Interpretation of Water Analysis Data

Fall 2021 Fertilization Program

TFL 23 and NACFOR areas

Prepared for

NACFOR and Interfor

By

Richard Johnson, P.Eng

March 4, 2022

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<u>Certification of Qualifications</u>

I, R. H. Johnson, P.Eng., hereby certify:

1. That I am a registered Professional Engineer in the Province of British Columbia and in the Province of Alberta

2. That I have prepared the attached document based upon data supplied to me by Frances Swan and other members of NACFOR, including:
   a. Maps of the fertilization program areas supplied by NACFOR and included in Appendix A.
   b. That a report of the program prepared by B.A. Blackwell and Associates was also supplied by NACFOR and used in my interpretation.
   c. That the chemical analyses used are from ALS Environmental reports

3. That other data used in this interpretation were obtained from public sources.

4. That I have no direct nor indirect interest in any of the companies related to this report, nor the forest licenses, permits or other rights in this area, nor do I expect to receive any.

5. The interpretation of chemical water analysis data has been part of my work since 1985. In addition, I have worked as a hydrogeologist for over thirty years. The interpretations in this report are mine alone.

6. The reader is directed to note that interpretations of water analysis are qualified by the limited amount of data that is available.

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A. Summary

A water sampling program was conducted by NACFOR to check for fertilizer runoff into creeks in the area of aerial fertilization program in the fall of 2021. Water samples were taken at seven sites on four creeks and the water samples were analyzed for ammonia and nitrogen. On three of the creeks (Valentine, McDonald, and Saddle Creeks.) sample points were established at a high elevation and a low elevation point. The high elevation point was chosen to attempt to collect water samples above any fertilizer drop zones, and thereby act as control analyses. The other four sites were chosen below the fertilizer drop zones to check if there was evidence of fertilizer in the water. On the fourth creek, Stobo, no high elevation sampling point was established because it was not easy to get to a point higher than the fertilizer drop areas.

Four sets of water samples were collected from the seven sample sites prior to the fertilization start date to establish a baseline for the sites. An additional eight sets of samples were taken at the sites after the fertilization applications began on October 15th . The samples were sent to the ALS Environmental laboratory in Burnaby, B.C. for analysis of ammonia and nitrogen, both byproducts of Urea decomposition.

The results of the water analyses were plotted against time for each site to enable interpretation. There were no anomalies in ammonia concentration at any of the sites that would indicate fertilizer runoff. The only site that showed a dramatic increase in nitrogen concentration was the McDonald Creek lower site. All other sites showed only small fluctuations in nitrogen content. These are interpreted as normal variations
.

At the McDonald Creek lower site a sample caught on November 17th shows nearly a 100 fold increase in nitrogen concentration. It is not known whether this is a true nitrogen concentration, a typographical error by the lab or a badly caught sample. If it is accurate then it indicates that runoff from some fertilization site in the McDonald Creek watershed reached the creek. Since no later samples were caught at this site we cannot determine its accuracy nor how fast it cleaned up if it was caused by fertilizer.

Historical rainfall measurements were downloaded for the weather station at Nakusp. They indicate that on November 14th , and continuing into the next day, an extraordinary amount of rain fell, in the amount of 7.7 centimetres. Residents on Box Mountain, approximately 7 kilometres north of the McDonald Creek site, said that many of the springs in that area, that dry out in the summer, were flowing again because of the rain (Personal communication). This high rainfall could account for the dramatically increased nitrogen concentration at the lower McDonald sample site in the November 17th sample.

B. Conclusions

1. There is no evidence of fertilizer runoff from the ammonia concentrations measured in the water sampling program.
2. Only one water sample analysis contained an abnormal nitrogen concentration that could be attributed to fertilizer contaminated water runoff from a fertilizer site (McDonald Creek, “treatment” site on November 17th, 2021).
3. It is not known whether the above sample concentration of nitrogen is real, a typo or a contaminated sample, since no additional or confirming samples were caught.
4. There are a lot of small variations in ammonia and nitrogen concentrations that appear significant on the graphs. These are normal variations in ammonia and nitrogen and do not necessarily mean that fertilizer was reaching the creeks.

C. Recommendations

1. In future programs such as this, it would be helpful if water flow rate measurements were measured on the creeks. Since this is an expensive proposition, specific conductivity measurements could be taken at sample time as a proxy. Concentrations of the main ions that cause the conductivity changes, calcium, magnesium, and bicarbonate, go down during high creek flow periods. The concentration of nitrogen chemicals in the creeks is too small to have a significant impact on the conductivity. So conductivity changes are correlatable to flow rate.
2. Water samples should be analyzed within the time period set by the laboratory.

D. Discussion

Description of the fertilization program

A fertilization program was carried out by NACFOR and Interfor on 302 areas on TFL 23 and NACFOR areas. Urea fertilizer (46-0-0) was dropped from helicopters on about 5,894 ha. at a rate of 435 kg/ha, using about 2,563 tonnes of fertilizer. B. A. Blackwell was hired to supervise the project and complete quality control. A Summary Report, entitled “ TFL 23 and NACFOR Aerial Fertilization Program Fall 2021”, submitted by B.A. Blackwell, was provided to the author by NACFOR. The fertilization program started on October 15th and was completed by November 27th, 2021

The water sampling began on September 13th prior to any fertilization, The last samples were taken on November 18th. This was before the end of the fertilization but after a significant rain event on November 14th and 15th when a rainfall of 7.7 cm (3 inches) was recorded at the meteorological station at the Nakusp airport. The water sampling followed the procedures described in the Forest Practices Code of BC (September 1995) Forest Fertilization Guidebook, Appendix 4. The three month follow-up sample is planned but timing depends on site access.

Maps of the area are included in Appendix A. Four of these maps show the seven water sample sites with the fertilizer drop sites in these areas. Overview maps of the east and west sides of Arrow Lakes are also in Appendix A and show all 302 fertilizer treatment sites.

Description of the water sampling program

A water sampling program was established by NACFOR to monitor creeks that could be affected by the aerial fertilization program. In three of the cases, Valentine Creek, McDonald Creek, and Saddle Creek, water sample points were established at two points,, one high in the watershed, that would hopefully not be impacted by the fertilization program, and a second below the fertilization areas, to check for contamination from the fertilizer.

The seventh water sampling point was below the treatment sites in Strobo Creek down stream from the junction with Sweeting Creek. There was no easy access to a control sample point above the fertilization plots in this area so interpretation of the water analyses is done without having a "control" sample.

The satellite image below shows the seven water sample points, labelled with their name and elevation in metres above sea level.

Details of the seven sample sites are shown in the table below. All values are approximate as they were obtained from satellite imagery and a SRTM Digital Elevation Model with a pixel size of 25 m. by 25 m.

Site name	**Easting**	**Northing**	**Elevation**
Valentine Control	445250	5555615	1235
Valentine Control	443944	5555962	628
McDonald Control	453419	5550241	1238
McDonald Treatment	443270	5555057	481
Saddle Control	437659	5556628	1528
Saddle Treatment	441072	5556125	498
Stobo/Sweeting Treatment	432287	5550611	501

The following data was obtained from the Kootenay Boundary Water Tool (see References):

The Valentine Creek watershed lies approximately 9 kilometres south of the Village of Nakusp. It is approximately 1.5 square kilometres is area and it flows directly into Arrow Lake at a mean annual rate of 0.051 cubic metres per second. There are four water licences for surface water removal with a maximum annual allowable of 3,321 cubic metres.

The McDonald Creek watershed lies approximately 10 kilometres south of the Village of Nakusp. It is immediately south of and contiguous to the Valentine watershed described above. It is much larger than the Valentine Creek watershed and is approximately 97.8 square kilometres in area. It has a mean annual discharge rate of 2.02 cubic metres per second. There are no recorded water licences on McDonald Creek. It is a designated fish stream and the author has observed spawning kokanee in it.

The Saddle Creek watershed lies on the west side of Arrow Lake, immediately opposite the McDonald Creek watershed. It is approximately 6.09 square kilometres is area and it flows directly into Arrow Lake at a mean annual discharge rate of 0.216 cubic metres per second. There are no water licences recorded for this stream.

The Stobo Creek watershed lies on the west side of Arrow Lake, about 18 mile linear distance from Nakusp but over 25 km. by vehicle. It is approximately 4.97 square kilometres in area and it flows directly into Arrow Lake at a mean annual discharge rate of 0.023 cubic metres per second. There are 7 water licenses on this creek, two of which are for irrigation, which account for 63,216 cubic metres of the total 64,876 cubic metres licensed.

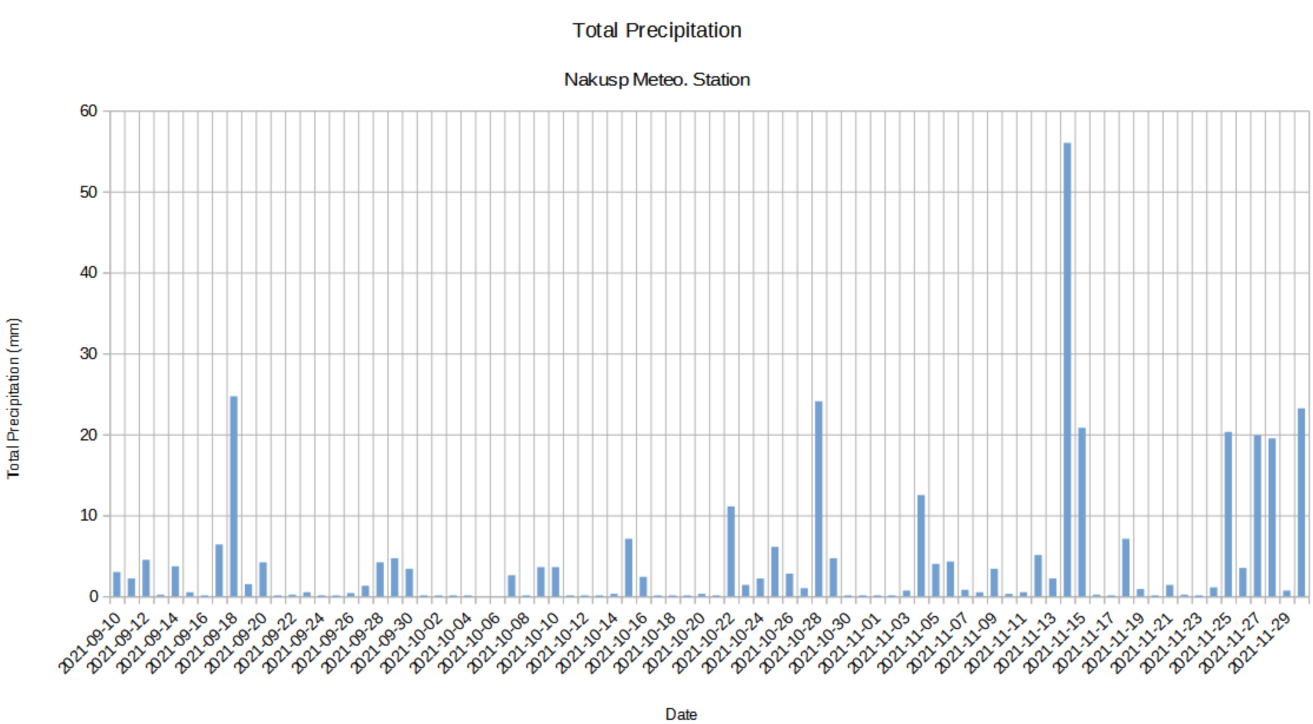
Rainfall

Daily Meteorological data was downloaded from the Government of Canada website for the Nakusp Weather Station located at the Nakusp airport. [50 deg-16 min-10 sec; 117 deg-49 min-2 sec (elev. 512 m.)]. This is about 11 kilometres north of the Valentine, McDonald, and Saddle sampling sites.

The water sampling began on September 13th and the last samples were taken on November 18th. The fertilization program began on October 15th and was completed by November 27th, 2021

The following graph displays the total precipitation by day. Significant rainfall events that might impact the water quality of the seven sample sites occurred on September 18th (25 mm), October 22nd (11 mm), Oct 28th (24 mm), Nov 4th (12 mm), Nov 14th (56 mm), and Nov 15th (21 mm). A graph of the rainfall, by day, is shown below.

The Nov 14-15 period records a heavy rainfall of 7.7 cm. (3 inches). This impacted the water quality at the McDonald Creek sample sites. See this report section on McDonald Creek for more information. The other three sites do not show any significant change that would indicate fertilizer runoff.



Analysis of the water sample chemistry

Water samples were taken from all of the seven sites at four dates, prior to the fertilizer application that started on October 15th, 2021. Details of the sample dates for each site was provided by NACFOR and is included as a table in Appendix B.

All of the water samples were sent to the ALS Environmental laboratory in Burnaby B.C. Ammonia was measured by florescence and total nitrogen by colourimetry. All of ALS quality control procedures were followed. The minimum detection limit of the laboratory methods used is 0.005 mg/l for ammonia and 0.030 mg/l for nitrogen. These values are the lowest points showing on the graphs. These should not be interpreted as the actual value but that the value is lower than that.

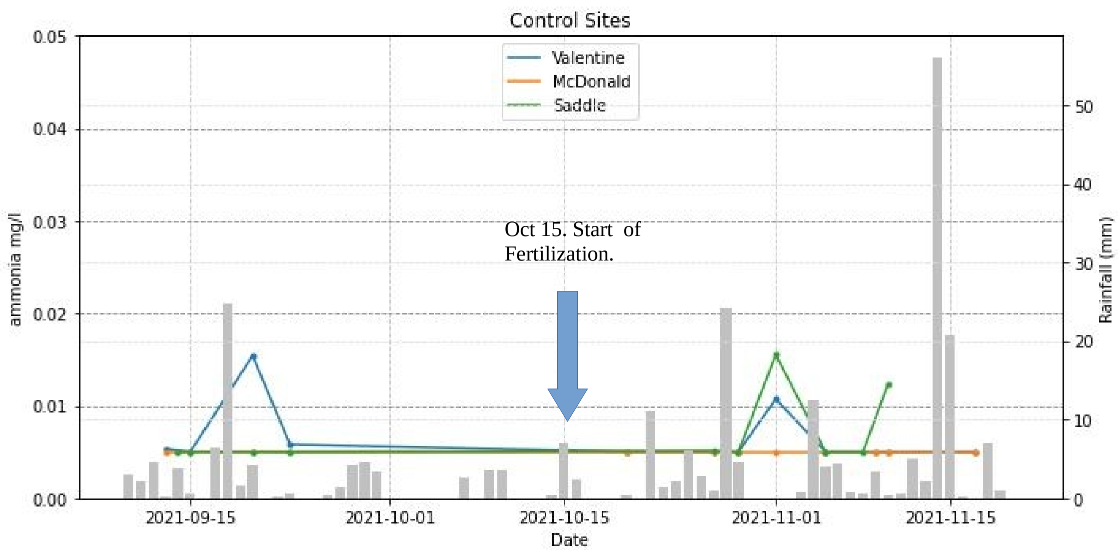
When interpreting the data in this study it is essential to look at the scale of the ammonia and nitrogen changes. Samples were taken on four different days prior to any fertilizer being applied. Triplicate samples were taken at all 7 sites during these first 4 samplings. Thus we have 12 samples at each site that show what the normal ranges in ammonia and nitrogen are due to naturally occurring events, such as rainfall.

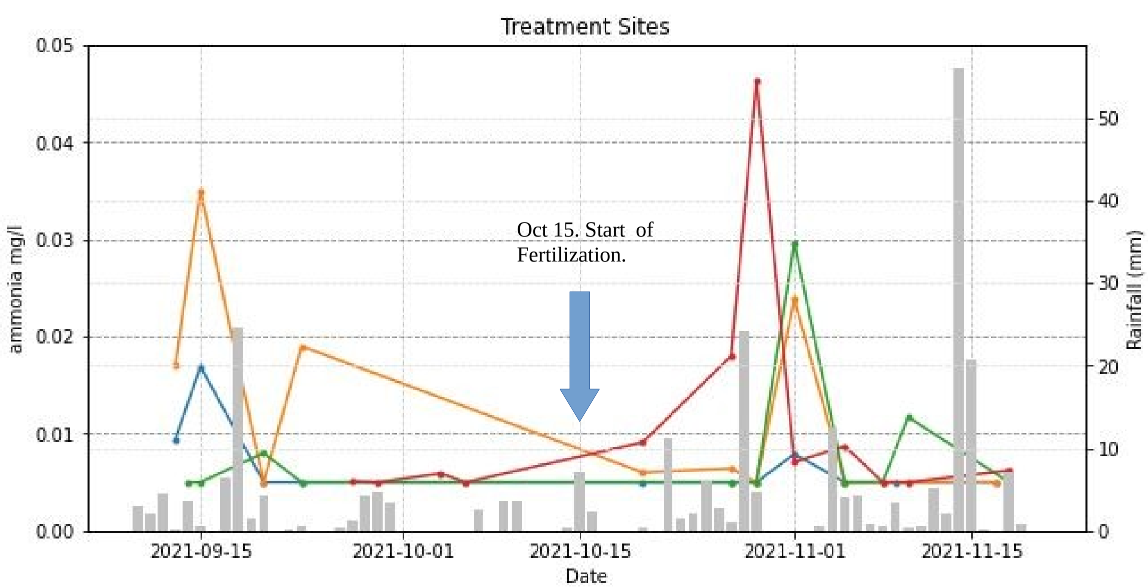
Since the triplicate samples were all analyzed on the same day, the spread in the three concentrations for those three samples indicates the natural variability in the analyses. The maximum spread in the triplicate samples was 0.040 mg/l for ammonia and 0.346 mg/l for nitrogen. Thus fluctuations within these ranges can be attributed to sampling procedure and to laboratory measurements and should not be interpreted as actual changes in the water chemistry due to fertilizer runoff. For the plots used in this interpretation an average value of the concentrations of the triplicate samples was used so the spread in the triplicate samples does not show on the graphs. Tables of the water sample analyses used to generate the maps in this report are included in Appendix B.

This group of samples was not analyzed by the laboratory before their recommended time of 28 days, with holding times up to 39 days. There is no obvious pattern that relates the holding time to the concentrations.

The amount of rain that falls on a watershed impacts watershed runoff and dissolved material concentrations. The concentration of most chemicals dissolved in the water of a creek gets diluted by the additional water from rainfall because the water does not have time to get into the soil and dissolve these ions. This is reversed in the case of ammonia and nitrogen because the increased runoff in a watershed tends to flow over the surface and dissolves these elements from vegetation, and in this case surface applied Urea. If there is runoff that is carrying ammonia and nitrogen from recently applied surface fertilizer we can expect large increases in the nitrogen concentration. Ammonia gas released by the hydrolysis of Urea is easily lost to the air (Cornell University Fact Sheet) so may not show in the lab analyses of waters from this project.

The two graphs below show the ammonia concentrations in the water for the three sites that had high elevation control sample sites. For comparison the second graph shows the ammonia concentrations in the water for the four sites that were at an elevation below the fertilized areas. The red line in the second graph is the data from the Stobo/Sweeting Creek site. The grey bars are the daily rainfall amounts.





Note the correlation between the rainfall of 24 mm (1 inch) on October 28, 2021 and the rise in ammonia concentration at nearly all sites, but that there was not a “spike” in the ammonia after the 77 mm rainfall on November 14-15, 2021. This may be attributed to natural variations in ammonia levels and variations in samples. (The maximum spread in the triplicate samples was 0.040 mg/l for ammonia).

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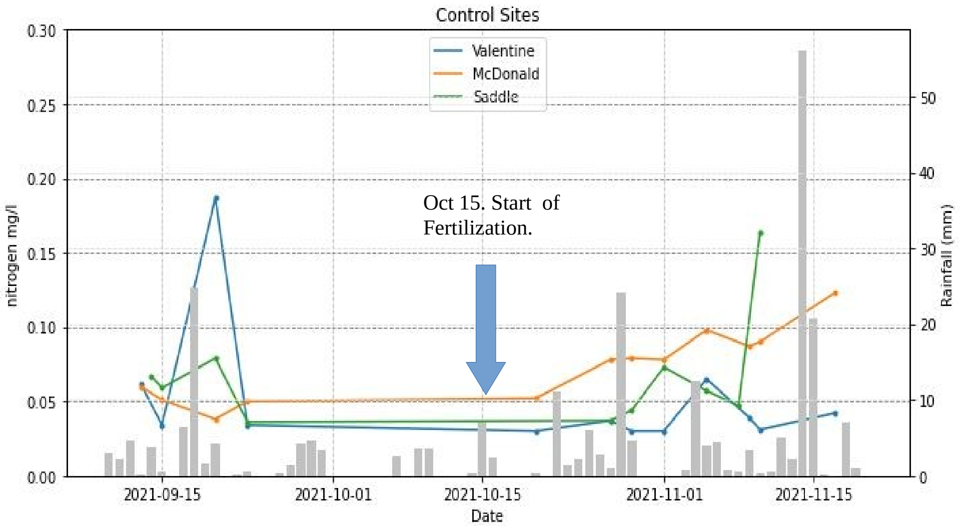
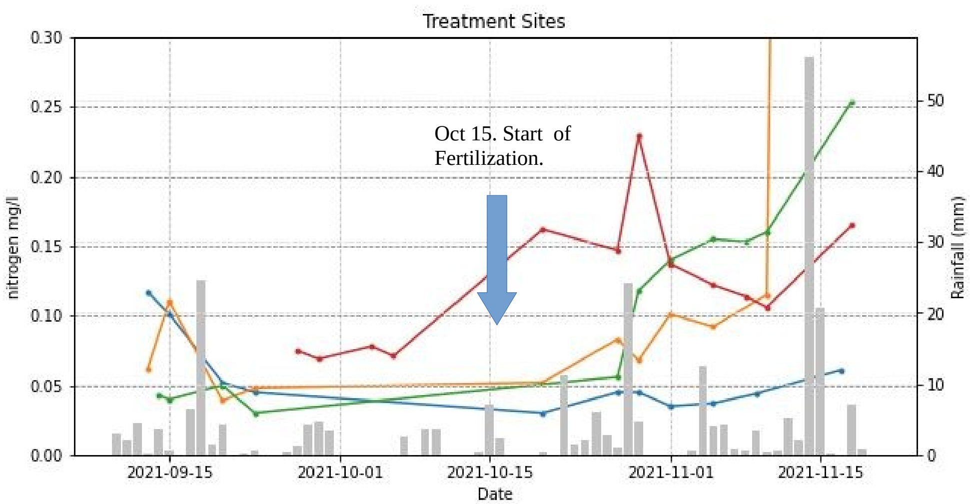
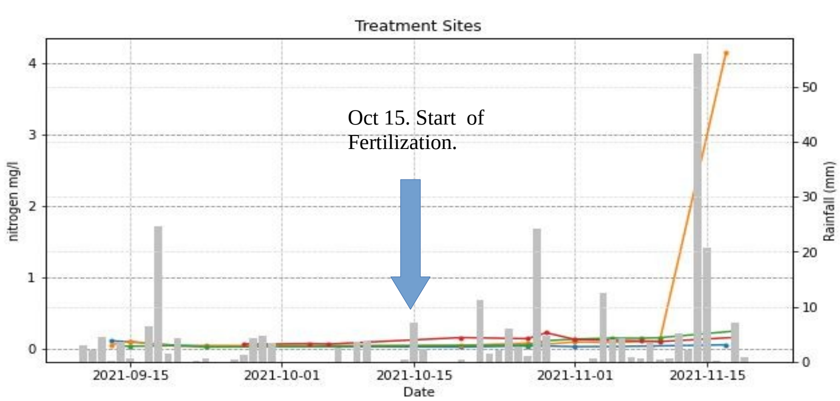
The following two graphs show the nitrogen concentrations at the same sites.





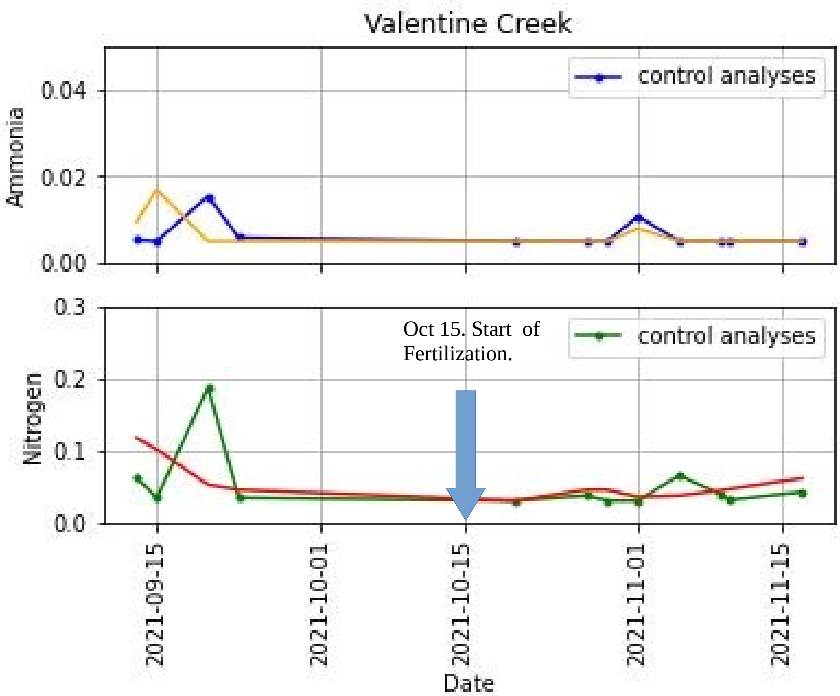
The above two nitrogen concentration graphs ar reproduced at the same scale for detailed comparison, but the graph showing the great change in nitrogen at McDonald Creek Treatment site is shown below.



The individual lines on the graphs on the previous page are not easy to sort out so detailed graphs, restricted to each area are shown in the following section of this report. The concentration values, shown on the left side of the graphs, are all set to the same range for ease of visual comparison, except for the McDonald Creek nitrogen graph.

Valentine Creek Area

Plots of the concentration of ammonia and nitrogen are shown below. The Control and Treatment graphs of ammonia show only two spikes above the baseline of 0.005 mg/l. To facilitate plotting of the data, ammonia measurements that fell below the detection limit of ALS Labs equipment was given a value of 0.005 mg/l which then becomes the lower limit of the plotted points. For nitrogen the lower detection limit is 0.03 mg/l



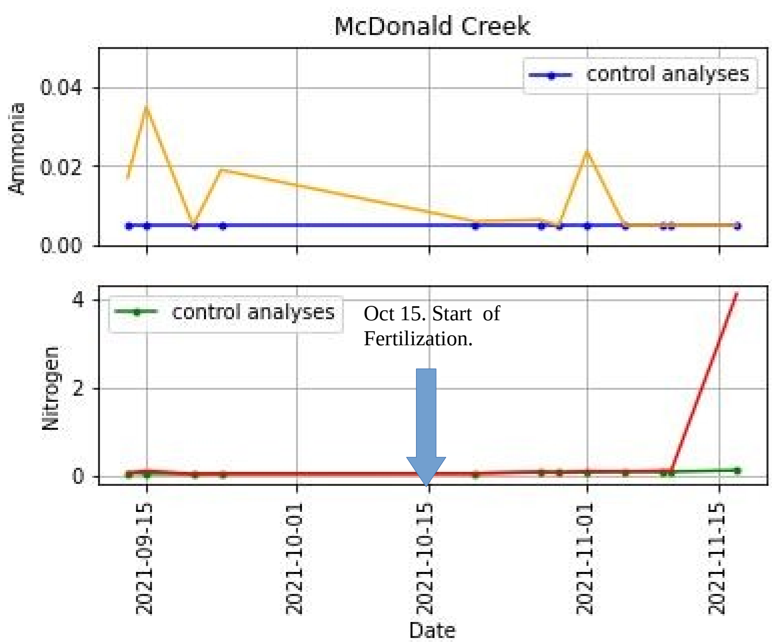
McDonald Creek

Plots of the concentration of ammonia and nitrogen are shown below. Note that the nitrogen concentration maximum scale (y axis) is just over 4 mg/l, not 0.3 mg/l as on the other three area graphs.

The ammonia concentration variations shown by the yellow line (treatment sample site) relate to "background" variations, normal to this site because the first four samples were taken before any fertilization took place.

The lower graph shows nitrogen concentrations at the "control" and "treatment' sites. This graph is unique among the graphs shown in this report for the four watershed because the y-axis is over 100 times greater than the scale of the other graphs. This is necessary because the last sample taken at the "treatment" site had a reported value of 4.14 mg/l. If this value is correct, and not a typographical error, then this sample shows evidence of runoff from a fertilized site. In hindsight, it would have been nice to have a couple of more samples taken after this day to confirm the concentration values and to see how fast the concentrations returned to normal.

Note that the abnormal nitrogen value was from a sample taken on November 17th, two days after the 7.7 cm. Rainfall event that occurred on November 14th and 15th. The ammonia stayed at <0.005 mg/l on Nov 17.

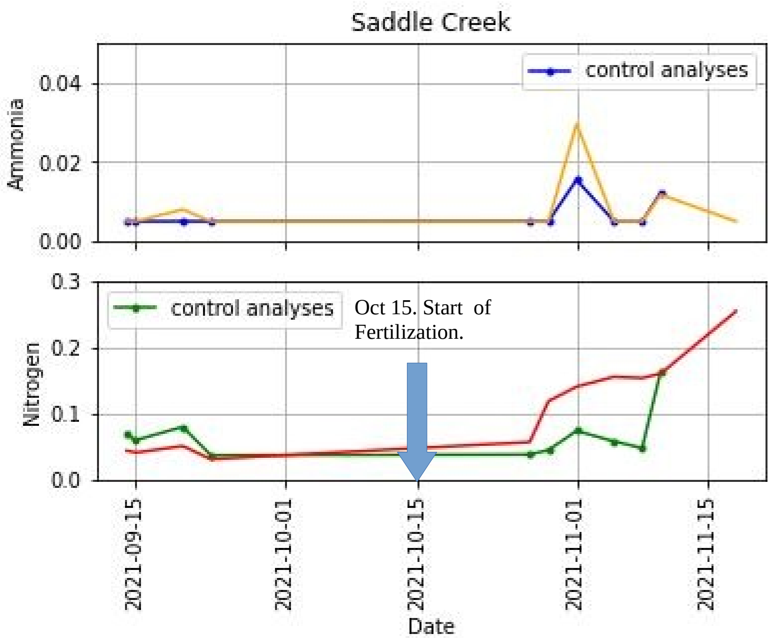


Saddle Creek

The graph below compares the ammonia measurements and the nitrogen measurements for two Saddle sites. The ammonia measurements do not show any evidence of fertilizer, the variations being well with the accuracy of the lab measurements and the samples “track” one another.

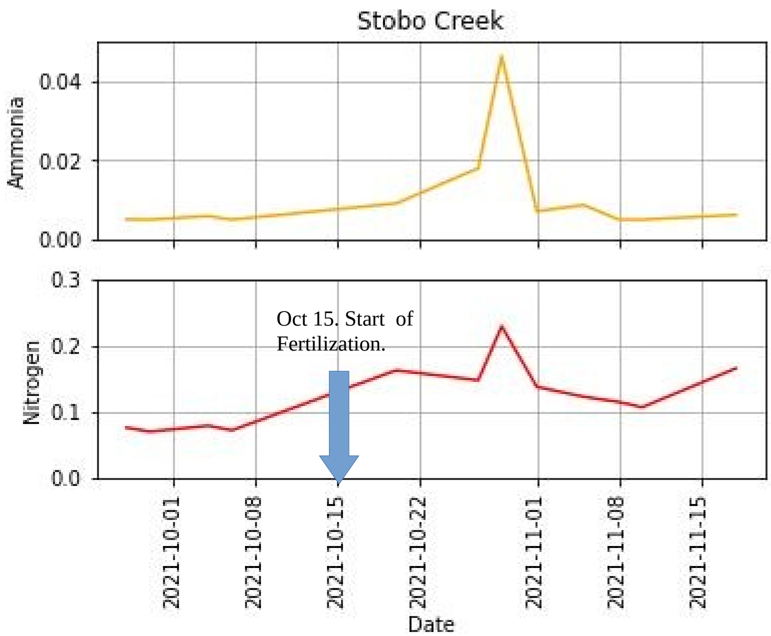
The Nitrogen curves both show an increase in concentration but the slight rise in November can be attributed to increased runoff from rainfall and are probably not caused by the fertilization program.

The control sample point is at a higher elevation than any of the nearby treatment plots so could not be affected by any fertilizer from the program unless it was dropped in the wrong place.



Stobo/Sweeting Creek

The Stobo/Sweeting graph shown below has ammonia and nitrogen concentrations for the sample site at a lower elevation than the fertilized blocks. The high concentration shown on October 29th is probably not caused by fertilizer but it should be noted that it is the highest Ammonia concentration of any of the 7 sites. It may be linked to the rain event on October 28 which was 2.4 cm. at the Nakusp airport.



E. References

Forest Practices Code of BC (September 1995) Forest Fertilization Guidebook
https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/silviculture/silvicultural-systems/silviculture-guidebooks/forest-fertilization-guidebook

Government of Canada, Environment and Natural Resources
https://climate.weather.gc.ca/historical_data/search_historic_data_e.html

Kootenay Boundary Water Tool
https://kwt.bcwatertool.ca/watershed

Cornell University Fact Sheet
http://nmsp.cals.cornell.edu/publications/factsheets/factsheet80.pdf

F. Glossary of Terms and Acronyms:

mg/l: milligrams per litre

INTERFOR: Interfor Corporation

NACFOR: Nakusp and Area Community Forest

NASA: National Aeronautics and Space Administration

SRTM: Shuttle Radar Topographic Mission (Digital Elevation Model raster data available from NASA.