PREPARED IN COOPERATION WITH THE
NEW HAMPSHIRE WATER RESOURCES BOARD

INTRODUCTION

The investigation was made in cooperation with the New Hampshire Water Resources Board. The purpose of this study was to obtain information on the quantity and quality of water being used in the area and to determine the potential for development of additional ground-water resources. The report is intended to provide information to guide water planners in the development of water supplies to meet future needs in southwestern New Hampshire. Data for many wells were obtained from well drillers or land owners.

GEOGRAPHY

The Ashuelot River basin occupies an area of about 420 square miles principally in Cheshire County but also including a small part of southeastern Sullivan County. It lies within the New England Upland physiographic province (Fenneman, 1938, p. 358) and is essentially a dissected peneplain which slopes gently southwestward. Altitudes range from about 2,000 feet near the headwaters of the Ashuelot River to about 200 feet where the Ashuelot joins the Connecticut River. Several isolated mountain peaks called monadnocks, stand above the general surface. Monadnock Mountain (altitude 3,165 feet) in the southeastern part of the basin is a prominent feature visible for many miles.

The Ashuelot River in its upper and lower reaches, and most of its tributaries, are confined to narrow steep-sided valleys cut into the underlying bedrock. The Ashuelot River valley broadens north of Surry and meanders over the bed of a former glacial lake now occupied in part by Surry Mountain Reservoir. About 2½ miles farther downstream, the valley again broadens to form a basin in which a much larger glacial lake deposited the fine sediments on which the city of Keene is built.

The climate of southwestern New Hampshire is continental; summers are warm and winters are cold. The normal annual precipitation at Keene is about 41 inches, and 75 years of record indicates it is generally rather evenly distributed throughout the year. During 1963–66, however, average annual precipitation was only about 75 percent of normal and was sporadic. In 1967 precipitation was 5 percent above normal. Approximately 40 percent of the precipitation is snow, which may persist from early November through March. The average annual temperature is about 47°F. In the upland areas precipitation is normally somewhat greater and the average annual temperature is slightly lower.

The population of Cheshire County in 1960 was 43,342, about 60 percent of which consisted of rural residents (Bowring, 1964, p. 5). This was an increase of 11.7 percent since 1950. The 1970 population is about 49,000 and the projected population for the year 2000 is 67,000, based on an estimated average decennial increase of about 13 percent (Bowring, 1964, p. 17). Keene is the principal urban center, with a population of 17,562 in 1960. The major industries in the Ashuelot River basin are the manufacture of textiles and wood products and the tanning of hides, principally at West Swanzey, Winchester, and Hinsdale. Many small industrial and commercial enterprises are concentrated in the Keene area.

GEOLOGY

The Ashuelot River basin is underlain by metamorphic and igneous rocks that are generally buried beneath a few to several hundred feet of glacial drift (see table of geologic units). Bedrock outcrops are confined principally to the crests and upper flanks of the higher mountains or where streams have stripped away overlying glacial drift. Glacial drift includes rock debris scraped and gouged from the underlying bedrock and unconsolidated material picked up and transported by the overriding ice sheet.

Till is the most widespread glacial drift; it underlies the surface of much of the upland region and is buried beneath younger stratified glacial drift in the valleys. Ice-contact deposits consist of rock fragments deposited by melt-water streams flowing along the margins of glaciers, between the ice and the confining valley wall, or through crevasses and caverns eroded in or beneath the ice. Except where exposed in terraces bordering a few of the present stream valleys, the deposits are buried beneath overlapping outwash deposits laid down by streams beyond the ice front. Many of these will remain undiscovered unless test drilling is carried to bedrock instead of being discontinued at "refusal." Small diameter testing rigs cannot ordinarily insure penetration of the complete section. Outwash deposits were spread widely over the former glacial valley floors. These deposits normally become increasingly fine grained downstream and at many places grade into and are interbedded with the clay, silt, and fine sand laid down in quiet bodies of water formed behind dams of glacial drift or in deep lakes marking sites of stagnant ice blocks. Alluvial deposits of coarse sand and gravel were dumped into the Ashuelot River valley by many tributary streams having steeper gradients than the Ashuelot while the main stream was depositing fine material derived from a more distant source. These deposits are generally in the form of deltas that interfinger with the finer sediments.

The thickness and composition of glacial drift differ greatly in the Ashuelot River basin. Lithologic sections across the valley of Ashuelot River and valleys of its major tributaries indicate that moderate to large supplies of water can be developed from outwash and ice-contact deposits within the stratified glacial drift in the Ashuelot River valley north of Surry and from just below Surry Mountain Dam to where the valley broadens to form the Keene plain. The erratic flows of Ashuelot River and its tributaries probably deposited along the axis of their valleys lenses of coarse material that subsequently were buried by silt and fine sand. These coarse ice-contact deposits, though of limited thickness and extent, may be capable of yielding large quantities of water to properly constructed wells. The areal extent of these potential aquifers can be located only by careful and systematic test drilling.

Generalized section of the geologic units

System	Series	Subdivision	Thickness (feet)	Physical character	Water-bearing character
QUATERNARY	Holocene	Alluvium	0–15+	Clay, silt, and fine sand that may contain lenses of coarse sand and gravel. Generally widely spread over river flood plains, but difficult to distinguish from underlying outwash deposits of glacial origin. Generally excellent source of recharge from precipitation where deposits overlie flat or undulated surfaces. Deposits not shown on the block diagram.	Yields small quantities of water to dug wells, but saturated thickness generally insufficient to yield larger supplies. Water is normally of good chemical quality, but subject to contamination from surface runoff. May contain undesirable amounts of iron and manganese.
	Pleistocene	Lake deposits	0–200+	Interbedded clay, silt, and fine sand, may contain scattered lenses of coarse sand and gravel of limited thickness and extent. Confined mainly to Keene and Swanzey areas. Generally excellent source of recharge because flat or undulated surfaces offer little opportunity for surface runoff.	Deposits too fine to yield more than small quantities of water to dug wells. Difficult to construct drilled wells that do not pump clay and silt.
		Outwash deposits	0–100+	Range from stratified fine sand containing lenses of coarse sand and gravel to well sorted coarse sand and gravel. Occur as outwash beneath lake deposits and alluvium and tributary delta deposits interbedded with lake sediments in most major stream valleys and in some areas as terrace remnants along their margins. Excellent source of recharge either from precipitation or runoff from adjacent till or bedrock surfaces.	Source of most municipal ground-water supplies and potential source of moderate to large supplies in other areas where thick, permeable, and saturated. Deep drilling may be required to reach these deposits in the Keene and Swanzey areas. Water is of good quality for most uses, except in wells having excessive concentrations of iron and manganese.
		Ice-contact deposits	0–100+	Distinguishable from outwash and associated alluvial and deltaic deposits by its generally wider range of grain size and less pronounced stratification. Normally buried by finer lacustrine and water laid sediments, except where preserved as terraces or kames. Generally composed of sand, fine to cobble gravel, and some boulders and silt. Excellent source of recharge where exposed to precipitation or surface runoff.	Have high permeability where free of silt and fine sand, and are potential sources of large quantities of water to properly constructed wells. Deposits are difficult to locate without careful, systematic test drilling. Water is generally of good chemical quality, but undesirable concentrations of iron and manganese may be a problem in some areas.
		Till	0–50(?)	Characteristically an unsorted mixture of rock fragments ranging from clay to boulders. Where a large part of the till is composed of clay and silt it is compact and hard to drill (hardpan). Forms mantle over most of the upland areas and lies beneath alluvium, lake, outwash, and ice-contact deposits in the larger valleys. Locally it may overlie preglacial alluvium or outwash overridden by glacier that deposited the till (see block diagram). Generally impermeable character and location on slopes and hill crests preclude any possibility of appreciable recharge.	Normally yields only enough water to dug wells to meet domestic and stock needs. Drilled wells in till generally are unsuccessful because of small storage capacity. Till wells are likely to go dry or yield inadequate supplies during dry periods. Water from till is generally of good quality but is susceptible to contamination from surface runoff.
PRE-QUATERNARY ROCKS		Bedrock		Metamorphic rocks, which consist principally of schist, gneiss, and quartzite, and granitic intrusives. Recharge capacity similar to till except where rock is extensively fractured or jointed.	Bedrock yields adequate supplies of water to domestic and farm wells in most areas. Water is contained in fractures and joints, and yield of wells depends on number and extent of saturated openings penetrated. Water is generally of good quality, but excessive iron and manganese are problems in some wells.

GROUND WATER

The ground-water phase of the hydrologic cycle begins with the seepage of rainfall or snowmelt into the soil and its percolation downward into the saturated zone (the ground-water reservoir). Water in the ground-water reservoir is seldom stationary but is constantly moving toward points of discharge—principally to streams and lakes and, to a lesser extent, to springs and wells. Precipitation is the principal source of ground-water recharge in the Ashuelot River basin. Except for water that is lost by evapotranspiration (transpiration by vegetation and evaporation), most of the precipitation within the basin eventually is discharged into Ashuelot River and its tributaries as ground-water seepage.

Precipitation that reaches the ground-water reservoir usually causes the water table to rise, thereby increasing the hydraulic gradient and underflow to surface-water bodies. Ground water is the principal source of streamflow during the periods of little or no rainfall. Conversely, during periods of high flow, infiltration from streams and lakes recharges the ground-water reservoir. Heavy pumping of wells adjacent to a stream may induce recharge from the stream if there is hydraulic continuity between surface- and ground-water bodies as shown on the diagrammatic section.

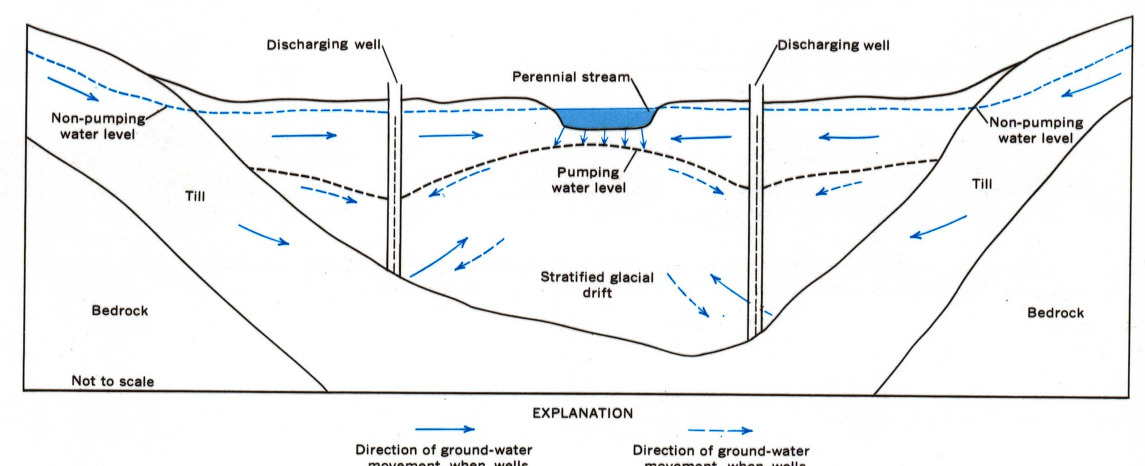
Ground water in bedrock occurs principally in discontinuous fissures and is commonly under sufficient artesian pressure to raise it several feet above the level at which the water-bearing fissure is first intercepted. In a few wells water has been encountered under sufficient pressure to cause it to flow at the surface. Because the capacity of bedrock to yield water to a well is dependent on the number, width, extent and recharge capability of water-filled fractures tapped by the well, prediction of the depth and yield of a proposed well generally is not possible.

The yield reported by drillers of 52 wells completed in bedrock (see graphs) in the Ashuelot River basin ranges from less than 1 gpm (gallon per minute) to 32 gpm and averages about 9 gpm. The available data indicate that 90 percent of the wells yield adequate supplies for normal domestic needs (2 gpm or more). The depth of penetration in bedrock ranges from about 12 to 387 feet, and the average is 127 feet. Only about 5 percent of the wells are more than 300 feet deep, which is generally considered to be the depth beyond which the chance of intercepting water-bearing joints and other fractures is sufficiently small not to warrant deeper drilling (Stewart, 1968, p. 20).

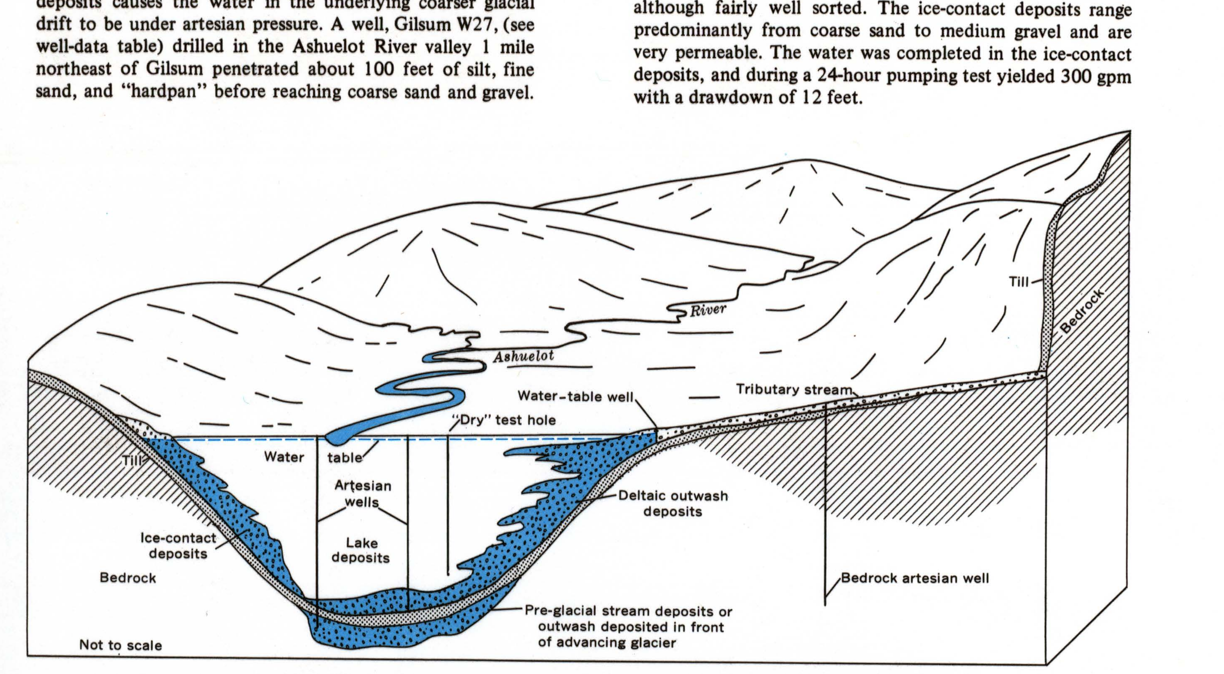
Water obtained from dug wells and springs in glacial till has supplied the principal needs for farm and domestic use in the upland areas since the region was first settled. Wide seasonal fluctuations of the water table of 10 feet or more may occur annually (see hydrographs). The water table rises in the fall when evapotranspiration ceases, generally reaching its peak during April, May, or June. The water table usually declines to its lowest altitude in September and October. During the drought of 1963–66, the water table declined to the point where many wells in till failed. Since the drought, many wells developed in till have been replaced with deeper wells finished in bedrock to insure an uninterrupted supply during periods of below-average precipitation.

Deposits of stratified glacial drift (ice-contact and outwash deposits) of considerable thickness (see block diagram) and extent underlie most of the major stream valleys and probably border some of the larger lakes in the basin. They are recharged principally by precipitation directly on the land surface. Where the deposits are adjacent to and hydraulically connected with streams and lakes, they provide recharge to those surface-water bodies by ground-water seepage. In some areas a confining bed of fine sand and silt within the outwash deposits causes the water in the underlying coarser glacial drift to be under artesian pressure. A well, Gilsum W27, (see well-data table) drilled in the Ashuelot River valley 1 mile northeast of Gilsum penetrated about 100 feet of silt, fine sand, and "hardpan" before reaching coarse sand and gravel. Drilling was terminated at 117 feet, and the well flows about 10 gpm. The potential yield of the well is estimated to be 300 to 400 gpm. Another well, Gilsum W22, drilled in similar sediments in the village yielded 8 gpm with a reported drawdown of less than 1 foot when completed. The water in the coarse sand and gravel reached at 87 feet rose to within a few feet of the land surface.

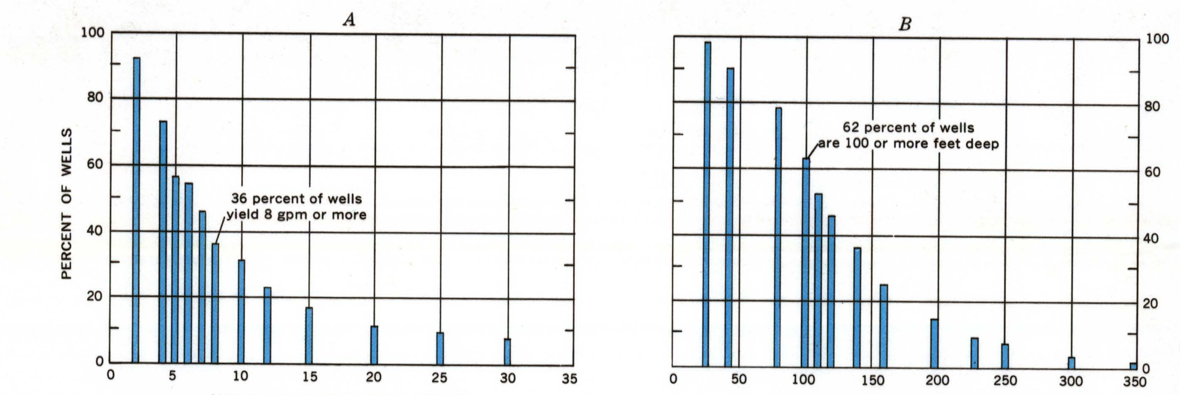
Depths and yields of large production wells and of test holes that indicate areas of excellent potential are shown in the well-data table. Undoubtedly, many other sites exist where wells of large yield may be constructed. Especially favorable are sites where tributary streams have deposited coarse material in the Ashuelot Valley as deltas that interfinger with fine-grained glacial-lake deposits. The particle-size distribution curves of samples obtained from a test well, Swanzey W54, illustrate the range in texture of material that may be penetrated by wells in glacial drift. The alluvial deposits are permeable (mostly medium to coarse sand), but they lie above the water table. Outwash deposits are principally fine sand of relatively low permeability, although fairly well sorted. The ice-contact deposits range predominantly from coarse sand to medium gravel and are very permeable. The water was completed in the ice-contact deposits, and during a 24-hour pumping test yielded 300 gpm with a drawdown of 12 feet.



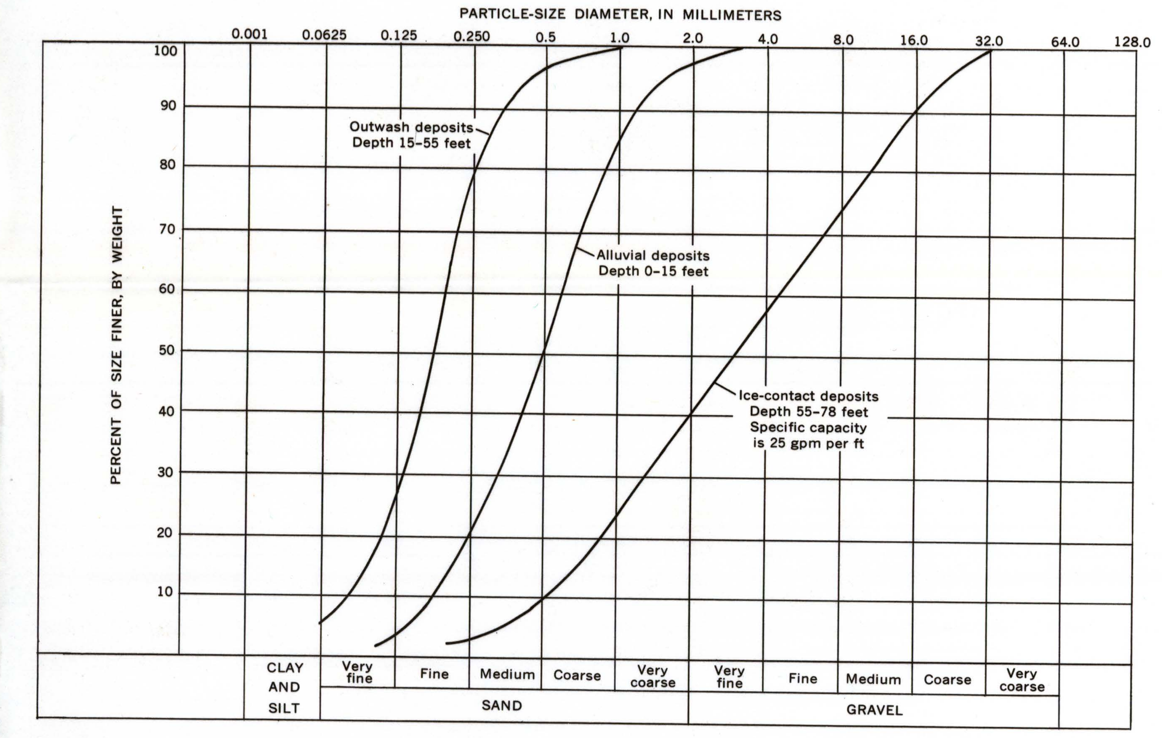
DIAGRAMMATIC SECTION ILLUSTRATING THE EFFECT OF PUMPING TO INDUCE RECHARGE FROM AN ADJACENT STREAM.



SCHEMATIC BLOCK DIAGRAM ILLUSTRATING GROUND-WATER CONDITIONS IN THE ASHUELOT RIVER VALLEY, NEAR KEENE AND SWANZEY



GRAPHS SHOWING YIELD (A) AND DEPTH (B) OF 52 WELLS DRILLED IN BEDROCK

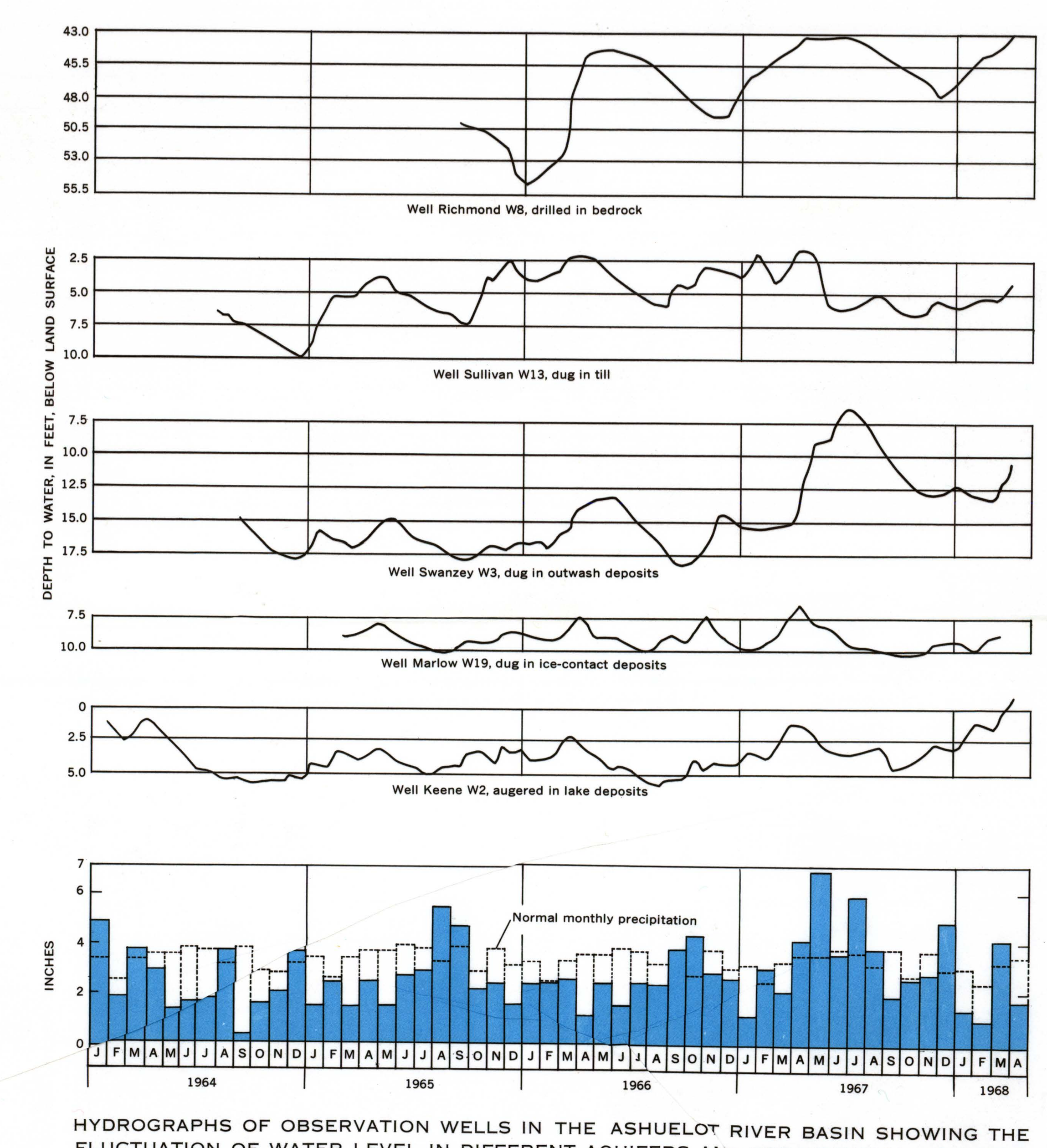


CUMULATIVE PARTICLE-SIZE DISTRIBUTION CURVES OF SAMPLES FROM WELL SWANZEY W54, WHICH PENETRATES ALLUVIAL, OUTWASH, AND ICE-CONTACT DEPOSITS

Records of large-yielding wells or of test wells drilled in areas of excellent potential

Well	Location Lat/Long	Depth (ft)	Overburden	Aquifer: Type of material	Aquifer: Depth to top of (ft)	Aquifer: Open to well (ft)	Yield (gpm)	Draw-down (ft)	Specific capacity (gpm per ft of drawdown)	Remarks
Gilsum W22; domestic well.	430257N 0721550	87	Clay, silt, and fine sand.	Ice contact; sand and gravel.	83	4	R8	R<1	8+	Open end 8-inch casing.
Gilsum W27; domestic well.	430322N 0721435	117	.....do.........	.....do..........	100	17	e25	e5	5+	Open end 6-inch casing.
Keene W32; public supply.	425540N 0721848	63	Clay and silt...	Outwash; coarse sand and gravel.	43	20	520	18	29	Twenty feet of 18-inch screen, gravel packed.
Keen W33; public supply.	425748N 0721822	102	.....do.........	.....do..........	82	20	950	30	32	.....do..........
Keene W34; test hole for public supply.	425900N 0721825	48	Clay, silt, and fine sand.	Outwash; sand and gravel.	20	3	R150	......	......	Three feet of 2-inch drive-point screen.
Marlboro W2; public supply.	425432N 0721238	54	Fine to medium sand.	.....do..........	44	10	108	14	7.7	Ten feet of 12-inch screen, gravel packed.
Richmond W6; industrial supply.	424615N 0721511	27	Coarse sand and gravel.	Ice contact; coarse sand and gravel.	......	......	150	......	......	......
Swanzey W19; test hole.	425227N 0722017	40	Sand and gravel.	Ice contact; sand and gravel.	3	......	e1000	......	......	Yield guaranteed by driller from gravel-packed well.
Swanzey W54; test well for industrial supply.	425210N 0722025	78	Silt and fine sand.	Ice contact; coarse sand, gravel, and cobbles.	68	10	300	12	25	Ten feet of 8-inch screen.
Winchester W28; public supply.	424800N 0722203	54	Clay, silt, and fine sand.	Outwash; coarse sand and gravel.	42	12	370	21	18	Twelve feet of 24-inch screen, gravel packed.
Winchester W29; public supply.	424759N 0722203	57	.....do.........	.....do..........	47	10	250	16	16	.....do..........

Data obtained from drillers' records, otherwise R is reported, e is estimated.



HYDROGRAPHS OF OBSERVATION WELLS IN THE ASHUELOT RIVER BASIN SHOWING THE FLUCTUATION OF WATER LEVEL IN DIFFERENT AQUIFERS AND PRECIPITATION AT KEENE

QUALITY OF WATER

The U.S. Public Health Service (1962) has recommended certain chemical-quality standards for water used for drinking and culinary purposes on interstate commerce carriers. The following apply to the chemical constituents most commonly found in ground water in the Ashuelot River basin. Concentrations are expressed in milligrams per liter.

Constituent	Maximum allowable concentration (mg/l)
Iron (fe) and Manganese (Mn)	0.3
Chloride (Cl)	250
Fluoride (F)	1.5
Dissolved solids	500

Hardness is caused principally by high concentrations of calcium and magnesium. Water has been arbitrarily classified by the U.S. Geological Survey in terms of hardness as follows: 60 mg/l or less, soft; 61 to 120 mg/l, moderately hard; 121 to 180 mg/l, hard; and 181 mg/l or greater, very hard. Specific conductance is a measure of the ability of water to conduct an electrical current and is directly related to the amount and the chemical type of dissolved material in the water. Water with a low pH is corrosive to metals and concrete; water with a high pH will cause scaling in boilers and hot-water pipes.

Ground water in the Ashuelot River basin is normally low in dissolved solids, characteristically soft, and suitable for most domestic and industrial uses without special treatment for iron or other undesirable substances. Chemical analyses of water from 27 wells sampled in 1967–68 indicate that the average dissolved-solids content of ground water is about 100 mg/l (milligrams per liter) (see water-quality table) and ranges from 305 mg/l in a well in Gilsum to 40 mg/l in the well at Dublin Golf Club. The maximum concentration, which is unusual in this region, is probably from the infiltration of snowmelt contaminated by salt from de-icing chemicals used on highways.

Hardness (reported as $CaCO_3$) ranges from 90 mg/l to 15 mg/l. When water is used for domestic purposes, hardness usually does not become particularly objectionable until it reaches a level of about 100 mg/l. As concentrations increase, the effects of hardness become more troublesome. Noticeable effects include the formation of scale on utensils used for boiling water and the need for greater quantities of soap to produce sudsing.

The chloride concentration in most ground water in the Ashuelot River basin is 20 mg/l or less. However, along the principal highways, where de-icing chemicals are used to clear snow and ice, there are occasional complaints by well owners that chloride in their well water has increased during recent years.

The electrical conductivity of the water in Ashuelot River was used as a measure of the dissolved-solids content. An approximation of dissolved solids obtained by multiplying specific electrical conductance by 0.6 indicates that the highest, lowest, and average concentration of the 20 water samples analyzed are 48, 18, and 42 mg/l, respectively. The highest concentration of dissolved solids in the Ashuelot River occurs below Keene.

The highest concentration of iron occurs about 20 miles south of Marlow below exposures of rock containing abundant iron-rich minerals that crop out in the streambed. One water sample collected during a period of low flow in September 1967 indicated the concentration of iron in surface water at that time was 0.96 mg/l. A concentration of this magnitude may present some undesirable effects for domestic or industrial use unless treated.

Analyses of selected chemical constituents in ground- and surface-water samples

Constituents (mg/l)	Iron (Fe)	Manganese (Mn)	Chloride (Cl)	Fluoride (F)	Dissolved solids	Hardness	Specific conductance[1]	pH[2]
Ground water								
Number of samples	52	23	47	22	27	40	50	52
Highest concentration	6.5	.48	220	.5	306	90	848	8.8
Lowest concentration	.00	.01	.0	.1	38	14	35	5.3
Average concentration	.29	.09	18	.2	112	27	176	7.1
Surface water								
Number of samples	20	......	20	......	......	......	20	20
Highest concentration	.94	......	24	......	......	......	120	7.5
Lowest concentration	.01	......	2.8	......	......	......	30	5.9
Average concentration	.09	......	9.2	......	......	......	70	6.4

[1]Micromhos per centimeter at 25°C.
[2]Measure of acidity or alkalinity of water. Based on a value of 7 for a neutral solution; lower values indicate an increasingly acidic water, higher values an increasingly alkaline water.

UTILIZATION AND AVAILABILITY OF WATER

Surface water is still the major source of community and industrial supplies in the Ashuelot River basin. Keene obtains about half of its average daily consumption of 3 mgd (million gallons per day) from pond reservoirs. Withdrawal from the reservoirs may reach 4 mgd in the summer. Hinsdale has an estimated daily consumption of about 200,000 gpd (gallons per day) and Troy uses about 70,000 gpd. Several other smaller towns use small quantities of surface water. Ashuelot River provides large amounts of water for industrial use, but much of the water is returned directly to the stream. Also, much of the surface water utilized by communities returns to the streams as raw sewage or, as at Keene, as treated water flowing from sewage settling tanks. Pumping from city wells at Keene, Marlboro, and Winchester may induce some infiltration from adjacent streams if there is hydraulic connection with the aquifer.

Few large supplies of ground water have been developed in the basin. Keene pumps an average of 1.5 mgd from three wells, although pumpage may increase to about 2.5 mgd during the summer. Winchester obtains about 410,000 gpd from two wells, and Marlboro pumps about 120,000 gpd from a single well. The amount of ground water developed for stock and domestic use is not known, but it is estimated that roughly 2 mgd is supplied by privately owned springs and wells. Much of the ground water is returned to the hydrologic system after use either as waste runoff into streams or by seepage into the soil to return to the ground-water reservoir.

Normal annual precipitation in Ashuelot River basin is estimated to be 41 inches, which is the equivalent of 920,000 acre-ft (acre-feet) of water or 820 mgd. The average discharge of Ashuelot River at the Hinsdale gaging station is 642 cfs (cubic feet per second) or 415 mgd. An additional but probably small amount of water bypasses the station as ground-water underflow. The average water loss in the basin is, therefore, about 405 mgd, or about 49 percent of the precipitation. Most of the loss is attributable to evapotranspiration. The remainder of the precipitation goes in part to replenish the soil moisture and in part percolates downward to recharge the ground-water reservoir. Insufficient data are available to determine what part of this "lost" water goes to meet the needs of the basin, but it is estimated that the amount used for domestic and industrial purposes is less than 2 percent of the water that normally leaves the basin as runoff.

Even during 1965, at the peak of the drought in the Northeast, when precipitation was only 75 percent of normal and runoff was only 70 percent of average, discharge of the Ashuelot River at Hinsdale on November 8 was 110 cfs (71.1 mgd). This discharge was measured after 15 days of minimal rainfall, ranging from only a trace at Marlow to 0.14 inch at Keene. Killing frosts had occurred early in October, and temperatures were below freezing 6 of the 8 days in November; consequently, there was little or no loss of water by evapotranspiration.

The runoff measured at Hinsdale on November 8 was principally base flow from ground-water seepage derived mainly from stratified drift and alluvium, which crops out in about 40 square miles in the Ashuelot River basin. Only a small part of the base flow is derived from till and bedrock, which are exposed over most of the remaining 90 percent of the basin. Of the total measured daily flow on November 8, probably less than 2 mgd was contributed by precipitation. Measurements of base flow in adjacent drainage basins, where discharge to streams is derived almost entirely from till or bedrock indicate that the average contribution to streamflow from these areas was about 0.04 mgd per square mile during November 1965. If it is assumed that the contribution to the base flow from till and bedrock was similar to that in adjacent valleys, the contribution from these sources is estimated to be 15 mgd. The balance of approximately 54 mgd (56 mgd -2 mgd), which is the equivalent of an average discharge of 1.4 mgd per square mile, is assumed to have been derived from the 40 sq. mi. of stratified drift and alluvium. In years of normal precipitation, ground-water discharge to streams may be appreciably greater.

Much of the ground-water seepage sustaining the base flow of the stream can be diverted to properly spaced wells adjacent to the streams, thereby eventually reducing streamflow. Assuming that the ecological environment of the area remains unchanged and that most ground-water seepage to the streams could be intercepted through wells, pumping theoretically could be maintained indefinitely at about 1.4 mgd per square mile or slightly more, depending on the amount of water salvable from natural discharge by underflow, reduction in evapotranspiration, and induced recharge. Of course, some areas will yield large quantities of water, and other areas will yield only small quantities—depending on permeability of the aquifer, thickness of saturated material, proximity to sources of recharge, and so forth. Obviously, there are large quantities of ground water available to meet man's present and projected needs in the more populous parts of the basin even during severe drought.

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GROUND-WATER RESOURCES OF THE ASHUELOT RIVER BASIN, SOUTHWESTERN NEW HAMPSHIRE

By
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