LOW-LEVEL TRITIUM MEASUREMENTS IN GROUNDWATER NEAR THE SAVANNAH RIVER SITE

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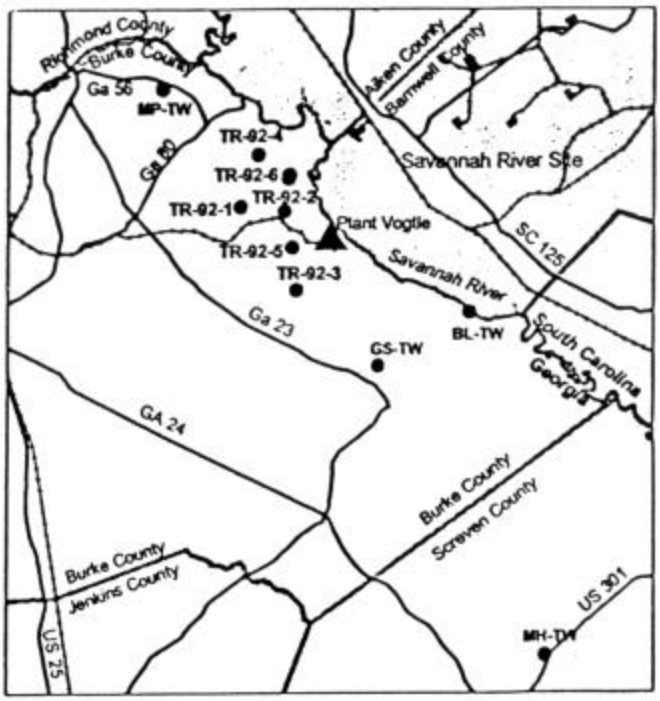
Abstract. The results of tritium analyses of ground water collected in 2001 and 2002 by the Georgia DNR in Burke and Screven counties near the Savannah River are reported. In some samples, the tritium concentration was below 10 pCi/L while in others it was between 1,010 and 13 pCi/L. With two exceptions, samples with detectable tritium concentrations were from the near-surface aquifer, while the other samples were from deeper-lying aquifers. The values are compared with results presented by others during the past 10 years. Inferences by others concerning these findings are reported.

INTRODUCTION

Water from a public water-supply well (a trailer park) in Burke county sampled in July 1991 as part of the routine environmental surveillance program by the Georgia Department of Natural Resources (DNR) contained tritium concentrations of 1,200 picocurie per liter (pCi/L). Although most of a number of public and private wells sampled in this vicinity during the remainder of the year had considerably lower concentrations, concentrations at three of these wells were between 1,000 and 1,300 pCi/L. These concentrations are far below the maximum contaminant level of 20,000 pCi/L established by the US Environmental Protection Agency (EPA), (Office of Water Supply 1976). Nevertheless, these findings suggested the possibility of more elevated tritium concentrations in the area and stimulated a study of tritium concentrations in groundwater near the Savannah River. The study was funded by the US Department of Energy (DOE) and performed by the Georgia Geologic Survey (GGS) of DNR, the US Geological Survey (USGS), and the Westinghouse Savannah River Site (SRS).

Sampling well clusters were drilled at sites selected in Burke county (with one cluster at Millhaven in Screven county) to survey possible tritium contamination in various aquifers. Water samples were collected at defined depths from these wells and also from previously drilled wells that were used as public and domestic water supplies. The samples were analyzed for tritium content variously by the Center for Applied Isotope Studies (CAIS) at the University of Georgia, SRS, the USGS, and the Environmental Radiation Laboratory (ERL) at the Georgia Institute of Technology. Analyses performed during 1991 – 1997 have been reported earlier (Summerour et al. 1994, 1998). Results obtained in the years 2001 and 2002 by ERL for samples provided by DNR are reported here to indicate the current magnitude and pattern of tritium concentrations.

The locations of the 42 wells from which water was analyzed for tritium are shown in Fig. 1. The code TR92-1A indicates tritium sampling well # 1 drilled in 1992 at depth A; GS, MH, MP, and BL indicate Girard



From Arnett and Mamatey 2002

Figure 1. Location of Study Area.

Site, Millhaven, Millers Pond and Brighams Landing respectively. The sampling depths in the drilled wells were selected to correspond to known aquifers. Sampling depths for home water supply wells are based on reported well depths. In the original study, nine wells out of 15 with tritium concentrations above 500 pCi/L were geophysically logged to determine the depth from which they were drawing their water.

The implications of finding tritium in ground water on the Georgia side of the Savannah River are discussed in detail in GGS reports (Summerour et al.1994, 1998), and the potential for its occurrence is modeled in USGS reports (Clarke and West 1997, 1998). In brief, potential sources for tritium in Burke County groundwater include: naturally occurring tritium produced by cosmic ray bombardment of the upper atmosphere; tritium resulting from atmospheric testing of nuclear weapons between 1952 and 1963; tritium releases from Plant Vogtle in Burke County; and tritium releases from the SRS. SRS is the overwhelming source of tritium (approximately 99 percent) in rainfall in Burke County. Atmospheric releases of tritium from SRS peaked in 1958, and have generally declined since that date (with secondary peaks in 1964, 1974, and 1984).

The aquifer pattern in the region of interest includes the near-surface, unconfined Upper Three Runs aquifer. Below, in sequence are the Gordon aquifer, Dublin aquifer system, and Midville aquifer system. These designations and information on their depths and characterizations are found in the Clarke 1997, Falls 1997, and Summerour et al. 1994 and 1998 publications.

The reported samples were collected at the end of February in 2001 and 2002. The samples were analyzed either directly or after electrolytic tritium enrichment. The detection limits were 150 - 200 pCi/L by direct measurement and 6 – 10 pCi/L after enrichment. Some measurement results from the same wells by other groups are reported for comparison.

Table 1. Tritium Concentration in Well Water

ID	Lab ID	Sample Date	Aquifer	Depth, ft	H-3 pCi/L direct	H-3 pCi/L enriched
TR92-1A	14053	2/28/2001	Upper Three Runs	90-100		100
TR92-1A	14567	2/25/2002				110
TR92-1F	14046	3/1/2001	Upper Three Runs	18.5-23.5		330
TR92-1F	14571	2/25/2002				220
TR92-1G	14132	3/3/2001	Upper Three Runs	33-38	500	
TR92-1G	14572	2/25/2002			400	
TR92-1H	13660	3/1/2001	Upper Three Runs	44-49	700	700
TR92-1H	14573	2/25/2002			600	
TR92-1I	14130	2/28/2001	Upper Three Runs	55-60	800	
TR92-1I	14131	3/1/2001			800	
TR92-1I	14574	2/25/2002			700	
TR92-1J	14047	3/1/2001	Upper Three Runs	70-75		260
TR92-1J	14575	2/25/2002				170
TR92-1K	14050	2/28/2001	Upper Three Runs	105-110		47
TR92-1K	14576	2/25/2002				30
TR92-1L	13658	2/28/2001	Upper Three Runs	115-120		60
TR92-1L	14577	2/25/2002				60
TR92-1M	13670	2/28/2001	Upper Three Runs	130-135		60
TR92-1M	14578	2/25/2002				60
TR92-2A	13662	2/27/2001	Upper Three Runs	105-115	1000	1010
TR92-2A	14579	2/25/2002			900	
TR92-4A2	14049	2/27/2001	Upper Three Runs	75-85		790
TR92-4A2	14583	2/27/2002			700	
TR92-5A	13665	2/26/2001	Upper Three Runs	145-155		50
TR92-5A	14586	2/27/2002				30
TR92-5B	13664	2/26/2001	Gordon	275-285		130
TR92-5B	14587	2/27/2002				170
TR92-6A2	14013	3/1/2001	Upper Three Runs	75-85		510
TR92-6A2	14589	2/27/2002			400	
GS-TW-1	13654	3/1/2001	Upper Three Runs	48-72		170
GS-TW-1	14592	2/26/2002				190
MH-TW-1	13669	2/26/2001	Upper Three Runs	50-80		13
MH-TW-1	14595	2/25/2002				13
MH-TW-2	14596	2/25/2002	Upper Three Runs	155-205		13
MH-TW-5	13653	2/27/2001	Lower Midville	1,340-1,380		<9
MH-TW-5	14599	2/26/2002				15
MP-TW-4	13656	3/1/2001	Upper Three Runs	80-100	400	430
MP-TW-4	14603	2/26/2002			300	

PROCEDURE

Prior to collecting the 1-L samples, each well was purged by pumping 2 well volumes when available. All groundwater monitoring wells were cased and screened across specified intervals. One monitoring well at Millhaven was an unscreened natural completion well. At the laboratory, direct tritium analysis was performed on 25-ml aliquots. These were distilled, and 10-ml distillates were transferred to 20-ml plastic scintillation vials and mixed with 10 ml scintillation cocktail. The counting vials were placed in a scintillation counter, dark adapted, and counted for two 50-minute periods. Also counted were blanks to measure the detector background count rate and vials with a standardized tritium solution. The background count rate was subtracted from the measured sample count rate.

Table 2. Well Water Without Detectable Tritium

ID	Lab ID	Sample Date	Aquifer	Depth, ft	H-3 conc. pCi/L
TR92-1B	14048	2/28/2001	Gordon	210-220	<9
TR92-1B	14568	2/25/2002			<8
TR92-1C	14052	2/28/2001	Millers Pond	290-300	<9
TR92-1C	14585	2/25/2002			<8
TR92-1D	14051	2/28/2001	Dublin	345-355	<9
TR92-1D	14569	2/25/2002			<8
TR92-2B	13651	2/27/2001	Gordon	310-320	<8
TR92-2B	14581	2/27/2002	not purged		<8
TR92-2B	14580	2/27/2002			<8
TR92-3B	13652	2/27/2001	Gordon	185-195	<8
TR92-3B	14582	2/27/2002			<8
TR92-4B	14007	2/27/2001	Gordon	175-185	<9
TR92-4B	14584	2/27/2002			<8
TR92-5C	13655	2/26/2001	Gordon	200-300	<9
TR92-5C	14588	2/27/2002			<8
TR92-6C	14005	2/27/2001	Lower Dublin	450-500	<7
TR92-6C	14590	2/27/2002			<8
TR92-6D	13663	2/27/2001	Lower Midville	800-830.5	<8
TR92-6D	14591	2/27/2002			<8
GS-TW-2	13659	2/26/2001	Dublin	743-773	<8
GS-TW-2	14001	2/27/2001			<7
GS-TW-2	14593	2/26/2002			<8
GS-TW-3	14594	2/26/2002	Midville	1,070-1,122	<8
MH-TW-2	13666	2/26/2001	Upper Three Runs	155-205	<8
MH-TW-3	13668	2/26/2001	Upper Three Runs	225-280.5	<8
MH-TW-3	14597	2/25/2002			<8
MH-TW-4	13657	2/27/2001	Lower Dublin	857-907	<9
MH-TW-4	14598	2/26/2002			<8
MP-TW-1	14000	3/1/2001	Lower Midville	705-735	<8
MP-TW-1	14600	2/26/2002			<6
MP-TW-2	14011	3/1/2001	Upper Midville	595-625	<9
MP-TW-2	14601	2/26/2002			<7
MP-TW-3	14012	3/1/2001	Allendale	518-548	<9
MP-TW-3	14602	2/27/2002			<7
MP-TW-5A	14002	3/1/2001	Upper Dublin	211-251	<10
MP-TW-5A	14604	2/26/2002			<7
MP-TW-6	14003	3/1/2001	Lower Dublin	299-325	<8
MP-TW-6	14605	2/26/2002			<9
MP-TW-7	14004	3/1/2001	Lower Dublin	450-475	<8
MP-TW-7	14606	2/26/2002			<6
BL-TW-1	13667	2/27/2001	Lower Midville	920-970	<9
BL-TW-1	14607	2/26/2002			<6
BL-TW-2	14006	2/27/2001	Lower Dublin	502-552	<8
BL-TW-2	14608	2/26/2002			<6
BL-TW-3	13661	2/27/2001	Gordon	150-200	<8
BL-TW-3	14609	2/26/2002			<7

Quenching and radioactive decay corrections (tritium half life is 12.3 y) were made if needed. The net count rate was converted to activity concentration in pCi/L by dividing by the counter efficiency determined with the standard solution.

For tritium enrichment, a 150-ml sample was reduced to 11 – 15 ml by vaporization during electrolysis. The 8 – 10 fold enrichment was calculated as a function of the fractional volume retained by tracer studies. A 10-ml aliquot of the concentrated solution was measured for tritium content as described above, except that the sample was counted for two 500-minute periods.

The standard deviation of counting samples was calculated from the accumulated counts, background counts, conversion factors, and counter efficiency to be between 200 and 300 pCi/L in the range of reported measurements for samples that were not concentrated. After tritium concentration, the standard deviation in the range of reported samples ranged from several pCi/L just above the detection limit to 50 pCi/L at the highest values.

RESULTS AND DISCUSSION

Water from 19 of the 42 sampled wells contained detectable levels of tritium; the detectable levels are listed in Table 1 and nondetectable levels, in Table 2. Almost all wells sampling the near-surface Upper Three Runs aquifer showed detectable tritium. Concentrations ranged from 1,010 to 13 pCi/L, with a median value of about 240 pCi/L. On the whole, concentrations decreased only slightly from 2001 to 2002; the ratio of concentrations in the second year to those in the first years ranged from 1.1 to 0.6, with a median value of 0.88. Among the water samples that were above about 200 pCi/L, earlier results were similar, and generally slightly higher.

In contrast, detectable tritium concentrations were rare in the deeper aquifers. Only two montoring wells screened below the Upper Three Runs aquifer had tritium above the detection limit (6-10 pCi/L). These are monitoring wells TR92-5B and MH-TW-5. Monitoring well TR92-5B is located at the Delaigle Trailer Park, and is screened in the Gordon aquifer, at a depth of 275-285 feet. It is located 94 feet from the damaged public water supply well at the Delaigle Trailer Park. Tritium in water from this well measured 130 pCi/L 2001 and 170 pCi/L in 2002. In 1995, the tritium concentration in this well was 13.9 pCi/L.

Table 3. Tritium Concentrations Measured by SRS in 2001

ID Location	Tritium concentration, pCi/L
TR 92-1A	ND
TR 92-1F	ND
TR 92-1H	1,070
TR 92-1J	ND
TR 92-1K	ND
TR 92-1L	ND
TR 92- 1M	ND
TR 92-2A	1,060
TR 92-4A2	730
TR 92-5A	ND
TR 92-5B	445
TR 92-6A2	750
GS-TW-1	ND
MP-TW-4	ND
MH-TW-1	ND
MH-TW-4	ND

Notes: ND; not detected, <440 pCi/L. Values are from Arnett and Mamatey, 2002.

Monitoring well TR92-5C also is screened in the Gordon aquifer and is located 50 feet from the damaged Delaigle Trailer Park well. Between August 1993 and May 1996 tritium concentrations in water from this well ranged from 300 to 500 pCi/L. Summerour et al.(1994) attributed the tritium seen in TR92-5C to point source contamination from the damaged Delaigle Trailer Park well. In May 1996, a groundwater sample from TR92-5C had 100 pCi/L of tritium, but samples in 2001 and 2002 were below detection limits of 9 and 8 pCi/L respectively. The long-term results from TR92-5B and TR92-5C are consistent with a pulse of tritiated water coming from the Delaigle Trailer Park water supply well, first impacting the nearby TR92-5C, and then impacting the slightly more distant TR92-5B. Monitoring well MH-TW-5 is located at the Millhaven Plantation in northeastern Screven County. The well is screened in the lower Midville aquifer system, between 1,340 and 1,380 feet below the ground surface. A tritium concentration of <9 pCi/L was measured in 2001 and 15 pCi/L was measured in 2002. Previous tritium analyses of samples from this well were below a detection limit of 100 pCi/L (Clarke et al. 1996). The results from the 2001 and 2002 sampling events are consistent with earlier results.

Table 4. Tritium Concentrations Measured by CAIS in 1995

ID Location	Tritium concentration, pCi/L
TR 92-1B	<3
TR 92-1C	4.1
TR 92-1D	23.7, 9.1
TR 92-2B	5.4
TR 92-3B	5.8
TR 92-4B	<1.4
TR 92-5B	13.9
TR 92-6B	5.4
TR 92-6C	1.9
TR 92-6D	4.1

Note: from Summerour et al. 1998, Table 18, rounded.

Results reported by SRS staff (Arnett and Mamatey 2002)) for samples collected in 2001, shown in Table 3, are consistent with the values shown in Table 1. The numerical values in Table 3 are within the measurement uncertainty of those in Table 1, while the results labeled ND, below the SRS detection limit of 440 pCi/L, match concentrations below this value in Table 1.

Results obtained by CAIS (Summerour et al. 1998) in 1995, shown in Table 4, are more sensitive, but in all except one of the two values for well TR92-1D are consistent with the "less than" values given in Table 2. No analytical results were obtained for well TR92-6B in 2001 and 2002.

Most (but not all) of the tritium contamination in Burke County groundwater is limited to the unconfined Upper Three Runs aquifer. Potential pathways for tritium into this aquifer fall into five categories: recharge of the aquifer by tritiated rainfall, recharge of the aquifer from tritium contaminated surface water, upwards transport from deeper aquifers, lateral transport from other parts of the same aquifer, and point source contamination from poorly constructed wells. Existing data eliminate some of these potential pathways (Summerour et al. 1994, 1998). Lateral transport within the Upper Three Runs aquifer from contaminated groundwater at the SRS cannot occur because the aquifer is completely incised by the Savannah River. Recharge of the aquifer from the Savannah River cannot occur because the strata forming the aquifer are well above the floodplain of the river. Point source contamination is not supported by the pattern of distribution of tritium within the aquifer. The remaining potential pathways include recharge and transport from other aquifers.

The hydrologic data from Burke County are consistent with a recharge pathway for the contamination to enter the aquifer (Summerour et al. 1994, 1998). The distribution of tritium in rainfall in Burke County is similar to the distribution of tritium in the Upper Three Runs aquifer. Tritium levels in the vadose zone are consistent with the concentration of tritium in rainfall, and those at the base of the vadose zone are consistent with tritium concentrations at the

top of the Upper Three Runs aquifer. The stratigraphic distribution of tritium in the combined vadose zone and Upper Three Runs aquifer appears to be correlated with the history of SRS atmospheric releases.

Existing data do not eliminate a transport pathway from deeper aquifers. The USGS computer modeling of groundwater flow shows the movement of groundwater in the Gordon and Dublin aquifers from the SRS recharge area, under the Savannah River, and into Georgia (Clarke and West. 1997, 1998). The present investigation showed one sample with low but unexplained concentrations of tritium in the Lower Midville aquifer. The highest concentrations of tritium observed in the Upper Three Runs aquifer occur directly over a fault system that underlies the SRS and passes underneath the Savannah River, into Georgia (Summerour et al. 1998). Information on a potential interaquifer transport pathway remains inconclusive, and additional research has been recommended.

The connection of tritium in rainfall to tritium in the near-surface aquifer is immediately apparent. Tritium concentrations in rainfall on the Georgia side of the Savannah River decreased steadily from more than 1,500 pCi/L in 1982 – 1986 (Summerour et al. 1994) to <200 pCi/L in 2001. The more elevated tritium concentrations in Table 1 may correspond to rainfall deposited 5 to 10 years ago. The tritium (see Table 4) in confined aquifers for which water may have been isolated from the surface for thousands of years, although at very low concentrations, requires an explanation. The existence of other pathways to these deeper aquifers, is the subject of continuing study by the GGS.

CONCLUSIONS

Tritium analyses in February of 2002 and 2001 at 43 wells in Burke and Screvens counties along the Savannah River near SRS show ground water concentrations between 1,010 and 13 pCi/L in 19 of the wells, and less than 10 pCi/L in all others. With one or possibly two exceptions, all measurable tritium concentrations were in the near-surface Upper Three Runs aquifer. Concentrations there decreased only by about 12 percent during the 1-year interval. This decrease is consistent, within the limits of analytical error, with simple radioactive decay of tritium.

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