TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION

DIVISION OF WATER RESOURCES

DRINKING WATER UNIT

Tennessee Ground Water Monitoring and Management

Ground Water 305(b) Report

2014

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2014 305(b) Addendum
Status of Ground Water Quality in Tennessee
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2014 305(b) Addendum
Status of Ground Water Quality in Tennessee

1.0 Introduction

This report was prepared by the Tennessee Department of Environment and Conservation (TDEC), Division of Water Resources (DWR), to fulfill the requirements of both federal and state laws. Section 305(b) of the Federal Water Pollution Control Act, commonly called the Clean Water Act, requires a biennial analysis of water quality in the state. The Tennessee Water Quality Control Act also requires that the Division produce a report on the status of water quality. This report satisfies those requirements.

This report presents a summary of activities of the Ground Water Management Section (GWMS) program in the protection and monitoring of the Source Water Areas both ground and surface that the Tennessee Department of Environment and Conservation (TDEC) uses in protecting water quality. A more thorough description of the items contained in the report may be found on the Department's web site:

Division of Water Resources Page:
http://www.tn.gov/environment/water/water-supply.shtml

Source Water Assessments Page:
http://www.tn.gov/environment/water/water-supply_source-assessment.shtml

Drinking Water Program Page:
http://www.tn.gov/environment/water/water-supply_drinking-water-program.shtml

2.0 Acknowledgements

The Director of the Division of Water Resources (DWR) is Tisha Calabrese Benton and the Deputy Director of the Water Quality Branch is Jennifer Dodd. The GWMS of DWR produced this report in cooperation with central and regional field office staff.

The Division of Water Resources (Division) maintains staff at eight of the regional Environmental Field Offices (EFO's) and the GWMS staff would like to express their appreciation to each office for their assistance in compiling information for this report. The managers of the staff in each EFO are as follows:

Jennifer Innes	Chattanooga EFO
Sherry Glass	Columbia EFO
Johnny Walker	Cookeville EFO
Conner Franklin	Jackson EFO
Chris Rhodes	Jonson City EFO
Michael Atchley	Knoxville EFO
Ann Morbitt	Nashville EFO
Joellyn Brazile	Memphis EFO

The information compiled in the 2014 water quality assessment document included data provided by many state and federal agencies. These agencies include:

Duck River Management Agency
Fleming Training Center
Tennessee Association of Utility Districts
Tennessee Department of Environment and Conservation Division of Water Resources Data Management Section
Tennessee Department of Environment and Conservation Division of Water Resources Watershed Management Section
Tennessee Department of Environment and Conservation Division of Water Resources Water Well program
Tennessee Valley Authority
United States Department of Agriculture
United States Geological Survey
University of Memphis Ground Water Institute
University of Tennessee Center for Environmental Biotechnology
Water Resources Technical Advisory Committee

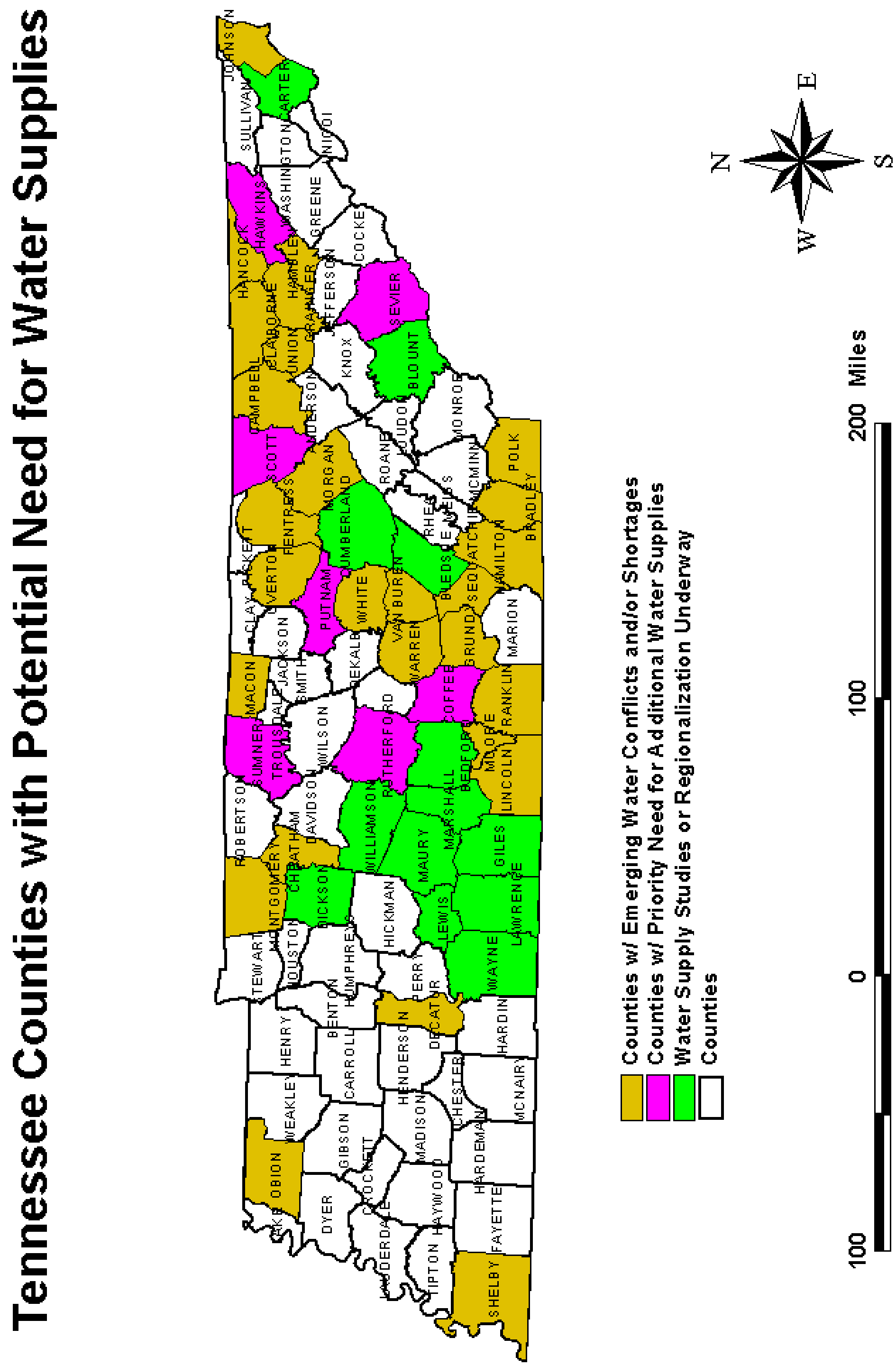
3.0 General Information

Tennessee has been blessed with an abundance of high quality and good quantity of ground water. With localized exceptions, Tennessee's ground water is good quality as is evidenced by the number of public water systems utilizing ground water and the dozen or more bottled water facilities. Once thought to be immune from contamination, there is increasing awareness that ground water should be protected as a valuable resource. There have been a limited number of reported contamination incidences of public water systems across the state.

The vulnerability of Tennessee's ground water sources is inextricably linked to the geology of the state. Ground water can be quite vulnerable to contamination, particularly in karst terrain (limestone characterized by caves, sinkholes and springs) and in unconfined sand aquifers. This vulnerability is particularly true for contamination from the highly mobile and widely used volatile organics (chlorinated solvents and gasoline components).

Both the availability and the quality of our drinking water are vital influences on public health and the economy. In Tennessee, approximately 1.5 million people rely on public water systems that use ground water as a source for their drinking water. There are approximately 400,000 people that receive their drinking water from a public water system whose source is a combination of ground water and surface water and an additional 500,000 people get their drinking water from private wells and springs. Most West Tennessee citizens rely on ground water for their drinking water. The City of Memphis has one of the largest ground water withdrawals (135 million gallons per day average production) of any municipality in the southeastern United States. The communities of Bartlett, Germantown and Collierville in Shelby County withdraw an additional 18.5 million gallons per day.

Long thought to be more of a western states matter, water needs in Tennessee are increasing. There are several counties in Tennessee with current or long-term issues with water supply (Figure 1). Water needs forecasting, even in relatively water-rich Tennessee, must reach decades into the future to provide for economic growth and the health of its citizens. The Department is encouraging water systems to look at a regional solution to future water needs and is strongly encouraging that all water systems be interconnected.



Tennessee Counties with Potential Need for Water Supplies
Counties w/ Emerging Water Conflicts and/or Shortages
Counties w/ Priority Need for Additional Water Supplies
Water Supply Studies or Regionalization Underway
Counties
100
0
100
200 Miles
N
E
S
W

Figure 1

4.0 Statutory Requirements

Since 1985, the Division of Water Resources (DWR) Drinking Water Unit (DWU), formerly known as the Division of Water Supply (DWS), has worked to ensure that public drinking water supplies are safe. DWR also regulates the construction of non-federal dams, enforces the Safe Drinking Water Act, monitors water withdrawals, and regulates the licensing of well drillers and pump setters. The Division contains the Ground Water Management Section (GWMS) which operates the Source Water Protection (SWP) Program, the Wellhead Protection (WHP) Program, the Underground Injection Control (UIC) Program and conducts monitoring and sampling as well as responds to ground water complaints. The GWMS also houses the Geographic Information System (GIS) portion of the Unit.

In addition to the federal requirements, the Tennessee Water Quality Control Act of 1977 requires DWR to produce the ground water report to the governor and the general assembly on the status of water quality in the state. The report can include a description of the water quality plan, regulations in effect, and recommendations for improving water quality. This report can be found on the Division's Web site at http://www.tn.gov/environment/water/docs/water-supply/2014gw305b.pdf. The 2014 305(b) Report serves to fulfill the requirements of both the federal and state laws.

This report covers only ground waters in Tennessee. The Department's Division of Water Resources Surface Water Unit is developing a report on ground water quality as well to fulfill their requirements. Their report can be found at http://www.tn.gov/environment/wpc/publications/pdf/2014_305b.pdf.

5.0 Public and Private Well/Spring Use

All public water systems are subject to strict testing and treatment requirements. Overall, public water systems in Tennessee have an excellent record of providing clean water to their customers. The Drinking Water Unit is responsible for regulating all public water systems to protect the state's drinking water quality. At this time, no source of water used by public water systems has been found to contain lead, copper, arsenic, radon or uranium in quantities of concern. Organic chemical contamination above drinking water standards, such as from petroleum products and chlorinated solvents, rarely occurs in Tennessee but can be a considerable hardship where it does occur. Prevention of contamination is a much more cost-effective method of ground water management.

Tennessee does not require persons using a private water source to test for contaminants. Water well construction is regulated in Tennessee and the well drillers are required to have a license and submit a Notice of Intent (NOI) for the proposed wells that they drill along with a Driller Report post drilling. Water well testing and maintenance are the responsibility of the individual homeowner. Springs used by private individuals by their very nature are not regulated since they are not constructed. Users of a private water source that have never tested the source do not know what they may be drinking. Chemical contamination is unusual; however, shallow wells and springs located in karst can be impacted by surface water with regard to bacteria and other naturally-occurring pathogenic organisms. Failing septic tanks (leaking directly into the ground water) are also a common cause of ground water contamination as is sinkhole dumping of garbage and other wastes. Wells and springs may contain pathogenic organisms and should be filtered and disinfected before being used.

Abandoned wells, both drilled and hand-dug can also be a significant hazard for contamination (illegal dumping, spills or contaminated runoff) as well as sinkhole dumps. Both the wells and sinkholes have direct connections to the ground water. There are thousands of abandoned wells across Tennessee. There is no mechanism or resources available for abandoned well identification and closure or for the cleanup of sinkhole dumps. These are currently addressed on an as located basis and usually require an enforcement package that may include a fine as well as a corrective action placed on the current property owner.

6.0 Critical Ground Water Issues in Tennessee

Ground water in Tennessee is an extremely valuable and finite resource. Ground water contamination has had more than a quarter century of a head start over ground water protection and management. The Ground Water Classification under the Tennessee Water Quality Control Act has been revised to better classify the waters of the state and track those areas with ground water contamination and in managed remediation.

There are a number of issues in ground water pollution prevention and ground water management including, but not limited to, the following:

- <u>Tennessee has variable and complex geology</u>.
  - The limestone aquifers that are prevalent in Middle and East Tennessee have rapid movements of contaminants and more complex flow paths.
  - East Tennessee faulting and folding associated with the Appalachians is a complicating factor for that region.
  - The unconfined sand aquifers in West Tennessee are also vulnerable to contamination, particularly chlorinated solvents and degreasers.

- <u>Contamination is not obvious or easily monitored</u>.
  - Ground water itself and ground water contamination cannot be seen.
  - Each well is an extremely narrow "window" into the aquifer.
  - A contamination plume is commonly limited in size (hundreds to thousands of feet), irregular in shape and not evenly distributed within the aquifer.

- ♦ The state has adopted a Ground Water Classification as it relates to the Remediation programs. This classification allows for tracking of contamination on a statewide basis.
- ♦ Variations in the physical and chemical characteristics of contaminants can also cause the contaminants to take widely different flow paths through the aquifer.

- Sampling a well is significantly different from sampling a stream.
  - ♦ Upstream and downstream are not obvious when sampling ground water.
  - ♦ There are no aquatic indicators to reveal the health of the ground water.
  - ♦ Locating the stream is not an issue, locating the ground water can be.

- Contamination in ground water tends to be from a different suite of chemicals and of much longer duration than in surface water.
  - ♦ Surface water is subject to more natural attenuation of contamination, with both physical and biological breakdown of the contaminants.
  - ♦ In recent years, "emerging contaminants" such as human and veterinary pharmaceuticals, industrial and household wastewater products, and reproductive and steroidal hormones in water resources, have become more of a focus (USGS Fact Sheet FS-027-02, Pharmaceuticals, Hormones and Other Organic Wastewater Contaminants in U. S. Streams; June 2002). Potential environmental pollutants include pharmaceutical, veterinary and illicit drugs, as well as active ingredients in personal care products (collectively referred to as PPCPs). These potential pollutants include prescription drugs and biologics, as well as diagnostic agents, fragrances, sun screen agents, ingredients in cosmetics, food supplements and numerous others. The introduction of PPCPs into the environment is not just by sewage treatment plants, but also by nonpoint runoff and failing septic systems as well as large capacity conventional and drip disposal systems.
  - ♦ Each chemical's physical and chemical properties have an effect on its movement in ground water.

- A more accurate picture of the health of Tennessee's aquifers is needed.
  - ♦ There has been not been a systematic statewide study of Tennessee's aquifers. The United states Geological Survey (USGS) conducted a "Reconnaissance of Quality of Water from Farmstead Wells in Tennessee 1989-90" This study focused on nutrients in groundwater. The GWMS is currently looking at the USGS sampling location to augment the states sampling program.
  - ♦ Tennessee's ambient (naturally-occurring or "background" water quality) ground water quality monitoring program is still in the formative stages.
  - ♦ Public water systems sample the treated water served to their customers; however, less often sample raw ground water.

- Private wells and springs are not routinely sampled in Tennessee.
- Tennessee does not have a statewide ground water contamination database or a requirement for ground water contamination to be reported.

7.0 Tennessee's Complex Geology

The geology of Tennessee makes certain aquifers (water bearing zones) more vulnerable to contamination where there is no clay confining layer or naturally filtering soil layer to deter contamination from reaching the ground water. The unconfined sand aquifers of West Tennessee, particularly the Memphis Sand Aquifer, are vulnerable to contamination as are the limestone (carbonates) aquifers of Middle and East Tennessee (see Figures 2 and 3). East Tennessee has the additional complicating factor of major rock deformation through faulting and folding associated with the forming of the Appalachian Mountains.

The video "Hollow Ground: Land of Caverns, Sinkholes and Springs" (http://www.tn.gov/environment/water/water-supply_water-withdrawal-program.shtml#uic) addresses karst limestone areas in Tennessee. Additionally, the video "Drops of Water in Oceans of Sand: Ground Water Resources of West Tennessee" addresses the sand aquifers of West Tennessee. Further, there is a multi-part video on source water protection (protection of the sources of public water) available on the Division's website.

Tennessee has an abundance of limestone rock types (approximately 2/3 of the state), which are highly susceptible to contamination. These limestone rock types develop a terrain that is referred to as "karst." The term "karst" is named for a region in what was then Yugoslavia. The term refers to limestone and dolomites (magnesium-rich limestone) where the dissolution of the rocks creates solution-enlarged channels, bedding planes and micro fractures for ground water flow.

Karst is characterized by sinkholes, springs, disappearing streams and caves. Karst systems have rapid, highly directional ground water flow in discrete channels or conduits. Karst aquifers have very high flow and contaminant transport rates under rapid recharge conditions such as storm events. This is a particular concern for public or private water supplies using wells or springs in karst areas where pathogenic organisms that would not be present in true ground water can survive in ground water under the influence of surface water.

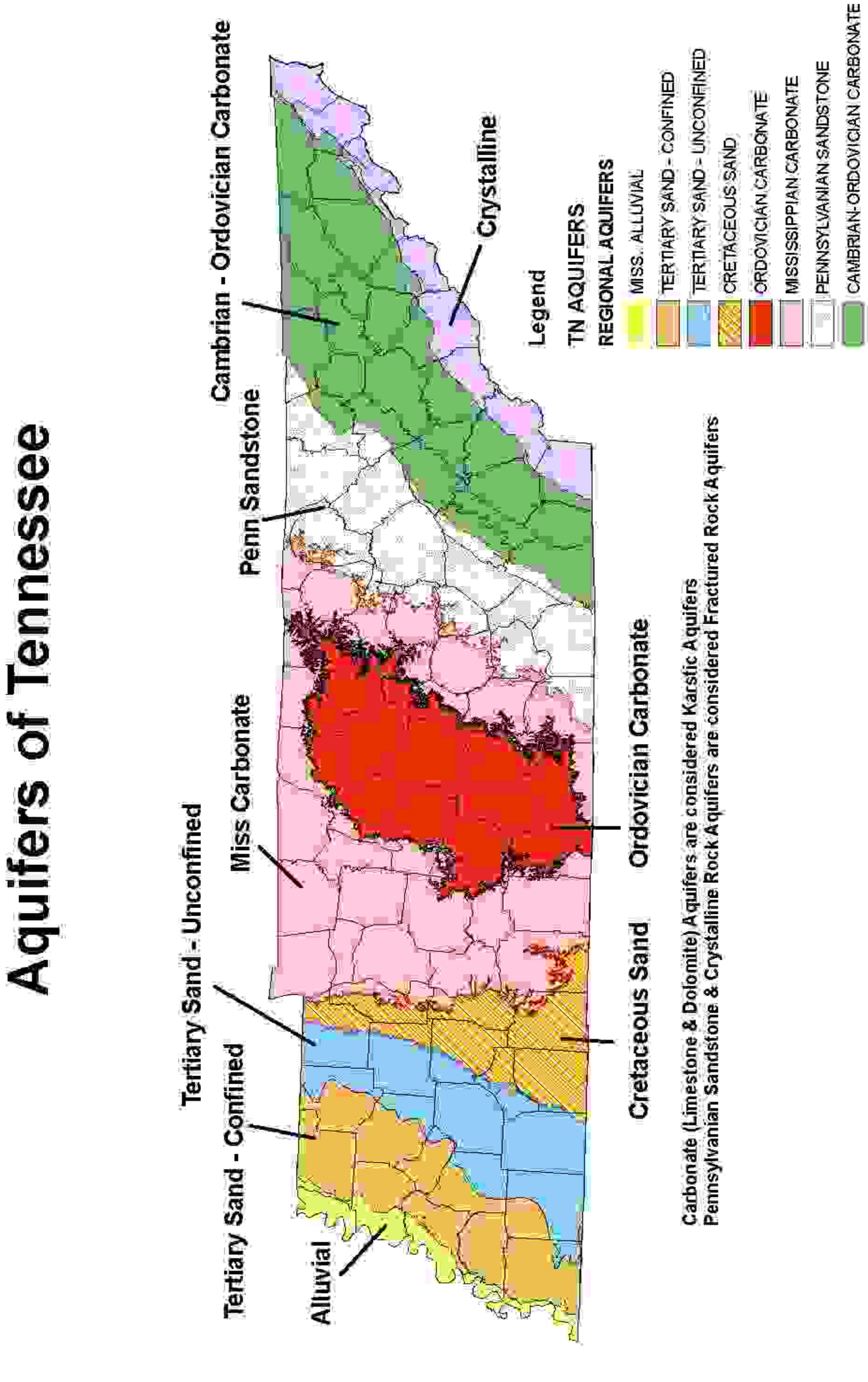
Karst systems are quite easily contaminated since the waters can travel long distances through conduits with no chance for natural filtering processes of soil or bacterial action to diminish the contamination. Transport times across entire karst flow systems may be as short as hours or weeks, orders of magnitude faster than that in sand aquifers.

Water in karst areas is not distinctly surface water or ground water. Surface water can enter into the ground water directly through sinkholes and disappearing streams. It is not uncommon for ground water to contaminate surface water, making surface water problems into ground water problems in Middle and East Tennessee. The reverse can also occur. There are a number of water systems in Middle and East Tennessee relying on ground water sources that have been determined to be under the direct influence of surface water. These systems are required to have filtration such as that required for surface water systems.

Ground water contamination (see Figure 4) is typically chlorinated solvents or degreasers and gasoline. These are all very volatile (evaporate rapidly) and are thus not a problem in surface water; however, they are a serious problem in ground water where they do not biodegrade and can be in the ground water for decades. Most chlorinated solvents or degreasers and gasoline have a very low drinking water standard (several volatiles are at 5 parts per billion or less). Another ground water problem for Middle and East Tennessee owing to the shallow bedrock associated with caves and sinkholes is contamination from septic tanks. Bacteria from septic tanks are a leading cause of private water well contamination.

Surface water contamination sources are typically nitrate (from fertilizer and animal waste), bacteria, protozoa and urban runoff (runoff from yards, asphalt, etc. that has heavy metals and pesticides/herbicides, etc.). There has been testing across the state showing atrazine (a herbicide) is getting into streams (eight across the state) after rains during growing season. Ground water in karst areas that are impacted by surface water is also subject to these same contaminants. Atrazine has also been detected at one Middle Tennessee water system where its ground water source is under the direct influence of surface water.

The protozoan cryptosporidium is a serious problem for surface water systems or ground water systems under the direct influence in that chlorine will not kill it and it is abundant in the environment. It is what gives cattle the “scours” (diarrhea). EPA’s Enhanced Surface Water Treatment Rule is predominantly the result of cryptosporidium concerns.



Aquifers of Tennessee
Cambrian - Ordovician Carbonate
Crystalline
Penn Sandstone
Miss Carbonate
Tertiary Sand - Unconfined
Tertiary Sand - Confined
Alluvial
Ordovician Carbonate
Cretaceous Sand
Legend
TN AQUIFERS
REGIONAL AQUIFERS
MISS. ALLUVIAL
TERTIARY SAND - CONFINED
TERTIARY SAND - UNCONFINED
CRETACEOUS SAND
ORDOVICIAN CARBONATE
MISSISSIPPIAN CARBONATE
PENNSYLVANIAN SANDSTONE
CAMBRIAN-ORDOVICIAN CARBONATE
CRYSTALLINE ROCK
Carbonate (Limestone & Dolomite) Aquifers are considered Karstic Aquifers
Pennsylvanian Sandstone & Crystalline Rock Aquifers are considered Fractured Rock Aquifers

Figure 2

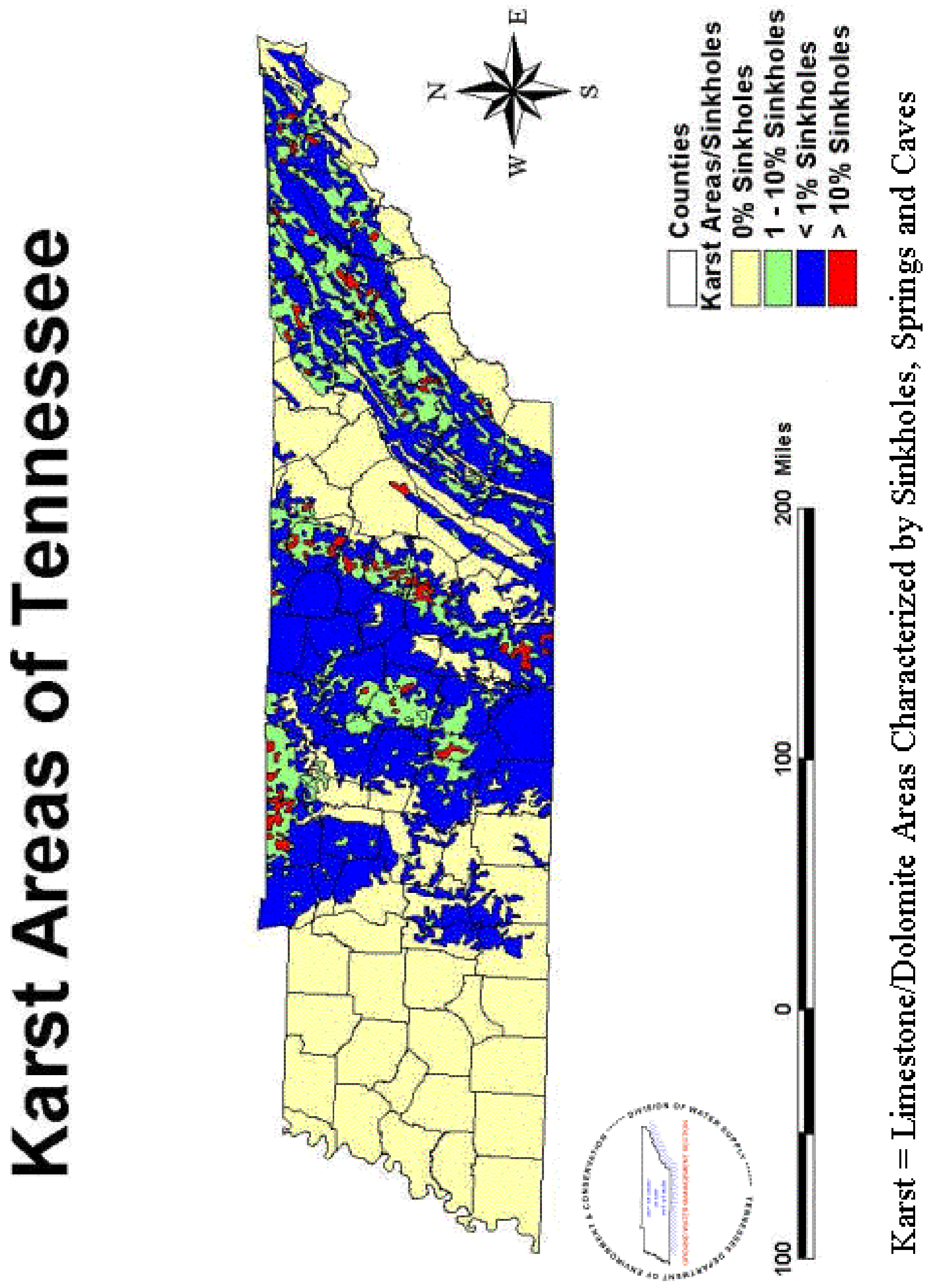
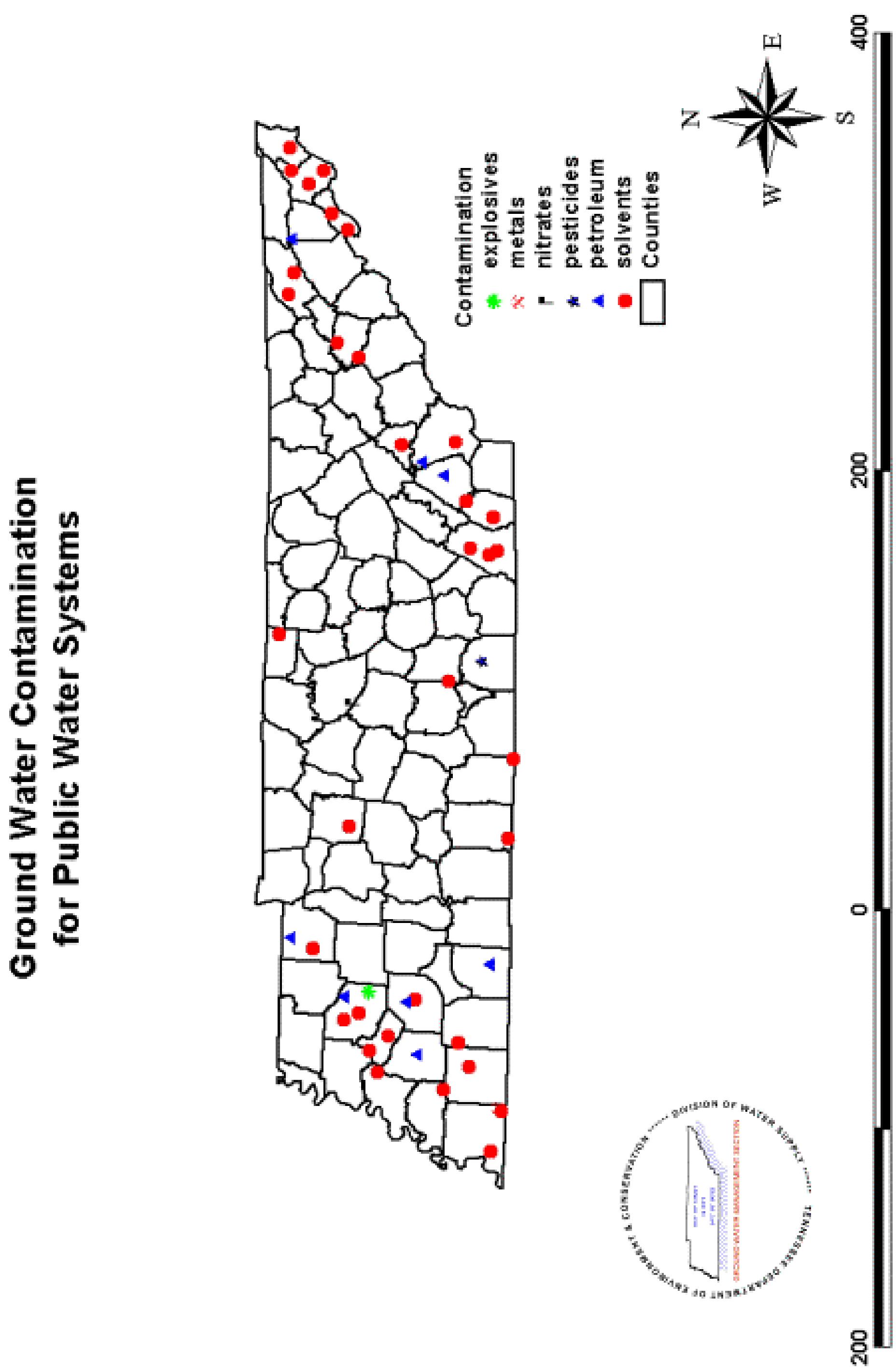

Karst Areas of Tennessee
N
E
S
W
Counties
Karst Areas/Sinkholes
0% Sinkholes
1 - 10% Sinkholes
< 1% Sinkholes
> 10% Sinkholes
100
0
100
200 Miles
Karst = Limestone/Dolomite Areas Characterized by Sinkholes, Springs and Caves

Figure 3

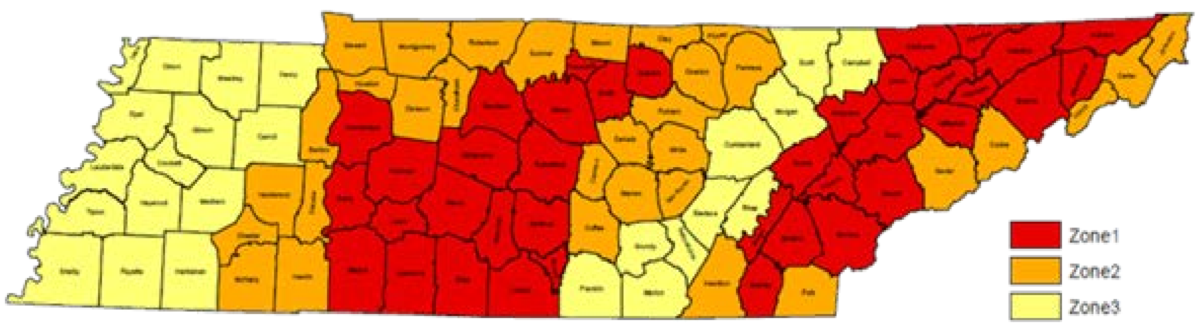


Ground Water Contamination
for Public Water Systems
Contamination
explosives
metals
nitrates
pesticides
petroleum
solvents
Counties
N
E
S
W
200
0
200
400

Figure 4

8.0 Naturally Occurring Radon

There are increasing concerns over naturally-occurring levels of radon, uranium and arsenic in drinking water supplies nationwide. Tennessee is fortunate in that the geology is such that the naturally occurring arsenic that plagues a number of the western states is not present in this state. Neither does there appear to be a problem with uranium. Studies of public ground water supplies across the state have determined that there are locations with elevated levels of radon (Figure 5). The Tennessee Department of Environment and Conservation (TDEC) considers radon to be a very serious problem in our state. No matter where you live in Tennessee, there is the potential for radon to enter your home.



Zone 1 - red - has a high risk factor for radon
Zone 2 - orange - has a moderate risk factor for radon
Zone 3 - yellow -has a low risk factor for radon

Figure 5

Testing conducted for radon in public water systems across the state in 1999 indicated that the radon in some water systems measured well above the EPA proposed 300 picocuries per liter (pCi/L) standard. Further radon testing was needed in that some of those systems were not in the expected geologic setting for high radon levels. The 1999 testing also appeared to indicate that lower flow volume wells and springs tend to have higher levels of radon, possibly due to there being less “flushing” of the relatively volatile radon gas. This trend of smaller systems having the higher radon readings is consistently holding true in the 2001 sampling as well. The high radon readings were typically from water systems with less than 200,000 gallons per day average daily production. (Figure 6)

It is not unexpected that there are high radon readings without corresponding uranium results in that the wells are typically going to be finished above shale formations. Wells are typically not drilled into shale formations that contain uranium for a ground water source because they have water quality problems from high metal and sulfur content. Radon as a gas will enter the wells drilled into the carbonate rocks overlying shale formations.

Of the 92 wells and springs sampled in 2001, 34 were above the proposed 300 pCi/L standard and six were above 1000 pCi/L. With the exception of West Tennessee (where no radon was expected) and the Cumberland Plateau, the sample choices were intentionally chosen that would likely have high radon readings. Of the 92 samples, 33 of the wells/springs have been determined to be under the direct influence of surface water. Of those 33, 13 yielded radon results of 300 pCi/L or higher.

In 2013, GWMS staff sampled 85 wells and springs in which 45 were above the proposed 300 pCi/L standard and 13 were above 100 pCi/L. Again, in West Tennessee (where no radon was expected) and the Cumberland Plateau, the sample choices were intentionally made that would likely have high radon readings. Of the 85, 34 of these wells /springs were under the influence of surface water.

Table 1shows the range by pCi/L of the samples for Radon taken in the 2001 and 2013 study. The number in parenthesis is the highest number for that sample year.

The most consistently high readings were for small community/noncommunity systems in the Highland Rim area of Middle Tennessee, although the highest reading was in East Tennessee. The majority of the high values for radon are from small community (subdivisions, trailer parks) or noncommunity (campgrounds) systems.

The Highland Rim wells/springs either side of Nashville have high readings as would be expected for Mississippian carbonates above the Chattanooga Shale. The Chattanooga Shale is the expected source of the radioactivity in that it has low levels of uranium found in it in much of the areas where it occurs. Similarly, in the Valley and Ridge (Cambrian Ordovician Carbonates) and Unaka Mountains (Crystalline Rock) of East Tennessee, there are shale formations that are expected to be low sources of low level radioactivity. The highest radon result in 2001 (3103 pCi/L) was from a subdivision in Polk County Tennessee in the southeastern corner of the state. The highest radon result in the 2013 study was from a school in Cocke County (8792 pCi/L).

The GWMS attempted to recreate the 2001 study in 2011-2012 but due to a laboratory error only Gross Alpha and Gross Beta were analyzed. Staff collected a total of 106 samples, ninety five (95) individual systems and eleven (11) duplicates samples. In comparison of the gross alpha and gross beta run in the 2001 sample event, there were no statistical differences to the 2001 and 2012 studies. Of the Gross Alpha, only three systems were above the initial 5 pCi/L screening result which would have them scanned for Radium 226. None of these were above any published limits.

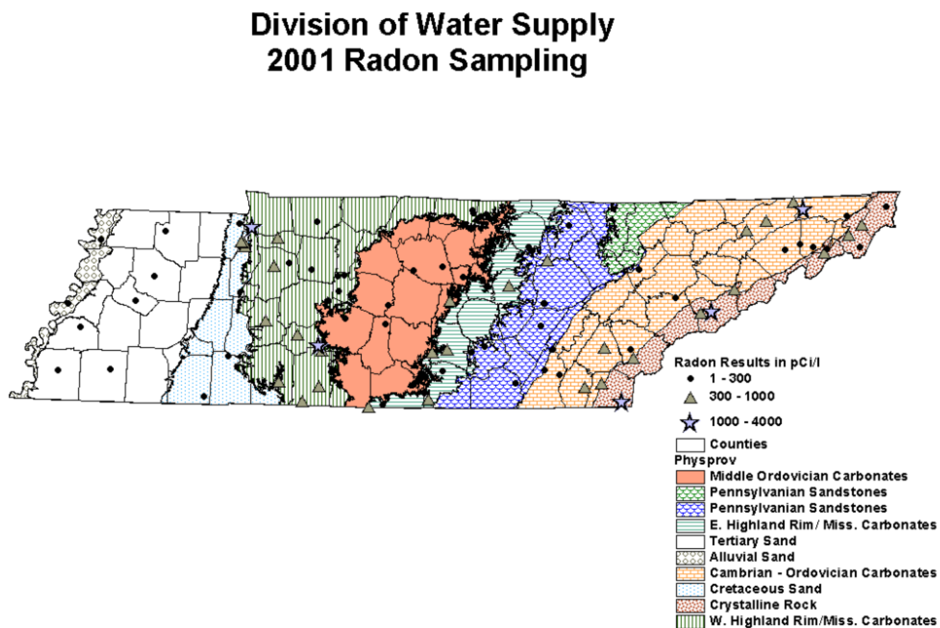

Division of Water Supply
2001 Radon Sampling
Radon Results in pCi/l
1 - 300
300 - 1000
1000 - 4000
Counties
Physprov
Middle Ordovician Carbonates
Pennsylvanian Sandstones
Pennsylvanian Sandstones
E. Highland Rim / Miss. Carbonates
Tertiary Sand
Alluvial Sand
Cambrian - Ordovician Carbonates
Cretaceous Sand
Crystalline Rock
W. Highland Rim/Miss. Carbonates

Figure 6

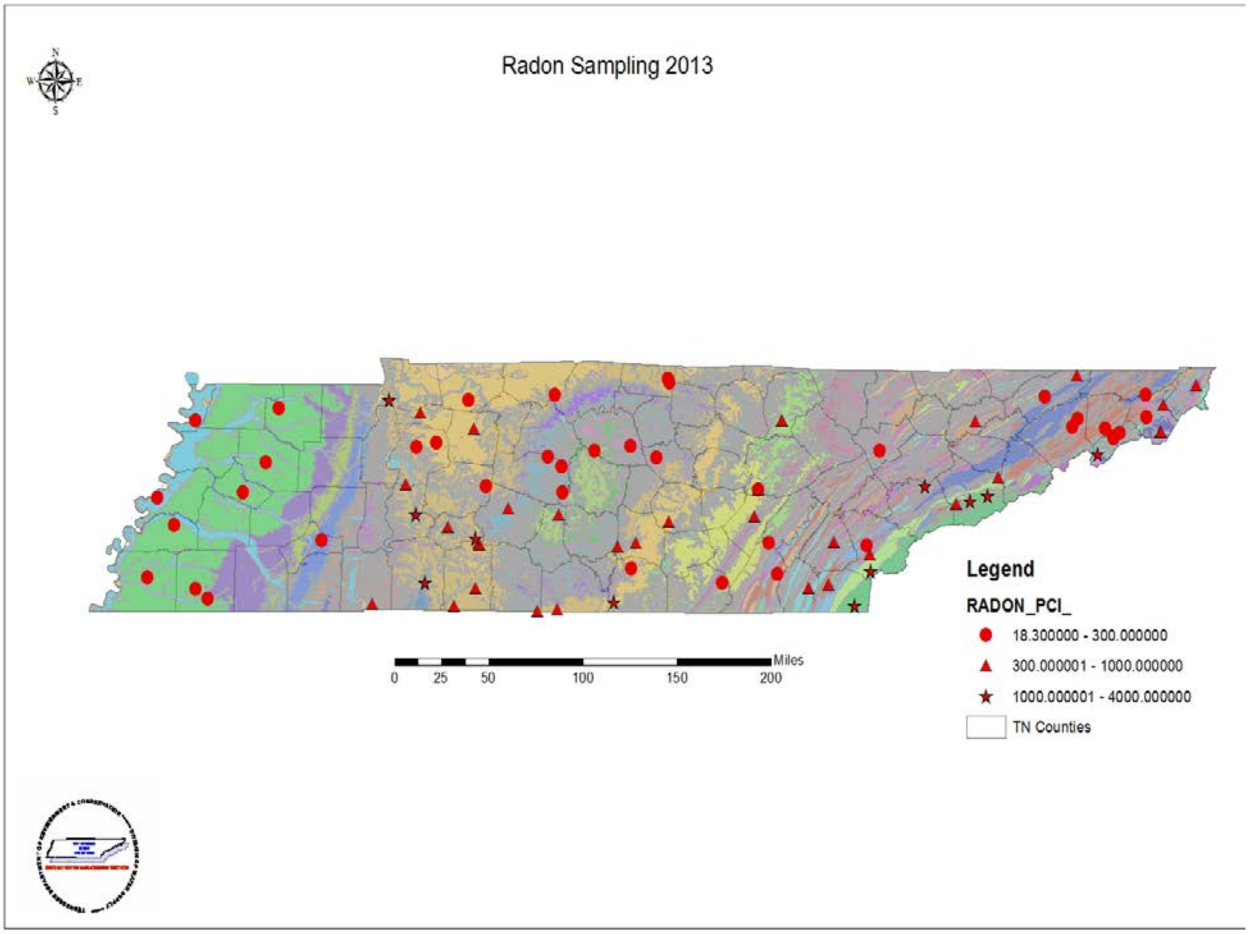


Figure 7

Range by pCi/L	2001 number of Systems	2013 number of Systems
0-300	62	40
301-400	13	11
401-500	7	6
501-600	4	3
601-700	5	3
701-800	3	5
801-900	0	3
901-1000	1	1
1001-2000	4	8
2001-3000	1	3
3001-	1 (3103)	2 (8792)

Table 1

9.0 Ongoing Activities

The Drinking Water Unit has been using Wellhead Protection set aside monies from the Drinking Water State Revolving Fund and EPA 106 Ground Water Grant monies to further ground water investigation and management activities.

9.1 Well Head Protection Work

Tennessee has completed the latest round of Wellhead Protection updates on all noncommunity and community water systems. The updates are completed every three years. The update includes the observation and documentation of any new potential contaminant source. Every sixth year, a new wellhead protection plan is submitted with new photographs and maps showing any new protection strategies that have been employed by the water system. The next new plan for community water systems is due to the Division by 2016. The noncommunity and small community water systems have a new plan every three years based on the grand division that they are located in, the 2013 series began with West Tennessee, 2014 is Middle Tennessee and 2015 is East Tennessee.

9.2 Department of Agriculture Pesticide Sampling Micro Pesticide Data Program (MPDP) and Ground Water Quality Assessment Study

The Division assisted the United States Department of Agriculture (USDA) in the collection of pesticide samples from twenty schools and head start facilities that utilize ground water across the state. **(Figure 8)** These samples were collected by Division staff from March 2011 through November 2011 and were analyzed by the Department of Agriculture. The study was one of the most comprehensive studies completed in Tennessee for ground water systems. The study was conducted in order to establish a baseline of micro pesticides data (MPD) in ground water. Previously, there had been very little MPD testing in Tennessee. From a health perspective, none of the MPD chemical concentrations analyzed were above any sort of hazard index or health based guidance.

This research was conducted through a partnership with the US Department of Agriculture and the Division of Water Resources' Ground Water Management Section and reflects a proactive effort to gain a statewide snapshot into certain micro pesticide levels in ground water sources. Perhaps equally as important, this research project has proven to be an effective communications tool in reminding citizens of our collective responsibility to protect our waters through important efforts, such as properly using and disposing of unused pesticides.

With the use of advanced analytical technology that is capable of accurately reflecting amounts in parts per trillion concentrations, Tennessee's waters were carefully sampled statewide for 146 specific compounds. As experienced in similar research across the country, certain MPDs were identified in some of Tennessee's ground water sources; however, it is important to note that none of the laboratory results reflected contaminants over published health advisory limits or EPA Maximum Contaminant Levels (MCL).

In frequency of occurrence, Desethyl atrazine (herbicide metabolite) was the most commonly encountered, followed by Tebuthiuron (herbicide), then Metolachlor ethanesulfonic acid (ESA) (herbicide metabolite).

The GWMS will continue to be in contact with the USDA and will continue to assist if funding is returned to the federal program.

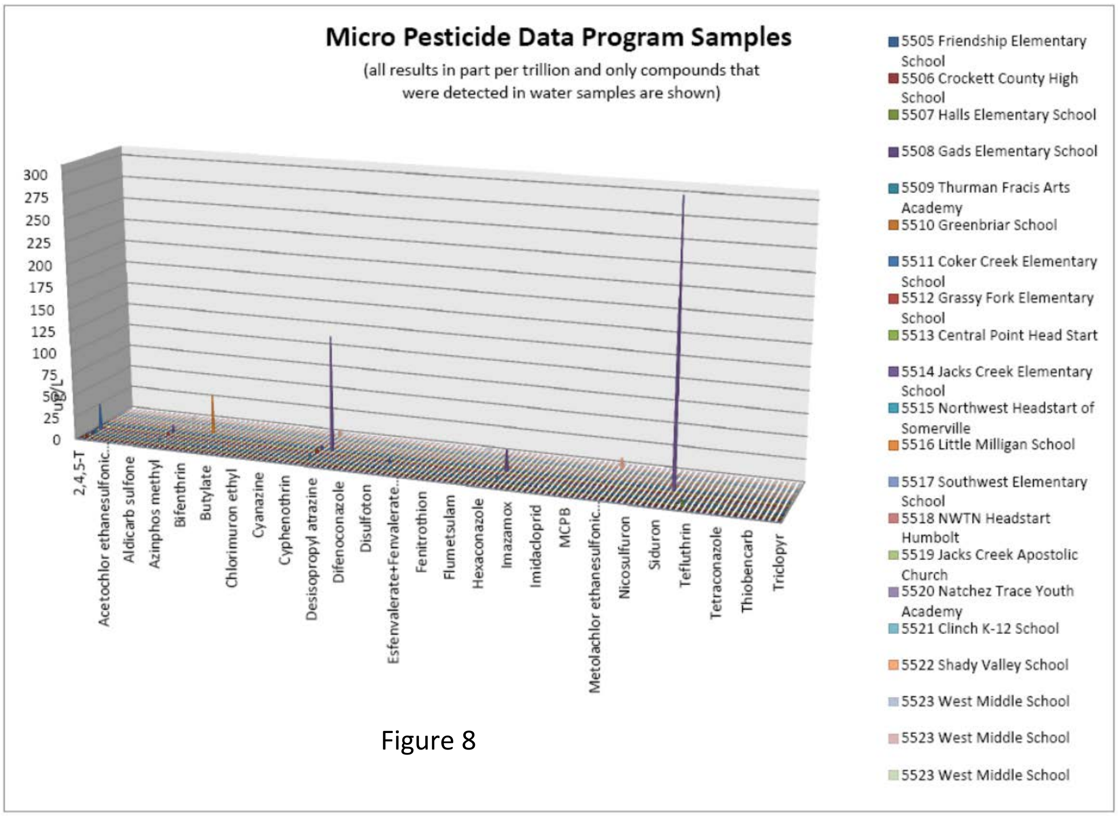


Figure 8

9.3 Pharmaceutical and Personal Care Product Sampling

The GWMS entered into a contract with the University of Tennessee in 2012. This contracted project was to provide TDEC with information on the prevalence and concentration of pharmaceutical compounds in select raw water treatments in Tennessee. The specific goals were to:

1) Analyze raw water treatment samples for select pharmaceutical compounds using analytical chemistry methods; and

2) Analyze raw water treatment samples for endocrine disrupting potential using recombinant yeast (*Saccharomyces cerevisiae*) bioreporter strains.

This project surveyed raw waters in Tennessee (surface water and ground water) for the presence of both pharmaceutical compounds and endocrine disrupting compounds. Initially, select pharmaceutical compounds, including: caffeine, carbamazepine, DEET, 17α-ethinyl estradiol, fluoxetine and ibuprofen were analyzed using GC/MS or LCMS analytical methods. In order to supplement analytical testing for endocrine disrupting compounds, bioluminescent-based yeast (*Saccharomyces cerevisiae)*, reporters for the detection and quantification of estrogenic and androgenic chemicals were used on each sample (Sanseverino et al. 2008). The combined use of these two strains allowed testing of chemicals for estrogenic and androgenic activity and provided rapid assessment of the prevalence of endocrine disrupting chemicals in water samples.

Fifteen chemicals were analyzed by gas chromatography mass spectroscopy (GC/MS) and hormonal activity for both estrogens and androgens using bioassays (Table 1). These compounds were selected to represent a range of chemical classes including household and industrial chemicals, herbicides, prescription and over the counter drugs and fecal indictors. The only chemical tested with a regulatory limit set by EPA was atrazine (3 µg/L) and no samples contained concentrations above this concentration. When detected, the chemical concentrations were consistent with the range of values reported for surface and drinking water (*1-3*) at concentration in the low ppb range (µg/L) and lower. The literature also indicates that chemical concentrations are generally higher and more frequently detected in surface than ground waters.

Table 2 conveys the Compounds tested, the functional class, the minimum detection limit, the maximum concentration detected in any of the 348 samples tested and reported acceptable concentrations.

Compound	**Class**	**MDL (µg /L)**	**Maximum Conc (µg/L)**
Diethyl phthalate	Plasticizer	10	4000 = 4.000 µg/L
Bisphenol A	Plasticizer	100	2305 = 2.3 µg/L
4-tert-Octylphenol	Nonionic detergent	10	92 = 0.092 µg/L
4-nonylphenol	Nonionic detergent	10	123 =0.123 µg/L
Irgasan (Triclosan)	Antimicrobial	250	324 = 0.243 µg/L
Atrazine	Herbicide	10	857 = 0.857 µg/L

DEET	Insect repellant	10	43 = 0. 043 µg/L
Fluoranthene	PAH	4	26 =0.026 µg/L
Ibuprofen	OTC painkiller	1000	5236 =5.236 µg/L
Cotinine	Nicotine metabolite	50	445 = 0.445 µg/L
Caffeine	Stimulant	10	210 = 0.21 µg/L
Fluoxetine (Prozac)	Antidepressant	50	0
Carbamazepine	Anticonvulsant	100	146 = 0.146 µg/L
Sertraline (Zoloft)	Antidepressant	10	281 = 0.281 µg/L
Coprostanol	fecal steroid	75	912= 0.912 µg/L
Estrogen	Hormone	0.5	10.3 = 0.010 µg/L
Androgen	Hormone	9	0

Table 2

Of the 348 water samples collected, positive for a particular chemical ranged from a high of 166 for diethyl phthalate (48%) to 0 (0%) for fluoxetine (Figure 9). The most frequently detected class of chemicals was the plasticizers, pesticides and detergents. The least frequently detected compounds were the pharmaceutical compounds (except sertraline). The number of chemicals detected out of 16 ranged from 0 to 10 (Figure 10). No chemicals were detected in 31% of the samples and only one chemical was detected in another 28% of the samples. Four or more chemicals were detected in 15% of the samples.

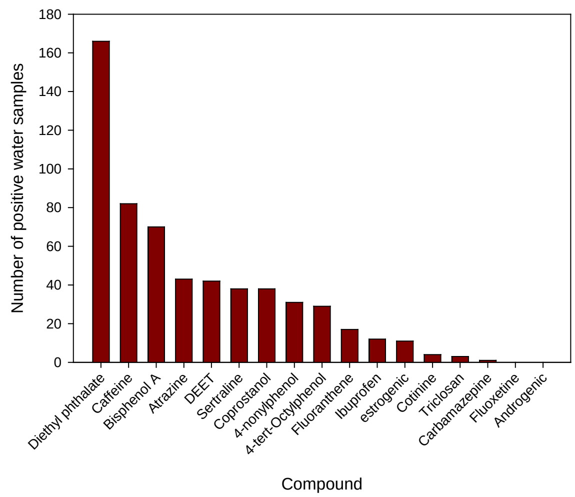


Figure 9. Number of water samples (out of 384 samples) positive for each chemical.

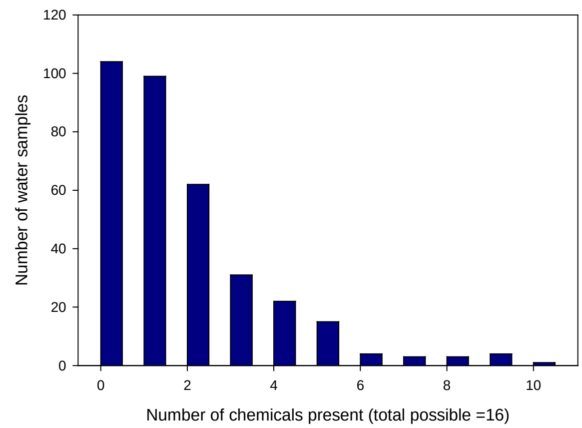


Figure 10. Number of chemicals (maximum 16) detected in each water sample (384 samples).

The percent of water samples with at least one detection at 69% is similar to percentages reported for ground water (81%) (*3*), untreated drinking water sources (91%) (*2*), streams (80%) (*1*) and summarized by USGS http://toxics.usgs.gov/highlights/gwsw_ec.html. Also, several compounds measured in the TN water samples and the 3 other studies were found at similar frequencies. For example, bisphenol A was found in 20% to 40% of the water samples in the above studies and at 20% in this study and ibuprofen was less abundant and found in 1.4% to 9.5% of the water samples in the above studies and in 3.4% of these water samples. Fluoxetine and androgens were not found in any of the samples.

In order to determine whether there was a difference in frequency or types of chemicals detected in surface water versus ground water, the dataset was sorted by water source with 185 samples representing ground water and 163 samples representing surface water. The surface water data contained a higher number of samples with 4 or more chemicals detected and fewer samples with <1 chemical detected than the ground water samples (Figures 11 & 12). In the surface water, the average number of chemicals detected for each sample was 4.7 whereas in groundwater the average number of chemicals detected was 1.1. The frequency of detection for several chemicals also differed greatly between the surface water and ground water, with caffeine and coprostanol found in 22- and 13-fold more frequently in surface water than ground water and DEET, diethyl phthalate, atrazine, Ibuprofen was found 2- to 5- fold more frequently in surface water than ground water. Two compounds, bisphenol A and 4- nonylphenol, were found more frequently in ground water than surface water.

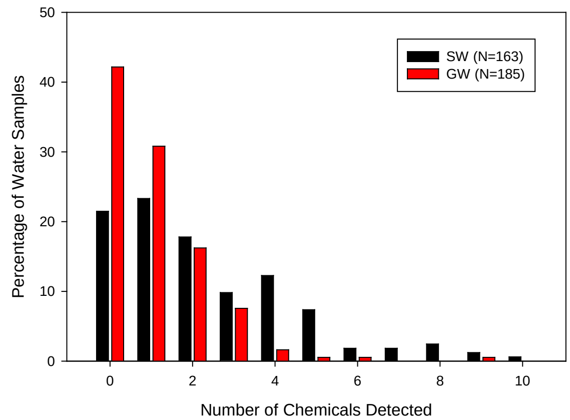


Figure 11. Percentage of surface water (SW samples and ground water samples containing 0 to 10 chemicals.

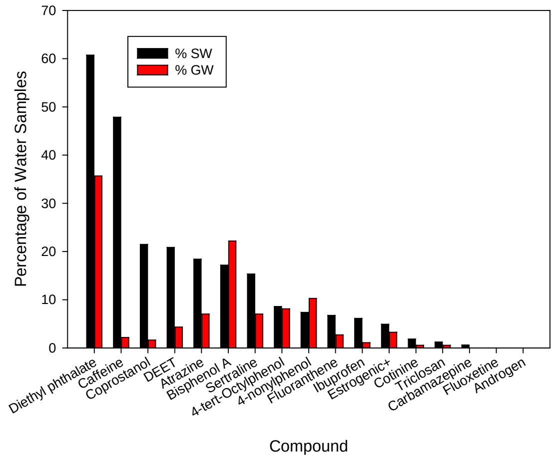


Figure 12. Percentage of surface water (SW) and ground water (GW) samples positive for each chemical.

These results suggest that untreated drinking water sources in Tennessee have similar levels of trace organic contaminants with respect to both concentration and frequency of occurrence to water found in other parts of the United States. In addition, as may be expected, the frequency of detection of most of the chemical contaminants was higher in surface water than ground water.

10.0 Source Water Protection: Protecting Public Drinking Water Supply Sources

10.1 Regulatory Changes

There have been significant developments at the State level since EPA's approval of Tennessee's Source Water Assessment Program in 1999 and the submittal of the assessments to EPA in 2003. Most significant for Source Water Protection are the changes made in the Tennessee Safe Drinking Water Act in 2002 at the request of the Division of Water Resources. Prior to this amendment, Tennessee Code Annotated (TCA) §68-221-711 (5) prohibited only the discharge of sewage above an intake.

After some difficulties in addressing a specific problem where it was difficult to ascertain which agency should/could respond, language was successfully added (bolded in italics) that prohibits:

> "The discharge by any person of sewage ***or any other waste or contaminant*** at such a proximity to the intake, ***well or spring*** serving a public water system in such a manner or quantity that it will or will likely endanger the health or safety of customers of the system or cause damage to the system."

Tennessee considers this a significant achievement toward Source Water Protection that is not available at the federal level. In addition, another amendment was proposed and successfully added to the Tennessee Safe Drinking Water Act that incorporates water quantity issues but that can easily become a water quality issue as well. Prior to amendment, TCA §68-221-711(8) prohibited heavy withdrawal from a water supply (water supply lines).

After concerns over addressing a major commercial water withdrawal in vicinity to a water supply spring and at the request of the Division of Water Resources, an additional prohibition was added (bolded in italics):

> "The heavy pumping or other heavy withdrawal of water from a public water system ***or its water supply source*** in a manner that would interfere with existing customers' normal and reasonable needs or threaten existing customers' health and safety."

With this new authority to protect water supply sources within the Act, the Division of Water Resources promulgated regulations in October of 2005 to include complimentary language to the former Wellhead Protection Rule 0400-45-1-.34. Language was added to the Rule that gives the Division authority to address certain high risk activities in the vicinity of water supply intakes, wells and springs that might otherwise be unregulated. The Rule is now titled "Drinking Water Source Protection" and also includes contaminant inventory and emergency operation requirements for water systems using surface water intakes in addition to the wellhead protection requirements for ground water systems that were present previously.

In 2014 the Division proposes to make minor changes in the timing that all Source Water protection Plans are updated.

10.2 Source Water Updates

The GWMS worked with the staff from the former Division of Geology (TDG), now called the Tennessee Geological Survey, to complete an update of potential contaminant sources within various source water protection areas across the state. Members of TDG were equipped with survey sheets and GPS units and were looking for on-site waste disposal systems and for any illicit discharges to the source water protection area. These efforts focused on areas shown by the State–EPA Nutrient Innovations Task Group when they released a document in August 2009 entitled "An Urgent Call to Action" which can be found at http://www.epa.gov/waterscience/criteria/nutrient/nitgreport.pdf. Water systems threatened by nutrients, pathogens, and Total Organic Carbon (TOC) are illustrated in Appendix A.

Every community public water system is also required to address their source water assessment in the Consumer Confidence Report that is required to be made available to its customers annually and advise customers of the location of the Division's website: http://www.tn.gov/environment/water/water-supply_source-assessment.shtml
The Drinking Water unit, in conjunction with the Tennessee Association of Utility Districts, is working with other state and local agencies, water systems and local governments to develop localized source water protection plans within counties and watersheds. The Drinking Water Unit has available resources to assist individual water systems with contaminant source issues as well. The Division has completed the contract with the University of Memphis to produce a multi-part video on source water protection, which is available at http://www.tn.gov/environment/water/water-supply_source-assessment.shtml

10.3 Water Resources Technical Advisory Committee (WRTAC)

TDEC partnered with the federal and state agencies, nongovernmental organizations and other regional planning experts to form a Water Resources Technical Advisory Committee (WRTAC) and to initiate a water resources planning pilot in two areas significantly impacted by the drought of 2007.

WRTAC was authorized by the Tennessee Water Resources Information Act in 2008. One of the first tasks that the committee completed was the development of a framework for regional water supply planning, which can be found at: http://www.tn.gov/environment/water/docs/regionalplanning/regional_water_resources_planning_guidelines.pdf.

The committee then developed a rational for establishing a ranking system for regional water supply plans as it relates to the State Revolving Fund (SRF) funding. This allowed regional plans to receive a higher ranking in the funding formula and also allowed a quicker review of regional plans with respect to TDEC reviews.

The current charge from the Commissioner can be located at: http://www.tn.gov/tacir/PDF_FILES/Agenda/Feb13/Tab9_Water.pdf. To fulfill a portion of this charge, the committee produced a "Statewide System of basic Hydrologic and Water System Information," which can be found at: http://www.tn.gov/environment/water/docs/regionalplanning/statewide-hydrologic-and-water-system-proposal.pdf. The committee also produced the "Regional Water Supply Plans Approval Process for Tennessee" which can be found at: http://www.tn.gov/environment/water/docs/regionalplanning/regional-water-supply-plan-approval-process.pdf.

10.4 Red River Study

Several surface water systems on the Red River are indicating increases in nutrients that potentially are from ground water sources. TDEC continues its study of karst terrain in the Red River Watershed. An EPA-funded study, in partnership with the United States Geological Survey (USGS) and the Red River Watershed Association, examined the relationship between surface water and ground water in five sub watersheds in the Montgomery, Robertson, and Stewart County portions of the Red River Watershed. The GWMS has contracted with the Tennessee Division of Geology to update the source water protection plan for systems on the Red River.

10.5 Mercury in Wayne County

As part of an ongoing investigation, TDEC has identified 86 county and private bridges in Wayne County, five bridges in Hickman County, and six bridges in Lewis County as being contaminated with elemental mercury. The mercury was found in material on the underside of the bridges which has characteristics similar to concrete. The bridges in question are small, typically one-lane, weathered bridges with metal driving surfaces primarily used on small public roads and for private driveway crossings.

Bridges suspected of containing mercury were stabilized and there is an ongoing action to remove and replace these bridges in a manner that allows transportation access to county residents. As of September 2014, 45 bridges in Wayne County had been removed and replaced. Under TDEC's direction, surface water samples were collected throughout Wayne County to determine if these bridges had impacted surface water. The results of this investigation found no mercury in surface water above the state's risk-based thresholds. An investigation in Lewis and Hickman counties began in October 2014 and samples of fish tissue will also be taken from streams in Wayne County at this time.

10.6 North Central Tennessee Region, Southern Cumberland Region, and Proposed Southwest Highland Rim Studies Water Resources Planning Pilot

In late 2008, TDEC partnered with the U.S. Army Corps of Engineers Nashville District, members of the Advisory Committee and other regional planning experts to initiate a water resources planning pilot in two areas significantly impacted by the drought of 2007:

1) **North Central Tennessee region –** Sumner County, including Portland, Gallatin, Castalian Springs/Bethpage, White House and Westmoreland; and

2) **Southern Cumberland region –** consisting of portions of Franklin, Grundy, Marion, and Sequatchie Counties and the towns of Tracy City, Sewanee, Altamont and Monteagle

The final reports for the South Cumberland Regional Water Resources Planning Study (June 2011) and the North Central Regional Water Resources Planning Study (December 2011) can be found at http://www.tn.gov/environment/regionalplanning/#ncentral.

TDEC is once again partnering with the U.S. Army Corps of Engineers Nashville District to look at the South Western Highland Rim Area. The purpose of this study is to assess water resource limitations, and develop and compare potential water source alternatives to meet future projected water supply shortfalls within the study region. This study will focus on Wayne County, in the Western Highland Rim region of Tennessee, and will be consistent with regional planning pilot studies conducted by TDEC in the Portland/North Central TN and Southern Cumberland Plateau areas. Representatives from TDEC and the Corps of Engineers will lead the study and collaborate on implementation. The first phase of the study is complete with the second phase being finalized in 2014.

The proposed study will address existing water sources, wastewater assimilation requirements, exceptional or scenic waters, wetlands, impaired waters, and a source's location relative to other withdrawals or discharges will be incorporated into analyses of water source yields. The study will also address water needs, water conservation measures and alternative sources.

11.0 Ground Water Protection and Remediation Activities

The Groundwater Management Program serves as the state's coordinating agency for the development of a Comprehensive State Ground Water Protection Plan with EPA and state agencies with ground water responsibilities. A major focus of the program is Wellhead Protection, which is protecting ground water sources of public water systems. The section also regulates ground water discharges through management of the Underground Injection Control (UIC) program (both deep well injection and shallow non-hazardous injection such as storm water discharge) under the authority of the Water Quality Control Act.

Authority to operate the statewide UIC program within the Tennessee Department of Environment and Conservation has been delegated to the Division of Water Resources (DWR), and is currently administered by the Ground Water Management Section (GWMS) in the Drinking Water Unit. Rule 0400-45-6 classifies injection wells as Class I through Class V. Tennessee has opted to ban all Class I hazardous waste injection wells (0400-45-6-.10(1)(a)) and Tennessee does not possess the mineral resources for Class III wells. Tennessee regulations do exist for Class I, Class II, Class III, Class IV, and Class V injection wells. Class IV wells are prohibited by Federal regulations, by provisions of state Rule 0400-45-6-.13 and are closed when encountered. Tennessee's UIC program maintains regulations and seeks primacy for all classes of the Underground Injection Control Program.

EPA has recently recognized a Class IV injection well class. This class is to regulate the Geo-sequestration of Carbon Dioxide. Tennessee will be studying this class of wells and will proceed with rulemaking once primacy for Class I-V has been established.

11.1 UIC Activities

11.1.1 Class I Injection Wells

Class I wells inject hazardous and non-hazardous wastes into deep, isolated rock formations that are thousands of feet below the lowermost Underground Source of Drinking Water (USDW).

Class I wells are used mainly by the following industries:

- Petroleum Refining
- Metal Production
- Chemical Production
- Pharmaceutical Production
- Commercial Disposal
- Food Production
- Municipal Wastewater Treatment

Currently, there are no active Class I injection wells. Previously, Tennessee had a total of eleven Class I wells; however, all Class I wells have been plugged and abandoned and all Class I hazardous wells are now banned in Tennessee.

Historical Class I wells:

- 1966 DuPont chemical –New Johnsonville 6 wells drilled injection depth from 3650 to 7000 feet all closed by 1998

    - 1969 Stauffer Chemical (ICI, Zeneca) –Mount Pleasant 4 wells drilled injection depth from 3000 to 6500 feet all closed by 1997
    - 1979 Mobil Chemical (Rhone-Poulenc Chemical) –Mount Pleasant 1 well drilled injection depth from 4583 to 6413 ft. closed 1990
- Currently there are no Class I injection wells in Tennessee

11.1.2 Class II Injection Wells

Class II wells inject fluids associated with oil and natural gas production. Most of the injected fluid is salt water (brine), which is brought to the surface in the process of producing (extracting) oil and gas. In addition, brine and other fluids are injected to enhance (improve) oil and gas production.

EPA currently identifies 12 active Class II Injection Wells in Tennessee. (Figure 13)

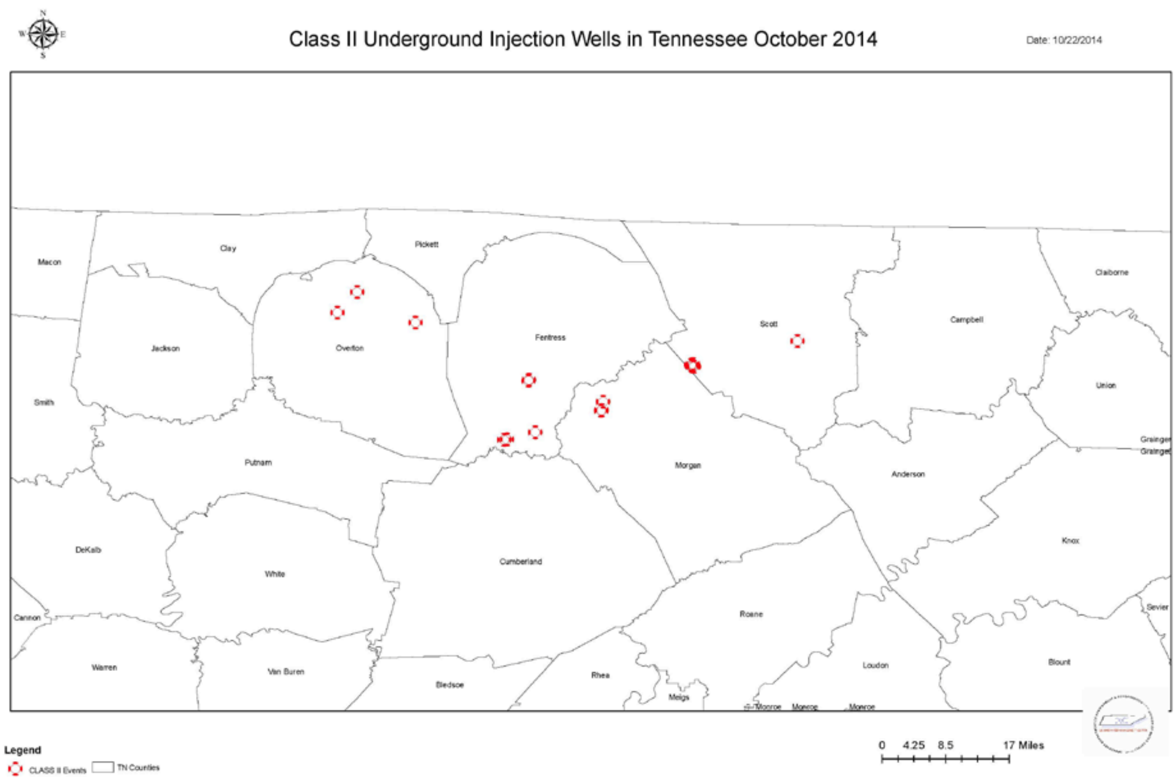


Figure 13

11.1.3 Class III Injection Wells

Class III wells inject fluids to dissolve and extract minerals such as uranium, salt, copper, and sulfur. More than 50 percent of the salt and 80 percent of the uranium extraction in the United States involves the use of Class III injection wells.

Currently, there are no Class III injection wells in Tennessee.

11.1.4 Class IV Injection Wells

Class IV wells are shallow wells used to inject hazardous or radioactive wastes into or above a geologic formation that contains a USDW. In 1984, EPA banned the use of Class IV injection wells for disposal of hazardous or radioactive waste. At this time, these wells may only be operated as part of an EPA- or state-authorized ground water clean-up action.

11.1.5 Class V Injection Wells

Class V wells are used to inject non-hazardous fluids underground. Most Class V wells are used to dispose of wastes into or above underground sources of drinking water and can pose a threat to ground water quality, if not managed properly.

Most Class V wells are shallow disposal systems that depend on gravity to drain fluids directly in the ground. There are over 20 well subtypes that fall into the Class V category and these wells are used by individuals and businesses to inject a variety of non-hazardous fluids underground. TVA estimates that there are more than 50,000 Class V wells in operation in Tennessee. We currently have over 4,000 in our inventory. Most of these Class V wells are unsophisticated shallow disposal systems that include storm water drainage wells, cesspools, and septic system leach fields. However, the Class V well category includes more complex wells that are typically deeper and often used at commercial or industrial facilities.

Other more sophisticated Class V well types could include aquifer storage and recovery wells or geothermal electric power wells that are used to inject geothermal fluids extracted from subsurface hydrothermal systems.

Tennessee currently tracks over 4,000 Class V injection points in the state. Figure 14 shows the distribution of the injection sites. Table 3 shows the number of Class V injection wells. Please note that a site may have more than one injection point.

Bio-remediation	303
Control Leak	3
Drilled injection well	7
Drinking water injection	1
Disposal Drip System	375
Dye trace	663
Geothermal heat pump	14
Illegal Septic to well	1
Infiltration cell	182
Mine injection	6
Municipality general permit	14
SFDS	1008
Sinkhole dump	12
Sinkhole modification	2691
Storm water to well	578
Technical assistance	85
Well abandonment	16
Total:	5987

Table 3

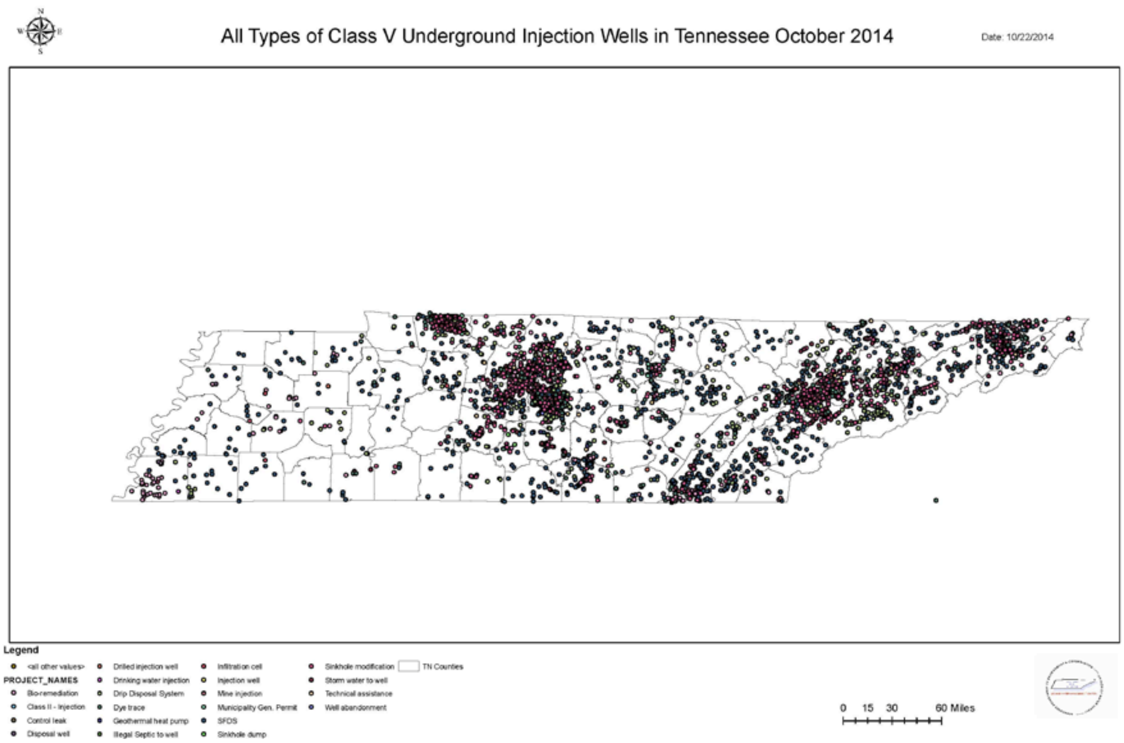


Figure 14

11.1.5.1 Storm Water Injection

In the karst areas of Tennessee, the majority of storm water runoff is injected into modified sinkholes. These sinkholes, along with the associated underground drainage system, take the place of surface discharges and surface streams. The shallow ground water in these areas often contains large amounts of sediment and other nutrients. Once a sinkhole is modified into a Class V injection well, precautions are taken to ensure that the sinkhole no longer allows for sediment or other pollutants to enter the ground water. (Figure 15)

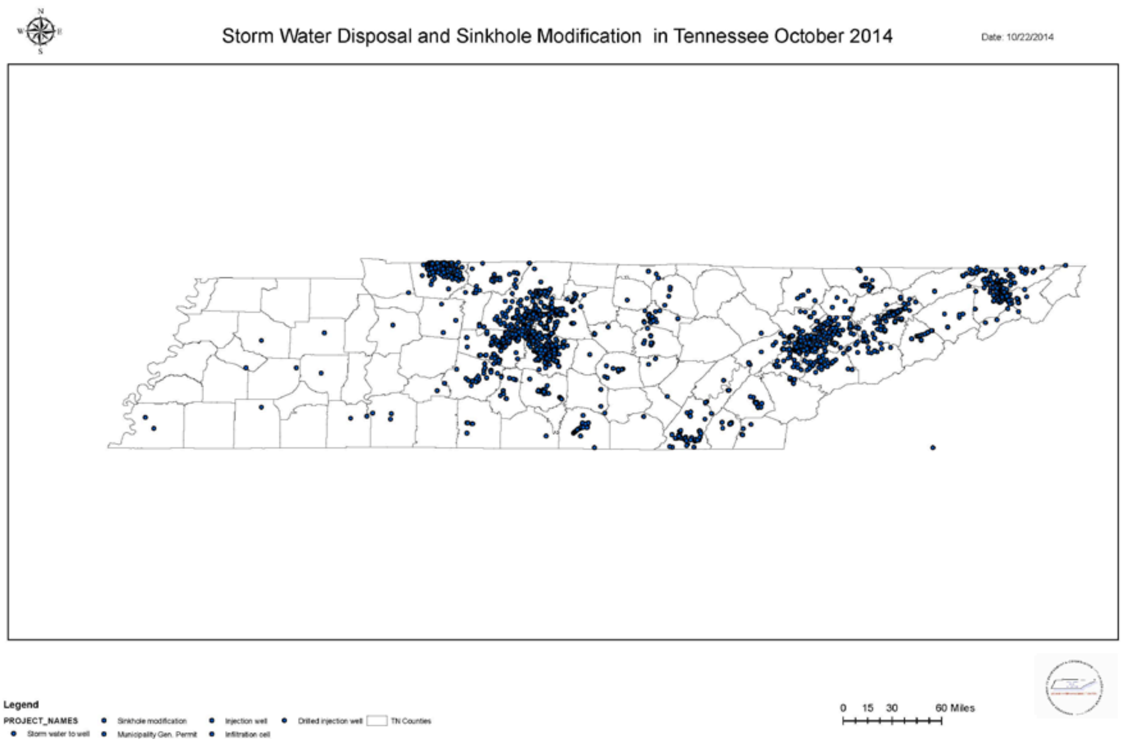


Figure 15

11.1.5.2 Large Capacity Septic Systems (LCSS) Subsurface Fluid Distribution Systems (SSFDS)

EPA considers any septic system that serves 20 or more persons to be a Class V Injection well. In Tennessee, the UIC program has 1008 registered conventional septic systems and 375 drip dispersal systems. The drip dispersal systems will serve multiple homes and or businesses. (Figure 16)

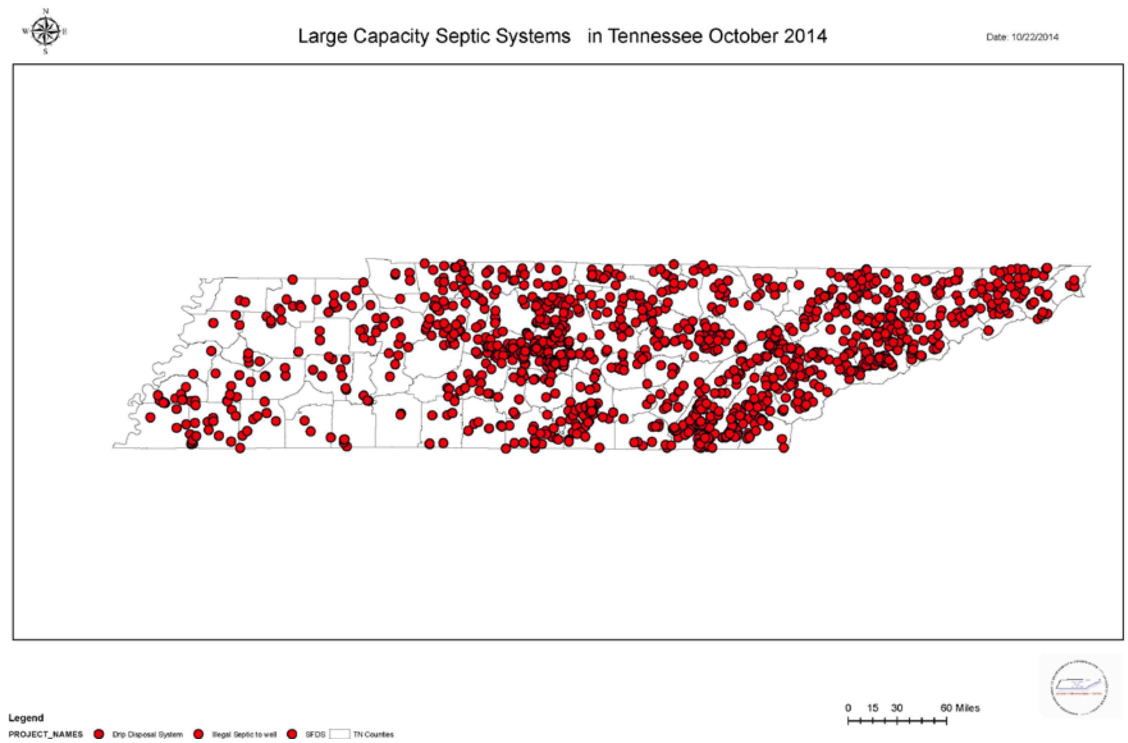


Figure 16

11.1.5.3 Remediation activities utilizing underground injection

In Tennessee, the UIC program works with various remediation programs. Tennessee has 303 locations that utilize some type of injection as a part of the ground water remediation. (Figure 17)

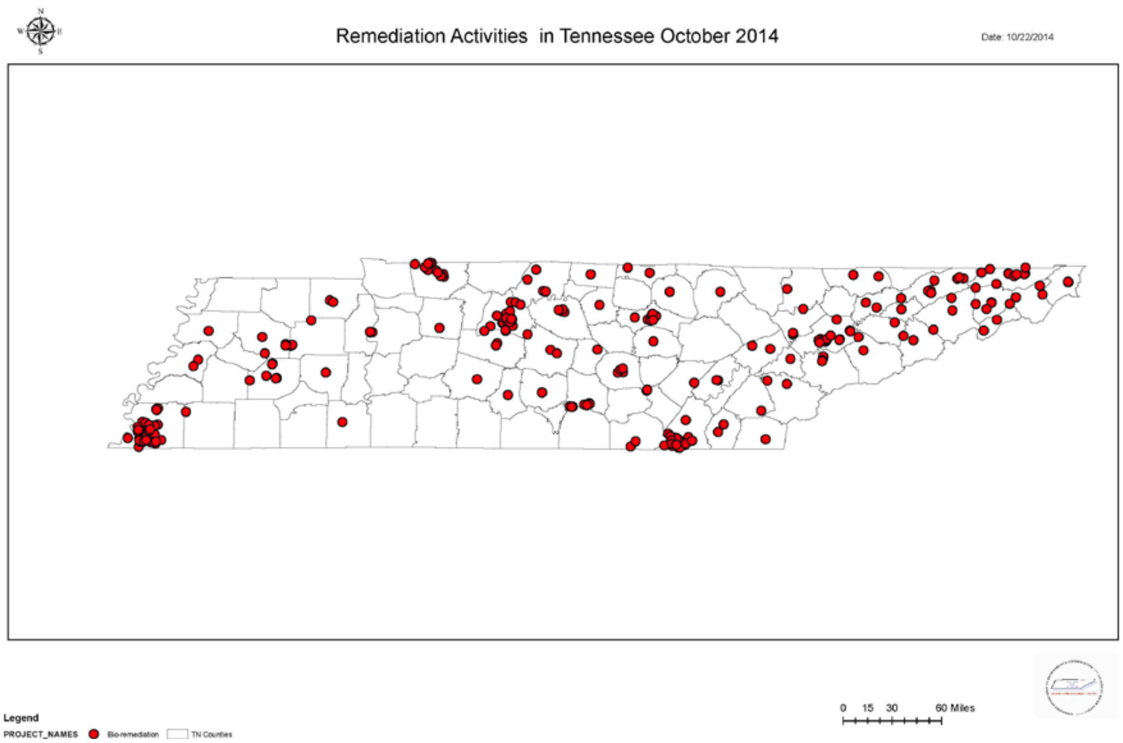


Figure 17

11.1.6 Class VI Injection Wells

Class VI wells are used for injection of carbon dioxide (CO_2) into underground subsurface rock formations for long-term storage, or geologic sequestration. Geologic sequestration refers to a suite of technologies that may be deployed to reduce CO_2 emissions to the atmosphere to help mitigate climate change.

Currently, there are no Class VI injection wells in Tennessee. Tennessee is preparing regulations for any potential Class VI Injection well.

12 Public Education and Outreach

October 2013	Oil & Gas Site Coordinator Workshop
November 2013	Tennessee American Water Resources Association
November 2013	Nolichucky Watershed Meeting
November 2013	Tennessee Water Well Association (West Tennessee Meeting)
December 2013	National Ground Water Association
December 2013	Duck River Association Meeting
March 2014	Tennessee Water Well Association (East Tennessee Meeting)
March 2014	Fleming Small System Operators Training (West Tennessee)
March 2014	Fleming Small System Operators Training (Middle Tennessee)
April 2014	EPA Spring Director Meeting
July 2014	Fleming Small System Operators Training (East Tennessee)
September 2014	Fleming Small System Operators Training (Middle Tennessee)
September 2014	Brentwood Environmental Education Day
October 2014	7th Grade Science Classes at LaVergne Middle School Geology and Ground Water of Tennessee

13.1 Ground Water Withdrawals and Use

13.1 Water Withdrawal Registration

The Water Resources Information Program collects information on the withdrawal and use of water within Tennessee. The information is used to identify water uses and resources that may require management at critical times, especially drought conditions. The purpose of the program is to protect the water resources of Tennessee from over-utilization.

Under the authority of the Water Resources Information Act of 2002 and TCA Section 69-7-301, water withdrawals of 10,000 gallons or more on any day in Tennessee must be registered. The total amount of water withdrawals in 2013 can be shown as:

Tennessee Annual Water Withdrawals (2013)

- Total= 2,308,376.858 MG
- Surface Water = 2,272,163.318 MG or **98%**
- Ground Water = 36,213.540 MG or 2**%**

Note: The Surface water values include Power Plant withdrawals; however, this in non-consumptive water withdrawals. Data does not include public water utility withdrawals.

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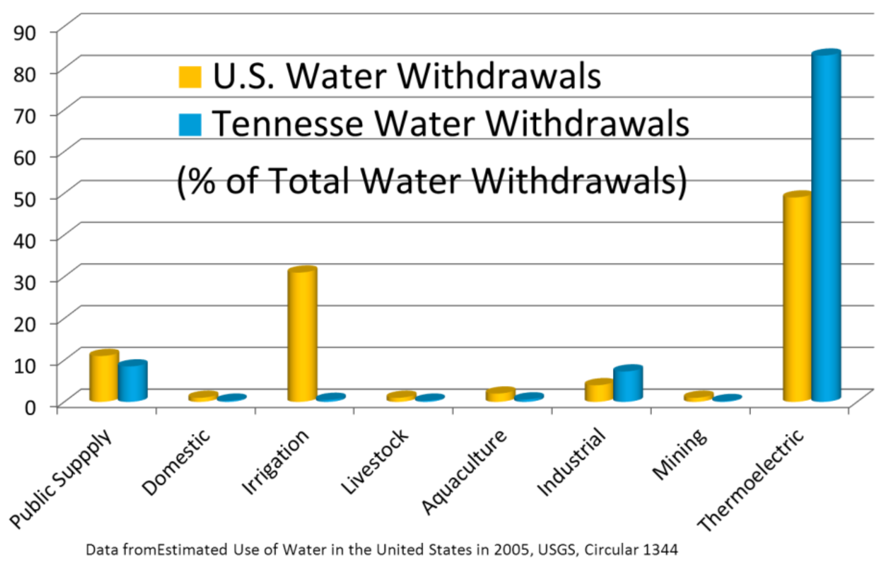

Table 4

This chart shows how Tennessee compares to the national average in ground water withdrawals for the 8 water withdrawal categories. A lot of ground water is used in Tennessee for public water systems. This is due to West Tennessee and the Memphis Sands Aquifer. Zero ground water is used to cool the TVA Thermoelectric Power Plants (Figure 19)

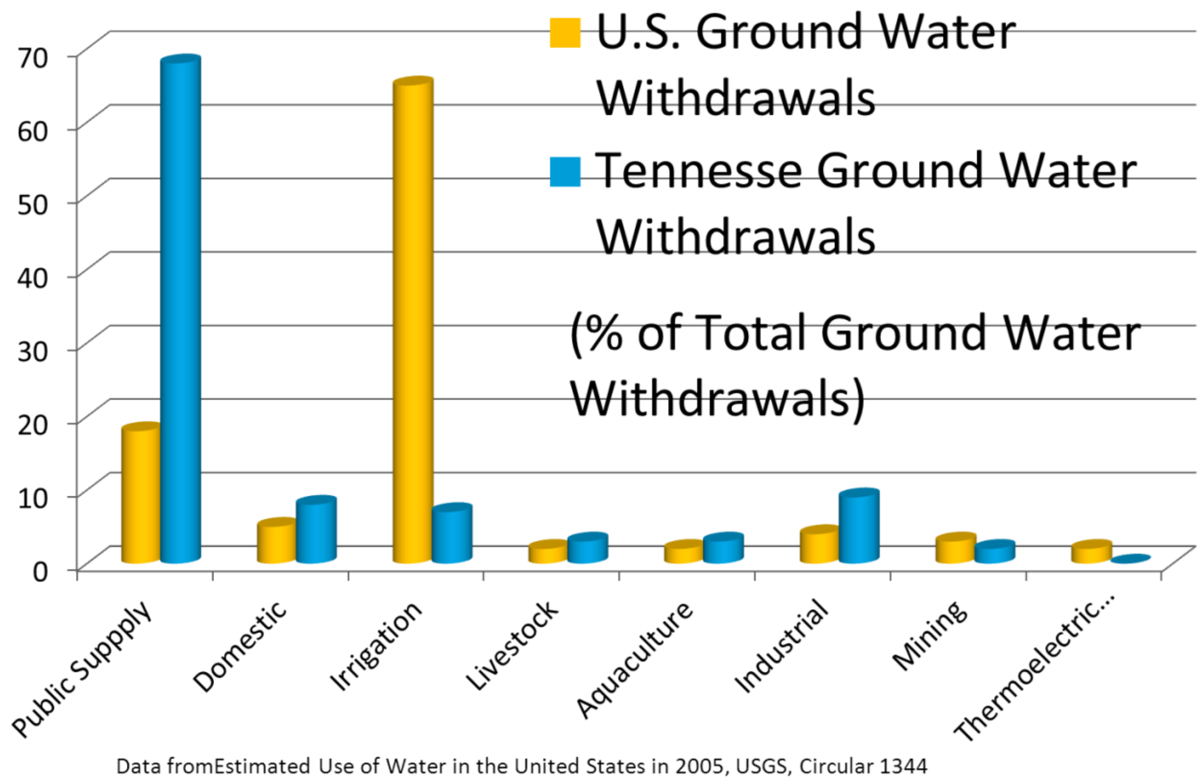

Table 5

13.2 Water Wells Program

The Well Driller Supervision Program licenses well drillers, pump setters, and water treatment device installers in Tennessee. Licensed individuals must develop wells and install equipment according to standards, which are designed to protect the resource and insure consumers of a safe and reliable structure.

The duties of the Commissioner are given in TCA Section 69-11-106 and include, among other things, the authority to:

- License drillers, pump installers, and water treatment device installers
- Inspect well construction
- Investigate complaints
- Promulgate Rules relative to well construction

Water well installation has been declining over the past five years. (Table 6)

Year	Total Number of Wells Reported
2007	5158
2008	4173
2009	2713
2010	2365
2011	2554
2012	2868
2013	2606
2014*	1781

*Well data through 3rd quarter

Table 6

A breakdown of newly drilled water wells and geothermal wells drilled in 2013 by county shows the most active counties for ground water use by private citizens (Figure 20). At this time, there is no requirement for test wells or monitoring wells to be reported. Geothermal wells, as listed on figure 20, represent the number of projects, not number of individual wells drilled on the site.

TENNESSEE

Total Wells Per County

2013	Water	Geo	Other	Total		Water	Geo	Other	Total		Water	Geo	Other	Total
Anderson	3	1	2	6	Hamilton	16	4	5	25	Morgan	4	0	4	8
Bedford	14	1	0	15	Hancock	38	0	1	39	Obion	49	2	2	53
Benton	25	0	0	25	Hardeman	34	0	1	35	Overton	5	0	2	7
Bledsoe	25	0	1	26	Hardin	15	0	1	16	Perry	16	0	0	16
Blount	38	2	4	44	Hawkins	61	0	0	61	Pickett	1	0	0	1
Bradley	18	0	0	18	Haywood	71	1	2	74	Polk	20	0	0	20
Campbell	5	0	1	6	Henderson	11	0	2	13	Putnam	3	1	2	6
Cannon	10	1	1	12	Henry	47	0	4	51	Rhea	10	0	0	10
Carroll	38	0	2	40	Hickman	20	0	1	21	Roane	9	1	0	10
Carter	12	0	1	13	Houston	4	0	0	4	Robertson	13	1	1	15
Cheatham	11	0	0	11	Humphreys	53	0	1	54	Rutherford	52	14	6	72
Chester	28	0	1	29	Jackson	7	0	0	7	Scott	1	0	0	1
Claiborne	31	1	0	32	Jefferson	41	0	5	46	Sequatchie	15	0	0	15
Clay	6	0	0	6	Johnson	28	0	0	28	Sevier	94	1	6	101
Cocke	23	0	1	24	Knox	37	5	2	44	Shelby	13	0	11	24
Coffee	25	1	1	27	Lake	17	0	1	18	Smith	9	2	0	11
Crockett	40	0	1	41	Lauderdale	17	0	2	19	Stewart	29	0	0	29
Cumberland	18	1	0	19	Lawrence	31	2	0	33	Sullivan	11	1	0	12
Davidson	20	61	3	84	Lewis	27	0	0	27	Sumner	26	4	3	33
Decatur	1	0	0	1	Lincoln	7	0	0	7	Tipton	30	3	4	37
DeKalb	15	1	0	16	Loudon	17	0	0	17	Trousdale	6	1	0	7
Dickson	21	0	0	21	McMinn	46	1	0	47	Unicoi	6	0	0	6
Dyer	54	0	2	56	McNairy	15	0	1	16	Union	31	0	0	31
Fayette	100	2	1	103	Macon	3	0	1	4	Van Buren	14	0	2	16
Fentress	10	0	0	10	Madison	46	1	0	47	Warren	10	0	2	12
Franklin	23	0	1	24	Marion	32	3	1	36	Washington	13	0	0	13
Gibson	82	1	1	84	Marshall	9	0	1	10	Wayne	61	0	5	66
Giles	13	0	1	14	Maury	21	2	2	25	Weakley	44	0	0	44
Grainger	51	0	1	52	Meigs	11	0	0	11	White	5	0	0	5
Greene	18	0	1	19	Monroe	47	0	5	52	Williamson	61	20	6	87
Grundy	7	0	0	7	Montgomery	11	3	0	14	Wilson	28	10	2	40
Hamblen	6	0	2	8	Moore	3	1	0	4					
										TOTAL				2606
										Water				2323
										GeoThermal				157
										Other				126

Figure 20

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APPENDIX A

Acronyms

CCR	Consumer Confidence Report
DRMA	Duck River Management Authority
DWR	Division of Water Resources
DWS	Division of Water Supply
DWU	Drinking Water Unit
EFO	Environmental Field Office
EPA	Environmental Protection Agency
GC/MS	Gas Chromatography Mass Spectroscopy
GIS	Geographic Information System
GWMS	Ground Water Management Section
µg/L	Microgram per liter
M/gal	Million Gallons
MCL	Maximum Contaminate Level
MPDP	Micro Pesticide Data Program
NOI	Notice of Intent
pCi/L	Picocurie per liter
PPCP	Pharmaceutical and Personal Care Product
SRF	State Revolving Fund
SWPA	Source Water Protection Area
TAUD	Tennessee Association of Utility Districts
T.C.A.	Tennessee Code Annotated
TDEC	Tennessee Department of Environment and Conservation
TDG	Tennessee Division of Geology
TGS	Tennessee Geologic Survey
TOC	Total Organic Carbon
TVA	Tennessee Valley Authority
UIC	Underground Injection Control
UM GWI	University of Memphis Ground Water Institute
USDA	United States Department of Agriculture
USDW	Underground Source of Drinking Water
USGS	United States Geologic Survey
UT CEB	University of Tennessee Center for Environmental Biotechnology
WHPA	Well Head Protection Area
WPC	Water Pollution Control
WRTAC	Water Resource Technical Advisory Committee

APPENDIX B

References

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USGS Circular 1344 Use of Water in the United States in 2005

Layton, Alice, Fu-Min Menn and Melanie Eldridge, Survey of pharmaceuticals and personal care products in untreated drinking water, University of Tennessee Center For Environmental Biotechnology June 2011

Protection of Potable Water Supplies In Tennessee Watersheds 2014 Report, Tennessee Department of Environment and Conservation Division of Water Resources 2014

The South Cumberland Regional Water Resources Planning Study and the North Central Regional Water Resources Planning Study can be found at the Water Resources Regional Planning web site: http://www.tn.gov/environment/regionalplanning/