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Mr. Donald Ouellette, P.E.
Department of Public Works
Town Office Building
41 Cochituate Road
Wayland, MA 01778

Re: Final Report
Phase II Hydrogeologic Investigation
Happy Hollow Wells

Dear Mr. Ouellette:

AECOM Technical Services, Inc. (AECOM) is pleased to present the results of our Phase II Hydrogeologic Investigation of the Happy Hollow Wells. Our investigation consisted primarily of:

- The installation of eight monitoring wells and three hand-driven well points in March-April 2009 and three additional monitoring wells in May 2010;
- A seven-day pumping test of the Happy Hollow wells in June 2010;
- An evaluation of hydrogeologic data, including the preparation of geologic cross-sections and water-table contour maps; and
- Approximating the capture zone for the Happy Hollow Wells under quasi-steady-state conditions.

Well Installation

AECOM contracted with Boart-Longyear Company of North Reading, MA to install eight monitoring wells, and three hand-driven well points in March and April 2009. The monitoring wells, labeled MW-1 through MW-8, were installed using a "cable-tool rig" by driving 2.5-inch diameter threaded/coupled steel well casing and washing out soil from inside the casing with a one-inch diameter steel wash rod (see Table 1 for construction details). Soils were classified in the field, and representative samples were jarred. Four of the monitoring wells were finished with 1.5-inch diameter PVC casing and screen, with a section of 2.5-inch diameter steel well casing left-in-place as a guardpipe. The remaining monitoring wells were installed as conventional 2.5-inch diameter test wells, with stainless steel well screen. Water used to drill the wells was obtained from a Wayland Water Department hydrant near the Happy Hollow Wells. In addition, all wells were chlorinated at the conclusion of drilling. These steps were to taken to minimize the potential for introducing bacteria into the aquifer. Well Logs are in Appendix A.

The three 1.25-inch diameter drive points, labeled DP-1 through DP-3, were driven by hand in the wetlands adjacent to the Happy Hollow Wells (see Table 1 for construction details). At the time of their installation, there were several inches of standing water at each drive point location. Each drive point was constructed of a five-foot section of galvanized steel and two-foot-long stainless steel well point. The soils at each location were determined by drilling a two-inch diameter auger hole several feet from each drive point. The auger holes were backfilled with bentonite to close any hydraulic connection that the borehole might have created between the surface water and groundwater.

AECOM determined the locations of each well and drive point with a hand held Global Positioning System (GPS) unit. AECOM contracted with Schofield Brothers of Framingham, MA to determine well elevations. Elevations are referenced to mean sea level (National Geodetic Vertical Datum of 1929).

AECOM contracted with F.G. Sullivan Drilling Co. to install three shallow monitoring wells in May 2010. These wells, labeled MW-1S, MW-2S and MW-5S, were installed above the clay layer two feet from existing monitoring wells MW-1, MW-2 and MW-5, respectively. The shallow wells were intended as a means of observing shallow groundwater flow conditions. The shallow wells are all constructed of 1.5" diameter PVC with a section of 2.5-inch diameter steel well casing for protection. The Town of Wayland determined the elevations of these three shallow wells relative to NGVD 1929. Table 1 summarizes construction details for the shallow wells.

AECOM incorporated three additional groundwater monitoring wells into the monitoring network: SH-2, SH-3 and SH-4. The primary purpose of these wells, installed in 2009 by Sanborn-Head, is to monitor the groundwater quality for the High School leaching fields.

Seven-Day Pumping Test

With the assistance of the Wayland Water Department, AECOM conducted a seven-day pumping test in June 2010. The ultimate goal of the pumping test was to approximate the capture zone of the Happy Hollow wells under normal pumping conditions. Water levels during the pumping test (and the preceding recovery period) were measured manually, normally twice daily, using an electronic water-level probe. In addition, water-level data loggers were installed in the "Test Well", IEP-B3, IEP-B1, MW-2 and MW-6 for automated reading.

At 1 p.m. on June 2, 2010, both Happy Hollow wells were taken out of operation and AECOM/Wayland began measuring water-level recovery in the monitoring wells. Water-level recovery measurements continued until June 7, when water levels reached static groundwater conditions (see Figure 1). Static conditions refer to natural groundwater flow conditions, unaltered by man-made influences, such as the pumping of wells.

TABLE 1
MONITORING WELL CONSTRUCTION DETAILS
HAPPY HOLLOW WELLS
WAYLAND, MASSACHUSETTS

Well ID	Well Type	Distance (feet) from Happy Hollow Well 1	Elevation, Top of Casing/PVC	Elevation, Ground Surface	Depth of Screened Interval (ft bgs)
MW-1	2.5" steel	880	123.84/NA	122.3	67-73
MW-1S	1.5" PVC	880	124.06/124.06	122.3	5-8
MW-2	2.5" steel	570	128.22/NA	125.2	60-63
MW-2S	1.5" PVC	570	127.58/NA	125.2	4-9
MW-3	1.5" PVC	1,270	137.35/137.43	134.4	32-42
MW-4	2.5' steel	920	130.90/NA	129.6	41-47
MW-5	2.5" steel	435	124.93/NA	121.2	70-74
MW-5S	1.5" PVC	435	123.65/NA	121.2	3-8
MW-6	1.5" PVC	245	124.51/124.58	122.2	60-65
MW-7	1.5" PVC	645	145.12/145.11	141.4	50-55
MW-8	1.5" PVC	1,215	130.45/130.53	127.4	50-60
IEP B-1S	2" PVC	485	134.27/133.62	132.1	18-28
IEP B-1M	2" PVC	485	134.37/133.82	132.4	38-48
IEP B-1D	2" PVC	485	134.30/134.13	132.3	55-65
IEP B-3S	2" PVC	340	130.63/130.00	127.9	15-25
IEP B-3M	2" PVC	340	130.07/128.69	127.3	38-48
IEP B-3D	2" PVC	340	130.18/128.64	127.8	65-75
Test Well	2.5" steel	110	124.17/NA	122.9	35 +/-
DP-1	1.25" steel	180	119.61/NA	116.1	3-5
DP-2	1.25" steel	175	117.39/NA	114.0	3-5
DP-3	1.25" steel	375	116.44/NA	113.2	3-5
SH-2	2" PVC	1,400	NA/153.21	153.3	35-45
SH-3	2" PVC	1,430	NA/130.15	130.2	20-25
SH-4	2" PVC	1,230	NA/130.71	130.7	20-25
Happy Hollow Well 1	24" x 54" GPW	N/A	NA	122 +/-	30-40
Happy Hollow Well 2	24" x 48" GPW	250	NA	122 +/-	35-50

All elevations in feet, NGVD 1929; NA = not available; bgs = below ground surface; GPW = gravel-packed well.

At 11 a.m. on Monday, June 7, 2010, Happy Hollow Well #1 began pumping into Wayland's water-distribution system. The well was pumped continuously at a rate of approximately 300 gallons per minute (gpm) until Tuesday, June 15, 2010. Between June 7 and June 10, the data loggers collected frequent and regular water-level drawdown measurements, sufficient to allow AECOM to compute aquifer hydraulic characteristics.

At 1 p.m. on Friday, June 11, 2010, Happy Hollow Well #2 began pumping into the distribution system. The well was pumped continuously at a rate of approximately 475 gpm until June 15, 2010. A final round of water levels was measured manually on June 14. Pumping was terminated early on June 15 because Wayland's water demand had declined due to cool, overcast weather conditions. Figure 2 shows the groundwater flow conditions based on the June 14 water-level measurements. Groundwater levels of June 14 were relatively stable in many of the wells. From this, we have concluded that water-levels had reached a quasi-steady state condition.

Pumping Test records are in Appendix B.

Stratigraphic Conditions

Based on the well drilling completed in 2009/2010 and previous drilling in the area, AECOM has constructed three geologic cross-sections. Surficial geologic mapping conducted by the U.S. Geological Survey (USGS) indicates that the Happy Hollow Wells are at the northern edge of a glacial delta, composed primarily of sand and gravel. USGS mapping further indicates that the flat areas to the north of the Happy Hollow Wells – the areas now occupied by Wayland High School ball fields – is underlain chiefly by clay deposited in a glacial lake.

AECOM's geologic cross sections – shown on Figure 3 – tend to confirm the USGS findings, though we have added considerable refinement and detail. The area around the Happy Hollow wells and the low hills nearby to the south and east (MW-7, MW-8, and the IEP wells) are underlain by thick (up to 75 feet thick) layers of sand and gravel, which can be silty. The sand-and-gravel layers constitute the aquifer that supplies the Happy Hollow Wells. The football field and tennis courts (MW-5 and MW-1) are underlain by a thick layer of clay (about 60 feet thick), though there is a thin sand-and-gravel unit on top of the clay and another sand-and-gravel unit below. These upper and lower sand layers are hydraulically connected to the aquifer that feeds the Happy Hollow Wells, though they do not contribute a significant proportion of well yield. The intervening areas (MW-2, MW-4 and MW-6) are transitional between glacial lake and glacial delta deposits, where the clay is 15 to 30 feet thick, and the remainder is sand and gravel.

The geologic cross sections shed considerable light on the structure of the aquifer system that supplies the Happy Hollow Wells. The presence of clay complicates the aquifer structure. Whereas, the sand-and-gravel units transmit water readily, the clay transmits water very poorly. Understanding the distribution of sand-and-gravel versus clay is one of the principle factors in understanding how groundwater moves toward the Happy Hollow Wells when they are pumped, and the proportionate contribution from each geographic area.

Aquifer Hydraulic Characteristics
AECOM collected water-level drawdown measurements using electronic data logging equipment during the pumping of Happy Hollow Well #1, and used this data to compute aquifer hydraulic characteristics. Data was collected from the "Test Well", IEP-B3, IEP-B1, MW-2 and MW-6, however only the data from the first three wells was suitable for aquifer analysis. Using time-drawdown analysis methods, we estimate an aquifer transmissivity of approximately 22,000 ft^2/day, and a specific yield of 0.03 to 0.11. Assuming an aquifer thickness of 55 feet, the hydraulic conductivity is estimated to be about 400 ft/day.

Using the distance-drawdown method, we computed an aquifer transmissivity of about 16,000 ft^2/day and a specific capacity of 0.12. Assuming an aquifer thickness of 55 feet, the hydraulic conductivity is estimated to be 290 ft/day.

Aquifer analysis curves are included in Appendix C.

Conclusions
Based on the Phase II Hydrogeologic Investigation, AECOM concludes the following:

- The U.S. Geological Survey has mapped the Happy Hollow wells at the northern edge of a large kame delta, which is bordered to the north by glacial lake deposits. In general, the kame delta is composed of sand and gravel; the lake deposits, which occupy the flat areas north of the well, generally contain thick clay sequences. Between the kame delta and the thick clay, the geology is transitional, with varying thicknesses of water-bearing sand-and-gravel and impermeable clay. For this reason, the aquifer supplying the Happy Hollow wells is geologically complex. See Figure 3 for detailed stratigraphic information.

- In the immediate vicinity of the Happy Hollow wells, the kame delta is composed largely of sand-and-gravel up to 75 feet thick. The glacial lake deposits beneath the tennis courts and football field north of the wells are largely made up of gray clay up to 65 feet thick. The clay is overlain and underlain by sand layers, as little as five feet thick.

- The distribution of glacial soils – especially the clay – plays an important role in controlling groundwater flow under both static and pumping conditions. The thick clay north of the wells acts as a partial barrier to groundwater flow.

- Under static conditions (see Figure 1), groundwater flows westerly toward the Sudbury River, and parallel to Dudley Brook. The drive points installed in the brook just north of the wells indicated that groundwater was discharging to Dudley Brook in June 2010. Under these conditions, Dudley Brook would be termed a "gaining stream".

- Under pumping conditions, most of the groundwater that reaches the wells originates from the east and probably the south of the Happy Hollow wells (see Figure 2). The groundwater contribution from the area of the High School tennis courts and football field is expected to be minor, transmitted only through a thin upper layer of sand that overlies thick clay deposits. Similarly, the groundwater contribution from the existing high school leach field is also expected to be minor. Much of the discharge to the leach fields appears to flow northwesterly to the wetlands bordering the Sudbury River.

- The drive points installed in the brook indicate that water from the brook is induced into the aquifer under pumping conditions, the more so when both wells are pumped simultaneously. The relative contribution of induced infiltration is relatively minor where the brook is narrow, but is likely to increase where the brook flows into the broad wetland directly north of Happy Hollow Well #2. Therefore, protecting water quality in the brook will protect water quality in the wells. It was beyond the scope of this investigation to evaluate how much water is induced into the wells from the wetlands bordering the Sudbury River (directly west of the wells), but it could be fairly significant.

- Figure 2 shows the approximate northern limit of the capture zone of the wells under pumping conditions of June 7 to June 14, 2010. By June 14, water levels in the area had reached a near-stable condition, indicating that the capture zone should not expand significantly under similar pumping and rainfall conditions. While most school activities are relatively benign, the sheer intensity of activities and their proximity to the Happy Hollow wells pose a threat to groundwater quality. Parking areas and drainage, in particular, are threats to water quality. These and other deleterious activities should be removed from Zone I and moved as far from the wells as practical.

In closing, it has been our pleasure to assist the Town of Wayland on this important project. We would be pleased to discuss this report with you in detail.

Very truly yours,

AECOM Technical Services, Inc.

Douglas DeNatale

Douglas DeNatale, PG
Senior Project Director