Regional District of Nanaimo Biosolids Management Program

TimberWest Properties Surface Water Quality Report 2017-2018

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LIST OF ABBREVIATIONS

General abbreviations used in this document:

BC – British Columbia
BCAWQG – British Columbia Approved Water Quality Guidelines
CCME – Canadian Council of Ministers of the Environment
CSR – Contaminated Sites Regulation
EC – electrical conductivity
OMRR – British Columbia Organic Matter Recycling Regulation
N – nitrogen
NO_3 – nitrate
RDN – Regional District of Nanaimo
TP – total phosphorus
VIU – Vancouver Island University

Unit abbreviations used in this document:

cm – centimetre
L – litre
m – metre
mg – milligram
mL – millilitres
mm – millimetres
MPN – most probable number
µg – microgram
µS – microSiemens

EXECUTIVE SUMMARY

This report summarizes the surface water monitoring program in 2017-2018 at privately owned forest lands located along Weigles Road in Nanaimo, BC (the TimberWest Properties), where Regional District of Nanaimo biosolids are managed in a forest fertilization program. This monitoring program is carried out as part of overall biosolids management services under provided by SYLVIS Environmental. Surface water quality is monitored in order to assess any potential adverse impacts of biosolids fertilization on surface water quality. From 2012 to 2017, Vancouver Island University managed the monitoring program, and as of November 2017, the monitoring program has been carried out by SYLVIS.

Surface water samples were collected biannually in the spring and fall of 2017-2018 from the following sampling locations at upstream and downstream locations:

- Flynfall Creek;
- Caillet Creek);
- Bonnell Creek;
- W1500 Creek; and
- Benson Creek (control sample location).

Surface water samples were analyzed for a full suite of parameters including the following:

1. Nutrients (nitrogen and phosphorus);
2. Chloride;
3. Electrical conductivity;
4. Trace elements regulated by the British Columbia *Organic Matter Recycling Regulation*; and,
5. Fecal coliforms.

Parameter values were compared to BC *Contaminated Sites Regulation* water quality limits, BC Approved Water Quality Guidelines, and Canadian Council of Ministers of the Environment Water Quality Guidelines. Exceeding a guideline does not imply that unacceptable risk exists, but rather that the potential for adverse effects may be increased and additional investigation may be required.

For the majority of parameters no exceedances of regulatory limits or guidelines were observed. Excluding pH, only 10 out of 600 measurements exceeded a guideline; no parameters exceeded a regulatory limit in any sample.

Overall, the available data suggest that biosolids fertilization activities are not impacting surface water quality with the possible exception of nitrate, which is expected for an intensively fertilized coastal site.

TABLE OF CONTENTS

APPENDIX ONE – TABLES

APPENDIX TWO – FIGURES

APPENDIX THREE – PHOTOGRAPHS

1 INTRODUCTION

Biosolids from the Regional District of Nanaimo (RDN) have been managed in a forest fertilization program at privately owned forested lands owned by TimberWest Forest Corporation (the TimberWest Properties) located along Weigles Road in Nanaimo, BC since 2003. The TimberWest Properties were formerly leased by Vancouver Island University (VIU) from 1988 to 2017. From 2013 to 2017, the biosolids forest fertilization program was managed under a tripartite agreement between the RDN, VIU, and SYLVIS Environmental (SYLVIS). From 2018 on, the program has been managed by SYLVIS under contract to the RDN.

The *Organic Matter Recycling Regulation* (OMRR), the regulation governing biosolids management in British Columbia (BC), does not require monitoring of water bodies proximate to biosolids land application sites but rather specifies setback distances for biosolids applications from surface water bodies and groundwater wells. These setbacks are required in order to ensure that biosolids constituents (nutrients, pathogens, trace elements) are not able to travel overland or through groundwater to water bodies. A surface water monitoring program, however, is advisable for sufficiently large and long-term projects in order to confirm the suitability and effectiveness of setback distances and other site management requirements in mitigating potential adverse effects on water quality from biosolids management.

During the period 2012 – spring 2017, VIU managed the surface water monitoring program at the site. In November 2017, the RDN entered into a land-use agreement with TimberWest as well as an agreement for biosolids management with SYLVIS, both expiring on May 31st, 2021. Under the current biosolids management agreement, SYLVIS manages surface water monitoring and reporting at the TimberWest Properties.

This report summarizes surface water quality sampling at the TimberWest Properties in 2017 and 2018 based on sampling conducted by SYLVIS and one sample set collected by VIU.

2 BIOSOLIDS MANAGEMENT AND WATER QUALITY

Biosolids are an organic fertilizer not unlike animal manures and thus have the same potential to cause contamination of water bodies. Just as for agricultural sites, nutrients such as nitrogen and phosphorus constitute the most mobile constituents with the most significant environmental impacts (e.g., eutrophication). The OMRR requires specific management techniques which are designed to protect surface and groundwater quality. These requirements are:

1. A setback distance of 30 metres (m) for biosolids applications from potable water sources, irrigation wells, lakes, rivers, and streams (OMRR Schedule 8(1)d(i));
2. A requirement to apply only when groundwater is more than 1 m below the soil surface (OMRR Schedule 8(1)b));
3. A requirement to locate biosolids storage facilities 15 m from any watercourse (OMRR Division 1, Section 18-19); and,

4. A requirement to cover stored biosolids from October 1st to March 31st in regions of the province where annual precipitation exceeds 600 millimetres (mm) (OMRR Division 1, Section 20).

In addition to these regulatory requirements, applying biosolids at an agronomic rate (i.e., supplying only as much nutrient as the site vegetation can take up), a best management practice, also reduces the risk of leaching of excess nutrients and other biosolids constituents.

3 WATER SAMPLING LOCATIONS AND FREQUENCY

In the fall of 2017 and throughout 2018, SYLVIS conducted surface water sampling at the same locations as were used in previous years with the addition of a "control" sample in 2018 from Benson Creek, located outside the Biosolids Area (Figure 1). Surface water sampling locations are presented in Table 1, Appendix One.

Surface water was collected in the spring and fall where water flow was sufficient for sampling. Samples were collected as grab samples in sampling bottles. A summary of sampling frequency at each location is given in Table 2, Appendix One. Total precipitation in the two weeks preceding sampling ranged from 16 to 213 mm (Table 3, Appendix One).

Samples collected in fall 2017, spring 2018, and fall 2018 were analyzed for a full suite of parameters which enable consideration of all the key parameters listed above. Samples collected in spring 2017 by Vancouver Island University were analyzed for a smaller set of parameters.

4 WATER QUALITY CRITERIA

As detailed in Section 2, the OMRR contains various requirements to protect water resources and thus does not contain or make reference to any water quality criteria. In BC both regulatory criteria as well as guidelines are available for water quality interpretation. Data presented in this report are compared to criteria from the following sources:

- The BC *Contaminated Sites Regulation* (CSR);
- The BC Approved Water Quality Guidelines (BCAWQG); and,
- The Canadian Council of Ministers of the Environment (CCME) Water Quality Guidelines.

Approved guidelines from BC for protection of freshwater aquatic life were used where possible, followed by national guidelines. Water quality guidelines provide a basis for water quality assessments and inform decision-making in the natural resource sector. Exceeding a guideline does not imply that unacceptable risk exists, but rather that the potential for adverse effects may be increased and additional investigation may be required.

5 WATER QUALITY PARAMETERS

Data presented in this report are for parameters which are relevant for determining potential impacts of biosolids fertilization on surface water. Typically, these parameters include soluble

nutrients, other soluble species linked to anthropogenic influence, microbiology associated with biosolids, and trace elements regulated in biosolids under the OMRR.

5.1 Macronutrients: Nitrogen and Phosphorus

Forms of nitrogen and phosphorus in surface water are typical indicator analytes used to assess surface water impacts following fertilization from chemical fertilizers, animal manures, or biosolids. Nutrients can enter surface water bound to fine soil particles via overland flow or as soluble species through groundwater or overland flow. Increased concentrations of nitrogen and phosphorus in surface waters can result in adverse environmental impacts such as eutrophication.

Recommended ambient surface water concentrations vary according to the reference. For nitrate, ambient concentration values of 0.3 milligrams per litre (mg/L) nitrate-nitrogen (NO_3-N) (BC Ministry of Environment, 1998), 1 mg/L NO_3-N (BC Ministry of Environment, 1986), and 2 mg/L NO_3-N (Vancouver Island Health Authority, personal communication, February 15, 2018) have been suggested, with the long-term BCAWQG for protection of aquatic life at 3 mg/L NO_3-N (BC Ministry of Environment, 2009). Increases in surface water nitrate concentrations are expected to occur following fertilization activities in forests. Binkley (1999) summarizes studies on surface water nitrate concentrations following forest fertilization with chemical fertilizer on Vancouver Island with nitrate concentrations ranging between 0.1 and 9.3 mg/L NO_3-N. This study references 4 mg/L NO_3-N as an upper limit for annual average nitrate concentration in surface water at fertilized forest sites. The short-term maximum BCAWQG for protection of freshwater aquatic life is 32.8 mg/L NO_3-N, and the CSR limit is 400 mg/L NO_3-N (with an assumption of a 10:1 dilution to 40 mg/L NO_3-N).

It is understood that both the short-term and long-term BCAWQG for nitrate are intended to be applied to a large dataset resulting from regular (e.g., daily) monitoring of surface water nitrate. While the data collected for this report do not fit that description, the long-term BCAWQG of 3 mg/L has been chosen as the guideline for comparison. This guideline provides a reference value for protection of aquatic freshwater life and is a more reasonable choice than the maximum guideline of 32.8 mg/L as there is no evidence that nitrate levels spike beyond that limit throughout the year, nor do any activities occur at the TimberWest Properties which would cause such a spike.

Phosphorus, along with nitrogen, is often implicated in water quality issues such as eutrophication. Due to the fact that phosphorus itself is non-toxic to aquatic organisms (i.e., rather, its side-effects such as eutrophication are harmful) and that aquatic ecosystems can adapt to different ambient phosphorus concentrations (Canadian Council of Ministers of the Environment, 2004), there is no “one-size-fits-all” phosphorus limit for surface water, nor is there a CSR limit. However, various guidelines for protection of freshwater aquatic life are available provincially or in other jurisdictions. The BCAWQG has no guideline for streams but recommends a limit of 0.005 – 0.015 mg/L total phosphorus (TP) (BC Ministry of Environment, 2001) for protection of aquatic life in lakes. A BC Ministry of Environment and Climate Change Strategy publication sets water quality objectives for the protection of Vancouver Island streams of 0.005 mg/L TP (average) and

0.010 mg/L TP (maximum) (BC Ministry of Environment, 2014). As a more general reference, Brady and Weil (1990) suggest 0.1 mg/L TP as the level at which eutrophication is likely. Due to the similarity between the BCAWQG values and the range suggested in BC Ministry of Environment (2014), a reference guideline of 0.010 mg/L TP has been chosen as the guideline for comparison.

These various limits, guidelines, and reference values for nitrogen and phosphorus are summarized in the following table.

Source	Jurisdiction	Value	Units
Guidelines for interpreting water quality data (BC Ministry of Environment, 1998)	BC	0.3	mg/L NO_3-N
Water Quality Criteria For Nitrogen - Technical Appendix (BC Ministry of Environment, 1986)	BC	1	mg/L NO_3-N
Vancouver Island Health Authority, personal communication	Vancouver Island	2	mg/L NO_3-N
Water Quality Guidelines for Nitrogen (Nitrate, Nitrite, and Ammonia) (BC Ministry of Environment, 2009) (long-term)	BC	3	mg/L NO_3-N
Water quality impacts of forest fertilization with nitrogen and phosphorus (Binkley et al., 1999)	Vancouver Island	4	mg/L NO_3-N
Water Quality Guidelines for Nitrogen (Nitrate, Nitrite, and Ammonia) (BC Ministry of Environment, 2009) (maximum)	BC	32.8	mg/L NO_3-N
Contaminated Site Regulation (assumes 10:1 dilution)	BC	400	mg/L NO_3-N
Water Quality Criteria for Nutrients and Algae (BC Ministry of Environment, 2001)	BC	0.005 – 0.015	mg/L TP
Phosphorous Management in Vancouver Island Streams (BC Ministry of Environment, 2014)	Vancouver Island	0.005 – 0.010	mg/L TP
The Nature and Properties of Soils (Brady and Weil, 1990)	North America	0.1	mg/L TP

5.2 Chloride

The chloride ion is highly mobile and concentrations in water are not affected by chemical reactions; chloride does not biodegrade, readily precipitate, volatilize, or bio-accumulate. Chloride does not adsorb readily onto mineral surfaces and therefore is a good indicator of anthropogenic influence. The Canadian Council of Ministers of the Environment (CCME), in the development of its water quality guidelines, identified that ambient chloride concentrations in un-impacted water bodies in the Pacific Region are < 5 mg/L, with potentially higher values in water bodies located close to the ocean (CCME, 2011). The BCAWQG for protection of aquatic life (600 mg/L) is well above this reference value.

5.3 Electrical Conductivity

Electrical conductivity (EC) in biosolids is typically much higher than in natural soils or water. Movement of biosolids constituents which contribute to EC into surface water bodies could potentially be indicated by increases in surface water EC. There is no limit or guideline for EC but the ambient coastal stream reference value is < 100 microSiemens per centimetre (µS/cm) (BC Ministry of Environment, 1998).

5.4 OMRR-Regulated Trace Elements

The mobility of most OMRR-regulated trace elements is highly dependent on soil pH. The acidic conditions of TimberWest Properties soils (pH 5 – 5.5) represent an elevated potential for movement for most of these trace elements due to their tendency to become more soluble at lower pH. CSR limits and water quality guidelines exist for OMRR-regulated trace elements.

5.5 Fecal coliforms.

Although biosolids are treated to reduce pathogen levels, they are not sterilized. Fecal coliform bacteria, which are used as an indicator for the potential presence of pathogenic microbiology in biosolids as well as in water, can be used to determine potential biosolids ingress into water bodies. Fecal coliforms can also originate from wildlife.

For microbiological parameters, guidelines exist for the protection of drinking water and recreational use but not for protection of freshwater aquatic life. As there are no known drinking water systems downstream from the TimberWest Properties, and because recreational activities (e.g., mountain biking, hiking) do occur on the property, the recreational use guidelines are used for microbiological parameters.

6 RESULTS AND DISCUSSION

Data is presented for the five sampling sites in sub-sections 6.1 to 6.5 below, along with a description of surface water sampling location. Complete data tables for each site, along with relevant guidelines, can be found in Table 4 through Table 8, Appendix One.

6.1 Benson Creek

Benson Creek, the control sample location, flows north along the eastern edge of the TimberWest Properties. Biosolids fertilization does not occur upstream from the sampling location, although some logging activity does. Benson Creek and its sampling point are depicted in Figure 1, Appendix Two, and Photograph 1, Appendix Three.

All water quality data for Benson Creek were below relevant guidelines. As a control sampling location, samples are not collected from an upstream/downstream location. Nitrogen forms, phosphorus forms, and chloride were well below guidelines and in some cases below analytical detection limits. For example, nitrate, a parameter of interest at fertilized sites, ranged from 0.03 to 0.10 mg/L, below any limit, guideline, or reference value. Total phosphorus was also the guideline in 2018. All analytical data for Benson Creek are presented in Table 4, Appendix One.

6.2 Flynfall Creek

Flynfall Creek is a major drainage at the TimberWest Properties. The creek originates from an area of high elevation which serves as the headwaters to Flynfall and Bonnell Creeks and generally flows eastward roughly parallel to Weigles Road. Upstream samples were taken at the outflow of the headwaters and downstream samples were taken at a bridge crossing over the creek outside the property boundary and roughly due south of the MotoCross track. Flynfall Creek

flows into Benson Creek before draining into Brannen Lake. No surface water diversion permits are in effect along Flynfall or Benson Creeks. Flynfall Creek and its sampling points are depicted in Figure 1, Appendix Two, and Photograph 2 and Photograph 3, Appendix Three.

All water quality data for Flynfall Creek were below relevant limits and guidelines with the following exceptions. Nitrate at the Upper Flynfall sampling location in winter 2018 was 3.4 mg/L (guideline is 3 mg/L). The occurrence of lower nitrate at the downstream sampling location does not suggest that nitrate is leaching across this drainage. pH at the Upper Flynfall sampling location in winter 2018 was 6.4 (guideline range is 6.5 – 9.0). Low pH surface water is common on Vancouver Island in forest environments due to high precipitation and the acidic nature of forest soils. While the BCAWQG for pH recommends 6.5 – 9.0 as a range over which unrestricted change in pH is permitted without risking harm to aquatic freshwater life, it also recognizes that many areas of Coastal BC have naturally occurring pH below this range. *Escherichia coli* concentration at the Upper Flynfall sampling location in winter 2018 was 173 most probable number per 100 millilitres (MPN/100 mL) (recreational guideline is 77 MPN/100 mL). The occurrence of lower *E. coli* at the downstream sampling location suggests that this is a feature of water quality where the outflow from the headwaters occurs. Previous samples collected at this sampling location did not indicate elevated microbiology.

For all parameters of interest (nitrogen, phosphorus, chloride, EC, OMRR trace elements, and fecal coliforms), concentrations at downstream sampling locations were, on average, observed to be lower in 50% of sample pairs, unchanged in 20% of sample pairs, and higher in 30% of sample pairs compared to the upstream sampling location. No parameter was consistently higher in downstream samples during all sampling events. This distribution of differences does not suggest a negative effect on water quality from biosolids applications within the Flynfall Creek drainage.

All analytical data for Flynfall Creek are presented in Table 5, Appendix One.

6.3 Caillet Creek

Caillet Creek drains the northern portion of the TimberWest Properties. The creek originates from roughly the center of the northern third of the TimberWest Properties and generally flows eastward parallel to Weigles Road. Upstream samples were taken at the location of suitable flow nearest to the headwaters and downstream samples were taken downstream of the entire biosolids application area. Caillet Creek flows into Brannen Lake. No surface water diversion permits are in effect along the length of the creek. Caillet Creek and its sampling points are depicted in Figure 1, Appendix Two, and Photograph 4 and Photograph 5, Appendix Three.

All water quality data for Caillet Creek were below relevant limits and guidelines.

For all parameters of interest (nitrogen, phosphorus, chloride, EC, OMRR trace elements, and fecal coliforms), concentrations at downstream sampling locations were, on average, observed to be lower in 45% of sample pairs, unchanged in 10% of sample pairs, and higher in 45% of sample pairs compared to the upstream sampling location. Total copper, nitrate, and chloride were consistently higher in the downstream sampling location. Total copper concentrations increased no more than 0.3 mg/L and no value was more than 16% of its calculated limit. Nitrate increased

from 0.3 – 0.7 mg/L at the downstream sampling location, and in the fall increased to within 80-90% of the guideline of 3 mg/L. Chloride increases were minimal (2-5%) and no value exceeded 45% of the reference value of 5 mg/L. Although for the majority of parameters the lack of exceedances and the pattern/incidence of change in parameter concentrations at the downstream sampling location do not suggest a negative effect on water quality from biosolids fertilization within the Caillet Creek drainage, the observed increase in nitrate at an intensively fertilized site is not unexpected.

All analytical data for Caillet Creek are presented in Table 6, Appendix One.

6.4 Bonnell Creek

Bonnell Creek drains a small portion of the TimberWest Properties to the west. The creek originates from an area of high elevation which serves as the headwaters to Bonnell and Flynfall Creeks and generally flows westward out of the TimberWest Properties. Upstream samples were taken at the outflow of the headwaters and downstream samples were taken before the next tributary flows into the creek. Bonnell Creek flows off the TimberWest Properties and then turns north, eventually draining into Nanoose Bay; no known surface water diversion permits are in effect along the creek. Bonnell Creek and its sampling points are depicted in Figure 1, Appendix Two, and Photograph 6 and Photograph 7, Appendix Three.

All water quality data for Bonnell Creek were below relevant limits and guidelines with the following exceptions. Total phosphorus at upstream and downstream locations was up to four times the quality objective of 0.01 mg/L on multiple sampling dates, with no clear pattern of downstream increases. Total silver at the downstream location in fall 2018 was 0.13 mg/L, above its limit of 0.1 mg/L. This parameter has not been found in exceedance during any other sampling event at this creek or any other creek at the site. pH at upstream and downstream locations in the fall was below the guideline range of 6.5 – 9.0. As mentioned previously, low pH surface water is common on Vancouver Island in forest environments.

For all parameters of interest (nitrogen, phosphorus, chloride, EC, OMRR trace elements, and fecal coliforms), concentrations at downstream sampling locations were, on average, observed to be lower in 70% of sample pairs, unchanged in 10% of sample pairs, and higher in 20% of sample pairs compared to the upstream sampling location. No parameter was consistently higher in downstream samples during all sampling events. This distribution of differences does not suggest a negative effect on water quality from biosolids fertilization within the Bonnell Creek drainage.

All analytical data for Bonnell Creek are presented in Table 7, Appendix One.

6.5 W1500 Creek

W1500 Creek drains a small portion of the TimberWest Properties to the north of the Caillet drainage. The creek generally flows eastward out of the TimberWest Properties. Upstream samples were taken at the nearest location of suitable flow to the headwaters and downstream samples were taken before the next tributary flows into the creek. There are no known surface water diversion permits in effect along this portion of the creek. W1500 Creek and its sampling

points are depicted in Figure 1, Appendix Two, and Photograph 8 and Photograph 9, Appendix Three.

All water quality data for W1500 Creek were below relevant limits and guidelines with the following exceptions. Nitrate at the Lower W1500 sampling location in fall 2018 was 3.9 mg/L (guideline is 3 mg/L). Total phosphorus at the upstream location was over twice the quality objective of 0.01 mg/L in spring 2018; no clear pattern of downstream increases is observable for this parameter. pH at upstream and downstream locations in the fall was below the guideline range of 6.5 – 9.0. As mentioned previously, low pH surface water is common on Vancouver Island in forest environments.

For all parameters of interest (nitrogen, phosphorus, chloride, EC, OMRR trace elements, and fecal coliforms), concentrations at downstream sampling locations were, on average, observed to be lower in 40% of sample pairs, unchanged in 15% of sample pairs, and higher in 45% of sample pairs compared to the upstream sampling location. No parameter was consistently higher in downstream samples during all sampling events except nitrate. Nitrate increased between 1.0 – 1.9 mg/L at the downstream sampling location, and at fall sampling events increased to 70-130% of the guideline of 3 mg/L. Chloride increased at two out of three sampling events, although the increase was not significant. EC increased at three out of four sampling events but increases were modest (~30%) and all values remained below the ambient reference value of 100 µS/cm. Although for the majority of parameters the lack of exceedances and the pattern/incidence of change in parameter concentrations at the downstream sampling location do not suggest a negative effect on water quality from biosolids fertilization within the W1500 Creek drainage, the observed increase in nitrate at an intensively fertilized site is not unexpected.

All analytical data for W1500 Creek are presented in Table 8, Appendix One.

7 DISCUSSION SUMMARY

For the majority of parameters, no exceedances of regulatory limits or guidelines were observed. Excluding pH excursions from the guideline range of 6.5 – 9.0, only 10 measurements exceeded a guideline (1.7% of all measurements with a corresponding limit/guideline); no parameters exceeded a regulatory CSR limit in any sample. As mentioned previously, the exceedance of a guideline indicates only the *potential* for an issue and suggests that further investigation may be warranted. Parameters that exceeded guidelines include nitrate (2 events), total phosphorus (6 events), *E. coli* (1 event), and silver (1 event). The pattern or isolation of these exceedances do not suggest a consistent site-wide impact on water quality from biosolids.

Among the parameters of interest, total copper and electrical conductivity showed a tendency to increase at downstream sampling locations, although each was observed at only one sampling location (Caillet and W1500 creeks, respectively). Chloride increased at downstream sampling locations at seven out of nine events, although increases were generally quite small (<5%).

Nitrate was observed to increase at every sampling event at downstream locations in Caillet Creek and W1500 Creek. As previously mentioned, the observed increase in nitrate at an intensively fertilized site is not unexpected. All nitrate values remain below the reference value of

4 mg/L for fertilized forestry sites on Vancouver Island (Binkley et al., 1999), although two out of 12 nitrate measurements exceeded the long-term BCAWQG of 3 mg/L for protection of aquatic freshwater life. Nitrate concentrations in creeks located within the TimberWest Properties were between three times and 58 times the average nitrate concentration in Benson Creek, the control location. As previously mentioned, the BCAWQG for nitrate are intended to be applied to a large dataset resulting from regular (e.g., daily) monitoring of surface water nitrate. The number of samples included in this analysis is not large (12 treatment samples, 2 control samples) and it is expected that this analysis will be refined following further sample collection.

Overall, the available data suggest that biosolids is not having a negative impact on surface water quality with the possible exception of nitrate, which is expected for an intensively fertilized coastal site.

8 DATA QUALITY CONTROL

Analysis of relative percent difference (RPD) was performed on a pair of duplicate samples from Benson Creek. Due to the low concentrations, RPD values were not available for most parameters of interest (RPD should not be performed where one value is less than five times the laboratory detection limit) (BC Ministry of Environment and Climate Change Strategy, 2013). EC and chloride showed the most variability between duplicate samples (30% and 49%, respectively). RPD values > 50% indicate a potential problem with the sampling approach; in the future additional duplicate samples will be collected in order to assess whether a change in sampling methodology is required.

9 OTHER REPORTS

Assessments of potential effects of biosolids on groundwater quality have been made twice in the past, in 2003 and 2012 (Dakin, 2003; Cleary and Tiplady, 2012). Both reports concluded that application of biosolids had low potential for impact on groundwater wells located in the vicinity of the TimberWest Properties.

In 2014, SYLVIS completed an enhanced surface water quality monitoring project in response to a concern from a property owner directly east (downhill) from the TimberWest Properties. Water quality in Caillet Creek and in a ditch on the neighboring property were sampled over a five-month period to investigate whether there were any effects from biosolids stockpiles and applications. Similar to results presented in this report, all parameters investigated (nutrients, chloride, caffeine) were below relevant guidelines while some parameters (nitrate, chloride) showed small increases in downstream samples (SYLVIS Environmental, 2014).

10 CONCLUSION

Data from two years of surface water monitoring at the TimberWest Properties suggest that there is no adverse effect on surface water quality from biosolids stockpiling or land applications with the possible exception of nitrate.

11 REFERENCES

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APPENDIX ONE – TABLES

Table 1: Surface water sampling locations at the TimberWest Properties.

Creek	Location	Coordinates	In Biosolids Area
Flynfall Creek	Upstream	49°11'50.24"N, 124° 7'8.61"W	Yes
	Downstream	49°11'30.86"N, 124° 6'13.96"W	Yes
Caillet Creek	Upstream	49°12'25.57"N, 124° 6'27.87"W	Yes
	Downstream	49°12'23.80"N, 124° 5'22.96"W	Yes
Bonnell Creek	Upstream	49°11'54.26"N, 124° 7'40.79"W	Yes
	Downstream	49°11'57.46"N, 124° 7'51.20"W	Yes
W1500 Creek	Upstream	49°12'22.78"N, 124° 7'13.78"W	Yes
	Downstream	49°12'39.87"N, 124° 6'34.74"W	Yes
Benson Creek	-	49°11'15.34"N, 124° 4'47.58"W	No

Table 2: Frequency of sampling at TimberWest Properties surface water sampling points, 2017-2018.

Location	Period			
	2017		2018	
	Spring	Fall	Spring	Fall
Caillet Creek Upper	✓	✓	✓	✓
Caillet Creek Lower	✓	✓	✓	✓
Flynfall Creek Upper	✓	✓	✓	✓
Flynfall Creek Lower	✓	✓	✓	✓
Bonnell Creek Upper		✓	✓	✓
Bonnell Creek Lower		✓	✓	✓
W1500 Creek Upper	✓	✓	✓	✓
W1500 Creek Lower	✓	✓	✓	✓
Benson Creek		✓	✓	✓

Note: Samples in spring 2017 were collected by Vancouver Island University.

Table 3: Precipitation during two weeks prior to sampling event. (Nanaimo City Yard weather data)

Sampling Date	Previous 14 days of precipitation
25-Apr-17	54.5 mm
23-Nov-17	213.4 mm
13-Dec-17	22.6 mm
1-May-18	15.9 mm
19-Nov-18	24.1 mm

Table 4: Surface water quality data from Benson Creek, 2018.

Date	Units	1-May-18	19-Nov-18	Water Quality Guidelines[a]	CSR Limits[b]
Sample Location		**Benson Creek**	**Benson Creek**		
Inorganic Nonmetallic Parameters					
Total Kjeldahl Nitrogen	mg/L	0.10	0.14	-	-
Total Organic Carbon	mg/L	3.5	4.2	-	-
Ammonia + Ammonium - N	mg/L	< 0.01 (18.4)	< 0.01 (17.1)	calculated[c]	18.4
Nitrate - N	mg/L	0.03	0.10	3[d]	40[d]
Nitrite - N	mg/L	< 0.003 (0.06)	< 0.003 (0.06)	calculated[c]	
Orthophosphate-P (dissolved)	mg/L	< 0.002	< 0.002		-
Phosphorus (total dissolved)	mg/L	0.005	< 0.003	-	-
Phosphorus (total)	mg/L	0.005	< 0.003	0.01[e]	-
Trace Elements Total					
Aluminum Al - total	µg/L	41	64	-	-
Arsenic As - total	µg/L	0.06	0.10	5	15
Boron B - total	µg/L	4	24	1,200	12,000
Cadmium Cd - total	µg/L	< 0.01 (0.18)	0.01 (0.22)	calculated[f]	
Chromium Cr - total	µg/L	< 0.5	0.2	1[f]	10
Cobalt Co - total	µg/L	< 0.10	0.06	110	40
Copper Cu - total	µg/L	0.6 (2.8)	0.9 (3.0)	calculated[c]	
Iron Fe - total	µg/L	9	17	1,000	-
Lead Pb - total	µg/L	< 0.01 (3.8)	< 0.01 (4.7)	calculated[c]	
Manganese Mn - total	µg/L	2.2 (639)	< 1.0 (658)	calculated	-
Mercury Hg - total	µg/L	< 0.01	< 0.01	0.02	0.25
Molybdenum Mo - total	µg/L	< 0.05	0.04	2,000	10,000
Nickel Ni - total	µg/L	0.4 (250)	0.3 (250)	-	calculated
Selenium Se - total	µg/L	< 0.1	< 0.2	2	20
Silver Ag - total	µg/L	< 0.05 (0.1)	0.07 (0.1)	calculated	-
Zinc Zn - total	µg/L	0.5 (33.0)	0.8 (33.0)	calculated	-
Routine Water					
pH (Laboratory)	pH at 25° C	7.1	7.0	6.5 - 9.0	-
Electrical Conductivity	µS/cm at 25° C	23	28	-	-
Calcium (total)	mg/L	2.5	2.9	-	-
Magnesium (total)	mg/L	0.7	0.8	-	-
Potassium (total)	mg/L	0.20	0.09	-	-
Sodium (total)	mg/L	1.2	1.3	-	-
Sulphur (total)	mg/L	0.4	0.4	-	-
Chloride (dissolved)	mg/L	0.88	1.36	5	1,500
Hardness (total)	mg $CaCO_3$/L	9	11	-	-
Microbiological Analysis					
Escherichia coli	MPN/100 ml	< 1	1	77[g]	-
Fecal Coliforms	MPN/100 ml	1	< 1	200[g]	-

Note: Exceedances of guidelines are shown in bold type. Calculated limits or limits are shown in brackets next to the parameter value.

a - Unless otherwise noted, British Columbia Approved Water Quality Guideline for protection of freshwater aquatic life.

b - Contaminated Sites Regulation limits for protection of freshwater aquatic life, Schedule 3.2.

c - The lowest calculated limit/guideline is shown in brackets next to the parameter value.

d - Guideline represents 30-day mean guideline; CSR limit represents a 10:1 dilution from original value of 400 mg/L as per CSR guidance.

e - Guideline value is a water quality objective for Vancouver Island streams from BC Ministry of Environment (2014).

f - Guideline value is the Canadian Council of Ministers of the Environment Water Quality Guideline for protection of freshwater aquatic life.

g - British Columbia Approved Water Quality Guideline for recreation/aesthetics primary contact.

Table 5: Surface water quality data from Flynfall Creek, 2017-2018.

Date	Units	25-Apr-17	25-Apr-17	23-Nov-17	23-Nov-17	1-May-18	1-May-18	19-Nov-18	19-Nov-18	Water Quality Guidelines[a]	CSR Limits[b]
Sample Location		**Flynfall Upper**	**Flynfall Lower**	**Flynfall Upper**	**Flynfall Lower**	**Flynfall Upper**	**Flynfall Lower**	**Flynfall Upper**	**Flynfall Lower**		
Inorganic Nonmetallic Parameters											
Total Kjeldahl Nitrogen	mg/L	-	-	0.23	0.19	< 0.07	< 0.07	0.56	0.24	-	-
Total Organic Carbon	mg/L	-	-	4.0	2.9	2.0	1.6	2.1	1.6	-	-
Ammonia + Ammonium - N	mg/L	-	-	< 0.01 (18.4)	< 0.01 (18.4)	< 0.01 (18.4)	< 0.01 (18.4)	< 0.01 (18.4)	< 0.01 (18.4)	calculated[c]	18.4
Nitrate - N	mg/L	-	-	0.5	0.8	0.2	0.2	**3.4**	1.5	3[d]	40[d]
Nitrite - N	mg/L	-	-	0.003 (0.06)	0.05 (0.06)	< 0.003 (0.06)	< 0.003 (0.06)	< 0.003 (0.12)	< 0.003 (0.06)	calculated[c]	
Orthophosphate-P (dissolved)	mg/L	-	-	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002		-
Phosphorus (total dissolved)	mg/L	-	-	0.004	< 0.003	0.003	0.004	< 0.003	< 0.003	-	-
Phosphorus (total)	mg/L	-	-	0.006	0.006	0.004	< 0.003	< 0.003	< 0.003	0.01[e]	-
Trace Elements Total											
Aluminum Al - total	µg/L	33	15	62	38	26	13	23	12	-	-
Arsenic As - total	µg/L	< 0.10	< 0.10	< 0.10	< 0.10	< 0.05	< 0.05	< 0.10	< 0.10	5	15
Boron B - total	µg/L	< 50	< 50	4	13	6	26	8	28	1,200	12,000
Cadmium Cd - total	µg/L	< 0.010 (0.40)	< 0.010 (0.40)	< 0.01 (0.33)	0.01 (0.41)	< 0.01 (0.41)	< 0.01 (0.41)	0.03 (0.50)	0.02 (0.50)	calculated[f]	
Chromium Cr - total	µg/L	< 1.0	< 1.0	0.1	0.1	< 0.5	< 0.5	0.1	0.1	1[f]	10
Cobalt Co - total	µg/L	< 0.20	< 0.20	0.06	0.05	< 0.10	< 0.10	0.06	0.09	110	40
Copper Cu - total	µg/L	< 0.5 (3.8)	< 0.5 (3.8)	0.7 (3.5)	2.8 (3.9)	0.6 (3.9)	0.4 (3.9)	0.3 (4.7)	0.3 (4.4)	calculated[c]	
Iron Fe - total	µg/L	13	< 10	17	21	9	5	2	< 2	1,000	-
Lead Pb - total	µg/L	-	-	< 0.01 (7.9)	< 0.01 (10.5)	< 0.01 (10.5)	< 0.01 (10.5)	< 0.01 (16.9)	< 0.01 (14.7)	calculated[c]	
Manganese Mn - total	µg/L	< 1.0 (755)	< 1.0 (756)	1.0 (716)	2.0 (760)	< 1.0 (760)	< 1.0 (760)	< 1.0 (860)	< 1.0 (827)	calculated	-
Mercury Hg - total	µg/L	-	-	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.02	0.25
Molybdenum Mo - total	µg/L	< 1.00	< 1.00	< 0.02	< 0.02	< 0.05	< 0.05	0.05	0.04	2,000	10,000
Nickel Ni - total	µg/L	< 1.0 (250)	< 1.0 (250)	0.7 (250)	0.4 (250)	1.6 (250)	0.4 (250)	0.6 (250)	< 0.2 (250)	-	calculated
Selenium Se - total	µg/L	< 0.1	< 0.1	< 0.2	< 0.2	< 0.1	< 0.1	< 0.2	< 0.2	2	20
Silver Ag - total	µg/L	< 0.02 (0.1)	< 0.02 (0.1)	0.01 (0.1)	0.01 (0.1)	< 0.05 (0.1)	< 0.05 (0.1)	0.09 (0.1)	0.08 (0.1)	calculated	-
Zinc Zn - total	µg/L	< 5.0 (33.0)	< 5.0 (33.0)	1.0 (33.0)	2.7 (33.0)	1.3 (33.0)	0.8 (33.0)	< 0.5 (33.0)	< 0.5 (33.0)	calculated	-
Routine Water											
pH (Laboratory)	pH at 25° C	7.0	7.2	6.5	7.0	6.9	7.2	**6.4**	7.0	6.5 - 9.0	-
Electrical Conductivity	µS/cm at 25° C	48	50	43	50	56	52	79	66	-	-
Calcium (total)	mg/L	5.7	5.7	4.5	5.6	5.7	5.9	8.5	7.4	-	-
Magnesium (total)	mg/L	1.3	1.3	1.1	1.4	1.3	1.3	2.0	1.8	-	-
Potassium (total)	mg/L	0.10	0.09	0.17	0.20	0.10	< 0.10	0.13	0.15	-	-
Sodium (total)	mg/L	2.2	2.0	2.1	2.2	2.1	2.1	2.4	2.5	-	-
Sulphur (total)	mg/L	< 3.0	< 3.0	2.1	2.0	3.1	2.0	2.8	2.1	-	-
Chloride (dissolved)	mg/L	-	-	1.56	1.57	1.13	1.18	2.42	1.76	5	1,500
Hardness (total)	mg $CaCO_3$/L	20	20	16	20	20	20	29	26	-	-
Microbiological Analysis											
Escherichia coli	MPN/100 ml	-	-	1	4	< 1	< 1	**173**	1	77[g]	-
Fecal Coliforms	MPN/100 ml	< 1	< 1	2	1	< 1	< 1	161	< 1	200[g]	-

Note: Exceedances are shown in bold type. Calculated limits or limits are shown in brackets next to the parameter value.

a - Unless otherwise noted, British Columbia Approved Water Quality Guideline for protection of freshwater aquatic life.

b - Contaminated Sites Regulation limits for protection of freshwater aquatic life, Schedule 3.2.

c - The lowest calculated limit/guideline is shown in brackets next to the parameter value.

d - Guideline represents 30-day mean guideline; CSR limit represents a 10:1 dilution from original value of 400 mg/L as per guidance.

e - Guideline value is a water quality objective for Vancouver Island streams from BC Ministry of Environment (2014).

f - Guideline value is the CCME Water Quality Guideline for protection of freshwater aquatic life.

g - British Columbia Approved Water Quality Guideline for recreation/aesthetics primary contact.

Table 6: Surface water quality data from Caillet Creek, 2017-2018.

Date	Units	25-Apr-17	25-Apr-17	23-Nov-17	23-Nov-17	1-May-18	1-May-18	19-Nov-18	19-Nov-18	Water Quality Guidelines[a]	CSR Limits[b]
Sample Location		**Upper Caillet**	**Lower Caillet**	**Upper Caillet**	**Lower Caillet**	**Upper Caillet**	**Lower Caillet**	**Upper Caillet**	**Lower Caillet**		
Inorganic Nonmetallic Parameters											
Total Kjeldahl Nitrogen	mg/L	-	-	0.34	0.21	< 0.07	< 0.07	0.44	0.53	-	-
Total Organic Carbon	mg/L	-	-	3.0	3.0	2.3	1.6	3.0	2.0	-	-
Ammonia + Ammonium - N	mg/L	-	-	< 0.01 (18.4)	< 0.01 (18.4)	< 0.01 (18.4)	< 0.01 (18.4)	< 0.01 (18.4)	< 0.01 (16.5)	calculated[c]	18.4
Nitrate - N	mg/L	-	-	1.7	2.4	0.6	0.9	2.0	2.7	3[d]	40[d]
Nitrite - N	mg/L	-	-	< 0.003 (0.12)	< 0.003 (0.12)	< 0.003 (0.06)	< 0.003 (0.06)	< 0.003 (0.06)	< 0.003 (0.12)	calculated[c]	
Orthophosphate-P (dissolved)	mg/L	-	-	< 0.002	0.003	< 0.002	< 0.002	< 0.002	< 0.002		-
Phosphorus (total dissolved)	mg/L	-	-	0.004	0.005	0.007	0.003	< 0.003	< 0.003	-	-
Phosphorus (total)	mg/L	-	-	0.006	0.005	< 0.003	< 0.003	< 0.003	< 0.003	0.01[e]	-
Trace Elements Total											
Aluminum Al - total	µg/L	24	26	31	23	43	10	36	22	-	-
Arsenic As - total	µg/L	< 0.10	< 0.10	< 0.10	< 0.10	0.06	< 0.05	< 0.10	< 0.10	5	15
Boron B - total	µg/L	< 50	< 50	6	8	6	6	8	6	1,200	12,000
Cadmium Cd - total	µg/L	< 0.01 (0.50)	< 0.01 (0.43)	< 0.01 (0.47)	< 0.01 (0.50)	< 0.01 (0.50)	< 0.01 (0.50)	< 0.01 (0.68)	< 0.01 (0.62)	calculated[f]	
Chromium Cr - total	µg/L	< 1.0	< 1.0	0.1	0.1	< 0.5	< 0.5	0.2	0.1	1[f]	10
Cobalt Co - total	µg/L	< 0.20	< 0.20	0.03	0.04	< 0.10	< 0.10	0.04	0.02	110	40
Copper Cu - total	µg/L	< 0.5 (4.5)	0.6 (4.0)	0.4 (4.2)	0.7 (4.4)	0.4 (4.6)	0.5 (4.4)	0.3 (5.1)	0.4 (4.8)	calculated[c]	
Iron Fe - total	µg/L	26	< 10	18	12	50	9	30	4	1,000	-
Lead Pb - total	µg/L	-	-	< 0.01 (12.6)	< 0.01 (14.7)	< 0.01 (16.1)	< 0.01 (14.0)	< 0.01 (19.9)	< 0.01 (17.6)	calculated[c]	
Manganese Mn - total	µg/L	1.8 (833)	< 1.0 (773)	1.0 (793)	< 1.0 (827)	2.8 (849)	< 1.0 (816)	< 1.0 (904)	< 1.0 (871)	calculated	-
Mercury Hg - total	µg/L	-	-	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.02	0.25
Molybdenum Mo - total	µg/L	< 1.00	< 1.00	< 0.02	0.02	< 0.05	< 0.05	< 0.02	< 0.02	2,000	10,000
Nickel Ni - total	µg/L	< 1.0 (250)	< 1.0 (250)	0.6 (250)	0.9 (250)	1 (250)	0.5 (250)	1.1 (250)	0.4 (250)	-	calculated
Selenium Se - total	µg/L	< 0.1	< 0.1	< 0.2	< 0.2	< 0.1	< 0.1	< 0.2	< 0.2	2	20
Silver Ag - total	µg/L	< 0.02 (0.1)	< 0.02 (0.1)	0.01 (0.1)	0.02 (0.1)	< 0.05 (0.1)	< 0.05 (0.1)	0.04 (0.1)	0.03 (0.1)	calculated	-
Zinc Zn - total	µg/L	< 5.0 (33.0)	< 5.0 (33.0)	0.5 (33.0)	2.4 (33.0)	0.8 (33.0)	0.7 (33.0)	0.8 (33.0)	< 0.5 (33.0)	calculated	-
Routine Water											
pH (Laboratory)	pH at 25° C	7.1	7.0	6.6	7.1	7.2	7.2	6.8	6.9	6.5 - 9.0	-
Electrical Conductivity	µS/cm at 25° C	71	56	62	68	72	67	82	81	-	-
Calcium (total)	mg/L	7.7	6.3	6.6	7.3	8.1	7.5	9.6	8.7	-	-
Magnesium (total)	mg/L	1.8	1.3	1.7	1.8	1.9	1.6	2.2	1.9	-	-
Potassium (total)	mg/L	0.16	0.10	0.24	0.24	0.20	0.20	0.23	0.14	-	-
Sodium (total)	mg/L	2.7	2.3	2.7	2.7	2.7	2.6	3.0	2.7	-	-
Sulphur (total)	mg/L	3.8	3.2	3.0	3.0	4.2	4.2	4.2	3.9	-	-
Chloride (dissolved)	mg/L	-	-	2.02	2.13	1.50	1.54	1.98	2.01	5	1,500
Hardness (total)	mg $CaCO_3$/L	27	21	23	26	28	25	33	30	-	-
Microbiological Analysis											
Escherichia coli	MPN/100 ml	-	-	12	11	1	< 1	5	1	77[g]	-
Fecal Coliforms	MPN/100 ml	< 1	< 1	26	12	2	< 1	3	< 1	200[g]	-

Note: Exceedances are shown in bold type. Calculated limits or limits are shown in brackets next to the parameter value.

a - Unless otherwise noted, British Columbia Approved Water Quality Guideline for protection of freshwater aquatic life.

b - Contaminated Sites Regulation limits for protection of freshwater aquatic life, Schedule 3.2.

c - The lowest calculated limit/guideline is shown in brackets next to the parameter value.

d - Guideline represents 30-day mean guideline; CSR limit represents a 10:1 dilution from original value of 400 mg/L as per guidance.

e - Guideline value is a water quality objective for Vancouver Island streams from BC Ministry of Environment (2014).

f - Guideline value is the CCME Water Quality Guideline for protection of freshwater aquatic life.

g - British Columbia Approved Water Quality Guideline for recreation/aesthetics primary contact.

Table 7: Surface water quality data from Bonnell Creek, 2017-2018.

Date	Units	25-Apr-17	25-Apr-17	23-Nov-17	23-Nov-17	1-May-18	1-May-18	19-Nov-18	19-Nov-18	Water Quality Guidelines[a]	CSR Limits[b]
Sample Location		**Upper Bonnell**	**Lower Bonnell**	**Upper Bonnell**	**Lower Bonnell**	**Upper Bonnell**	**Lower Bonnell**	**Upper Bonnell**	**Lower Bonnell**		
Inorganic Nonmetallic Parameters											
Total Kjeldahl Nitrogen	mg/L	-	-	0.32	0.26	0.53	0.28	0.87	0.48	-	-
Total Organic Carbon	mg/L	-	-	7.4	6.3	15.2	9.8	18.7	12.6	-	-
Ammonia + Ammonium - N	mg/L	-	-	< 0.01 (18.4)	< 0.01 (18.4)	< 0.01 (18.4)	< 0.01 (18.4)	0.05 (18.4)	< 0.01 (18.4)	calculated[c]	18.4
Nitrate - N	mg/L	-	-	0.5	0.2	< 0.01	0.03	1.9	1.2	3[d]	40[d]
Nitrite - N	mg/L	-	-	0.006 (0.06)	0.004 (0.06)	0.004 (0.06)	< 0.003 (0.06)	0.006 (0.12)	0.003 (0.12)	calculated[c]	
Orthophosphate-P (dissolved)	mg/L	-	-	< 0.002	< 0.002	0.010	0.005	0.006	< 0.002		-
Phosphorus (total dissolved)	mg/L	-	-	0.009	0.005	0.028	0.013	0.015	0.007	-	-
Phosphorus (total)	mg/L	-	-	**0.011**	0.009	**0.035**	**0.016**	**0.015**	**0.027**	0.01[e]	-
Trace Elements Total											
Aluminum Al - total	µg/L	-	-	82	90	179	140	220	180	-	-
Arsenic As - total	µg/L	-	-	< 0.10	0.10	0.23	0.16	0.30	0.20	5	15
Boron B - total	µg/L	-	-	4	5	5	9	5	10	1,200	12,000
Cadmium Cd - total	µg/L	-	-	< 0.01 (0.31)	< 0.01 (0.26)	0.01 (0.33)	< 0.01 (0.31)	0.02 (0.50)	0.06 (0.45)	calculated[f]	
Chromium Cr - total	µg/L	-	-	0.2	0.1	< 0.5	< 0.5	0.3	0.3	1[f]	10
Cobalt Co - total	µg/L	-	-	0.07	0.04	0.40	< 0.10	0.26	0.19	110	40
Copper Cu - total	µg/L	-	-	0.5 (3.4)	0.5 (3.2)	0.9 (3.5)	0.7 (3.4)	1.2 (4.5)	0.9 (4.1)	calculated[c]	
Iron Fe - total	µg/L	-	-	49	47	294	123	280	160	1,000	-
Lead Pb - total	µg/L	-	-	< 0.01 (7.3)	< 0.01 (5.8)	0.01 (7.9)	< 0.01 (7.3)	< 0.01 (15.4)	< 0.01 (11.9)	calculated[c]	
Manganese Mn - total	µg/L	-	-	6.0 (705)	2.0 (679)	43.6 (716)	6.4 (705)	25.0 (838)	8.0 (782)	calculated	-
Mercury Hg - total	µg/L	-	-	< 0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01	0.02	0.25
Molybdenum Mo - total	µg/L	-	-	< 0.02	< 0.02	< 0.05	< 0.05	0.03	0.07	2,000	10,000
Nickel Ni - total	µg/L	-	-	< 0.2 (250)	0.3 (250)	0.4 (250)	0.3 (250)	0.5 (250)	0.4 (250)	-	calculated
Selenium Se - total	µg/L	-	-	< 0.2	< 0.2	< 0.1	< 0.1	< 0.2	< 0.2	2	20
Silver Ag - total	µg/L	-	-	0.02 (0.1)	0.01 (0.1)	< 0.05 (0.1)	< 0.05 (0.1)	0.08 (0.1)	**0.13 (0.1)**	calculated	-
Zinc Zn - total	µg/L	-	-	0.8 (33.0)	< 0.5 (33.0)	0.9 (33.0)	< 0.7 (33.0)	0.7 (33.0)	0.9 (33.0)	calculated	-
Routine Water											
pH (Laboratory)	pH at 25° C	-	-	**6.1**	**6.4**	7.1	7.1	**6.0**	6.5	6.5 - 9.0	-
Electrical Conductivity	µS/cm at 25° C	-	-	40	33	36	35	65	54	-	-
Calcium (total)	mg/L	-	-	4.2	3.5	4.8	4.5	7.9	6.4	-	-
Magnesium (total)	mg/L	-	-	1.2	0.9	1.1	1.0	1.9	1.5	-	-
Potassium (total)	mg/L	-	-	0.09	0.09	0.20	0.10	0.14	0.12	-	-
Sodium (total)	mg/L	-	-	1.6	1.5	1.8	1.8	2.2	2.1	-	-
Sulphur (total)	mg/L	-	-	2.1	1.4	0.6	0.7	2.6	2.0	-	-
Chloride (dissolved)	mg/L	-	-	1.42	1.46	1.20	1.12	2.28	2.01	5	1,500
Hardness (total)	mg $CaCO_3$/L	-	-	15	13	16	15	27	22	-	-
Microbiological Analysis											
Escherichia coli	MPN/100 ml	-	-	1	1	1	< 1	2	4	77[g]	-
Fecal Coliforms	MPN/100 ml	-	-	3	3	< 1	< 1	10	< 1	200[g]	-

Note: Exceedances are shown in bold type. Calculated limits or limits are shown in brackets next to the parameter value.
a - Unless otherwise noted, British Columbia Approved Water Quality Guideline for protection of freshwater aquatic life.
b - Contaminated Sites Regulation limits for protection of freshwater aquatic life, Schedule 3.2.
c - The lowest calculated limit/guideline is shown in brackets next to the parameter value.
d - Guideline represents 30-day mean guideline; CSR limit represents a 10:1 dilution from original value of 400 mg/L as per guidance.
e - Guideline value is a water quality objective for Vancouver Island streams from BC Ministry of Environment (2014).
f - Guideline value is the CCME Water Quality Guideline for protection of freshwater aquatic life.
g - British Columbia Approved Water Quality Guideline for recreation/aesthetics primary contact.

Table 8: Surface water quality data from W1500 Creek, 2017-2018.

Date	Units	25-Apr-17	25-Apr-17	13-Dec-17	13-Dec-17	1-May-18	1-May-18	19-Nov-18	19-Nov-18	Water Quality Guidelines[a]	CSR Limits[b]
Sample Location		**Upper W1500**	**Lower W1500**	**Upper 1500**	**Lower 1500**	**Upper W1500**	**Lower W1500**	**Upper W1500**	**Lower W1500**		
Inorganic Nonmetallic Parameters											
Total Kjeldahl Nitrogen	mg/L	-	-	< 0.07	0.35	0.07	< 0.07	0.43	0.68	-	-
Total Organic Carbon	mg/L	-	-	3.6	2.2	3.2	2.0	3.9	2.4	-	-
Ammonia + Ammonium - N	mg/L	-	-	0.01 (18.4)	0.02 (18.4)	< 0.01 (18.4)	< 0.01 (18.4)	< 0.01 (18.4)	< 0.01 (18.4)	calculated[c]	18.4
Nitrate - N	mg/L	-	-	1.0	2.1	0.2	1.2	2.0	**3.9**	3[d]	40[d]
Nitrite - N	mg/L	-	-	< 0.003 (0.06)	< 0.003 (0.12)	< 0.003 (0.06)	< 0.003 (0.06)	< 0.003 (0.12)	< 0.003 (0.06)	calculated[c]	
Orthophosphate-P (dissolved)	mg/L	-	-	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002		-
Phosphorus (total dissolved)	mg/L	-	-	0.006	0.010	0.012	0.003	< 0.003	< 0.003	-	-
Phosphorus (total)	mg/L	-	-	0.005	0.006	**0.025**	0.004	< 0.003	< 0.003	0.01[e]	-
Trace Elements Total											
Aluminum Al - total	µg/L	34	48	24	25	41	16	46	15	-	-
Arsenic As - total	µg/L	< 0.10	< 0.10	< 0.10	< 0.10	< 0.06	< 0.05	< 0.10	< 0.10	5	15
Boron B - total	µg/L	< 50	< 50	6	8	4	7	6	10	1,200	12,000
Cadmium Cd - total	µg/L	< 0.01 (0.50)	< 0.01 (0.44)	< 0.01 (0.50)	0.02 (0.62)	< 0.01 (0.39)	< 0.01 (0.50)	< 0.01 (0.50)	< 0.01 (0.76)	calculated[f]	
Chromium Cr - total	µg/L	< 1.0	< 1.0	0.1	0.1	< 0.5	< 0.5	0.1	0.1	1[f]	10
Cobalt Co - total	µg/L	< 0.20	< 0.20	0.03	0.09	< 0.10	< 0.10	0.06	0.03	110	40
Copper Cu - total	µg/L	0.6 (4.3)	0.5 (4.0)	0.6 (4.7)	0.6 (4.8)	0.6 (3.8)	0.4 (4.4)	0.7 (4.4)	1.1 (5.5)	calculated[c]	
Iron Fe - total	µg/L	< 10	39	17	9	9	4	10	3	1,000	-
Lead Pb - total	µg/L	-	-	< 0.01 (16.9)	< 0.01 (17.6)	< 0.01 (9.9)	< 0.01 (14.7)	< 0.01 (14.7)	< 0.01 (23.0)	calculated[c]	
Manganese Mn - total	µg/L	< 1.0 (812)	1.5 (778)	< 1.0 (860)	3.0 (871)	2.2 (749)	< 1.0 (827)	< 1.0 (827)	< 1.0 (948)	calculated	-
Mercury Hg - total	µg/L	-	-	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.02	0.25
Molybdenum Mo - total	µg/L	< 1.00	< 1.00	< 0.02	< 0.02	< 0.05	< 0.05	< 0.02	< 0.02	2,000	10,000
Nickel Ni - total	µg/L	< 1.0 (250)	1 (250)	< 0.2 (250)	< 0.2 (250)	0.4 (250)	< 0.2 (250)	0.3 (250)	0.2 (250)	-	calculated
Selenium Se - total	µg/L	< 0.1	< 0.1	< 0.2	< 0.2	< 0.1	< 0.1	< 0.2	< 0.2	2	20
Silver Ag - total	µg/L	< 0.02 (0.1)	< 0.02 (0.1)	< 0.01 (0.1)	0.02 (0.1)	< 0.05 (0.1)	< 0.05 (0.1)	0.04 (0.1)	0.02 (0.1)	calculated	-
Zinc Zn - total	µg/L	< 5.0 (33.0)	< 5.0 (33.0)	0.9 (33.0)	0.5 (33.0)	0.5 (33.0)	0.6 (33.0)	< 0.5 (33.0)	< 0.5 (33.0)	calculated	-
Routine Water											
pH (Laboratory)	pH at 25° C	7.1	7.3	**6.2**	**6.4**	7.0	7.2	**6.3**	6.9	6.5 - 9.0	-
Electrical Conductivity	µS/cm at 25° C	63	52	56	75	53	69	71	93	-	-
Calcium (total)	mg/L	7.2	6.4	8.5	8.8	5.7	7.8	7.7	11.0	-	-
Magnesium (total)	mg/L	1.6	1.3	1.9	1.9	1.3	1.6	1.7	2.3	-	-
Potassium (total)	mg/L	0.17	0.09	0.20	0.18	0.20	0.20	0.13	0.18	-	-
Sodium (total)	mg/L	2.8	2.1	2.8	2.8	2.3	2.6	2.6	2.9	-	-
Sulphur (total)	mg/L	4.1	< 3.0	3.6	3.5	3.1	3.7	3.3	3.7	-	-
Chloride (dissolved)	mg/L	-	-	1.85	2.36	1.36	1.39	2.09	1.93	5	1,500
Hardness (total)	mg $CaCO_3$/L	25	22	29	30	19	26	26	37	-	-
Microbiological Analysis											
Escherichia coli	MPN/100 ml	-	-	4	24	1	5	8	16	77[g]	-
Fecal Coliforms	MPN/100 ml	< 1	1	7	15	< 1	< 1	10	12	200[g]	-

Note: Exceedances are shown in bold type. Calculated limits or limits are shown in brackets next to the parameter value.

a - Unless otherwise noted, British Columbia Approved Water Quality Guideline for protection of freshwater aquatic life.

b - Contaminated Sites Regulation limits for protection of freshwater aquatic life, Schedule 3.2.

c - The lowest calculated limit/guideline is shown in brackets next to the parameter value.

d - Guideline represents 30-day mean guideline; CSR limit represents a 10:1 dilution from original value of 400 mg/L as per guidance.

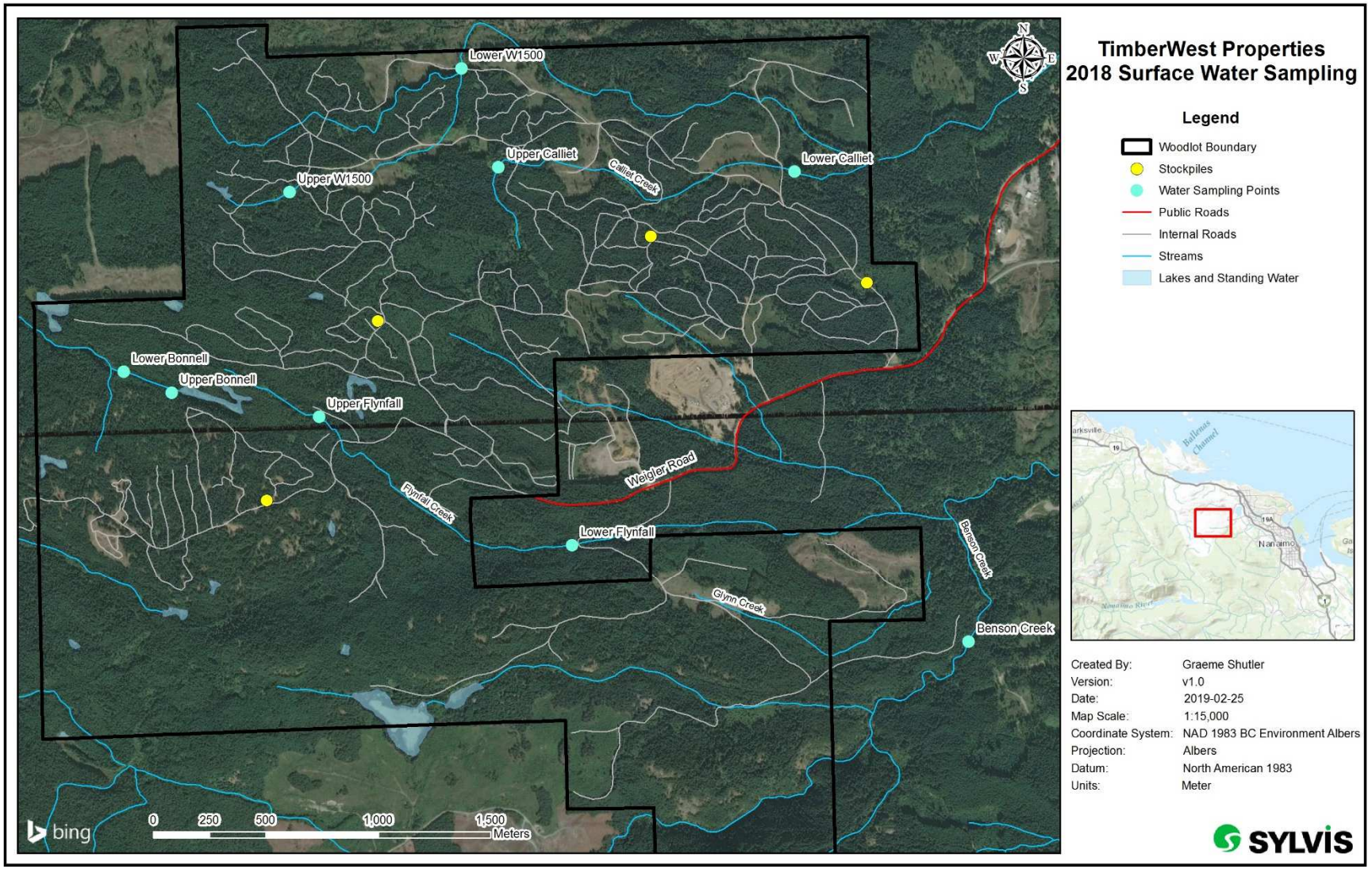
e - Guideline value is a water quality objective for Vancouver Island streams from BC Ministry of Environment (2014).

f - Guideline value is the CCME Water Quality Guideline for protection of freshwater aquatic life.

g - British Columbia Approved Water Quality Guideline for recreation/aesthetics primary contact.

APPENDIX TWO – FIGURES

Figure 1: Overview of sampling locations at the TimberWest Properties.



APPENDIX THREE – PHOTOGRAPHS

Photograph 1: Benson Creek sampling location. (November 2018)

Photograph 2: Upper Flynfall Creek sampling location. (November 2018)

Photograph 3: Lower Flynfall Creek sampling location. (November 2018)

Photograph 4: Upper Caillet Creek sampling location. (November 2018)

Photograph 5: Lower Caillet Creek sampling location. (November 2018)

Photograph 6: Upper Bonnell Creek sampling location. (November 2018)

Photograph 7: Lower Bonnell Creek sampling location. (November 2018)

Photograph 8: Upper W1500 Creek sampling location. (November 2018)

Photograph 9: Lower W1500 Creek sampling location.(November 2018)