BRISTOL ENGINEERING ADVISORS, INC.
Infrastructure and Water Resources Engineering

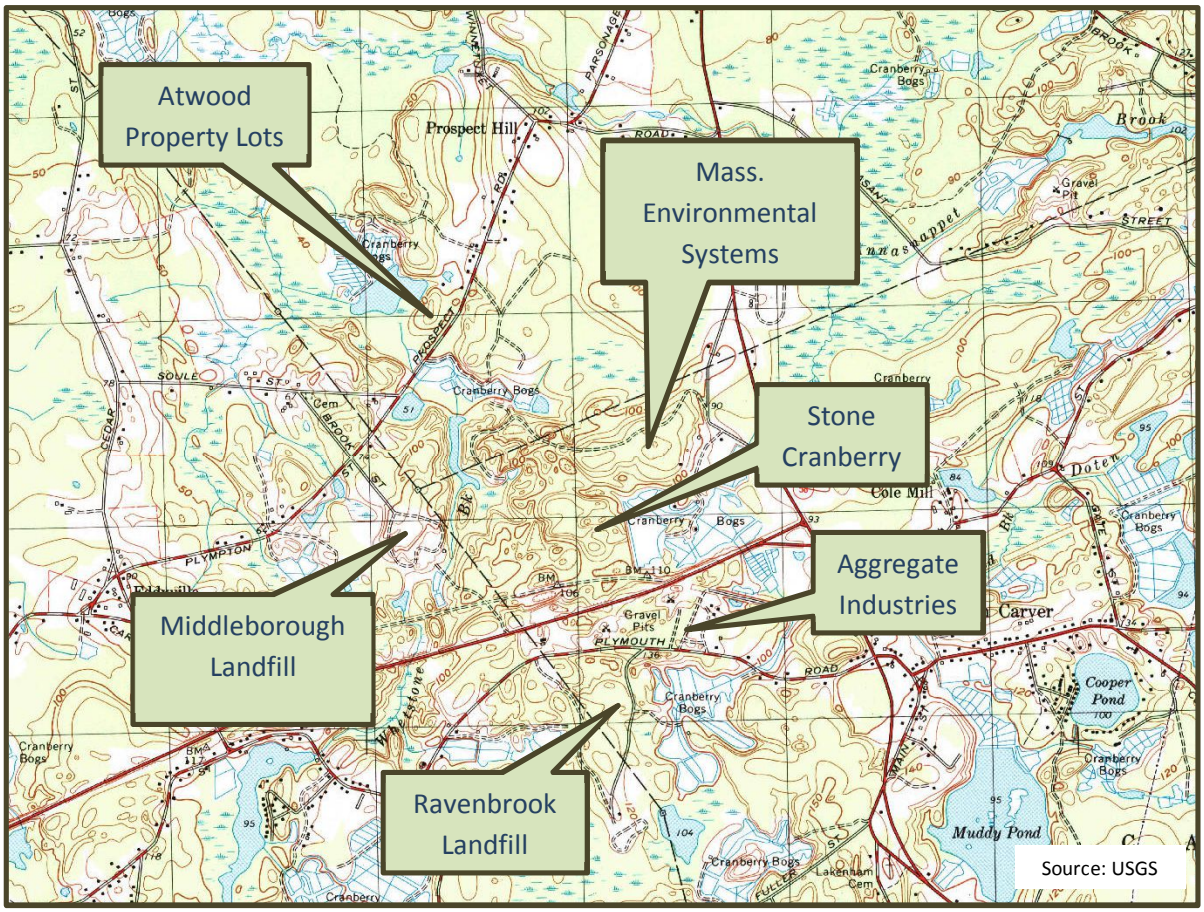
June 26, 2018

Ms. Linda Leddy, Chair
Open Space Committee
5 Palmer Road
Plympton, MA 02367

Re: Hydrogeologic Assessment of Atwood Property
Plympton, MA

Dear Ms. Leddy:

Bristol Engineering Advisors, Inc. (Bristol) is pleased to provide the Plympton Open Space Committee (Committee) this letter report detailing our findings pursuant to the geology and hydrogeology of the Atwood property. Our review was undertaken in an effort to determine whether nearby land uses, specifically the Middleborough Sanitary Landfill and the Ravenbrook Landfill, have adversely impacted groundwater and more specifically, whether their presence precludes the potable water potential at house lots along Prospect Road.

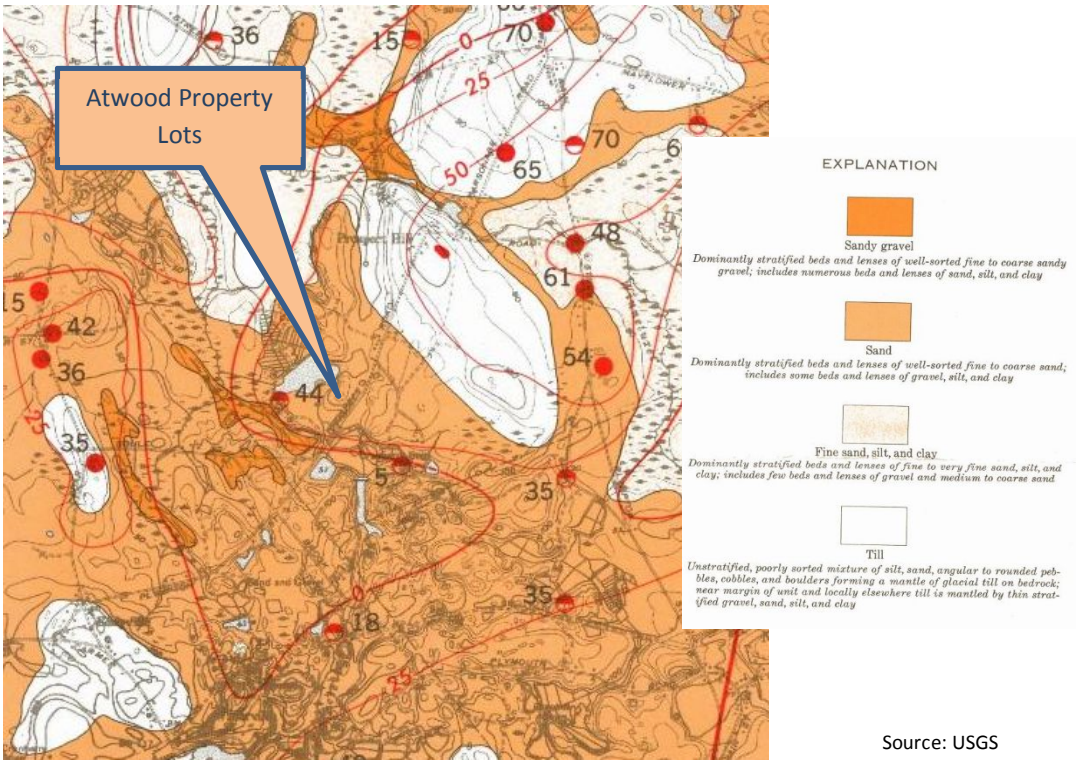


This letter report has been prepared based on data and records obtained from MassDEP during a file review conducted on June 12, 2018, a site walk performed on June 12, 2018 and on a review of publicly available documents obtained from MassDEP and from the Plympton Board of Health. No independent data collection or field work was performed. This document represents a collation and interpretation of existing information and is, therefore, entirely dependent upon the integrity of the data reviewed.

Site Geology and Hydrogeology

The Atwood property is located within the upper reaches of the Taunton River Basin, in an area of glacial outwash deposits that are contiguous with the Plymouth-Carver aquifer complex, though hydrologically separate. Thus, surface water at the site flows northward through Whetstone Brook and ultimately toward the Taunton River. Groundwater is expected to roughly follow surface water, and discharges to and recharges the local streams and bogs during periods of low precipitation. This discharge is referred to as base-flow and often represents the entirety of streamflow in late summer. This "baseflow" usually represents discharge of shallow groundwater and may not significantly alter the overall groundwater flow pattern.

Geologically, the soils underlying the site are of glacial origin. They consist largely of sorted sands and gravels, along with finer grained lake-bottom deposits. The interpreted depositional history of the area suggests that as the glacier melted and receded between 8,000 and 12,000 years ago, small lakes and pools filled with meltwater and were later overtopped and buried by sediments. These lakes and pools were filled with silts and clays and can represent barriers to vertical groundwater flow. However, because these features are horizontal, unless they are significant in extents they often have little effect on groundwater transport across a site.



Source: USGS

Bedrock at the site lies approximately 50 feet below grade at the Atwood property, and is reported to consist of the sedimentary rock (SAIC 1990; Williams and Willey 1973) of the Narragansett Basin. The Comprehensive Site Assessment for the Ravenbrook Landfill (SAIC 1990) indicated that the bedrock beneath that site is highly fractured for the top 30 – 50 feet, and as such may serve as a conduit for the flow of groundwater. However, bedrock throughout the region is overlain by a dense basil till, which typically is a poor conductor of water. Thus, while fractures in the shallow bedrock may transmit groundwater, recharge from overburden is likely to be limited.

Groundwater flow in the area of the Atwood property is generally to the north, along the axis of Whetstone Brook. Locally, there are numerous hydrologic features which likely alter the regional flow patterns. Whetstone Brook, the many cranberry bogs and ponds in the vicinity of the property will locally affect groundwater flow. Whetstone Brook, for example, likely is the driver for regional groundwater flow, as it serves as a sink for groundwater, transporting it north toward the Winnetuxet River and, ultimately, the Taunton River and Narragansett Bay. While some documents reviewed (Weston & Sampson 1998) suggest that Whetstone Brook may be a losing stream – that is, it contributes to groundwater recharge – the location in the headwaters of the watershed and its perennial nature rebut this contention, though it is certainly possible that the brook discharges to groundwater during periods of heavy precipitation and high streamflows. As such, Whetstone Brook, coupled with the numerous cranberry bogs and ponds through which it meanders, is the dominant hydrologic feature in the vicinity of the Atwood property.

Hydraulic Conductivity

Groundwater flow is dictated by the permeability of the soils through which it flows, the pressure driving the flow as determined by the slope of the water table and by the size of the pore spaces through which the water flows. The hydraulic conductivity of an aquifer is typically represented as distance per unit time (feet per day, for example), but is more accurately represented as a volume per unit time per cross-sectional area through which it flows (gallons per day per square foot, for example). This second representation tends to be more consistent with the original equation for groundwater flow:

$$\boldsymbol{Q = kiA}$$

Known as Darcy's Law, it forms the basis of virtually all hydrogeologic assessments. Q is volumetric flow within an aquifer, *i* is the hydraulic gradient and A is the cross-sectional area of the aquifer. From this equation one can derive many aquifer properties. It is particularly useful in estimating groundwater flow velocity across a site. However, the value k is generally calculated using data obtained by performing aquifer tests such as pump tests or slug tests. No testing was performed as part of this review; however, slug tests were performed by others (W&S 1998) on a number of monitor wells installed at the Middleboro landfill.

The slug testing performed at the landfill implies that aquifer materials are reasonably permeable near the surface, and become less permeable with depth, ranging from 22-55 $f^3/d/f^2$ in the shallow wells to 4.5-9 $f^3/d/f^2$ in deep wells. These values are consistent with published values for medium sands to fine sands. Using these values, we can use an estimate of porosity (*n*) to estimate groundwater seepage velocity across the site. Weston & Sampson used a value of 0.0081 feet per foot (f/f) for the hydraulic gradient. Seepage velocity (*V*) is calculated according to the following formula:

$$V = \frac{ki}{n}$$

Typical porosity values are in the range of 0.15 for poorly sorted mixed deposits to around 0.3 for well sorted sand. It is very difficult to measure actual porosity in the field, so using a value in the middle of this range is typical for real-life circumstances. Using 0.22, we arrive at a range of groundwater seepage velocity of between 0.8 and 2 feet per day in the upper sediments and 0.17 to 0.33 feet per day in the deeper sediments. Therefore, groundwater flowing in the upper aquifer will travel between 300 and 700 feet in a year, while that in the deeper portions of the aquifer will only travel between roughly 60 and 120 feet in a year.

Surrounding Land Use

The land uses surrounding the Atwood property are largely low-impact. The land to the north of the site is largely undeveloped. To the east, across Prospect Road is the Toby Lane development, established in the late 1980's. South of Toby Lane is a cranberry bog complex, through which Whetstone Brook meanders. There are two culverts under Prospect Road, the southern culvert appears to drain into a wetland complex on the Atwood property, and may connect with Whetstone Brook during periods of high flows. The culvert was wet but did not appear to be taking flow during the June 12 site walk. The northern culvert appears to be the main course of Whetstone Brook and was observed to be flowing abundantly during the site walk.

Abutting the site to the south and southwest are Soule Street, Soule Farm and several residences along Soule near Prospect Road. Beyond Soule Street and to the south of Plympton Street in Middleborough is the active Middleborough Landfill, approximately 2,000 feet upgradient from the Atwood property. To the east of the landfill, in Carver is a large gravel pit operated by 44 Gravel & Sand Inc. South of the gravel operation is the former Ravenbrook Landfill, located approximately 5,000 feet south of the Atwood property.

There has been significant investigation into the impact that the two landfills have had on local groundwater conditions. These investigations are summarized in the subsequent section.

Landfills and Other Groundwater Impacts

Ravenbrook Landfill

The Ravenbrook Landfill in Carver received Site Assignment from Carver Board of Health in 1975. It is an unlined landfill and was approved to receive only construction and demolition waste. In around 1980, it received 400 tons of polymer concrete material used by the US Air Force to test a quick cure runway patch material. It was later determined that this material contained high levels of chlorinated solvents, specifically tetrachloroethylene (PCE). Unfortunately, the PCE leached into and contaminated groundwater beneath the landfill. From the Response Action Outcome Statement (RTN: 4-0951) prepared by MT Environmental (October 2012):

> The polymer plume originated at the Ravenbrook Landfill and migrated north then northwest with groundwater flow over a total distance of approximately 5,000 feet. The tail end of the plume detached from the Landfill area in the early 1990s. As the

> plume migrated with groundwater flow in a northerly and then northwesterly direction, it migrated beneath Route 44, passing through portions of the Lawrence Cole (Cole), Stone Cranberry, Inc. (Stone Cranberry) and David Maurer (Maurer) properties. The polymer plume was defined in the 2000s within the "intermediate" portion of the aquifer, generally at depths of approximately 60 to 100 feet below ground surface (bgs), extending across the Stone Cranberry property from the southeastern corner to the northwestern boundary and onto the Maurer property near the Carver-Plympton town line. (MT Environmental 2012)

From the figures presented in this report, groundwater appears to flow from the Ravenbrook Landfill toward Cobb Pond in Plympton, roughly following the drainage of Whetstone Brook, as would be expected. Groundwater was impacted by several volatile organic compounds (VOCs), including PCE, trichloroethylene (TCE), cis-1,2-dichloroethylene (cis-1,2-DCE) and vinyl chloride. This transition from PCE to VC is likely due to biological de-chlorination of the initial slug of PCE.

Dozens of monitoring points have been installed at and downgradient from the landfill to track the progress of the groundwater plume. Wells and well points were installed as far north as the intersection of Prospect Road and Toby Lane, directly across from the Atwood property. According to the MT Environmental report (2012), "In 2004, the leading edge of the plume was defined near the Carver-Plympton town line…as defined by the presence of VC in groundwater." (p. 26) Based on this information, the farthest north the plume is known to have extended is the town line; approximately 1,200 feet south of the Atwood property.

Of the three wells along Prospect Road, only the westernmost well is known to have been sampled for VOCs. Well RB-65i was sampled annually in June 2004, 2005, 2006, 2008 and 2009. No VOCs were detected in any of the samples. Field screening of monitor well RB-55 and RB-56 were conducted up to three times during the period from 2000 – 2007, though it appears no VOC analyses were performed so it is not known whether residual chlorinated solvents may be present.

Bristol obtained several well logs for residential wells installed along Toby Lane as part of that development. The majority of the wells were installed in 1988 – around the same time as the Ravenbrook Landfill was accepting the contaminated debris. This was also the time that the groundwater contamination at the landfill was discovered, but its extents not yet known. Several – though not all - of the well reports had VOC analytical results and none were detected. While the MT Environmental RAO Statement states that the plume may not have reached the town line until 2004, it also defines the plume width at 200 feet, meaning that Toby Lane would likely be outside the plume if it were to extend all the way to Prospect Street. However, each of the wells along Toby Lane were installed into bedrock and the available drillers logs indicate a layer of fine sand and till above bedrock.

The reports reviewed on the Ravenbrook Landfill make it clear that contamination from the Ravenbrook Landfill is/was contained to the intermediate aquifer and that it did not migrate into bedrock; did not greatly disperse laterally; and, attenuated biologically along its flow path to the north. Therefore, it is unlikely that the Toby Lane wells have been impacted by the release at the Ravenbrook Landfill.

Middleborough Landfill

The Middleborough Sanitary Landfill, located approximately 1,500 feet south-southwest of the Atwood property received site assignment in 1967. Approximately 22 acres in the southern portion of the 63-acre site were used for the acceptance of household waste until late 2004, at which operations temporarily ceased while the landfill was capped. In 2008, Middleborough received approval to operate a portion of the landfill as a lined landfill, complete with a leachate collection system. Operations in the lined portion continue.

The landfill is located on the Middleboro/Plympton town line, south of Plympton Road and on the west side of Whetstone Brook, which continues to flow north beneath Prospect Road.

The geologic material underlying the Middleborough Landfill is consistent with that underlying the Ravenbrook Landfill, being glacial outwash deposits that get increasingly fine with depth, ultimately being underlain by till on top of bedrock. Groundwater flows northward across the site, toward the Atwood property.

As early as 1979, residents in the vicinity of the landfill raised concerns with the Board of Health regarding the foul taste and odor of their well water. A review of documents supplied by the Plympton Board of Health found that at least one of the wells was a 32-foot deep driven well point. The records, consisting primarily of hand-written meeting minutes, are unclear about the nature and extent of testing that was done. It is clear, however, that the problem was significant enough to warrant bringing town water from Middleborough to service several homes on Prospect Road and Soule Street. No additional monitoring well data was located.

The landfill has been undergoing both post-closure and operational groundwater monitoring since the early 1990's. Over this period, levels of groundwater contaminants at and downgradient from the landfill have declined to essentially non-detect. However, levels of some metals in groundwater remain persistent, particularly arsenic, iron and manganese, and may represent residual impact from pre-capping activities.

Based on the data reviewed for the Middleborough Landfill, it does not appear that any wells were completed in bedrock to evaluate potential groundwater flow or quality within bedrock fractures. However, the logs and geologic cross-sections presented by Weston & Sampson (1998) suggest that the sediments underlying the landfill consist of 20 – 30 feet for coarse, high-permeability deposits on top of 30 – 50 feet of fine-grained, low-permeability deposits. While this configuration does not mean that contamination could not migrate deep within the aquifer, the preferential flow, coupled with the discharge of groundwater to Whetstone Brook during most of the year suggests that the only likely mechanism for deeper penetration absent a release of dense non-aqueous phase liquids (DNAPL), would be chemical and mechanical dispersion within the aquifer.

Given the lack of any known release of DNAPL and the low levels of contaminants observed, it would be unlikely to find contamination from the Middleborough Landfill within bedrock.

Other Groundwater Impacts

Aggregate Industries (formerly Simeone Asphalt)

Aggregate Industries, formerly Simeone Asphalt, operated a sand and gravel and asphalt processing facility in Carver, approximately 1,000 feet east of the Ravenbrook Landfill. According to records reviewed, the Aggregate site had a release of 3,000 gallons of fuel oil in 1980, as well as the release of VOCs presumably from quality testing of asphalt samples (GEI 2005). Extensive remedial activities have taken place, including the removal of 700 cubic yards of soil as well as an unknown quantity of light non-aqueous phase liquids (LNAPL). Numerous monitor wells have been installed at and downgradient from the site, though none appear to have been advanced into bedrock. The interpreted geology is consistent with that reported in the landfill documents – permeable sands and gravels overlying fine-grained sands and silts, with preferential flow in the upper portion of the aquifer.

Remedial activities consisted solely of tank removal, soil excavation, LNAPL skimming and monitored natural attenuation. Several VOCs and petroleum compounds have been detected at the site since remedial activities began in 1990. Concentrations in groundwater appear to have decreased over time.

There has been some discussion in the record about a possible co-mingling of groundwater plumes with the Ravenbrook Landfill. This is discussed extensively in the Ravenbrook files, in which claims are made that certain downgradient impacts have chemistry inconsistent with landfill leachate (MT Environmental 2015). However, the consultant for Aggregate Industries refutes this claim of commingling (GEI 2016). What is evident is that both Aggregate and Ravenbrook activities have resulted in downgradient impacts to groundwater.

Monitoring of this site is continuing on a semi-annual basis; with the most recent results exhibiting no VOCs in groundwater, though an apparently isolated pocket LNAPL is present that continues to be treated (GEI 2018).

Stone Cranberry Property

The Stone Cranberry Property – also known as the Whitworth property and also as Rt 44 Sand and Gravel – is a 130(+/-)-acre parcel (MT Environmental 2016) located north of both the Ravenbrook Landfill and the Aggregate Industries site and is east of the Middleborough Landfill. The northern extents of the property straddle the Plympton/Carver town line. The property has historically been the site of sand and gravel processing; with portions of the site used for other activities. In 1986 the Carver Board of Health granted site assignment for the landfilling of stumps and wood waste. Later, Chip Tech used the site as a wood chip and mulch processing facility.

The property has been investigated several times over the years for the presence of groundwater contamination. Largely it has been determined that contaminated groundwater at the site has migrated from upgradient sources, including the Ravenbrook Landfill and, contentiously, the Aggregate Industries site.

In 2005, elevated levels of methyl-ethyl-ketone (MEK) and acetone were detected in an on-site drinking water well. It was determined that these compounds were attributed to the biologic decay of wood chip and cranberry waste and not the result of the illicit discharge of oil or hazardous material (OHM). The site was declared closed under the Massachusetts Contingency Plan in 2016 following the collection of groundwater samples that indicated the site had achieved a Permanent Solution (MT Environmental 2016).

Massachusetts Environmental Services, Inc.

Massachusetts Environmental Services, Inc. (MES), located at 1 Park Avenue in Carver is or was a privately owned wastewater treatment facility, about which no information is readily available. The site abuts the Stone Cranberry property to the east and is about 200 feet south of the Plympton/Carver town line – approximately 3,000 feet upgradient from the Atwood property. It would be expected that a Groundwater Discharge Permit would have been issued by MassDEP for this site, though no record of an active permit could be found in the MassDEP database.

The site is readily identifiable on aerial photos by the four, approximately 6,000 square foot leaching beds adjacent to a receiving building. It is not known when the facility began operations, but the site is active as observed in aerial photos from 1996, the oldest photo record readily available. Likewise, it is not known when the facility ceased operation, though an aerial photo from 2008 shows flooded beds. It appears that the site was decommissioned sometime before 2014, as an aerial photo from that year shows dry infiltration beds and an empty lot where the intake structure/office building once stood.

This site is of interest with respect to the Atwood parcel in that it is directly upgradient from the proposed house lots and would have been subject to wastewater loading to groundwater that would be expected to flow toward the Atwood property. Depending upon its source, residential wastewater can contain, in addition to excessive nitrogen, trace amounts of chemicals used in everyday life.

Residential wastewater is known to contain numerous pharmaceuticals and personal care products (PPCPs), some of which can pass through wastewater treatment facilities and remain biologically active in the environment. However, these impacts would get mitigated in the environment over time, and it appears to be at least four (4) and perhaps as many as 10 years since the facility was last operated. That said, nothing is known about the origin or quantity of the wastewater disposed, nor was any information on the design of the treatment works or infiltration beds reviewed. Therefore, while unlikely, it can not be said with certainty that the presence of the former wastewater infiltration beds has not had an adverse impact on groundwater quality, though any impact would be expected to be in the shallow portion of the aquifer and would not have migrated into the deep aquifer or bedrock.

Summary

There are numerous sites and facilities within 5,000 feet of the Atwood property that are known or suspected to have adversely impacted groundwater. Some of these site, the Middleborough Landfill,

the Ravenbrook Landfill and the Aggregate Industries site for example, are known to have caused groundwater impact that has migrated considerable distance downgradient from the source.

With the exception of the Massachusetts Environmental Services site, however, each site has been thoroughly evaluated, and where needed, remediated to the point where the contamination has been largely mitigated to levels at which it would not currently be considered a threat to human health.

Furthermore, the geology of the area is favorable in that the aquifer is quite permeable in the upper 20 – 30 feet but becomes less permeable with depth. Glacial till is reportedly present throughout the region on top of fractured bedrock. There is limited characterization of the till or bedrock, but it is not uncommon to drill into a "basal" till – that is, till overlying bedrock – and find it to be dry despite many tens of feet of water in the overlying aquifer. The till in this area of Carver and Plympton would impede the migration of water into the underlying bedrock.

While not discussed above, groundwater in this area is known to have high levels of naturally occurring iron and manganese and may have other naturally occurring minerals that make human consumption less than desirable. Likewise, the presence of elevated levels of sodium is becoming more common as impacts from roadway de-icing activities

Therefore, with that caveat that naturally occurring minerals and sodium may be present in groundwater at elevated levels, it is my opinion that groundwater extracted from a properly constructed well installed into bedrock at the general location along Prospect Road, as proposed by the Committee is likely to be considered to be potable.

We appreciate the opportunity to be of service to you. If you have any questions, please do not hesitate to contact me (508)758-8270 or at peter.newton@bristolea.com.

Respectfully,

BRISTOL ENGINEERING ADVISORS, INC.

Peter L. Newton

Peter Newton, PG

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