Radionuclides in the Miocene Aquifers of Coastal Georgia

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ABSTRACT: Chronic exposure to radionuclides can pose serious health risks. This study was conducted to verify measurable levels of radon in the Upper and Lower Brunswick aquifers and evaluate the presence of dissolved uranium in groundwater from these aquifers. Two one-gallon (3.8 L) samples were taken from each of 13 wells near Brunswick, Georgia. Portions of each sample were prepared and tested in the Environmental Radiation Laboratory at Georgia Institute of Technology for uranium and gross alpha radiation. Samples for uranium analyses were prepared using an ion-exchange technique, and both tests were conducted using an Alpha Beta Proportional Counter. Later, two samples from each well and a trip blank were collected for radon testing in the Liquid Scintillation Analyzer at Georgia Tech. The data show that levels of uranium dissolved in the groundwater itself are negligible. Radon and gross alpha levels were consistent with values found in phase one. Lower Brunswick wells tended to have radon levels above the Maximum Contamination Level (MCL) of 300pCi/L, while Upper Brunswick wells were below the MCL. Both aquifers have gross alpha activity levels far above the MCL of 5pCi/L. In conclusion, the uranium that produces gamma radiation in these aquifers is not dissolved in the groundwater, but probably exists as a solid contained in the phosphate sands that comprise the aquifers. In addition, there are consistent levels of radon and gross activity within both aquifers throughout the area, although levels are higher in the Lower Brunswick.

KEYWORDS: radionuclides, Upper and Lower Brunswick aquifers, groundwater, dissolved uranium.

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1. INTRODUCTION

Radionuclides, specifically uranium, are known to exist in the phosphate sands that make up the aquifers of the Brunswick region of Georgia. This is evident from the United States Geologic Survey (USGS) geophysical logs of wells in the area [3], in which peaks in natural gamma radiation, an indicator of uranium, are used to determine the locations of the two Miocene aquifers. In phase one of this study, I found radon in these two aquifers, which I concluded to be the result of radioactive decay from this uranium. The radon detected in the previous experiment could also have been an isolated occurrence, or have decayed from uranium ions dissolved in the groundwater. This could indicate the possibility of an outside source of contamination. In phase one, however, dissolved radium was negligible in the groundwater, and I concluded that the source of these radionuclides may be the phosphate sands that comprise the aquifers. Information is needed on the distribution of radon within these two aquifers in the Brunswick area, and testing done for uranium rather than just its products. This year, I was not testing for radium, but continued to test gross alpha activity as an indicator of alpha emitting radionuclides.

The purpose of this experiment was to expand upon research conducted in phase one by performing an expanded study of measurable radon levels in the Upper and Lower Brunswick Aquifers, and determine the presence of dissolved uranium in the groundwater from these aquifers.

I hypothesized that if uranium, like radium, is in these aquifers as a solid within the phosphate sands only, and there are moderate levels of radon throughout the Brunswick aquifer system, then there is little to no uranium actually dissolved in the groundwater.

2. MATERIALS AND METHODS

Thirteen wells in the Upper and Lower Brunswick Aquifers were sampled for uranium, gross alpha, and radon testing (Table 1). In late July, two one-gallon samples were collected from each well, adding 10 mL 4N nitric acid preservative to each. Each well location, aquifer, and other basic information was recorded. In addition, each new well was marked on a map with those from phase one using a GPS. The wells were resampled in early October for radon assessments, except for well 037, since it had been damaged in a storm. The flow of each purged well was slowed; a funnel attached to a length of hose was used to direct the water and achieve linear flow. Using a syringe, rinsed with water from the well being sampled, two 11 mL samples were collected from the funnel, ejecting any air in the syringe. The samples were injected below the pre-prepared scintillation fluid to trap all radon in the sample. The time of collection was recorded, and the vials were labeled 'a' and 'b.' These samples were placed in a Liquid Scintillation Analyzer (LS count) before the radon was lost through radioactive decay.

Well #	**Well Ownership/Use**	**Location (GPS Coordinates)**	**Depth of Well** (ft.)	**Aquifer**
w1	Private	N31°05'27.8" W81°35'0.9"	240	Upper Brunswick
w2	Private	N31°05'19.9" W81°33'58.1"	480	Lower Brunswick
w3	Private	N31°02'27.1" W81°32'24.5"	480	Lower Brunswick
w4	Private	N31°07'43.2" W81°37'43.6"	240	Upper Brunswick
w5	Private	N31°06'2.9" W81°42'36.7"	450	Lower Brunswick
w6	Private	N31°06'2.9" W81°42'36.7"	280	Upper Brunswick
w7	Municipal	N31°16'41.5" W81°28'36.8"	540	Upper and Lower
032	Public Drinking	N31°08'11.9" W81°37'46"	450	Upper and Lower
033	Public Drinking	N31°07'58.2" W81°35'54.4"	540	Upper and Lower
034	Municipal	N31°08'0.3" W81°33'35.3"	540	Upper and Lower
035	Private**	N31°04'31.5" W81°24'41"	560	Lower Brunswick
036	Private**	N31°04'14" W81°24'55.5"	540	Lower Brunswick
037	Private	N31°02'28.8" W81°32'26.7"	180*	Upper Brunswick

* Depth is uncertain, it may be much shallower. ** May be used by general public.

Table 1. Summary of basic information.

Gross alpha samples were prepared using the *EPA Gross Alpha/Beta Analysis of Water* [4] also used in phase one. A 200 mL sample was taken from each set of cubitainers, as well as a duplicate sample from cubitainer 6b (well w7), which was randomly selected. These were each put into a labeled beaker and boiled down on a large hotplate to a residue. hese residues were rinsed with nitric acid, and rubber policemen were used to place each sample into a labeled planchet. These planchets were placed under a heat lamp until all liquid evaporated. Each sample was then flamed over a Bunsen burner, to burn off any organic matter, and allowed to cool. Planchets were then weighed and placed into the Alpha-Beta Proportional Counter for analysis.

For the uranium testing, I followed the *EPA Prescribed Procedures for the Measurement of Radioactivity in Water* [7]. A 1 L sample was taken from each set of cubitainers and a sample from 5b (well 034) was used as a duplicate. Iron chloride carrier and 12N HCl were added to each one. Each sample was covered, heated to a boil, and stirred, during which time 10 mL 6N ammonium chloride was added. Each resulting precipitate collected on a filter using a 3 L flask with suction. The samples were transferred to a 250 mL flask and dissolved with 25 mL of 8N HCl, filtered with suction. The resulting solutions were then transferred to ion exchange columns, along with 50 mL of HCl used to rinse the flasks, in order to separate unwanted ions and elute the uranium. Because the sample from well w3 was having difficulty dripping through the column, the process was repeated twice more with this sample. However, there was no improvement. Each elute was evaporated to residue. The residues were washed into planchets using 4N nitric acid, placed under a heat lamp to dry and flamed over a Bunsen burner. Finally, they were put into the Alpha-Beta Proportional Counter for testing.

3. RESULTS

The majority of the wells in the Lower Brunswick aquifer had higher levels of radon than those the Upper Brunswick (Figure 1). Levels were below the MCL of 300 pCi/L allowable by the EPA for several wells. Radon levels for each well were fairly consistent between phase one and phase two, although some variation was noted (Figure 2). Variations in gross alpha activity were also present (Figure 3), some being more drastic than others. In phase one, w3 showed an already high gross activity level of 16.4 pCi/L, which increased to 112 pCi/L in phase two. Only wells w6 and 032 were below the MCL for gross alpha activity of 5 pCi/L (Figure 4). Except for w5, all wells in the Lower Brunswick and two of the four wells in both aquifers (w7 and 034) were above 15 pCi/L. The uranium testing, like the radium test in phase one, showed such minute traces of uranium dissolved in the water it is possible to say there was no uranium in the water (Table 2).

Well Number	**Uranium Content** Trial 1 (pCi/L)	**Uranium Content** Trial 2 (pCi/L)	**Uranium Content** Trial 3 (pCi/L)	**Avg. Amount Uranium** (pCi/L)
w1 (9)	.00004	.00001	.00002	.000023
w2 (13)	.000005	.00003	.00002	.000018
w3 (10a)	.00031	.00031	.00025	.00029
w3 (10b-1)	.00024	.00024	.0003	.00026
w3 (10b-2)	.00024	.00024	.00032	.000267
w3 (10 -avg.)				.000272
w4 (3)	.00002	.00003	Nothing (.000)	.000017
w5 (2)	.00003	.00005	.00001	.00003
w6 (12)	.00001	.00001	.00001	.00001
w7 (6)	.00004	.00002	.00002	.000027
032 (1)	.00007	.00005	Nothing (.000)	.00004
033 (4)	.00002	.00001	Nothing (.000)	.00001
034 (5a)	.00003	Nothing (.000)	.000005	.000027
034 (5b)	.00002	Nothing (.000)	.00002	.000013
034 (5 -avg.)				.00002
035 (7)	.00001	Nothing (.000)	.00003	.000013
036 (8)	.00001	.00002	.00003	.00002
037 (11)	.00003	.00004	.000005	.00004
Sample 14 (trip blank)	.00001	Nothing (-.00003)	.00002	Nothing (.00000)

Table 2. Uranium levels in ground water samples from wells of Upper and Lower Brunswick aquifers

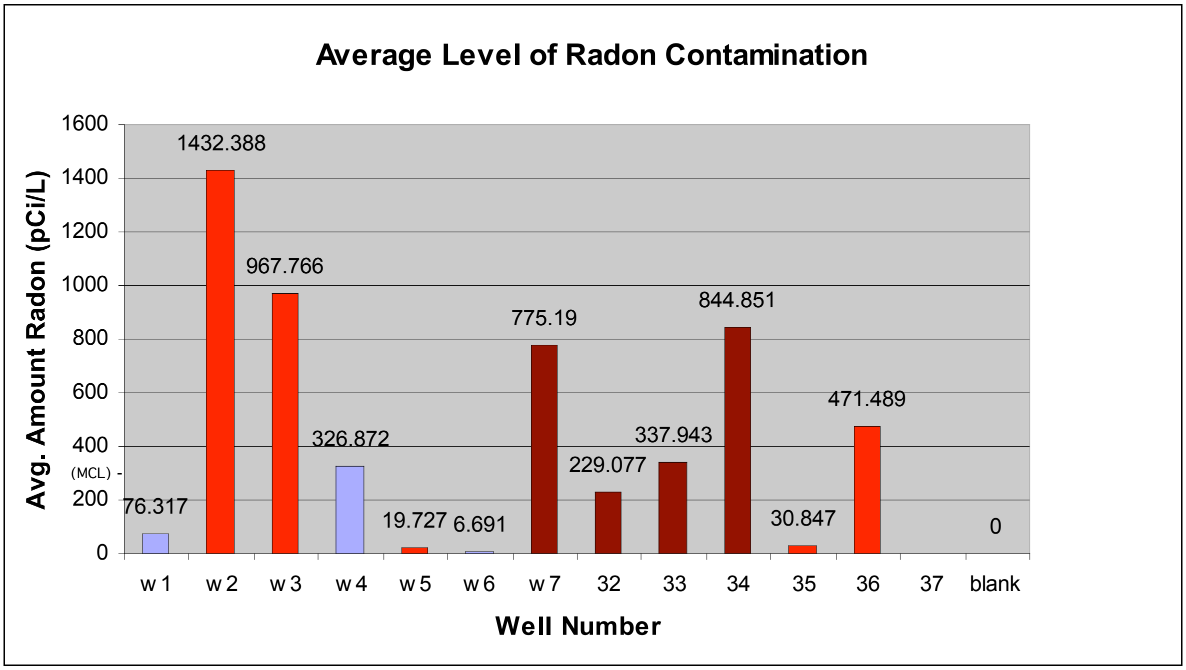

Figure 1. Average level of radon contamination.

Legend:
Upper Brunswick –
Lower Brunswick –
Upper and Lower Brunswick –
MCL – Maximum Contamination Level

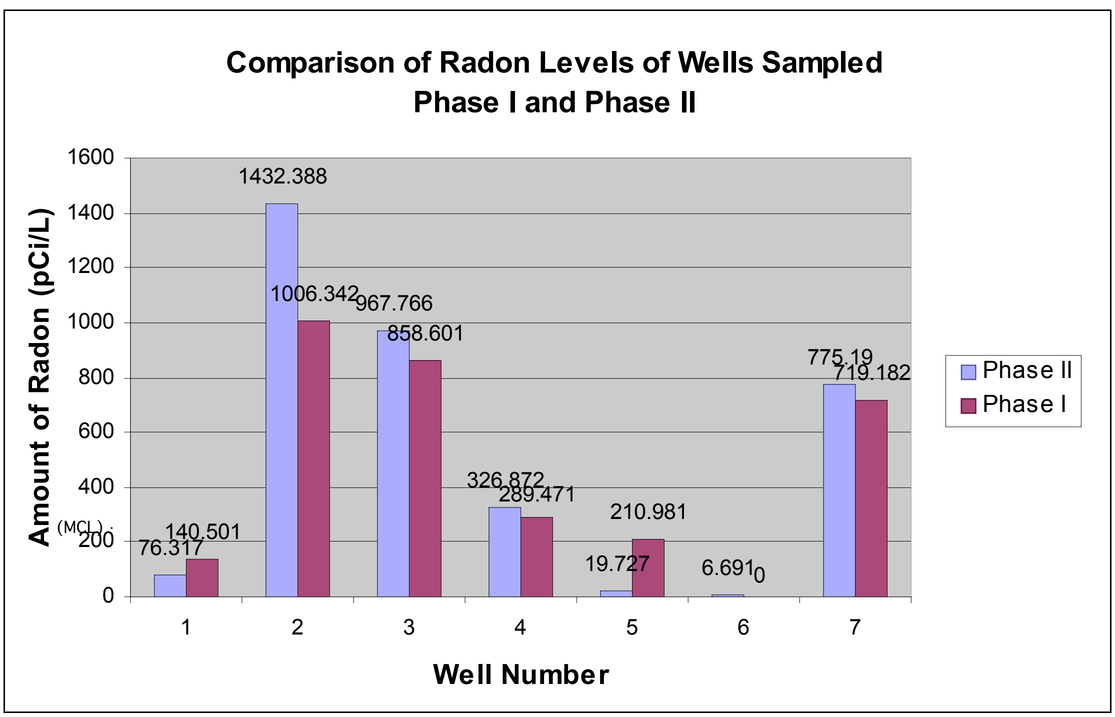

Figure 2. Comparison of radon levels of wells sampled phase I and phase II.

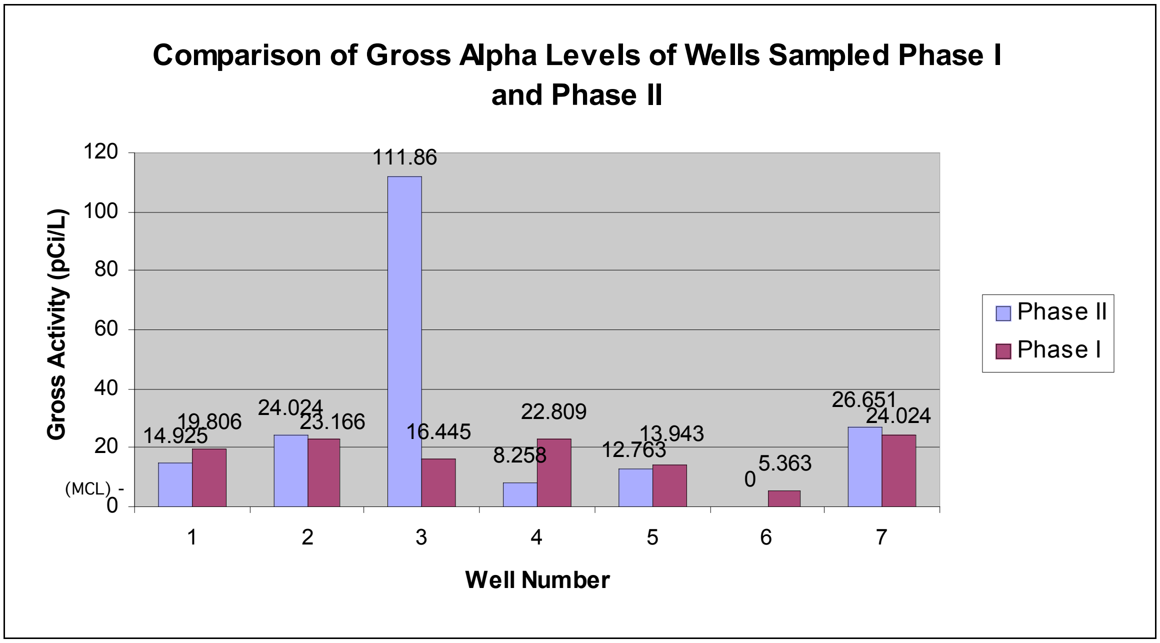

Figure 3. Comparison of gross alpha levels of wells sampled phase I and phase II.

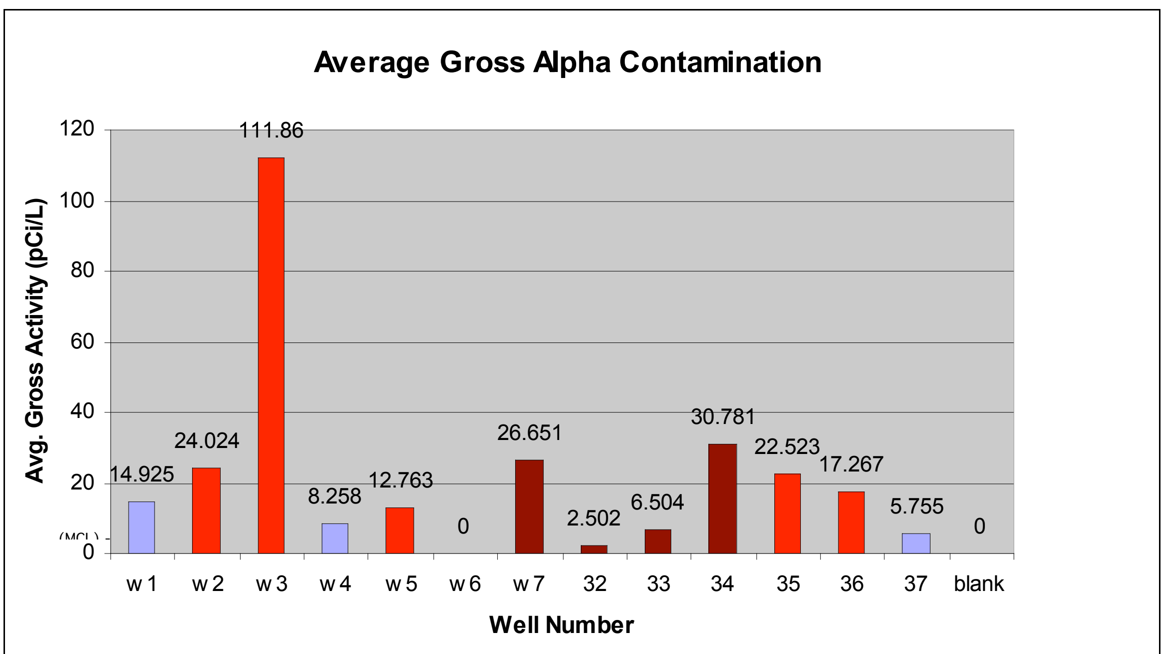

Figure 4. Average gross alpha contamination.

Legend:
Upper Brunswick –
Lower Brunswick –
Upper and Lower Brunswick –
MCL – Maximum Contamination Level

4. DISCUSSION

In phase one of this study, radon levels in some wells in both the Lower and Upper Brunswick Miocene aquifers were above the MCL considered allowable by the EPA. This is an area where radionuclides are not considered to be present in large high concentrations [2], and are not regarded as a potential hazard. However, these aquifers are rarely tested for radon or other radionuclides because they lie directly above the limestone Floridon aquifer, which is remarkably free of radionuclides. This aquifer is very extensive and, unfortunately, its water often disputed over between Florida, Georgia, South Carolina, and Alabama. Thus, most residents in the Brunswick area have begun relying on the Miocene Brunswick aquifers as an alternate water source. Some residents have tried to use Floridon wells and claim them as Miocene wells, or pass off poorly constructed wells as fully functional to save money. By confirming the presence of radon in properly drilled Miocene wells, it may be possible to use a radon test to determine if a well has been constructed correctly. Currently, the USGS uses peaks in gamma radiation as stratographic makers to find each of these aquifers in geophysical logs of wells in the area [3]. This indicates the presence of uranium and by products of its radioactive decay in the phosphate sands that make up the two aquifers [6]. The possibility exists that uranium is even dissolved in the groundwater. It was this possibility that prompted me to test the water for uranium this year.

Contrary to geophysical logs of wells in the area [3] and gross alpha levels typical of a uranium source [1], data from this study indicate that uranium is not dissolved in the groundwater. Even w7, which exhibited difficulty going through ion exchange during testing, showed negligible results. A similar result was noted during phase one when testing for radium, the immediate predecessor of radon in the radioactive decay chain. There was radon in the water of these confined aquifers, yet tests for the presence of radium in groundwater showed negligible results. Therefore, it was concluded that since radium is not dissolved as an ion in the groundwater, it may exist as an elemental solid with the phosphate sands that make up the aquifers. Decay of radium in sands would produce radon, which is a gas and would escape from the sands into the groundwater [6]. The problem associated with the uranium testing may be similar. The USGS suspects that there is some uranium within the phosphate sands. It is possible that these sands are the primary source of uranium in the Upper and Lower Brunswick aquifers, and that all other radionuclides in these aquifers stem from this source. This is further corroborated when examining water pH in the area. In previous studies conducted by, or with the support of, the EPA, it has been found that uranium is insoluble with pH range between 6 and 9 [5], indicating that uranium precipitates along with any other solids in the system. The groundwater of coastal Georgia falls into this range.

Awareness of the presence of radon and alpha radiation in the Upper and Lower Brunswick aquifers is important to the communities of the Brunswick area. Many people in the region have become dependent these aquifers as their primary water source. Since radon in air is not a danger, it is not often thought of as a potential hazard. By confirming the presence of such contaminants in the groundwater, it becomes apparent that citizens using wells are becoming exposed to these radon and gross alpha levels. In many cases, all water faucets and fixtures pull groundwater directly from a well, without any form of aeration that would allow radon to escape. This means that a person drinking water from a sink would be ingesting both radon and alpha radiation, which are absorbed by the body along the digestive tract, liver, and circulatory system [2, 8]. Both of these can pose potential health risks, causing complications such as cancer.

Between phases one and two of this project, there were variations in radon and gross alpha levels in each well. This is to be expected. Although radon and gross activity are consistently present in both aquifers, the level at which they occur varies. This is because the location and flow of water in the aquifers is constantly changing. Water begins to flow through the aquifers as amounts are pumped out through wells. When it flows, its contact time with the radionuclide containing sands changes, thus varying the amount of radon or gross alpha activity released into a volume of water. However, a change as large as that in w3, from 16.4 pCi/L to 112 pCi/L in one year, is unexpected. This huge increase could simply be the result of natural variation, but additional factors could be involved. In reviewing data from phase one, it became apparent that for the first two trials of this sample, gross activity was near 30 pCi/L, but the third trial came out negative. It is likely that that mechanical error caused the negative value, skewing phase one results for gross activity of this well, causing a larger variation than expected.

As found in phase one, w5 and w6 had very low levels of gross activity and radon levels far below the MCL of 300 pCi/L. Well w5, a Lower Brunswick well, is drilled so close to a Floridon well, that water from the radionuclide-free Floridon aquifer is flowing into this well, diluting the radionuclides and making this well cleaner than other Lower Brunswick wells. In the case of w6, an Upper Brunswick well, it was shallow and had a very slow flow rate, which could allow much of the radon in its water to escape during sample collection. In addition, 032 was the only well other than w6 with levels of gross activity below the MCL. During the initial sampling of this well, it would not turn on and water was sampled from a storage tank. It is possible that any radionuclides in this water fixed to rough surfaces in the tank and separated from the water. In contrast, well 035, in the Lower Brunswick aquifer, had expected gross alpha levels but only 31 pCi/L radon. It is possible that this well was drilled too deep, and includes water from the Floridon aquifer, depleting the radon level.

5. CONCLUSION

My research and the data collected support my hypothesis that there is little to no uranium dissolved in the groundwater itself. Thus, all gamma-emitting uranium in the area likely exists as a solid within the phosphate sands that make up the aquifers. In the future, the sands themselves will be tested for uranium to confirm this.

From the lack of radium found in my samples in phase one, it would seem that all uranium decay products remain in solid form throughout the radioactive decay chain until it reaches the radon stage, when this gas is able to escape the phosphate sands and enter the groundwater.

Furthermore, this research confirmed that there are consistently measurable levels of radon and gross activity in both the Upper and Lower Brunswick aquifers throughout the Brunswick area. As previously suspected, the Lower Brunswick has higher levels of both contaminants, and the four wells that pump water from both aquifers have levels between those only in one aquifer. Several of the wells tested require treatment, and those with high levels of radon (around 1,000 pCi/L) will be brought to the attention of those who use them.

6. ABBREVIATIONS AND ACRONYMS

EPA – Environmental Protection Agency

MCL – Maximum Contamination Level

USGS – United States Geological Survey

GPS – Global Positioning System
pCi/L – Pico curies per liter
LS count – Liquid Scintillation Analyzer/Liquid Scintillation Counter

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Credits

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Author

As a young girl, my interest in science was fed through science summer day camps and extra-curricular activities, including Girl Scouts. When I was five years old, I began taking violin lessons. I continued with the violin and later learned to play the oboe. Now I play both instruments in local symphonies. I began competing in the Georgia Science and Engineering Fair in seventh grade, and have enjoyed participating ever since. In high school, I have taken every science course possible, and just last summer participated in the Georgia Governor's Honors Program, majoring in analytical chemistry with a minor study in computer science. I participate in five after-school clubs that focus on community service, and have been an officer for National Honor Society and Interact International. I am still a Girl Scout. Having completed my Silver Award, I am currently working on my Gold Award. Although I enjoy all sciences, my primary interests are chemistry, environmental sciences, and engineering. In college, I hope to study engineering and eventually work as an aerospace engineer for NASA.

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