Soil Nitrate Survey of Agricultural Fields in the Hullcar Valley in 2024

Final Report

BRITISH COLUMBIA
Ministry of Agriculture and Food

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Short title: 2024 Soil Nitrate Survey: Hullcar Valley

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November 2025

By Josh Andrews[1]

B.C. Ministry of Agriculture and Food

[1]Nutrient Management Specialist, M.Sc. P.Ag, Abbotsford, B.C.

Acknowledgements

Thanks to the producers who volunteered their fields for soil sampling. Doug Macfarlane and Ruth McDougall helped with soliciting producer cooperation, sampling the fields, and arranging soil testing. Greg Rekken provided editorial comments.

Disclaimer

Summary

The nitrate (NO_3-N) left in the soil profile after harvest is susceptible to leaching to groundwater during cooler months when precipitation exceeds plant evapotranspiration. By measuring the amount of nitrate in soil following crop harvest, some agronomic inferences can be made about N management over the course of the growing season. Additionally, this measurement can also be used as an environmental tool to determine how much soil nitrate may be at risk of leaching loss to groundwater.

Post-harvest soil sampling after the 2024 growing season was completed on 50 fields lying above Aquifer 103 in the Hullcar Valley of the North Okanagan to a 90-cm depth. These are the same fields sampled after both the 2021, 2022, and 2023 growing seasons. Overall, the area-weighted average soil nitrate value for the entire sampling area for 2024 was slightly lower than for 2023 (76 and 78 kg NO_3-N ha^{-1}, respectively), while the median soil nitrate value was unchaged (62 and 62 kg NO_3-N ha^{-1}, respectively). From the 2023 to the 2024 post-harvest periods, the area-weighted average soil nitrate value decreased slightly for fields cropped with alfalfa/grass and was unchanged for silage corn. During this period, however, the median soil nitrate value increased for fields with alfalfa/grass and silage corn.

Among the fields sampled, 62% of the nitrate in the sampled 90 cm of soil was found in the 0-30 cm layer on average, while 21% and 16% was found in the 30-60 and 60-90 cm layers, respectively.

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1 Introduction

In recent years, the water in Aquifer 103, located in the Hullcar Valley in the North Okanagan of British Columbia, has had elevated concentrations of nitrate (NO_3-N). Some environmental impact studies have suggested that the elevated concentration of NO_3-N is due to over-application of nitrogen (N) on agricultural fields, as this region of British Columbia is dominated by forage crops grown for livestock feed (Associated Environmental 2016, Associated Environmental 2017a, Associated Environmental 2017b, Poon and Code 2017). However, it has not yet been established the rate at which NO_3-N moves from the crop rooting zone to the aquifer, which may range from a few years to several decades. Therefore, it is prudent for agricultural producers to minimize the amount of NO_3-N remaining in the soil after crop harvest, as this NO_3-N may contribute to contamination of the underlying aquifer (Andrews 2020b). Several studies have been conducted over the past few years to monitor residual soil nitrate after crop harvest in the Hullcar Valley above Aquifer 103 (Andrews 2020a, Andrews 2020b, Andrews 2021, Andrews 2022, Andrews 2023, Andrews 2024, Poon and Code 2017, Poon and Code 2018). The results reported for residual soil nitrate in the 0-90 cm of soil after the 2024 crop harvest in this study are a continuation of this work.

Sampling for soil nitrate (NO_3-N) after crop harvest can be used as both an agronomic and an environmental tool. When sampled to a 30-cm depth, the amount of soil nitrate can be used to evaluate the balance between N supply and crop uptake, commonly referred to as a post-harvest nitrate test (PHNT) (B.C. Ministry of Agriculture 2020, Sullivan et al. 2021). In the coastal regions of B.C., the amount of soil nitrate represents NO_3-N susceptible to leaching due to humid, mild winters (Kowalenko 2000). However, recent reports for the Okanagan show that, unlike in coastal regions, not all soil nitrate is susceptible to leaching during the following non-growing season (Andrews 2020a, Andrews 2020b, Poon and Code 2017, Poon and Code 2018).

Sampling in this study includes the zone of soil recommended for agronomic PHNT and deeper zones to monitor presence of nitrate down to 90 cm. The sampling and analysis employed do not allow for the determination of the origin or fate of nitrate.

The objective of this report is to determine the amount and distribution of soil nitrate after crop harvest in sampled fields in the Hullcar Valley to inform area producers' decisions on N management.

Primary Questions

1. Overlying Aquifer 103 and the nearby area, how many agricultural fields had elevated levels of soil nitrate in the 0-90 cm layer of soil after crop harvest in 2024?
2. How is nitrate distributed throughout the 0-30 cm, 30-60 cm, and 60-90 cm soil sampling depths after crop harvest in 2024?
3. How did soil nitrate levels compare between the 2023 and 2024 sampling periods in fields that had the same crop type?

Hypotheses

1. Most agricultural fields in the area had less than 100 kg ha^{-1} of soil nitrate (0-90 cm soil layer) after crop harvest in 2024.
2. The majority (>50%) of nitrate was found in the 0-30 cm soil layer for each crop type after crop harvest in 2024.
3. The area-weighted average and median soil nitrate values of the entire study area did not increase from the 2023 sampling period.

Out of Scope

- Measuring nitrate leaching during the growing season, possibly due to over-irrigation or quantities of rainfall significant enough to cause leaching
- Measuring nitrate leaching from non-cropped areas, such as manure storage areas
- Measuring N transformations, such as mineralization or denitrification, that influence soil and water nitrate concentrations
- Measuring N uptake or N use efficiency of harvested crops
- Measuring soil water movement or retention
- Updating nutrient management plans, including assessing relationships between nitrogen management practices and post-harvest soil nitrate testing results

2 Materials and Methods

Study area

The study area was mostly overlying Aquifer 103 in the Hullcar Valley of the North Okanagan, located south of Grindrod, B.C. The agricultural activity, crops, and soils of the region have previously been described by Poon and Code (2017). The average annual precipitation of the study area is 480 mm and the daily mean temperature ranges from a low of -2.3C in January to a high of 20.2C in July (Andrews 2020b). Weather data from the survey area during the relevant growing season is not reported, as nearby weather stations used in previous reports have either been decommissioned or have incomplete datasets.

Field Selection and Sampling Methodology

Fifty agricultural fields above Aquifer 103 were selected for sampling after crop harvest in 2024, which were the same fields sampled as part of the survey in 2021, 2022, and 2023. Field delineation was based on consistent N management within the area and to keep total field size under 25 hectares. The total study area was 775 hectares, with 302 hectares (20 fields) of the area cropped with alfalfa/grass, 437 hectares (28 fields) of the area cropped with silage corn, and 35 hectares (2 fields) cropped with sorghum. In 2023, the study area was cropped with 262 hectares (17 fields) of alfalfa/grass, 469 hectares (30 fields) of silage corn, and 44 hectares (3 fields) cropped with winter wheat. The period of N application and management, as well as post-harvest sampling, ranged from April through October 2024.

The soil sampling methodology was consistent with those used previously from 2016 to 2023, with the exception of 2022 when resampling was required at a later date (Andrews 2020a, Andrews 2020b, Andrews 2021, Andrews 2022, Andrews 2023, Andrews 2024, Poon and Code 2017, Poon and Code 2018). For each sampling area, one composite soil sample was taken at the 0-15, 15-30, 30-60, and 60-90 cm depths from at least twenty random locations throughout each field.

Analyses

The laboratory and data analyses were the same as in previous years (Andrews 2020a, Andrews 2020b, Andrews 2021, Andrews 2022, Andrews 2023, Andrews 2024, Poon and Code 2017, Poon and Code 2018). After sampling, soil samples were refrigerated during delivery to prevent changes in nitrogen concentrations through microbial activity. Samples were then air-dried, sieved, extracted with potassium chloride, and analyzed by A&L Laboratories (London, ON).

The concentrations of extractable soil nitrate-nitrogen was converted to kg NO_3-N ha^{-1} using soil bulk densities of 1300 kg m^{-3} for the 0-15 and 15-30 cm soil layers and 1500 kg m^{-3} for the 30-60 and 60-90 cm soil layers. The total amount of nitrate-nitrogen found in the 0-90 cm soil layer was categorized into four categories (modified from Kowalenko et al. 2009): Low (0-49 kg NO_3-N ha^{-1}), Medium (50-99 kg NO_3-N ha^{-1}), High (100-200 kg NO_3-N ha^{-1}), and Very High ($\geq$200 kg NO_3-N ha^{-1}).

The environmental risk categories originally described by Kowalenko et al. (2007, 2009) classified total nitrate-nitrogen for the 0-60 cm sampling depth. However, the category names and ranges used in this study are based on a 0-90 cm sampling depth, which may increase the total measured amount of NO_3-N for each field and increase the likelihood of a field being placed into a higher NO_3-N category.

3 Results and Discussion

Overall, 34% of the total sampled land area had a ‘Low’ rating (16 fields), 40% had a ‘Medium’ rating (21 fields), and 26% had a ‘High’ rating (13 fields). No fields had a ‘Very High’ rating. 74% of the total sampled land area, a total of 37 fields, had less than 100 kg NO_3-N ha^{-1}, which supports the hypothesis (Hypothesis 1) that the majority of fields had soil nitrate values below 100 kg NO_3-N ha^{-1}.

There were differences in average soil nitrate (0-90 cm) between the two crop types for the 2024 post-harvest period (Table 1). Silage corn had the highest area-weighted average soil nitrate value of 98 kg NO_3-N ha^{-1} and accounted for the greatest proportion of sampled land area, 56%. Alfalfa/grass accounted for 39% of the sampled land area and had an area-weighted average soil nitrate value of 48 kg NO_3-N ha^{-1}. Sorghum accounted for the remaining 5% of the sampled land area and had an area-weighted average soil nitrate value of 40 kg NO_3-N ha^{-1}. Note that percentages may not add up to 100% due to rounding.

For the 2024 post-harvest period, 62% of the total area-weighted average soil nitrate was found in the uppermost 0-30 cm sampling zone (Table 2), 21% was found in the 30-60 cm sampling zone, and 16% was found in the 60-90 cm sampling zone. This supports the hypothesis (Hypothesis 2) that the majority of nitrate would be found in the 0-30 cm sampling zone.

To interpret these results, the difference between agronomic N and crop N removal rates needs to be understood. The agronomic N rate is the N application rate at which crop growth and yield is not limited. This rate is always greater than the crop N removal rate, which is the amount of N that the crop removes from the soil. Since no crop uses all N in the soil, a certain amount of post-harvest nitrate is expected. The amount depends on several factors, including crop, soil type, and weather.

Table 1. Sampling area and soil nitrate statistics for the 2024 post-harvest sampling period.

Crop type	No. of sampling areas	Area sampled	Area-weighted average PHNT[a]	Maximum PHNT	Median PHNT	Minimum PHNT
	-	(ha)	------------------kg NO_3-N ha^{-1} ------------------			
Alfalfa/grass	20	302	48	92	46	18
Silage corn	28	437	98	191	95	37
Sorghum	2	35	40	59	43	28
All crops	50	775	76	191	62	18

[a] In an area-weighted average, sampling areas that were larger in size contributed more to the average PHNT value compared to areas that were smaller. In contrast, all areas contribute equally to a simple average regardless of the size of the area.

Table 2. The proportion of all nitrate found in the 0-30 cm, 30-60 cm, and 60-90 cm sampling depths for the 2024 post-harvest sampling period.

Crop	0-30 cm	30-60 cm	60-90 cm
Alfalfa/grass	69%	19%	12%
Silage corn	60%	23%	18%
Sorghum	66%	15%	19%
All crops	62%	21%	16%

The amount of nitrate found in the soil after crop harvest can be used to make inferences about N application rates and use (Sullivan et al. 2021). Based on the range of soil nitrate values it appears that most fields had a greater N uptake than the typical assumption of 50% of applied N (Hermanson et al. 2000) or did not receive significant amounts of supplemental N. This indicates for these fields that N was applied at an agronomic rate and was managed for optimal crop uptake (Sullivan et al. 2021).

Kowalenko et al. (2009) cautions against the use of PHNT values alone to describe the risk of nitrate leaching in the Okanagan. Recent studies during the non-growing season in the Hullcar Valley show that movement of NO_3-N through the soil is fairly limited, and that NO_3-N can be expected to be present at planting the following year (Poon and Code 2017, Poon and Code 2018, Andrews 2020a, Andrews 2020b). In this area, producers should expect some soil NO_3-N to be present at the beginning of the growing season and incorporate it into their N management strategies for the next season. Monitoring PHNT values, crop yield, and crop quality on an annual basis provides information to minimize excess nitrate over time without compromising crop production goals (Poon and Code 2017).

Comparisons between years

The area-weighted average and median soil nitrate values for the study area were similar for the 2024 post-harvest period in comparison to the 2023 period (Table 3). In the 2023 sampling period, the area-weighted average and median soil nitrate value was 78 and 62 kg NO_3-N ha^{-1}, respectively. In the 2024 sampling period, the area-weighted average and median soil nitrate value was 76 and 62 kg NO_3-N ha^{-1}, respectively. While the differences in soil nitrate values from 2023 to 2024 were relatively minor, these changes support the hypothesis that the area-weighted average and median soil nitrate values did not increase from the 2023 sampling period (Hypothesis 3).

From the 2023 post-harvest period to the 2024 period, the area-weighted average soil nitrate value decreased for alfalfa/grass, from 49 to 48 NO_3-N ha^{-1}, while the median value increased from 43 to 46 NO_3-N ha^{-1} (Table 3). For silage corn, the area-weighted average soil nitrate value was 98 kg NO_3-N ha^{-1} in each year, while the median value increased from 86 to 95 NO_3-N ha^{-1}. Nitrate values for sorghum could not be compared as sorghum was not harvested in 2023.

4 Conclusions

Overall, the vast majority of the sampled land area, 74%, was below 100 kg NO_3-N ha^{-1} in the 0-90 cm sampling zone, which was 37 of the 50 sampling areas. The 2024 post-harvest period's area-weighted average and median soil nitrate value of the study area was similar to the 2023 period's value. On a crop type basis, both alfalfa/grass and silage corn had a lesser or unchanged area-weighted average soil nitrate value compared to 2023. Changes in soil nitrate measures, while minor, may be due to several factors, such as changes in N management or other management changes that affect crop N uptake or the mineralization of N in soil. However, due to the position of the fields above the aquifer, soil nitrate and N management practices should continue to be monitored to ensure the efficient uptake of applied N and minimize the amount of nitrate vulnerable to leaching loss.

Table 3. Sampling area and post-harvest nitrate statistics for the 2023 and 2024 post-harvest sampling periods.

Crop type	2023 No. of sampling areas	2023 Area sampled	2023 Area-weighted average PHNT[a]	2023 Median PHNT	2024 No. of sampling areas	2024 Area sampled	2024 Area-weighted average PHNT[a]	2024 Median PHNT
	-	(ha)	---kg NO_3-N ha^{-1}---		-	(ha)	---kg NO_3-N ha^{-1}---	
Alfalfa/grass	17	262	49	43	20	302	48	46
Silage corn	30	469	98	86	28	437	98	95
Winter wheat	3	44	42	30	-	-	-	-
Sorghum	-	-	-	-	2	35	40	43
All crops	50	775	78	62	50	775	76	62

[a] In an area-weighted average, sampling areas that were larger in size contributed more to the average PHNT value compared to areas that were smaller. In contrast, all areas contribute equally to a simple average regardless of the size of the area.

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6 Supplemental Materials

Supplemental Table 1. The amount of soil nitrate by soil layer (depth) in sampling areas that were cropped with silage corn in 2024.

Depth (cm)	NO3-N (ppm)	kg NO3-N ha^{-1}	Depth (cm)	NO3-N (ppm)	kg NO3-N ha^{-1}	Depth (cm)	NO3-N (ppm)	kg NO3-N ha^{-1}
0-15	34.8	67.9	0-15	9.6	18.7	0-15	9.2	17.9
15-30	10.4	20.3	15-30	5.0	9.8	15-30	4.9	9.6
30-60	5.3	23.9	30-60	3.1	14.0	30-60	2.1	9.5
60-90	6.8	30.6	60-90	3.4	15.3	60-90	2.6	11.7
0-15	37.4	72.9	0-15	27.0	52.7	0-15	4.5	8.8
15-30	11.1	21.6	15-30	5.9	11.5	15-30	6.8	13.3
30-60	2.9	13.1	30-60	2.5	11.3	30-60	2.2	9.9
60-90	5.5	24.8	60-90	3.5	15.8	60-90	1.1	5.0
0-15	7.7	15.0	0-15	46.5	90.7	0-15	19.5	38.0
15-30	7.6	14.8	15-30	16.5	32.2	15-30	4.0	7.8
30-60	2.2	9.9	30-60	5.3	23.9	30-60	1.7	7.7
60-90	0.3	1.4	60-90	5.2	23.4	60-90	1.8	8.1
0-15	16.1	31.4	0-15	37.3	72.7	0-15	25.4	49.5
15-30	4.5	8.8	15-30	12.2	23.8	15-30	7.3	14.2
30-60	3.1	14.0	30-60	6.4	28.8	30-60	2.9	13.1
60-90	1.8	8.1	60-90	2.6	11.7	60-90	4.1	18.5
0-15	9.6	18.7	0-15	17.0	33.2	0-15	24.7	48.2
15-30	4.4	8.6	15-30	6.4	12.5	15-30	22.2	43.3
30-60	2.7	12.2	30-60	6.8	30.6	30-60	18.4	82.8
60-90	1.1	5.0	60-90	3.1	14.0	60-90	3.8	17.1

Supplemental Table 2. The amount of soil nitrate by soil layer (depth) in sampling areas that were cropped with silage corn in 2024 (continued).

Depth (cm)	NO_3-N (ppm)	kg NO_3-N ha^{-1}	Depth (cm)	NO_3-N (ppm)	kg NO_3-N ha^{-1}	Depth (cm)	NO_3-N (ppm)	kg NO_3-N ha^{-1}
0-15	14.7	28.7	0-15	23.3	45.4	0-15	22.1	43.1
15-30	5.5	10.7	15-30	7.2	14.0	15-30	20.6	40.2
30-60	2.3	10.4	30-60	6.1	27.5	30-60	5.0	22.5
60-90	3.2	14.4	60-90	4.6	20.7	60-90	2.0	9.0
0-15	16.3	31.8	0-15	23.2	45.2	0-15	18.3	35.7
15-30	7.2	14.0	15-30	15.9	31.0	15-30	12.8	25.0
30-60	5.4	24.3	30-60	8.6	38.7	30-60	14.6	65.7
60-90	5.3	23.9	60-90	5.9	26.6	60-90	5.9	26.6
0-15	13.9	27.1	0-15	24.6	48.0	0-15	23.5	45.8
15-30	8.0	15.6	15-30	6.6	12.9	15-30	18.7	36.5
30-60	9.1	41.0	30-60	3.9	17.6	30-60	5.0	22.5
60-90	8.1	36.5	60-90	6.9	31.1	60-90	1.6	7.2
0-15	27.0	52.7	0-15	23.4	45.6			
15-30	9.8	19.1	15-30	7.6	14.8			
30-60	1.9	8.6	30-60	4.8	21.6			
60-90	1.1	5.0	60-90	8.5	38.3			
0-15	18.6	36.3	0-15	9.6	18.7			
15-30	4.8	9.4	15-30	2.4	4.7			
30-60	2.3	10.4	30-60	3.5	15.8			
60-90	2.4	10.8	60-90	4.9	22.1			

Supplemental Table 3. The amount of soil nitrate by soil layer (depth) in sampling areas that were cropped with alfalfa/grass or sorghum in 2024.

Depth (cm)	NO_3-N (ppm)	kg NO_3-N ha^{-1}	Depth (cm)	NO_3-N (ppm)	kg NO_3-N ha^{-1}	Depth (cm)	NO_3-N (ppm)	kg NO_3-N ha^{-1}
0-15	11.2	21.8	0-15	11.6	22.6	0-15	12.3	24.0
15-30	5.9	11.5	15-30	6.7	13.1	15-30	4.5	8.8
30-60	2.1	9.5	30-60	1.8	8.1	30-60	1.4	6.3
60-90	0.8	3.6	60-90	3.4	15.3	60-90	1.3	5.9
0-15	14.3	27.9	0-15	11.9	23.2	0-15	17.0	33.2
15-30	4.5	8.8	15-30	5.1	9.9	15-30	6.8	13.3
30-60	1.5	6.8	30-60	0.9	4.1	30-60	1.6	7.2
60-90	0.6	2.7	60-90	0.6	2.7	60-90	1.9	8.6
0-15	10.2	19.9	0-15	10.1	19.7	0-15	21.4	41.7
15-30	3.6	7.0	15-30	6.1	11.9	15-30	7.1	13.8
30-60	1.8	8.1	30-60	1.3	5.9	30-60	4.3	19.4
60-90	0.8	3.6	60-90	1.1	5.0	60-90	1.3	5.9
0-15	5.4	10.5	0-15	10.1	19.7	0-15	14.4	28.1
15-30	5.5	10.7	15-30	3.6	7.0	15-30	8.9	17.4
30-60	1.9	8.6	30-60	1.2	5.4	30-60	3.8	17.1
60-90	0.5	2.3	60-90	0.8	3.6	60-90	1.0	4.5
0-15	11.1	21.6	0-15	10.9	21.3	0-15	8.5	16.6
15-30	18.3	35.7	15-30	8.7	17.0	15-30	2.0	3.9
30-60	5.0	22.5	30-60	3.6	16.2	30-60	1.0	4.5
60-90	2.8	12.6	60-90	1.6	7.2	60-90	0.6	2.7

Supplemental Table 4. The amount of soil nitrate by soil layer (depth) in sampling areas that were cropped with alfalfa/grass or sorghum in 2024 (continued).

Depth (cm)	NO_3-N (ppm)	kg NO_3-N ha^{-1}	Depth (cm)	NO_3-N (ppm)	kg NO_3-N ha^{-1}	Depth (cm)	NO_3-N (ppm)	kg NO_3-N ha^{-1}
0-15	9.3	18.1	0-15	15.8	30.8	0-15	6.4	12.5
15-30	4.5	8.8	15-30	4.9	9.6	15-30	1.4	2.7
30-60	1.6	7.2	30-60	1.5	6.8	30-60	1.1	5.0
60-90	0.5	2.3	60-90	0.9	4.1	60-90	1.4	6.3
0-15	7.3	14.2	0-15	20.7	40.4	0-15	5.8	11.3
15-30	2.9	5.7	15-30	9.2	17.9	15-30	1.3	2.5
30-60	1.5	6.8	30-60	3.6	16.2	30-60	0.5	2.3
60-90	6.8	30.6	60-90	2.9	13.1	60-90	0.5	2.3
0-15	11.2	21.8						
15-30	7.8	15.2						
30-60	1.6	7.2						
60-90	1.4	6.3						