and business owners in these communities. Flood insurance can be purchased through a local insurance agent and covers the cost of structural damage to a home. If an insurance agent is unable to write a flood policy, call 1-800-638-6620 for information. The contents of a home, such as appliances, furniture and clothing are typically insured at additional cost. There is a 30 day waiting period for new policies.

Flood damage is reduced by nearly $1 billion a year through partnerships with communities and the insurance and lending industries. Further, buildings constructed in compliance with NFIP building standards suffer approximately 80 percent less damage annually than those not built in compliance. And, every $3 paid in flood insurance claims saves $1 in disaster assistance payments (FEMA, 2004). Flood Insurance rates for individual policyholders of a community can be reduced if the community improves its "*community rating*" by participating in flood disaster planning efforts and takes action to reduce or avoid flood losses. The NYSDEC Flood Bureau within the Division of Water, together with SEMO can help the community identify ways to improve the community's rating under the Community Rating System (CRS). Additional information is available at: http://www.fema.gov/fima/nfip.shtm (Verified 12-08-04).

For those who live in a floodprone area, there are several practical steps that can be taken to protect a home or business in preparation for a flood. Irreplaceable valuables should be moved out of the cellar and first floor. If an oil tank exists in the basement, it should be securely anchored according to code to prevent it from floating and spilling during a flood. Electrical components, including the washer and dryer, within the house should be raised above the level of potential flood waters. Consideration should be given whether to raise the furnace and water heater above the level of potential flood waters. These suggested actions could help avoid the common repairs homeowners may have to undertake after a flood.

In the event of a flood, FEMA recommends the following actions to make sure a family stays safe until the water levels recede:

- Fill bathtubs, sinks, and jugs with clean water in case water becomes contaminated.
- Listen to a battery-operated radio for the latest storm information.
- If local authorities instruct the community to do so, turn off all utilities at the main power switch and close the main gas valve.
- If told to evacuate your home, do so immediately.
- If the waters start to rise inside a house before evacuation, retreat to the second floor, the attic, and if necessary, the roof.
- Floodwaters may carry raw sewage, chemical waste and other disease-spreading substances, wash hands with soap and disinfected water.
- Avoid walking through floodwaters. As little as six inches of moving water can knock a person off their feet.
- Don't drive through a flooded area. If you come upon a flooded road, turn around and go another way. A car can be carried away by just 2 feet of flood water which is very hard to judge.
- Electric current passes easily through water, so stay away from downed power lines and electrical wires.

Following a flood, individuals should take special care to document their damages and losses. Receipts for repairs and materials as well as photographs of damages should all be kept by home and business owners.

5.14.2 Flood Response

During major flood events that cause road and bridge closures, the Delaware County Department of Emergency Services (DCDES) activates its emergency operations center. All emergency response agencies including FEMA, SEMO, NYS Office of Fire Prevention Control, law enforcement agencies, and fire departments are contacted and put on alert. DCDES monitors all emergency situations and provides for emergency evacuations, if necessary.

5.14.3 Flood Recovery

Following a flood that has been declared as a Presidential disaster, several forms of assistance become available to individuals and communities. There can be both Public Assistance and Individual Assistance programs depending upon the severity of the flood event. Declarations are made on a county by county basis. Less severe events may only trigger a declaration enacting Public Assistance programs to assist with infrastructure recovery, such as the repair of roads and public facilities. If a disaster is declared for Individual Assistance, then programs are deployed to address the property losses of individuals, farmers and other businesses.

Public Assistance is managed by the state through the Emergency Services Coordinator and local government representatives. A SEMO team will organize initial contact meetings to inform local government representatives of the assistance process and initiate project identification. It is important to document all actions taken to repair damages to a flood and carefully track the use of materials, equipment and labor for later reimbursement. Attendance at these meetings is critical especially if local leadership has changed and the new leadership has not experienced a flood event. Documents regarding flood recovery efforts should be held and shared with those considering flood hazard mitigation planning. The SEMO website is an excellent resource for obtaining the latest information on the status of a disaster recovery effort or finding out who to contact for more information: http://www.nysemo.state.ny.us (Verified 12-08-04).

Individual Assistance is typically made available following a flood where there has been widespread damage to homes and businesses. The American Red Cross is a first responder helping flood victims with their immediate needs for food, shelter, medical attention and clean up provisions. Within 12-36 hours of an event, FEMA deploys its staff of inspectors to assess the damage and meet with state and local officials. Once the declaration is made, FEMA will announce an 800 telephone number for individuals to seek assistance and file claims. One of the primary forms of individual assistance is the Assistance for Individuals and Households Program which can help with lodging or temporary housing, home repair grants, and other personal needs. The Small Business Administration (SBA) offers low interest loans to eligible individuals, farmers and businesses to repair or replace damaged property and belongings not covered by insurance. Other assistance is available as tax rebates, veterans benefits and unemployment benefits. Following a flood, individuals should take special care to document their damages and losses. Receipts for repairs and materials as well as photographs of damages should all be kept by home and business owners. If individuals have flood insurance they should initiate a claim immediately.

5.14.4 Flood Hazard Mitigation

Hazard Mitigation is any sustained action taken to reduce or eliminate long-term risk to people and property from natural hazards and their effects. Examples of hazard mitigation are the acquisition and removal of hazard prone property, retrofitting of existing buildings and facilities, elevation of floodprone structures, and infrastructure protection measures. The federal government provides funding for hazard mitigation following disasters through two programs; the 404 Hazard Mitigation Program and the 406 Hazard Mitigation Program.

FEMA provides funding to States under section 404 of the Stafford Act for the Hazard Mitigation Grant Program (HMGP). The funds are to provide state and local government, certain private non-profit organizations and Native American tribes with the incentive and capacity to take critical mitigation measures during the flood recovery and reconstruction process to protect life and property from future disasters (FEMA, 2001). The eligibility of a community requires a community to have prepared and filed with the SEMO, a Hazard Mitigation Plan which describes the local priorities for mitigation. Funding is competitive with other communities around the State, and will be ranked by the results of a benefit-cost analysis with others possible projects for having the greatest potential to reduce future losses. Delaware County received significant levels of funding through this program following the January 1996 flood disaster for the Flood Property Buyout Program and other mitigation projects. Delaware County Planning Department is currently preparing a Hazard Mitigation Plan for the county to enable any community within the county to apply for funding under this program. HMGP funds require a 25 percent local commitment in cash or in kind for total project costs. For more information about this program contact the Delaware County Planning Department or the Hazard Mitigation Program Director within SEMO. The web site for the state program is: http://www.nysemo.state.ny.us/MITIGATION/mitigation.html (Verified 12-08-04).

The Section 406 Hazard Mitigation program is available for public assistance projects (those dedicated to the recovery and reconstruction efforts of local government) for the reduction or elimination of future damages to a facility damaged during a disaster. Hazard mitigation funding can be sought for infrastructure damage where the funds would enable the applicant to upgrade the structure to a standard that will avoid future flood damages. Undamaged structures would not be eligible under this program. 406 Hazard mitigation funds are added to the reconstruction costs normally used to return a structure to its pre-flood condition. Typically, there is a 25% local cost share for the mitigation activity. This program is not cost competitive and can be very useful in preventing future flood damages, especially where recurrent flood losses are avoidable through a retrofit. Questions about this and other flood recovery programs should be directed to:

New York State Emergency Management Office
1220 Washington Avenue
Building 22, Suite 101
Albany, New York 12226-2713 Telephone: (518) 485-2713

5.15 Recreational Opportunities

"I have never seen a river that I could not love. Moving water…has a fascinating vitality. It has power and grace and associations. It has a thousand colors and a thousand shapes, yet it follows laws so definite that the tiniest streamlet is an exact replica of a great river."

- Roderick Haig-Brown, fisherman and conservationist

The West Branch basin, located in a transitional area between the Catskill high peaks and the rolling hills of central New York has a uniqueness all its own. Its verdant springs, warm summers, cool and colorful falls, and snowy winters offer four season recreational opportunities for the outdoor enthusiast.

5.15.1 Fishing, Hunting, Canoeing & Hiking

Fishing

Fishing is perhaps the most popular sport enjoyed along the river and its tributaries and is a great recreational activity for all age groups and genders. Fishing in the West Branch attracts people from across New York and neighboring states. As mentioned in **Section 5.11.1** the NYSDEC puts forth considerable effort in managing the trout fishery in the basin. With its roots in the Catskills, fly fishing is an ever popular means of pursuing West Branch trout. Local tackle shops supply flies that match the hatches found on the river. Other methods include the use of live bait and artificial spinning lures. Although the NYSDEC has purchased public fishing rights on much of the West Branch main stem and some tributary reaches, most riparian property is under private ownership and anglers are requested to seek permission to access anyone's stream. Trout season is generally from April 1 – October 15, although seasons, fish size and creel limits vary between water bodies, with some waters having additional regulations. Ice fishing is a popular winter sport for species that have an open season during that time of the year, particularly on lakes and ponds. Fishing is also permitted on the Cannonsville Reservoir and is described in **Section 5.15.2.** Information for special trout regulations and specific information for seasons and creel limits on other fish species are found in the New York State Fishing Regulations Guide. The guide and a required New York State fishing license are available from town clerk's offices, the Regional NYSDEC office in Stamford, and most sporting goods stores in the area. The Delaware County Chamber of Commerce and the NYSDEC have compiled a fishing map of Delaware County which is available at the Chambers' website: http://www.delawarecounty.org/fishing/fishing.pdf (Verified 11-23-04).

Hunting

Hunting is another popular outdoor activity in the West Branch watershed, the fall white-tailed deer hunt being the most popular. Many residents, both permanent and seasonal, eagerly participate in the pursuit of this sought-after game species. Wild turkey hunters enjoy both a spring and fall season, with the spring gobbler-(male)-only season the more popular of the two. Both these species are currently present in good numbers in the watershed, and have an affinity for the many acres of land under agricultural production. Other species of interest include black bear, grouse, other wildfowl, rabbit, squirrel, fox and coyote (the latter two may also be taken by trapping, as may beaver, mink and muskrat). Seasons for species that may be hunted *or* trapped are fall and winter seasons. As with fishing, a license is required. This can be issued in combination with a fishing license, and can be obtained from the sources listed in the above paragraph. Permission should also be requested prior to entering on private land. Public lands open to hunting (other than NYCDEP lands, see **Section 5.15.2**) include the 7,186 acre Bear Spring Mountain Wildlife Management Area, which is maintained by the NYSDEC and is partially located in the West Branch watershed. Specific season information and bag limits are listed in the New York State Hunting and Trapping Regulations guide. Additional information on fishing and hunting in New York State can also be found on the DEC website: http://www.dec.state.ny.us/ (Verified 11-23-04)

Canoeing and Kayaking

Canoeing, kayaking and tubing are summer season activities that begin around the Memorial Day weekend and usually end in October, when water temperatures begin to cool. This activity offers scenic views of the West Branch its surroundings, often with a glimpse of riparian wildlife including the bald eagle, and some canoeists also enjoy fishing. Many residents own their own watercraft, while some participants rent them from local businesses. According to Ken Landry, owner of Catskill Outfitters in Walton, the West Branch is classified according to seasonal water flow: In the spring or during other periods of higher flow the river is considered to be "intermediate" class, while the lower flows are classified as "beginner". The frequency of equipment leasing can vary from year to year depending on water levels. The higher flows during the wet 2003 and 2004 summers reduced canoeing/kayaking activities.

Hiking

Hiking can be a four season activity along four managed trail systems in the West Branch basin. Each trail system offers its own unique vista, and plant and wildlife viewing opportunities.

The Catskill Scenic Trail lies atop the former Ulster and Delaware railroad bed. The 19 miles of trail extends from Bloomville to Grand Gorge (near the headwaters of the East Branch of the Delaware River). A unique feature of this trail is the very gentle grade. It parallels the West Branch, crossing it at several points. Several access points along its path offer hikers of all ages an enjoyable trek. Along the trail are several resting benches and fishing access points. The trail is open year-round for hiking, biking, horseback riding, cross-country skiing and snowmobiling.

The Utsayantha Trail System is another picturesque trail located in the mountains surrounding Stamford. Several places along the marked trail provide a stunning view of the West Branch and neighboring valleys and their surrounding mountaintops. Accepted uses are hiking, horseback riding, cross-country skiing, and snowmobiling.

The West Branch preserve is a 446 acre site in the Town of Hamden donated to the Nature Conservancy in 1973 by Dr. Charles Jones and his family. There are two trails, a 0.7 mile trail with a moderate ascent and marked in blue, and a 2.0 mile trail marked in orange. The latter trail has a steep climb and should be attempted only by experience hikers.

Additional information on these trail systems is available from the Delaware County Chamber of Commerce website: http://www.delawarecounty.org/hiking (Verified 11-23-04)

The Bear Spring Mountain Wildlife Management Area is state owned land which is maintained by the NYSDEC. A network of trails of various degrees of difficulty are marked and maintained for hiking, horseback riding, mountain biking and snowmobiling. Additional information is available from the NYSDEC Regional office in Stamford at (607) 652-7365.

5.15.2 NYCDEP Lands

New York City owns considerable acreage around the Cannonsville Reservoir. The DEP has begun purchasing additional watershed properties in its efforts at water supply protection under its Land Acquisition and Stewardship Program. Many of these lands are open to the public for low-impact recreational activities where compatible with water supply protection. To responsibly provide recreation access to city property, NYCDEP issues a comprehensive Access Permit that allows for fishing and hiking. Access Permit holders may also obtain a NYCDEP hunting tag for deer hunting in designated areas and a NYCDEP boat tag for keeping a rowboat at the reservoir for fishing.

Fishing on the Cannonsville Reservoir has long been a popular activity enjoyed by permanent and seasonal residents alike. Properly tagged boats may be moored at specific locations designated by NYCDEP. Boats may be stored above the high water mark over winter, which most boat owners take advantage of. In order to preclude Zebra mussels (*Dreissena polymorpha*) and other “hitchhiking” species from entering the reservoir, all fishing boats must be steam cleaned and inspected by the DEP before being moved onto the reservoir or its shores. The reservoir is home to popular fish species including brown trout, smallmouth and largemouth bass, yellow perch and brown bullhead. Brown trout are much sought after and many weigh-in well over five pounds, with some even topping ten pounds. Special fishing regulations for the Cannonsville Reservoir are found in the New York State Fishing Regulations Guide.

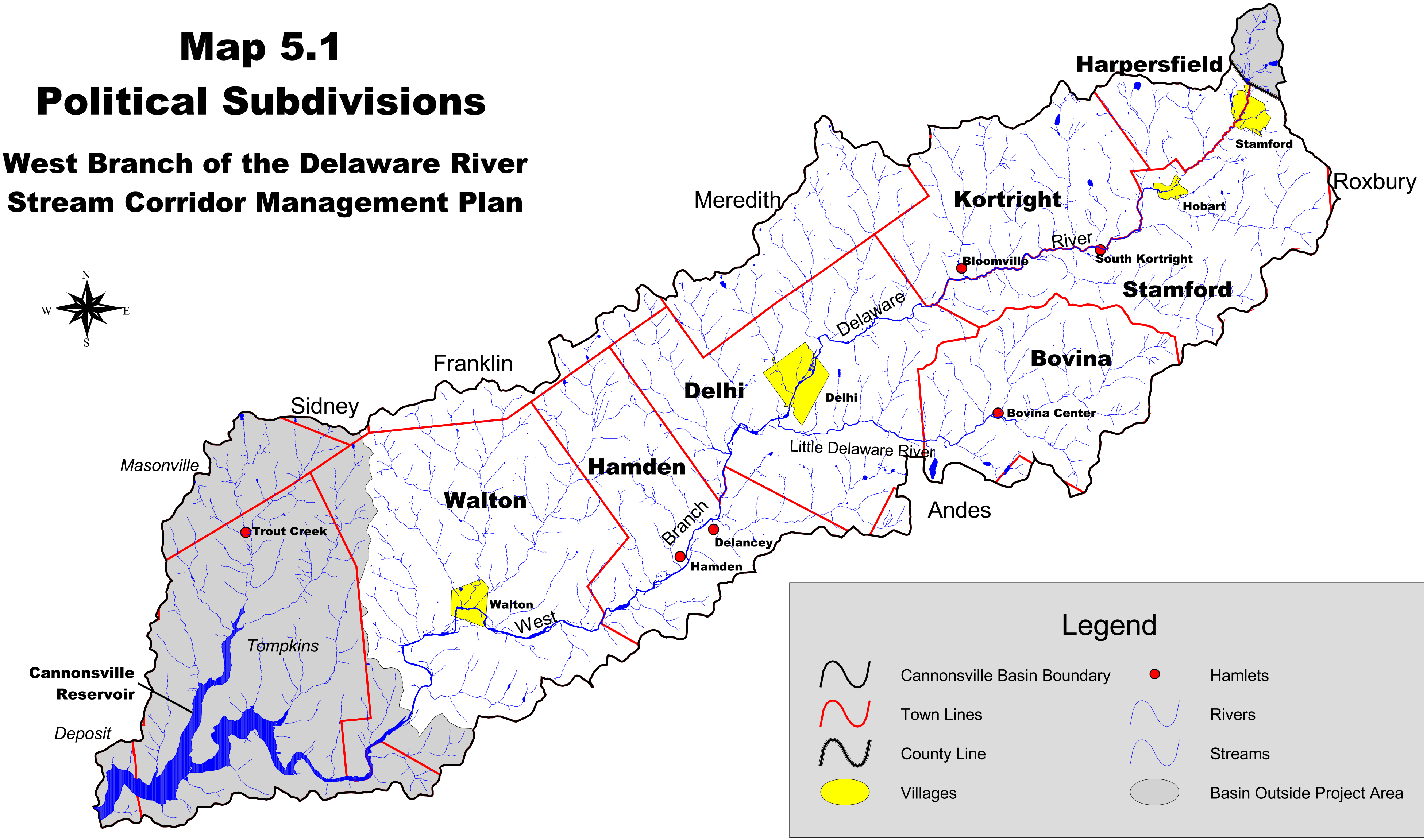
Hiking is not allowed at or around the Cannonsville Reservoir, but a number of other City properties throughout the watershed are open for hiking year round. People must have a valid Access Permit in order to enter these areas and they must agree to abide by the permit conditions.

Deer hunting is allowed under the Access Permit system on designated City water supply lands. NYCDEP Hunting Tags are issued annually to valid Access Permit holders who apply or who complete the prior year’s hunting survey by the due date. NYCDEP Access Permit holders who wish to apply for the current season’s DEP Hunting Tag may do so starting in late summer of each year by mailing a completed NYCDEP Hunting Tag application or sending an e-mail request including their Access Permit number to the NYCDEP Access Permit Office. Hunters must also possess a valid New York State hunting license for deer.

Additional information, regulations, permit conditions, maps, Access Permit applications and applications for hunting and boating tags are available at local NYCDEP offices, by calling 1-800-575-LAND, or on the NYCDEP website:
http://www.ci.nyc.ny.us/html/dep/watershed/html/wsrecreation.html (Verified 11-23-04).

Map 5.1
Political Subdivisions

West Branch of the Delaware River
Stream Corridor Management Plan



Base data provided by NYCDEP
Map data provided in NAD 27 UTM Zone 18 North
GIS data are approximate according to their scale
and resolution. Data may be subject to error and
are not a substitute for on-site inspection or survey.

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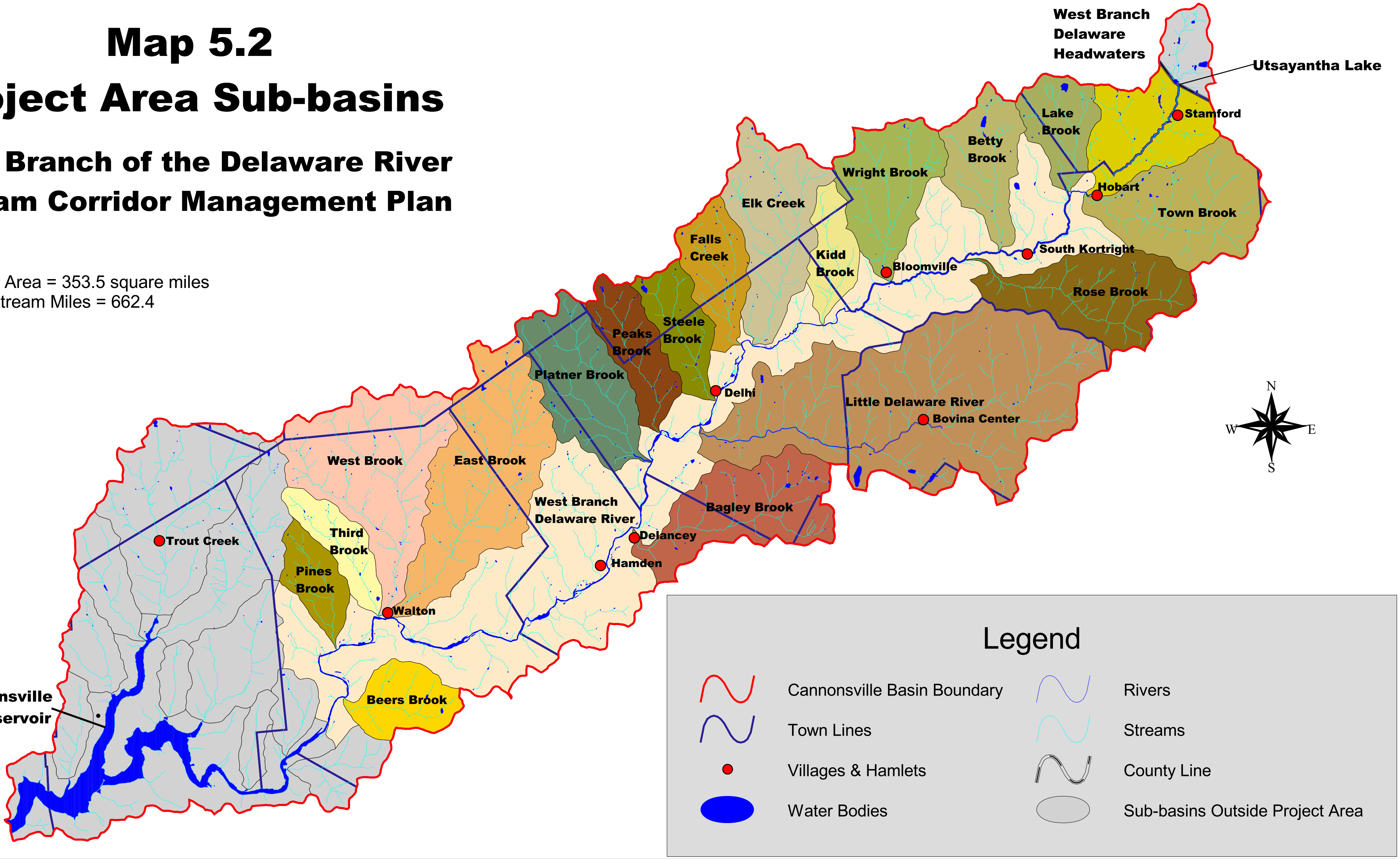
Map 5.2
Project Area Sub-basins

West Branch of the Delaware River Stream Corridor Management Plan

Project Area = 353.5 square miles
Total Stream Miles = 662.4



Data provided by NYCDEP
Map data provided in NAD 27 UTM Zone 18 North
GIS data are approximate according to their scale
and resolution. Data may be subject to error and
are not a substitute for on-site inspection or survey.

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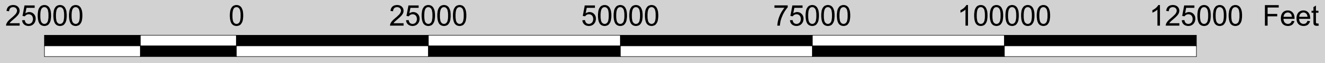
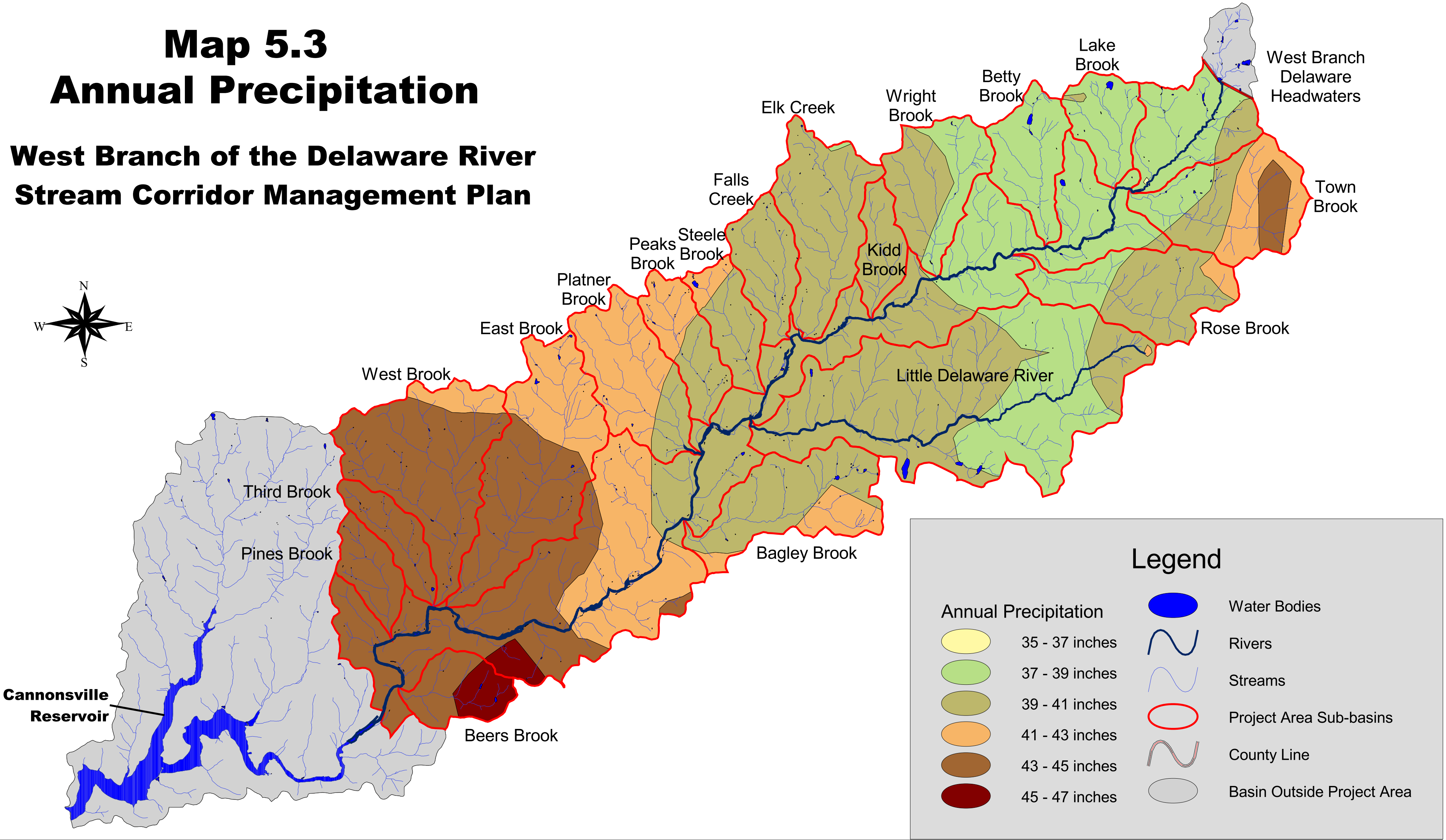


Map 5.3
Annual Precipitation

West Branch of the Delaware River
Stream Corridor Management Plan



Base data provided by NYCDEP
Rainfall data provided by NRCS
Map data provided in NAD 83 UTM Zone 18 North
GIS data are approximate according to their scale
and resolution. Data may be subject to error and
are not a substitute for on-site inspection or survey.

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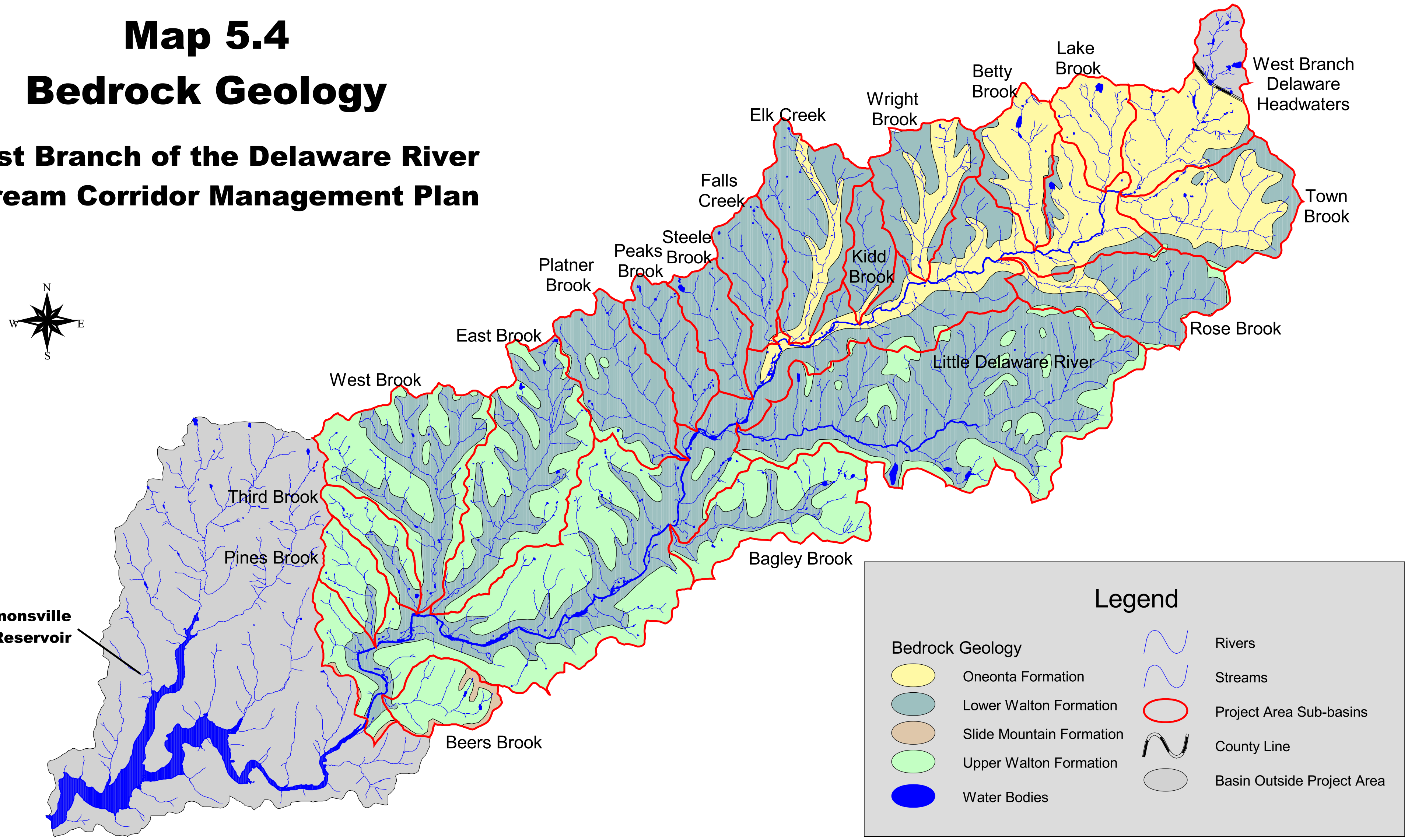
Map 5.4
Bedrock Geology

West Branch of the Delaware River Stream Corridor Management Plan



Base Data Provided By NYCDEP
GIS bedrock geology coverage provided by NYSGS
Map data provided in NAD 27 UTM Zone 18 North
GIS data are approximate according to their scale
and resolution. Data may be subject to error and
are not a subsitute for on-site inspection or survey.

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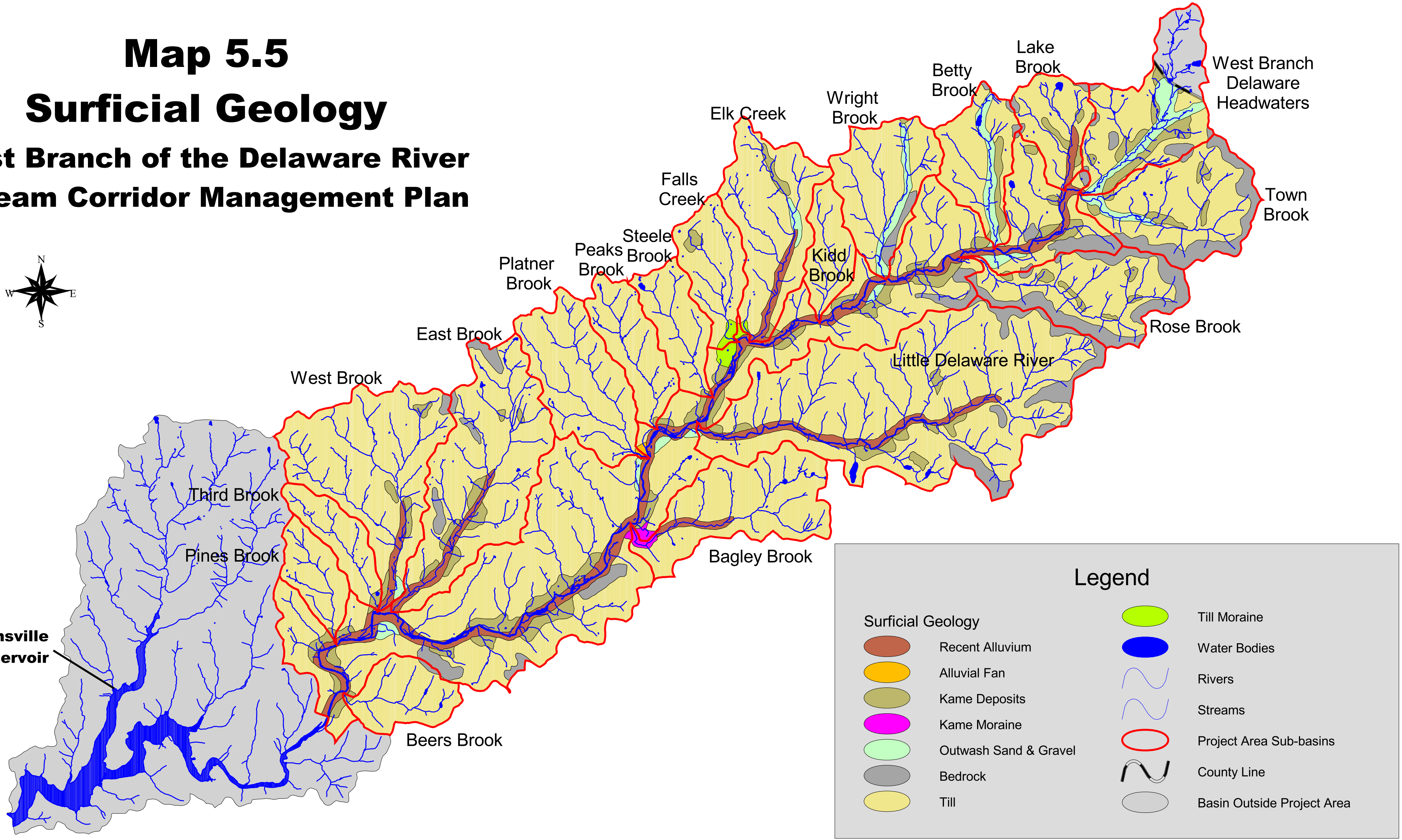
Map 5.5
Surficial Geology
West Branch of the Delaware River
Stream Corridor Management Plan



Legend

Surficial Geology
- 🟫 Recent Alluvium
- 🟧 Alluvial Fan
- ▨ Kame Deposits
- 🟪 Kame Moraine
- 🟩 Outwash Sand & Gravel
- ⬛ Bedrock
- 🟨 Till
- 🟩 Till Moraine
- 🟦 Water Bodies
- ∼ Rivers
- ∼ Streams
- ○ Project Area Sub-basins
- ∼ County Line
- ⬜ Basin Outside Project Area

Base data provided by NYCDEP
GIS surficial geology coverage provided by NYSGS
Map data provided in NAD 27 UTM Zone 18 North
GIS data are approximate according to their scale
and resolution. Data may be subject to error and
are not a subsitute for on-site inspection or survey.
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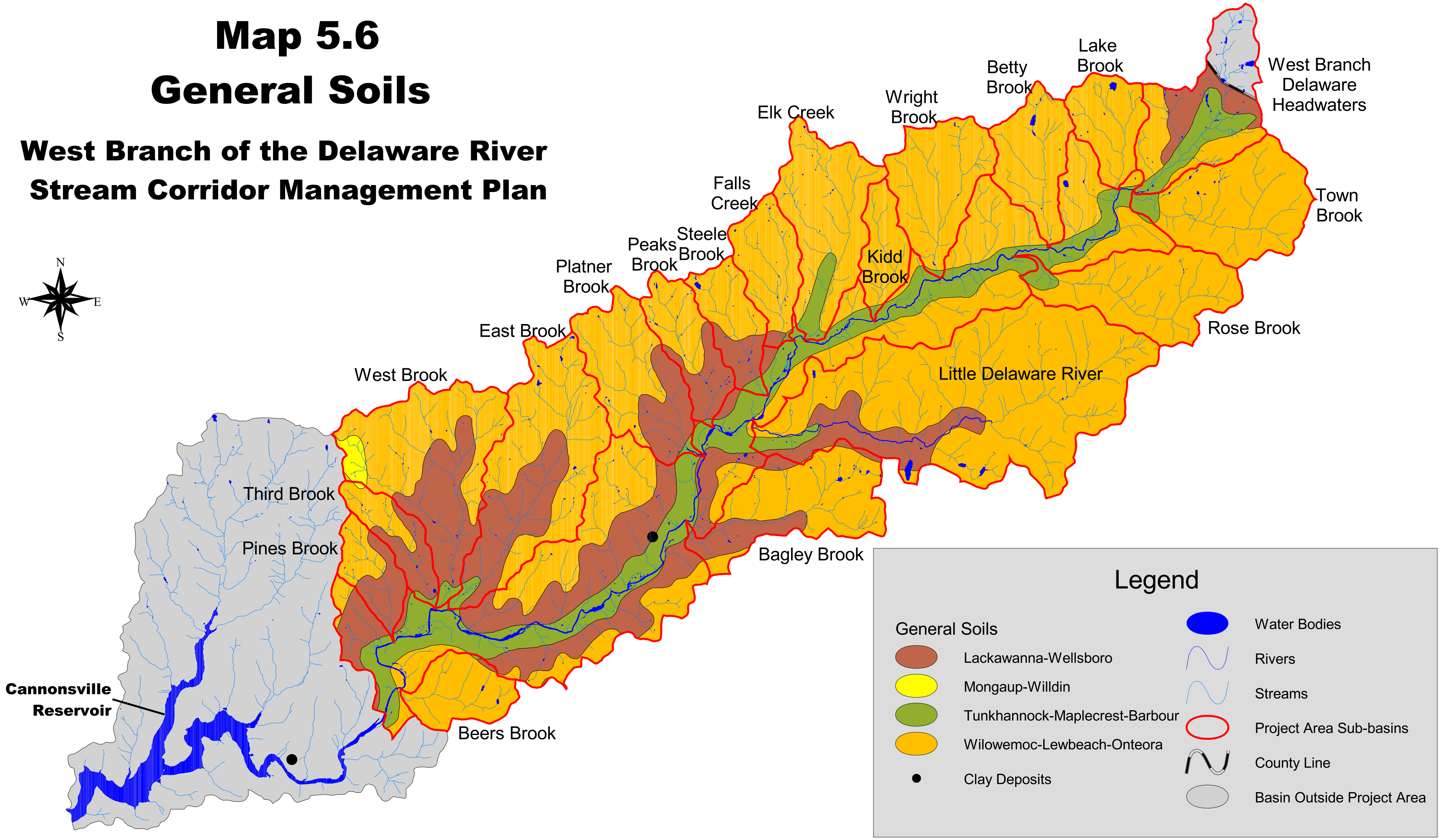
Map 5.6
General Soils

West Branch of the Delaware River
Stream Corridor Management Plan



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GIS soil type coverage provided by NRCS
Map data provided in NAD 27 UTM Zone 18 North
GIS data are approximate according to their scale
and resolution. Data may be subject to error and
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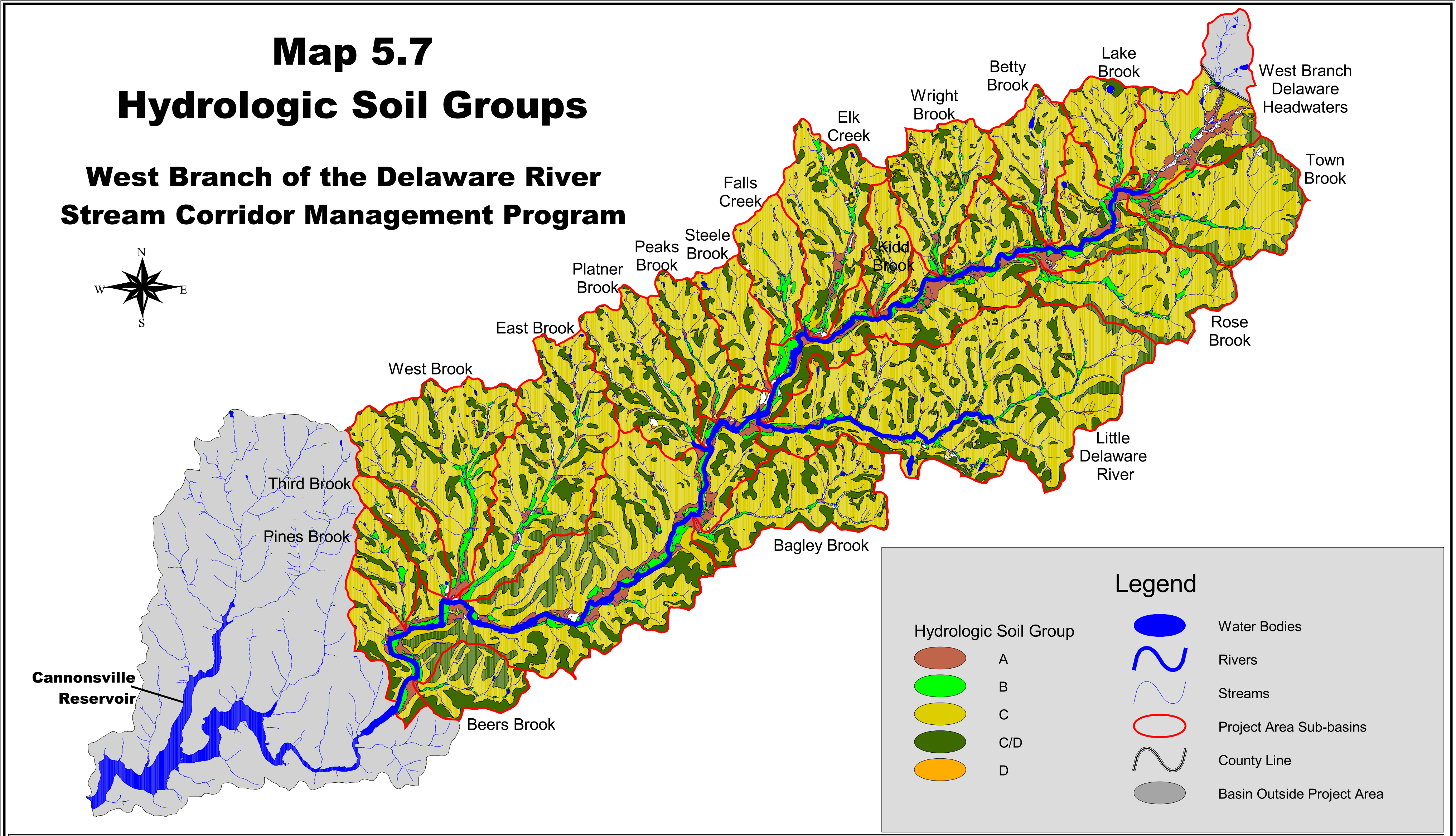
Map 5.7

Hydrologic Soil Groups

West Branch of the Delaware River Stream Corridor Management Program



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GIS hydrologic soil group coverage provided by NRCS
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GIS data are approximate according to their scale
and resolution. Data may be subject to error and
are not a substitute for on-site inspection or survey.

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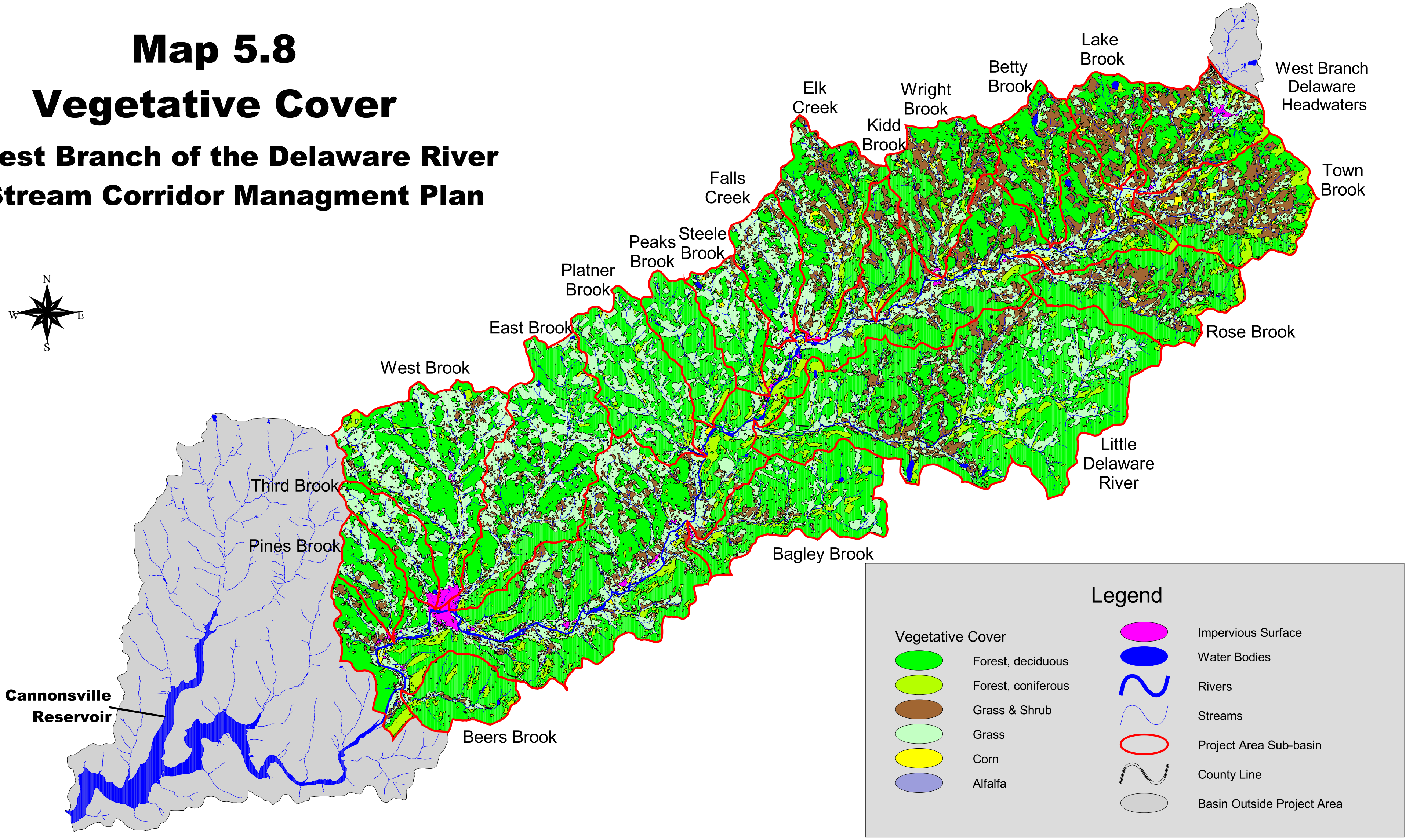
Map 5.8
Vegetative Cover

West Branch of the Delaware River
Stream Corridor Managment Plan



Data provided by NYCDEP from July 1992 & May 1993 datasets
Updated January 1999
Map data provided in NAD 27 UTM Zone 18 North
GIS data are approximate according to their scale
and resolution. Data may be subject to error and
are not a substitute for on-site inspection or survey.

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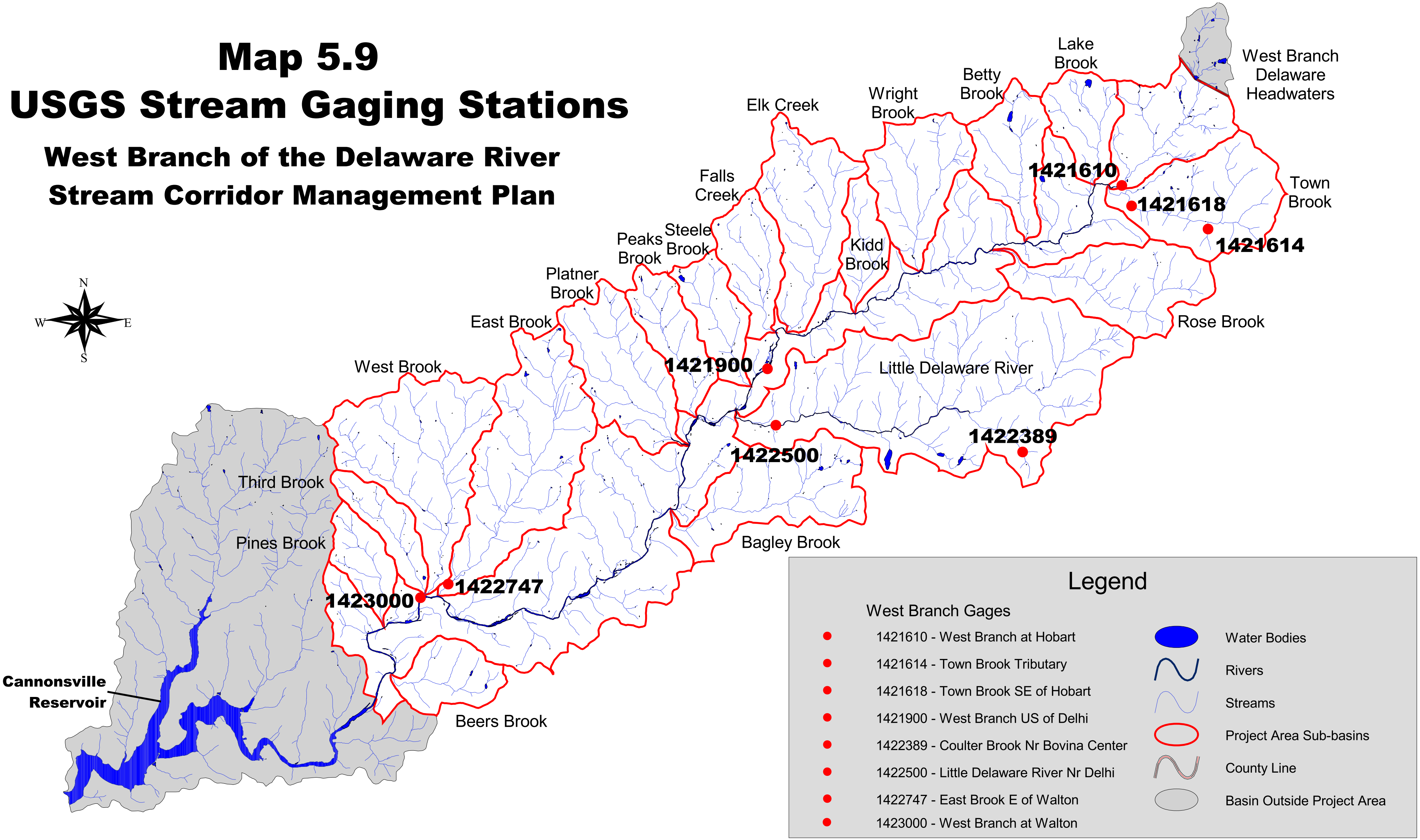
Map 5.9
USGS Stream Gaging Stations

West Branch of the Delaware River
Stream Corridor Management Plan



Base data provided by NYCDEP
USGS Gage data provided by USGS
Map data provided in NAD 83 UTM Zone 18 North
GIS data are approximate according to their scale
and resolution. Data may be subject to error and
are not a substitute for on-site inspection or survey.

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TOC AND INTRO--SECTION 1-4

FINDINGS--SECTION 6

STREAM SEGMENTS--SECTION 7

LANDOWNER SURVEY INFO--SECTION 8

REF & GLOSSARY--SECTIONS 9 & 10