Chapter 3

HYDROLOGY

Introduction

Water is probably the natural resource we know best, since all of us have had firsthand experience with rain, hail, snow, ice, and dew. Yet water is also the natural resource we least understand. The science dealing with the properties of water, the distribution of water on earth, and the effects of that distribution is known as hydrology.

All the water on earth — rainfall, waves pounding on a beach, the flow from a faucet, a still lake in the morning, or a drop of dew — is part of a continuous physical process known as the hydrologic (or water) cycle (Figure 9). Water evaporates into the air from bodies of water and land, cooling as it rises. When the water vapor reaches the condensation point, clouds form. Eventually precipitation in the form of rain or snow occurs, often many miles from the area of evaporation. When the water falls back to earth, it may evaporate, transpire back into the atmosphere through trees and plants, infiltrate into the soil, or flow across the surface of the land into a stream, river or lake. Ultimately the water will flow back to the ocean.

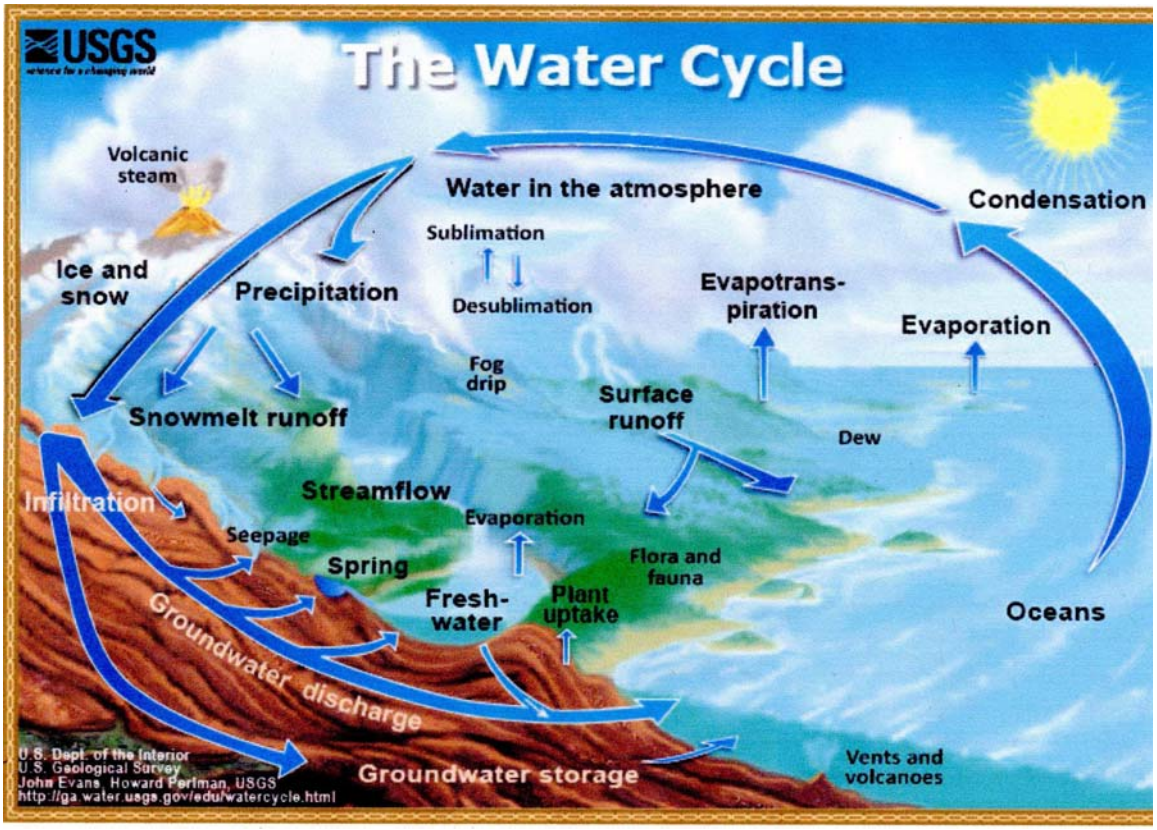

Figure 9—Hydrologic Cycle
Source: U.S. Geological Survey, August 2012

The source of most atmospheric water is the ocean. The continuous movement of water from ocean to atmosphere to land and back to the sea is the major flow path of the hydrologic cycle. In the subterranean portion of the cycle, underground stores of water called aquifers may discharge some water directly to rivers and some directly to the sea.

Groundwater and surface water are the major sources of water supply. Groundwater is water stored in the ground and is the largest single source of fresh water on earth. Surface water is stored in ponds, streams, rivers, lakes, and

eservoirs. Both sources are recharged directly or indirectly through precipitation, and both can serve as sources of drinking water. In New Jersey, sixty percent of our drinking water comes from underground sources.

Groundwater
Nearly all the ground water in Morris County originates from local precipitation. A large part of the precipitation either flows overland directly to the streams or is retained in the soil from which it is returned to the atmosphere by evapotranspiration. The remaining precipitation percolates through the soil to the zone of saturation, where it is called ground water.

Ground water occurs under unconfined or water table conditions throughout Morris County. However, in much of the lowland areas, the consolidated rocks are covered by unconsolidated deposits that contain one or more relatively impermeable clay and silt beds. The impermeable layers confine the water in the underlying permeable zones which consist of sand and gravel deposits and the consolidated rocks. Hence, wherever such confinement occurs, water beneath the confining layers is under hydrostatic pressure. In many places, the resulting artesian head is above land surface as indicated by numerous flowing wells. This is particularly true of the extensive swampland areas through which the Passaic River meanders.

The movement of ground water is in response to hydraulic gradients. In Morris County, the direction and magnitude of the natural gradients are controlled largely by the topography, and the resulting water-table profile approximates the local topographic profile except that it has less relief. Water that enters the ground water body in the interfluve areas (upland recharge areas) where the water table is at relatively higher elevations moves slowly toward the intervening stream channels lying at lower elevations. Ground water is discharged directly to the streams wherever they intersect the water table and supports stream flow during periods of no precipitation.

In the Great Swamp areas that are underlain by clay and silt, such as those along the Passaic River, discharge of ground water to the streams is restricted by low permeability of the materials and the slight hydraulic gradients. During the vegetative growing season, most of the groundwater discharge occurs in these areas as evapotranspiration and very little is discharged to the streams. Consequently, dry weather stream flow is not augmented significantly by these areas and is reduced by the high rate of evapotranspiration during the growing season.

Shallow Groundwater Levels Around The Great Swamp
In 1969 the U.S. Fish and Wildlife Service established shallow groundwater observation wells of from 8 feet to 15 feet around the Refuge perimeter at 9 locations. They monitored the water elevation in these wells 27 times from 1969 to 1974. Another set of monitoring data was collected 25 times during 1995 and 1996. The results show that water levels in the shallow aquifer below the Great Swamp have remained fairly level. There has been no appreciable increase despite observations by residents of Green Village who believe the water table is rising. Some of the change residents are observing could be caused by old drainage tiles that previously drained open fields falling into disrepair.

Chatham Township's Wells and Water Supply
As of 2010 fewer than 2% of the 4012 housing units in Chatham Township relied upon private water wells as the source of water. The remainder of the housing units in Chatham Township obtain water from the New Jersey American Water Company (NJAWC), an investor-owned, private water utility.

All of the public drinking water supply in Chatham Township comes from three primary sources. From the north, a thirty-inch supply line brings treated water from the Passaic Valley Water Commission plant located on the Passaic River in Little Falls, NJ. On occasion, this water supply may be supplemented from the North Jersey Water Supply Commission plant located in Wanaque, NJ. The Chatham Glen development in the southeastern portion of the Township receives water from the New Jersey American Canoe Brook Treatment Plant in Millburn. This supply can be a blend of well water from the Canoe Brook and Passaic River well fields along with surface water supply from the Passaic River and Canoe Brook. The well fields draw from the Buried Valley Aquifer. From the southwest - the third major water supply for the Township comes from an interconnection with the Elizabethtown Water Company at Diamond Hill Road in Berkeley Heights. The Elizabethtown Water Company

supply is all surface water and originates at the Round Valley / Spruce Run reservoir systems in the vicinity of Clinton, NJ.

One water storage tank, a 1.42 million gallon standpipe, is located in Chatham Township on Huron Drive. Additional storage capacity for the Township is also provided by a 1.0 million gallon tank on the Sisters of Charity property in Florham Park and a 3.0 million gallon tank at Benders Corner in Berkeley Heights.

There are seven additional water system interconnections with Madison and Chatham Borough to provide service reliability. For public fire protection, there are approximately 292 public fire hydrants located throughout the Township. Chatham Township pays an annual fee of approximately $110,000 to the New Jersey American Water Company to maintain the public fire hydrants in the Township.

HYDROLOGICAL FEATURES

Chatham Township has two watershed areas - the Great Swamp and the Passaic River. Stormwater runoff from most of the Township flows into the Great Swamp watershed. The other runoff flows from the crest of Long Hill directly into the Passaic River watershed. The water in the Great Swamp flows westward into the main channel of the Passaic River at Millington Gorge.

Several miles downstream, the Passaic River, as it enters Chatham Township, is a small, slowly-flowing river whose immediate environs indicate considerable variation in water level. For 3-1/2 miles, it flows through a wide, nearly flat stretch of woods and fields extending from low muddy banks across to the steeply rising slope of Long Hill. Many houses are built close to the river along the south bank, while the Chatham Township side is in a more natural state. The drainage area on the Chatham Township side, from the ridge top to the river, is of sufficiently small size that the ditches and brooks entering the river are small. Two small sewage treatment plants on the Chatham Township side, serving the one hundred-unit Cardinal Hill apartments and the nine hundred-unit Chatham Glen condominium development, discharge into the river. Those two treatment plants will be removed and all sewage pumped to the Tanglewood plant on Tanglewood Lane. The effluent from the Tanglewood plant will be pumped to the Passaic River. The New Providence and Berkeley Heights municipal treatment plants discharge from the south side of the river.

In its final mile of passage through the Township, the river and its environs change character completely. The effects of glaciation are immediately apparent as the river flows through the moraine and into the glaciated portion of New Jersey in the vicinity of Mt Vernon Avenue. Muddy banks and channels, bordered by a well-developed floodplain, are replaced by a gravelly river bottom with small beaches and mounds of rounded stones of granite and other foreign material. The floodplain narrows and then disappears. The banks become high, with steep cliffs on the south side and a wooded hillside on the Chatham Township side. The river flows more swiftly through this section, riffling around randomly located stones. It passes under Stanley Bridge and, once out of the Township, is soon encroached upon by industry and other development.

Passaic River

The Passaic River is northeastern New Jersey’s largest source of water supply. The river is the source of water supply for over 500,000 people. The natural quality of water in the river as it enters Chatham Township has been altered by the discharge of at least six municipal sewage treatment plants located upstream, as well as leachate from dump areas, and agricultural enterprises. Dumping, treatment plant outflow, industrial waste, and the salt and petroleum residue of street runoff are added to the river from the Chatham Township / Berkeley Heights / New Providence area. As a result of diminished water quality, people along the Chatham Township portion of the river forego some of the pleasures and amenities the river used to offer, such as swimming. Because the ability of aquatic life to live in the river is controlled by the conditions it experiences, there is less abundance and variety of river-dwelling and plant life in the Chatham Township stretch of the river than is found further upstream.

All along the river channel the proportion of effluent and other wastes increases during periods of dry weather. These concentrations become more diluted with increased amounts of direct precipitation and runoff. Even so, the lower Passaic River used to be notoriously polluted. Over the last decade several sewage treatment plants have

upgraded their treatment processes and recent studies by the New Jersey DEP show substantial improvements in the river.

Floods

The river receives water from precipitation that falls in its watershed and flows above or below ground to the stream channel. Many factors, both natural and man-made, complicate this process so it can become very difficult to predict the height of water in the river at any given moment. The Great Swamp and the Millington Gorge, increasing development within the watershed, and additional water introduced from outside the watershed for water supply are all factors in the dynamics of water flow in the Passaic River. The highest flood ever recorded at the Millington Gorge gauge occurred in January, 1903. The flow was measured at 2000 cubic feet per second (Water Resources Data for New Jersey, 1972).

This watershed area, if it did not contain the storage area provided by the Great Swamp, could have been expected to discharge 6500 cubic feet per second (computation based on the method developed by Stankowski, 1973). However, while the Gorge is large enough to allow free passage of average flows, it restricts passage of flood levels. The detention provided by the Great Swamp substantially prolongs the time of higher-than-average water levels downstream from the Gorge, but reduces the highest level of the flood peak (Ebasco Services, Inc.).

Peak flow from any design storm will increase with increased development in the watershed. Precipitation, which would have evaporated directly from leaf surfaces or been retained in the natural mulch of the forest floor, or retarded in its rate of runoff by natural conditions (and thereby be given more opportunity to sink into the ground and enter the water table), runs off the paved and roofed surfaces with no absorption into the ground and no time delay or interception by vegetation. A greater volume of water arrives at the stream in a shorter period of time, raising the height of floods and shortening the time that elapses between the onset of rainfall and the peak flow. The proportion of runoff to rainfall increases during long wet periods when the soil remains saturated and cannot absorb more precipitation. When a higher percentage of precipitation becomes runoff, less water is retained in the ground to replenish the river during periods of low flow.

Floods are natural phenomena that occur whenever the amount of water exceeds the capacity of the channel that must carry it. Floods on the Passaic River are not limited to particular seasons, but may happen at any time because of the generally even distribution of rainfall throughout the year. When the defined river channel overflows, water spreads out into the floodplain adjacent to the river. The effects of flooding are intensified when the floodplain becomes restricted by filling and construction. Increased stormwater runoff also increases flooding. When sediment is deposited in the river channel, the capacity of the channel to carry floodwater is decreased.

The New Jersey DEP has compiled a variety of historic data on local flooding between 1903 and 1971. These data have been used to delineate the area on either side of the channel of the Passaic River and its principal tributaries that are necessary to allow for the storage and passage of floodwater. About 190 acres of this delineated floodplain lie in Chatham Township. Any development in the floodplain is regulated by the New Jersey DEP under the Stream Encroachment Permit program.

Loantaka Brook

The valley of Loantaka Brook in the northern part of the Township is also subject to flooding. This primarily affects houses along Green Village Road. Most recently, the road was closed because of the October 1996 nine-inch (approximate) rainfall and 1999 Hurricane Floyd which caused severe flooding. A tributary of the Passaic, Loantaka Brook flows from Morris Township through Chatham Township and enters the Great Swamp. There it joins Great Brook and flows southwest into the Passaic River. Loantaka Brook's valley in Chatham and Morris Townships descends from gently rolling hillsides and open fields to the mostly wooded environs of the brook itself. Most of the brook's adjacent flood area is preserved as the Morris County Loantaka Brook Reservation. From 1954 to 1974 approximately 18% of the watershed had been developed. Since 1974, some large multi-density housing developments have been built, one on Madison Avenue and one on Woodland Avenue, both in Morris Township. In addition, office buildings and site improvements on Giralda Farms all drain to Loantaka Brook. Increased stormwater runoff from the new development augments natural flow in the brook. An additional 1.6 million gallons per day is added by treated sewage effluent from the Woodland Road Treatment Plant in Morris Township, which began operations in 1968.

A prolonged severe drought during the mid-1960's lowered water tables and stream levels throughout the northeastern United States. This was followed by record precipitation in the early 1970's. Since then, development and periodic extremes in weather have changed significantly the shape of the stream channel as well as the amount of water carried by Loantaka Brook. These changes include serious erosion with the resultant sedimentation and broader, shallower channels. In addition to increased flooding, the stream has suffered from the loss of wetlands and the recharge they provide which has resulted in lower base flows during dry periods.

Black Brook

A number of streams of varying size drain from the terminal moraine in the area of the shopping centers on Shunpike Road and the north side of Long Hill down into Black Brook. The 1972 U.S.G.S. quad shows three major branches of Black Brook. The brook also receives effluent from the Chatham Township Tanglewood Wastewater Treatment Plant. The Black Brook branch receiving substantial drainage from the Shunpike area - shopping centers, roads, and the Chatham Hill Apartments - flows into the Swamp, then directly into the Rolling Knolls Landfill, a 200 acre sanitary landfill shut down in the 1960's. The status of impacts to the landfill and potential leachate problems are currently under investigation. All branches of Black Brook join before meeting the Passaic River in Long Hill Township.

The Great Swamp

The Great Swamp is the focus of the natural systems of much of Chatham Township. A major portion of the swamp is protected as the 7,454 acre Great Swamp National Wildlife Refuge. Established in 1964, the Refuge is divided into two major areas - the Wilderness area and the management area. The 3,660 acre Wilderness area is located in the eastern part of the Great Swamp in Chatham, Harding, and Long Hill Townships, east of Long Hill Road. It was created by an act of Congress in 1968 to preserve and restore the area in its pristine uniqueness for future generations. The U.S. Fish and Wildlife Service manages the other 3,794 acres of the Refuge for the protection of migratory waterfowl, the preservation of the diverse vegetation and wildlife, to provide a program of interpretation and education to the public, and to provide an outdoor laboratory for observation by the people of the heavily populated surrounding area.

From the crest of Long Hill northward, almost all of the Township's water flows into the Great Swamp. Its alternations of wet and drier areas, open and wooded sections, flowing water and ponded water provide extensive and varied habitat for most kind of wildlife found in the Township. The swamp acts as a modifier of local climate, as well as an air and water purifier. It serves important flood control functions. It is of aesthetic and recreational value to people.

Water is an essential element in all of these functions. In combination with geologic and soil conditions, it has given rise to a further dependent complex of vegetation and wildlife. For the swamp to maintain its multiplicity of function, its natural state as a swamp is essential. Construction of a jetport and building a dam across the Millington Gorge are plans for the swamp that have been rejected as too destructive of its integrity. Similarly, impure water, too much water, rapid changes in water level and other conditions often created by a developing watershed can also be destructive of its functioning. Like the river, the Great Swamp must be viewed in terms of its whole watershed. In addition to the precipitation that falls on it directly, water flows into the swamp in major brooks, through 77 stormwater outfalls, intermittent streams, wastewater treatment plant discharge, and by seepage from shallow groundwater. Loantaka Brook flows into Great Brook in Harding Township. Great Brook is also joined by Primrose Brook. Further to the west, Black Brook drains the terminal moraine area by the Green Village / Shunpike Road intersection area to the north side of Long Hill. For many decades, surface drainage in the swamp was augmented by an extensive system of man-made ditches that reduced the time required for water to reach an established channel.

The usual result of development in a watershed is to increase peak flows from storms and decrease low flows due to loss of recharge. (See Figure 10.) Streams in the watershed also carry an increased amount of salt, petroleum and rubber residue from streets, as well as sediment from construction projects. Vegetation and animal life of the Great Swamp are sensitive to these factors and cannot live with variable water levels, long periods of too much water, reduced water quality, or inundations of sediment. Changes in the Great Swamp caused by watershed development could be interpreted as being in conflict with the spirit of the federal government's designation of the east end of the Great Swamp National Wildlife Refuge as a Wilderness Area.

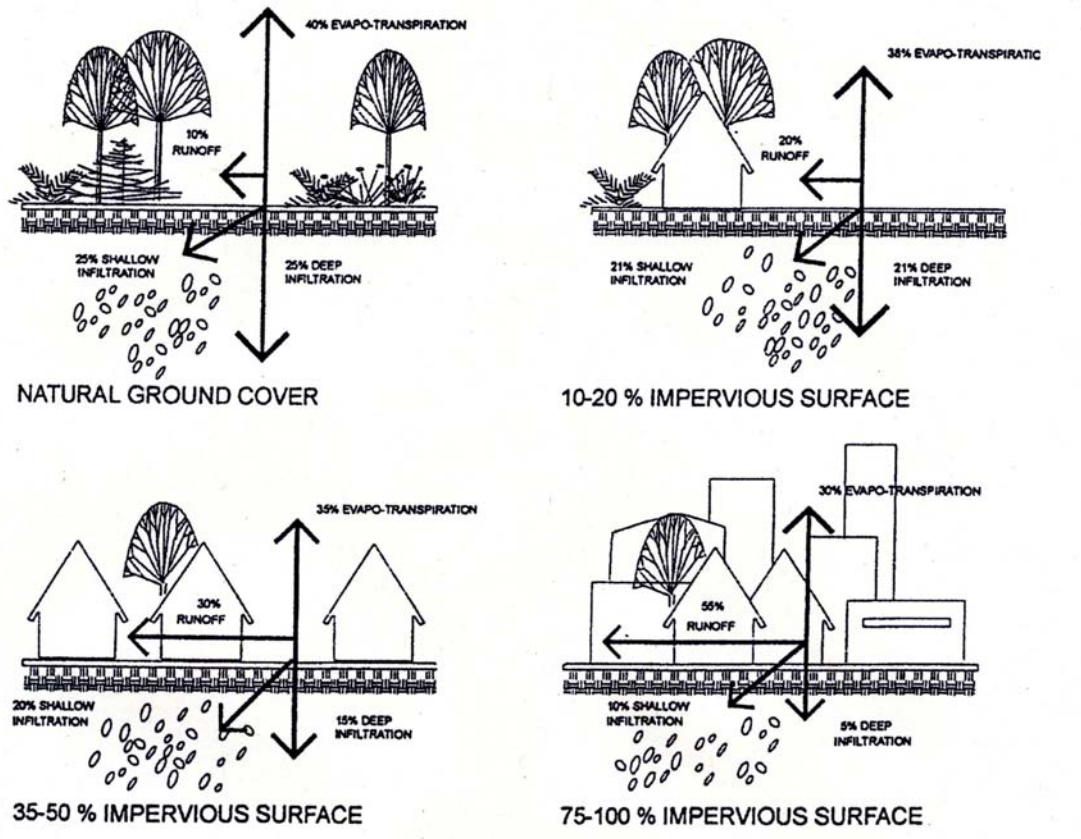

Figure 10—Evapotranspiration Chart
Source: U.S. Environmental Protection Agency

The swamp is a composite of natural features and must be defined from that viewpoint. Chronically wet soils (Soil Conservation Service definition) and vegetation that reflects a requirement for water (information obtained from infrared photographs) delineate the natural entity of the swamp. The swamp is made up of contiguous wetlands as defined in the New Jersey Freshwater Wetlands Protection Act as:

"areas inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances does support, a prevalence of vegetation typically adapted for life in saturated soil conditions, commonly known as hydrophytic vegetation…"

The 240-foot contour line which reflects the flood hazard area for the Great Swamp in Chatham Township also helps to define the limits of the swamp. The swamp is also dotted with higher lands, a legacy of ancient Lake Passaic.

Development occurred in parts of the Great Swamp before the federal and state wetlands laws were enacted. High water tables and poorly drained soils have resulted in flooding or wet basement problems for structures there. Runoff from higher lands has traditionally been directed to the Great Swamp. A stormwater study completed in 1997 identified 77 stormwater outfalls carrying substantial quantities of runoff that otherwise would have reached the swamp more gradually as flow over land and from groundwater replenishment from infiltration.

Hydrology in the Great Swamp Basin
The Great Swamp is critically affected by the five major streams flowing into and through it. From east to west they are: Black Brook and Loantaka Brook in Chatham Township, Great Brook, Primrose Brook and the Passaic

River. (See Figure 11.) The Great Swamp reduces extremes of streamflow from the four major feeder streams caused by weather and seasonal changes in two ways: by holding peak flows from storm events and discharging stored groundwater during dry periods. Land use changes in the watershed affect the swamp to various degrees depending on the nature and the location of the change.

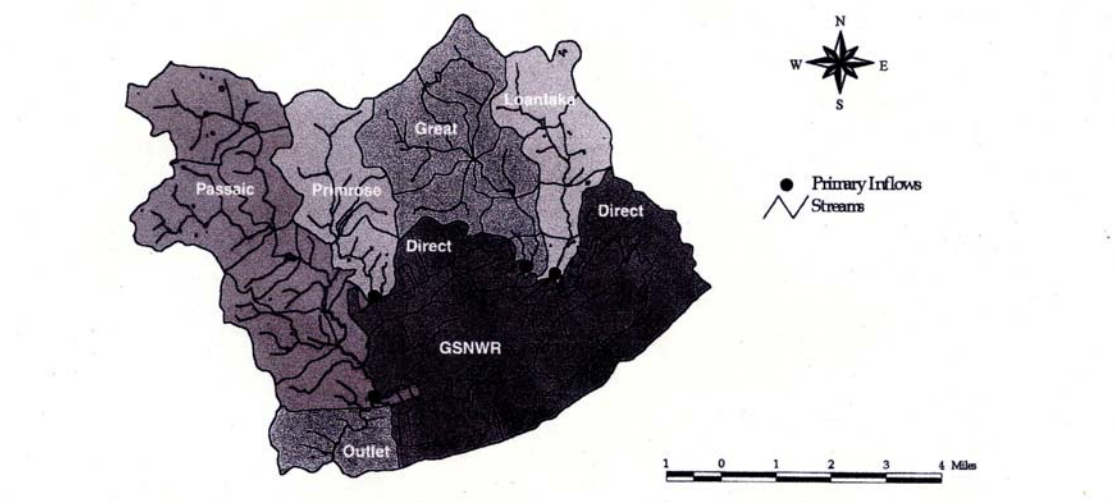

Figure 11 - Subwatersheds Tributary to the Great Swamp

Observations by the U.S. Fish and Wildlife Service, the Soil Conservation District, consultants and residents include increased frequency of road flooding, flooded basements, an increase in the frequency and magnitude of peak stream flows causing erosion of stream banks and downstream deposition of sediment. The U.S. Fish and Wildlife Service is experiencing difficulties in managing the water levels in the refuge. There is concern that increasing development will increase flooding.

Because of concerns regarding negative impacts to the swamp from increasing development and expanded sewer facilities, the Commissioner of the New Jersey Department of Environmental Protection in 1989 issued an administrative order establishing the Great Swamp Watershed Advisory Committee (GSWAC). The committee was created to study and make recommendations regarding the Great Swamp.CH2M Hill, hydrologists, evaluated the hydrology of the Great Swamp by developing a hydrologic budget to study water flow into and out of the swamp. The budget helps us to understand the problems identified above and the effects that future land use changes will have on the swamp's hydrologic process. The water that enters the system (inflow) minus the water that leaves the system (outflow) equals the change of storage of water within the basin. On an annual basis, a change in storage could be caused by depletion of groundwater which would lower groundwater levels. Another mechanism for changing the annual storage would be to construct or remove a surface water reservoir, changing the volume of surface water that can be stored within the system.

The inflows to the basin and the outflows from the basin can be summarized by the following terms:

Inflows

Precipitation	– average annual precipitation
Subsurface Inflow	– regional groundwater flow into the basin
Imported Water	– water supply from outside the basin and transferred into it, e.g,. sewage treatment plant discharges)
Flow from Surface Storage	– flow from draining wetlands
Flow from Groundwater Storage	– depletion of groundwater

Outflows

Surface Outflow	– total runoff / stream flow leaving the basin
Evapotranspiration	– water leaving the basin via evaporation from all water, soil, snow, ice, vegetation, and other surfaces, plus plant transpiration
Consumptive Use	– domestic, commercial, and industrial use
Flow to Surface Storage	– increase in surface water storage, such as flooding wetlands, raising reservoir levels, or forming new impoundments
Flow to Groundwater Storage	– artificial recharge

CH2M Hill conducted the hydrologic budget study in 1991. The results of the study indicate that increased volumes of runoff flow into the swamp, but not necessarily through it. Increased annual volumes of surface runoff from land use changes between 1963 and 2000 were assumed by the study to be mostly the result of decreased evapotranspiration, and, to a lesser extent of decreased groundwater recharge. Should this continue, the duration and depth of water ponded within the Great Swamp may increase over present levels for the same amount of rainfall. Available data are insufficient to quantify these changes directly; however, various methodologies were used to investigate the impacts of land use changes. For example, past land use changes from open or forested sites to less pervious land coverage have probably resulted in the bulk of the change in runoff volumes and peak flows. However, less intensive land use changes, such as substantial large-lot residential development, may have a long-term impact on the budget through changes or loss of evapotranspiration. This strongly suggests that retention of shade trees is extremely important to help control stormwater runoff.

A more recent study completed in 1997 by environmental consultants verifies that developed areas in the watershed are contributing much higher than expected stormwater runoff volumes to the swamp. The results were from monitoring in Chatham Township at a 42” diameter pipe draining a 269.8 acre area of 1/2 acre zoning with 20% impervious cover in Wickham Woods. The study pointed out that this must be due to the fact that 75% of the area is composed of extensively disturbed soils, disturbed by the 1/2 acre density residential development.

New Jersey Department of Environmental Protection
Surface Water Quality Classifications in Chatham Township

The New Jersey Department of Environmental Protection (DEP) establishes classifications for water bodies in the state. These classifications are in place to protect designated uses and give DEP a basis for regulating discharges to these waterbodies. The state also assigns an antidegradation category to all waters.

Loantaka and Black Brooks are classified as Non-trout, Category Two waters. This means that all discharges must meet certain standards and must also establish that the discharge will create minimal, if any, degradation. The Great Swamp National Wildlife Refuge is classified as a Non-trout, Category One water. This means that any discharge to the refuge cannot cause a measurable or calculable change to its water quality. In addition, any discharge to Loantaka Brook or Black Brook or any tributary must result in no measurable or calculable change to the downstream Refuge.

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