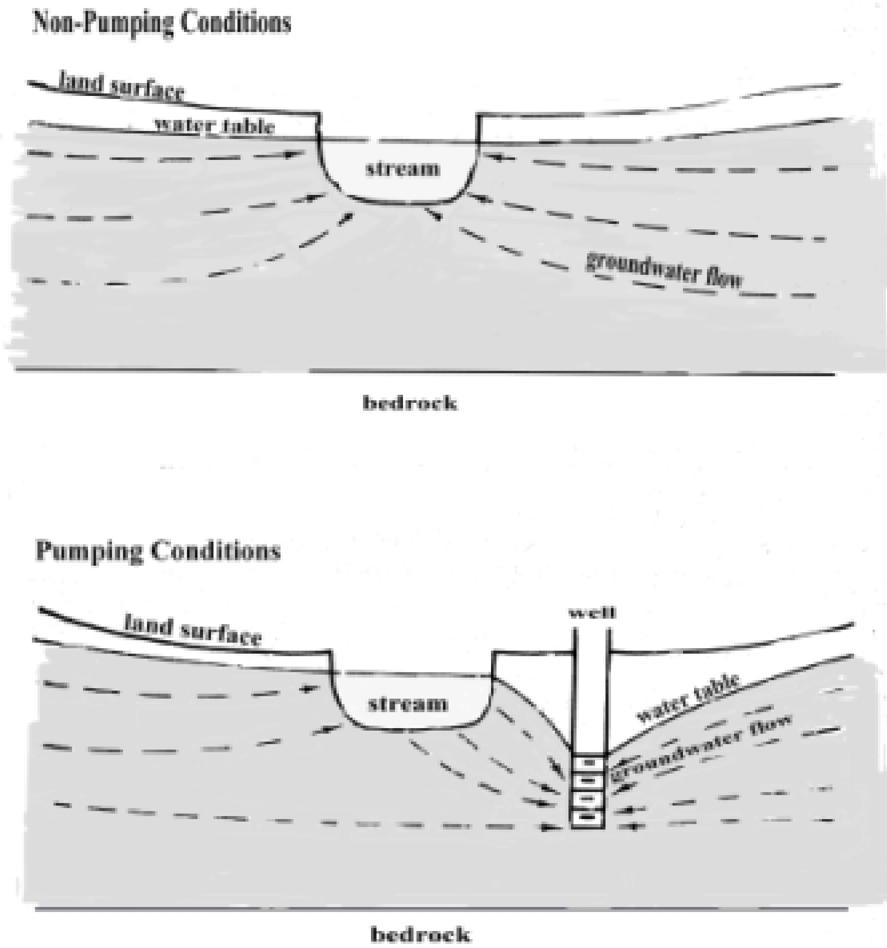
diversions up to that point may have decreased summertime flows in the Pomperaug River by 30-40 percent (Marin, 1990). Figure 7 illustrates how high-yielding wells in stratified drift aquifers can reverse the normal flow of groundwater. In this model, the river recharges the aquifer. This process is called *induced infiltration*. In addition to drawing ground water away from the river, induced infiltration can also affect water quality in the aquifer. Wastewater, which is discharged into the Pomperaug River and its tributaries, becomes more concentrated during low river flows. This more highly concentrated effluent could be induced into the aquifer by wells pumping near the river.

WATER RESOURCES

Safe Yield and Recharge

Safe yield is the term used to express the amount of water an aquifer or well can yield for consumption without producing unacceptable negative effects. Connecticut defines the safe yield for public water as, “the maximum dependable draft, which can be made continuously from a water supply source without causing unacceptable effects during a critical dry period with a one percent chance of occurrence.” However, *unacceptable effect* is not well defined in the regulations, and therefore it is often difficult to reach a consensus on the actual safe yield of an aquifer. Potential unacceptable effects discussed previously are contamination of the aquifer water by induced infiltration, decreased river flows, and lowering of the water table.

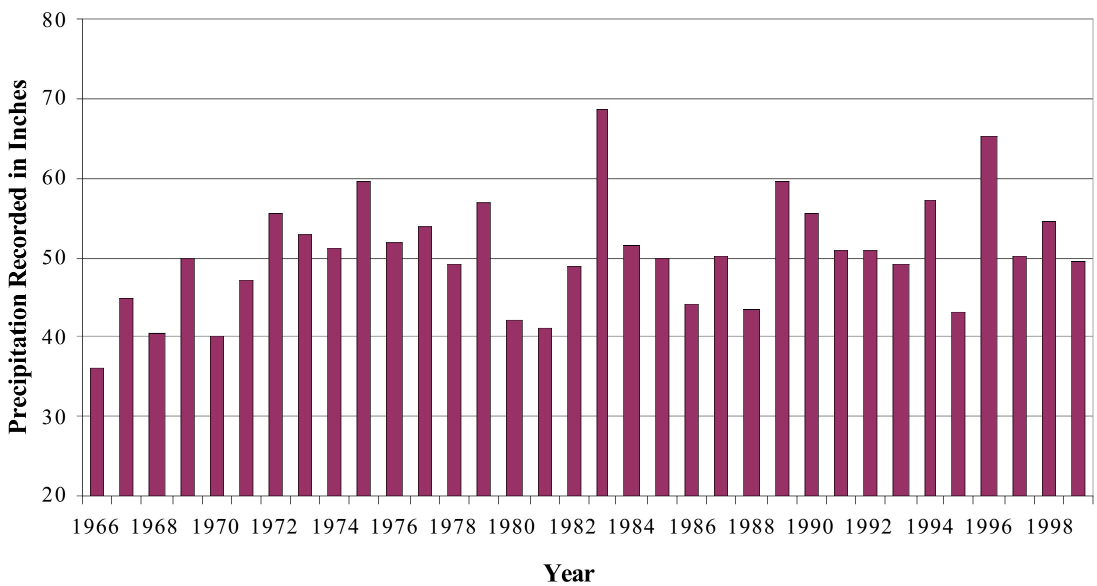
Figure 7. Groundwater flow under pumping and non-pumping conditions, modified from Mazzaferro, 1986.



Changes in land use within a watershed can change the rate of recharge to an aquifer. An increase in impervious cover over areas of stratified drift prevents water from percolating into the soil as quickly as it would under natural conditions. As infiltration rates are decreased, surface water volume and runoff rates are increased. Unless Best Management Practices (BMPs) are employed, increased runoff can lead to erosion and flooding. Many Connecticut towns, including Southbury and Woodbury, have adopted aquifer protection zones in their planning and zoning regulations to address these potential problems.

Precipitation has been identified as the principal source of recharge to the Pomperaug Aquifer (Mazzaferro, 1986). Annual precipitation rates can vary substantially, and therefore the amount of water the aquifer yields also varies. For example, the average annual precipitation in the town of Woodbury between 1966 and 1999 was 50.6 inches (Mr. Earl Gillette, personal communication). However, in 1966 the total annual rainfall was only 36.1 inches, with a mere 1.7 inches of rain falling in August. Conversely, in 1985 the total rainfall was 49.99 inches, with 8.21 inches falling during the month of August (Figure 8). According to a USGS 1989 report, there was a statewide drought in Connecticut between 1961 and 1971.

Figure 8. Precipitation data (inches per year) recorded in Woodbury by Earl Gillette between 1966 and 2000.



Water Quantity

To date, there have been sufficient water resources in the watershed to meet regional demands. However, as the demand for water increases, so will withdrawal rates from the aquifer. The current registered diversions in the watershed exceed USGS estimates for the aquifer's water capacity. Heritage Water Company (HWC), United Water Connecticut (UWC), and Watertown Fire District (WFD) are allowed by registration under the 1982 Connecticut Water Diversion

Policy Act to withdraw a total of 4.142 million gallons per day (mgd) from the Pomperaug Aquifer. Presently, these companies withdraw less than half of what they are legally allowed by the CTDEP. In addition, other large water users such as the Southbury Training School, golf courses, local farms, and local businesses have registered diversions with the CTDEP. A diversion is not necessarily a water withdrawal from the aquifer. It can be one of many types of water use, including the redirection of a stream channel, the use of surface waters for irrigation, or the creation of a stormwater detention basin. All of these uses can affect the river and the aquifer.

The CTDEP classifies the State's existing diversions in two ways - registered and permitted. Registered diversions came into being with the 1982 Diversion Act. Prior to the Act, the CTDEP did not regulate water diversions. The Diversion Act gave the CTDEP limited authority to regulate the use of ground and surface waters in the state. Under the Act, existing diversions were grandfathered and registered with the CTDEP. Registrants had to inform the CTDEP of the location, capacity, frequency, and rate of the withdrawal of the diversion, as well as give a description of the water use and/or distribution system. According to the CTDEP's 2000 Report to the General Assembly on State Water Allocation Policies Pursuant to Public Act 98-224, "These registered diversions may continue indefinitely, regardless of their environmental effects and their impact on the water needs of others."

Since the Water Diversion Act of 1982, new applicants for a water diversion need to apply for a permit and undergo an environmental review process. However, by Special Act of the State Legislature, fish farms can be allowed to divert water by the Connecticut Department of Agriculture. These diversions do not appear on either the DEP's Registered or Permitted Diversions list and do not need to pass an environmental review process. There is at least one such diversion in the Pomperaug Watershed for a fish farm in Bethlehem that is allowed to divert 250,000 gallons per day (gpd) from the Nonnewaug River.

According to the CTDEP Inland Water Resources Division records, the sum of the registered diversions for the Pomperaug River Watershed equals 16.9 mgd (See Appendix 2). Based on available information, it does not appear that the total registered amounts are being used. The water utilities monitor and report their usage to the CTDEP, the Department of Public Utilities (DPUC), the Department of Public Health (DPH), and others. Other registrants are not required to monitor or report their usage and therefore determining exactly how much is water is being used is difficult to assess. In the town of Southbury, for instance, there are four registered agricultural diversions equaling 9.6 mgd (twice what the three water companies are permitted to divert) with few conditions placed on where or how that water is used. The Town of Southbury recently purchased the Berry Farm, which has two registered diversions totaling four mgd, for use as a town recreational facility.

Since the 1982 Diversion Act, six other water diversions in the watershed have been issued permits withdrawing a total of 600,000 gpd. Diversions of less then 50,000 gpd do not need a permit from the CTDEP despite the fact that the Pomperaug River is currently on the CTDEP's Impaired Waterbodies 303(d) list for flow impairment. The CTDEP Report to the State Legislature in January of 2000 discussed these issues and indicated the need to institute greater protection for Connecticut's water resources. Because the State of Connecticut does not have minimum stream flow standards, it is particularly important that stakeholders from the watershed work cooperatively to preserve stream flows**.**

Table 2. Reductions in stream flow due to leakage to the aquifer and reduced groundwater runoff for four pumping rates and 10-year average recharge conditions, from Mazzaferro, 1986.

Pump Rates		Reduction in groundwater runoff	Reduction due to leakage from the stream	Total reduction in stream flow
mgd*	cfs	cfs	cfs	cfs
8.3	12.8	8.1	4.3	12.4
11.2	17.3	9.7	7.1	16.8
11.5	17.7	8.2	8.9	17.1
14.3	22.2	10.0	11.6	21.6

*Units are: million gallons per day (mgd); cubic feet per second (cfs).

The 1986 study conducted by Mazzaferro suggested that increasing water diversion quantities would have a measurable impact on Pomperaug River flows. Table 2, taken from Mazzaferro's report, illustrates the connection between pumping rates of wells near the

Pomperaug River and river flow. The 10-year average recharge that Mazzaferro used to create the following table was the average precipitation for the 10 years preceding his study (51.4 inches).

These data were the product of an aquifer model Mazzaferro developed for the Pomperaug. In Mazzaferro's model, hypothetical wells pumped at the rates listed above. The river in the model then exhibited decreases in flow ranging from 12.4 to 21.6 cubic feet per second (cfs), or 8 to 14 million gallons per day (mgd). However, it is important to note that in the model Mazzaferro assumed that all of the water pumped from the aquifer would not be returned and was a net loss from the watershed.

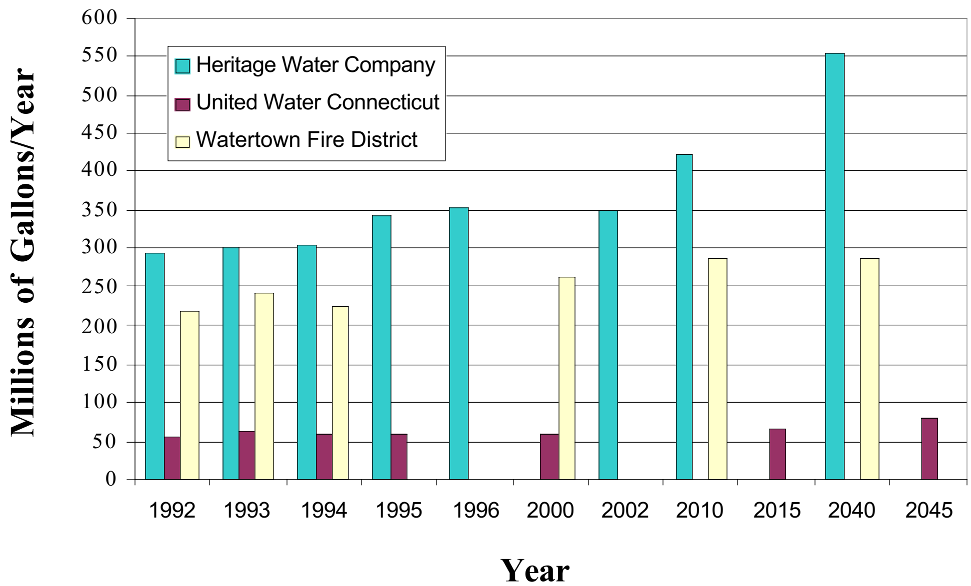
The accuracy of these data are limited by the methodology used, but the model does indicate the substantial effect pumping rates and diversions may have on stream flow. In the drier summer months and during periods of drought when river flows are already diminished, the effects can be substantial. Water withdrawals combined with low rates of precipitation can lower the water table dramatically, impacting river flow, degrading fish and wildlife habitat, increasing the potential for low water yields, and decreasing the dilution of treated wastewater discharged into the Pomperaug River system. Mazzaferro concluded that the Pomperaug Aquifer had a potential long-term yield of 5.0 to 8.8 mgd. The registered and permitted diversions in the watershed exceed this amount by 9 to 12 mgd. If the Mazzaferro model is correct, future water shortages in the Pomperaug River Watershed are probable.

Water Companies

Water utilities operating in the Pomperaug Watershed represent a considerable percentage of the total registered diversions. Their withdrawals have a direct impact on the water table and flow rates in the Pomperaug River. Based on the water supply plans for Heritage Water Company (HWC), United Water Connecticut (UWC), and the Watertown Fire District (WFD), the demand for water is going to continue to increase in the future (Figure 9). HWC expects the greatest increase in its future demand. Its total water consumption is predicted to rise 66% between 1996 and 2040 (Leggette, Brashears and Graham, 1996).

In 1994, these three water companies withdrew almost 589 million gallons of water from the Pomperaug Aquifer. By the year 2040, this number is expected to exceed 900 million gallons. Over one third of the water pumped in 1995 was transferred outside of the watershed to the towns of Middlebury, Oxford, and Watertown. HWC's service area includes two out-of-basin towns, Middlebury and Oxford. WFD's usage is presently entirely out of basin.

Figure 9. Historic and projected pumping rates for Heritage Water Company, United Water Connecticut, and Watertown Fire District based on data available in their water supply plans.



Tests completed for Watertown Fire District's 1996 Water Supply Plan, indicated in the Mazzaferro study, noted a connection between pumping rates and river flow. During the first two days of a pump test conducted in November, 1995 at the Hart Farm Well Field (located near the Nonnewaug River), the Nonnewaug River's flow rate was diminished by 0.88 cfs or 0.567 mgd. At the time, nine wells located at the field were pumping slightly above their registered diversion of 1.73 mgd. If these tests are accurate, pumping at this rate could seriously impact the Nonnewaug River. For instance, in the drought of 1964 the Nonnewaug River Gauge recorded flows at levels below 0.88 cfs on numerous days. In the months of August, September, and October 1964, for example, 25 days had average flows of less than 0.88 cfs. On days in which the flow is below 0.88 cfs or 0.567 mgd and WFD is pumping at its registered diversion limit, there would theoretically be times when the Nonnewaug River was dry. Understanding the relationship between withdrawals and river flow rates is critical to the protection of our water resources, which is why continuous stream flow data is a priority for the Watershed Coalition. The Nonnewaug Gauge was discontinued in 1979 after seventeen years of use, but was reactivated in September of 2000.

Although UWC and HWC both have wells in close proximity to either the Pomperaug River or a tributary, neither provided data concerning the relationship of pumping rates to river flow in their last water supply plans.

Non-Revenue and Unaccounted-for Water

The Department of Public Utility Control (DPUC) recommends that no more then 15 percent of a utility's total diversion be *unaccounted-for water*. This is water that is pumped from its source, but is lost in transport or appears to have been lost due to inaccurate meters. Water companies, in their water supply plans, report the percentage of unaccounted-for water in their systems if possible. Water companies can also report the percentage of non-revenue water. *Non-revenue water* is the difference between the water that was produced and/or purchased by the water company, minus what was actually sold, such as water for fire protection.

The accuracy of both non-revenue and unaccounted-for water figures are highly dependent on the status of metering in the water system. If there are numerous un-metered customers in the water distribution system, as is the case in the Pomperaug Watershed, the results, whether they are reported as non-revenue or unaccounted-for water, are merely estimates. Therefore metering is an important first step in any water conservation program. Heritage Water Company has the highest percentage of un-metered customers of the three water companies. In 1996, 74% of all HWC customers were un-metered (Leggette, Brashears and Graham, 1997). To determine the percentage of non-revenue water, consumption rates were estimated for un-metered consumers.

United Water Connecticut and Watertown Fire District reported their percentage of *unaccounted-for* water in their last water supply plans, but Heritage Water Company only provided the percentage of their *non-revenue water* (Table 3). WFD's *unaccounted-for* water figures were not adjusted for non-revenue usage, and therefore an unknown percentage of their *unaccounted-for* water was used for *non-revenue* purposes. In 1994, Watertown Fire District's unaccounted-for water equaled 46,624,000 gallons, United Water's equaled 10,112,000 gallons, and Heritage's non-revenue water equaled 32,266,000 gallons.

Table 3. Percentages of Unaccounted-for or Non-Revenue Water reported by Heritage Water Co., United Water CT, and Watertown Fire District in their water supply plans.

Year	Heritage Water Company (Non-revenue water)	United Water Connecticut (Unaccounted-for water)	Watertown Fire District (Unaccounted-for water)
1991	N/A	15.6%	18.3%
1992	11.1%	16.8%	16.6%
1993	10.6%	28.8%	17.7%
1994	10.6%	17.0%	20.8%
1995	12.4%	19.5%	29.5%*

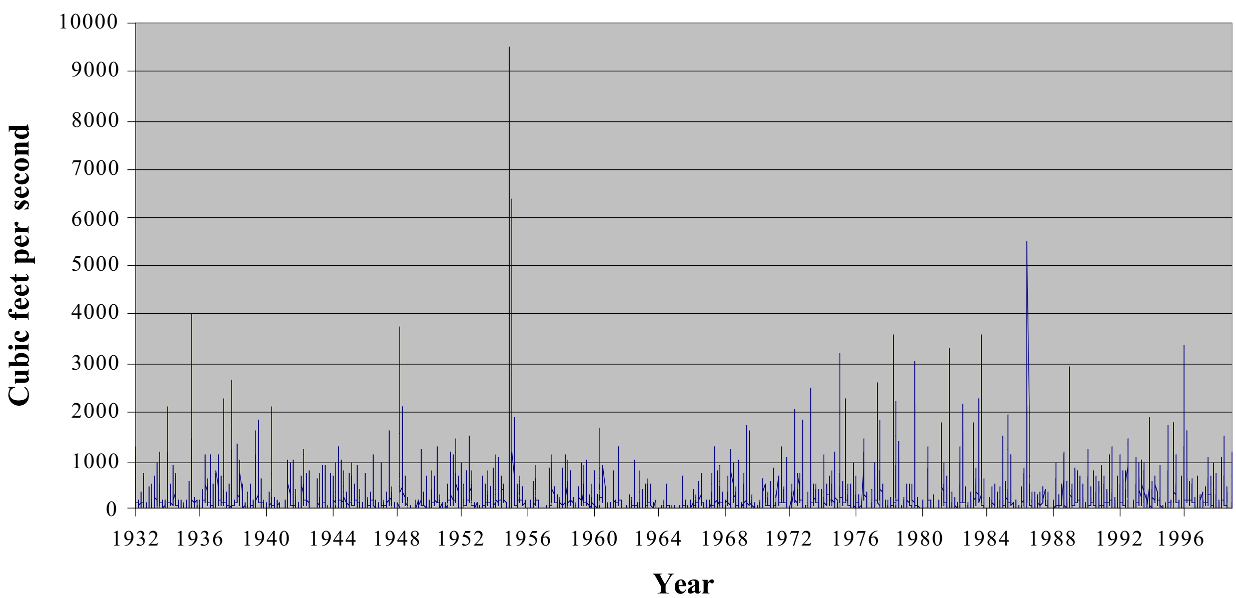
*Partial recording year.

Watertown Fire District has had the highest percentage of unaccounted-for water of the three water companies. According to data supplied in its Water Supply Plan of 1996, its lowest percentage of unaccounted-for water since 1983 was 14% in 1985. Its highest percentage of unaccounted for water was 35.8% in 1987. In the past few years, WFD has made successful efforts to lower their percentage of unaccounted for water and in 1999 it met the DPUC criteria. WFD's percentages for unaccounted-for water for years 1997 through 1999 were 33.1%, 24.4%, and 14.8%, respectively (Mr. Ernie Coppock, Superintendent of the Watertown Fire District, personal communication).

Gauging Stations and Groundwater Wells

Three USGS gauging stations have recorded river flow data in the Pomperaug Watershed (See Figure 14). Two stations, one located on the Weekeepeemee and the other on the Nonnewaug River, have only recorded data intermittently; and were discontinued due to lack of funding. These two gauging stations were reactivated in summer 2000 due to the collaborative efforts of the Pomperaug River Watershed Coalition, the Town of Woodbury, the USGS, and Towantic Energy, LLC.

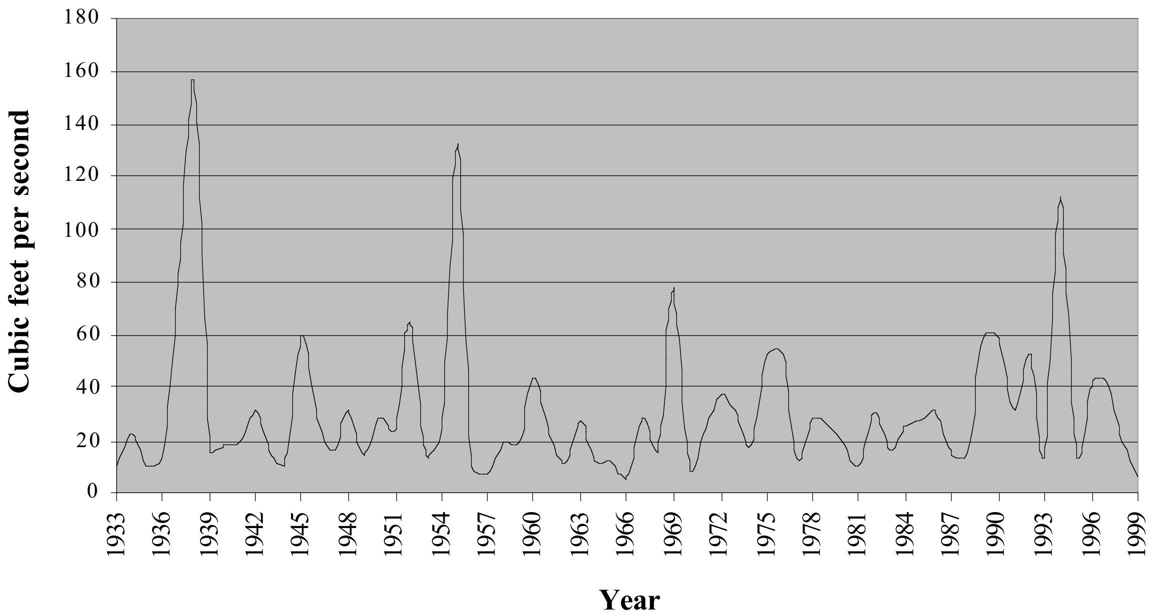
Figure 10. Mean daily flows at the USGS Pomperaug Gauging Station between 1932 and 1999.



The Pomperaug River Gauge in Southbury has been recording flows rates since 1932 (Figure 10). These historical data can be used to track changes in river flow data over time. Periods of flooding and of drought are evident in the graph. Major droughts occurred during the following time periods: 1940 to 1945, and 1961 to 1971. According to the USGS, the most phenomenal flood in the watershed occurred in 1955 when Hurricane Diane stalled over New England.

One measure of the health of a river is its median flow rate over time, especially during the summer when flows are typically lower. The median flow rate for the month of August (typically a month exhibiting low flow rates) between 1933 and 1999 was calculated for the Pomperaug River using USGS stream gauge data (Figure 11). The median for each month was determined by taking the thirty-one daily average flow rates and finding the middle (median)

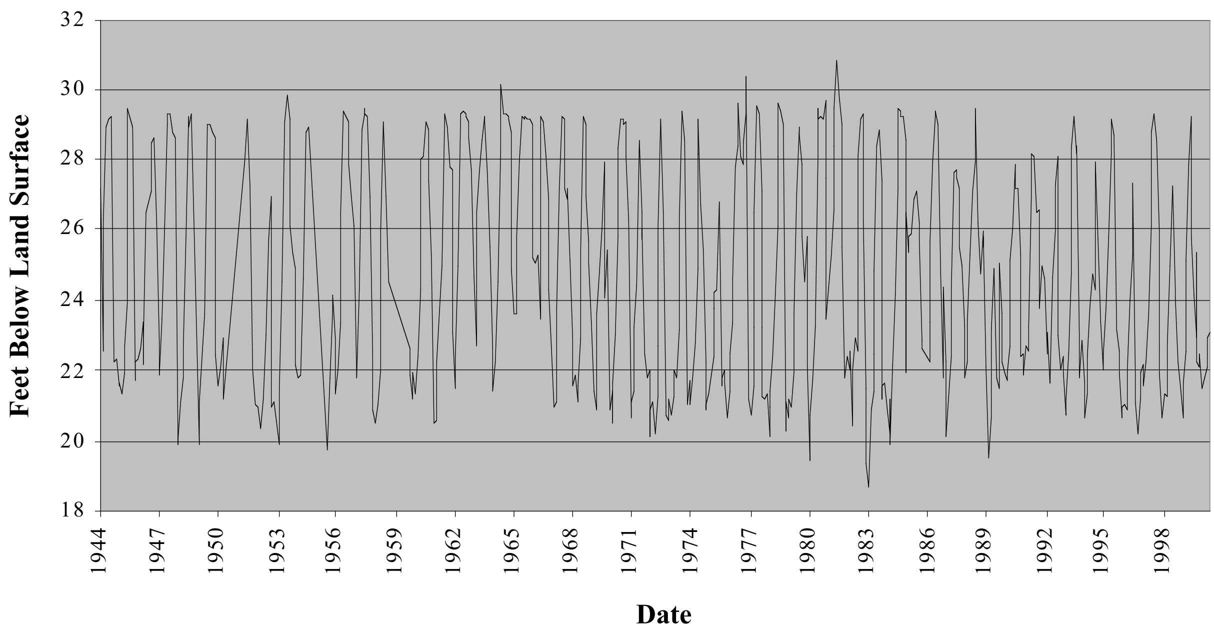
Figure 11. August median flows at the USGS Pomperaug Gauging Station between 1933 and 1999.



value. Since a single very high or low flow (such as during a large flood event or drought) can disproportionately affect the average flow rates, the median flow rate is a more accurate depiction of the rivers' health over time.

While the median August flow rate varies considerably from year to year, it has not decreased precipitously since 1933 despite the large diversions that are occurring in the watershed. Fluctuating precipitation rates, changes in the quantities of discharges into the river, and changing land use and water use patterns can all affect river flows. Today a higher percentage of the river flow may come from discharges and runoff into the river than in the past. A primary function of The Pomperaug River Watershed Coalition is to determine a water budget for the watershed and better understand the relationship between water withdrawals and stream flows. Due to rising costs and static or decreasing funding, many stream gauges around the state are in jeopardy of being discontinued, including the Pomperaug Gauge. Without this important stream data, it will be difficult, if not impossible, to quantify the health of the Pomperaug River.

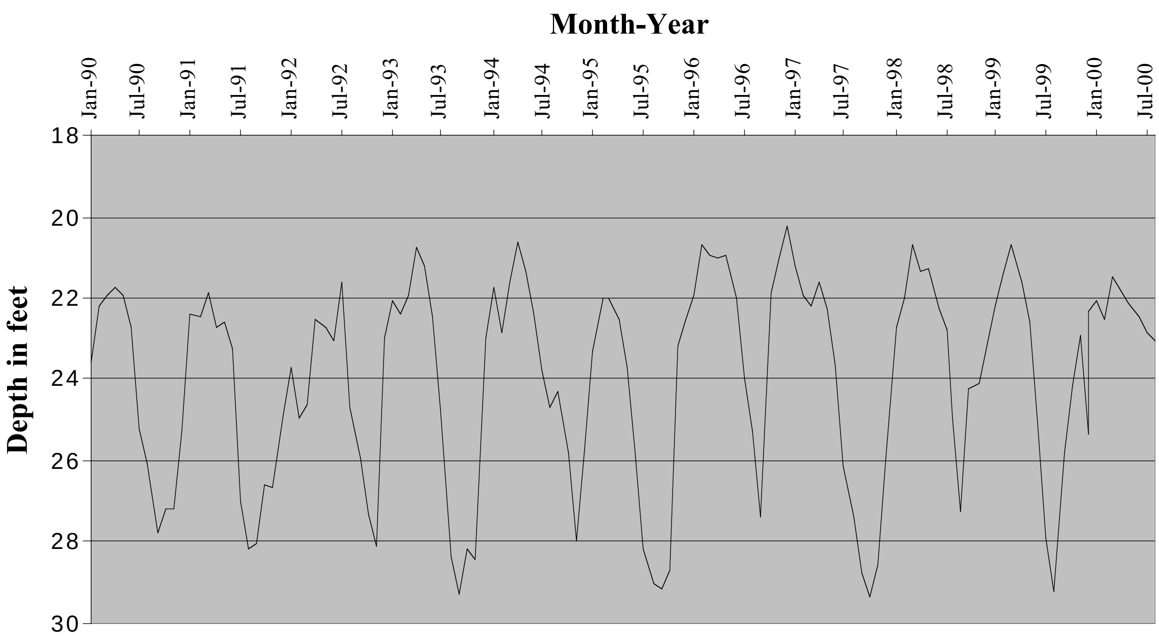
Figure 12. Average monthly ground water levels at USGS Well WY1 in Woodbury between 1944 and 2000.



Another type of water gauge is groundwater-monitoring wells. These wells are used to monitor changes in the depth from the land surface to the water table. The USGS has four groundwater-monitoring wells in Southbury and one in Woodbury where the local water table depth are recorded. Water levels in the Southbury wells have been monitored consistently since the early 1990's. The well in Woodbury (WY1) has data from 1913 to the present, although no measurements were taken between 1916 and 1944. Figure 12 is a graph of ground water measurements (in feet below the surface) from 1944 to 1999, illustrating seasonal and annual fluctuations in groundwater levels.

Figure 13 shows the well data for Woodbury Well WY1 for the period January 1990 to August 2000. At this scale, the seasonal fluctuations in the groundwater level are more evident. The water table is typically highest (closer to the surface) during the winter and spring months, and lowest in the summer and fall. This information is useful for watershed modeling to help predict the quantities of water that will be available from the aquifer for future withdrawals.

Figure 13. Ground water levels at USGS groundwater monitoring well (WY1) in Woodbury, January to August, 2000.



Dams, Reservoirs, and Storage Tanks

Dams, reservoirs, and storage tanks were historically constructed in the Pomperaug Watershed to ensure an adequate water supply for customers of the local water companies, as well as to serve industrial and commercial interests. Dams and reservoirs can function together as a storage facility, retaining water during periods of high flow for use during periods of low flow. If stored water is unavailable during peak periods of water use, water company supply wells are forced to pump at accelerated rates in order to meet demands. Stored water enables the water utilities to save a surplus of water as reserve for peak demand periods. Small dams (or weirs) are also used to divert water into water company well fields. The Watertown Fire District, for instance, uses two weirs to divert water from the Nonnewaug River into its Woodbury well fields, thus ensuring it has an adequate supply of water at the well pumps. The Fire District also releases water from the Bronson-Lockwood Reservoir to augment flows in the Pomperaug River.

Existing reservoirs in the Pomperaug watershed are no longer used to supply drinking water directly. After new drinking water standards were implemented by the CTDEP in 1974, it became more cost-effective for the water companies to use groundwater sources for drinking water supply. Many of the dams previously used to retain surface drinking water or constructed for industrial, commercial, and private purposes remain on the river (including at least one from the colonial era).

Dams alter the natural flow of rivers and streams, affecting riparian habitat along the entire course of the waterway. Dams can decrease natural flow rates, increase water temperatures, lower the dissolved oxygen content, cause sediment buildup, and prevent migrating fish populations from entering spawning grounds. Figure 14 illustrates the locations of the water companies' supply wells, major dams, and the three USGS gauging stations in the watershed.

Water Quality

According to CTDEP Water Quality Standards and Classifications, the surface waters of the Pomperaug Watershed are classified from Class AA to B (Figure 15). These classifications indicate the water is generally of high quality and is suitable for multiple uses. The Pomperaug River is rated class B/A along its entire course until the discharge of the Heritage Village Sewage Treatment Plant in Southbury, where it is rated B. The rating of B/A indicates that it is presently Class B, but that the water quality goal is to achieve Class A status. Class A surface water does not accept waste water