5: GROUND WATER

A. Ground Water

Water is essential to all life on Earth. The abundance of water distinguishes the Earth from any other planet, but the amount of water on Earth has remained constant for millennia. Even though the quantity of water is great, only a small portion can be used for drinking water and other human needs. Ninety-seven percent of the world's water supply is saltwater stored in the oceans. The remaining 3% is fresh water. However, most of this is unavailable for human use because it is frozen in the polar ice caps, glaciers, and icebergs; too difficult to tap (below 1.6 miles depth); or too polluted. This leaves 0.003% of water that is available as fresh surface or ground water that humans can use (Miller, 1988).

Surface water is water that is visible above the ground surface, such as creeks, rivers, ponds, lakes, and wetlands. *Ground water* means that portion of water beneath the land surface that is within the zone of saturation (below the water table) where pore spaces are filled with water. An *aquifer* is a water-bearing rock or rock formation where water is present in usable quantities. Water is constantly recycled through the *hydrologic cycle*, also known as the *water cycle* (see **Figure 5a**). Precipitation falls on the ground and some travels on the surface of the land (called *surface runoff*), entering streams (where it can be seen as high flows after rain events), and eventually making its way back to the ocean. Some of the water from precipitation enters the ground but remains in the shallow layers where it is available for use by plants, where it returns to the atmosphere through *transpiration* by plants, while some water re-enters the

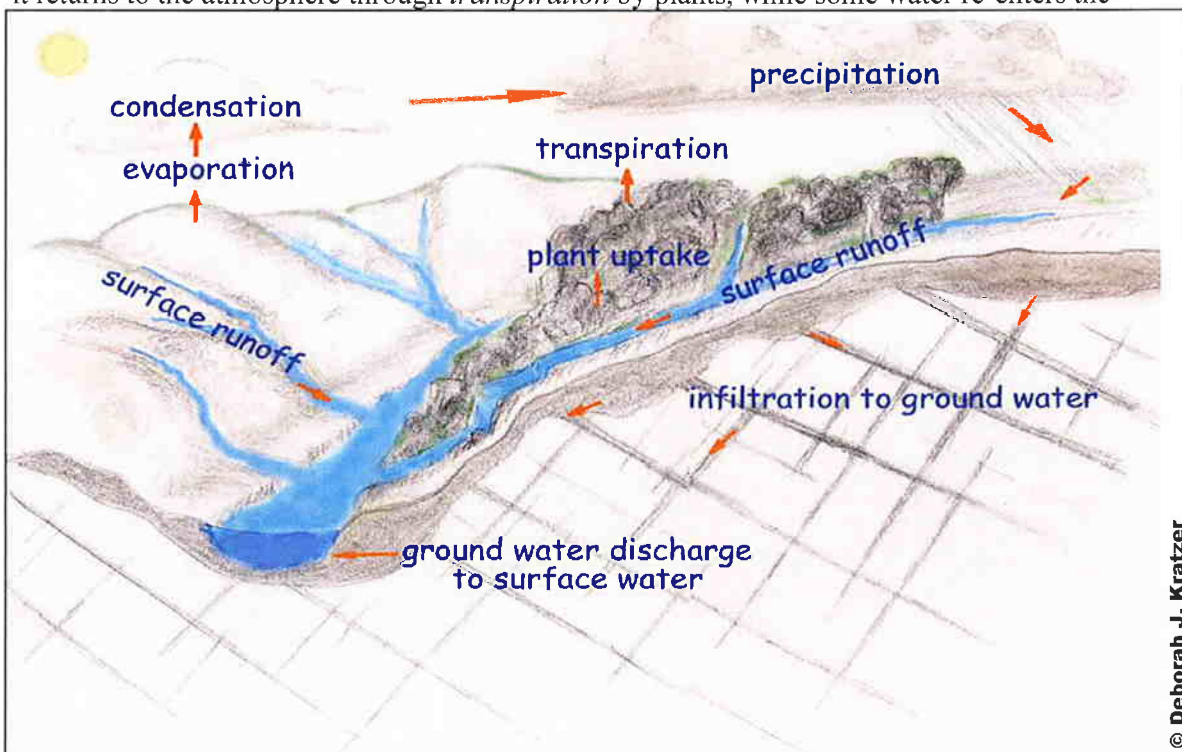


Figure 5a: The Water Cycle

atmosphere directly through *evaporation* from surface water. Evaporation and transpiration combined are known as *evapotranspiration.* The water that migrates below the root zone travels underground and exits the system as stream flow, known as *ground water baseflow* or *ground water recharge.* Ground-water baseflow can be calculated by measuring stream flow during dry weather conditions. A smaller portion of the water penetrates deeper into the ground and enters (or recharges) the saturated zone of the fractured bedrock, where most wells obtain their water, called the *aquifer.*

In the most basic and simplistic terms, one can visualize long term balance in the water cycle as follows: Expressing the water cycle in mathematical terms is known as the *hydrologic water budget.* An equation balances the mass of all water entering the basin with that leaving the basin, in simple terms, as follows (DeMicco, 2004):

Water Entering Basin – Water Leaving Basin = Change in Aquifer Storage

Or

Precipitation – Surface Water Runoff – Evapotranspiration – Ground Water Baseflow) = Change in Aquifer Storage

Long term, if water entering the basin equals water leaving the basin, there is no change in aquifer storage (DeMicco, 2004).

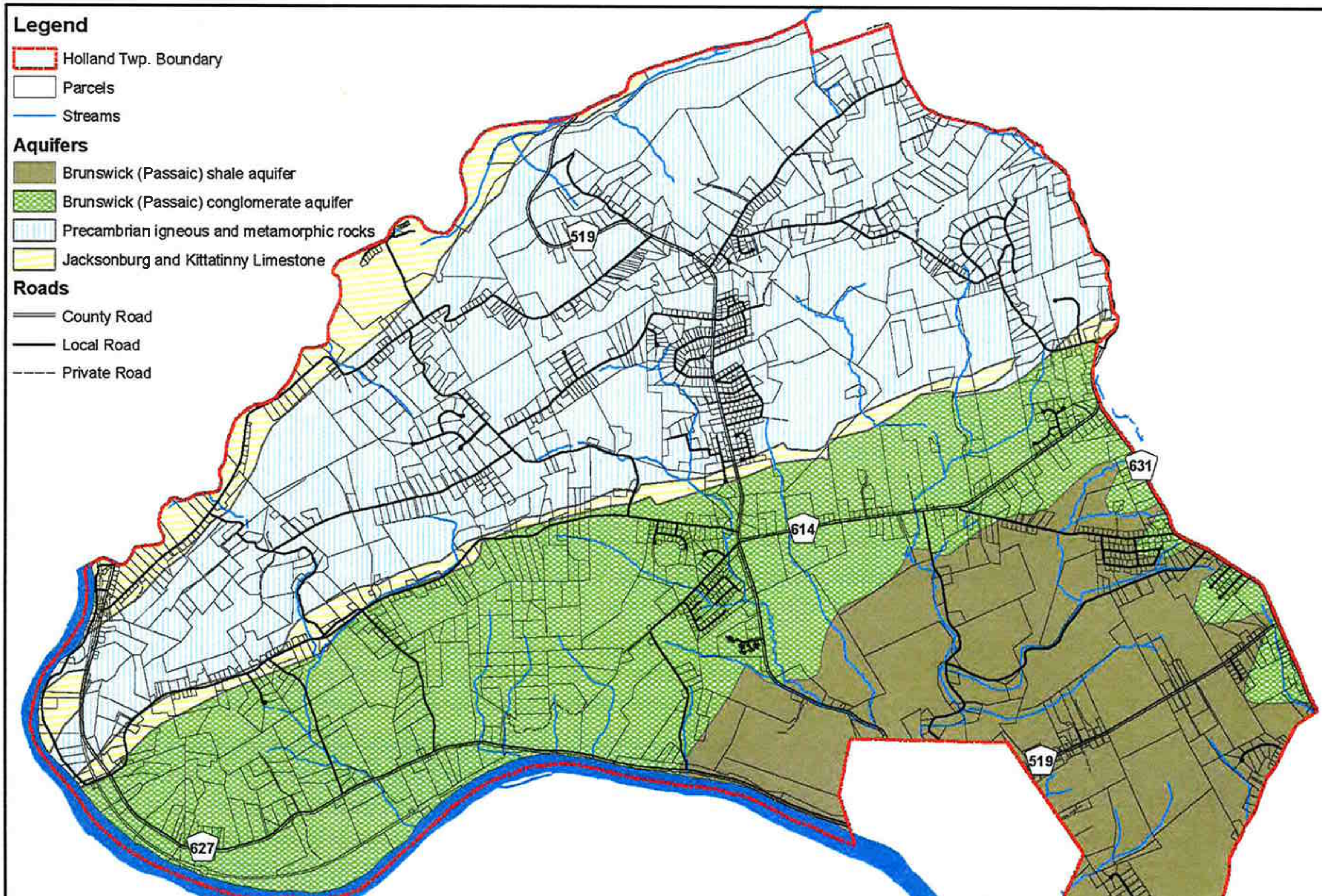
Pollutants can enter water as it travels the water cycle. Surface runoff can pick up chemicals and soil on its way, depositing these pollutants in waterways. This is especially true of "uncontrolled runoff" on soils which are vulnerable to erosion, as discussed in **Section 6G** of this report. Water seeping into the soil can be cleansed of many pollutants by natural soil processes. However, if the pollutant is one which is resistant to break-down, or if the pollutant doesn't get exposed to the soil long enough (such as by entering a bedrock fracture or by entering the ground water through sub-surface disposal), pollutants can spread underground and pollute sources of drinking water..

B. The Aquifers in Holland Township

Almost half of New Jersey's drinking water comes from ground water. Holland Township relies exclusively on ground water.

In the northern half of New Jersey, aquifer boundaries roughly correspond to the physiographic provinces (see **Figures 3a: Physiographic Provinces** and **5b: Aquifers**). The majority of Holland Township is underlain by aquifers in either the Late Triassic Newark Group of sedimentary rocks (the Piedmont province in the southern half of the township) or Precambrian crystalline rocks (the Highlands province in the northern region). Both types of bedrock yield water mostly from *secondary porosity*[1] and permeability provided by fractures. Therefore, the distribution and orientation of these fractures controls the rates and directions of ground water flow. The water bearing structures underground may bear little resemblance to the overlying topography. Another aquifer type is found in the alluvial or limestone material bordering the Delaware and Musconetcong Rivers and the limestone units along the fault zone

[1] *Porosity* is the measure of voids in soil or rock, which are available to hold water (like holes in a sponge). *Primary porosity* is due to spaces between the soil or rock particles or within porous rock particles. *Secondary porosity* is found in fractures in bedrock. Aquifers with primary porosity store far more water than those with only secondary porosity.



Data Sources: See Appendix B.
Note: Map accuracy is limited to the accuracy and scale of the original data sets; see Appendix B.
Disclaimer: This map was developed using NJDEP and Hunterdon County GIS digital data, but this secondary product has not been verified by NJDEP or Hunterdon County and is not NJDEP or county authorized.

Figure 5b: Ground Water - Aquifers

Holland Township NRI, 2007
Prepared by Kratzer Environmental Services

through the center of the township. The alluvial material is generally less than 50 feet deep and is therefore not suitable for domestic wells, but some industrial wells have particularly high yields of 1,000 gpm (DeMicco, 2004).

In bedrock aquifers such as are found in Holland, rocks near the land surface experience weathering, caused by freezing and thawing of water, which has widened fractures and dissolved some of the intergranular cement in the sedimentary rocks. Rocks below the weathered zone, which is usually about 75 feet thick, have no primary porosity (Lewis-Brown, 1995). *Unconfined* conditions commonly exist above this level because pores and fractures in this material are usually well-connected. Below this level, *confined* conditions are caused by the presence of low-permeability layers containing relatively few fractures.

In general, water that flows to pumped wells is derived mostly from the fractures intersected by the well opening. Other water-bearing units provide water by leakage through confining units. Wells near surface water bodies can also derive a significant amount of water from the surface water body by *induced infiltration* (Lewis-Brown, 1995). These wells located near surface water often have higher yields (Vecchioli and Palmer, 1962 in Lewis-Brown, 1995), but can be vulnerable to pollution, if the surface water carries pollutants.

The aquifers in Holland Township are shown in **Figure 5b**, while aquifer characteristics are summarized in **Table 5.1**.

The **Brunswick (Passaic) Aquifer** is composed of sandstone, siltstone, and shale of the Passaic Formation. Ground water is stored and transmitted in fractures. The water-bearing units are composed of fissile[2] shale and siltstone, and the confining units are composed of massive siltstone. Water is normally fresh, slightly alkaline, non-corrosive and hard. Calcium-bicarbonate type waters dominate. Subordinate calcium-sulfate waters are associated with high total dissolved solids. The Passaic formations are characterized by several layers of extensively fractured rocks (water-bearing units) that typically are 1 to 10 feet thick interbedded with layers of sparsely fractured rocks (confining units) that typically are 30 to 100 feet thick. These geologic formations extend thousands of feet below ground, but the density of fractures decreases with depth. Water-bearing, interconnected fractures are present only from the land surface to a depth of about 500 feet (Houghton, 1990 in Lewis-Brown, 1995). For this reason, wells extended beyond 500 feet usually do not increase well productivity (the extra storage provided by the greater length of the well bore-hole may be necessary, however, to supply enough water for the well's intended use). The aquifer consists of the whole 500 foot thick sequence of water bearing units and confining units.

Glacial Valley-Fill Aquifers exist where glacial outwash has been deposited along stream valleys. They consist of sand, gravel, silt and clay, and are generally unconfined, except where layers of silt and clay form a confining layer (USGS, 2005b). These are the most productive source of ground water in some northeastern counties in New Jersey (Vecchioli and Miller, 1973). These aquifers may yield as much as 2,000 gpm to public supply and industrial wells. Glacial valley-fill aquifers are not shown on Figure 5b, but exist along the Delaware and Musconetcong Rivers (mainly within the floodplains), where some high yielding industrial wells exist in Holland (DeMicco, 2004).

The **Highlands Crystalline Aquifer units** include gneiss and granite within Holland, and like the Brunswick are both confined and unconfined. Water is mostly obtained from the weathered and fractured zone in the upper 399 feet. High yields may be found in or near major fault zones (USGS, 2005b). All the formations in the Highlands transmit water due to secondary porosity. Measurements indicate that fracture closure occurs within 300 feet of the surface in the Highlands (EPA, 1987). A primary purpose of the Highlands Water Protection and Planning Act

[2] *Fissile* means capable of being split.

(Highlands Act) (NJSA 13:20-1 et al) (see **Section 10A**) is to protect the precious water resources that supply drinking water to more than half of New Jersey's population.

The **Limestone (Jacksonburg, Kittatinny and Leithsville) Aquifer** is found in a relatively small area of Holland Township. Limestone is subject to solution weathering, therefore karst features may occur, including solution channels, sinkholes, soil piping sinks and caverns. While some industrial wells have extremely high yields, domestic wells in the limestone units in this area are not unusually high, and are similar to the yields in the Brunswick (Passaic) Formation (DeMicco, 2004).

Table 5.1: Characteristics of the Aquifers of Holland Township

Aquifer Unit	Source*	Median Yield (gallons per minute)	Median Well Depth (feet)	Median Static Water Level (feet)	State Rank**
Precambrian (igneous and metamorphic crystalline rocks of the Highlands crystalline units)	A	15	105	-	D
	B	13.5	280	30	
	C	5 – 50	35 – 800	-	
Brunswick (Passaic) conglomerate	A	10	174	-	C
	B	15	220	40	
	C	10 – 500	30 – 1,500	-	
Brunswick (Passaic) shale (sedimentary rock)	A	15	200	-	C
	B	15	325	115	
	C	10 - 500	30 – 1,500	-	
Glacial valley-fill (not shown on map)	A	-	-	-	
	B	-	-	-	
	C	100 – 1,000	10 – 300	-	
Jacksonburg Limestone, Kittatinny Limestone	A	20	130	-	C
	B	15♦	133♦	-	
	C	5 - 500	150 - 400	-	

*Source A: Kasabach (1966) in DeMicco, 2004 (Holland wells only)
Source B: Hunterdon County Health Dept in DeMicco, 2004 (Holland wells only, except ♦ is Hunterdon County)
Source C: USGS, 2005b, Aquifer and Well Characteristics in NJ: http://nj.usgs.gov/gw/table_1.html

** **State Rank** is based on High Capacity Wells (such as water-supply, irrigation, and industrial-supply wells sited and tested for maximum yield. Many of the wells have boreholes exceeding the standard six-inch diameter for domestic wells. State Rank is best viewed on a relative basis, with "A" yielding the most water, and "E" the least. Median High Capacity Wells Yield (in gpm): [A] > 500; [B] 251 to 500; [C] 101 to 250; [D] 25 to 100; [E] <25

Sources: NJGS Readme.txt with GIS data; DeMicco, 2004; USGS, 2005b, http://nj.usgs.gov/gw/table_1.html.

A Groundwater Resource Evaluation of Holland Township, Hunterdon County, New Jersey was completed by DeMicco and Associates in 2004 for the Holland Township Planning Board. Two sources of well records were analyzed: the Geology and Groundwater Resources of Hunterdon County (Kasabach, 1966) and Hunterdon County Health Department records. However, the latter did not include geologic data, so wells were divided into three major geologic zones (Precambrian, Triassic Conglomerates, and Triassic Passaic Shale). The study revealed the following:

- Median well yields are similar for both sets (pre-1966 and post-1966) of well records.
- Median well yields are similar for all geologic formations, although conglomerates have slightly better yield than either shale or Highlands.
- Well depth is significantly deeper in the newer (post-1966) wells.

- Increased well depth did not result in increased well yield, evidence that the productive zones of the aquifer are located in the upper portion of the aquifer.

- The best wells are likely to be shallow; i.e. if a well does not obtain a yield ≥ 10 gpm in the upper 100 – 125 feet, the well will end up with very low yield.

- The depth to water (*static water level*) in the Triassic shale is unusually deep. The presence of perched water table on top of the bedrock occurs in this area, but the shallow ground water is not directly connected to the deeper zones of the Triassic shale.

- Deep depth to water tends to indicate a highly transmissive aquifer, i.e. the water rapidly moves through the ground to discharge to surface water.

- The sedimentary rock has more open fractures at a greater depth than the Precambrian and conglomerate units.

Movement of ground water is usually quite slow, on average; ranging from about one foot per day to perhaps ½ inch per month. Therefore, in some areas, it might take days for water to travel from the point where it enters the ground, to a point of discharge into a stream, or it might take millennia (Heath, 1983). However, ground water in Holland, because it is present in fractures, can potentially move much more quickly. "The rates of movement in … large fractures may approach those observed in surface streams" (Heath, 1983; Freeze and Cherry, 1979). A contaminant could travel quickly through fractures, with little soil contact to allow for filtration or degradation of pollutants. Thus, a well located on a large fracture might have a very good yield, but may be highly susceptible to contamination.

The response of the aquifer to withdrawals from a well or wells determines the well's performance. Drawdown and recovery tests may be performed to determine whether the well will produce enough water for its intended use, and whether that use can be sustained for the foreseeable future. The well's *drawdown* is the difference between the water level before pumping (*static water level*) and the water level during pumping (see **Figure 5c**). A *cone of depression* is the conical-shaped depression of the water table around a pumping well caused by the withdrawal of water. Because of pumping, ground water in the vicinity of the well will deviate from the natural direction of ground water flow and flow towards and into the well (see **Figure 5c**). A cone of depression that extends to an area another well draws from may interfere with the performance of both wells.

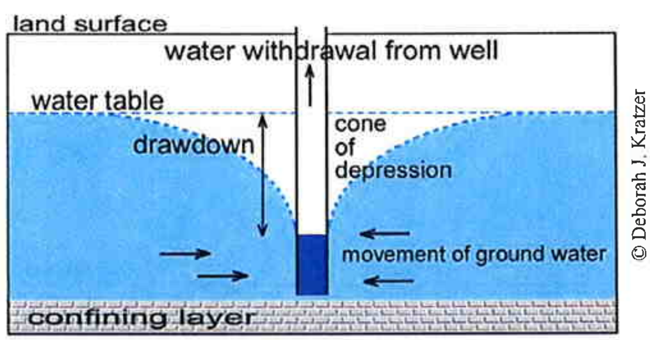


Figure 5c: Illustration of Drawdown and Cone of Depression

Controlled aquifer tests with observation wells provide additional ground water information which is not available from well drilling completion records, such as drawdown and interference. Aquifer tests are included in the *NJGS Hydro database*, which provides a compilation of values for the hydrologic properties of geologic materials in New Jersey by the New Jersey Geological Survey. The database includes values derived from the analysis of aquifer pumping tests and other tests, performed over the past century and updated as new ones are completed. The data are intended to be used for characterization of the hydrogeologic properties of individual geologic and hydrogeologic units throughout the state. Using these data, NJGS has compiled summaries for geologic and hydrogeologic units in New Jersey of horizontal hydraulic conductivity values, transmissivity values, and vertical hydraulic conductivity values (NJGS, 2002).

Only one such controlled aquifer test is available for Holland Township (DeMicco, 2004). This study was completed in the Precambrian Highlands aquifer, where one on-site well was pumped at a rate of 30 gpm for 6 hours while three other on-site wells were used as observation wells. The observation wells showed *no* interference effects, which indicates that the aquifer does not have well-connected fractures in any direction. The lack of interference indicates that the aquifer has poor water transmitting capacity. In contrast, the best aquifers show very small interference effects over a very wide area. The fracture supplying this test well was very limited in areal extent, i.e. "the geologic equivalent of a bathtub" (DeMicco, 2004), making it vulnerable to the effects of drought. The aquifer is also susceptible to contamination from a septic system (or other potential pollutant source) located over fracture zones intercepted by a well because there will be little contribution from other fracture zones for dilution of septic effluent (DeMicco, 2004).

C. Recharge

Ground water *recharge* is defined as water added to an aquifer (for example, precipitation that seeps into the ground). A *ground water recharge area* is the land area that allows precipitation to seep into the saturated zone. These areas are generally at topographically high areas with discharge areas at lower elevations, commonly at streams or other water bodies (i.e. the ground water returns to surface water). In general, ground water divides coincide with, or are slightly offset from, surface water divides (Lewis-Brown, 1995) (watersheds are described in **Section 6A** and shown in **Figure 6a**). Most ground water flows through the shallow layers of soil and weathered bedrock to the nearest stream. A smaller percentage penetrates deeper and recharges the aquifer.

Recharge rates are expressed in terms of the amount of precipitation that reaches the aquifer per unit of time (e.g. inches/year is used in **Figure 5d**). New Jersey receives an average of 44 inches of precipitation annually, and references vary widely about how much reaches the aquifer (Lewis-Brown, 1996; Kasabach, 1966; USGS, 2005a) in areas like Holland. This is because of the complexity of many factors that affect the amount of recharge that will occur in a given area, including climate (e.g. the amount, intensity, and form of precipitation, and the effect of wind, humidity and air temperature on evapotranspiration), soil, surficial geology, and vegetation factors. In addition, recharge of ground water varies seasonally. During the growing season, precipitation is intercepted by plants and returned to the atmosphere through transpiration (part of the hydrologic cycle, see **Figure 5a**). Evaporation likewise, is higher during the warmer months. Therefore, most recharge occurs during late fall, winter, and early spring, when plants are dormant and evaporation rates are minimal (Heath, 1983). Relative to land use, recharge rates in forests are much higher than those in urban areas (Heath, 1983). This is because urban areas have large areas covered with impermeable surfaces, hastening runoff to surface water, instead of allowing precipitation to percolate into the ground.

After estimating recharge, an evaluation of *safe yield* can be used for planning purposes. *Safe yield*, or *dependable yield*, is defined as "the water yield maintainable by a ground-water system during projected future conditions, including both a repetition of the most severe drought of record and long-term withdrawal rates without creating undesirable effects" (New Jersey Statewide Water Supply Plan 1996 in DeMicco, 2004). Robert Canace, of the NJ Geological Survey, suggested that 20% of the estimated recharge should be used for planning purposes, representing the portion of recharge actually available for use during drought conditions (Canace, 1995). Returning to the equations for the ground water budget in **Section 5A**, if withdrawals of ground water are greater than the recharge amounts, the aquifer would experience a continuous net reduction in the available water supply, obviously a situation which effective planning seeks to avoid.

In view of the importance of not exceeding the aquifers' safe yield, NJDEP has attempted to quantify recharge, as described in the sections below. However, these methods did not attempt to quantify the loss in aquifer recharge due to water diverted to public sewers.

New Jersey Geological Survey Recharge Method

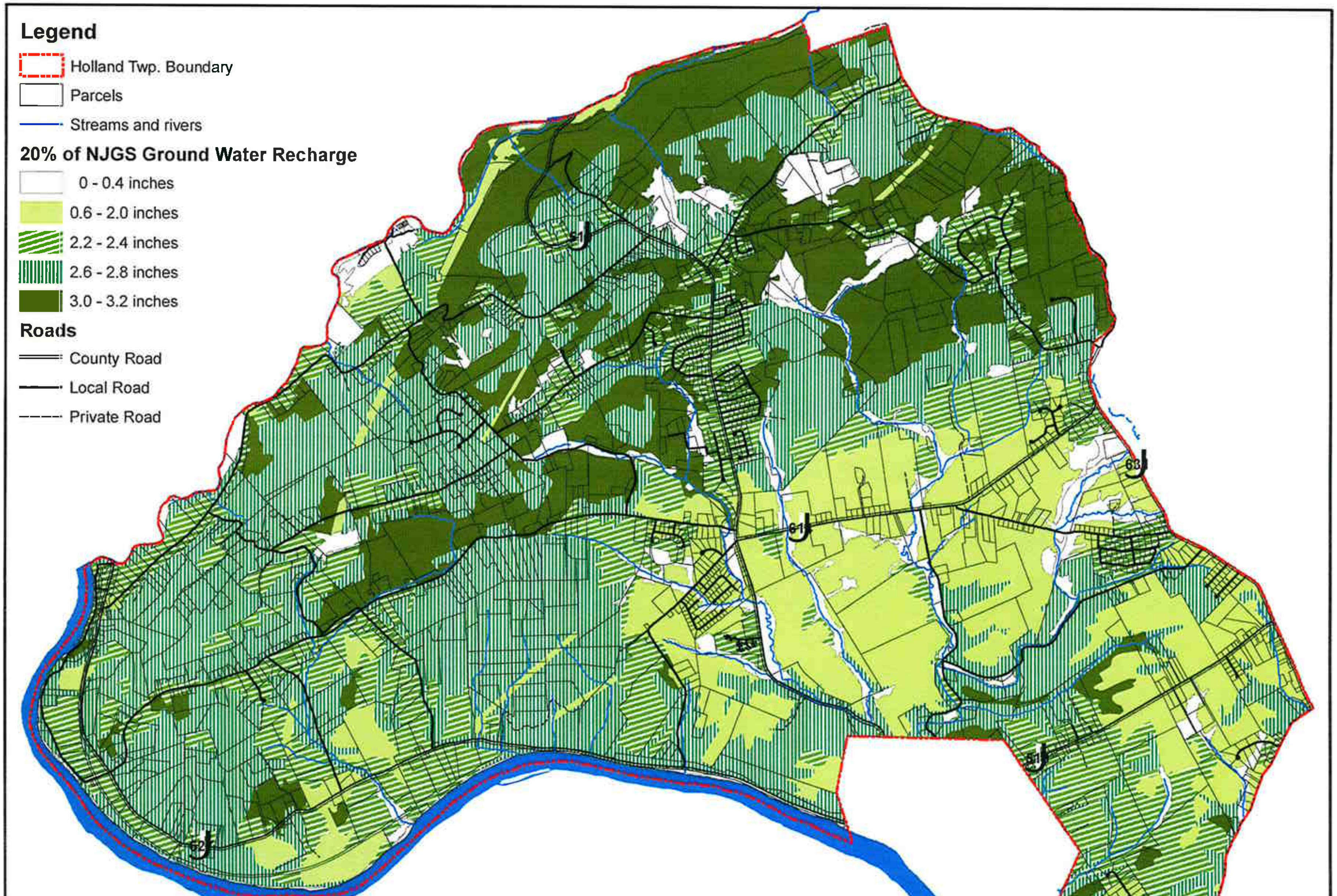
N.J.S.A. 58:11A, 12-16 required the NJDEP to publish a methodology to map and rank aquifer-recharge areas. In addition, the legislation required the development of ground-water protection practices designed to encourage ecologically sound development in aquifer-recharge areas (Charles et. al., 1993). To fulfill the requirements of this legislation, the NJ Geological Survey developed GSR-32, which estimates ground water recharge (but not aquifer recharge), and is useful for evaluating the relative effect of present and future land uses on recharge areas (Charles et. al., 1993). For this method, recharge was calculated based on data for precipitation, soil, land-use/land-cover, surface runoff, and evapotranspiration. This method was then applied by NJGS to create a GIS coverage (see **Figure 5d**). There were a number of assumptions made for the calculations and model inputs which limit the accuracy of the method: 1.) the calculated ground water recharge includes any water entering the ground (lesser amounts actually enter the aquifer); 2.) assumes that all water which migrates below the root zone recharges the aquifer (which doesn't happen); 3.) addresses only natural ground water recharge, and does not include artificial recharge, withdrawals or natural discharge; 4.) wetlands and water bodies were eliminated from analysis, because the direction of flow between ground water and surface water is site-specific and also varies seasonally, and this level of detail was beyond the scope of the study (these areas were assumed to provide no recharge or discharge); and 5.) stream baseflows used may not be representative of local streams (Charles et. al., 1993). An additional limitation of the data is that they estimate long-term average annual recharge, which does not represent the reduced recharge during critical summertime conditions (NJ Water Supply Authority, 2002).

Keeping these limitations in mind, the method estimated recharge rates from 1 to 16 inches per year in Holland (excluding surface water, wetlands and hydric soils), for estimated average annual subsurface recharge. Applying the 20% consumptive use limit to these figures results in usable recharge from 0 to 3.2 inches per year (see **Figure 5d**). However, the resulting relative rank of aquifers (see **Figure 5e**) may be more useful than the actual rates, in view of the method's limitations, for general identification of high versus low recharge for municipal planning purposes (DeMicco, 2004).

As previously mentioned, only a portion of water entering the ground actually recharges the aquifer, but the GSR-32 did not attempt to quantify this amount.

Holland Groundwater Resources Study

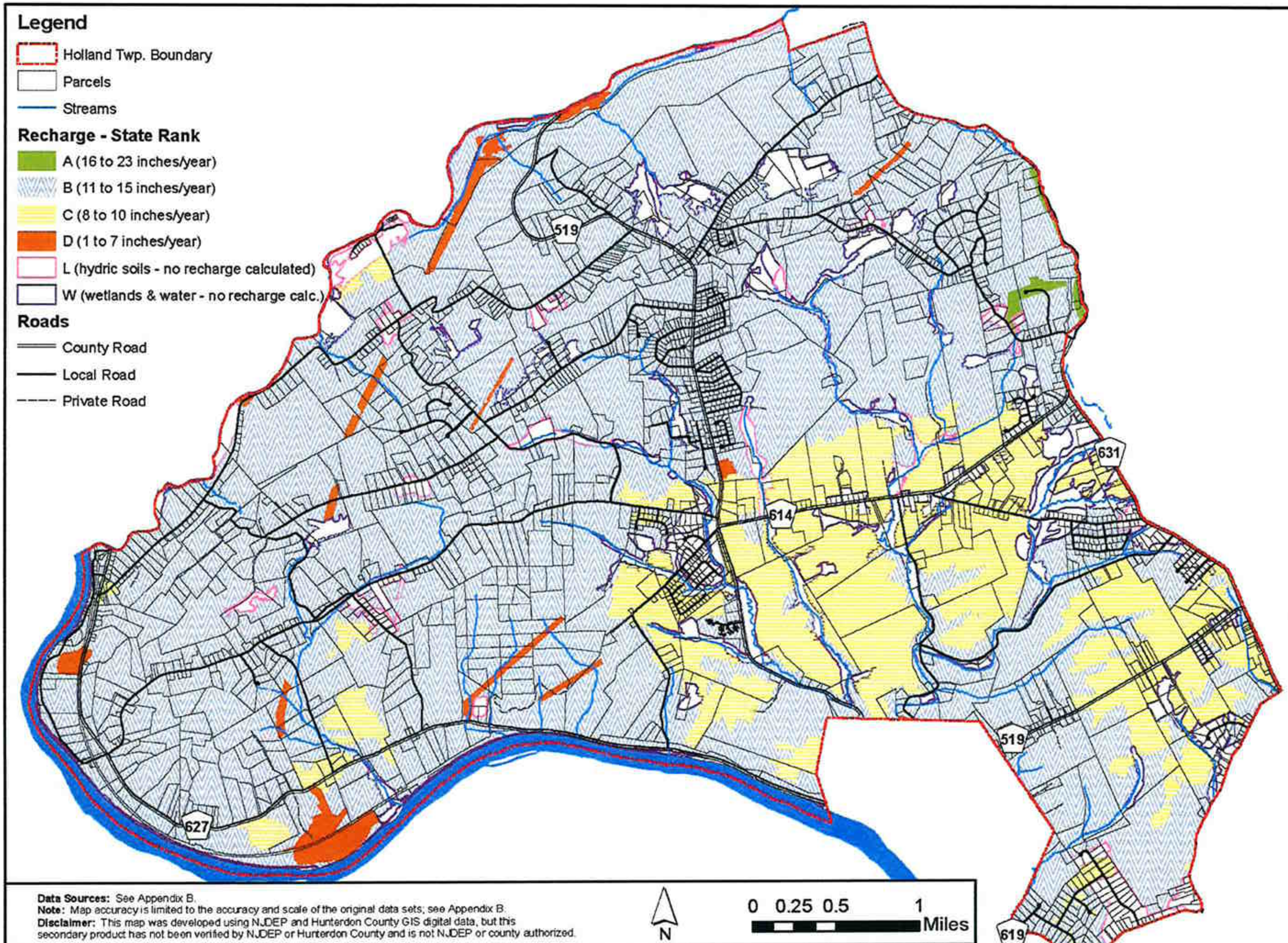
In 2004, the previously mentioned <u>Groundwater Resources Evaluation of Holland Township</u> (DeMicco, 2004) used additional available data on ground water recharge estimates to provide an updated assessment of Holland's ground water conditions.



Data Sources: See Appendix B.
Note: Map accuracy is limited to the accuracy and scale of the original data sets; see Appendix B.
Disclaimer: This map was developed using NJDEP and Hunterdon County GIS digital data, but this secondary product has not been verified by NJDEP or Hunterdon County and is not NJDEP or county authorized.

Holland Township NRI, 2007
Prepared by Kratzer Environmental Services

Figure 5d: Ground Water - Recharge - estimated inches



Data Sources: See Appendix B.
Note: Map accuracy is limited to the accuracy and scale of the original data sets; see Appendix B.
Disclaimer: This map was developed using NJDEP and Hunterdon County GIS digital data, but this secondary product has not been verified by NJDEP or Hunterdon County and is not NJDEP or county authorized.

Figure 5e: Ground Water - Recharge - State Rank

Holland Township NRI, 2007
Prepared by Kratzer Environmental Services

Of several methods for evaluating baseflow, the Posten method was selected by DeMicco, as it represents a relatively reproducible method of evaluating the recharge to the ground water and the aquifers by measuring the outflow of streams during dry weather and in defining safe yield for bedrock aquifers (DeMicco, 2004).

The final assessment of dependable yield is based on selecting appropriate planning criteria, including estimating daily water demand[3] and how much of aquifer recharge can safely be used[4]. "While the most aggressive assumptions use 100 percent of recharge in drought years for human consumption, this would result in substantial degradation of ground- and stream-water quality. Reasonably conservative assumptions of dependable yield indicate 5.1 to 6.0 acres per lot, based on average yields, which can sustain sufficient *quantity* of water for domestic use" [emphasis added] (DeMicco, 2004, p.46). Selected calculations of recharge and safe yield are shown in **Table 5.2**. In addition to these estimates of safe yield, sound planning must also consider septic system impacts on the aquifer (DeMicco, 2004), which is discussed in the next section.

Table 5.2: Aquifer Recharge and Safe Yield in Holland Township

Major Geologic Unit	Aquifer Recharge	Safe Yield					
	Average Year (Posten Method)	Drought Year				Consumptive Limit	
		75% of average year		50% of average year		20% of average Year	
Precambrian (Unglaciated portions of Highlands within Hunterdon County)	4.5 inches per year	3.37 inches per year	250 gallons per day per acre	2.25 inches per year	167 gallons per day per acre	0.9 inches per year	67 gallons per day per acre
Passaic (Brunswick) Shale and Conglomerate and Limestone	5.2 inches per year	3.9 inches per year	290 gallons per day per acre	2.6 inches per year	193 gallons per day per acre	1.0 inch per year	78 gallons per day per acre
Source: DeMicco, 2004, from Tables 9 and 10.							

D. Ground Water Quality

Pollution, such as nitrates, bacteria, metals, pesticides and antibiotics, can enter ground water via non-point sources (including septic systems and runoff from fields and roads), point sources (including discharge pipes), and rain. The New Jersey Comparative Risk Project (2003) identified a number of possible human health risks from drinking water, including lead (which, when present, is usually from the plumbing (NJDEP, 2004)), radon, arsenic, MTBE, nitrates, and waterborne pathogens.

The New Jersey Private Well Testing Act (N.J.S.A. 58:12A-26 et seq.) became effective in September 2002. The PWTA requires mandatory statewide private well testing upon the sale

[3] Daily water demand varies depending on the size of the home, number of persons per household, the presence of pools, hot tubs, lawn watering, etc. The N.J.A.C 7:10-3.32 uses 100 gallons per day per person. During the warm months, water used outdoors is largely lost to evapotranspiration, while water sent to septic systems is mostly recharged to the aquifer (DeMicco, 2004).

[4] Two such methods are to estimate the worst drought of record or to use the NJDEP planning threshold of 20% of recharge for consumptive use.

of a house. The well water must be tested for primary contaminants[5] (bacteria, volatile organic compounds, arsenic, lead and nitrates) and secondary contaminants[6] (pH, iron and manganese). Beginning March 16, 2004, gross alpha particle activity is also required in Hunterdon County. A report summarizing the first year of data (September 2002-March 2003) generated by the PWTA revealed that, out of 24 wells sampled in Holland Township, 1 well (4%) exceeded a maximum contaminant level for a primary drinking water standard (for arsenic). This is significantly lower than the statewide exceedance rate of 8% and in Hunterdon County the number was 11% (NJDEP Division of Science, Research and Technology, 2004). The report concluded that: 1.) certain geologic formations in the Piedmont region contain layers that may leach arsenic into the ground water as it passes through, and 2.) wells drilled into bedrock aquifers are more susceptible to fecal coliform contamination than wells in the coastal plain. In time, the data from the PWTA may be used to determine water quality trends and assessments of the safety of private well sources.

New Jersey's Ambient Ground-Water Quality Network (AGWQN) is a cooperative program between the NJDEP and United States Geological Survey (USGS) that started in 1983. The AGWQN is designed to monitor the quality of ground water at or near the water table throughout the State. Shallow ground water is generally the first and most significantly affected part of the ground water system, and the quality of this water is directly related to human activities at the land surface. The network consists of 150 shallow ground water wells throughout the state. Every year approximately 30 sites are sampled, with the cycle of sampling all 150 wells to be completed every 5 years. Results of the sampling are reported by the USGS in their yearly series on water resources data of New Jersey. None of these sites are located within Holland Township. One well is located just outside Holland's boundary in Pohatcong Township in Hughesville, in the sand and gravel aquifer (see **Figure 5f**). This dataset is of limited usefulness because of it's location in the sand and gravel aquifer, where few residential wells are located, and because it was sampled only once (2001).

Another method of protecting ground water quality through science-based planning is the use of *Nitrate Dilution Modeling* to evaluate the potential impacts to ground water from septic systems. The model predicts quality based on recharge, levels of nitrate (current and predicted) and different lot size averages. DeMicco and Associates (2004) calculated nitrate dilution models for Holland Township using alternative zoning lot size densities based on several potential impacts (differing levels of acceptable nitrate in well water). During droughts, dilution that usually comes from precipitation is reduced or absent, which could result in elevated nitrate levels in the ground water. Therefore, annual average should not be relied on for nitrate dilution analyses for Holland Township. DeMicco used a drought recharge of 75% of the average annual recharge. Even more conservative would be the use of 50% or 20%, as done for safe yield estimates. **Table 5.3** shows a summary of these results.

It should be noted that nitrates are only one contaminant released from septic systems and can be considered an indicator that septic field effluent is reaching domestic wells. Bacteria is another, while less is known about the movement and potential impacts of viruses and other waste products and chemicals. For additional information, see **Internet Resources**, NJDEP 2005.

---

[5] Primary contaminants are contaminants that may a cause potential health risk if consumed on a regular basis above the established maximum contaminant levels (MCLs).

[6] Secondary parameters are regulated by the State for aesthetic or other concerns (taste, odor, staining, scaling of home fixtures) rather than health effects. Whether or not these natural water quality parameters are a problem depends on the amount of the substance present.

Table 5.3: Nitrate Dilution Results for a Drought Year Using 75% Annual Average Recharge

Recharge (using 75% NJGS Drought)	Persons per Home*	Pounds per person per year**	Nitrogen Standard mg/l***	Acres per home
Precambrian: Recharge estimate at long term drought 3.37 inches per year				
3.41	3	10	5.5	7.5
3.34			3	13.8
3.42			2	20
3.38	4		5.5	10
3.39			3	18
3.36			2	27
Passaic Formation: Recharge estimate at long term drought 3.9 inches per year				
3.89	3	10	5.5	6.6
3.88			3	11.9
3.90			2	17.6
3.94	4		5.5	8.6
3.92			3	15.6
3.96			2	23

*Holland households consist of 3 persons based on 2000 census data. Calculations are also presented for 4 persons per household to account for possible demographic changes.
**10 pounds per person per year nitrate loading rate
***The N.J.A.C. 7:9-6 applies a nitrate standard of 5.2 mg/l based on anti-degradation ground-water quality regulations. A non-degradation standard of 2.0 mg/l may be applied where the goal is to maintain ground water concentrations near the range of naturally occurring background concentrations. An intermediate target value of 3.0 mg/l is also used. Assumed background nitrate level is 1.0 mg/l.

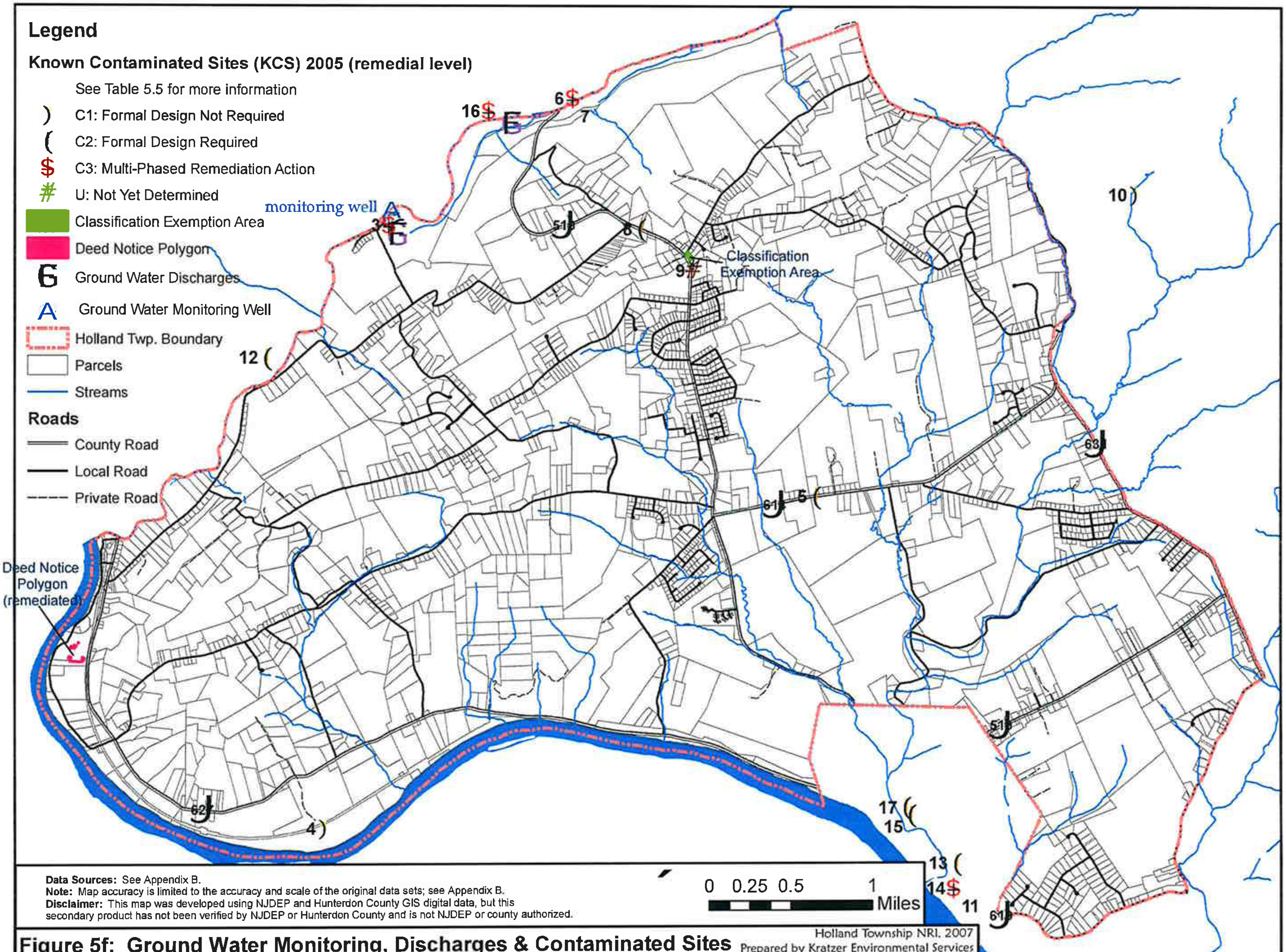
Source: DeMicco, 2004, adapted from text and Table 12b.

E. Ground Water Quality Standards

The New Jersey Ground Water Quality Standards (GWQS; N.J.A.C. 7.9-6) specify the quality criteria and designated uses for ground water, and serve as the basis for setting ground water discharge standards under the New Jersey Pollutant Discharge Elimination System program, as well as for establishing standards for ground water cleanups and other relevant laws. The criteria are numerical values assigned to each constituent (pollutant). The GWQS also contain technical and general policies to ensure that the designated uses can be adequately protected.

Ground water within watersheds of FW1 surface waters (see **section 6D** for surface water classifications), state-owned Natural Areas, and the major aquifers of the Pinelands Area are designated *Class I.* The designated use for Class I ground water is the maintenance of special ecological resources, with secondary uses being potable, agricultural and industrial water. *Class II* waters are those not specifically designated Class I or Class III. The designated use of Class II ground waters is to provide potable water using conventional treatment. Class II criteria specify the levels of constituents above which the water would pose an unacceptable risk for drinking water. *Class III* ground waters can be used for anything other than for potable water (NJDEP, 2004).

Holland is designated Class II (to provide potable water with conventional treatment). It should not be assumed that ground water quality everywhere meets the criteria for each classification area in view of natural variability and the possibility of localized pollution. In fact, NJDEP has designated one site in Holland where ground water contamination has been identified (see **Figure 5f,** near site 6). This area at the intersection of Route 519 (Milford-Warren Glen



Data Sources: See Appendix B.
Note: Map accuracy is limited to the accuracy and scale of the original data sets; see Appendix B.
Disclaimer: This map was developed using NJDEP and Hunterdon County GIS digital data, but this secondary product has not been verified by NJDEP or Hunterdon County and is not NJDEP or county authorized.

Figure 5f: Ground Water Monitoring, Discharges & Contaminated Sites

Holland Township NRI, 2007
Prepared by Kratzer Environmental Services

Road) and Hawk's Schoolhouse Road is designated a *Classification Exemption Area (CEA).* Within a CEA, the New Jersey Ground Water Quality Standards (GWQS) for specific contaminants have been exceeded. When a CEA is designated for an area, the constituent standards and designated aquifer uses are suspended for the term of the CEA.

F. Ground Water Discharges

New Jersey regulates the discharge of pollutants to ground water under the authority of the New Jersey Water Pollution Control Act (WPCA) N.J.S.A. 58:10A. The New Jersey Pollutant Elimination System (NJPDES) permit program regulations are contained in N.J.A.C. 7:14A.

NJPDES permits are required for discharges to ground water of both sanitary and industrial wastes. These permits, which limit the mass and/or concentration of pollutants discharged, are issued to sanitary and industrial facilities that have ongoing, operational discharges of wastewater to ground water. The purpose is to restrict the discharge of pollutants to the ground waters of the state and protect the public health and the environment. Discharges from past activities may continue to be regulated under the Site Remediation Program or the Division of Solid and Hazardous waste.

There are three existing NJPDES discharges in Holland Township (as of the 2002 GIS data update), which are listed in **Table 5.4** and mapped in **Figure 5f**.

Table 5.4: NJ Pollution Discharge Elimination System - Ground Water Discharges in Holland Township

Site Identification Number	Facility Name	Discharge Type	Discharge to Receiving waters
NJ0089109.I01I	Fibermark - Warren Glen	infiltration lagoon	infiltration pond Musconetcong River Watershed
NJ0107701.G01G	Fibermark	infiltration lagoon	infiltration pond Musconetcong River Watershed
NJ0107701.I01I	Fibermark	infiltration lagoon	infiltration pond Musconetcong River Watershed
Sources: NJDEP GIS layer NJPDESgwd.zip			

G. Known Contaminated Sites and Underground Storage Tanks

There are 3 Underground Storage Tanks (UST) listed within Holland (see **Table 5.5**). One UST located at the Holland Township Municipal Garage is undergoing active remediation. One of the USTs is reported as in compliance with the requirements for leak detection, spill, overfill and cathodic protection required by N.J.A.C. 7.14B-1, based on information the owner/operator provided to the NJDEP.

The NJDEP Bureau of Planning and Systems compiled a list of Known Contaminated Sites (KCS). The *Known Contaminated Sites List* for New Jersey 2001 (as required under N.J.S.A. 58:10-23.16-17) are those sites and properties within the state where contamination of soil or ground water has been identified or where there has been, or there is suspected to have been, a discharge of contamination (see **Table 5.5**) and shown in **Figure 5f**. It is important to note that some of the cases listed may have been fully remediated and should no longer be considered contaminated sites. Additionally new contaminated sites may have been identified

Table 5.5: Underground Storage Tanks in Holland Township

Identification Number	Name	Address	Status	Lead Bureau
010101	KWIK PIK OF MILFORD	1050 Milford Warren Glen Road	Regulated, Compliant	
010188	HOLLAND TWP SCHOOL	710 MILFORD-WARREN GLEN RD	Regulated	
030253	HOLLAND TWP MUNICIPAL GARAGE	129 SPRINGMILLS RD	Active Remediation	Bureau of Southern Case Management
Source: NJDEP Dataminer website, 2006: http://datamine.state.nj.us/DEP_OPRA/OpraMain/categories?category=Underground+Storage+Tanks				

since the creation of this list and are not included here. For further information contact NJDEP's Site Remediation Programs (SRP) lead program, which are identified with each site listed in this data base.

Sites identified in the Known Contaminated Sites list can undergo a variety of activities, ranging from relatively simple soil removals to highly complex remedial activities. The sites included in this dataset are handled under various regulatory programs administered by the NJDEP's Site Remediation and Waste Management program, including the New Jersey Brownfield and Contaminated Site Remediation Act, Industrial Site Recovery Act, Solid Waste Management Act, Spill Compensation & Control Act, Underground Storage of Hazardous Substances Act, Water Pollution Control Act and the Federal Comprehensive Environmental Response, Compensation and Liability Act, Superfund Amendments and Reauthorization Act, and Resource Conservation and Recovery Act Corrective Action Program. A site can be regulated under more than one of these regulatory programs.

The Federal legislation, collectively known as Superfund, requires that a National Priorities List (NPL) of sites throughout the United States be maintained and revised at least annually. NJDEP and USEPA conduct and oversee cleanups at Superfund sites with both public and private funds. The lead agency maintains direct oversight of the work at the site and has the most current and detailed information about the status of the cleanup (NJDEP, 2006).

Within Holland, there are 9 KCSs, none of them on the National Priorities (Superfund) List, plus an additional 8 KCSs nearby in watersheds shared with Holland (the Musconetcong River and Hakihokake Creek) (see **Table 5.6** and **Figure 5f**).

H. Ground Water Level Monitoring

The *ground water level* is the distance from the land surface (i.e. top of well casing) to the water in a well. Ground water level monitoring is critical for determining the current state of the ground water, identifying trends and predicting ground water drought. In addition to drought, over-withdrawal of ground water can occur in areas where more ground water is being pumped out of the aquifer than is replenished through recharge. This could lead to a drop in the ground water level, affecting well performance, and sometimes causing wells to go dry; as well as causing a decrease in the baseflows of adjacent streams.

The Hunterdon County Master Plan of 1972 recommended that "a network of observation wells be established… several years prior to …development so that gradual changes from the natural environment will be recorded." (Elam and Popoff, 1972).

Table 5.6: Known Contaminated Sites in and near Holland Township

MAP #	Site Identification Number	Name & Address	Status* Date	Lead Agency**	Remedial Level***
Sites Below are in Holland Township (listed alphabetically)					
1	261698	117 Spring Mills Road (not shown on map)	8/24/2005	BFO-N	C1
2	264597	97 Crab Apple Hill Road (not shown on map)	10/18/2005	BFO-N	C1
3	016275	FIBERMARK HUGHESVILLE MILL Cyphers Road	10/5/1992	BNCM	C3
4	009965	GILBERT GENERATING STATION 315 Riegelsville Road	12/1/1998	BFO-N	C2
5	030253	HOLLAND TWP MUNICIPAL GARAGE 129 Spring Mills Road	3/12/1997	BSCM	C2
6	016276	JAMES RIVER-WARREN GLEN MILL 1 Route 519 (same site as #7)	11/7/1996	BNCM	C3
7	032480	JAMES RIVER RIEGELSVILLE MILL Riegelsville-Warren Glen Road (same site as #6)	11/07/1996	BNCM	C3
8	010101	KWIK PIK OF MILFORD 1050 Milford Warren Glen Road	6/24/1996	BOMM	C2
9	215833	WARREN GLEN LANDFILL & SLUDGE LAGOON Milford Warren Glen Road	11/5/2003	OWR	U
Sites Below are Nearby and in Watersheds Shared with Holland (listed alphabetically)					
10	G000043079	262 264 GORITZ ROAD Alexandria Township, Hakihokake Creek	03/15/2000	BFO-N	C1
11	006924	CURTIS PAPER INC, 404 Frenchtown Road Milford Boro, Hakihokake Creek (same site as #14)	06/19/2001	BNCM	C3
12	002856	FINESVILLE MOTORS, 180 RT 627 Pohatcong Township, Musconetcong River	07/09/1992	BSCM	C2
13	G000009765	JAMES RIVER PAPER COMPANY OLD LANDFILL Milford Frenchtown Road Milford Boro, Hakihokake Creek	03/10/2003	OWR	C2
14	016274	JAMES RIVER RIEGEL PRODUCTS CORP Box R Frenchtown Road, Milford Boro, Hakihokake Creek (same site as #11)	06/19/2001	BNCM	C3
15	030462	MILFORD SERVICE CENTER, 30 Frenchtown Road Milford Boro, Hakihokake Creek	10/24/2001	BSCM	C2
16	G000014314	RIEGEL PRODUCTS CORP, Route 627 Pohatcong Township, Musconetcong River	01/24/2001	BNCM	C3
17	000255	STEM BROTHERS, 11 Frenchtown Road Milford Boro, Hakihokake Creek	01/26/1995	BSCM	C2

***STATUS – all sites in this list are Active:** This status is designated when a contaminated site is assigned to a remedial program and measures such as a preliminary assessment, remedial investigation or cleanup work is underway; **Status Date:** The date that the site was assigned to the contact bureau.

****Lead Agency: BFO-N** = Bureau of Field Operations – Northern (973) 631-6401; **BNCM** = Bureau of Northern Case Management (formerly BEECRA) (609) 777-0899; **BOMM** = Bureau of Operation, Maintenance & Monitoring (609) 984-2990; **BSCM** = Bureau of Southern Case Management (formerly BUST) (609) 292-8761; **OWR** = Office of Wellfield Remediation (609) 984-2990

*****Remedial Level: A:** Emergency Action – stabilization; **B:** A single phase remedial action with a single contaminant affecting only the soil; **C1:** Remediation does not require a formal design. The source of the contamination is known or has been identified. There is a potential for ground water contamination; **C2:** Remediation requires a formal design. The source of the contamination is known OR the release has caused ground water contamination; **C3:** A multi-phased remediation action. Where the source of the contamination is either unknown or there is an uncontrolled discharge to Soil and/or ground water; **D:** A multi-phased remediation with multiple sources/releases to multiple media including ground water; **U:** not yet determined

Sources: NJDEP Known Contaminated Sites GIS data, 2005 and NJDEP Site Remediation and Waste Management, 2006.

There are no wells monitored regularly for static water level within Holland. However, the USGS maintains a nation-wide network of wells to monitor the effects of droughts and other climate variability on ground-water levels. There are 20 wells within New Jersey, one of which is located just outside Holland Township in the stratified drift aquifer (see **Figure 5g**). In addition, two USGS monitoring wells are located in the Passaic aquifer (one in Whitehouse Station and the other near Lambertville); and one is located in the Precambrian aquifer near Chester, Morris County, although not the same geologic unit that occurs in Holland (see **Table 5.7**). Unfortunately, all of these are of limited use for Holland Township because the stratified drift aquifer is not commonly used for domestic wells, and the other three are a good distance from Holland Township.

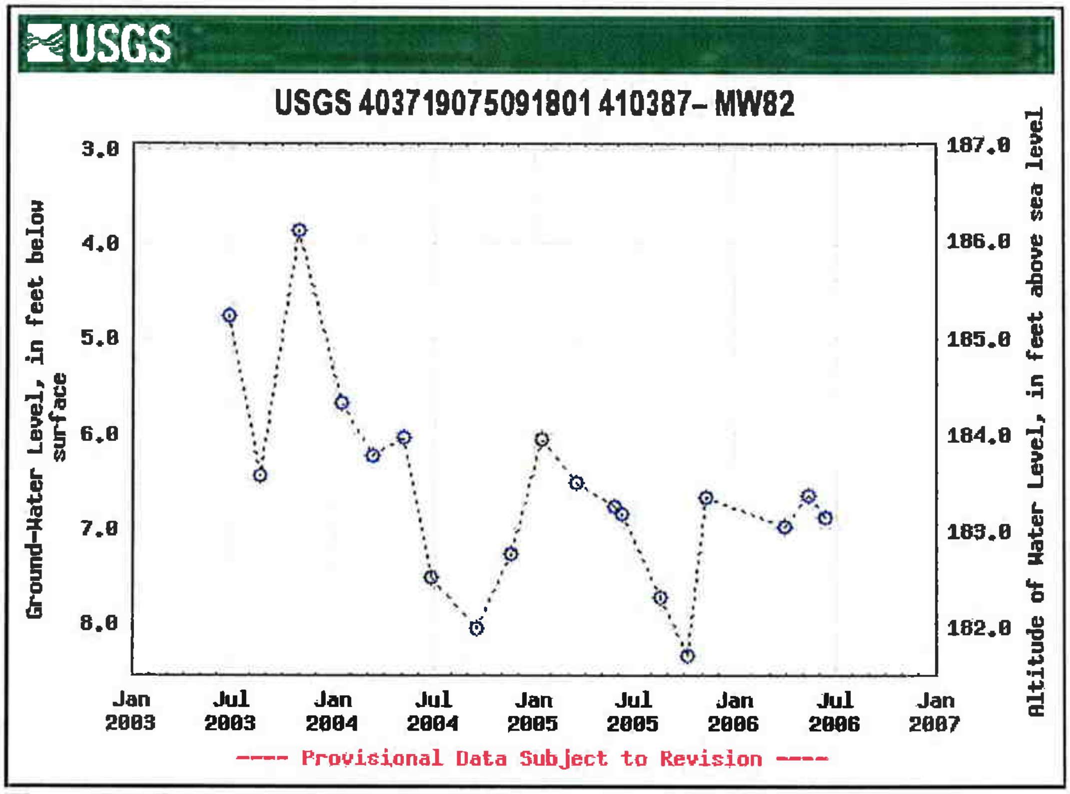


Figure 5g: Ground Water Level at Hughesville, NJ monitored by USGS
Source: USGS, 2006b

I. Public Water and Sewer Areas

Public Community Water Supply (PCWS) Wells are wells that supply potable water to public communities, and serve at least 15 connections used by year-round residents or which serve at least 25 year-round residents. Public water purveyors may be government agencies, private companies, or quasi-government groups. A *Well Head Protection Area* (WHPA) in New Jersey is a map area calculated around each PCWS well in New Jersey that delineates the horizontal extent of ground water captured by a well pumping at a specific rate over a two-, five-, and twelve-year period of time for unconfined wells (Tier 1, Tier 2 and Tier 3, respectively). WHPA delineations are conducted in response to the Safe Drinking Water Act Amendments of 1986 and 1996 as part of the Source Water Area Protection Program (SWAP). The delineations are the

Table 5.7: USGS Ground Water Climate Response Network – wells currently monitored near Holland

STRATIFIED DRIFT AQUIFER
Site Number: 403719075091801 - 410387--MW82 **LOCATION:** Hughesville, Warren County, New Jersey, Hydrologic Unit 02040105 Latitude 40°37'19", Longitude 75°09'18" NAD27 **Well depth:** 12 feet **Hole depth:** 12 feet **Land surface altitude:** 190 feet above sea level NGVD29 Well completed in "Sand and gravel aquifers (glaciated regions)" (N100GLCIAL) national aquifer. Well completed in "STRATIFIED DRIFT" (112SFDF) local aquifer **Begin date (periodic record):** 06/24/2003 **Begin date (continuous record):** 06/25/2003 **Periodic record summary stats**: *Highest Water Level*: 3.86' *Lowest Water Level*: 8.35'
PASSAIC AQUIFER
Site Number: 403517074452501 - 190270--READINGTON SCHOOL 11 OBS **LOCATION:** Whitehouse Station, Hunterdon County, New Jersey , Hydrologic Unit 02030105 Latitude 40°35'17", Longitude 74°45'25" NAD27 **Well depth:** 101 feet **Hole depth:** 101 feet **Land surface altitude:** 224.99 feet above sea level NGVD29 Well completed in "Early Mesozoic basin aquifers" (N300ERLMZC) national aquifer. Well completed in "PASSAIC FORMATION" (227PSSC) local aquifer **Begin date (periodic record):** 07/14/1989 **Begin date (continuous record):** 04/25/1990 **Continuous record summary stats**: *Highest Water Level*: 8.74' *Mean*: 18.80' *Lowest Water Level*: 29.84'
Site Number: 402151074525301 - 190251--CORSALO RD TB1 OBS **LOCATION:** near Lambertville, Hunterdon County, New Jersey, Hydrologic Unit Code 02040105 Latitude 40°21'51", Longitude 74°52'53" NAD27 **Well depth**: 299 feet **Hole depth**: 299 feet **Land-surface elevation**: 405 feet above sea level NGVD29 This well is completed in the Early Mesozoic basin aquifers (N300ERLMZC) national aquifer. This well is completed in the PASSAIC FORMATION (227PSSC) local aquifer **Begin date (periodic record):** 07/05/1989 **Begin date (continuous record):** 06/28/1989 **Continuous record summary stats:** *Highest Water Level:* 0.01' *Mean*: 2.54' *Lowest Water Level*: 10.56'
PRECAMBRIAN AQUIFER
Site Number: 404934074400501 - 271190--BLACK RIVER 10 OBS **LOCATION:** near Chester, Morris County, New Jersey, Hydrologic Unit 02030105 Latitude 40°49'04", Longitude 74°40'53" NAD27 **Well depth**: 200 feet **Hole depth**: 200 feet **Land surface altitude**: 890 feet above sea level NGVD29 Well completed in "Piedmont and Blue Ridge crystalline-rock aquifers" (N400PDMBRX) national aquifer. Well completed in "PRECAMBRIAN ERATHEM" (400PCMB) local aquifer **Begin date (periodic record):** 10/05/1989 **Begin date (continuous record):** 05/21/1992 **Continuous record summary stats:** *Lowest Water Level*: 16.32' *Mean*: 8.29' *Highest Water Level*: 0.0'
Note: The above sites are maintained by USGS New Jersey Water Science Center. Source: USGS, 2006a

first step in defining the sources of water to a public supply well. Within these areas, potential contamination will be assessed and appropriate monitoring will be undertaken as subsequent phases of the NJDEP SWAP.

There are 4 PCWS wells in Holland Township (see **Figure 5h**) and parts of two additional Well Head Protection Areas for public wells located within Milford Boro. Areas served by these wells are shown as "Water Purveyor Areas" on **Figure 5h**. According to the description of the GIS data layer, the boundaries mapped are those of the actual water delivery or service area, but do not include areas with legal rights for future service.

The public Sewer Service Areas (SSA) (and proposed revisions) mapped on **Figure 5h** show the planned method of wastewater disposal for specific areas. Areas not designated as SSA's are planned for service by individual subsurface disposal system discharging less than 2,000 gallons/day (gpd). This mapping is used by NJDEP, together with the Water Quality Management Plan (WQMP), to make consistency determinations under the Water Quality Management Planning rules found in N.J.A.C. 7:15. No changes in SSA's within Holland resulted from the passage of the Highlands Water Protection and Planning Act, which repealed SSA's not yet constructed with the Highlands Preservation Area.

J. Sole-Source Aquifers

The Safe Drinking Water Act (SDWA) of 1974 contains a provision in Section 1424(e), which provides for designating an aquifer which is the sole or principal drinking water source for an area and which, if contaminated, would create significant hazard to public health. As defined by the U.S. Environmental Protection Agency (EPA), *sole-source aquifers* (SSA) are those aquifers that contribute more than 50% of the drinking water to a specific area and the water would be impossible to replace if the aquifer were contaminated. Once designated, no Federal financial assistance may be approved for any project which may contaminate the aquifer through a recharge zone so as to create a significant hazard to public health (US EPA, June 1988). Therefore, the EPA must review any federally-funded project in an area that could affect ground water in a sole-source aquifer, including the *aquifer's recharge zone* (the area through which water recharges the aquifer) and its *stream-flow source zone* (the upstream area that contributes recharge water to the aquifer).

In December 1978 the Environmental Defense Fund and the Sierra Club petitioned the EPA to designate the Coastal Plain a SSA. According to EPA, in certain areas along the Delaware River, heavy pumping has caused a reversal in the normal discharge from the aquifer so that the Delaware River now recharges the Coastal Plain aquifer. As a result, even though most of the recharge of the Coastal Plain aquifer is from precipitation, a major portion of the Delaware River Basin was designated a stream-flow source zone of the Coastal Plain SSA. The project review area is two miles on either side of the Delaware River (US EPA, May 1988). Roughly the southern half of Holland is within the area designated as part of the Coastal Plain SSA (see **Figure 5i**).

In November 1985, NJDEP petitioned the EPA to designate nearly all of the state as a SSA (excluding urban areas around Trenton and in Northeastern NJ). However, some areas did not meet the technical criteria for SSA designation (US EPA, June 1988). The portion of Holland Township within the Musconetcong watershed is designated part of the Northwest New Jersey 15 Basin SSA (see **Figure 5i**).