Changes in Nitrate-N Concentration in the Sumas-Blaine Aquifer Between 1997 and 2018

By: Eric Daiber, Eugene Freeman L. Hg., and Pam Marti L. Hg., Washington State Department of Ecology

Introduction

In spring 2018, the Washington State Department of Ecology (Ecology) sampled 178 wells in the Sumas-Blaine aquifer (SBA) to determine whether groundwater nitrate concentrations have changed since the last large-scale sampling of the aquifer by Erickson, in 1997 (3).

The Sumas-Blaine aquifer straddles the international boundary between the United States and Canada in northwestern Whatcom County. The aquifer encompasses approximately 150 square miles of mostly rural farmland in the United States and an additional 50 square miles in Canada.

The Sumas-Blaine aquifer is the uppermost surficial aquifer in the region and the primary source of drinking water for approximately 25,000 to 35,000 Whatcom County residents.

Large portions of the aquifer have often exceeded the 10 mg/L-N drinking water standard for nitrate+nitrite-N* during the past five decades (1–9, 14). Agricultural activities, on-site septic systems, and groundwater contributions from Canada have been identified as likely potential sources of nitrate-N (4, 5, 10).

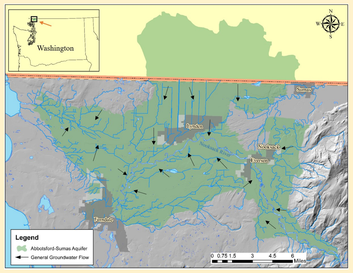


Figure 1: Location of the Sumas-Blaine aquifer, with directional arrows indicating the general groundwater flow direction (13).

The aquifer has been studied extensively both at the regional and local scales for nitrate-N contamination since the early 1970s. When 100 or more locations were sampled for nitrate-N in regional studies, the percentage of wells exceeding the 10 mg/L-N nitrate-N standard remained around 20%.

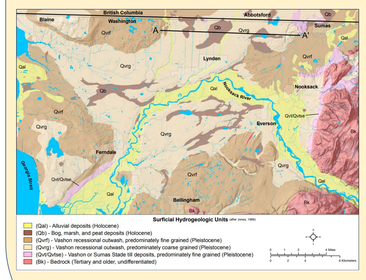
Table 1: Studies conducted by federal, state, and university groups.

Dates	Number of wells	Percentage of wells exceeding 10 mg/L-N nitrate-N	Author (date of publication)	Reference number
1970 – 1973	100	19	Obert (1973)	(1)
1990	27	26	Erickson and Norton (1990)	(2)
1990 – 1991	230	21	Cox and Kahle (1999)	(4)
1997	248	21	Erickson (1998)	(3)
1999	53	50	Erickson (2000)	(5)
2002 – 2004	26	64	Mitchell et al. (2005)	(6)
2003 – 2005	35	26	Redding (2008)	(7)
2009	27	41	Redding (2011)	(8)
2009 – 2016	25	24	Carey (2017)	(9)
2018	178	17	Daiber and Marti (2019)**	(16)

Physiographic Setting

The Sumas-Blaine aquifer is largely comprised of stratified coarse-grained sand and gravel outwash deposits interspersed with coarse-grained alluvium from the Nooksack and Sumas Rivers. These deposits overlie low-permeability glacio-marine drift of the Everson-Vashon semi-confining unit. The aquifer is typically less than 50 feet thick (Figure 2) (9). The depth to groundwater is commonly less than 10 feet below ground surface, especially in the winter (4).

The SBA is highly vulnerable to contamination from overlying land uses due to its permeable hydrologic properties, shallow depth to groundwater, and the area's heavy seasonal rainfall.



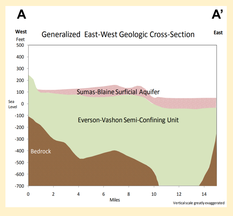


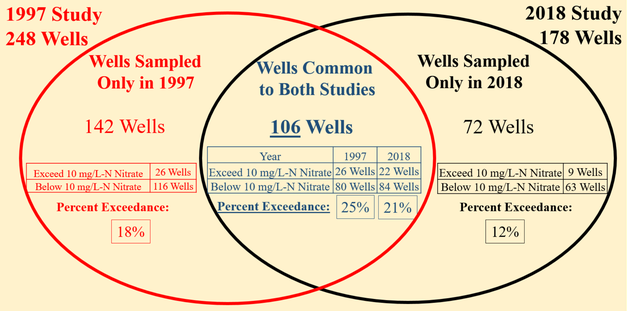
Figure 2: *–Left.* Surficial hydrogeologic units in Sumas-Blaine aquifer. *–Above.* A transect A-A' near the Canadian border (12).

* "Nitrate+nitrite-N" is referred to as "nitrate-N" in this poster, because of the negligible contribution of nitrite-N in surface water and groundwater (17).
** Daiber and Marti (2019) is currently in draft.

Well Populations

Ecology attempted to collect nitrate-N samples from the 248 private domestic supply wells sampled in 1997. However, we were able to sample only 106 wells common to the two studies. To supplement the 106 common wells, 72 wells were added in locations lacking coverage.

These additional wells included almost two dozen group A or B public water systems (PWS) wells and eight city supply wells. The PWS sampled serve approximately 11,000 residents of Whatcom County (11).



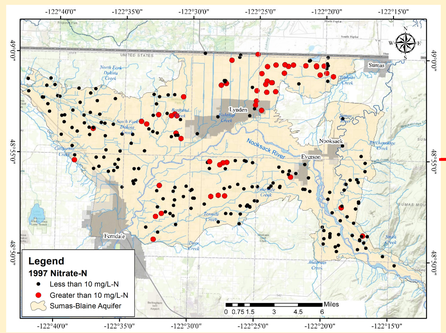
Results (Entire Population)

Results for the entire population represent two unique nitrate-N data populations collected 21 years apart.

Table 2: Nitrate-N summary statistics of the *entire population* of wells sampled in 1997 and 2018 (3, 16)

Year	Number of wells	Minimum~	Maximum⊥	Arithmetic mean⊥	Standard deviation⊥	Percentage in exceedance
1997 Study	248	< DL	53	5.81	7.45	**21%**
2018 Study	178	< DL	24.8	5.11	5.67	**17%**

~ Below detection limit (< DL). ⊥ Units are in mg/L-N.



21 Years Later

Figure 3: All 248 wells sampled for nitrate-N in 1997 (3).

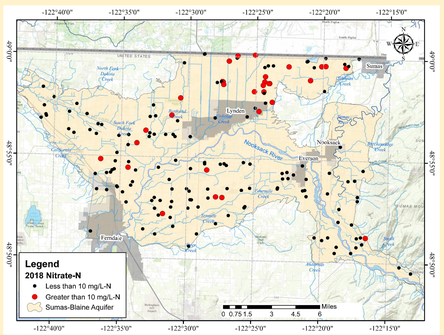


Figure 4: All 178 wells sampled for nitrate-N in 2018 (16).

The locations exceeding the nitrate-N standard occur in similar areas to those identified in 1997 and other studies (3, 15, 16).

Results (106 Common Wells)

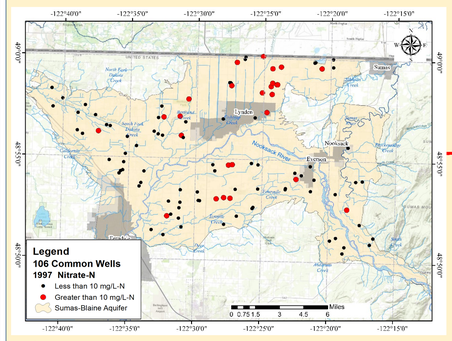
The 106 common wells represent a subset of wells that were sampled in both studies and were used to determine if the aquifer's nitrate-N concentration changed since 1997.

Table 3: Nitrate-N summary statistics for the 106 common wells between the 1997 and 2018 study (3, 16).

Year	Number of wells	Minimum~	Maximum⊥	Arithmetic mean⊥	Standard deviation⊥	Percentage in exceedance
1997 Study	106	< DL	53	6.83	8.55	**25%**
2018 Study	106	< DL	24.8	5.75	6.05	**21%**

~ Below detection limit (< DL). ⊥ Units are in mg/L-N.

Although we see a 4% decrease in the percentage of wells exceeding the nitrate-N standard, a similar pattern of exceedances is noted in Figures 5 and 6.



21 Years Later

Figure 5: The 106 common wells' nitrate-N results from 1997 (3).

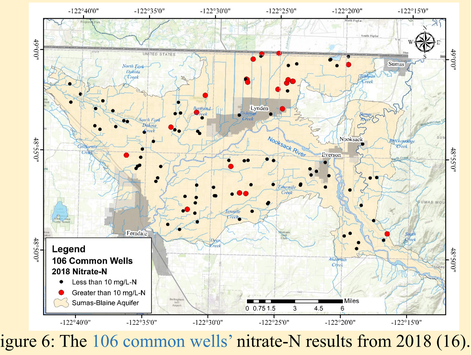


Figure 6: The 106 common wells' nitrate-N results from 2018 (16).

The map below (Figure 7) displays the difference in nitrate-N concentration between the two studies.

$$\text{Difference} = \text{Concentration [Nitrate-N]}_{2018} - \text{Concentration [Nitrate-N]}_{1997}$$

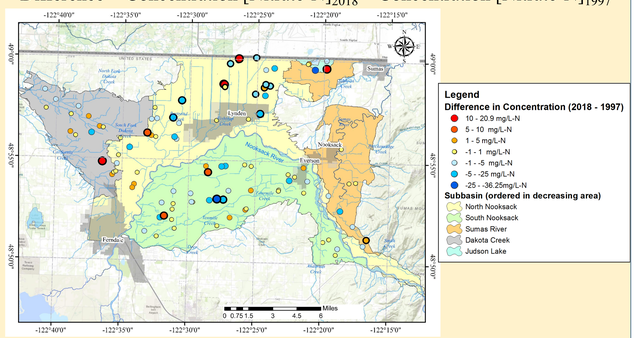
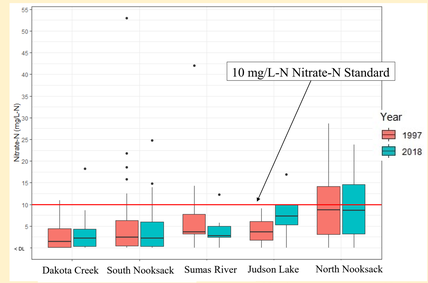


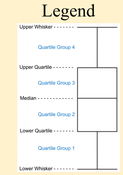
Figure 7: The difference in nitrate-N concentrations between 1997 and 2018 (16).

Wells highlighted with a black halo exceeded the nitrate-N standard in 2018 (16).

With respect to the 106 common wells, the subbasin with the largest number of exceedances of the nitrate-N standard in 2018 and 1997 was the North Nooksack.

Results (106 Common Wells) Cont.





The dots above the box plot indicate that the nitrate-N results are outliers.

Figure 8: A box plot of the nitrate-N results from the 106 common wells from 1997 and 2018, parsed by subbasin (3, 16).

The nitrate-N distribution did not change appreciably in the North Nooksack, South Nooksack, and the Dakota Creek subbasins. However, changes occurred in the nitrate-N distribution of the Sumas River and Judson Lake subbasins.

Conclusions

- The mean nitrate-N concentration for the 106 wells common to both studies declined by **1.08 mg/L-N** between 1997 and 2018. However, 21% of the wells still exceeded the nitrate-N standard.
- The mean nitrate-N concentration for the *entire population* decreased by **0.70 mg/L-N** from 1997 to 2018.
- The spatial distribution of nitrate-N exceedances occurred in similar locations to the exceedances from 1997, particularly in the North Nooksack subbasin.
- The largest number of exceedances of the nitrate-N standard occurred in the North Nooksack subbasin in both studies.
- Continued work is needed in the Sumas-Blaine aquifer to monitor and mitigate the nitrate-N concentrations.

Future Work

- Continue nitrate-N sampling of the 25 to 35 private domestic wells included in the long-term ambient groundwater monitoring program, thereby monitoring efforts to improve groundwater through best management practices on the aquifer.
- Construct wells along the international border to determine the component of nitrate-N entering the United States from Canada.
- Evaluate the nitrate-N concentration in the wells on the Canadian side of the border to aid our understanding of the component sourced from Canada.
- Develop a dedicated monitoring network across the aquifer to end reliance on and unknowns of the private domestic supply network used for sampling of nitrate-N.

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Contact: Eric Daiber: eric.daiber@ecy.wa.gov or (360) 407-7169.

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