Trends at Individual Wells

As indicated in Table 2-1, there are more increasing trends than decreasing trends within the network. Of the 31 wells that have been sampled since 1991, 16 (52%) exhibit increasing trends, 10 (32%) exhibit decreasing trends, 1 (3%) exhibit a flat trend, and 4 (13%) exhibit statistically insignificant trends. The average slope of all trends is increasing.

Table 2-1
Individual Well Nitrate Trends - LUB GWMA Well Network
Second LUBGWMA Action Plan

Sample Location	Data Set Statistics								Trend Analysis Results		Trend Direction
	Starting Date	Ending Date	Minimum	Maximum	Mean	Median	n	% BDL	Slope (ppm/yr)	Confidence Level	
UMA033	Sep-91	May-16	2.38	13.8	7.29	6.98	105	0%	0.002	30%	NS80
UMA034	Sep-91	May-16	0.186	7.37	3.82	3.5	97	0%	0.04	96%	Increasing
UMA038	Sep-91	May-16	1.09	9.68	2.93	2.7	92	0%	-0.06	99%	Decreasing
UMA046	Sep-91	May-16	0.19	4.9	0.85	0.6	98	0%	-0.02	99%	Decreasing
UMA048	Sep-91	May-16	1.30	3.82	2.08	1.9	97	0%	0.04	99%	Increasing
UMA056	Sep-91	May-16	0.58	7.32	6.13	6.2	99	0%	-0.05	99%	Decreasing
UMA084	Sep-91	May-16	3.61	22	10.2	10.45	90	0%	-0.16	99%	Decreasing
UMA094	Sep-91	May-16	4.62	13	8.54	8.2	97	0%	-0.08	99%	Decreasing
UMA096	Sep-91	May-16	12.8	42.8	31.7	32.8	101	0%	0.47	99%	Increasing
UMA103	Sep-91	May-16	9.1	30.5	21.2	21.7	91	0%	0.15	99%	Increasing
UMA109	Sep-91	May-16	1.3	7.22	4.21	4	93	0%	0.15	99%	Increasing
UMA110	Sep-91	May-16	1.89	21	8.31	6.850	98	0%	0.31	99%	Increasing
UMA112	Sep-91	May-16	0.97	5.5	2.66	2.60	100	0%	-0.14	99%	Decreasing
UMA116	Sep-91	May-16	2.3	5.15	3.95	3.98	97	0%	0.04	99%	Increasing
UMA119	Sep-91	May-16	3.5	22.4	13.0	13.3	102	0%	0.08	93%	Increasing
UMA133	Sep-91	May-16	1.8	35	16.6	15.7	101	0%	-0.56	99%	Decreasing
UMA144	Sep-91	May-16	1.46	42.3	13.9	13.3	97	0%	-0.12	96%	Decreasing
UMA156	Sep-91	May-16	2.86	32	18.6	18.6	96	0%	-0.10	69%	NS80
UMA160	Sep-91	May-16	<0.005	27.5	4.29	1.01	94	15%	0.14	99%	Increasing
UMA168	Sep-91	May-16	0.68	5.8	2.87	2.90	97	0%	-0.13	99%	Decreasing
UMA180	Sep-91	May-16	<0.02	29.2	7.44	5.41	80	1%	0.78	99%	Increasing
UMA185	Sep-91	May-16	0.006	0.164	0.14	0.14	88	0%	0.001	99%	Increasing
UMA187	Sep-91	May-16	<0.005	0.134	0.0056	<0.005	91	89%	0	nc	Flat
UMA190	Sep-91	May-16	<0.005	11	2.56	2.15	92	2%	0.038	91%	Increasing
UMA191	Sep-91	May-16	0.16	6.11	0.98	0.86	97	0%	-0.005	70%	NS80
UMA198	Sep-91	May-16	5.80	58.1	21.8	19.4	91	0%	0.85	99%	Increasing
UMA201	Sep-91	May-16	3.36	36.9	21.1	21.9	96	0%	0.81	99%	Increasing
UMA312	Mar-12	May-16	5.55	9.26	7.5	7.24	17	0%	0.74	99%	Increasing
UMA313	Mar-12	May-16	0.18	0.426	0.3	0.322	17	0%	-0.03	99%	Decreasing
UMA029	Sep-91	May-16	25.0	61.3	41.7	44	93	0%	-0.58	99%	Decreasing
UMA047	Sep-91	May-16	2.5	4.18	3.35	3.40	94	0%	0.06	99%	Increasing
UMA106	Sep-91	May-16	0.42	2.02	0.96	0.851	98	0%	0.003	70%	NS80
UMA164	Sep-91	May-16	<0.02	6.12	4.11	4.44	92	1%	0.12	99%	Increasing

Notes:

nc = not calculated

n = number of samples

BDL = below detection limit

NS80 = not significant at an 80% confidence level

[ ] = well only sampled since March 2012

E:\LUB\2017 Trend Analysis\[All Trends - bimonthly wells.xlsx]Individual Well Trends

	31 Long Term Wells	All 33 Wells
# of Increasing Trends ==>	16	17
# of Decreasing Trends ==>	10	11
# of Flat Trends ==>	1	1
# of Insignificant Trends ==>	4	4
Avg slope of significant trends at the wells ==>	0.08	0.10
Avg slope of all trends at the wells ==>	0.07	0.07

The trends summarized in Table 2-1 are grouped by magnitude in Table 2-2. Small trends are defined as up to 0.1 milligrams per liter per year (or parts per million per year (ppm/yr)). Medium trends are defined as between 0.1 and 0.5 ppm/yr. Large trends are defined as greater than 0.5 ppm/yr. As indicated in Table 2-2, there are more small, medium, and large increasing trends than small, medium, and large decreasing trends. When comparing trend *magnitudes*, the average slope of small decreasing trends is steeper than the average slope of small increasing trends, but the average slope of medium and large increasing trends is steeper than medium and large decreasing trends. In summary, comparing nitrate trends by magnitude indicates nitrate concentrations are going up more than they are going down.

Table 2-2
Summary of Individual LUBGWMA Well Trends by Magnitude
Second LUBGWMA Action Plan

Sept 1991 through May 2016
31 Long Term Wells

Trend Magnitude	# of Wells with Increasing Trends	Average slope of Increasing Trends (ppm/yr)	# of Wells with Decreasing Trends	Average slope of Decreasing Trends (ppm/yr)	# of wells with Flat Trend	Slope of Flat Trend (ppm/yr)	# of Wells with Statistically Insignificant Trends	Average slope of Statistically Insignificant Trends (ppm/yr)
Small (up to 0.1 ppm/yr)	**7**	0.04	4	**-0.05**			4	-0.02
Medium (0.1 to 0.5 ppm/yr)	**6**	**0.22**	4	-0.14			0	
Large (greater than 0.5 ppm/yr)	**3**	**0.82**	2	-0.57			0	
TOTAL	**16 (52%)**		10 (32%)		1 (3%)	0.00	4 (13%)	
OVERALL AVERAGE		**0.26**		-0.19				

Sept 1991 through May 2016
All 33 Wells

Trend Magnitude	# of Wells with Increasing Trends	Average slope of Increasing Trends (ppm/yr)	# of Wells with Decreasing Trends	Average slope of Decreasing Trends (ppm/yr)	# of wells with Flat Trend	Slope of Flat Trend (ppm/yr)	# of Wells with Statistically Insignificant Trends	Average slope of Statistically Insignificant Trends (ppm/yr)
Small (up to 0.1 ppm/yr)	**7**	0.04	5	**-0.05**			4	-0.02
Medium (0.1 to 0.5 ppm/yr)	**6**	**0.22**	4	-0.14			0	
Large (greater than 0.5 ppm/yr)	**4**	**0.80**	2	-0.57			0	
TOTAL	**17 (52%)**		11 (33%)		1 (3%)	0.00	4 (12%)	
OVERALL AVERAGE		**0.28**		-0.17				

bold = Larger number of wells or steeper trend

33 Well Summary:

When viewed in total, there are more increasing trends than decreasing trends (52% vs 33%).

When viewed in total, average increasing trends are steeper than average decreasing trends (Increasing at 0.28 ppm/yr vs Decreasing at 0.17 ppm/yr).

When viewed by magnitude, there are more increasing trends than decreasing trends in each category (7 vs 5 small, 6 vs 4 medium, and 4 vs 2 large).

When viewed by magnitude, average small decreasing trends are steeper than small increasing trends (0.05 ppm/yr vs 0.04 ppm/yr)

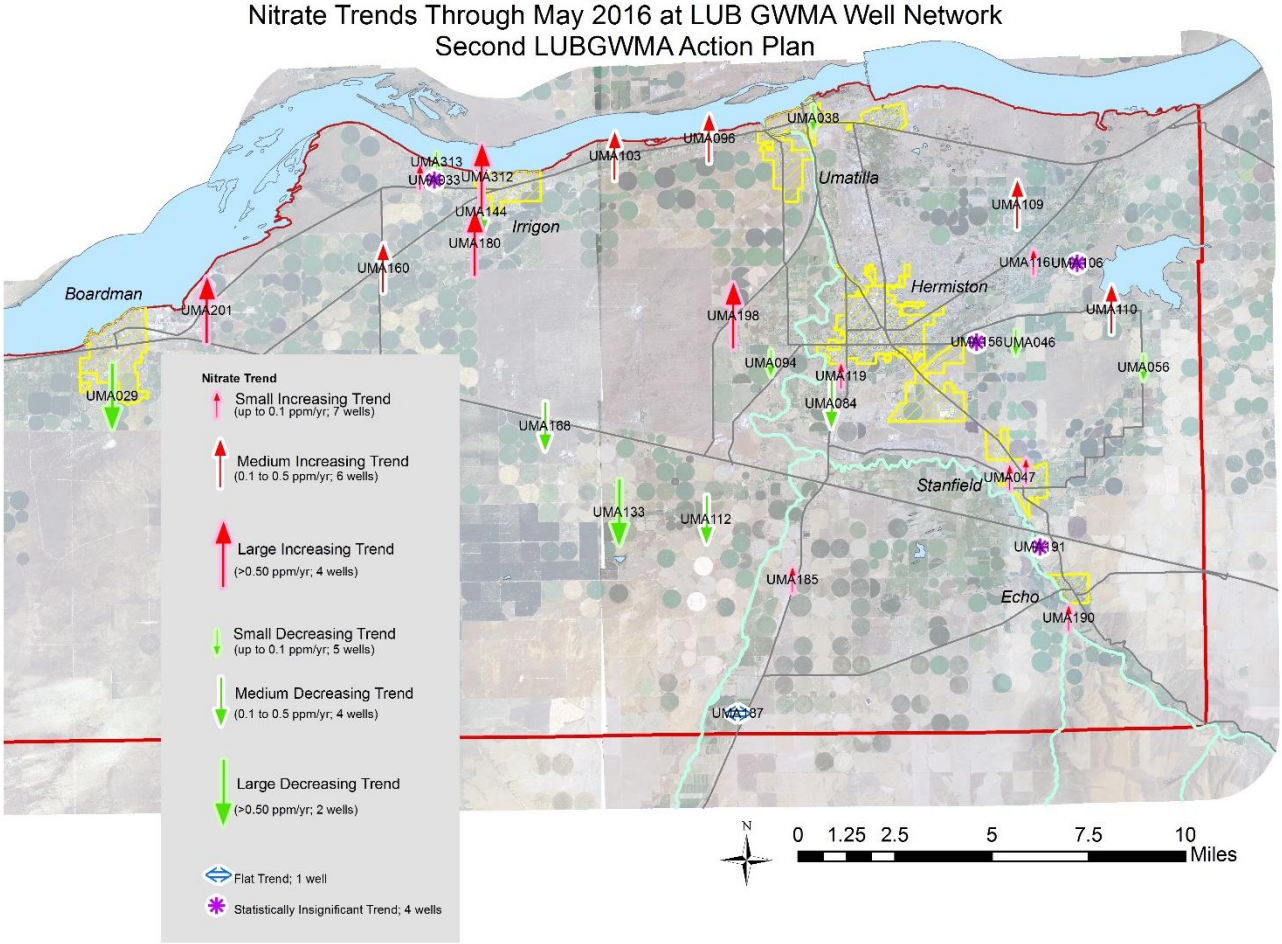
When viewed by magnitude, average medium increasing trends are steeper than medium decreasing trends (0.28 ppm vs 0.17 ppm/yr)

When viewed by magnitude, average large increasing trends are steeper than large decreasing trends (0.80 ppm vs 0.17 ppm/yr)

Figure 2-6 shows the location of the wells and the general magnitude of the nitrate trend (i.e., small, medium, or large) at that well from September 1991 through May 2016. Upward pointing red arrows represent increasing trends while downward pointing green arrows represent decreasing trends. Purple asterisks represent statistically insignificant trends. A blue double-sided horizontal arrow represents the flat trend.

As indicated in Figure 2-6, there does not appear to be a consistent geographic pattern to nitrate trends (i.e., both increasing trends and decreasing trends occur throughout the region). In addition to the lack of a regional geographic pattern, wells showing increasing trends can be relatively close to wells showing decreasing trends. These results reflect some of the complexities affecting the interpretation of groundwater nitrate results discussed later in Section 2.5.2.

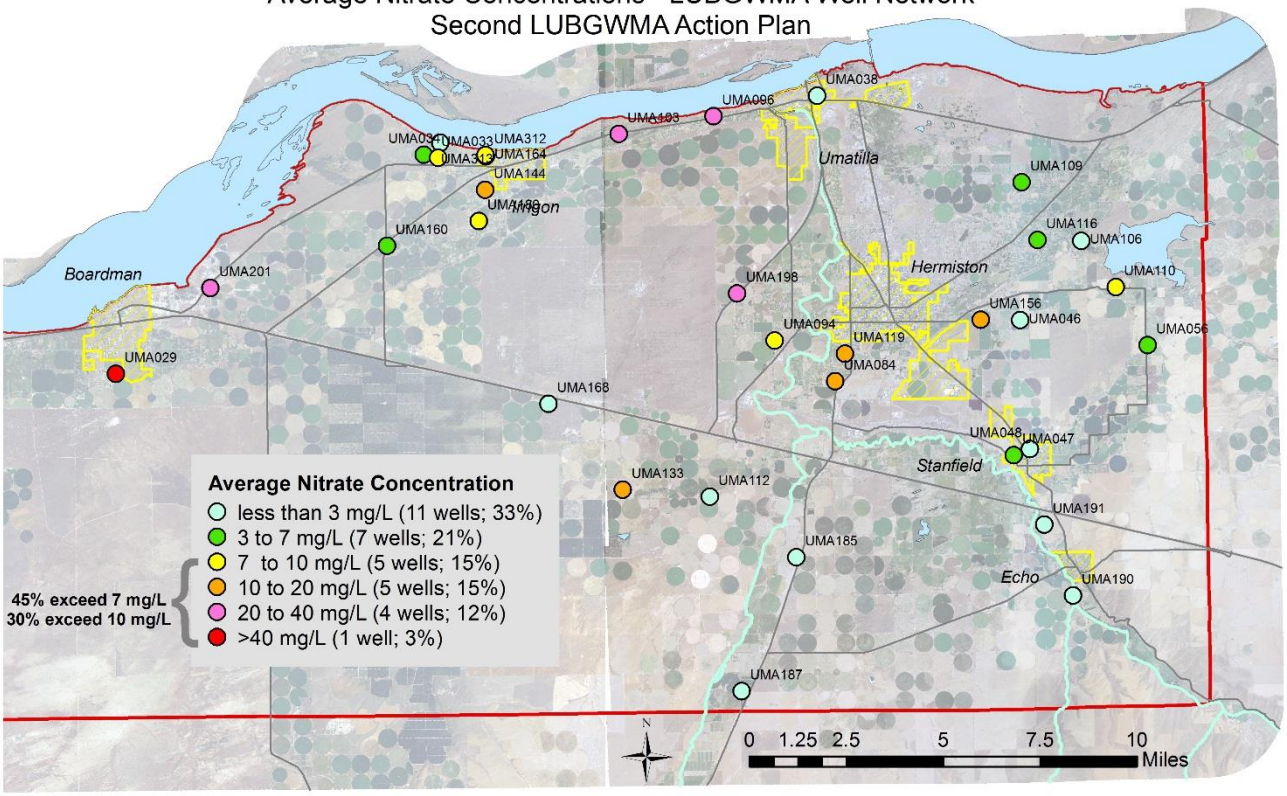
Figure 2-6
Nitrate Trends Through May 2016 at LUB GWMA Well Network
Second LUBGWMA Action Plan



Average Nitrate Concentrations

Figure 2-7 shows the location of the wells and the average nitrate concentration at that well from September 1991 through May 2016 as color-coded dots. Wells with low nitrate concentrations are represented by "cool" colors while wells with higher nitrate concentrations are represented by "warm" colors. As shown in Figure 2-7, wells with lower nitrate concentrations are generally in the southeast portion of the GWMA while wells with higher nitrate concentrations are generally in the north-northwest portion of the GWMA. This pattern is consistent with the generally higher nitrate leaching potential in the western portion of the GWMA as compared to the eastern portion (Section 2.1.7 and Figure 2-3). The long-term average nitrate concentration exceeds the 7 mg/L GWMA trigger level at 45% of the wells. The long-term average nitrate concentration exceeds the 10 mg/L drinking water standard at 30% of the wells.

Figure 2-7
Average Nitrate Concentrations - LUBGWMA Well Network
Second LUBGWMA Action Plan

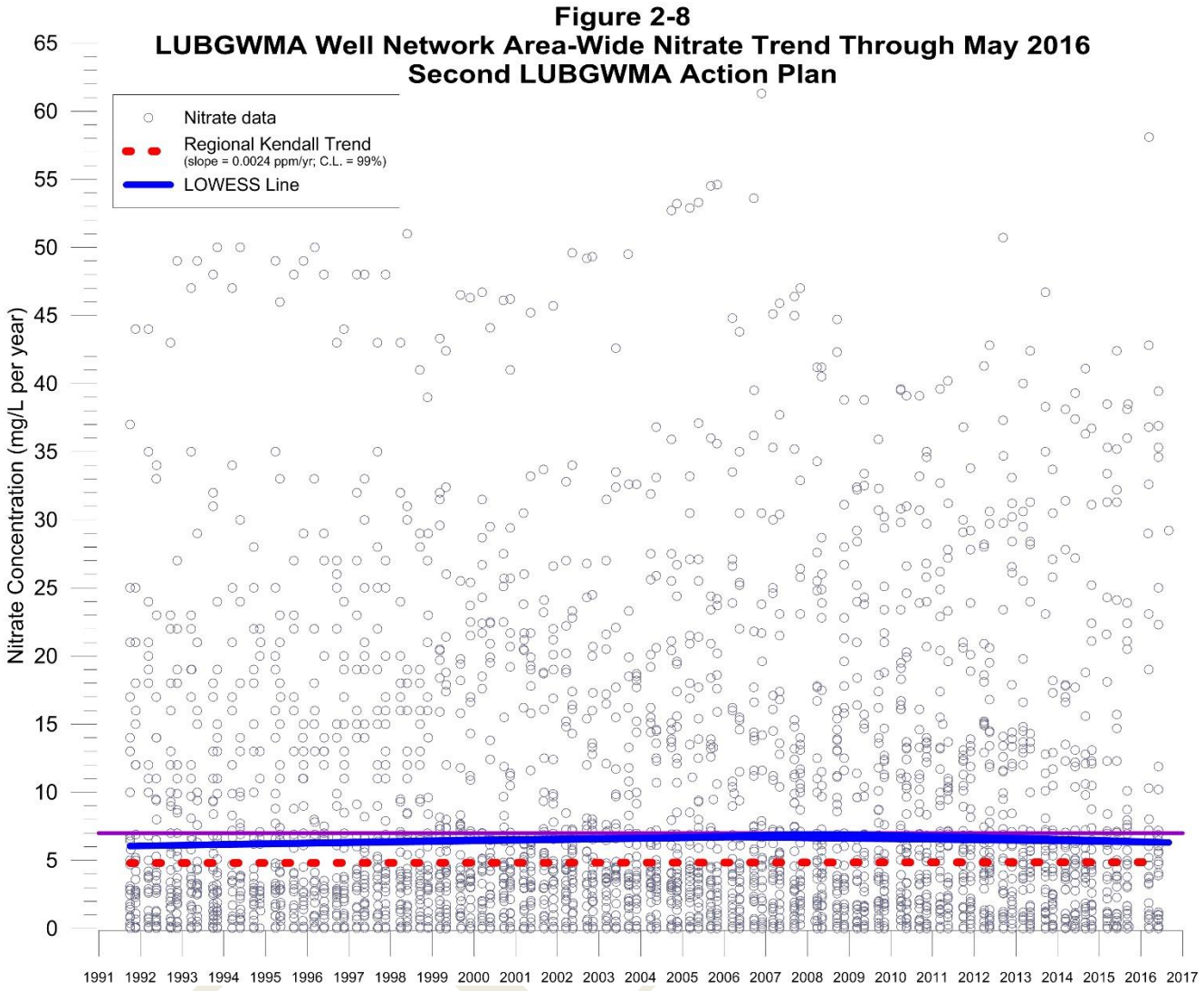


The mix of trends (dominated by increasing trends) discussed above is reflected in changes in average nitrate concentrations. For example, the most recent annual average nitrate concentration (i.e., May 2015 through May 2016; not shown in Table 2-1) is lower than the long-term average in more wells than it is higher. However, the increases in average nitrate concentrations are larger in magnitude than the decreases in average nitrate concentrations. This is reflected in the most recent annual average nitrate concentration (10.51 mg/L) being larger than the long-term average nitrate concentration (9.26 mg/L).

Area-Wide Nitrate Trend

Figure 2-8 shows all nitrate results from the LUBGWMA well network collected in September, November, March, and May as open circles. In addition to the individual data points, the figure also shows the area-wide Regional Kendall trend as a dashed red line and the LOWESS line (which is a data smoothing technique similar to a moving average) as a thick solid blue line. For reference, a thin purple line indicates the 10 mg/L drinking water standard. The figure shows the area-wide trend increases very slightly (0.0024 mg/L per year) over the timeframe of September 1991 through May 2016. The LOWESS line increased until about 2009 then began decreasing.

In order to see the change in trend over time, one year of data was removed from the dataset at a time and the area-wide trend recalculated. Results show the area-wide trend has been increasing since enough data was collected to calculate a trend. The slope of the trend line consistently decreased in magnitude (while remaining positive) from about 0.04 mg/L per year (in 1998) to about 0.005 mg/L per year in 2004. Since 2004, the trend line continues some reduction in slope while also fluctuating, but remains slightly increasing through May 2016 (0.0024 mg/L per year).



Seasonal Trends

As part of the area-wide trend calculation, the Regional Kendall test calculates individual "seasonal trends" that describe changes in nitrate concentrations at a particular well during a particular time of year (e.g., changes in nitrate concentrations at well #1 during March of every year). When those seasonal trends are examined in total, there are more increasing trends than decreasing trends. In addition, increasing trends are steeper than decreasing trends. When compared by month, there are more increasing trends than decreasing trends in all four months sampled. In addition, increasing trends are steeper than decreasing trends in all four months. Overall, seasonal nitrate trends indicate nitrate concentrations are increasing more than they are decreasing.

DEQ's experience in the Northern Malheur County GWMA shows that before the area-wide trend decreases, decreasing individual seasonal trends will start to dominate in number and magnitude. This is not yet happening in the Lower Umatilla Basin GWMA.

Indications of Improving and Worsening Water Quality

Table 2-3 summarizes indications of improving and worsening water quality using the LUBGWMA well network data set. The table includes inferences from both the area-wide trend and from the 31 individual wells used to calculate the area-wide trend.

As shown in Table 2-3, there are both indications of improving water quality and worsening water quality. However, there are more indications of worsening water quality including the most important indicator, which is nitrate trends. For example, the area-wide trend continues to increase. Similarly, there are more small, medium, and large increasing trends than small, medium, and large decreasing trends. Medium and large increasing trends are also greater in magnitude than medium and large decreasing trends.

Based on data collected from the LUBGWMA well network, it is conclusive that nitrate concentrations are increasing more than they are decreasing, and that the goal of reducing nitrate concentrations below 7 mg/L has not been met.

Table 2-3
Indications of Improving and Worsening Water Quality – LUBGWMA Well Network
Second LUBGWMA Local Action Plan

Data Set	Variable	Indications of Improving Water Quality	Indications of Worsening Water Quality
Area-Wide Trend calculated using 31 Long Term Wells *(Sept 1991 through May 2016)*	Overall area-wide nitrate trend	When comparing trends through 2009 to trends through May 2016, Increasing trend is increasing less steeply *(from 0.003 to 0.002 ppm/yr)*	Area-wide trend continues to increase
	Area-wide trends by month (or season)		Overall, there are more increasing trends than decreasing trends; and increasing trends are steeper than decreasing trends. By month, there are more increasing trends than decreasing trends in all four months; and increasing trends are steeper than decreasing trends in all four months
	LOWESS line through all data	Values rise from 1991 through 2008, then decrease through May 2016	Most recent values are higher than initial values
31 Individual Wells *(Sept 1991 through May 2016)*	Number of small, medium, and large trends *Small= up to 0.1 ppm/yr* *Med = 0.1 to 0.5 ppm/yr* *Large = > 0.5 ppm/yr*		All sizes of increasing trends are more frequent than all sizes of decreasing trends *(7 vs 4) Small* *(6 vs 4) Med* *(3 vs 2) Large* *16 increasing vs 10 decreasing*
	Magnitude of small, medium, and large trends	Small decreasing trends are steeper than small increasing trends *(-0.05 vs 0.04 ppm/yr)*	Medium and large increasing trends are steeper than medium and large decreasing trends *(0.22 vs -0.14 ppm/yr) Med* *(0.82 vs -0.57 ppm/yr) Large*
	Average slope of all trends		*Average slope is increasing at 0.07 ppm/yr*
	New minimum concentrations *	23% of wells (7 wells) exhibited new minimum concentrations	
	New maximum concentrations *		32% of wells (10 wells) exhibited new maximum concentrations
	Mean concentrations *	36% of wells (11 wells) exhibited lower mean concentrations	45% of wells (14 wells) exhibited higher mean concentrations
	Median concentrations *	29% of wells (9 wells) exhibited lower median concentrations	55% of wells (17 wells) exhibited higher median concentrations

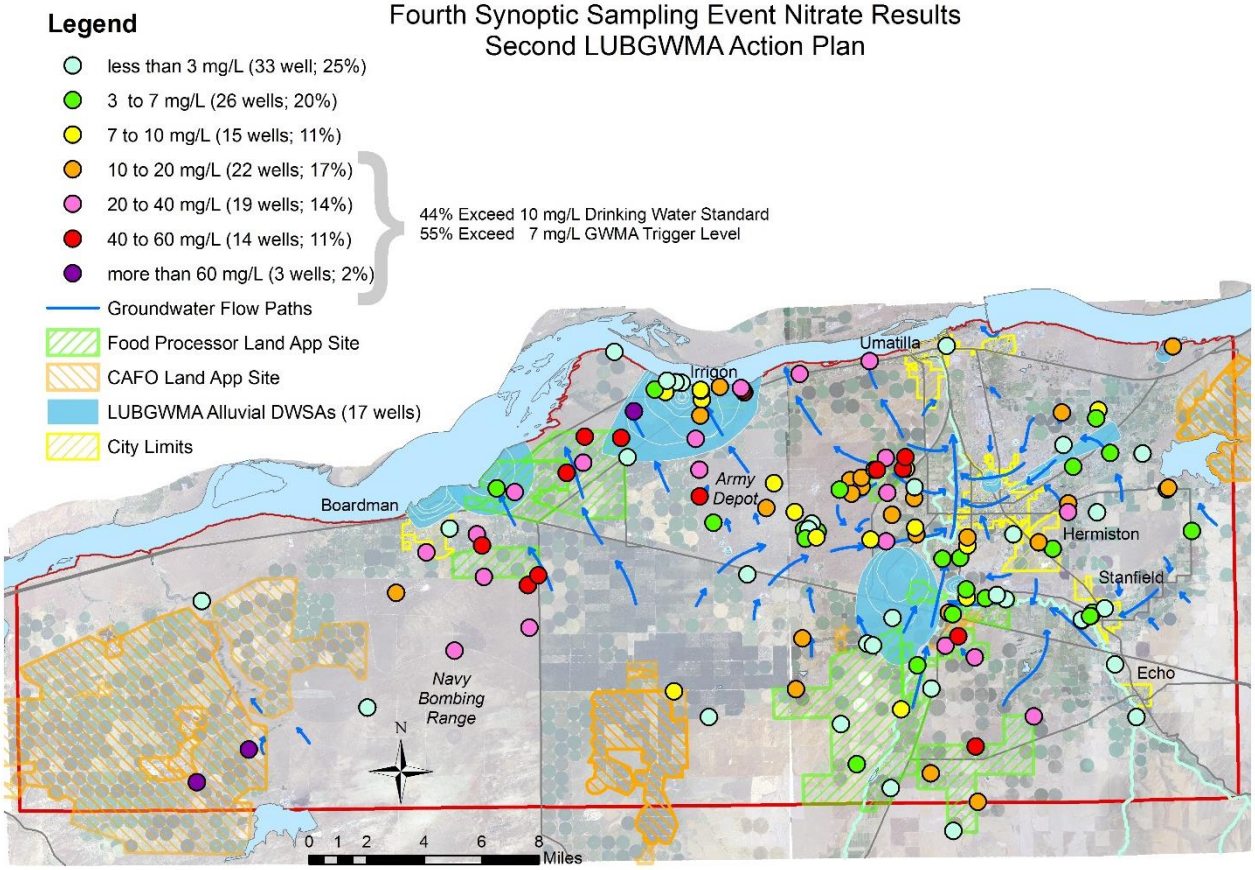
* = These are not perfect comparisons because sampling frequency at these wells was changed from six times per year to four times per year in 2011. Sampling events occurring in January and July were dropped, and data from those months were not used in subsequent trend analysis calculations or data set summaries. This caused 7 previous minimums and 4 previous maximums to be culled from the data set.

2.4.5 Synoptic Sampling Event Results

As described in Section 2.4.1.3, the first synoptic sampling event was conducted in 1992, and involved approximately 250 samples including 205 wells. Subsequent synoptic sampling events have been conducted in 2003, 2009, and 2015 and involved 107 to 132 wells. These snapshots of groundwater quality allow both a comparison of snapshots over time, as well as a comparison of sampling events that contained a large amount of wells sampled infrequently to events that contained a small amount of wells sampled frequently.

Figure 2-9 illustrates the nitrate results from the fourth synoptic sampling event. The figure shows nitrate results from 132 wells sampled between November 2015 and April 2016, including the LUBGWMA network wells. Most wells were sampled in November and December 2015. Most irrigation wells were not available for sampling until spring of 2016. In addition to the nitrate results, Figure 2-9 also shows the locations of the sites that land apply food processing wastewater, sites that land apply CAFO waste, the locations of the Drinking Water Source Areas for the 17 alluvial aquifer public supply wells, and general groundwater flow paths.

Figure 2-9
Fourth Synoptic Sampling Event Nitrate Results
Second LUBGWMA Action Plan

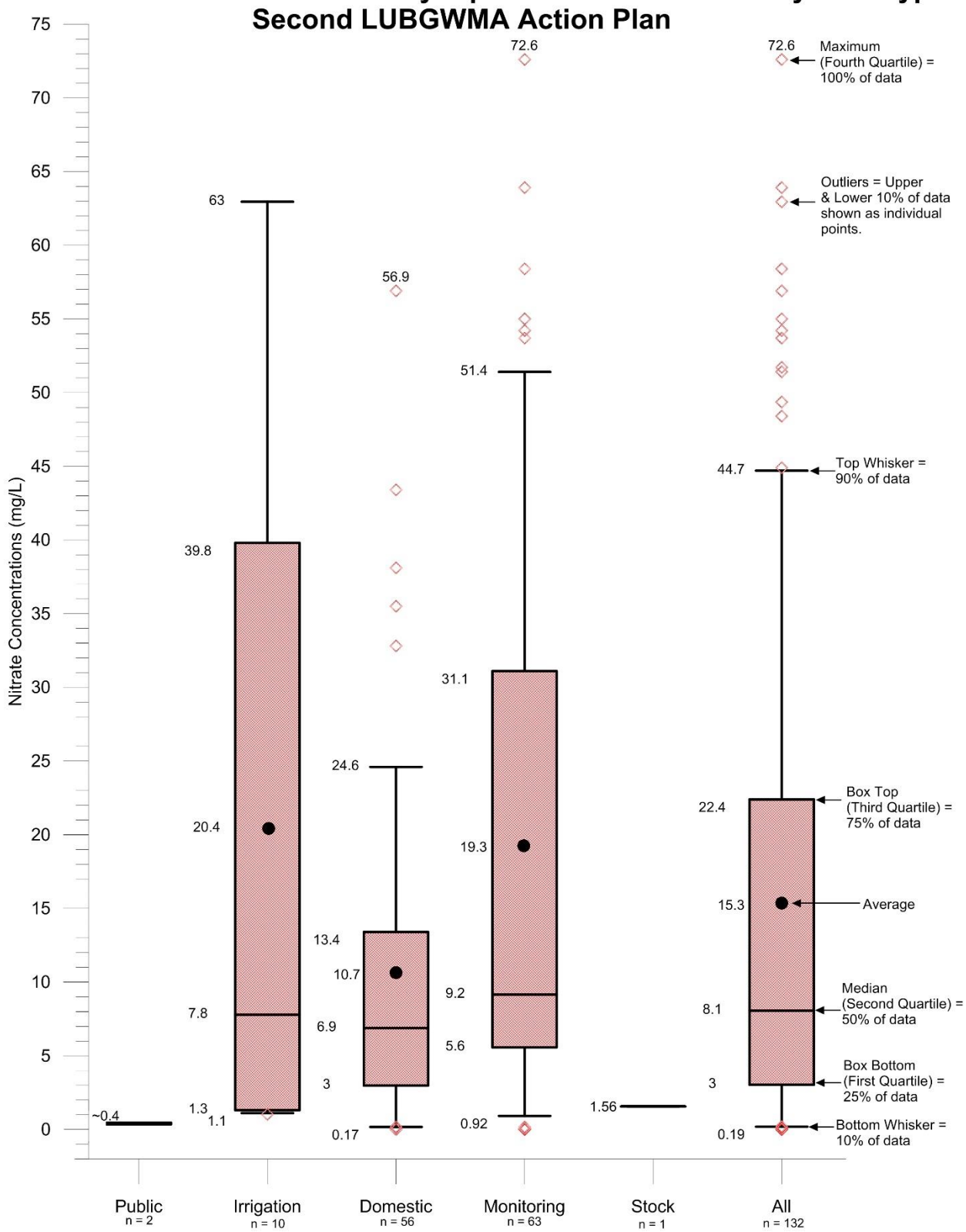


132 wells sampled between November 2015 and April 2016.

Nitrate results ranged from non-detectable (i.e., < 0.005 mg/L) to 72.6 mg/L with a median of 8.06 mg/L and an average of 15.3 mg/L. The nitrate concentration exceeded the 7 mg/L GWMA trigger level in 55% of the samples. The nitrate concentration exceeded the 10 mg/L drinking water standard in 44% of the wells. These percentages are higher than those of just the LUBGWMA well network sampled at the time (i.e., 42% > 7 mg/L; 32% > 10 mg/L). As discussed in Section 2.4.1.2, the LUBGWMA well network is predominantly private domestic wells. This synoptic sampling event added both monitoring wells and domestic wells, but more monitoring wells than domestic wells.

Figure 2-10 uses box plots to illustrate the fourth synoptic event nitrate concentrations by well type.

Figure 2-10
Box Plots of Fourth LUBGWMA Synoptic Event Nitrate Data by Well Type
Second LUBGWMA Action Plan



The figure shows a box plot for all 132 wells in addition to a box plot for each of the five well types (i.e., public supply, irrigation, domestic, monitoring, and stock watering). Ninety percent of the wells tested were either domestic (56 wells) or monitoring (63 wells). The category of monitoring wells include 33 wells at food processing wastewater land application sites, 18 wells at the Umatilla Army Chemical Depot (UMCD), five wells at the Boardman Bombing Range, four wells at CAFO waste land application sites, and three wells near an old sewage lagoon. Other types of wells sampled include two public supply wells, ten irrigation wells, and one stock watering well. Figure 2-10 visually illustrates the lower nitrate concentrations observed in domestic wells compared to monitoring wells. The small number of other types of wells sampled (e.g., public, irrigation, and stock) limits the usefulness of comparing results by those well types.

While Figure 2-10 visually illustrates the lower nitrate concentrations at domestic wells compared to monitoring wells, both the Mann-Whitney Test and the Wilcoxon Signed Rank Test indicates there is a statistically significant difference between nitrate concentrations at the monitoring wells and at the domestic wells. The higher nitrate concentrations at monitoring wells compared to domestic wells is likely because monitoring wells are generally installed at locations where groundwater contamination is known, suspected, or believed to be a significant potential. Another factor is that monitoring well screens are generally installed at the water table while domestic well screens are generally installed tens of feet below the water table. Wells screened at or near the water table are more likely to show contamination from nearby land surface activities than deeper wells.

For a variety of reasons, not all wells were sampled during all four synoptic sampling events. However, 85 wells have been sampled in all four events. Table 2-4 summarizes the changes in some summary statistics of the four events. Section A of the table shows the minimum, median, average, and maximum nitrate concentration for the four complete events. Section B of the table shows the same summary statistics for just the 85 wells sampled all four events.

Table 2-4 shows the minimum concentration during each event was at non-detectable levels (e.g., <0.02 mg/L in 1992 and 2003 but <0.005 mg/L in 2009 and 2015). These “non-detects” show that unaffected areas are being sampled and the detection limit has been lowered over time. The table also shows the median nitrate concentration increased twice then decreased, suggesting that some wells are recently decreasing. However, average nitrate concentrations consistently increased, suggesting that increases are greater than decreases. The table also shows that the well exhibiting the highest nitrate concentration was the same well in the first three events.

In summary, regardless of whether the entire data sets are compared or just the 85 wells sampled in all events, nitrate concentrations are increasing more than they are decreasing.