Groundwater Quality Assessment of Private Well Water in Cheapside and East Horntown, Virginia

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Executive Summary

The project-based curriculum of Randolph-Macon College's Environmental Studies Program (R-MC) enabled a partnership with the Accomack-Northampton Planning District Commission (A-NPDC) to determine the extent of drinking water impairment in two economically-disadvantaged communities on the Eastern Shore, Virginia. Previous studies of private wells on the Eastern Shore had determined that nitrate and *Escherichia coli* (*E. coli*) bacteria, two potentially harmful constituents if ingested in high amounts, were found in levels that exceeded Safe Water Drinking Act standards (A-NPDC 2001, EJSG Work Plan-and several others). However, wells in the communities of East Horntown and Cheapside had never been sampled and the quality of drinking water in these communities was unknown. The A-NPDC suspected that groundwater may be polluted given the ubiquitous on-site sewage systems and/or potential for substandard plumbing and/or no indoor plumbing (pit privies), and the location of these communities in proximity to agricultural practices.

The primary objective of this study was to determine whether the drinking water quality of private wells in Cheapside and East Horntown were in compliance with standards established by the Safe Water Drinking Act. To accomplish this goal, we met with residents to document any complaints associated with their drinking water. We then sampled their water and tested for seven constituents. We conclude that:

1. The majority of residents complained that their water was aesthetically unpleasing and noted odor, distaste, and/or smells as the primary problems. As such, many residents choose to buy bottled water for consumption.
2. The majority of constituents analyzed tested below Maximum Contaminant Levels (MCLs) recommended by the EPA.
3. Iron and total dissolved solids (TDS) did exceed Secondary Maximum Contaminant Levels (SMCLs). These constituents are likely the source of residents' complaints about water aesthetics. One home in the Cheapside community and three homes in the East Horntown Community tested had TDS values approaching or exceeding 1,000 mg/L. We do not recommend drinking this water given these very high values.
4. Installation of faucet filtration attachments would likely benefit these homes. However, remediation options should be considered on a house-by-house basis, and

recommendations made only after considering water quality results and well properties for each residence.

Based on land use and existing water quality information, the constituents that would most likely cause water quality problems on the Eastern Shore were tested. Of the constituents tested, none exceeded a Primary Drinking Water Maximum Contaminant Levels (MCLs). However, not all constituents that that could cause water quality problems were tested, so it is possible that some issues were not detected. Therefore, we recommend additional sampling of constituents for which we did not test or additional sampling over longer time periods that would provide insight into the seasonal dynamics of groundwater quality in these communities. Finally, given our assessment of on-site well locations relative to septic system locations, relative to Virginia Department of Health regulations for private wells (requires a minimum setback of 50 feet from a septic tank or drain field), we also recommend verifying the location of the well-septic locations to ensure regulation compliance.

Introduction

Originally established in 1974, the Safe Drinking Water Act (SDWA) is the primary federal law that regulates and oversees public drinking water quality (Pontius 1990). Under the SDWA, the Environmental Protection Agency (EPA) is authorized to set health-based standards for drinking water. These Maximum Contaminate Levels (MCLs) are legally enforceable and designed to protect consumers from pollutants that pose a significant human health risk. The EPA also sets unenforceable Secondary Maximum Contaminate Levels (SMCLs) to provide a guideline for water constituents that do not pose a health risk, but do contribute to drinking water aesthetics (e.g. taste, smell, color).

The SDWA mandates regular testing of all public water supplies that serve 25 or more people and all contaminant levels must fall below MCL standards. However, the SDWA does not apply to private wells serving fewer than 25 people. As such, private wells are not subject to regular testing and drinking water is not required by law to be below MCLs (Levin et al. 2002). The lack of legal enforcement and homeowner awareness, in concert with financial constraints, often result in a small number of homeowners who regularly have the quality of their private well water tested and/or treat harmful contaminants properly (Levine et al. 2002, Charrois 2010).

The Eastern Shore of Virginia, which is comprised of Accomack and Northampton counties, relies entirely on groundwater for all water supplies (Sanford et al. 2009). Previous studies of private wells on the Eastern Shore have concluded that nitrate and fecal coliform exceeded MCLs in as many as half of all wells sampled. Furthermore, these studies concluded that wells in the shallow Columbia Aquifer were more susceptible to contamination than wells in the deeper Yorktown Aquifer. The cause of impairment has not been definitively determined, but pesticides from agricultural farms, waste from livestock operations, and leaking septic systems have been identified as possible suspects (A-NPDC 2001, EJSG Work Plan). The risk of contamination from any point source is particularly high on the Eastern Shore as the sandy substrates have a low attenuation, thus reducing the ability of sediments to filter out contaminates before reaching wells.

Despite these previous studies, the quality of drinking water is presently unknown for many communities in the Eastern Shore. Therefore, in partnership with the Accomack-Northampton

Planning District Commission (A-NPDC), students enrolled in Environmental Problem-Solving II/III at Randolph-Macon College (R-MC) studied the extent of drinking water impairment in two economically-disadvantaged communities on the Eastern Shore: East Horntown in Accomack County and Cheapside in Northampton County (Figure 1). Neither of these communities had been previously sampled, and threats from neighboring farms, outdated septic systems, and improper waste disposal methods made these communities candidates for potential contamination. In addition, the A-NPDC suspected that some of the residents living in these communities did not have indoor plumbing and that pit privies (or other crude waste disposal methods) could have served as a source of fecal bacteria, phosphates, or surfactants to the groundwater. For this project, students sought to provide realistic remediation options for any groundwater impairment discovered and provide remediation funding options for the A-NPDC to pursue.

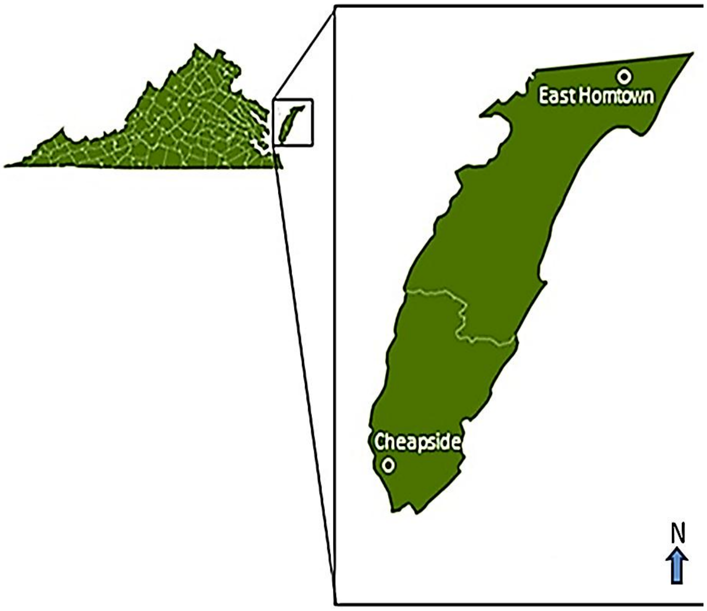

Figure 1. Location of Cheapside and East Horntown on the Eastern Shore, Virginia

Methods

Resident Recruitment

We held community meetings in Cheapside and East Horntown on 16 March 2013 to recruit resident into our study (Figure 2). During the meetings, we distributed an informational brochure which outlined the objectives and methods of our study. We also administered a survey to collect information about well properties and resident complaints about drinking water. This survey also included a page for informed consent which granted R-MC permission to sample water from a homeowner’s well and/or faucet. The survey was approved by the R-MC Institutional Review Board.

Figure 2. Randolph-Macon College students recruiting residents of the Cheapside community on the Eastern Shore of Virginia to participate in a groundwater quality study of homeowner well water.

Because all residents could not attend these information meetings, we also recruited homeowners during the water sampling efforts. While one team worked on sampling, another team of students went door-to-door to distribute the brochure and survey. Local residents also aided this project by recruiting their neighbors into the study. In total, we sampled seven residences in East Horntown (five well and seven faucets) and 14 residences in Cheapside (six well and 13 faucets).

Field Sampling

Using protocols adopted from the United States Geological Survey (USGS) and the Virginia Department of Environmental Quality (VADEQ), we sampled all residences during April 2013. Before collecting water samples, R-MC students completed an outdoor environmental hazard check on each property to note incidences of land use(s) that could potentially influence water quality negatively such as adjacent agricultural fields and livestock farms, as well as on-site problems such as compromised septic systems, improper waste disposal devices, and/or burn piles. We also completed an indoor environmental hazard check to note whether a residence used a water filter, to examine the integrity of the water distribution system, and to ask residents to explain, in more detail, any problems they had experienced with their water.

In accordance with the USGS Clean Hands/Dirty Hands protocol, only individuals with sterile gloves collected the water samples (Myers, 2006). All samples were collected in sterile bottles and placed on ice immediately after collection. Samples were returned to the laboratory at R-MC and analyzed within the time frame required by the EPA.

Faucet Sampling

To ensure that water samples represented the well water and not stagnant water in the water distribution system, we ran cold water for five minutes prior to sample collection. For each faucet sampled, we collected one sample for coliform bacteria and an additional 1L of water for other parameters that required a lab analysis (Figure 3).

Figure 3. Randolph-Macon College students obtaining a faucet sample at a resident in the Cheapside community on the Eastern Shore of Virginia.

Well Sampling

We collected well water samples from a hose connected to an outdoor faucet or from the valve located adjacent to the water pump (both locations provided a water sample before entering the resident's water distribution system). Immediately after turning on the water, we collected one sample for coliform bacteria testing. This sample would indicate possible bacteria contamination from sources other than the aquifer. To ensure all remaining well samples were representative of the aquifer and not stagnant well water, we purged the well of water with a volume equivalent to three times the volume of the well as per USGS protocol (Myers 2006). During this purging process, we obtained measurements every 5-10 minutes for dissolved oxygen (DO), turbidity, pH, conductivity, specific conductance, salinity, and temperature using the devices YSI 55, YSI 30, pH 100, HACH 2100P Turbidimeter (Figure 4). Once purging was complete and measured parameters reached stable values, we collected another coliform bacteria sample and 1L of water for lab testing of additional parameters.

Figure 4. Parameter measurements made by Randolph-Macon College students during the purging processes.

Lab Testing

We tested each resident's drinking water for *Escherichia coli* and total coliform bacteria using methods described in the Coliscan Easygel water monitoring kit. The samples were incubated at 35°C and counts of *E. coli* colony forming units (cfu) were made at 24, 36, and 48 hours.

Figure 5. Lab analysis of nitrates at Randolph-Macon College.

Ferrous iron, surfactants, nitrate, sulfate, and phosphate were tested using the HACH DR/ 2000 spectrophotometer with methods outlined by HACH. Total dissolved solids (TDS) were tested using HACH methods (Figure 5). For all samples, appropriate QA/QC measures were completed including instrument calibration with reagent blanks.

Groundwater Flow Direction

We used a standard USGS geometric approach to determine hydraulic gradient and groundwater flow directions of the shallow Columbia Aquifer in each community with the intent of identifying potential pollutants sources (Heath, 2006). The method involved determining the total hydraulic head (altitude of measuring point - depth to water in a nonflowing well = elevation head + pressure head) for three wells in each community.

Groundwater moves in the direction of decreasing total head. Once the total heads are determined at each well, a line drawn perpendicular to a water-level contour determined by the well with the intermediate head and the well with either the highest or lowest head parallels the direction of groundwater movement. In short, a three point problem is based on a simple principle of geometry in which three points define a plane, and, defining the position of a plane in space enables determination of the dip (inclination) of the plane. Because groundwater flows down-gradient, it will flow in the direction of dip of the plane.

The depth to the static water level from the top of the casing at each well was determined using a Topcon RL-H3C transmitter and LS-80 series surveying equipment (Figure 6).

Figure 6. Surveying top of well riser pipe in the Cheapside community using a Topcon RL-H3C transmitter and LS-80 series surveying equipment.

Results

Resident Survey

We obtained a total of 27 responses from the residents of both communities, with 21 residents filling out the entire survey and the remaining six only providing consent for sampling. Of the 27 responses, 17 came from Cheapside and ten from East Horntown. We were unable to sample six residences that were recruited into the study.

The majority (71%) of surveyed residents had aesthetic complaints about their drinking water. Five residents complained of poor taste, and six noted their water had a rust-like tinge to it. Home observations confirmed the presence of orange sink stains, likely from excessive iron. Six residents noted a peculiar smell, with one resident complaining of rotten eggs and another commenting that water smelled of chicken manure. One of the complaints regarding smell likely came from the need to have the septic system either cleaned or repaired. Six residents had no complaints.

Bottled water is regularly purchased by 16 of the surveyed residents. Only one person uses tap water as their sole water source. Two residents drink from both tap and bottled water, and only one resident uses a filter before drinking water from their tap.

Prior to visiting these communities, we had a strong suspicion that pit privies served as a source for drinking water contamination. From our surveys and on-site examinations, we discovered that there were no pit privies on any of the residents' properties. Septic systems were noted on 19 properties surveyed and ranged from 1-30 m away from the well. Given that Virginia Department of Health (VDH) regulations for private wells require a minimum setback of 15.2 m (50 feet) from a septic tank or drain field, we recommend verifying the location of the well-septic locations to ensure regulation compliance. Seven homeowners indicated that they had livestock on their property; however, we did not notice livestock during sampling. As such, we presume residents considered household pets as livestock or their homes were located close enough to a livestock farm to be considered as part of "their" property.

Characterization of Sites

Cheapside

Based on measured well depths, we conclude that one well was located in the shallow Columbia Aquifer (9.07 m in depth), while five were located in the deeper Yorktown Aquifer (average depth =34.8 m). For one house, we could not determine well depth because of a cap buried below the ground surface.

While conducting faucet sampling, we noted rotten egg odors in four houses. During the process of purging the well, we found that two houses had noticeable discolored (brown) water. We suspect this discoloration came from sediment that had accumulated in the well and was dislodged while measuring well depth. Potential sources of contamination in Cheapside included adjacent agricultural fields, compromised septic tanks, and outdated infrastructure.

One of the residents gave us brine that had evaporated from pots left on his home radiator (Figure 7). We attempted a gas chromatography–mass spectrometry analysis to determine the chemical make-up of the evaporite, but faulty equipment rendered this method unusable. Our less sophisticated method of analyzing the brine (pouring 1 HCl on it) provided CO_2 (fizz),

suggesting the brine consisted, in part, of calcium carbonate – a constituent of hard water (or scale).

Figure 7. Cheapside community resident providing a brine sample from evaporated sink water to Randolph-Macon College students for analysis.

East Horntown

Based on well depths, one surveyed well in East Horntown was located in the Columbia Aquifer (25.6 m in depth) and five in the Yorktown Aquifer (average depth=34.2 m). During faucet sampling, we noted that water in two houses had a rotten egg odor. During well purging, two houses had brown discoloration which, like Cheapside, we suspect is from sediment accumulation. One house abutted next to an agricultural field, but no other potential environmental hazards were noted.

Water Quality Results

Cheapside

For both well and faucet samples, no residences exceeded MCL or SMCL standards for coliform, *E. coli*, nitrate, phosphate, or surfactants. Five households exceeded the iron SMCL with four houses exceeding those standards in sink samples only, and one both in sink and well samples. One household exceeded the SMCL for TDS with exceedances in both the faucet and well sample (Figure 8, Appendix 1). Field parameter values are given in Appendix 3.

East Horntown

For both well and faucet samples, no residence exceeded MCL and SMCL standards for coliform, *E. coli*, nitrate, phosphate, and surfactants. Four households exceeded the iron SMCL with three of the samples coming from faucets and two samples from wells. Four households

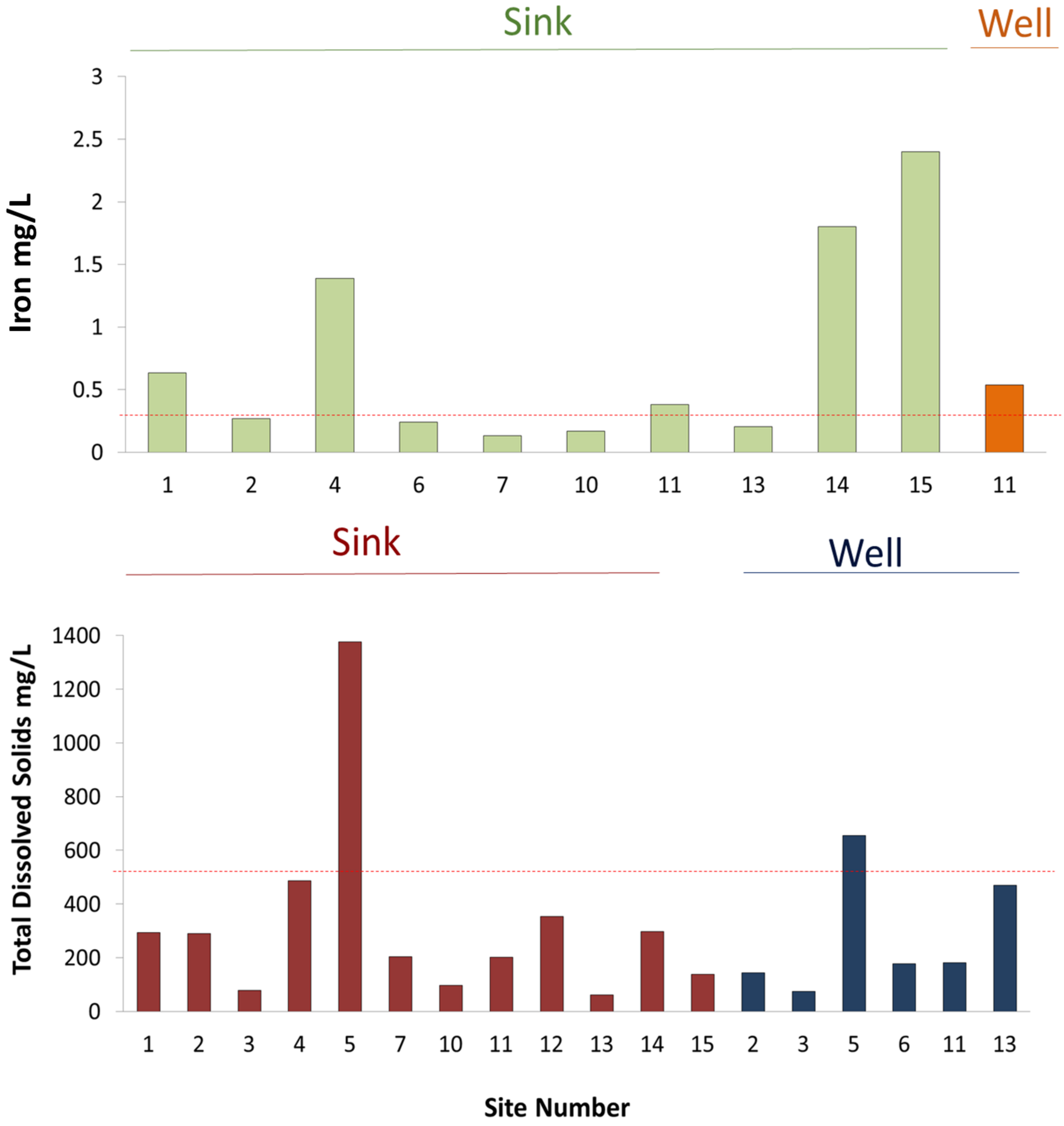

Figure 8. Iron (top) and TDS (bottom) results for sinks and wells sampled in Cheapside. Red line indicates SMCL level.

exceeded the SMCL for TDS with two samples from faucets and two samples from wells (Figure 9, Appendix 2). Field parameter values are given in Appendix 3.

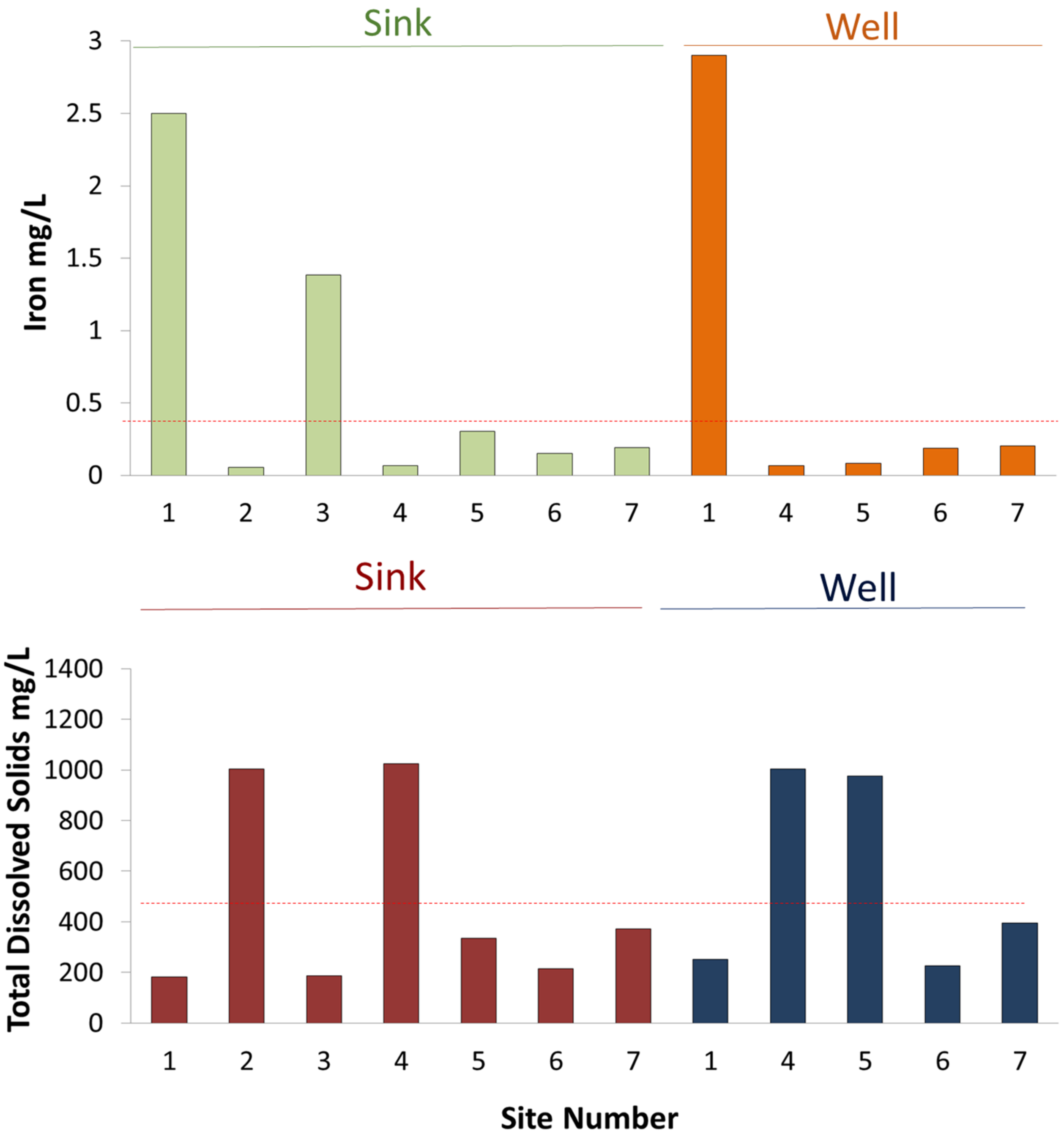

Figure 9. Iron (top) and TDS (bottom) results for sinks and wells sampled in East Horntown. Red line indicates SMCL level.

Groundwater Flow Analysis

Determination of the hydraulic gradient showed that flow directions in each community generally conformed to known flow directions, i.e., groundwater flows toward the east on the east side of Route 13 (the "spline" or topographic high of the DELMARVA peninsula) and west on the west side of Route 13 (Figure 10, Sanford et al. 2009). However, minor differences from this generalized understanding did exist. In the Cheapside community, water flowed northwest on a compass bearing of 340° and, in the East Horntown community, water flowed toward the southeast on a compass bearing of 105°.

The difference in reported and measured flow directions could have resulted from local variations in subsurface stratigraphy or errors in the analysis. For example, the East Horntown community had a local topographic high that may serve as a groundwater flow divide between the two southern wells used in the analysis and the well at East Horntown. We did not account for this topographic boundary condition in this analysis.

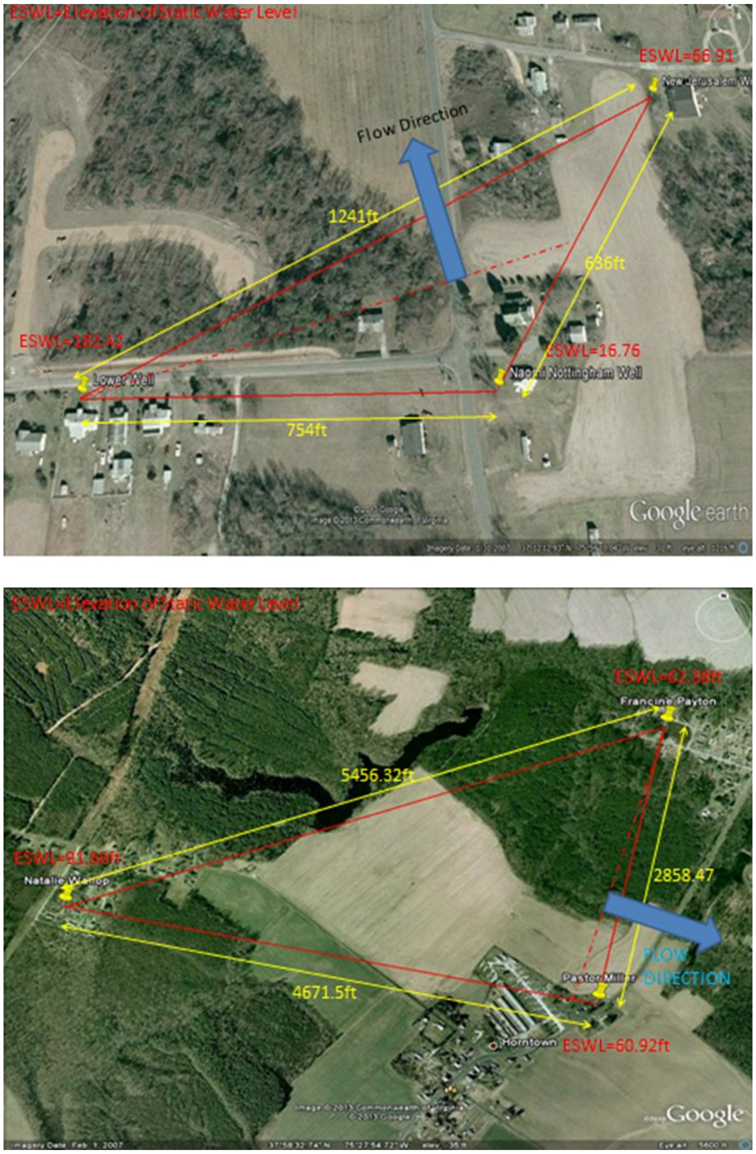

Figure 10. Groundwater flow direction (blue arrow) for Cheapside (top) and East Horntown (bottom). Yellow pins show locations of wells used for the analysis, yellow lines give the distances between wells (in feet), red dashed line shows the contour for the intermediate head in the region

Possible up-flow sources of groundwater contaminates for Cheapside could include mostly agricultural land uses, particularly a large farm owned and operated by Yaros Farms, Inc. (located at 37.20° N,-75.98° W). When questioned about their fertilizer practices, the owners refused an interview. Like East Horntown, our results are sensitive to local variations in subsurface stratigraphy, and several surface water bodies between the farm and residents may act as local discharge boundaries for groundwater. As a result, groundwater flow between the farm and residences we sampled may be disconnected.

Of course, any up-flow land uses of residents could have an impact on the water quality of wells down-flow. For example, one resident had an open-pit refuse burn pile with burnt metals that could have leached into the groundwater. The other up-flow land uses in East Horntown were similar to those of Cheapside because of the rural setting of this community as well. However, it is unlikely that a chicken farm and abandoned land fill would affect the water quality of East Horntown assuming the accuracy of the calculated flow directions. The lack of *E. coli* in any samples corroborates the former assumption.

Summary

A study of 11 wells and 20 faucets in Cheapside and East Horntown indicated that private water supplies in these communities largely comply with MCL and SMCL standards for the constituents tested. The exception to compliance included iron and TDS, both of which exceeded SMCL standards. These exceedances were not consistent within each community, and were only seen in a subset of households. While iron and TDS do not pose a health risk, they do contribute to drinking water aesthetics and could explain why 71% of residents complained of discoloration, odor, and/or poor taste.

The results of our survey distributed to residents provided information about water quality complaints, but also indicated that the majority of homeowners lack knowledge about their water supply. Many did not know the age, depth, or location of their well. Residents were also unaware of land use activities that could contribute to poor water quality or that contamination could pose serious health risks. These findings corroborate other studies that indicate homeowners are often uninformed about their water supply source which, in turn, often results in neglecting the need for regular well water testing and treating (Charrois 2010). As such, future efforts to educate residents about groundwater properties and how to maintain wells could prevent future health hazards and/or provide knowledge that could improve aesthetic water characteristics.

The MCLs and SMCLs established by the EPA are based on dissolved concentration loads which are measured using water that passes through a 0.45 micron filter during collection. We did not filter our water samples; consequently, all measurements are based on the *total* concentration load which equals *dissolved* concentration plus *suspended* concentration. Thus, our values are not directly comparable to EPA standards. However, because total concentration is always greater than the dissolved concentration, we can conclude that any values below MCL and SMCL standards would have fallen below federal standards had we tested for the dissolved concentration exclusively. As such, we can conclude that total coliform bacteria, *E. coli,* nitrate, phosphate, and surfactants are below EPA recommended levels.

Because we tested total concentrations, we cannot conclusively state that iron and TDS exceeded SMCL standards. However, the anecdotal evidence clearly points to a TDS and/or an iron "problem." These constituents do not pose a significant health risk, but do contribute to drinking water aesthetic properties. High iron can contribute to the growth of iron bacteria, which often discolors water and exudes a rotten egg smell (Smith 1984). In addition, high TDS levels can indicate the presence of hard water. Hard water has the undesirable properties of leaving a sticky film on skin or causing scaling on the pipes which will decrease the longevity of the piping system and make the water unpalatable. In addition, hard water routinely interferes with daily tasks such as washing clothes and dishes (Godskesen et al. 2012). A simple chemical analysis of water residue from one resident in Cheapside confirmed that hard water may be common in these communities.

Based on water quality results and the groundwater flow directions, we are unable to identify any point sources of contamination. Further, given that residences with high iron and TDS were distributed patchily in the communities, we have no reason to believe that iron and TDS concentrations are driven by regional processes. It is most likely that high iron and TDS is the result of leaching from local geologic strata (either laterally constrained or at the depth commensurate with the screened well), leaching from the water distribution system, and/or sediment accumulation in wells.

Our study focused on seven contaminates that were identified as potentially suspect based on regional land use and previous studies. We did not test for all possible contaminants including several contaminates that could pose significant health risks. As such, we recommend additional sampling that expands the scope of this study to include addition constituents. It would also be of benefit for future sampling to include a seasonality component. Nitrate concentrations are positively correlated to DO which, in turn, is negatively correlated to water temperature. If samples were collected at lower water temperature or during fertilizer application periods, it is possible that nitrate concentrations would be higher and, in fact, exceed MCL standards.

Remediation Recommendations

Total Dissolved solids (TDS) and iron problems can be attributed to a naturally occurring process and consequently, any efforts taken to remediate poor drinking water quality in Cheapside and East Horntown must be household-specific with funding coming from residents, grants, or donations. Given the results of our study, we conducted a cost-benefit analysis to determine the value of remediation efforts. We also determined the feasibility of various remediation options and identified potential funding sources to aid in funding these projects.

Cost-Benefit Analysis

Because of the variability associated with identifying all variables and associated dollar amounts, cost-benefit analyses (CBAs) are not common in environmental health risk assessments. The difficulty involved in placing a value on the worth of a human life at various ages and with unrelated health concerns makes this type of analysis beyond the scope of this study. Because of this issue, we chose to conduct a modified CBA by calculating costs and benefits on items we could reasonable estimate with the resources at hand. One key assumption of our CBA was that residents of Cheapside and East Horntown are at risk of health effects from poor groundwater quality, an assumption that may be inaccurate given the results of our study.

Costs that were included in this study included the price of resources and/or solutions required to maintain improved water that meets or exceeds federal standards. These costs included product pricing, cost of implementation, opportunity costs, and recurrent costs such as replacement, operation, and regulation. The net benefits of having access to clean water assume that benefits can be realized by fixing common contaminated drinking water problems, reducing the amount of time away from the household, enabling fewer weekly (monthly and yearly) purchases of bottled water, and improving the well-being of residents. While we were able to estimate some costs specific to the Eastern Shore, many numbers were derived from studies conducted in other regions of the United States.

The costs of improving household drinking water and appropriate household sanitation varied depending upon the type of technology used. The costs of improving drinking water increased as technological sophistication, investment planning, and maintenance requirements increased. In contrast, costs decreased when lesser forms of technology resulted in a lower purchase price and less maintenance. Most of the benefits did not include dollar value estimates because of our inability to estimate health benefits accurately. However, we assumed that the willingness to pay for such solutions would increase as poor water quality correlates with greater health risks. Therefore, if a high willingness to pay for such a product exists, we also assumed that the benefits of this particular solution will outweigh the cost of its purchase.

The results of our CBA are incomplete, but do provide initial guidance to suggest that remediation of drinking water would result in a worthwhile investment. A general CBA study conducted by the World Health Organization concluded that water filters could provide an economical benefit between $5-60 USD (Hutton and Haller 2004). As such, we can conclude that, at a minimum, low cost remediation options would likely provide an economic benefit to residents of Cheapside and East Horntown. We also point out the importance of maintaining water filters once installed: Water filters that are not changed out can create water quality problems of their own.

Remediation Options

The use of water filtration systems will only net the most economic benefit if they are the appropriate remediation option. As such, remediation options should be considered independently for every house, and recommendations made only after considering water quality results and well properties.

For houses with wells tapped into the Yorktown Aquifer and only minimal iron and TDS impairment, remediation may be as simple as a faucet attachment used to filter water. The price per attachment ranges from $20 to $100. Faucet attachments are effective for removing iron concentrations up to 3.0 mg/L, and could also filter constituents for which we did not test (e.g., lead) to use as a precautionary measure. Faucet attachments are the simplest remediation option to install, but do incur regular maintenance costs for filter replacement.

Households with iron concentrations that exceed 3.0 mg/L would benefit most from a whole-house filtration system. Filtration systems can be purchased from specialized water filtration stores, the internet, and some home improvement stores. Whole-house filtrations systems range in size and type, and costs range from $20 to $5,000. Whole-house filtration systems are more complicated to install, and also require regular maintenance.

Homeowners with shallow wells could also consider reconstructing their well to a deeper depth. The results of our study provide no evidence to indicate deeper wells protect against iron and TDS impairment; however, deeper wells are generally less susceptible to contamination and could aid in future protection of well water quality. Moreover, deeper wells are less likely to run dry; a motivation many owners of deeper wells had for replacing their shallow well. Well reconstruction can costs several thousands of dollars, but does not require maintenance as often as filtration systems. That said, shallower wells (but still screened in the Yorktown-Eastover aquifer) can sometimes provide a solution to high TDS (Britt McMillan, personal communication, July 24, 2013).

Funding Opportunities

When searching for potential funding sources, we focused on state and local entities as national-level services had previously been pursued by the A-NPDC. In doing so, we determined that the Commonwealth of Virginia has several opportunities to resolve water quality issues and provide financial assistance ranging from hundreds to hundreds of thousands of dollars. Because Cheapside and East Horntown are relatively small communities, with few identified water quality problems, remediation may be less expensive than previously thought and funding can be provided from a variety of organizations.

Non-profit organizations (NPOs) and charities, particularly those already working on the Eastern Shore may provide financial and education remediation assistance. For example, the Community Foundation of the Eastern Shore (CFES) has provided up to $300,000 to advance its mission of strengthening the community by building charitable funds, maximizing benefits to donors, and issuing effective grants. The CFES frequently partners with other NPOs including the United Way and Habitat for Humanity, both of which have chapters located on the Eastern Shore. The United Way has given millions of dollars to service projects in lower income communities over the last several years on the Eastern Shore, and raised $236,000 last year alone. Habitat for Humanity, whose goal is to provide safe and efficient home ownership for those citizens in substandard housing on the Eastern Shore, may not be able to provide direct monetary assistance, but could create projects to help the residents of Cheapside and East Horntown improve the quality of well water and thus, living conditions in their communities.

The Virginia Drinking Water State Revolving Fund, a state grant, provides low interest loans and grants for drinking water projects to local governments and privately organized water suppliers. Furthermore, the fund is perpetual and receives grants and state matched funding from the EPA. Although a large grant may not be needed for these communities, funding from the Revolving Fund may be utilized to consolidate nonpublic drinking water systems if the water is contaminated or inadequate in quantity.

Another grant entitled “Improving state and local capacity to assess and manage risks associated with private wells and other small drinking-water systems by using the Environmental Health Specialist Network” (funding opportunity number: CDC-RFA-EH13-1301; CFDA number: 93.070) is provided by the Centers for Disease Control and Prevention and is only eligible for state or county governments, or Native American tribal governments or organizations. The goal of this grant is to improve state and local health departments’ ability to improve well water in private neighborhoods that may be at risk, and targets the general health of the public. It is possible to obtain anywhere from $100,000 to $175,000.

The Virginia Environmental Endowment is a state-level grant program targeted at eliminating water pollution and educating the public on the importance of clean water. The goal of the Virginia Environmental Endowment “is to improve the quality of the environment by using its capital to encourage all sectors to work together to prevent pollution, conserve natural resources, and promote environmental literacy.” One of the grants that they offer is the Mini-Grant. Because the Mini-Grant is tailored for small projects with the goal of education, this grant is an ideal fit for this project. A mini-grant enables people to solve environmental problems actively in their hometowns. Grants range from $100 up to $5,000. All organizations are eligible, except governmental organizations. Furthermore, they prefer to give grants to programs that are advocating environmental education and striving for water quality protection. The Virginia Environmental Endowment requires a detailed proposal, estimated costs and completion dates, as well as weekly updates, if awarded, to make sure the grant is being used properly.

Conclusion

Private well water in Cheapside and East Horntown did not exceed MCL and SMCL standards for coliform, *E. coli*, nitrate, phosphate, and surfactants. Many resident complaints about their water quality (mostly aesthetic) could be alleviated through the use of low-cost filtrations systems. Further, this remediation is likely the most cost-effective option as exceedances are patchily distributed in each community; an indication that no regional cause or point source exists. We recommend further testing to expand the scope of this study to include additional constituents and seasonal variability.

Acknowledgements

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Literature Cited

A-NPDC. 2001. Water Supply Evaluation of Economically Disadvantaged Communities on the Eastern Shore of Virginia. 1-25

Charrois, J. W. A. 2010. Private drinking water supplies: challenges for public health. Canadian Medical Association Journal 182: 1061-1064.

EJSG Work Plan. 2013. Evaluation of Economically Disadvantaged Community Water Supplies on the Eastern Shore of Virginia.

Godskesen, B., M. Hauschild, M. Rygaard, K. Zambrano, and H.J. Albrechsten. 2012. Life cycle assessment of central softening of very hard drinking water. Journal of Environmental Management 105: 83-89.

Heath, R.C., 2006. Basic Ground-Water Hydrology. U.S. Geological Survey Water-Supply Paper 2220.

Hutton, G. and L. Haller. 2004. Evaluation of the costs and benefits of water and sanitation improvements at the global level. Water, Sanitation, and Health, Protection of the Human Environment, World Health Organization.

Kendall, P. 2010. Drinking water quality and health. Food Science and Human Nutrition 9. 307.

Levin, R. B., P. R. Epstein, T. E. Ford, W. Harrington, E. Olson, and E. G. Rechard. 2002. Drinking water challenges in the twenty-first century. Environmental Health Perspectives 110: 43-52.

Myers, M. D. 2006. Collection of water samples. U.S. Geological Survey Techniques of Water Resources Investigations. Book 9. Chapter A4.

Pontius, F. W. 1990. Complying with the new drinking water quality regulations. Journal (American Water Works Association) 82: 32-52.

Sanford, W. E., J. P. Pope, D. L. Nelms. 2009. Simulation of Groundwater-Level and Salinity Changes in the Eastern Shore, Virginia. Scientific Investigations Report U.S. Geologic Survey 5006: 126.

Smith, S. 1984. Detecting iron and sulfur bacteria in wells. Water Well Journal 38: 58-63.

Appendices

Appendix 1. Laboratory results for sink samples (top) and well samnples (bottom) for Cheapside, Virginia. Missing values indicate a sample was not tested for that parameter. Sample ID numbers correspond to Figure 8.

Resident	ID	Nitrate mg/l	Phosphate mg/l	Sulfate mg/l	Iron mg/l	Surfactants mg/l	Total Dissolved Solids mg/l	Coliform Bacteria
Z. Favors	1	0.10	0.01	63	0.64	0.01	293	0
A. Ames	2	0.00	0.00	51	0.27	0.00	290	0
L. Smith	3	0.00	0.17	55		0.02	79	0
S. Ames	4	0.00	0.20	6	1.39	0.00	487	0
N. Nottingham	5	0.00	0.01	48		0.01	1377	0
D. Lower	6	0.60	0.00	12	0.24	0.01		0
A. Smaw	7	0.80	0.03	17	0.13	0.01	204	0
J.Smith	10	0.00	0.07		0.17	0.01	97	0
L. Ames	11	0.70	0.02	75	0.38	0.01	202	0
N. Brown	12	0.40	0.09	48		0.00	354	0
J. Knottingham	13	0.00	0.04	28	0.21	0.01	61	0
K Phillips	14	> 5.0	0.07	75	1.80	0.01	298	0
Douglas	15	0.00	0.03	30	2.40	0.02	139	0

Resident	ID	Nitrate mg/l	Phosphate mg/l	Sulfate mg/l	Iron mg/l	Surfactants mg/l	Total Dissolved Solids mg/l	Coliform Bacteria
A. Ames	2	0.4	0.07	53		0.01	143	0
L. Smith	3	0.0	0.02	35		0.01	74	0
N. Nottingham	5	0.0	0.13	44		0.02	655	0
D. Lower	6	0.0	0.02	12		0.00	178	0
L. Ames	11	0.6	0.18	68	0.539	0.05	181	0
J. Knottingham	13	0.0	0.00	26		0.00	470	0

Appendix 2. Laboratory results for sink samples (top) and well samnples (bottom) for East Horntown, Virginia. Missing values indicate a sample was not tested for that parameter. Sample ID numbers correspond to Figure 9.

Resident	ID	Nitrate mg/l	Phosphate mg/l	Sulfate mg/l	Iron mg/l	Surfactants mg/l	Total Dissolved Solids mg/l	Coliform Bacteria
N. Wallop	1	0.10	0.06	73	2.50	0.01	181	0
P. Miller	2	0.70	0.04	0	0.06	0.00	1004	0
Bailey	3	0.50	0.00	1	1.39	0.00	187	0
F. Payton	4	0.00	0.71	26	0.07	0.01	1025	0
Townsend	5	0.50	0.20	1	0.31	0.01	336	0
Ross	6	0.00	0.25	1	0.15	0.01	214	0
Wise	7	0.40	0.43	0	0.19	0.01	372	0

Resident	ID	Nitrate mg/l	Phosphate mg/l	Sulfate mg/l	Iron mg/l	Surfactants mg/l	Total Dissolved Solids mg/l	Coliform Bacteria
N. Wallop	1	0.90	0.01	72	2.90	0.01	251	0
F. Payton	4	0.00	0.79	24	0.07	0.01		0
Townsend	5	0.80	0.04	15	0.08	0.01	976	0
Ross	6	0.60	0.14	0	0.19	0.01	225	0
Wise	7	0.00	0.40	0	0.18	0.01	432	0

Appendix 3. Field parameters obtained from Cheapside and East Horntown communities during sampling. Key to sample site location i.d. in Appendix 4.

CHEAPSIDE

	DO			Turbidity			Temperature			pH			Conductivity			Specific Conductance			Salinity		
Site	(mg/L)			(NTU)			(°C)						(µS/cm)			(µS/cm)			(ppt)		
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
CS-2	<.1	<.1	<.1	N/A	N/A	N/A	16	16.3	16.8	7.02	7.72	7.94	296.1	298.8	303.0	357.5	359.3	363	0.2	0.2	0.2
CS-3	0.11	0.14	0.2	2.13	4.24	7.87	15.7	15.8	15.9	7.02	7.8	7.94	234.9	236.8	237.5	287.7	287.8	288.3	0.1	0.1	0.1
CS-5	0.17	0.23	0.4	0.33	0.5	0.76	15.1	15.8	16.2	7.98	8.02	8.04	252.1	256.8	258.8	311	311.6	312.3	0.2	0.2	0.2
CS-6	0.15	0.18	0.27	0.25	0.39	0.54	16.8	17	17.1	7.88	7.96	7.99	219.5	220.2	220.6	260	260.2	260.5	0.1	0.1	0.1
CS-11	0.23	0.24	0.27	0.17	0.31	0.57	16.0	16.1	16.2	7.64	7.8	7.88	300	301.4	302.5	362.1	363.8	365.0	0.2	0.2	0.2
CS-102	<.1	<.1	<.1	N/A	N/A	N/A	16.0	16.1	16.1	7.81	7.8	7.91	209.2	210	210.5	252	253	253.7	0.1	0.1	0.1
CS-801	0.42	0.46	0.49	0.12	0.15	0.19	14.9	14.9	15.0	4.87	5.0	5.09	165.7	166.6	168.0	205.3	206.4	207.8	0.1	0.1	0.1

EAST HORNTOWN

	DO			Turbidity			Temperature			pH			Conductivity			Specific Conductance			Salinity		
Site	(mg/L)			(NTU)			(°C)						(µS/cm)			(µS/cm)			(ppt)		
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
HT-1	<.1	0.18	0.7	0.18	0.22	0.25	14.9	15.5	15.6	8.04	8.10	8.12	134.7	138.3	140.3	164.9	169.0	170.9	0.8	0.9	0.9
HT-2	0.27	0.34	0.61	1.18	2.00	4.26	15.1	15.1	15.2	5.09	5.20	5.42	283.7	302.9	313.2	349.7	373.6	387.0	0.2	0.2	0.2
HT-210	0.12	0.22	0.76	0.18	0.45	1.59	15.1	15.7	15.8	7.81	8.07	8.12	803.0	1121.0	1182.0	980.0	1363.0	1436.0	0.5	0.7	0.7
HT-211	<.1	<.1	0.23	N/A	N/A	N/A	15.6	15.6	15.7	8.11	8.23	8.27	473.0	516.9	524.0	559.0	627.6	639.0	0.3	0.3	0.3
HT-240	<.1	<.1	0.2	0.47	2.51	>9.99	15.3	15.3	15.4	7.40	7.64	7.68	301.9	302.51	302.8	370.5	371.0	371.3	0.2	0.2	0.2

Appendix 4. Key to identifying sample site locations (ND = no data, sink sample only)

Cheapside

CS-1: Z. Favors (ND)
CS-2: A Ames
CS-3: L Smith
CS-4: S. Ames (ND)
CS-5: N. Nott.
CS-6: D. Lower
CS-7: A Smaw (ND)
CS-10: J. Smith (ND)
CS-11: L. Ames
CS-101: N. Brown (ND)
CS-102: J. Nottingham
CS-801: Douglas
CS-802: Phillips (ND)

Horntown

HT-1: F. Payton
HT-2: N. Wallop
HT-200: E. Mille (ND)
HT-202: B.Bailey (ND)
HT-210: B. Townsend
HT-211: S. Wise
HT-240: E. Ross

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