INSTALLATION OF WELL 4
VILLAGE OF CROTON-ON-HUDSON
WELL FIELD
CROTON-ON-HUDSON, NEW YORK

April 1992

Prepared for

The Village of Croton-on-Hudson
Croton-on-Hudson, New York

Prepared by

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Geraghty & Miller, Inc. is submitting this report to The Village of Croton-on-Hudson for work performed at the Croton-on-Hudson well field. The report was prepared in conformance with Geraghty & Miller's strict quality assurance/quality control procedures to ensure that the report meets the highest standards in terms of the methods used and the information presented. If you have any questions or comments concerning this report, please contact one of the individuals listed below.

Respectfully submitted,

GERAGHTY & MILLER, INC.

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INTRODUCTION

The Village of Croton-on-Hudson retained Geraghty & Miller, Inc. to provide hydrogeologic consulting services in connection with the drilling, installation, development, and testing of a replacement production well in the Village's well field. At the same time, Geraghty & Miller was retained to design a pumphouse and associated piping for the replacement well. The installation of a replacement production well necessitated the modification of the Village's water supply permit, and Geraghty & Miller assisted the Village in this process. This report describes the work that was recently performed and presents recommendations for future management of the well field.

HYDROGEOLOGIC SETTING

The Village of Croton-on-Hudson well field extracts ground water from an accumulation of glacial deposits of sand and gravel that occur in the narrow V-shaped bedrock valley of the Croton River. Discontinuous layers of silt and clay are mixed with the coarser sediments. The steep walls of the valley are composed of fractured and faulted crystalline bedrock. The maximum thickness of the unconsolidated sediments is approximately 100 ft and the width of the valley floor ranges from 100 to 700 ft (Leggette and Jacob 1938). The well field is located within the broadest section of the valley, approximately 4,000 ft downstream from the New Croton Dam and spillway (Figure 1). Croton River is fed by the overflow at New Croton Dam and flows through the well field. The Croton well field aquifer is in direct hydraulic connection with the Croton River. The depth to ground water in the well field is generally about 5 ft below land surface, but fluctuates in response to the river stage and precipitation events.

PREVIOUS INVESTIGATIONS

Geraghty & Miller first evaluated the Village's ground-water resources in 1970 to assist the Village in planning for future water needs (Geraghty & Miller, Inc. 1970). The study included a review of a U. S. Geological Survey (USGS) 1938 report entitled "Report on the Water Resources of Croton Valley, New York below New Croton Dam," prepared by R. M. Leggette and C. E. Jacob (Leggette and Jacob 1938). Geraghty & Miller concluded in the 1970 report that the availability of ground water was likely to be greater than originally speculated by the USGS 1938 study and recommended various measures to improve the yield of the well field.

In 1988, Geraghty & Miller carried out investigatory work at the well field, including several tasks that had been recommended in 1970. An exploratory boring program was conducted in conjunction with the installation of piezometers to measure water-level drawdown during an aquifer test. To determine the hydraulic properties of the aquifer and also the true potential of Well 3, a controlled aquifer test was performed by pumping Well 3 at a rate of 1,328 gallons per minute (gpm) for 4 days. The pumping test data were used in a numerical computer flow model to predict the long-term performance of the aquifer under various pumping scenarios with normal precipitation conditions and also under severe drought conditions (Geraghty & Miller, Inc. 1988).

The model predicted that the aquifer has the capacity to sustain a yield of at least 5 million gallons per day (mgd) during periods of normal precipitation and stage in the Croton River. The model also estimated that during severe drought periods when no precipitation occurs and no water is flowing in the Croton River, the aquifer could produce 1.3 mgd for more than 1 month while maintaining ground-water levels above the well screens. Because no data were available, the computer model could not take into account underflow from New Croton Dam or upward leakage from the underlying bedrock; as such, Geraghty & Miller considers the model to be conservative.

WELL FIELD PUMPING SYSTEM

The Village withdraws between approximately 1.0 and 1.5 mgd from the well field (Table 1). The well field currently consists of three operational production wells, although, until recently, the Village had been obtaining its water supply from five wells: Well 1, Well 2, Well 3, Upper Well 1, and Upper Well 2 (Figure 2). The two Upper Wells were taken off line because of insufficient yields (Upper Well 1 is designated OW-1U on Figure 2). The three currently used wells are pumped on a rotating schedule to meet the variable water demands of the Village throughout the day. The existing production wells are described below.

Well 2 is a shallow dug well, 20 ft deep, that was installed in the early 1900s. The yield of Well 2 is highly dependent on the level of the water table because of its relatively shallow depth. In the early to mid-1960s, two deeper drilled wells were installed in the upper part of the well field to feed Well 2 (Upper Well 1 was 60 ft deep and Upper Well 2 was 68 ft deep). The water pumped from the two Upper Wells was piped directly to Well 2, from where it was then pumped into the distribution system. The original, reported combined pumping capacity of these three wells was 1.0 mgd. The two Upper Wells have reportedly declined in yield over time and in recent years have not substantively replenished Well 2. As indicated in Table 1, the monthly yield of Well 2, including the minimal contributions from Upper Well 1 and Upper Well 2, ranged between 0.6 and 8.8 million gallons during 1991. The maximum monthly pumpage (8.8 million gallons in May) corresponds to an average daily rate of approximately 0.3 mgd.

Well 3 was installed in 1967 and is 72 ft deep. A Kelly type screen, set from 44 to 72 ft below land surface, extends to the bottom of the unconsolidated deposits. During 1991, the monthly pumpage ranged from 4.8 to 16.5 million gallons; the maximum volume (16.5 million gallons during May) is equivalent to an average daily pumping rate of 0.5 mgd. The current productivity of the well is limited by the size of the existing pump, not by the well's capacity. In 1988, a 4-day aquifer test was performed by pumping Well 3 at a rate of

1,328 gpm, using a temporarily installed pump; the results indicated that Well 3 can yield as much as 1.5 to 2.0 mgd with a larger capacity pump (Geraghty & Miller, Inc. 1988).

Well 1 was installed in 1977 to replace Well 1A, which was a shallow-dug former production well identified as OW-1A on Figure 2. Well 1 is constructed with a stainless-steel screen set from 51 to 65.5 ft below land surface (Geraghty & Miller, Inc. 1978). Well 1 has declined in yield from its original capacity of 1.0 mgd to between 0.6 mgd and 0.7 mgd. Redevelopment efforts were carried out in April and May 1991; however, the efforts were unsuccessful in improving the yield (Geraghty & Miller, Inc. 1991). The maximum monthly pumpage from Well 1 during 1991 was 19.1 million gallons during December; this is equivalent to an average daily volume of 0.6 mgd.

SUMMARY OF WELL FIELD WATER SUPPLY PERMITS

The Village of Croton-on-Hudson has been issued a series of water supply permits for the well field by the New York State Department of Environmental Conservation (NYSDEC) dating back to 1910 (Behn, pers. comm. 1991). The most recent permitted withdrawal volumes are based on the pumping capacities of the wells. The Well 2 system, which consists of Well 2 plus the two Upper Wells, was permitted for a total of 1.0 mgd. Well 3 was permitted for 0.65 mgd, and Well 1 was permitted for 1.0 mgd. The total allocation for the well field is approximately one-half of the potential sustained yield of the aquifer during normal conditions that Geraghty & Miller had calculated as being 5 mgd using a computer model (Geraghty & Miller, Inc. 1988).

In 1990, the Village decided to replace the Well 2 system (including the two Upper Wells), with a new, more efficient well that would be piped directly into the distribution system. The Village applied to the NYSDEC for a Water Supply Permit Modification and also performed a State Environmental Quality Review of the proposed activities. It was determined that the proposed project would not have a significant impact on the environment. A permit was issued on January 22, 1991 (NYSDEC Permit # 3-522-123/1-0) for a replacement well with a capacity of 700 gallons per minute (gpm) (equivalent to 1.0 mgd), which equaled the combined permitted capacity of Well 2 and the two Upper Wells (NYSDEC 1991a). On August 21, 1991, the NYSDEC issued a permit modification authorizing up to 1,000 gpm (1.4 mgd) for the new replacement well to compensate for the 300-gpm (0.4 mgd) drop in the yield of Well 1 that had been identified during April 1991 (NYSDEC 1991b).

FIELD ACTIVITIES

The principal objective of the field activities was to develop an additional supply well within the Village of Croton-on-Hudson well field that would replace the two Upper Wells. R.E. Chapman Company of Oakdale, Massachusetts was selected by competitive bid as the drilling contractor. Geraghty & Miller provided oversight during the field activities.

ABANDONMENT OF UPPER WELLS

Upper Well 1 and Upper Well 2 were recently taken out of service because of the declined yields. The R.E. Chapman Company removed the pumps from both wells, converted Upper Well 1 into a monitoring well, and abandoned Upper Well 2. Upper Well 1 was modified to a monitoring well, designated OW-1U, by welding a lockable, water-tight, threaded, 6-inch diameter steel cover to the steel well casing. Upper Well 2 was filled from the bottom to land surface with cement grout.

DRILLING OF TEST BORING 8

An initial test boring, designated Test Boring 8, was drilled in the upper part of the well field, at the location shown on Figure 2. Test Boring 8 was located approximately 200 ft from the northern and western property boundaries of the well field. This location was selected to ensure that the Village would have control over activities occurring on the property within a 200 ft radius of the well, as specified by the Village Water Supply Protection Law, Croton-on-Hudson Code 223-15 through 223-20 (Croton-on-Hudson 1990).

During July 17 and 18, 1991, a surface casing was set to a depth of 30 ft below land surface, using the mud-rotary drilling method. During August 6 through 8, 1991, the cable-tool drilling method was used to drive an 8-inch diameter casing from a depth of 30 ft downward to the top of the bedrock. Bedrock was encountered at a depth of 78 ft below land surface. During the drilling from 30 to 78 ft, two types of sediment samples were collected at each 5-ft interval; one was an undisturbed sample collected with a split-spoon sampler and the other was a grab sample collected with a bottom-filling sand bailer. The sediment samples were described by a Geraghty & Miller hydrogeologist and placed in labeled jars.

The geologic log for Test Boring 8 indicated that the aquifer formation at that location was not likely to produce the quantities of water that had been anticipated. The geologic log for Test Boring 8 is included in Appendix A. R. E. Chapman Company performed sieve analyses of nine bailer samples and six split-spoon samples. The sieve results are included in Appendix B and indicate a high percentage of fine particles in the formation between 30 and 78 ft below land surface, confirming the field observations that the material would not be expected to have a high yield. The steel casing was later removed from the ground and the borehole was grouted to land surface.

DRILLING OF TEST BORING 9

After determining that the aquifer formation at the location of Test Boring 8 was not likely to produce the volume of water that the Village was seeking, Geraghty & Miller recommended that a test boring be drilled at another location within the well field. The geologic logs for the piezometers that had been installed during 1988 (Geraghty & Miller, Inc. 1988) were evaluated. Based on the presence of coarse sand and gravel and the reported loss of drilling water to the aquifer during installation, the location of Observation

Well OW-6 appeared promising. Therefore, Geraghty & Miller recommended that a test boring be installed adjacent to Observation Well OW-6. This location also met the well head protection requirements of being at least 200 ft from the property boundaries of the well field. A drilling location was selected 20 ft northeast of Observation Well OW-6 (Figure 2) where the ground surface was approximately 2 ft lower than at Observation Well OW-6 and in the general surrounding area.

Test Boring 9 was drilled between September 4 and 6, 1991 by driving an 8-inch diameter casing by the cable-tool drilling method until bedrock was encountered at a depth of 70 ft below land surface. Samples of the aquifer material were collected at 5-ft intervals and from each formation change, using a bottom-filling sand bailer. To confirm selected bailer samples, three split-spoon samples were also collected from the depth intervals of 48 to 50, 63 to 65, and 68 to 70 ft below land surface. The aquifer material appeared significantly coarser than at Test Boring 8; the material was less dense to drill through; and drilling water was lost to the formation. The samples were described and placed in jars by a Geraghty & Miller hydrogeologist. The geologic log for Test Boring 9 is included in Appendix A.

Sieve analyses were performed for nine sediment samples that had been collected with a bailer; the results are included in Appendix B. The results of the sieve analyses for Test Boring 9 confirmed the field observations during drilling that the formation material from 38 to 63 ft below land surface consists of coarse sand and gravel. The percentage of fine particles in Test Boring 9 is relatively low in comparison with the concentration of fines observed in Test Boring 8. Geraghty & Miller recommended installing a new production well at the location of Test Boring 9. The 8-inch diameter steel casing was pulled out of the ground in preparation for drilling the larger diameter borehole required for the production well.

WELL 4

The large diameter production well installed at the location of Test Boring 9 was designated Well 4.

Drilling and Installation

During September 23 and 24, 1991, Well 4 was drilled at the location of the borehole of Test Boring 9 using the cable-tool drilling method. A 30-inch diameter steel surface casing was driven to a depth of 30 ft below land surface and then a 24-inch diameter casing was driven inside of the 30-inch casing to a depth of 69 ft below land surface.

Well 4 was installed during three working days between October 25, 1991 and November 4, 1991. The well was constructed with a 20-ft section of 16-inch diameter, 100-slot, stainless-steel, wire-wrapped Johnson screen set from 43 to 63 ft below land surface. A 5-ft section of 16-inch diameter stainless-steel sump was welded to the bottom of the screen, and 45.6 ft of 16-inch diameter steel casing were welded to the top of the screen. The 16-inch diameter screen and casing were set with centralizers inside the 24-inch diameter casing to ensure accurate centering. The annular space between the 16-inch diameter screen and casing and the 24-inch diameter casing was filled with 0.125-inch to 0.250-inch gravel pack; after approximately 10 ft of gravel pack was emplaced, a 10 ft section of the 24-inch diameter casing was pulled up. Within the gravel pack, a 2-inch diameter PVC riser pipe was installed to provide access for water-level measurements. The bottom of the 24-inch diameter casing was set at 39 ft below land surface, and the top extended 2.6 ft above land surface. The gravel pack was brought up to land surface. The 16-inch diameter casing also was left with a stick-up of 2.6 ft for the well development and aquifer testing activities. After the well development and aquifer testing activities (described in the following sections) had been completed, 16-inch diameter and 24-inch diameter extension casings were welded to the well to extend the casings 11 ft above land surface.

This additional height was needed to bring the well head above the flood level of the well field. The construction details for Well 4 are shown on Figure 3.

Development

Well 4 was developed for 100 hours between November 5 and 14, 1991, using a cable-tool rig with a double surge-block and air lift pumping assembly. The surging action was applied to 8-ft long intervals of the well screen by moving the surge blocks up and down, similar to a piston in a cyiinder. The motion forced water in and out of the screen and removed fine particles from the aquifer around the well screen. The well screen was surged gently for the first 44 hours of development, at a rate of approximately 15 strokes per minute, more aggressively during the next 36 hours, at approximately 25 strokes per minute, and back to a more gentle pace for the last 20 hours.

To evaluate the effectiveness of the surging, the specific capacity of the well, measured in gallons per minute per foot of drawdown (gpm/ft), was calculated after surging an interval of the screen. The specific capacities were measured after 15 minutes of pumping with a centrifugal pump. Development improved the measured specific capacity from 13.8 gpm/ft to 31.3 gpm/ft. The depth of the gravel pack was also measured to monitor settling during development. Table 2 summarizes the development efforts.

Step-Drawdown Pumping Test

On November 19, 1991, a step-drawdown pumping test was conducted on Well 4 to evaluate the efficiency of the well and to select the optimal flow rate for a 3-day aquifer test. Two submersible pumps were installed in Well 4, and the well was constantly pumped at the following increasingly high rates: 280 gpm, 510 gpm, 700 gpm, and 900 gpm. The first three steps were each run 1 hour and the last step was run for 2 hours. The flow rates were measured with a 5-inch diameter orifice and a manometer. A valve was located on the discharge line to adjust the rates. Throughout the test, the water-level drawdowns in Well

4 were measured with an electronic water-level indicator (M-scope). The specific capacity was initially measured at 28.9 gpm/ft at the pumping rate of 280 gpm and decreased to 25.4 gpm/ft at the pumping rate of 900 gpm. Figure 4 presents the drawdown measurements and the calculated specific capacities for all four steps.

Aquifer Pumping Test

To evaluate the performance of Well 4 and to select an appropriately sized pump, a 3-day constant-rate aquifer test was carried out. Based on the data obtained from the step-drawdown pumping test, a pumping rate of 750 gpm was selected for the aquifer test of Well 4. The aquifer test was run for 73 hours from 9:00 a.m. on November 20, 1991 until 10:00 a.m. on November 23, 1991. Water-level measurements were measured throughout the test in Well 4 and in Observation Well OW-6, using submersible electronic pressure transducers, and were recorded with a Hermit Model SE1000B data logger. The data logger was programmed to record data at the following intervals: every second for the first half-minute; every 5 seconds from the first half-minute to 2 minutes, every 30 seconds from 2 to 10 minutes; every 2 minutes from 10 to 100 minutes; every 10 minutes from 100 to 1,000 minutes; and every 100 minutes from 1,000 to 4,300 minutes. The water-level measurements were frequently confirmed manually using an M-scope. The drawdowns measured by the pressure transducers are presented in Table 3. A semi-logarithmic plot of time versus the uncorrected drawdown measurements in Well 4 is presented on Figure 5. Figures 6 and 7 are logarithmic and semi-logarithmic plots, respectively, of time versus the drawdown measurements in Observation Well OW-6 that have been corrected for unconfined aquifer conditions.

To monitor water-level fluctuations throughout the well field, Observation Well OW-5, Well 1A, and the distributary of Croton River designated SW-1 on Figure 2, were equipped with continuous water-level recorders. Copies of the recorder charts are included as Appendix C. A synoptic round of water levels was collected from all water-level monitoring locations on a daily basis from November 18, 1991 through November 23, 1991 and on November 25, 1991; the measurements are presented in Table 4.

During the aquifer testing period, the production wells for the Village public water supply were pumping; the operating schedule for the well field from November 18 through 25, 1991 is shown in Table 5. Three precipitation events occurred during the aquifer test, starting after 32 hours of pumping. Table 6 presents the times of these events and the amount of precipitation that was measured for each event.

The flow rate of 750 gpm was measured using a 5-inch diameter orifice plate and a manometer, and the rate was maintained constant by adjusting a valve on the discharge line. To avoid recharging the aquifer in the area where drawdown measurements were being collected, the water that was withdrawn from Well 4 during the step-drawdown test and the 3-day aquifer test was discharged to the Croton River, approximately 250 ft from the pumping well. Water-level recoveries following the shutdown of the 3-day aquifer test were measured in Well 4 and Observation Well OW-6 with pressure transducers and recorded with a data logger from 10:00 a.m. on November 23, 1991 until 9:00 a.m. on November 25, 1991.

AQUIFER TEST ANALYSIS

The slopes of the drawdown curves of Well 4 and Observation Well OW-6 throughout the aquifer test do not show any significant effects from the irregular pumping of the other Village production wells. However, the impact on the water levels in the wells from the precipitation towards the end of the test is evident from the decreasing water-level drawdown. Only the early drawdown data prior to the observed impact of precipitation were evaluated in the analyses discussed below.

The data collected from Observation Well OW-6 during the 3-day aquifer test were analyzed to determine the hydraulic properties of the aquifer in the vicinity of Well 4.

These properties include transmissivity and specific yield. Because the aquifer is unconfined and the amount of drawdown observed in the monitoring well was sufficient to affect the analysis, the raw data were adjusted to obtain the true transmissivity using the following formula (Driscoll 1986):

$$s_t = s_a - \frac{s_a^2}{2b}$$

where

s_t = drawdown adjusted to its theoretical value, in ft

s_a = actual or measured drawdown, in ft

b = saturated thickness of the unconfined aquifer under nonpumping conditions, in ft

The corrected drawdown data from Observation Well OW-6 was analyzed using AQTESOLV, a computer program developed by Geraghty & Miller for use on personal computers. In this case, the data from Well 4 were analyzed using the Boulton delayed drainage method (Boulton 1963) and the Cooper-Jacob straight line method (Cooper 1946). In addition, the drawdown data from all the observation wells were analyzed using a distance-drawdown calculation.

BOULTON DELAYED DRAINAGE ANALYSIS

A logarithmic plot of the corrected time-drawdown relationship for Observation Well OW-6 was matched to a set of type curves developed by Boulton (1963) and later improved by Neuman (1975). Calculations of aquifer hydraulic properties were made using the following formula by Boulton:

$$s = \frac{114.6\ Q}{T} W(UA,\ UB,\ \beta)$$

where

W (UA, UB, β)	=	well function for water-table aquifers with fully penetrating wells having no storage capacity (dimensionless)
UA	=	$\frac{2693\ r^2\ S}{T\ t}$ applicable for small values of time (dimensionless)
UB	=	$\frac{2693\ r^2\ S_y}{T\ t}$ applicable for large values of time (dimensionless)
s	=	drawdown, in ft
Q	=	production well pumping rate, in gpm
T	=	coefficient of transmissivity, in gallons/day/ft (gpd/ft)
	=	radial distance from production well, in ft
S	=	storage coefficient (fraction)
t	=	time after pumping started, in minutes
Sy	=	aquifer specific yield (fraction)

Figure 6 illustrates the logarithmic plot for the time-drawdown relationship for Observation Well OW-6 and the calculated values of transmissivity and storage coefficient for the early time curve match and the specific yield for the late time curve match.

COOPER-JACOB STRAIGHT LINE ANALYSIS

The second analytical method used to calculate aquifer coefficients involved plotting the time-drawdown data on semi-logarithmic graph paper (Cooper 1946). The aquifer coefficient of transmissivity is calculated as follows:

$$T = \frac{264Q}{\Delta s}$$

where

T	=	coefficient of transmissivity, in gpd/ft
Q	=	pumping rate, in gpm
Δs	=	slope of the time drawdown graph expressed as the change in drawdown between any two times over one logarithmic cycle

The aquifer coefficient of storage is calculated as follows:

$$S = \frac{0.3Tt_0}{r^2}$$

where

S	=	storage coefficient
T	=	coefficient of transmissivity, in gpd/ft
t_0	=	intercept of the straight line at zero drawdown, in days
r	=	distance in ft from the pumped well to the observation well where the drawdown measurements were made

Figure 7 illustrates the semi-logarithmic plot for the time versus drawdown relationship for Observation Well OW-6 and the calculated values of transmissivity and storativity.

DISTANCE-DRAWDOWN ANALYSIS

The third analytical method used to calculate aquifer coefficients involved plotting, on semi-logarithmic graph paper, the distance-drawdown relationship for all the observation wells measured at approximately the same time during the test (Driscoll 1986). Because of the effects of precipitation towards the end of the test, the measurements collected at the end of 24 hours of pumping were used for the analysis. The aquifer coefficient of transmissivity is calculated as follows:

$$T = \frac{528Q}{\Delta s}$$

where

T	=	coefficient of transmissivity, in gpd/ft
Q	=	pumping rate, in gpm
Δs	=	slope of the distance-drawdown graph expressed as the change in drawdown between any two distances over one log cycle

The aquifer coefficient of storage is calculated as follows:

$$S = \frac{0.3\ Tt}{r_o^2}$$

where

S	=	coefficient of storage
T	=	coefficient of transmissivity, in gpd/ft
		time since pumping started, in days
r_o	=	intercept of extended straight line at zero drawdown, in ft

Figure 8 illustrates the distance-drawdown relationship for all the observation wells at the end of one day of pumping Well 4 and presents the calculated values of transmissivity and storativity.

Based on the analyses of the data described above, in the vicinity of Well 4, the aquifer coefficient of transmissivity ranges from 99,000 to 132,000 gpd/ft. These values are consistent with the type of geological materials encountered during the drilling programs conducted in the area. These values are lower than, although within the same order of magnitude as, the transmissivity values (ranging from 237,000 gpd/ft to 506,000 gpd/ft) that were calculated from the 1988 aquifer test using Well 3 (Geraghty & Miller, Inc. 1988). Because no confining units were identified during the drilling of Well 4, the aquifer is unconfined, as reflected by the calculated storage coefficients that range between 0.05 and 0.25.

WELL EFFICIENCY ANALYSIS

The efficiency of Well 4 was evaluated by analyzing the pump test data by two different methods. This evaluation indicated the well had an efficiency on the order of 33 percent. These results suggest that the well could be further developed to substantially increase the specific capacity, and thereby the yield.

Well 4 was developed using a double surge block and airlift assembly; the development continued until no further improvement could be discerned in the field. The double surge block and airlift technique is an accepted development technique with a proven track record in unconsolidated aquifers. However, the large range in grain sizes in the Croton aquifer may inhibit the effectiveness of this technique.

. It is possible that jetting, implemented by an experienced driller with proper equipment, could remove a greater percentage of the fine material from the aquifer in the immediate vicinity of Well 4 and thereby further enhance the specific capacity and yield of the well. Furthermore, if the specific capacity and yield of Well 4 declines with time, jetting should be given serious consideration as a redevelopment technique. Most production wells in unconsolidated aquifers show a decline in efficiency over time as pumping brings fine sediment from the formation inward toward the gravel pack and well screen. This process is accelerated if the well is turned on and off frequently; wells benefit by being pumped continually.

CRITERIA FOR PUMP DESIGN

The aquifer test data were evaluated to determine the maximum volume of water that can safely be withdrawn from Well 4. The safe yield of a well depends on the specific capacity of the well and on the amount of available drawdown. Specific capacity is a measurement of the productivity of a well and is defined as the pumping rate divided by the amount of water-level drawdown in the well. Well 4 had a specific capacity of 23.8 gpm/ft with the pumping rate of 750 gpm during the November 20 to 23, 1991 aquifer test.

The lower limit of the available drawdown is fixed by the well screen setting. The upper limit, defined by the water table, fluctuates in response to precipitation, the stage of the Croton River, and the impact from pumping the other production wells within the well field. The lower limit of available drawdown in Well 4 is 41 ft below land surface, which is 2 ft above the top of the well screen. A 2 ft interval is necessary to provide room for the pump intake and a safety factor so that air is not pulled through the pump and into the system.

The lowest measured static level of the water table in the vicinity of Well 4 (including measurements from adjacent Observation Well OW-6 prior to the installation of Well 4) was 7.65 ft below the top of the well casing (equivalent to 5 ft below land surface) on November 18, 1991. This water-level measurement was collected during a period of seasonally low water-table conditions. The water level is approximately 1 ft lower than the static level, because of the induced drawdown from the pumping of the Village production wells at the time of the measurement.

A limited amount of historic data on the natural fluctuations of the water table within the Croton-on-Hudson well field and on the lowest levels that occur during droughts is available. Geraghty & Miller recommends that the Village of Croton-on-Hudson Water Department initiate a weekly aquifer water-level monitoring program to document seasonal fluctuations. In the case of a drought, the Water Department will need to be vigilant in monitoring water levels in pumping wells.

To select an appropriately sized pump for Well 4, Geraghty & Miller assumed an available drawdown of 37 ft (the 41 ft low-water cutoff depth minus the 4 ft static water depth). With the specific capacity of 23.8 gpm/ft, Well 4 should be able to produce on the order of as much as 850 gpm during normal water-level conditions. The pump for Well 4 should be designed to be most efficient in the pumping range of 750 to 800 gpm, equivalent to approximately 1.1 mgd. The pump should also be capable of pumping at somewhat greater rates up to 900 gpm to provide flexibility to meet short-term needs, such as in the case of a fire.

To allow for the possibility of a significant lowering of the water table during drought periods, the pump to be installed in Well 4 should be capable of being decreased to a pumping rate of 600 gpm. It would also be advisable during droughts to distribute pumpage among several production wells in the well field to spread out water-level drawdowns.

WATER QUALITY

The water in the Croton-on-Hudson well field is enjoyed for its purity and agreeable taste. On November 22, 1991, a water sample was collected from Well 4 for the full set of analytical parameters required by Part 5 of the New York State Sanitary Code for public water systems, including volatile organic compounds, inorganic constituents, metals, and bacteria. The sample from Well 4 was collected 51 hours into the aquifer test. Geraghty & Miller collected the sample from a spigot at the well head, filled the appropriate laboratory-supplied bottles, and immediately delivered the sample bottles to the Westchester County Environmental Laboratories in Valhalla, New York. The results indicate that the water is of excellent quality and does not exceed any maximum contaminant levels established by the NYSDEC or the Westchester County Department of Health. The results are presented in Table 7 and the laboratory report is included in Appendix D.

SUMMARY

The aquifer that supplies ground water to the Village of Croton-on-Hudson well field has the capacity to provide more ground water than is needed to meet the current demands of the Village. The maximum daily pumpage is approximately 1.5 mgd and is extracted by pumping three wells on a rotating schedule. During 1991, the maximum average rates that each well was pumped at were as follows: 0.6 mgd from Well 1; 0.3 mgd from Well 2; and 0.5 mgd from Well 3.

The aquifer material in the vicinity of Test Boring 8 does not appear to have as high a permeability as other parts of the well field.

Based on the analysis of data collected from the aquifer test using Well 4, the aquifer material in the vicinity of Well 4 has an aquifer coefficient of transmissivity that ranges from 99,000 to 132,000 gpd/ft and storage coefficients that range from 0.05 to 0.25. These values are comparable to values previously determined for the aquifer.

A specific capacity of 23.8 gpm/ft was calculated for Well 4 at a pumping rate of 750 gpm. It is expected that Well 4 can sustain a yield of at least 750 gpm, equivalent to approximately 1.1 mgd, during normal hydrologic conditions.

Well 4 produces water of excellent quality that meets all water-quality standards established by the NYSDEC and the Westchester County Department of Health.

RECOMMENDATIONS

Based on these findings, Geraghty & Miller recommends the following:

1. A pump should be installed in Well 4 that can work at a maximum efficiency in the range of 750 to 800 gpm, is capable of producing as much as 900 gpm, and can be valved back to withdraw as little as 600 gpm.

2. The Village of Croton-on-Hudson Water Department should revise the pumping schedules of the production wells so that pumpage is at a continuous rate. Continuous pumpage is better for the pumps and the wells and uses less electricity than frequently turning them on and off. Wells 3 and 4 can provide the water needs of the Village, and Wells 1 and 2 could be available as supplemental resources when either Well 3 or Well 4 is out of service for repair or maintenance.

3. If a drought should lower water levels in the aquifer, pumpage should be distributed among all three of the deeper wells (Well 1, Well 3, and Well 4) to minimize the interference of water-level drawdowns. The Village of Croton-on-Hudson Water Department should also be careful to monitor water levels in pumping wells during periods of seasonally low water levels.

4. The well field water supply permit should be modified as follows: Well 4 should be permitted for its safe yield of 1.1 mgd instead of the anticipated 1.4 mgd yield; Well 2 should remain permitted as an operational well although, with the two Upper Wells now out of service, the current yield of Well 2 is approximately 0.3 mgd. The total allocation for the well field would remain at 2.65 mgd from the following water

supply sources: 0.6 mgd from Well 1, 0.3 mgd from Well 2, 0.65 mgd from Well 3, and 1.1 mgd from Well 4.

5. A data base that monitors the fluctuations in the static water levels within the aquifer should be developed. Once a week, for an indefinite period of time, the Village of Croton-on-Hudson Water Department should collect a depth-to-water measurement from Observation Well OW-5. Suggested procedures are provided in Appendix E.

6. A program should be implemented to systematically evaluate the performance of each production well. The Village of Croton-on-Hudson Water Department should measure the specific capacity of each operational supply well every 6 months. Specific procedures are provided in Appendix E. The jetting and airlift development method should be considered for future redevelopment efforts.

7. An application should be made to the NYSDEC to modify the well field permit to allow the installation of a larger capacity pump in Well 3. This application should be made under any of the following circumstances: if a new pump is installed to replace the existing pump; if the overall water demand of the Village increases; or if the capacities of the other wells diminish.

8. If the Village of Croton-on-Hudson seeks additional water resources, an exploratory program to evaluate potential ground-water resources within the bedrock that underlies the well field should be considered.

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