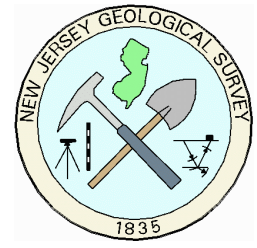




**NEW JERSEY GEOLOGICAL &
WATER SURVEY**
Technical Memorandum 12-1



**Results of an Aquifer Test in Chatham Borough,
Morris County, New Jersey, May 1992**



New Jersey Department of Environmental Protection

STATE OF NEW JERSEY

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Kim Guadagno, *Lieutenant Governor*

Department of Environmental Protection

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On the cover:

The Sheppard Kollock Park deep observation well in May 1992. A packer is in this well. The cylinder to the right of the well contains nitrogen which inflates the packer.

Results of an Aquifer Test in Chatham Borough,
Morris County, New Jersey, May 1992

by
Jeffrey L. Hoffman
2012

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"Ground-water systems are dynamic and adjust continually to short-term and long-term changes in climate, ground-water withdrawal and land use. Water-level measurements from observation wells are the principal source of information about the hydrologic stresses acting on aquifers and how these stresses affect ground-water recharge, storage, and discharge" --- Taylor and Alley, 2001.

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Abstract

The New Jersey Geological & Water Survey (NJGWS) conducted a 72-hour aquifer test in Chatham Borough, Morris County, New Jersey, in May 1992. The test yielded information on aquifer properties and on the hydraulic connections between the unconsolidated sand-and-gravel aquifer, the upper bedrock zone, and a lower bedrock zone. In this area the overburden sand-and-gravel aquifer is termed the buried-valley aquifer given its location in a buried bedrock depression. The test consisted of a 24-hour background period, a 24-hour pumping period, and a 24-hour recover period.

The NJGWS measured water levels at three wells in Chatham Borough -- two wells in Sheppard Kollock Park and one well in Memorial Park. In Sheppard Kollock Park the shallow well (136' deep and called SKP-shallow) is in the buried-valley aquifer. The deeper well (241' deep and called SKP-deep) is in the bedrock Towaco Formation. During the pumping period an inflatable packer in the SKP-deep allowed measurement of water levels in upper and lower bedrock zones. The third well, in Memorial Park, is 197' deep, called the Recreation Field well, and is completed in the buried-valley aquifer.

Two nearby well fields created the drawdowns observed during the test. Both well fields tap the buried-valley aquifer. The New Jersey-American Water Company's Passaic River well field consists of two wells, PR51 and PR52. During the entire 72-hour test the PR51 was pumped at 600 gpm. During the 24-hour pumping period PR52 was pumped at 600 gpm. PR52 was not pumped during the background or recovery periods. The Chatham Borough Water Department's well field consists of three production wells which were pumped as needed during the aquifer test at a combined rate of 1,050 gpm.

Water levels at Sheppard Kollock Park fluctuated in response to pumpage at the nearby Passaic River well field. Water levels in the upper bedrock zone were nearly identical to that of water levels in the overlying buried-valley aquifer. The lower bedrock zone had water levels 3' to 3.5' lower than levels in the upper bedrock zone. Water levels in both zones of the bedrock aquifer fluctuated in response to pumpage in the buried-valley aquifer. This shows that the buried-valley aquifer is in direct hydraulic contact with the bedrock and that there is a good hydraulic connection between the upper and lower bedrock zones. A Theis analysis of drawdown in the shallow Sheppard Kollock Park well yields a transmissivity of $8,088 \text{ ft}^2/\text{day}$ with a storativity of .000785.

A leaky-aquifer (Hantush) multi-pumping-well analysis of drawdown at the Recreation Field observation well in Memorial Park results a transmissivity of 5,804 ft²/day, a storativity of 0.00286, and a leakance of 3,675 feet. These aquifer properties are reasonable values for the buried-valley aquifer in southeastern Morris County.

Introduction

The New Jersey Geological & Water Survey (NJGWS), in conjunction with the New Jersey-American Water Company (NJAWC) and the Chatham Borough Water Department (CBWD), conducted an aquifer test in Chatham Borough, Morris County, New Jersey, in May 1992. The goals were to investigate the hydraulic connection between the overlying buried-valley aquifer, the upper bedrock zone, and a lower bedrock zone, and to determine aquifer properties.

Aquifer properties are determined by analyzing water level changes due to pumping. This process is called an aquifer test. Under the best scenario, water-levels changes in an observation well are caused by controlled withdrawals in a pumping well and are monitored at frequent intervals. All outside influences on the water level are either eliminated or controlled.

During this test the NJGWS monitored water levels in two observation wells in Sheppard Kollock Park in eastern Chatham Borough. The shallow well (SKP-shallow) was drilled to the bedrock surface and allowed measurement of water level in the sand-and-gravel buried-valley aquifer. The deeper well (SKP-deep), completed in the underlying Towaco Formation, allows water-level measurements in the bedrock aquifer. During the aquifer test a packer was inflated in the SKP-deep to temporarily create two zones, shallow and deep. This allowed observation of the vertical movement of water in the bedrock at the site during the test. NJGWS also monitored water levels in the Recreation Field observation well in Chatham's Memorial Park.

Water level changes were caused by a pulsing of pumpage at New Jersey-American's nearby Passaic River well field. The Chatham Borough Water Department's wells were pumped as needed.

Acknowledgements

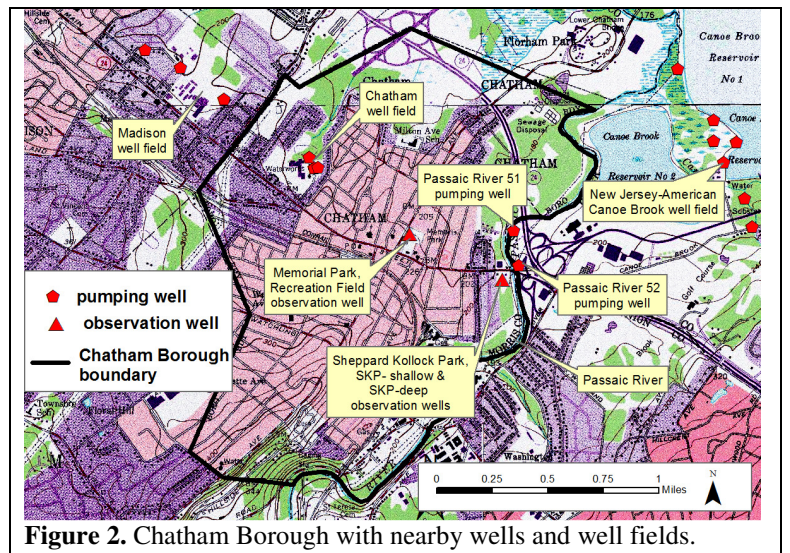
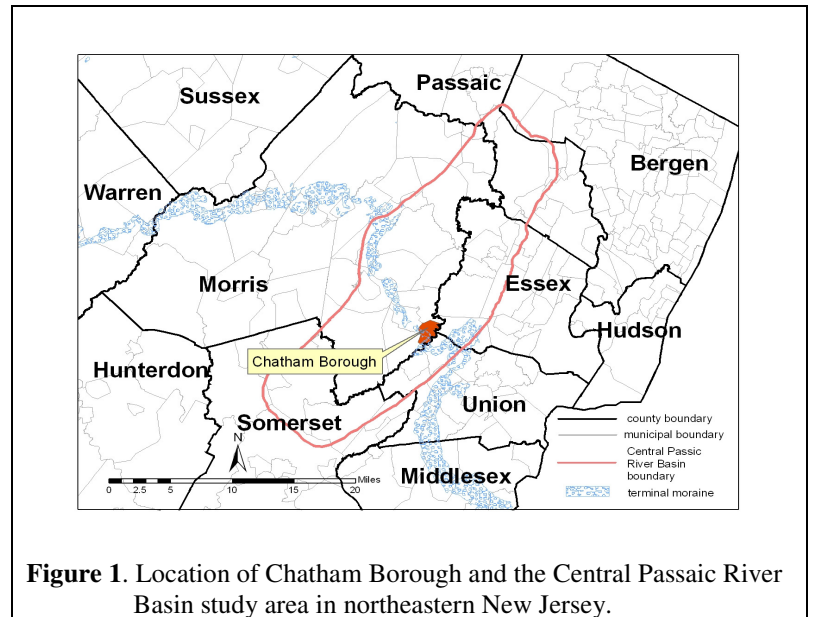
Many groundwater professionals assisted in the conduct of this aquifer test. Dave Travis and Mike Zack of the NJGWS drilled the Sheppard Kollock Park observation wells. Mark French, Ken Bacorn, Mike Zack, Jeff Waldner, and Jim Boyle of NJGWS installed and inflated the packer, installed water-level monitoring equipment, and recorded water levels. Herb Canon, Chatham Borough Engineer, assisted with selection of an appropriate

location and obtaining permission to drill the Sheppard Kollock Park observation wells. He also monitored Chatham's pumpage. Tony Tigre and Bill Osterly of New Jersey-American Water Company supervised the controlled withdrawals at their Passaic River well field.

Location

Chatham Borough is on the eastern edge of Morris County in northern New Jersey (fig. 1). Sheppard Kollock Park is on the eastern edge of Chatham Borough, adjoining the Passaic River (fig. 2). Memorial Park is near the center of Chatham Borough. The Chatham Borough Water Department wells are near the western border of Chatham Borough. The New Jersey-American Water Company's Passaic River well field is just east of Chatham Borough, in Millburn Township, Essex County. The Passaic River forms the boundary between Chatham Borough and Millburn Township. There are numerous other well fields in the area (fig. 2).

Chatham Borough is within the Central Passaic River Basin (CPRB). This area is defined by the crest of the Second Watchung Mountain on the north, east and south, and by the Ramapo Fault on the west. (fig. 3).



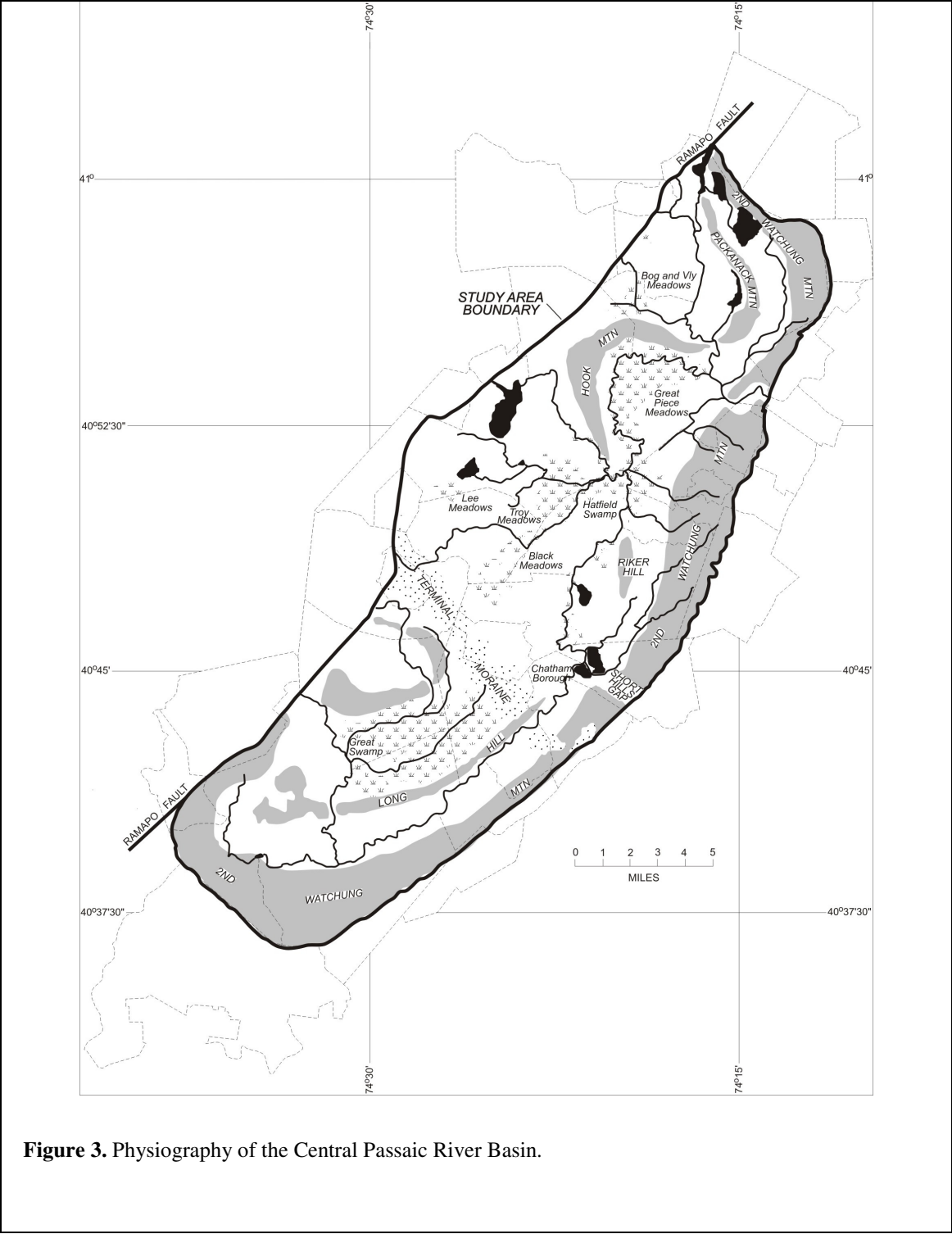


Figure 3. Physiography of the Central Passaic River Basin.

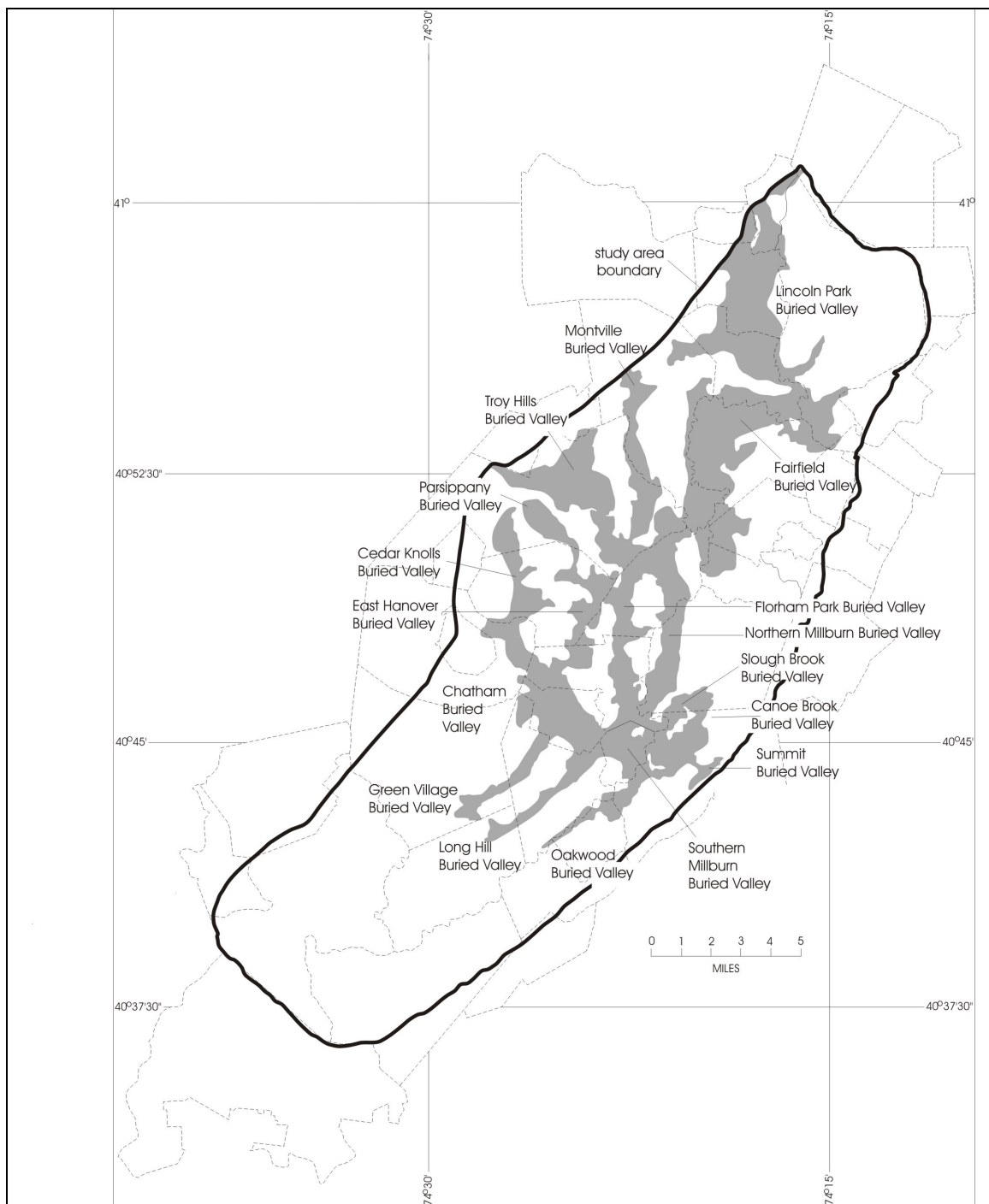


Figure 4. Buried valleys in the Central Passaic River Basin

Geology and Hydrogeology

The following discussion of the bedrock and surficial geology of the Central Passaic River Basin (CPRB) is a summary. More detail on the bedrock geology is in Drake and others (1996). Surficial geology is described by Stone and others (2002).

The bedrock surface retains the imprint of a pre-glacial drainage pattern that slopes generally southeast towards the Short Hills Gap in Millburn Borough (fig. 3). The pre-glacial Passaic River is presumed to have exited the CPRB through gaps there in the Watchung Mountains at Millburn. These bedrock depressions are termed ‘buried valleys.’ Figure 4 shows buried valleys throughout the Central Passaic River Basin. Figure 5 shows the buried valleys in the Chatham Borough area.

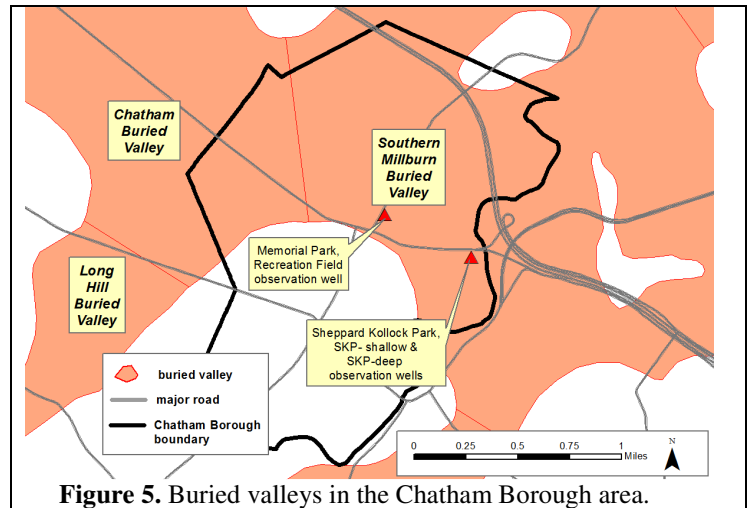


Figure 5. Buried valleys in the Chatham Borough area.

Bedrock in the Central Passaic River Basin (CPRB) consists of alternating layers of sedimentary rocks (primarily claystone, shale, siltstone and sandstone) with igneous basalt (table 1). These formations are part of the Brunswick group of the Newark Supergroup. The sedimentary units are much better water producers than the basalt units which are not normally considered to be aquifers.

Bedrock under the western portion of Chatham Borough consists of the sedimentary Boonton Formation (fig. 6). The igneous Hook Mountain Basalt underlies the center of Chatham Borough and the sedimentary Towaco Formation the eastern portion.

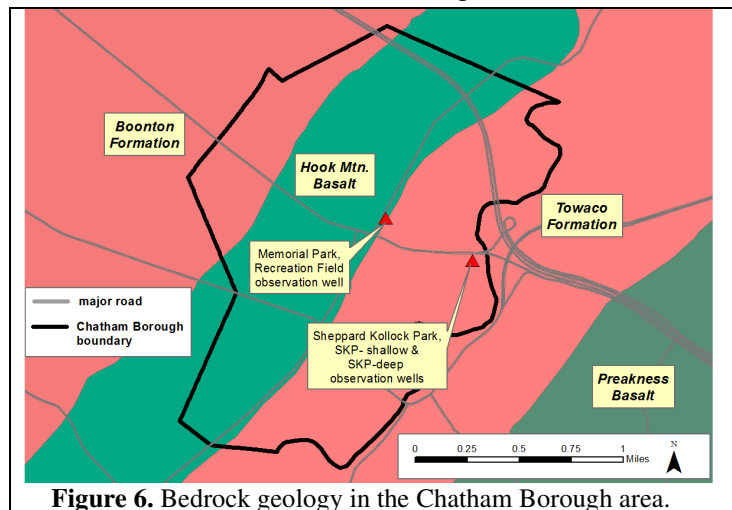
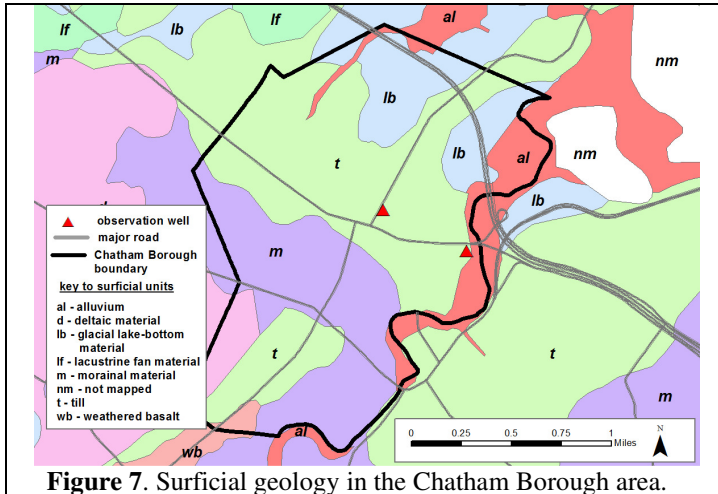
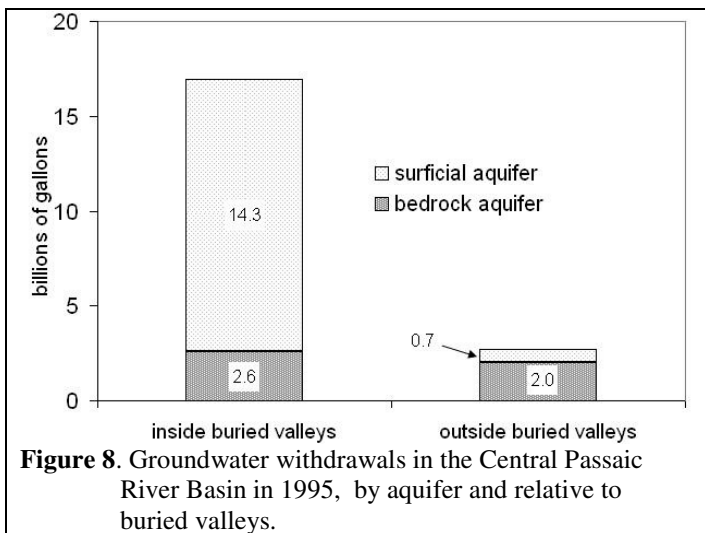


Figure 6. Bedrock geology in the Chatham Borough area.



Surficial sediments in the CPRB are primarily glacial in origin left during the advance and retreat of the Wisconsin glaciation (fig. 7). The buried valleys in the Chatham Borough are filled by fluvial sand and gravel deposited as the Wisconsin glacier advanced southward. They are covered by fine-grained lacustrine material and by glacial till. The higher elevations are either morainal material or till deposited on bedrock

highs. The terminal moraine, which crosses the southern portion of Chatham Borough marks the southernmost extent of the Wisconsin glaciation (fig. 3, fig. 7).



The fluvial sand and gravel deposits in the buried valleys are commonly referred to as the buried-valley aquifer. This is an extremely productive unit. In 1995 it supplied 14.3 billion gallons, or 73%, of the 19.6 billion gallons of water withdrawn in the CPRB (fig. 8). Unconsolidated units outside of the buried valleys supplied only 0.7 billion gallons (4%) (Hoffman and Quinlan, 1994).

Observation Wells

The NJGWS installed two observation wells at the northern end of Sheppard Kollock Park in Chatham Borough, Morris County, NJ in December 1990 (fig. 9). The wells are located about 20 feet apart.

The first, called SKP-shallow, is 136' deep. It is screened from 124-134' below land surface and taps the buried-valley aquifer. At this location the buried-valley aquifer is termed the Southern Millburn buried valley and is 24' thick starting 120' below land surface.

The second, called SKP-deep, is 241 feet deep. The well casing extends a total of 189 feet below land surface. The bottom 52 feet of the well consists of open hole. Competent bedrock was encountered at a depth of 144 feet at the site. Thus the well casing extends a total of 45 feet into the bedrock. The observed water level in this well is an average of the water level in the aquifer along the well length.

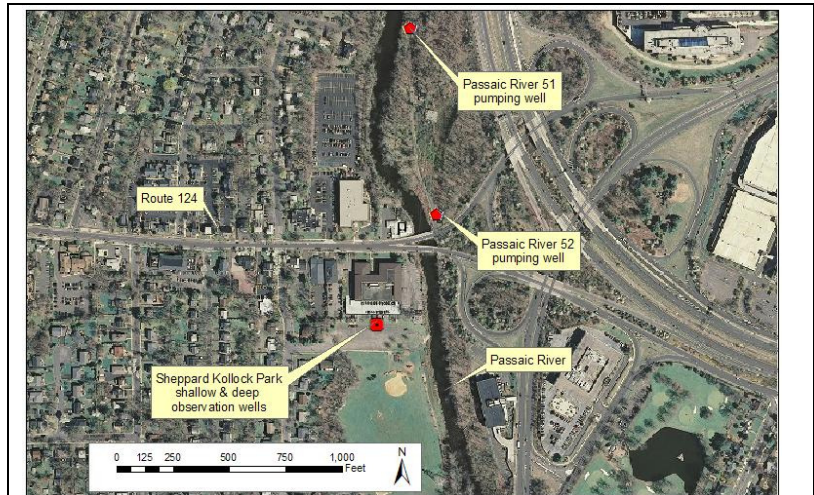


Figure 9. Sheppard Kollock Park with nearby wells and 2007 imagery.

Table 2 presents compiled data from well construction and geologic logs for these two observation wells in addition to data for nearby production and observation wells. The land surface elevation at the site is approximately 200 feet above mean sea level. The top of casing for both wells was surveyed relative to a nearby fixed point. For the purposes of this analysis, the elevation of the casing top of SKP-deep was assigned to be 200.28 feet above mean sea level (MSL) and that of SKP-shallow to be 201.13 feet above MSL. All observed depth-to-water measurements were subtracted from these elevations to produce the elevation of the groundwater surface in the well for analysis purposes.

The U.S. Geological Survey (USGS) maintains observation wells in the CPRB. Their Recreation Field observation well is in Memorial Park near North Passaic Avenue (fig. 10). It was installed in 1967 and is 197 feet deep. It is screened at a depth of 140-150 foot depth in the unconsolidated sand and gravel of the buried-valley aquifer. This well is approximately midway between Chatham Borough's well field and Sheppard Kollock Park. Water levels were measured in this USGS well in order to determine what effects, if any, Chatham's three production wells had on observed groundwater levels at Sheppard Kollock Park during the aquifer test.

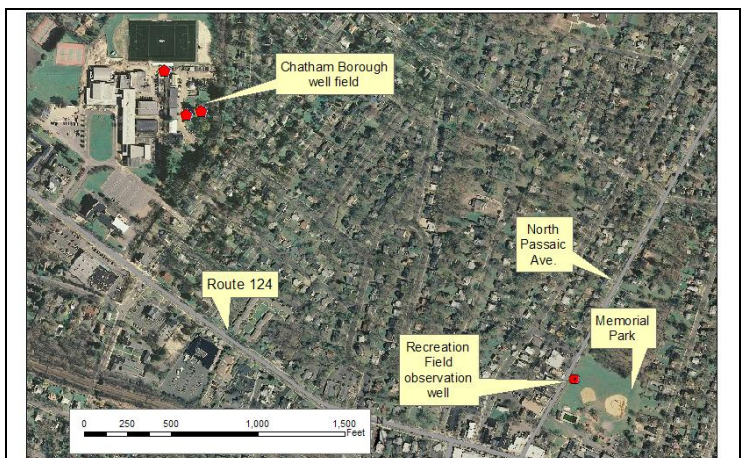


Figure 10. Memorial Park with nearby wells and 2007 imagery.

Table 1. Geologic column of the Central Passaic River Basin with stratigraphic descriptions and maximum thicknesses.

Era	System	Series	Time (million of years before present)	Stratigraphic unit (1)		Maximum thickness (feet) (2)	Older usage (3)	Lithology (1)	Aquifer
Cenozoic	Quaternary	Holocene	0.0-0.01	alluvial and marsh deposits (al)		20		sand, gravel, silt, mud and peat	SUR-
		Pleistocene	0.01-1.0	deltaic and lacustrine fan deposits (d)		200	stratified drift	sand and gravel	
				fluvial sediments (f)		30		sand and gravel	
				Lake-bottom sediments (l)		200		clay, silt and fine sand	IAL
				Morainal material (m)		100?	Terminal moraine	nonstratified silt, sand, gravel and boulders	
				till (t)		40	till	nonstratified silt, sand, gravel and boulders	
		~~~~~ major unconformity ~~~~~							
Mesozoic	Jurassic	Lower Jurassic	187 - 208	Newark Super Group	Boonton Formation (Jb)	1,640	Brunswick Formation	sandstone, siltstone, shale, conglomerate	BED- ROCK
					Hook Mountain Basalt (Jh)	361	3rd Watchung Basalt	basalt	
					Towaco Formation (Jt)	1,115	Brunswick Formation	Sandstone, siltstone, shale, conglomerate	
					Preakness Basalt (Jp)	984	2nd Watchung Basalt	basalt, intercalated sedimentary rock	
					Feltonville Formation (Jf)	1,969	Brunswick Formation	sandstone, siltstone, shale, conglomerate and limestone	
					Orange Mountain Basalt (Jo)	656	1st Watchung Basalt	basalt	
	Triassic	Upper Triassic	208 - 230	Brunswick Group	Passaic Formation (JTrp)	8,760	Brunswick Formation	sandstone, siltstone, shale, conglomerate	
~~~~~ major unconformity ~~~~~									
Proterozoic	Middle Proterozoic		900 - 1,600	granite (Ybh) gneiss (Ylo)		Unknown	Losee gneiss Byram gneiss	hornblende and biotite granite oligoclase-quartz gneiss	

Based on New Jersey Geological Survey 1990.

Notes: (1) Modified from Stanford and others, 1990; Lyttle and Epstein, 1987.

(2) Estimated maximum thicknesses for Cenozoic units apply only to the study area. Measured maximum thicknesses for Mesozoic units from statewide data (Lyttle and Epstein, 1987).

(3) The older usage for the Jurassic and Triassic units (Lewis and Kummel, 1912) is still in common usage but has been officially superseded (Lyttle and Epstein, 1987).

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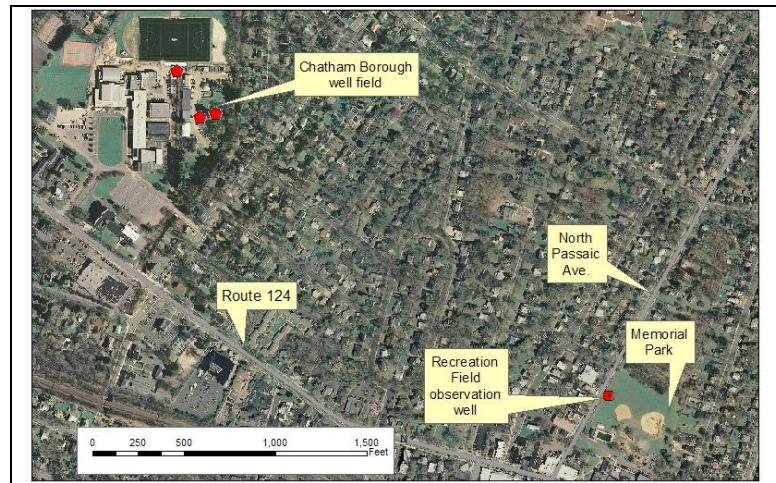


Figure 10. Memorial Park with nearby wells and 2007 imagery.

Table 2. Well information

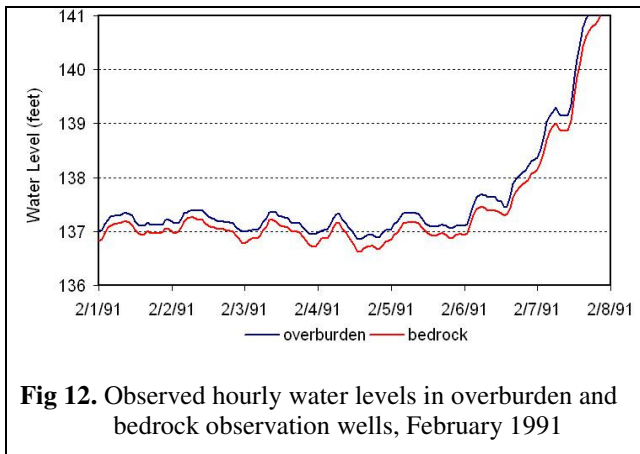
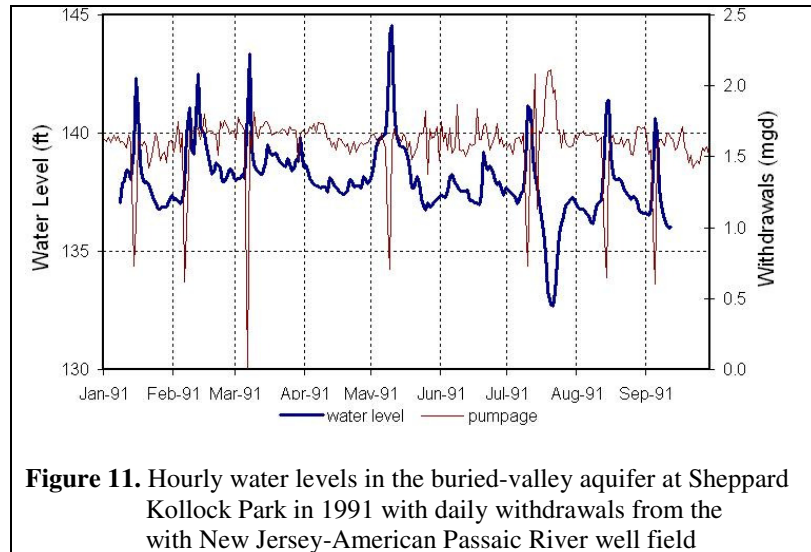
Well name	Permit Number	Date Drilled	Total Depth	Depth of Screened/ Open Interval	Aquifer ¹	Geologic Log
Sheppard Kollock Park (SKP)-deep	25-37620	12/06/1990	242	189-241	Towaco	0-15 fill, construction debris; 15-30 C gravel, angular, little sand; 30-40 C gravel, more F sand; 40-60 gravel decreasing w/ depth, some clay showing in wash; 60-75 tight clay, big clay balls in wash; 75-85 tight clay, some gravel; 85-90 interbedded clay, gravel; 90-105 gravel fining downward, some silt; 105-110 less gravel more sand, silt; 110-120 silt, little gravel; 120-135 well sorted gravel, sand; 135-144 gravel, some shale chips; 144-155 red shale, siltstone, soft; 155-160 red siltstone; 160-165 red siltstone w/ clay seams, weathered; 165-170 brown siltstone, 170-241 red siltstone & shale
Sheppard Kollock Park (SKP) - shallow	25-37544	12/14/1990	136	124-134	Qsd	Do.
Passaic River 51	25-04873	09/08/1955	121.5	84-124	Qsd	0-1 top soil; 1-8 brown silt, clay; 8-18 sand stone, large rocks; 18-21 sand stone, gravel; 21-24 brown sand, gravel; 24-46 brown clay; 46-63 brown, red clay; 63-74 red clay; 74-79 sand stone, gravel; 79-92 C brown sand, gravel, some stones; 92-122 C sand, gravel; 122-124 red, gray clay, sand; 124-127 weathered rock.
Passaic River 52	25-18486	--	--	--	Qsd	No log
Chatham Production Well # 3	25-05687	11/05/1956	150	94-150	Qsd	0-4 fill; 4-20 sand, clay, stones, gravel; 20-25 hardpan, large stones; 25-27 sand, gravel; 27-87 clay, sand, boulders, gravel, hardpan; 87-95 FC sand; 95-105 C sand, large & small gravel; 105-149 C sand, gravel, small boulders; 149-150 hardpan, boulders.
USGS Recreation Field Observation Well	25-14164	01/27/1967	197	140-150	Qsd	0-38 till, silty, sandy, pebbly, boulders from 0-20 (brown); 38-42 M sand, well sorted; 42-62 clay, silty & silt, clayey, laminated, brown; 62-73 MC sand, well sorted; 73-76 silt, clayey, brown; 76-98 MC sand, w/ little F gravel, well sorted in part; 98-110 clay, silty, w/ some F sand below 105, brown; 110-120 sand, vF to vC, w/ F gravel, poorly sorted; 120-161 MC sand to F gravel, poorly sorted in part, silty. 161-191 till?, sandy, silty, pebbly, compact, brown 191-193 sandstone, red/brown, unweathered 193-197 shale, red/brown, unweathered.

1. Qsd - overburden stratified sand-and-gravel buried-valley aquifer
Towaco - Towaco Formation bedrock aquifer

Pretest Water Levels

NJGWS staff installed automatic monitoring equipment in the two Sheppard Kollock Park observation wells. This equipment measured water levels at hourly intervals from January to September 1991.

Figure 11 shows water levels SKP-shallow along with daily withdrawal volumes from the nearby New-Jersey American's Passaic River well field (wells PR51 and PR52) for the period January to September 1991. The inverse correlation between water levels and pumpage show that SKP-shallow is in the cone of influence of the Passaic River well field.



shows this relationship using data only from during the first week of February 1991, for graphical clarity.

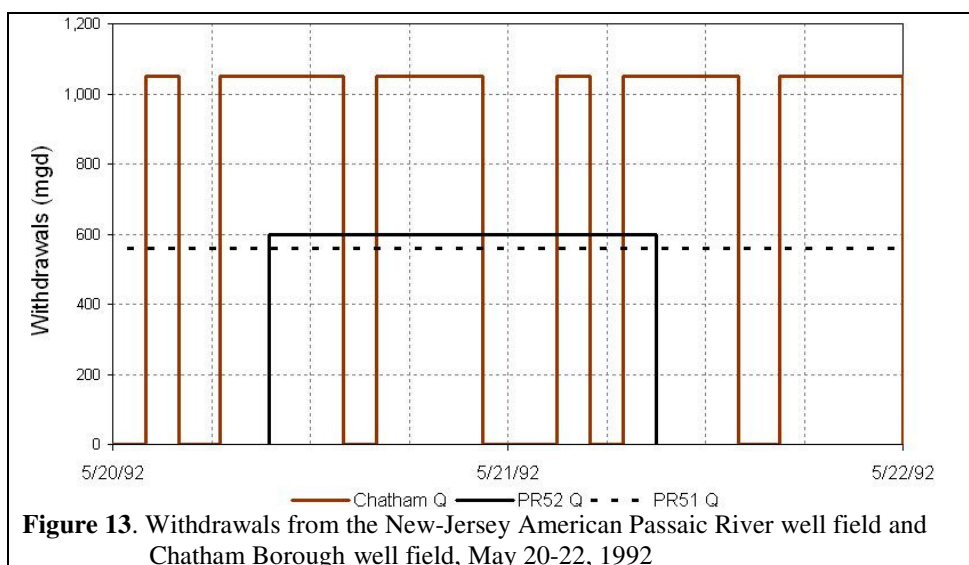
SKP-deep is open to the bedrock aquifer from 189 to 244 feet below land surface. The reported water level in this well is an average of the water level in the bedrock aquifer over this depth range.

Additionally, overburden and bedrock water levels are correlated as shown by hourly measurements over the period January to September 1991. Water levels in SKP-shallow are consistently 0.2 to 0.3 feet higher than in SKP-deep but both fluctuate simultaneously in response to nearby withdrawals. This relationship shows that the bedrock and buried-valley aquifers are in hydraulic connection, with a slight downwards gradient. Figure 12

Test Procedure

The May 1992 aquifer test was designed to determine aquifer properties and to investigate the vertical hydraulic connection between the overburden buried-valley aquifer and the bedrock aquifer at Sheppard Kollock Park. The test consisted of a 24-hour back-ground period, a 24-hour pumping period, and a 24-hour recovery period. It ran from 9 AM on Tuesday, May 19, 1992 to 9 AM on Friday, May 22, 1992. The test was run with the assistance of the New Jersey-American Water Company (NJAWC) and the Chatham Borough Water Department (CBWD).

NJAWC closely controlled pumpage from its two production wells in the Passaic River well field throughout the 72 hours. For the entire length of the test the PR51 was pumped at a rate between 550 and 660 gallons per minute. NJAWC tried to keep pumpage steady



at 560 gpm and this is the pumpage assumed by this analysis. PR52 was turned on at 9:31 AM on 21 May 1992 at an initial rate of 600 gpm (table 2, fig. 13).

Table 3. Withdrawal times and volumes

Owner & Well Field	Well	Q (gpm)	Withdrawal Date & Time ¹	
			On	Off
Chatham Borough Water Department	Combined well field	1,050	5/20 02:00	5/20 04:00
			5/20 06:30	5/20 14:00
			5/20 16:00	5/20 22:30
			5/21 03:00	5/21 05:00
			5/21 07:00	5/21 14:00
			5/21 16:30	5/22 00:00
			5/22 04:00	5/22 12:00
New Jersey-American Passaic River well field	51	560	5/19 09:00	5/23 09:00
	52	600	5/21 09:31	5/22 09:00

1. All dates in May, 1992. Times given in military time format.

The pumping rate varied over the next 24 hours from 550 to 620 gpm. (Exact pumping rates and times were not reported, only the extremes of volume.) A value of 600 gpm was assumed to represent the average pumpage. PR52 was turned off at

approximately 9:00 AM on 22 May 1992.

During the entire aquifer test CBWD pumped its wells to meet normal operating demands (table 3, fig. 13). The CBWD well field consists of three wells located within 300 feet of each other. Their joint impact on the observation wells is assumed to be accurately simulated by a single well located at the centroid of the well field. This is not considered to be a significant source of error in this study.

Other wells in the area operated normally during the aquifer test. NJAWC withdrew water from its Canoe Brook well field, about 6,000 feet from Sheppard Kollock Park. The East Orange Water Department operated normally its well fields in the area, Canoe Brook (~11,000 feet from Sheppard Kollock Park), Slough Brook (~10,000'), Braidburn (~11,000') and Dickinson (~9,000') (fig. 2). Pumpage at these well fields was not recorded due to their distance from the Sheppard Kollock Park wells.

Table 4. Distances from Observation Wells to Pumping Wells

From	To	Distance (feet)
	Passaic River 52	560
Sheppard Kollock Park observation wells	Chatham Borough well field	5,300
	Recreation Field observation well	2,750
Recreation Field observation well	Passaic River 52	2,800
	Chatham Borough well field	2,630
	Sheppard Kollock Park observation wells	2,750

A series of bedrock wells about 4,000 feet southwest of Sheppard Kollock Park was operated at that time by the Ciba-Geigy corporation. They reportedly pumped their wells at a constant rate of about 500 gpm throughout the aquifer test. Further information on pumpage times was not available.

A packer was installed in SKP-deep and pressurized on May 19. The 10-foot long packer was located from 210 to 220 feet below land surface. Thus there was approximately 20 feet of the well bore open to the aquifer above the packer and 21 feet below the packer. This packer created a block in the well and prevented the vertical movement of water. Thus it created isolated zones above and below the packer. Water-level monitoring instrumentation, attached to automatic data recorders (ADRs) were installed both above and below the packer. Water levels both above and below the packer could also be measured manually.

The packer deflated overnight due to a technical problem. It was reinflated on May 20 at 9:21 AM. Due to coordination issues the pumping test could not be significantly delayed. Pumpage from PR52 began at 9:32 AM on May 20.

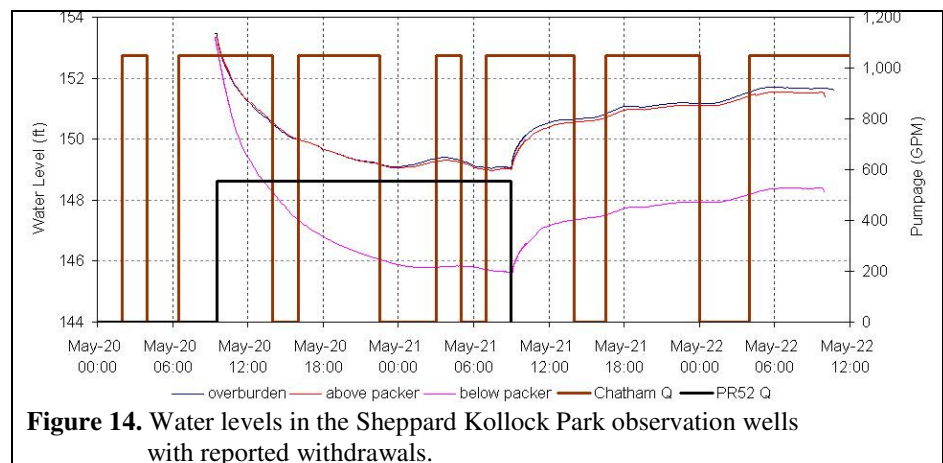
An ADR attached to water-level monitoring instrumentation was also installed in SKP-shallow well on May 19. Water levels were observed in this observation well throughout the 72-hour test.

Sheppard Kollock Park Observed Water Levels with Analysis

The aquifer test was designed to observe water levels in the overburden buried-valley aquifer, the upper bedrock zone, and a lower bedrock zone during background, drawdown, and recovery periods, each 24 hours long. A packer was installed in SKP-deep at the start of the background period to create two zones in

this well, upper and lower. Water levels in both zones were to be monitored with an automatic data recorder. Unfortunately, technical difficulties resulted in the packer deflating overnight in addition to the loss of background water levels from both the overburden and the bedrock wells. Due to coordination issues the pumping period could not be postponed. The packer was reinflated at 9:21 AM on May 21, about 10 minutes before pumpage began in the nearby PR52. The packer stayed inflated for the drawdown and recovery periods.

During the pumping period water levels in the SKP-shallow and both zones of SKP-deep were monitored by an ADR and manually. Observed water levels, with PR52 pumpage, are shown in figure 14.



Buried-Valley-Aquifer Water Levels

Water levels in SKP-shallow were affected by pumping at PR52. Water levels began to drop immediately once PR52 began pumping at the start of the pumping period. Total drawdown was about 4.5 feet 24 hours after the pumping began. Drawdowns in the overburden aquifer appear to have nearly stabilized.

At about 875 minutes into the drawdown test, water levels rose about six inches in SKP-shallow (fig. 14). This indicates a lessening of withdrawals at some nearby pumping source. About 1,100 minutes into the drawdown test, water levels again started to decline.

During the recovery period water levels in the SKP-shallow did not recover to levels seen at the start of the pumping period. Water levels appeared to have nearly stabilized in SKP-shallow about one foot lower than at the start of the test (fig. 14). This indicates the presence of a nearby pumping during the recovery period that was either not there at the beginning of the pumping period or had increased its withdrawal rate during the test. The available data do not allow a more definitive determination of a cause.

Figure 14 also shows withdrawals at the Chatham well field which is about 5,300 feet away from SKP-shallow. These reported withdrawals do not appear to be correlated with the unexplained water-level fluctuations in SKP-shallow.

The fluctuations in SHP-shallow show that either the withdrawals at PR51 and PR52 were not as steady as desired, or there is an unidentified pumping well nearby.

Due to these complications, only early-time drawdown data in SKP-shallow were analyzed in order to determine aquifer properties. During the early portion of the test it is assumed that drawdown due to withdrawals at PR52 overwhelm the effects of other, unidentified, withdrawals. Thus analysis of this early time data yields some useful data on aquifer properties.

Drawdowns in SKP-shallow in the first 875 minutes of the pumping period appear to be primarily due to withdrawals at PR52. Assuming the aquifer responds as a confined aquifer during this period of drawdown, estimated aquifer properties are 8,088 ft²/day with a storativity of .000785. Figure 15

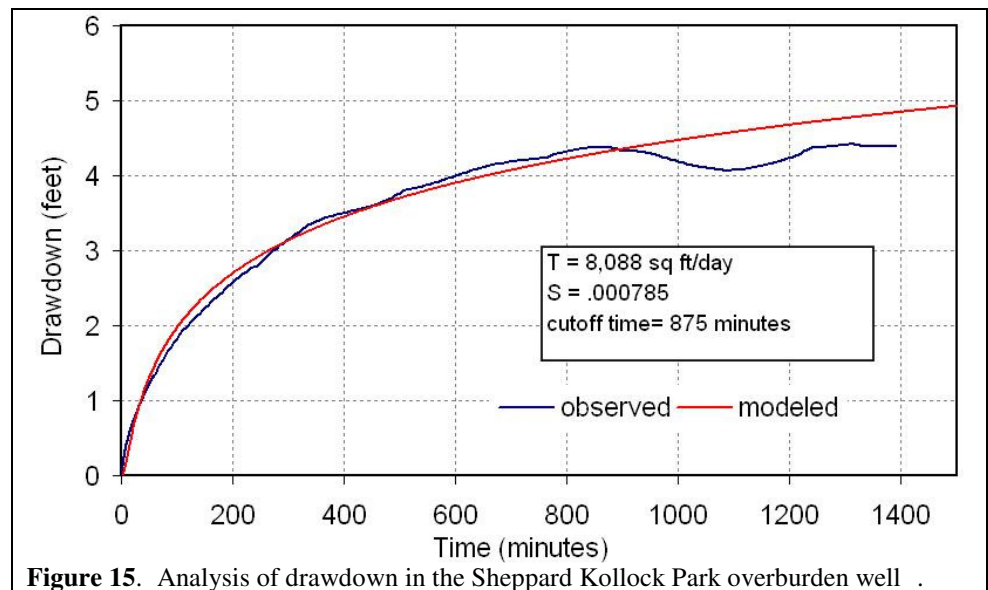


Figure 15. Analysis of drawdown in the Sheppard Kollock Park overburden well .

shows observed drawdown during the pumping period in SKP-shallow along with modeled drawdown assuming these aquifer properties.

This analysis does not account for the possibility of recharge to the aquifer. It also assumes the aquifer is uniform and of infinite areal extent. This is obviously an incorrect assumption because the overburden aquifer is found in relatively narrow buried valleys and boundary effects are to be expected. This complication was not considered in this analysis.

Bedrock-Aquifer Water Levels

Long-term monitoring in 1991 (fig. 12) showed that water levels in SKP-shallow were consistently a few inches higher than in SKP-deep. The May 1992 test was designed to investigate the possibility that there were different zones with different water levels in the bedrock aquifer.

The packer in the SKP-deep was inflated at the start of the background period. However, overnight it deflated. It was reinflated, to a pressure of 500 PSI, approximately 10 minutes before the pumpage began in PR52. This short lead time proved to be a significant limitation to the data analysis. Water levels below the packer did not come into equilibrium with the surrounding lower bedrock unit before the beginning of the pumping period. This means that the initial drawdown data from below the packer show the effect both of this equilibration process and drawdown due to PR52 pumpage. This complication means early-time drawdown data from the lower bedrock zone cannot be analyzed with accuracy using traditional approaches. Thus these data were not analyzed for aquifer properties.

Once the packer was reinflated, water levels in the upper and lower zones in SKP-deep diverged (fig. 14). Upper-zone water levels became practically identical to those in the SKP-shallow. The lower bedrock zone water levels fluctuated in unison with overburden water levels, but were consistently between 3 and 3.5 feet

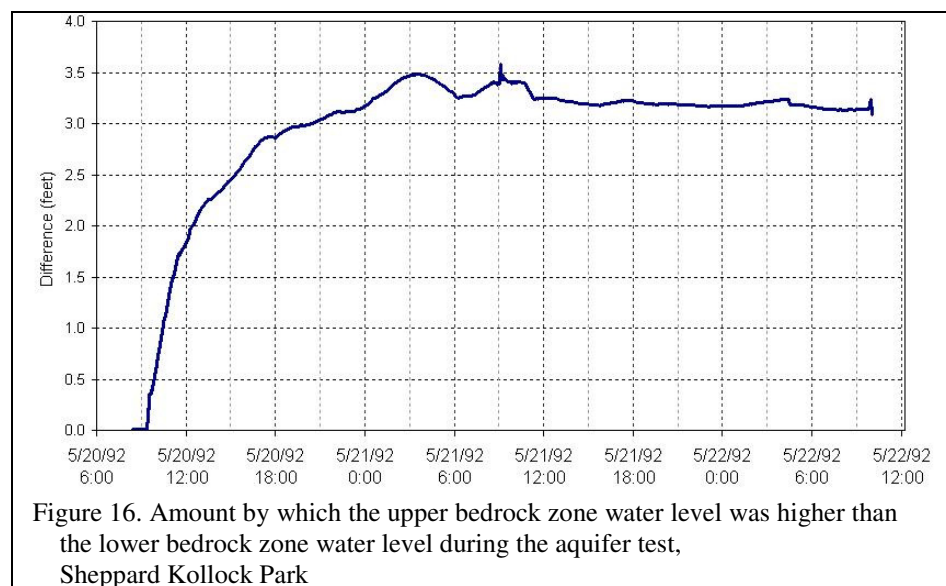


Figure 16. Amount by which the upper bedrock zone water level was higher than the lower bedrock zone water level during the aquifer test, Sheppard Kollock Park

lower (fig. 16). During the recovery test (after PR52 was turned off) the heads in the two bedrock zones recovered at nearly identical rates.

The downward gradient indicates that at this location groundwater travels from the upper portion of the aquifer down toward the lower. It also means that when no packer is present, SKP-deep itself acts as a conduit, with water flowing out of the upper bedrock zone in the well bore and then into the lower bedrock zone. The actual volume of water flowing is unknown since there are no data available on the relative ability of the upper and lower bedrock zones to transmit water.

Additionally, the response of water levels in SKP-deep makes it evident that the upper bedrock zone is in direct hydraulic connection with the semi-confined valley-fill aquifer at this location and that the two have nearly identical water levels.

Water levels in the deeper bedrock zone are lower, showing a flow of water down into the bedrock at Sheppard Kollock Park. These lower bedrock water levels also fluctuate in response to nearby pumping. The cone of depression in the buried valley aquifer, created by the NJAWC Passaic River wells, is mirrored in the bedrock aquifer. Thus at Sheppard Kollock Park the groundwater flow direction in the valley-fill aquifer is primarily toward the Passaic River well field but with a downward component, into the bedrock.

It is unlikely that drawdown observed in the bedrock at Sheppard Kollock Park is primarily due to pumpage from the bedrock because nearby bedrock production wells do not withdraw significant volumes of water. Withdrawals from the Ciba-Geigy wells approximately 3,500 feet southwest of Sheppard Kollock Park were 120 million gallons in 1990 (Hoffman and Quinlan, 1994). The next closest major bedrock pumping is from the East Orange Water Department's Slough Brook well field, also pumping from the Towaco unit of the bedrock aquifer, approximately 11,000 feet away. This well field produced 373 million gallons in 1990 (Hoffman and Quinlan, 1994).

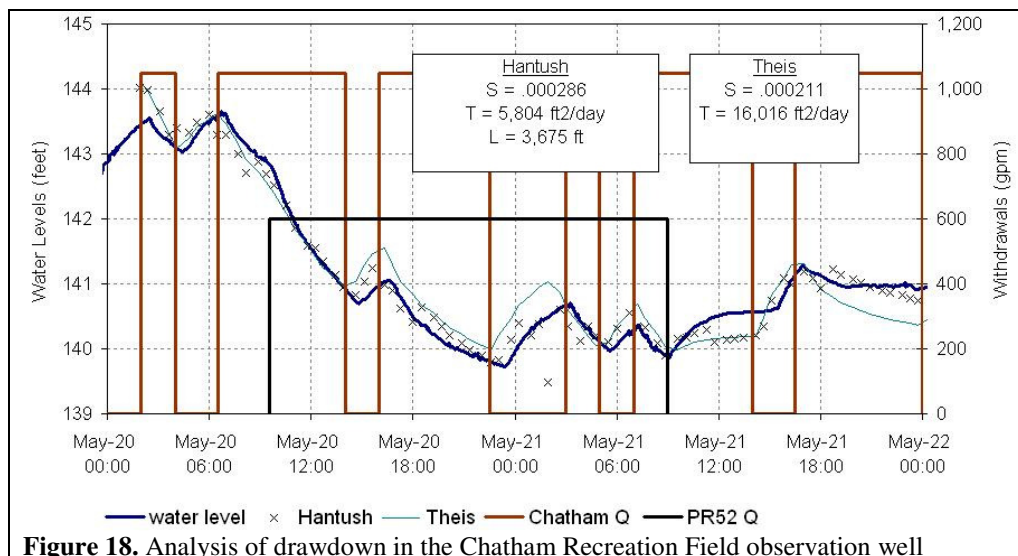
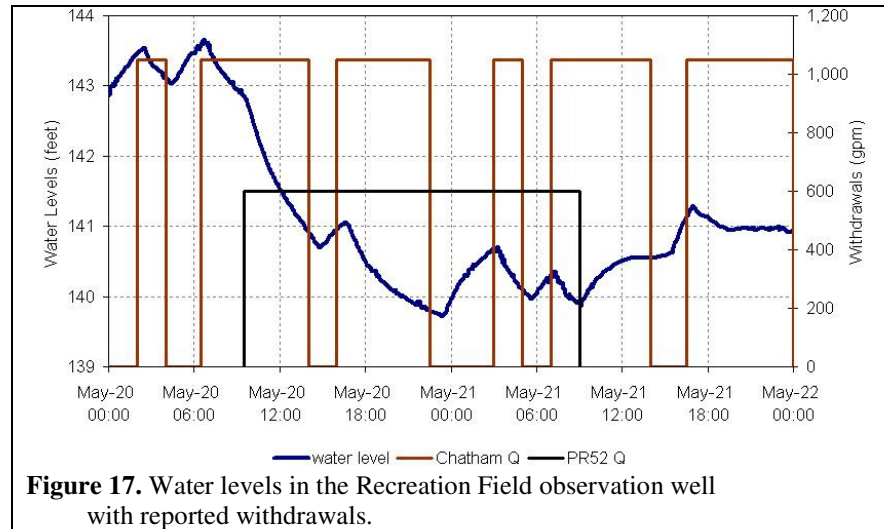
Memorial Park Observed Water Levels with Analysis

Water levels were recorded in the USGS Recreation Field observation well located in Chatham's Memorial Park during the background, drawdown, and recovery periods of the aquifer test. This observation well is located approximately half way between the Chatham Water Department well field and the Sheppard Kollock Park observation wells (fig. 2). An automatic data recorder measured water levels at two-minute intervals from 11:40 AM on May 19, 1992 until 11:04 AM on May 22, 1992 in this well. Observed water levels, and nearby withdrawals, are shown on figure 17. Distances from the production wells to the observation wells are shown in table 4. Reported pumpages in PR51, PR52 and the Chatham Borough well field are in table 3.

Drawdown in the Recreation Field well clearly shows the influence of multiple pumping sources. The New Jersey Geological and Water Survey developed an aquifer-test inversion program (called WFINV) to estimate aquifer properties using water-level data influenced by multiple

pumping wells with multiple pumping periods (James Boyle, NJGWS, written communication, 1992). The submitted aquifer data can be analyzed assuming the aquifer is either confined (using the Theis equation) or leaky (using the Hantush equation). In both cases, WFINV uses a Marquadt algorithm to optimize aquifer properties by fitting a generated drawdown curve to observed drawdowns. Where there is only one pumping well and one pumping period the solution defaults to the traditional Theis or Hantush approach.

Figure 18 shows the WFINV analysis results of water levels in the Recreation Field overburden observation well considering withdrawals at the Chatham Water Department Park and PR52.



If the aquifer is assumed to be confined, then a Theis solution results in a transmissivity estimate of 9,065 ft²/day and a storativity of 0.00149. The light blue line on figure 18 shows modeled water levels assuming these aquifer properties and the reported with-

drawals. If the aquifer is assumed to be leaky, then a Hantush solution results in an estimate of transmissivity of 5,804 ft²/day, a storativity of 0.00286, and a leakance of 3,675 feet. The 'x's on figure 18 shows estimated water levels assuming these aquifer properties and the reported withdrawals.

The Hantush analysis results in a generally better fit of simulated to observed water levels. The aquifer properties must be considered to be spatial averages for the area between the Chatham Water Department well field and the New Jersey-American Passaic River well field.

Conclusions

A 72-hour aquifer test has yielded information on the aquifers of eastern Morris and western Essex Counties, New Jersey. The test was divided into three 24-hour periods: background, pumping, and recovery. Water levels were observed in two wells in Sheppard Kollock Park in Chatham Borough, Morris County. The shallower well (SKP-shallow) is completed in a semi-confined glacial sand-and-gravel deposit that is located in a bedrock depression. Locally this deposit, and others in a similar setting, are termed buried-valley aquifers. The deeper well (SKP-deep) is located in the bedrock aquifer, the Towaco Formation. Drawdowns were also observed in a shallow observation well in Memorial Park, Chatham Borough. This well is called the Recreation Field well and also taps the buried-valley aquifer.

Pumpage was monitored at two pumping centers, both in the buried-valley aquifer. The New Jersey American's Passaic River well field consists of two production wells, PR51 and PR52. Withdrawals from PR51 were held roughly constant at a rate of 560 gpm during the background, pumping and recovery periods. PR52 was not pumped during the background and recovery periods, and was pumped at roughly 600 gpm during the pumping period. PR52 is about 560' from the Sheppard Kollock Park observation wells, and about 2,800' from the Recreation Field well. The Chatham Water Department withdraws water from three production wells located within 300 feet of each other. During the background, pumping and recovery periods these wells were pumped to meet demand at about 1,050 gpm. The centroid of this well field is about 5,300 feet from the Sheppard Kollock Park observation wells, and about 2,630 feet from the Recreation field observation well.

Aquifer properties are estimated based on the first 875 minutes of drawdown in SKP-shallow. This drawdown is due to withdrawals at PR52. A Theis analysis yields estimated transmissivity of 8,088 ft²/day and a storativity of .000785. Water levels during the background period were lost due technical difficulties. Only drawdown during the first 875 minutes of the pumping period were used due to unexplained water-level fluctuations.

Water levels in the Recreation Field observation well showed fluctuations that could be correlated to both to withdrawals at PR52 well (2,800 feet away) and the Chatham Water Department well field (2,630 feet away). An analysis program capable of handling multiple pumping wells and pumping periods was used to estimate aquifer properties based on water levels in this well. Estimated confined aquifer properties, using a Theis analysis, are a transmissivity of 9,065 ft²/day and a storativity of 0.00149.

If the aquifer is assumed instead to be leaky then a Hantush analysis of water level changes yields a transmissivity of 5,804 ft²/day, a storativity of 0.00286, and a leakance of 3,675 feet. Given the location of the observation well midway between two major pumping centers, the longer period of analysis and the greater likelihood that leakage affected the water levels, these aquifer properties are judged to better represent the regional aquifer properties.

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