GROUND WATER

RECHARGE OF GROUND WATER

GENERAL HYDROGEOLOGY

The quantity of ground water that can be developed at a given place in the Blackstone River basin depends on the local geologic formations and the sources of recharge. The two major aquifers in the basin are the bedrock and the sand and gravel of glacial origin in lowlands and valleys. Precipitation is the only source of recharge in the uplands; whereas, in the lowlands, it may be possible to augment recharge from precipitation by inducing infiltration from streams, lakes, or ponds.

The bedrock of the Blackstone River basin consists of consolidated rock which can yield water in various quantities depending on the degree of fracturing. The bedrock is an important aquifer because it usually yields sufficient water to wells for rural domestic supplies in the upland areas. However, it is generally not considered to be a source capable of sustaining public supplies.

A nearly continuous sheet of till overlies bedrock, covers uplands and slopes, and extends beneath most valleys. Till is an unstratified glacial deposit of unsorted materials ranging in size from boulders to clay. Some of the till was deposited beneath advancing glacial ice, and some was deposited from within the ice as it melted. In the Blackstone River basin, the known thickness of till ranges from none at outcroppings of bedrock to as much as the 186 feet reported in a well in Douglas. Till generally has a low permeability, and yields from wells dug in till are rarely enough for a modern home. Most of the old wells dug in till have been replaced by deeper, more reliable wells drilled into the bedrock aquifer.

Water in unconsolidated deposits and bedrock of the Blackstone River basin is generally under water-table conditions. Below the water table, water fills the spaces between grains of sediment or the fractures in bedrock. The water table may be many tens of feet below land surface under uplands and hills, and near or intersect land surface at the shores of streams, ponds, and lakes. At a few places wells tap water that is confined, commonly by a layer of till or clay, and under enough pressure to cause water to rise above the level at which it enters the well or even flow out of the well at land surface.

The stratified glacial deposits may be divided into two general types. The first consists of fine-grained sand, silt, and clay deposited in temporary lakes that formed in valleys as the ice melted. The second consists of medium- to coarse-grained sand or sand and gravel deposited by streams flowing from the melting glacier. Only the coarse-grained deposits contribute significantly to the water supply of the basin.

Well yields of 5 to 50 gal/min can be obtained locally from sand layers in the fine-grained sediments. The coarsely textured deposits of the Blackstone River basin are the principal aquifer tapped by public-supply and industrial wells. Pumpage from most wells in this aquifer induce recharge from streams or lakes, and well yields range from a few hundred to more than 1,000 gal/min.

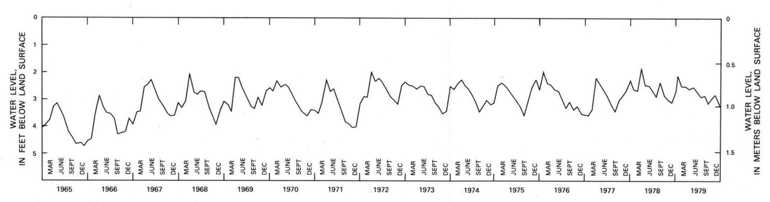


FIGURE 10—WATER-LEVEL FLUCTUATION IN OBSERVATION WELL NORTHBRIDGE 1.

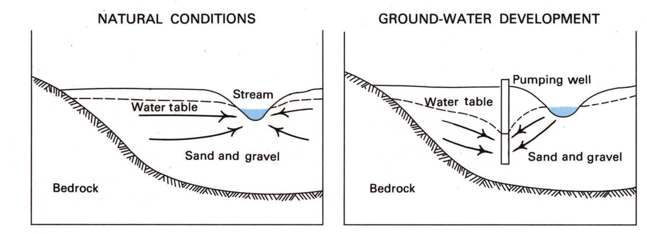
The graph of water levels from observation well Northbridge 1 (Maevsky, 1976) shows annual fluctuation due to changes in rate of recharge. During the cool months of autumn and winter, water consumption by evaporation and transpiration is minimal, and rain and snowmelt exceed the capacity of the soil layer and percolate downward to recharge ground water. In spring and summer, plants grow and transpire and evaporation increases markedly, so that most precipitation is returned to the atmosphere and little or none remains to recharge ground water.

The average annual water-level fluctuation in the sand and gravel aquifer penetrated by Northbridge 1 well is about 1.5 feet. The sand and gravel aquifer has a storage coefficient of about 25 percent, which means that about 25 percent of a given volume of the sand and gravel consists of intergranular space that will store or release water. A 1.0 foot thickness of the aquifer can contain 3.0 inches of water.

Recharge on areas of low relief underlain by sandy soils, as in the vicinity of the Northbridge 1 observation well, may be as much as 0.9 [(Mgal/d)/mi²] (Williams and Tasker, 1974). Where soils are derived from till, or where bedrock crops out extensively, recharge will be considerably less, perhaps 0.3 [(Mgal/d)/mi²].

FIGURE 11—MOVEMENT OF GROUND WATER NEAR A STREAM AND A PUMPING WELL.

Wells that induce recharge from streams are capable of much higher sustained yields than wells in aquifers for which recharge is obtained only from precipitation. Public-supply wells in the sand and gravel aquifer are located near bodies of surface water, commonly streams, to obtain maximum yields. The first water pumped from wells comes from aquifer storage close by the well, but continued pumping will intercept ground water that is moving toward the stream. Continued pumping may lower the water table sufficiently to reverse the hydraulic gradient and induce water to flow from the stream into the aquifer and to the well.



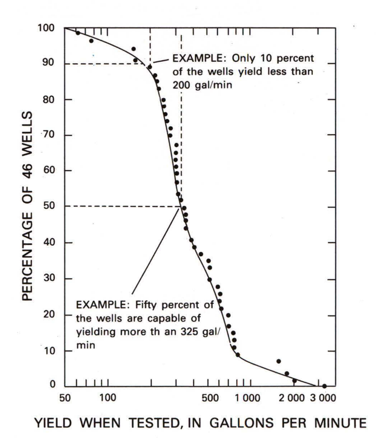


FIGURE 12—YIELDS OF PUBLIC-SUPPLY WELLS IN THE SAND AND GRAVEL AQUIFER.

Public-supply wells in the sand and gravel aquifer have yields ranging from 45 to 3,300 gal/min. The median yield is 325 gal/min. The yields of many wells decline with time because ground water contains iron and manganese that may precipitate and encrust well screens, thereby impeding the entrance of water to the wells.

FIGURE 13—SPECIFIC CAPACITIES OF PUBLIC-SUPPLY WELLS IN THE SAND AND GRAVEL AQUIFER.

The specific capacity of a well is largely dependent on the hydraulic conductivity of the aquifer and is obtained by dividing the yield (in gallons per minute) by the drawdown (in feet) in the well. It is commonly determined by pumping a well until the rate of increase in drawdown becomes very slow.

The short-term yield of a well site can be estimated from the product of specific capacity and available drawdown. Long-term yields are affected by aquifer storage, impermeable boundaries such as till and bedrock, recharge boundaries such as streams and lakes or reservoirs, and recharge rates.

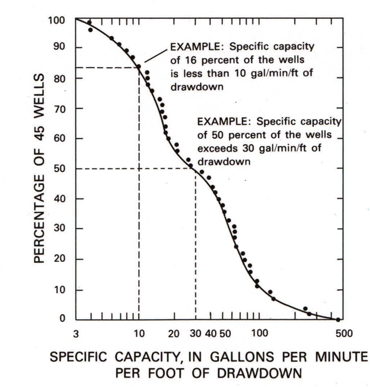
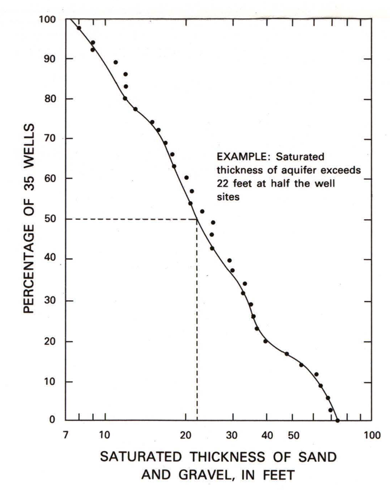
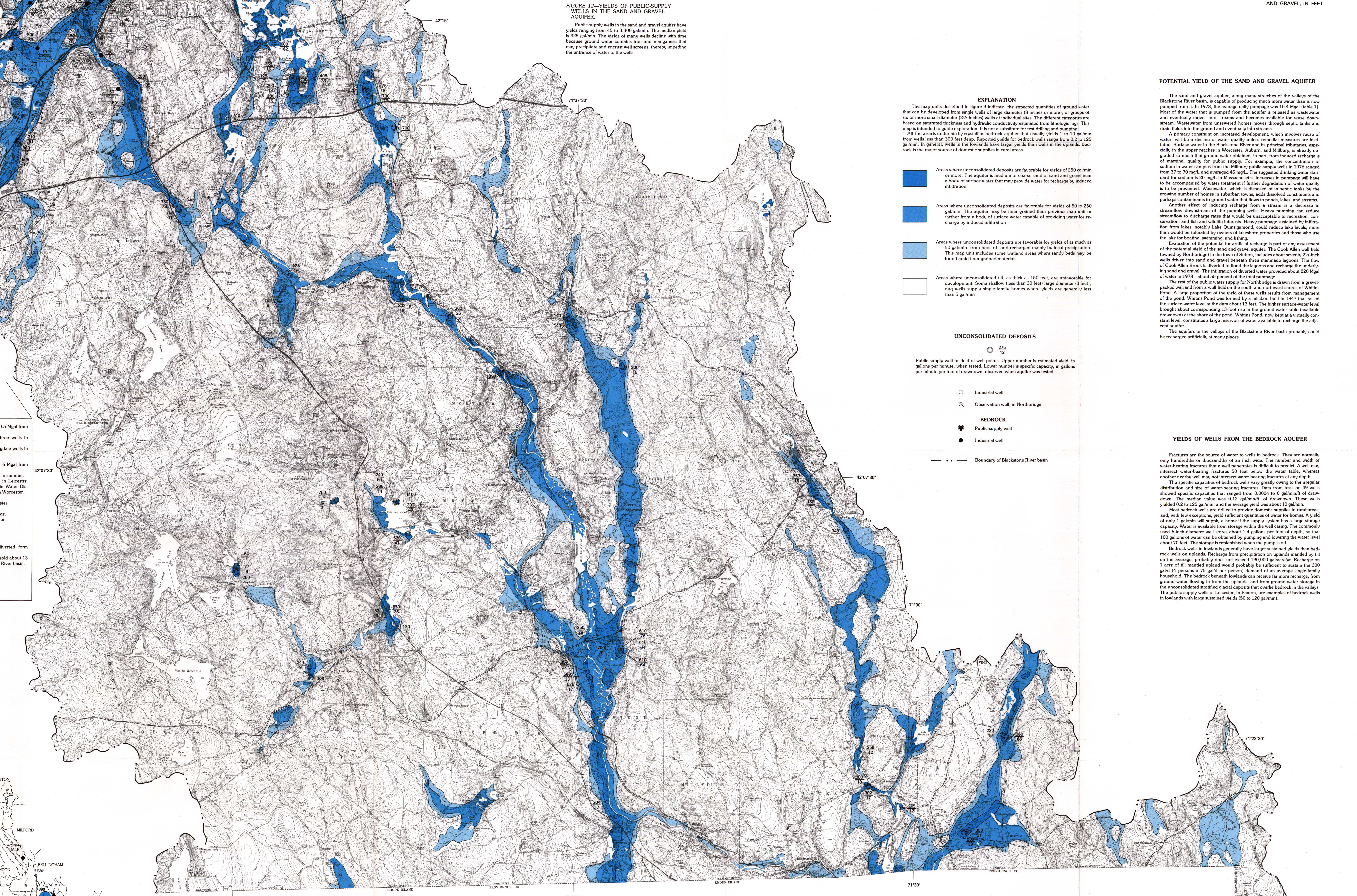


FIGURE 14—SATURATED THICKNESS OF THE SAND AND GRAVEL AQUIFER AT PUBLIC-SUPPLY WELLS AND WELL YIELDS.

Other factors being equal, the largest yields are obtained where the saturated thickness of the aquifer is greatest. However, yields of up to 580 gal/min have been obtained at sites where the aquifer has a saturated thickness of 9 feet or less because they are near sources of recharge. Yield depends on the hydraulic conductivity and the saturated thickness of the aquifer, closeness of wells to sources of infiltration, rate of recharge from precipitation, and well design.





Base from U. S. Geological Survey, 1:24,000, Blackstone, 1953; Franklin, 1964; Grafton, 1953; Leicester, 1953; Milford (Mass) 1953; Oxford, 1953; Paxton, 1953; Shrewsbury, 1953; Uxbridge, 1953; Worcester North, 1960; Worcester South, 1960; Wrentham, 1964

SCALE 1:48,000
CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

FIGURE 9—AREAS FAVORABLE FOR DEVELOPING GROUND WATER.

EXPLANATION

The map units described in figure 9 indicate the expected quantities of ground water that can be developed from single wells of large diameter (8 inches or more), or groups of six or more small-diameter (2½ inches) wells at individual sites. The different categories are based on saturated thickness and hydraulic conductivity estimated from lithologic logs. This map is intended to guide exploration. It is not a substitute for test drilling and pumping.

All the area is underlain by crystalline bedrock aquifer that usually yields 1 to 10 gal/min from wells less than 300 feet deep. Reported yields for bedrock wells range from 0.2 to 125 gal/min. In general, wells in the lowlands have larger yields than wells in the uplands. Bedrock is the major source of domestic supplies in rural areas.

Areas where unconsolidated deposits are favorable for yields of 250 gal/min or more. The aquifer is medium or coarse sand or sand and gravel near a body of surface water that may provide water for recharge by induced infiltration

Areas where unconsolidated deposits are favorable for yields of 50 to 250 gal/min. The aquifer may be finer grained than previous map unit or farther from a body of surface water capable of providing water for recharge by induced infiltration

Areas where unconsolidated deposits are favorable for yields of as much as 50 gal/min. from beds of sand recharged mainly by local precipitation. This map unit includes some wetland areas where sandy beds may be found amid finer grained materials

Areas where unconsolidated till, as thick as 150 feet, are unfavorable for development. Some shallow (less than 30 feet) large diameter (3 feet), dug wells supply single-family homes where yields are generally less than 5 gal/min

UNCONSOLIDATED DEPOSITS

275/13 Public-supply well or field of well points. Upper number is estimated yield, in gallons per minute, when tested. Lower number is specific capacity, in gallons per minute per foot of drawdown, observed when aquifer was tested.

Industrial well

Observation well, in Northbridge

BEDROCK

Public-supply well

Industrial well

Boundary of Blackstone River basin

POTENTIAL YIELD OF THE SAND AND GRAVEL AQUIFER

The sand and gravel aquifer, along many stretches of the valleys of the Blackstone River basin, is capable of producing much more water than is now pumped from it. In 1978, the average daily pumpage was 10.6 Mgal (table 1). Most of the water that is pumped from the aquifer is released as wastewater and eventually moves into streams and becomes available for reuse downstream. Wastewater from unsewered homes moves through septic tanks and drain fields into the ground and eventually into streams.

A primary constraint on increased development, which involves reuse of water, will be a decline of water quality unless remedial measures are instituted. Surface water in the Blackstone River and its principal tributaries, especially in the upper reaches in Worcester, Auburn, and Millbury, is already degraded so much that ground water obtained, in part, from induced recharge is of marginal quality for public supply. For example, the concentration of sodium in water samples from the Millbury public-supply wells in 1976 ranged from 37 to 70 mg/L, and averaged 45 mg/L. The suggested drinking water standard for sodium is 20 mg/L in Massachusetts. Increases in pumpage will have to be accompanied by water treatment if further degradation of water quality is to be prevented. Wastewater, which is disposed of in septic tanks by the growing number of homes in suburban towns, adds dissolved constituents and perhaps contaminants to ground water that flows to ponds, lakes, and streams.

Another effect of inducing recharge from a stream is a decrease in streamflow downstream of the pumping wells. Heavy pumping can reduce streamflow to discharge rates that would be unacceptable to recreation, conservation, and fish and wildlife interests. Heavy pumpage sustained by infiltration from lakes, notably Lake Quinsigamond, could reduce lake levels, more than would be tolerated by owners of lakeshore properties and those who use the lake for boating, swimming, and fishing.

Evaluation of the potential for artificial recharge is part of any assessment of the potential yield of the sand and gravel aquifer. The Cook Allen well field (owned by Northbridge) in the town of Sutton, includes about seventy 2½-inch wells driven into sand and gravel beneath three manmade lagoons. The flow of Cook Allen Brook is diverted to flood the lagoons and recharge the underlying sand and gravel. The infiltration of diverted water provided about 220 Mgal of water in 1978—about 55 percent of the total pumpage.

The rest of the public water supply for Northbridge is drawn from a gravel-packed well and from a well fieldon the south and northwest shores of Whitins Pond. A large proportion of the yield of these wells results from management of the pond. Whitins Pond was formed by a milldam built in 1847 that raised the surface-water level at the dam about 13 feet. The higher surface-water level brought about corresponding 13-foot rise in the ground-water table (available drawdown) at the shore of the pond. Whitins Pond, now kept at a virtually constant level, constitutes a large reservoir of water available to recharge the adjacent aquifer.

The aquifers in the valleys of the Blackstone River basin probably could be recharged artificially at many places.

YIELDS OF WELLS FROM THE BEDROCK AQUIFER

Fractures are the source of water to wells in bedrock. They are normally only hundredths or thousandths of an inch wide. The number and width of water-bearing fractures that a well penetrates is difficult to predict. A well may intersect water-bearing fractures 50 feet below the water table, whereas another nearby well may not intersect water-bearing fractures at any depth.

The specific capacities of bedrock wells vary greatly owing to the irregular distribution and size of water-bearing fractures. Data from tests on 49 wells showed specific capacities that ranged from 0.0004 to 6 gal/min/ft of drawdown. The median value was 0.12 gal/min/ft of drawdown. These wells yielded 0.2 to 125 gal/min, and the average yield was about 10 gal/min.

Most bedrock wells are drilled to provide domestic supplies in rural areas; and, with few exceptions, yield sufficient quantities of water for homes. A yield of only 1 gal/min will supply a home if the supply system has a large storage capacity. Water is available from storage within the well casing. The commonly used 6-inch-diameter well stores about 1.4 gallons per foot of depth, so that 100 gallons of water can be obtained by pumping and lowering the water level about 70 feet. The storage is replenished when the pump is off.

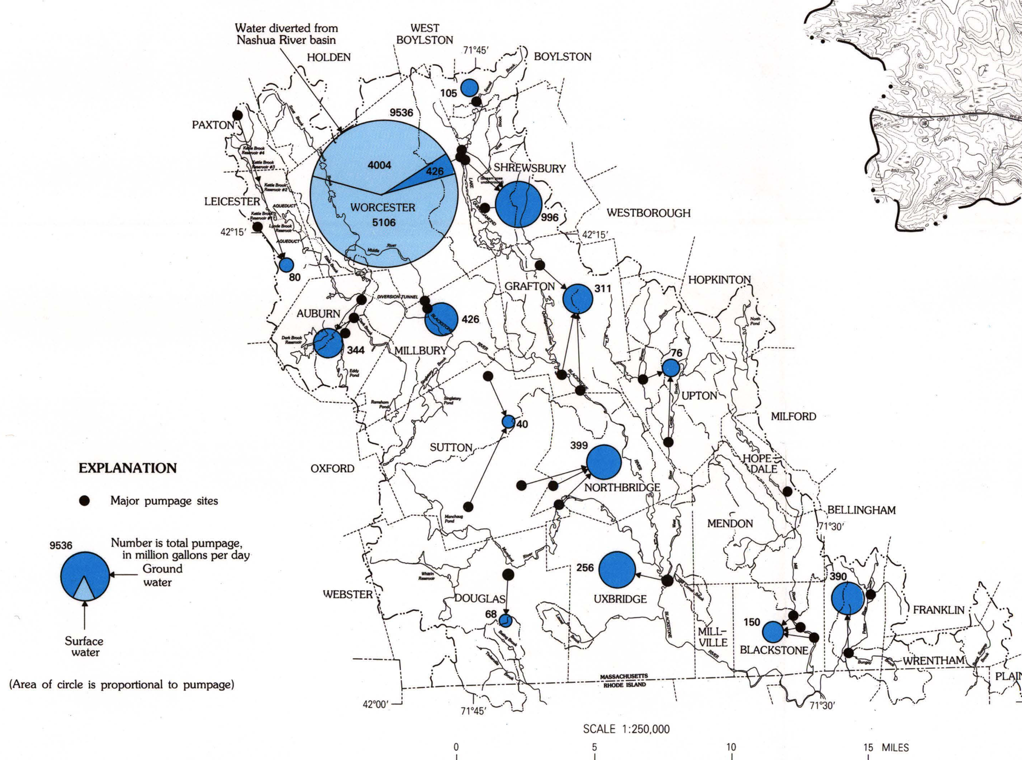
Bedrock wells in lowlands generally have larger sustained yields than bedrock wells on uplands. Recharge from precipitation on uplands mantled by till on the average, probably does not exceed 190,000 gal/acre/yr. Recharge on 1 acre of till mantled upland would probably be sufficient to sustain the 300 gal/d (4 persons x 75 gal/d per person) demand of an average single-family household. The bedrock beneath lowlands can receive far more recharge, from ground water flowing in from the uplands, and from ground-water storage in the unconsolidated stratified glacial deposits that overlie bedrock in the valleys. The public-supply wells of Leicester, in Paxton, are examples of bedrock wells in lowlands with large sustained yields (50 to 120 gal/min).

TABLE 1—PUMPAGE OF WATER FOR PUBLIC SUPPLY IN 1978

Town or city	Population in 1975	Area in Blackstone River basin in percent	Source of water	Capacity of system, in million gallons per day	Pumpage, in million gallons per day: Total	Average daily	Maximum daily	Date of maximum daily	Remarks
Auburn	15,626	94	Wells	2.75	344	0.94	2.29	7–7	Auburn Water District received 0.5 Mgal from Worcester.
Bellingham	14,461	50	do.	1.61	192	.52	—	—	Listed pumpage is from the three wells in Blackstone River basin.
Blackstone	6,486	100	do.	.93	150	.41	.67	5–25	Listed pumpage is from Morningdale wells in Blackstone River basin.
Boylston	3,326	20	do.	3.02	41	.11	—	—	
Douglas	3,174	83	do.	.9	68	.19	.28	7–1	Grafton State Hospital received 6 Mgal from Worcester.
Grafton	10,630	93	do.	1.8	311	.85	—	—	Bought some water form Milford in summer.
Hopedale	4,014	80	do.	.43	—	—	—	—	Four wells in Paxton, one well in Leicester. Cherry Valley and Rockdale Water Districts received 3.4 Mgal from Worcester.
Leicester	8,887	40	do.	.6	80	.22	.32	6-4	No public supply.
Mendon	2,714	100	—	—	—	—	—	—	Received 0.24 Mgal from Worcester.
Millbury	12,121	100	Wells	2	426	1.17	1.61	5–30	No public supply.
Millville	1,744	100	—	—	—	—	—	—	Wells in Sutton and in Northbridge.
Northbridge	12,165	100	Wells	3.1	399	1.09	1.66	11–11	Received 2.8 Mgal from Worcester.
Shrewsbury	21,963	62	do.	5.5	996	2.73	4.60	7–14	
Sutton	4,969	98	do.	.5	40	.11	—	—	
Upton	3,777	96	do.	.8	76	.21	.57	7–29	
Uxbridge	8,528	100	do.	2.9	256	.70	.76	4–3	
Worcester	172,342	99.7	Reservoirs	26.8	9,110	24.96	37.06	7–13	Forty-four percent of water diverted form Nashua River basin.
			Well	1.7	426	1.17	1.25	6–11	Well in Shrewsbury. Worcester sold about 13 Mgal to towns in Blackstone River basin.
			Total surface water		9,110	24.96			
			Total ground water		3,805	10.42			
			Total water		12,915	35.38			

FIGURE 15—PUMPAGE OF WATER FOR PUBLIC SUPPLY IN 1978

All the towns in the Blackstone River basin rely on ground water; Worcester (city) relies mainly on surface water from the following reservoirs: Kettle Brook, Lynde Brook, Holden, Kendall, Pinehill and Quinapoxet.



WATER RESOURCES OF THE BLACKSTONE RIVER BASIN, MASSACHUSETTS

By

Eugene H. Walker and Bruce E. Krejmas

1986

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