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Study of Water Quality of Public Wells Serving City of Denmark's Public Water System

Measuring pH, bacteria, chlorine residual, lead, iron and manganese in untreated and treated well water

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EXECUTIVE SUMMARY

The City of Denmark Public Water System is a small rural water system in South Carolina serving a population of approximately 4,900 customers. Water is supplied by four active groundwater wells.

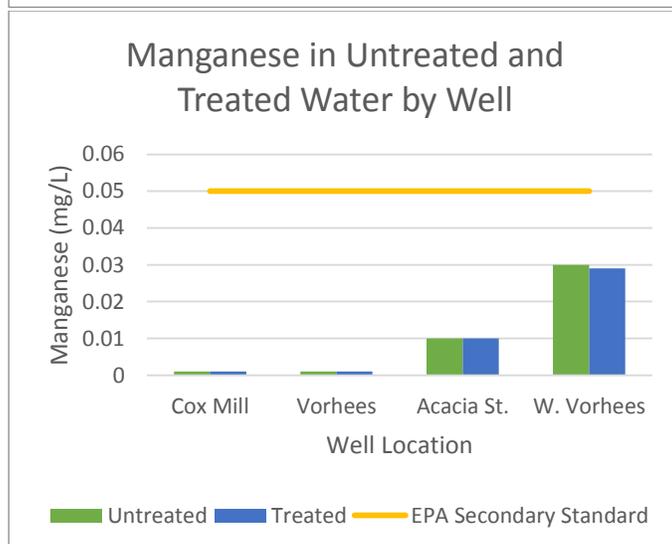
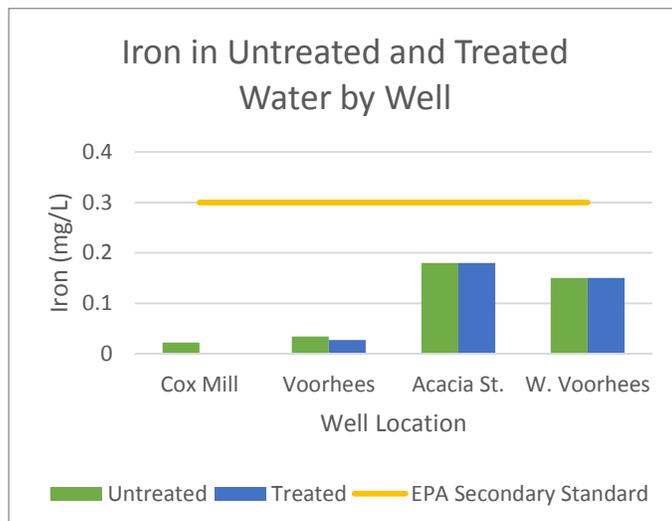
In response to concerns expressed by customers during a SC Department of Health and Environmental Control (DHEC) community meeting on April 5, 2018, the agency agreed to work collaboratively with statewide partners to perform a special sampling study of the water quality of the four public wells serving the City of Denmark.

This study incorporated independent analysis of samples of untreated (raw) water and treated water collected at the well house of each of the four public wells: Cox Mill, Voorhees, Acacia Street and West Voorhees. Each sample from each location was analyzed for pH, bacteria, chlorine residual, lead, iron and manganese.

Partnering organizations included The University of South Carolina Department of Chemistry (USC), and The Edisto Riverkeeper with support of the SC Rural Water Association. Partners collected samples at the same locations and times, but used independent laboratories to perform analysis and prepared independent reports for comparison. This report summarizes DHEC's findings.

KEY FINDINGS from DHEC's SAMPLING

- The pH was within EPA guidelines, close to neutral and less likely to be corrosive.
- No samples from any well detected a measurable concentration of lead.
- There was no evidence of bacteria, and chlorine residuals in treated water indicated that water treatment is effective.
- All levels of iron and manganese in the raw and treated water from wells were below the standards set by the US Environmental Protection Agency (EPA).



STUDY OVERVIEW

BACKGROUND

The SC Department of Health and Environmental Control (DHEC) administers and enforces drinking water quality standards and regulations set by the Environmental Protection Agency (EPA) and the SC State Legislature through compliance testing and monitoring. The City of Denmark's drinking water meets all requirements of all EPA health-based standards. During the last 10 years, the City of Denmark public water system has not exceeded the 90th percentile Action Level for Lead or Copper.

Historically, iron and manganese concerns had been addressed in enforcement actions in 2010 and 2011. The EPA has non-mandatory water quality standards for both iron and manganese which are established as guidelines for public water systems to manage drinking water for aesthetic considerations, such as taste, color and odor. Within the last year, DHEC became aware that some residents in the City of Denmark continued to have concerns about discoloration of drinking water which could be indicators of these metals.

On February 23, 2018, DHEC conducted a sanitary survey inspection on the public water system serving the City of Denmark to evaluate the public water system's ability to provide a continuous supply of safe drinking water to its customers. The City of Denmark received an overall rating of "Needs Improvement" for operational procedures and storage tank maintenance. This rating was **not** related to water quality, but to equipment maintenance that, if not corrected, could result in future water quality issues.

In order to gather a better understanding of customer concerns and strengthen relationships with the community, DHEC hosted a community meeting about the City of Denmark's Public Water System on April 5, 2018. This meeting brought together citizens, customers, town leaders and statewide resources from government, academia and professional partnering organizations to:

- Share information on the City of Denmark's drinking water and DHEC's role with public water systems;
- Introduce partnering organizations that may provide additional resources or expertise to this public water system;
- Hear customer experiences and perspectives on the drinking water; and
- Determine next steps.

During the meeting, questions arose regarding the water quality from the four wells. DHEC does routine monitoring to test water at the wells and along different locations of the distribution system; however, the agency is not required to regularly test for iron, manganese and lead in the wells.

Due to concerns expressed by customers during this meeting, DHEC committed to perform a sampling study in partnership with other statewide academic and non-profit entities to test both the untreated and treated water from the City's four wells. DHEC would test for bacteria (*E. coli* and total coliform), lead, iron and manganese. Iron and manganese were included as a focus of this special study both because of historical concerns and more recent citizen complaints.

Additionally, lead and bacteria would be assessed as indicators for health-based standards, and pH could determine the potential corrosiveness of the water.

DHEC coordinated with the following partners to participate in this special study:

- Dr. John Ferry and Dr. Susan Richardson of the University of South Carolina Chemistry Department (USC); and
- Meg Adams, the Edisto Riverkeeper (Riverkeeper) with support from the SC Rural Water Association.

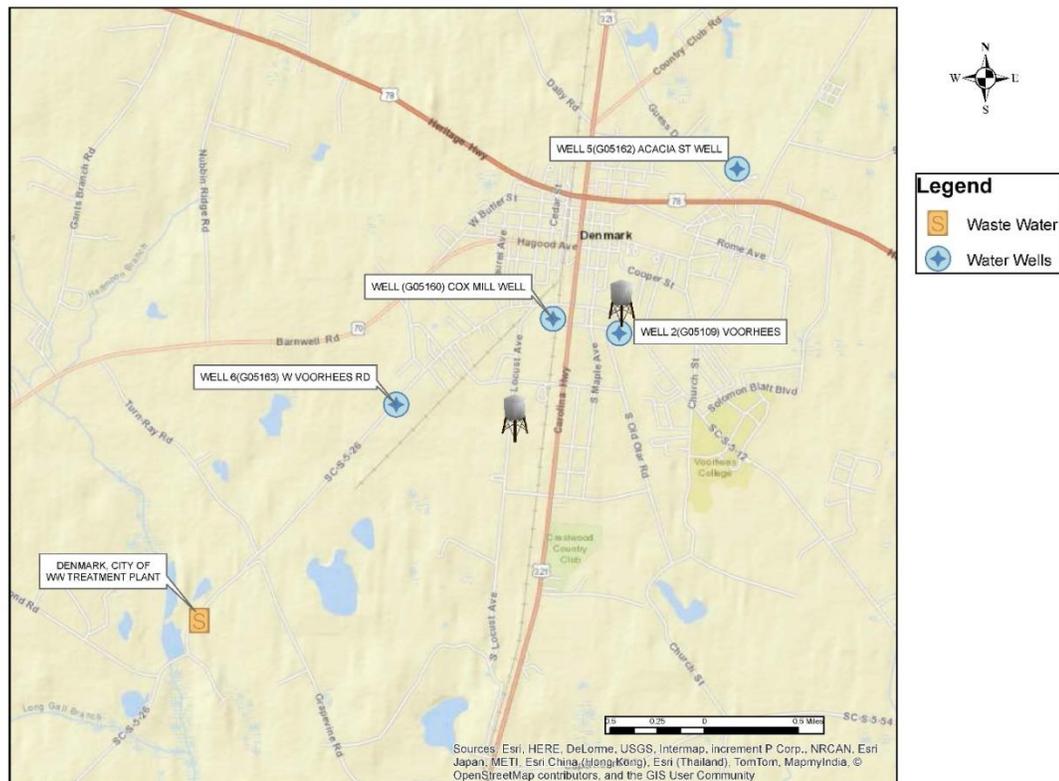
These partners agreed to a coordinated sampling plan with independent analysis and independent reporting. This study was designed to produce more comparable data, provide independent analysis and support better understanding of the City of Denmark's drinking water quality.

COORDINATED SAMPLING PLAN

For this study, partners adhered to a coordinated plan to independently collect raw (untreated) and treated samples at the same time and from the same locations. Sampling was done on April 16, 2018. The following provides details about the water system and sampling locations.

The City of Denmark is served by four public wells known as the Cox Mill, Voorhees, Acacia Street, and West Voorhees wells. Because the City of Denmark public water system distributes water from all four wells throughout its system, the sampling plan was designed to test all four public wells. The Cox Mill and Voorhees wells are the older wells. The Acacia Street and West Voorhees were added to the system in 2010. The location of each well is noted in the map.

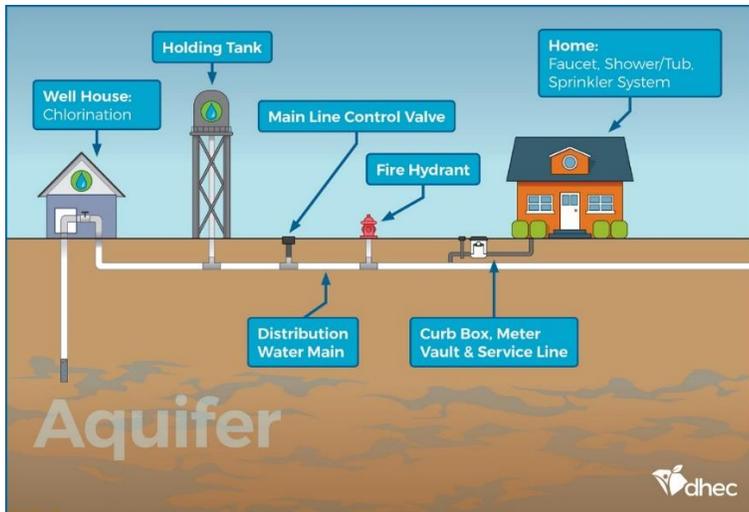
City of Denmark water supply wells and waste water treatment plant locations



All four wells have individual well houses. The well houses contain valves, control switches, meters, chemicals used in treatment and sampling spigots. There are two types of sampling spigots required at well houses: an untreated water spigot, providing raw water as it comes from the ground, and a treated water spigot, providing water after any treatment is added.

Within the well houses, chlorine is added to the water for treatment. Chlorine treatment is very common in public water systems. Chlorine is added to disinfect the water by killing any harmful bacteria if any is present. The Cox Mill Well has an additional treatment for iron bacteria which consists of an automatic injection of HaloSan tablets.

Water samples were collected at each of the four wells in the individual well houses on April 16, 2018.



Untreated water, also known as raw water, is pumped out of the underground aquifer into the pump house and has not been treated with chlorine or any other treatment method. The untreated sampling spigot is located very close to the pump that is pumping the water out of the underground aquifer.

Treated water is water that has been injected with chlorine, and at the Cox Mill Well also receives additional HaloSan treatment. The treated sampling spigot is always downstream of the untreated spigot.

DHEC, USC and the Edisto Riverkeeper independently collected water samples at both untreated and treated water spigots at each of the four wells. Separate samples were collected for metals analysis and bacteriological analysis. The metal samples were analyzed for lead, iron and manganese. The bacteriological samples were analyzed for total coliform and *E. coli*.

In addition to the bacteriological and metal analysis, the temperature, pH, and chlorine residual of the untreated and treated water samples from each well were measured and recorded. Temperature, chlorine residual and pH were all tested using calibrated field meters and results were recorded in the field at the time of sample collection.

A good chlorine residual indicates whether or not a sufficient amount of chlorine was added to the water to kill the bacteria that could cause harm if present. The measure of pH indicates whether the water is acidic or basic. The pH range goes from 0 to 14, (from acidic to basic). The EPA recommends a pH from 6.5-8.5 to be more neutral and less corrosive.

When conducting a study that involves data collection, quality control measures are also essential. Quality control ensures the data collected is valid and that data can be compared from multiple labs.

Results from the analysis of blind samples were used as a quality control measure. In this study, a USC chemist who was not involved in the sampling event created three sets of identical blind samples containing known quantities of each metal, one set for each lab. The blind samples included known concentrations for lead, iron and manganese. These blind samples were distributed to each of the partners, who did not know the concentrations of each metal.

DHEC TECHNICAL REPORT

METHODOLOGY

DHEC followed its Standard Operating Procedures (SOPs) when collecting, storing, transporting and delivering samples, as required for all regulatory sampling and monitoring. Bacterial samples were delivered and analyzed at the certified lab at the DHEC Aiken Regional Office. All other samples were delivered and analyzed at the DHEC State Lab, Columbia, SC, which is certified by the EPA.

Three groups of samples were received by the DHEC labs. Samples labeled AE10898 – AE10905 were collected from the four public wells in Denmark and analyzed for lead, iron and manganese. Samples AE10948-AE10955 were also collected from the four public wells of Denmark and analyzed for the presence of total coliform and *E.coli* bacteria. Samples AE-11141-AE11143 were the blind metals concentration samples prepared by the USC Chemistry Department of a known quantity of lead, iron and manganese.

All samples were analyzed using EPA-approved methods. Lead samples were analyzed using DHEC Standard Operating Procedure (SOP) IX-D-5 Trace Metals by Graphite Furnace Atomic Absorption (GFAA), based on EPA Method 200.9. Iron and manganese samples were analyzed using DHEC SOP IX-D-6 Trace Metals by ICP, based on EPA Method 200.7. The bacteriological samples were analyzed using DHEC SOP VIII-B-1, based on Standard Methods 9223 B.

Here are brief summaries of the three methods used by the DHEC Division of Analytical and Radiological Environmental Services Laboratory to analyze the samples.

Determination of Lead by GFAAS (DHEC SOP IX-D-5)

This method describes the determination of elements in water using Graphite Furnace Atomic Absorption Spectroscopy (GFAAS). The sample is introduced onto a graphite platform and is heated rapidly causing the sample to atomize. A hollow cathode lamp produces specific wavelengths of light for each metal. The amount of light the sample absorbs is proportional to the concentration of the target metal in the sample.

Determination of Iron and Manganese by ICP (DHEC SOP IX-D-6)

This method describes a technique for determination of metals in water using Inductively Coupled Plasma (ICP). The method uses spectrometry (measurement of light) to determine the identity and concentration of metals. The sample is introduced into high temperature argon plasma as an aerosol, where metal electrons are excited. The excitation causes the emission of light at wavelengths specific to each metal. The emitted light is measured, and the concentration of the target metal is proportional to the intensity of the light that is emitted by the excited metal atoms.

Determination of Total Coliform and E.coli bacteria by Enzyme Substrate (DHEC SOP VIII-B-1)

The appropriate Enzyme Substrate Test (EST) media packet is added to the sample and the sample is incubated to allow any bacteria to multiply. The presence of total coliform is indicated by a pre-determined color change after incubation. The presence of *E. coli* can be detected by fluorescence stimulated using a 365 nanometer ultraviolet light source in a dark room.

All results for metals of lead, iron and manganese were measured in milligrams per liter (mg/L). All sampling methods included a minimum amount detectable, also known as the detection limit. Sample results below these analytical limits were expressed as less than (<) the limit of detection.

RESULTS AND DATA BY WELL LOCATION

Cox Mill Well	Sampling	DHEC Lab Results	EPA Standards
<i>Temperature</i> (degrees Fahrenheit)	Untreated well water	66.7	
	Treated water	68.0	
<i>pH</i>	Untreated well water	7.47	6.5-8.5
	Treated water	7.43	6.5-8.5
<i>Total Residual Chlorine</i> (mg/L)	Untreated well water	0.81	
	Treated water	0.89	
<i>Bacteria</i> (<i>E. coli</i> & total coliform)	Untreated well water	Absent	Absent
	Treated water	Absent	Absent
<i>Lead</i> (mg/L)	Untreated well water	Less than 0.0020*	Below 0.0150
	Treated water	Less than 0.0020*	Below 0.0150
<i>Iron</i> (mg/L)	Untreated well water	0.022	Below 0.300
	Treated water	Less than 0.020*	Below 0.300
<i>Manganese</i> (mg/L)	Untreated well water	Less than 0.010*	Below 0.050
	Treated water	Less than 0.010*	Below 0.050

*Values of less than 0.0020 mg/L for lead, less than 0.020 mg/L for iron and less than 0.010 mg/L for manganese are considered below the minimum detection limit.

Voorhees Well	Sampling	DHEC Lab Results	EPA Standards
<i>Temperature</i> (degrees Fahrenheit)	Untreated well water	67.8	
	Treated water	67.1	
<i>pH</i>	Untreated well water	7.86	6.5-8.5
	Treated water	7.80	6.5-8.5
<i>Total Residual Chlorine</i> (mg/L)	Untreated well water	Less than 0.05	
	Treated water	0.58	
<i>Bacteria</i> (<i>E. coli</i> & total coliform)	Untreated well water	Present, retest Absent**	Absent
	Treated water	Absent	Absent
<i>Lead</i> (mg/L)	Untreated well water	Less than 0.0020*	Below 0.0150
	Treated water	Less than 0.0020*	Below 0.0150
<i>Iron</i> (mg/L)	Untreated well water	0.034	Below 0.300
	Treated water	0.027	Below 0.300
<i>Manganese</i> (mg/L)	Untreated well water	Less than 0.010*	Below 0.050
	Treated water	Less than 0.010*	Below 0.050

*The value of less than 0.0020 mg/L for lead and less than 0.010 mg/L for manganese are considered below the minimum detection limit.

**The initial sample for untreated water at the Voorhees Well for total coliform bacteria had a positive result. Resampling is required for any positive bacteria reading and DHEC collected a repeat sample on April 17, 2018. The repeat sample was negative for total coliform and the Edisto Riverkeeper also confirmed negative results. USC did not conduct bacteriological sampling.

Acacia Street Well	Sampling	DHEC Lab Results	EPA Standards
<i>Temperature (degrees Fahrenheit)</i>	Untreated well water	69.6	
	Treated water	68.2	
<i>pH</i>	Untreated well water	7.68	6.5-8.5
	Treated water	7.56	6.5-8.5
<i>Total Residual Chlorine (mg/L)</i>	Untreated well water	Less than 0.05*	
	Treated water	0.84	
<i>Bacteria (E. coli & total coliform)</i>	Untreated well water	Absent	Absent
	Treated water	Absent	Absent
<i>Lead (mg/L)</i>	Untreated well water	Less than 0.0020*	Below 0.0150
	Treated water	Less than 0.0020*	Below 0.0150
<i>Iron (mg/L)</i>	Untreated well water	0.180	Below 0.300
	Treated water	0.180	Below 0.300
<i>Manganese (mg/L)</i>	Untreated well water	0.010	Below 0.050
	Treated water	0.010	Below 0.050

*The value of less than 0.0020 mg/L for lead and less than 0.05 mg/L for chlorine are considered below the minimum detection limit.

West Voorhees Well	Sampling	DHEC Lab Results	EPA Standards
<i>Temperature (degrees Fahrenheit)</i>	Untreated well water	65.7	
	Treated water	66.0	
<i>pH</i>	Untreated well water	7.68	6.5-8.5
	Treated water	7.73	6.5-8.5
<i>Total Residual Chlorine (mg/L)</i>	Untreated well water	Less than 0.05*	
	Treated water	0.4	
<i>Bacteria (E. coli & total coliform)</i>	Untreated well water	Absent	Absent
	Treated water	Absent	Absent
<i>Lead (mg/L)</i>	Untreated well water	Less than 0.0020*	Below 0.0150
	Treated water	Less than 0.0020*	Below 0.0150
<i>Iron (mg/L)</i>	Untreated well water	0.15	Below 0.300
	Treated water	0.15	Below 0.300
<i>Manganese (mg/L)</i>	Untreated well water	0.030	Below 0.050
	Treated water	0.029	Below 0.050

*The values of less than 0.0020 mg/L for lead and less than 0.05 mg/L for chlorine are considered below the minimum detection limit.

Blind Samples

Blind samples were used as a quality control measure. For this study, a USC chemist not involved in the sampling event created three sets of identical blind samples containing known concentrations of lead, iron and manganese. These blind samples were distributed to each of the partners, who did not know the concentrations of each metal until after the analysis had been reported. Each of the three

partners analyzed the blind samples independently using the same methods and labs as analysis of other samples.

<i>Blind Sample Comparison</i>	<i>Known Standards</i>	<i>DHEC Lab Results</i>
<i>Lead (mg/L)</i>	0.015	0.017
<i>Iron (mg/L)</i>	0.200	0.200
<i>Manganese (mg/L)</i>	0.150	0.150

ANALYSIS & DISCUSSION

The results of this sampling study did not indicate any significant issues with the water quality at any of the public wells serving the City of Denmark.

The pH was with a range of 7.43-7.86 as field tested during sampling of untreated and treated water at all four wells. These values are close to a neutral reading of 7.0 and within the recommended EPA range of 6.5-8.5. These pH levels indicate that the water is not corrosive.

There was no detectable or measurable concentration of lead in any of the samples of untreated or treated water from the four wells. The minimum detection level for lead at the DHEC State Lab is 0.0020 mg/L. All samples were below this detection level and significantly below the EPA action level of 0.0150 mg/L.

DHEC collected bacteriological samples from all wells on April 16, 2018. Bacteriological sampling is very sensitive. The result of the first sample of untreated water from the Voorhees well came back positive for total coliform. Positive total coliform can be a result of several issues and is not always indicative of the presence of bacteria in the source water. For example, positive samples can be a result of the sample bottle cap touching a non-sterile environment, water splashing off areas around the sample spigot or even bacteria that is growing on the sample spigot.

It is standard practice that whenever a positive reading is returned, resampling is required. DHEC collected and analyzed a repeat sample on raw, untreated water at the Voorhees Well on April 17, 2018 which came back negative for total coliform. In addition, the results from samples collected by the Edisto Riverkeeper also came back negative for total coliform. Therefore, the initial positive total coliform sample from the untreated spigot was determined to be due to a sampling error.

All other bacteria readings showed no indication of the presence of E. coli and total coliform.

Chlorine residuals measured in treated sample water indicated that water treatment was effective. Because gaseous chlorine is used as a treatment at all four wells, chlorine levels are expected to be

Lead, iron and manganese in drinking water are measured in milligrams per liter (mg/L).

One mg/L is equal to one part per million, and it would be equivalent to

- one minute in two years or*
- one single penny in \$10,000.*

higher in treated samples than in the raw, untreated water samples, and findings were consistent with proper operation of the treatment system.

All levels of iron and manganese in the untreated and treated water from all wells were below the standards set by the EPA.

The EPA has non-mandatory water quality standards for both iron and manganese which are established as guidelines for public water systems to manage drinking water for aesthetic considerations, such as taste, color and odor. The standard for iron is 0.300 mg/L and for manganese is 0.050 mg/L.

All samples results were below these levels. Additionally, the manganese results were below measurable detection levels for the untreated and treated samples of Cox Mill and Voorhees wells, and iron was below measurable detection levels for the treated water of the Cox Mill well.

Blind samples were used as a quality control measure. All results from analysis of the blind samples were within the expected analytical variability range, supporting validity of all the data collected in this study.

In sharing preliminary data, DHEC data appears to be consistent with blind sample results of the partners. Each partner will be producing independent analysis and reports for further coordination.

The DHEC Division of Analytical and Radiological Environmental Services Laboratory is certified by EPA. Results from certified labs have legal regulatory authority. **Based on DHEC State Lab results, no regulatory actions are necessary.**

NEXT STEPS

DHEC, USC and the Edisto Riverkeeper will be sharing their findings from the well sampling study with each other for comparison and further analysis. Each partner has also agreed to share findings and recommendations with the City of Denmark and its community members. Reports from all partners will be made available online.

DHEC will continue to administer and enforce drinking water quality standards and regulations set by the EPA and the state legislature through compliance testing and monitoring. DHEC staff will continue to promote the best possible water quality levels by providing technical assistance and education to all public water systems in the state. Additionally, DHEC will coordinate and work collaboratively with the State Drinking Water Technical Advisory Committee, with individuals and with stakeholders to help us enhance monitoring and share resources with the City of Denmark and the state's public water systems. DHEC will continue to respond to any complaints that citizens make regarding the quality of their drinking water.