Minnesota Department of Agriculture

# Nitrate Trends in Private Well Networks

## Central Sands Private Well Network and the Southeast Volunteer Nitrate Monitoring Network

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# MINNESOTA PRIVATE WELL NETWORKS

The Minnesota Department of Agriculture (MDA) has been working closely with other state and local agencies on developing regional private well nitrate-nitrogen (nitrate) networks. Homeowner volunteers are the cornerstone of the private well networks. Homeowners collect their own water sample and send it by mail to be tested by a laboratory or a county collaborator using MDA equipment at no cost to the homeowner. This method has been developed from years of collaboration with other state and local agencies through pilot projects testing different methods of collection and sample delivery. The MDA currently coordinates two volunteer nitrate monitoring networks with assistance from other state agency and local partners. The two networks are discussed in greater detail below.

## SOUTHEAST VOLUNTEER NITRATE MONITORING NETWORK 2008-2015

Drinking water quality is a concern across southeastern Minnesota where nitrate loading to the subsurface can be significant and hydrogeologic sensitivity is highly variable within short distances. In 2008, the Southeast Minnesota Water Resources Board (SEMNWRB) and several state agency partners (MPCA, MDA, MDH) began collecting samples and data from the "Volunteer Nitrate Monitoring Network" (VNMN). This region was selected as a pilot because of its vulnerable and complex geology.

This pilot began as a network of 675 private drinking water wells representing a stratified-random distribution across the nine counties (Dodge, Fillmore, Goodhue, Houston, Mower, Olmsted, Rice, Wabasha and Winona) of southeastern Minnesota. The wells included in the network represent groundwater nitrate concentration data from several aquifers.

Before data collection began, well network coordinators (county staff) enrolled volunteers (well owners) into the program by collecting detailed information about well location, well construction, and nearby nitrate sources. Between February 2008 and August 2015, ten sampling events occurred representing approximately 4,300 samples. During this period, the percentage of wells exceeding the Health Risk Limit (HRL) for each sampling event ranged between eight and fifteen percent (Table 1). The most recent sampling results from 2015 are presented in Figure 1.

A study conducted by the Minnesota Department of Health (MDH, 2012) evaluated factors related to well construction and geology and the corresponding relationship with nitrate concentration in the Southeast VNMN. Well construction (the documented presence or absence of casing grout) and overlying geologic protection (shale or at least ten feet of clay above the open interval of the well) had the strongest positive association with observed nitrate concentrations. Low nitrate concentrations were measured in 97.7 percent of wells with the most-desirable well protection characteristics, based upon well construction and geology. It should be noted that the results are only applicable to the nine counties in the study area.

**Table 1.** Summary of the 2008 through 2015 long- term Southeast Volunteer Nitrate Monitoring Network results.

| Date | Total Wells | 50th Percentile (Median) Nitrate-N (mg/L) | 90th Percentile Nitrate-N (mg/L) | % ≥ 10 Nitrate-N (mg/L) | % < 10 Nitrate-N (mg/L) |
|---|---|---|---|---|---|
| 2/1/2008 | 519 | 0.3 | 12.0 | 15% | 85% |
| 8/1/2008 | 510 | 0.3 | 11.0 | 11% | 89% |
| 2/1/2009 | 494 | 0.2 | 11.0 | 11% | 89% |
| 8/1/2009 | 471 | 0.3 | 11.5 | 11% | 89% |
| 8/1/2010 | 422 | 0.7 | 9.5 | 9% | 91% |
| 8/1/2011 | 428 | 0.6 | 10.0 | 10% | 90% |
| 8/1/2012 | 411 | 0.4 | 8.8 | 8% | 92% |
| 8/1/2013 | 315 | 0.1 | 8.8 | 8% | 92% |
| 8/1/2014 | 361 | 0.2 | 9.4 | 9% | 91% |
| 8/1/2015 | 373 | 0.2 | 9.4 | 9% | 91% |

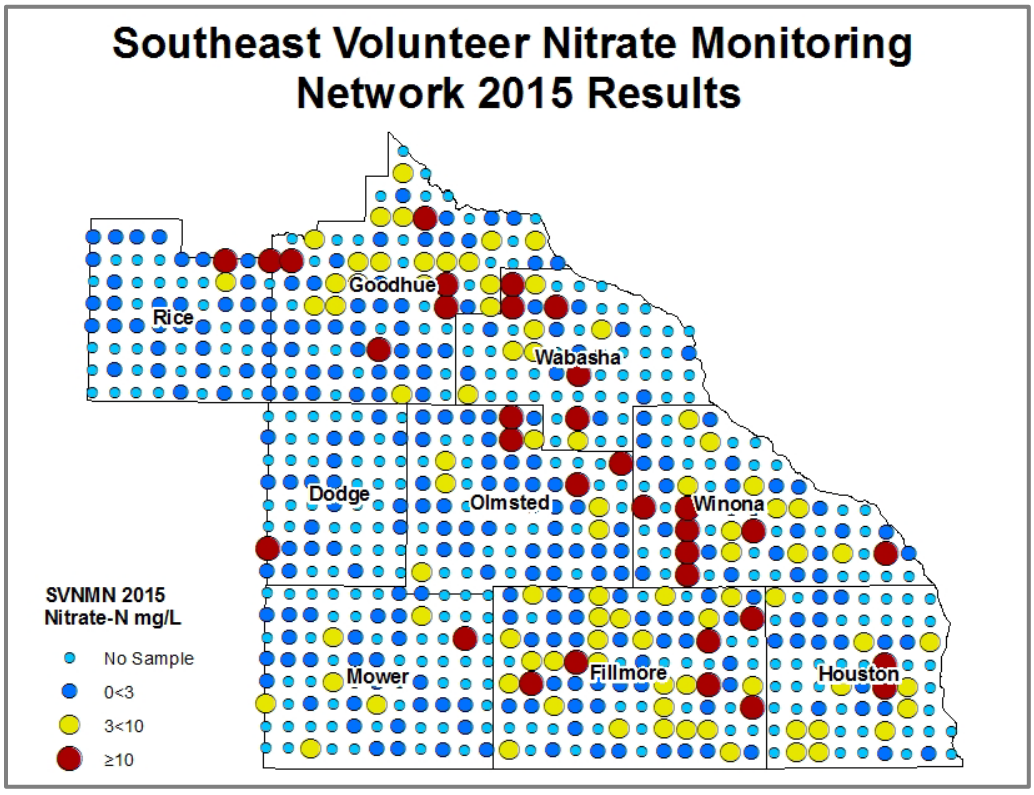


**Figure 1.** Southeast Volunteer Nitrate Monitoring Network 2015 results.

As Table 1 indicates, the number of homeowners (wells) participating in the project is variable with time, ranging from 519 in 2008 to 373 in 2015. To investigate the possible impact of this change, a comparison of well characteristics (depth and age) was performed for the Southeast VNMN, for wells that had known information. The results suggest that, with respect to well

characteristics, there did not appear to be large differences in the sampled population over time, as the median well depth and age did not change (see Table 2). However, to increase confidence in the findings from the monitoring network, further analysis of the changing well population in the network will be conducted in 2017.

**Table 2.** Summary of well characteristics between 2008 and 2015 in the Southeast VNMN.

| Date | Total Wells | Average Depth (feet) | Median Depth (feet) | % of wells with known depths | Average Age (Year) | Median Age (Year) | % of wells with known age |
|---|---|---|---|---|---|---|---|
| 2008 | 519 | 255.3 | 220 | 85% | 1966 | 1975 | 69% |
| 2015 | 373 | 253.8 | 220 | 88% | 1963 | 1975 | 73% |
| Difference | 146 | 1.5 | 0 | 3% | 3 | 0 | 4% |

## TREND ANALYSIS- SOUTHEAST VNMN

Groundwater nitrate concentration measurements are often not normally distributed data sets. Consequently, using parametric trend analysis is not appropriate. For this analysis, a nonparametric Mann-Kendal test for the time trend analysis (Helsel and Hirsh, 2002) was determined to be the most appropriate.

There were two sampling events early on in the network that occurred in February; otherwise, sampling occurred in August of each year. The February and August sampling events in 2008 and 2009 were evaluated to see if there were any differences between the events in these years. A boxplot was produced (Figure 2) and nonparametric Kruskal-Wallis comparison testing was performed (Table 3) to assist with this evaluation. It was found that there were no significant differences between the events in 2008 and 2009, so only the August event data from each year was utilized. This also permitted traditional trend testing, where time steps between the data being analyzed were consistent.

**Table 3.** Comparison test results for the Southeast VNMN data during the February and August sampling events in 2008 and 2009.

| Sample Events Tested | Kruskal-Wallis Test p-Value | Result |
|---|---|---|
| February 2008 & August 2008 | 0.875 | No Difference |
| February 2009 & August 2009 | 0.658 | No Difference |

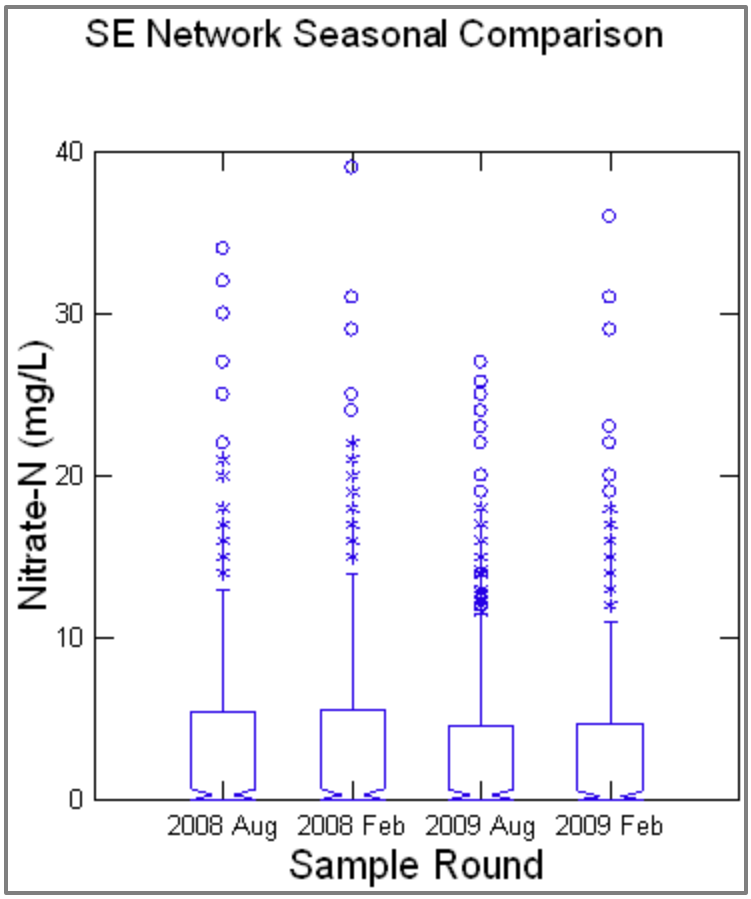


**Figure 2.** Boxplot of nitrate concentrations from the Southeast VNMN during the February and August sampling events in 2008 and 2009.

It was found that there was no statistically significant trend (H0: No Trend vs. H1: Two-Sided Trend) for any of the percentile data (Table 4). Figure 3 shows the percentiles for the nitrate concentration data over time plotted with binomial fit lines, which are used in nonparametric methods to illustrate the central tendency of data over time (Helsel and Hirsch, 2002).

**Table 4.** Trend analysis for the Southeast VNMN data.

| Percentile | Mann-Kendal Test p-Value | Trend ($95^{th}$ confidence level) |
|---|---|---|
| 50th | 0.248 | No Trend |
| 75th | 0.215 | No Trend |
| 90th | 0.097 | No Trend |

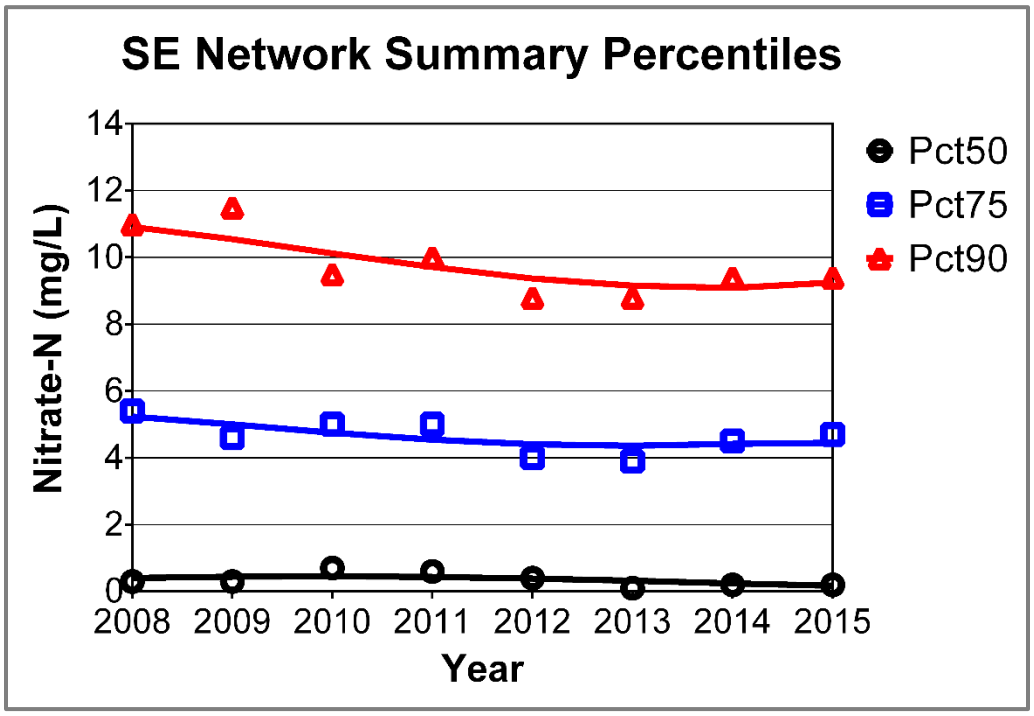


**Figure 3.** Binomial lines fit to nitrate percentile concentrations from the Southeast VNMN.

## CENTRAL SANDS PRIVATE WELL MONITORING NETWORK 2011-2015

Due to the success of the Southeast VNMN, as well as the availability of newly acquired funding from the Clean Water Legacy Amendment, the MDA launched a similar project in the Central Sands area of Minnesota, which includes 14 counties. The MDA determined that, because high levels of nitrate had been measured in MDA's Central Sands monitoring wells, it was important to expand nitrate monitoring to private drinking water wells to determine if the concentrations were similar to concentrations found in MDA's monitoring wells. In the spring of 2011, the MDA began the Central Sands Private Well Monitoring Network (CSPWN). The goals of this project were to look at current nitrate concentrations in private wells across the Central Sands region and assess nitrate concentration trends over time using a representative subset of this data.

The CSPWN was designed as an unaligned grid across the 14 county area. Homeowners from within the grids in agricultural areas were randomly invited to participate in the network. By July 1, 2011, the MDA had analyzed 1,555 samples for nitrate (MDA 2012). Over 88 percent of the wells sampled had concentrations below 3 mg/L nitrate-N, 6.8 percent of the wells ranged from 3-10 mg/L of nitrate-N and 4.6 percent were greater than the nitrate-N HRL (Table 5). These results were similar to findings from a 2010 U. S. Geological Survey (USGS) report on nitrate concentrations in private wells in the glacial aquifer systems across the upper United States

(Warner and Arnold 2010). The USGS report found that less than 5 percent of sampled private wells had concentrations greater than or equal to 10 mg/L nitrate-N. The 2011 CSPWN results indicated nitrate concentrations varied widely over relatively short distances. The USGS report on glacial aquifer systems indicated similar findings related to spatial variability in nitrate concentration.

**Table 5.** Summary of Central Sands Private Well Network 2011 data.

| Number of Samples | Minimum (mg/L) | Median (mg/L) | 75th Percentile (mg/L) | 90th Percentile (mg/L) | Maximum (mg/L) | % ≤ 3 (mg/L) | % 3<10 (mg/L) | % ≥10 (mg/L) |
|---|---|---|---|---|---|---|---|---|
| 1,555 | <0.03 | 0.01 | 0.66 | 4.15 | 31.9 | 88.6% | 6.8% | 4.6% |

Over 500 homeowners volunteered to participate in long-term annual sampling of their private wells. Participation in sampling decreased over time, similar to the Southeast VNMN; however, results from 2011 through 2015 have indicated minimal variation in nitrate concentration with time. Thus, it was determined not to perform an analysis of well characteristics as was completed for the Southeast VNMN. The 2015 results indicate 4 percent of the wells had nitrate concentrations greater than or equal to10 mg/L nitrate-N (Table 6). Overall, 96-97 percent of wells in the CSPWN have been below the 10 mg/L HRL for nitrate-N. The most recent sampling results from 2015 are shown in Figure 4. For further information on this sampling project, see http://www.mda.state.mn.us/en/protecting/cleanwaterfund/gwdwprotection/characterizingnitrates.aspx

**Table 6.** Summary of 2011 through 2015 long-term Central Sands Private Well Network.

| Year | Total Wells | 50th Percentile (Median) Nitrate-N (mg/L) | 90th Percentile Nitrate-N (mg/L) | % ≥ 10 Nitrate-N (mg/L) | % < 10 Nitrate-N (mg/L) |
|---|---|---|---|---|---|
| 2011 | 534 | <0.03 | 3.3 | 4% | 96% |
| 2012 | 506 | 0.2 | 3.6 | 3% | 97% |
| 2013 | 487 | 0.2 | 3.6 | 3% | 97% |
| 2014 | 432 | <0.03 | 3.2 | 3% | 97% |
| 2015 | 402 | <0.03 | 3.5 | 4% | 96% |

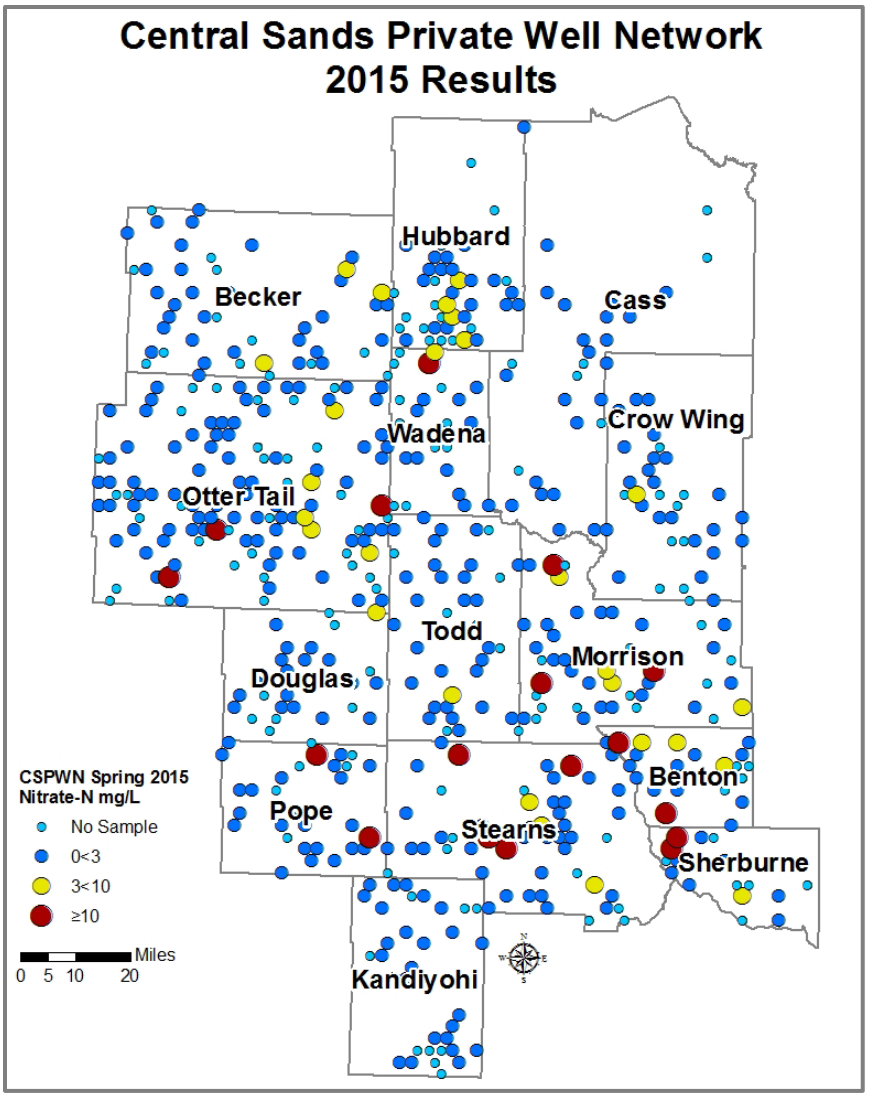


**Figure 4.** Central Sands Private Well Network 2015 Results.

## TREND ANALYSIS-CSPWN

The non-parametric time series analysis for the CSPWN indicates that there is not enough information to reject the null hypothesis (H0: No Trend vs. H1: Two-Sided Trend) that there is no statistically significant trend in any of the nitrate percentiles (50$^{th}$, 75$^{th}$, and 90$^{th}$) (Table 7). Figure 5 presents the percentiles for the nitrate concentrations plotted overtime with binomial fit lines, which indicate the central tendency of the data (Helsel and Hirsch, 2002).

**Table 7.** Trend analysis for the Central Sands Private Well Network.

| Percentile | Mann-Kendal Test p-Value | Trend (95th confidence level) |
|---|---|---|
| 50th | 0.717 | No Trend |
| 75th | 0.950 | No Trend |
| 90th | 0.717 | No Trend |

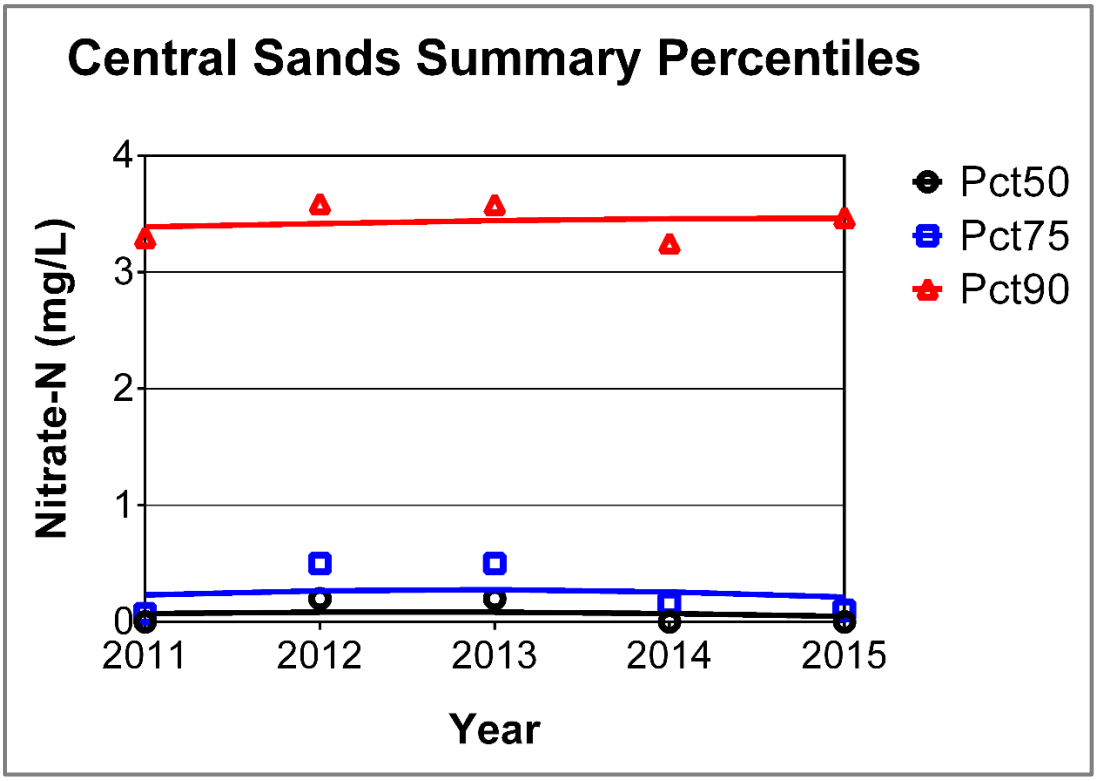


**Figure 5.** Central Sands Private Well Network binomial fit lines.

## SUMMARY

Although there can be variability in some individual wells from year to year, the regional data presented in this report is useful for evaluating long term trends. Analysis of the data from these private well monitoring networks indicates a concern for nitrate in groundwater from vulnerable aquifers in central and southeast Minnesota.

Data from the Southeast Volunteer Nitrate Monitoring Network was analyzed for trend. To ensure all years were treated equally, the February sampling period data from 2008 and 2009

were removed prior to the trend analysis. The data from the August event sampling from each year showed that there was no statistically significant trend for the 50th percentile (median), 75th or 90th percentile data in the Southeast Volunteer Nitrate Monitoring Network. Likewise, data from the Central Sands Private Well Network showed no statistically significant trend in any of the percentile data over the five years of monitoring in that network.

Over time network participation did decline in both networks, so additional analysis of which wells leave the network will be completed in 2017. However, based on an analysis of wells with known characteristics (well depth and age) in the Southeast Volunteer Nitrate Monitoring Network, from the first to the last sampling periods, it would appear that there are not large differences in the population of wells being sampled with respect to depth and age. Reasons volunteers leave the networks may include selling a home, not seeing a change in nitrate results, replacing an old well with a new well, and homeowners are too busy. Future work will include emphasis on keeping volunteers engaged and participating in the network on an annual basis.

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