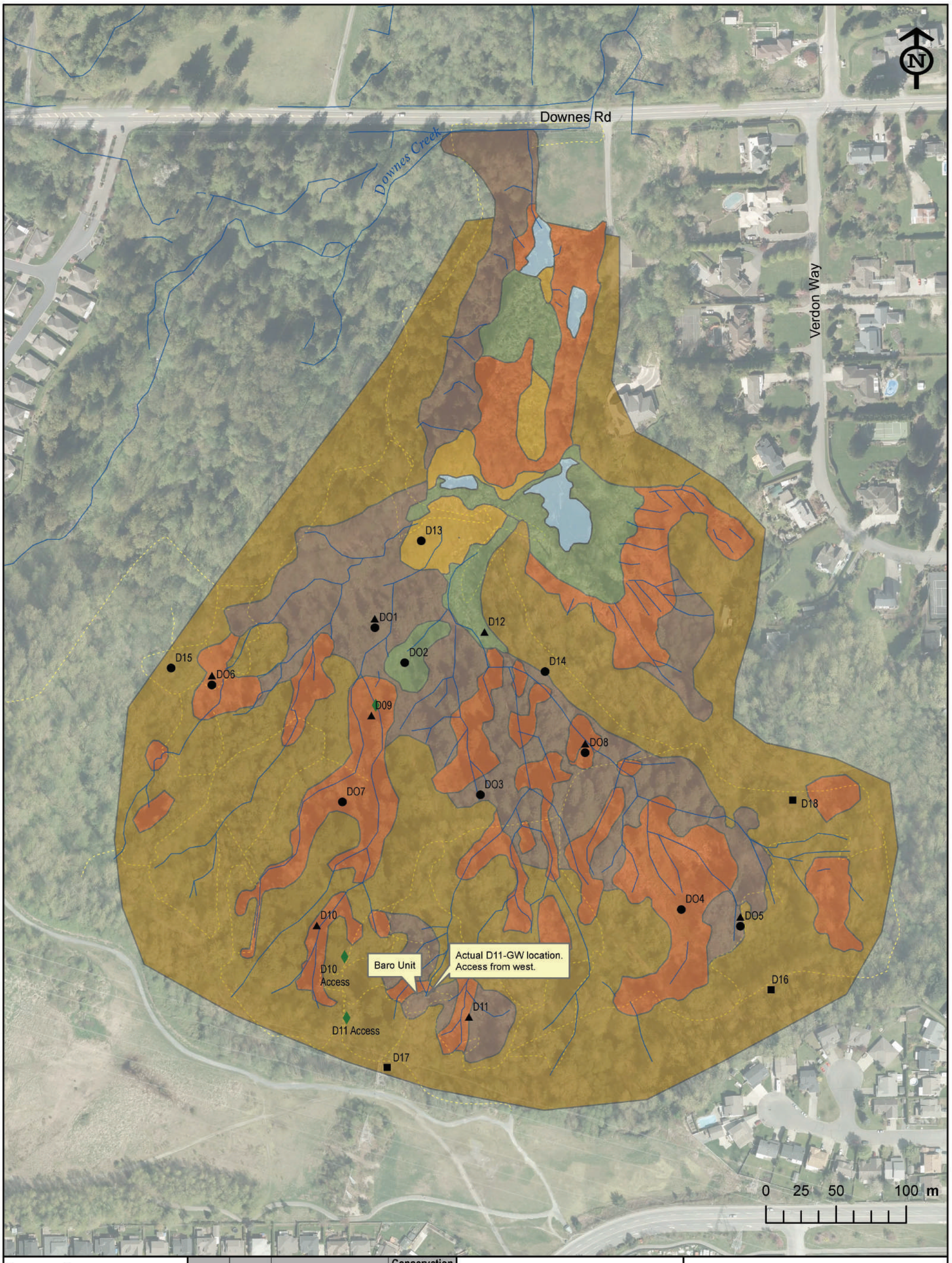


Legend

- TEM Plots
- Indicator plant plot & shallow groundwater well
- Snail plot
- Plot access
- Trail
- Watercourse

	Code	Site Series	Conservation Status
	OW	Shallow open water	NA
	Ws51	Sitka willow-Pacific willow-skunk cabbage	Red Listed
	Ws52	Red alder- skunk cabbage swamp	Red Listed
	Ws53	Western redcedar-swordfern - skunk cabbage	Blue Listed
	Wm05	Cattail marsh	Blue Listed
	07	Western redcedar-foamflower	Blue Listed

Prepared by:
ENKON Environmental Ltd.

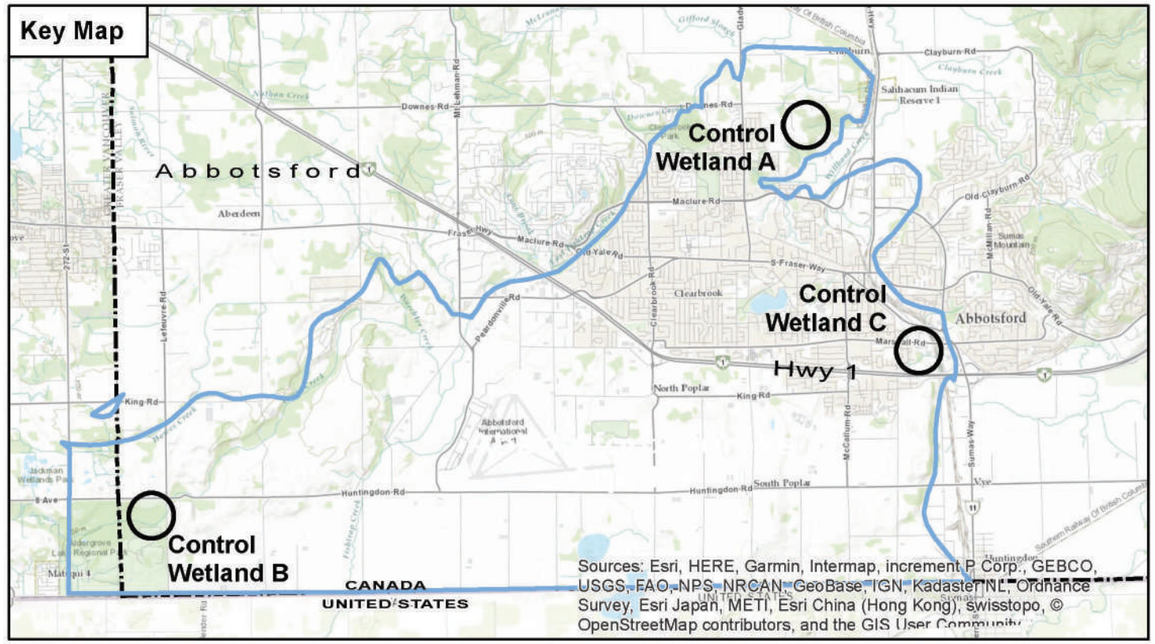
Created: March 2018
Projection:
NAD 83 UTM Zone 10N
1:2,500

Downes Creek Ecosystem Mapping & Monitoring Locations

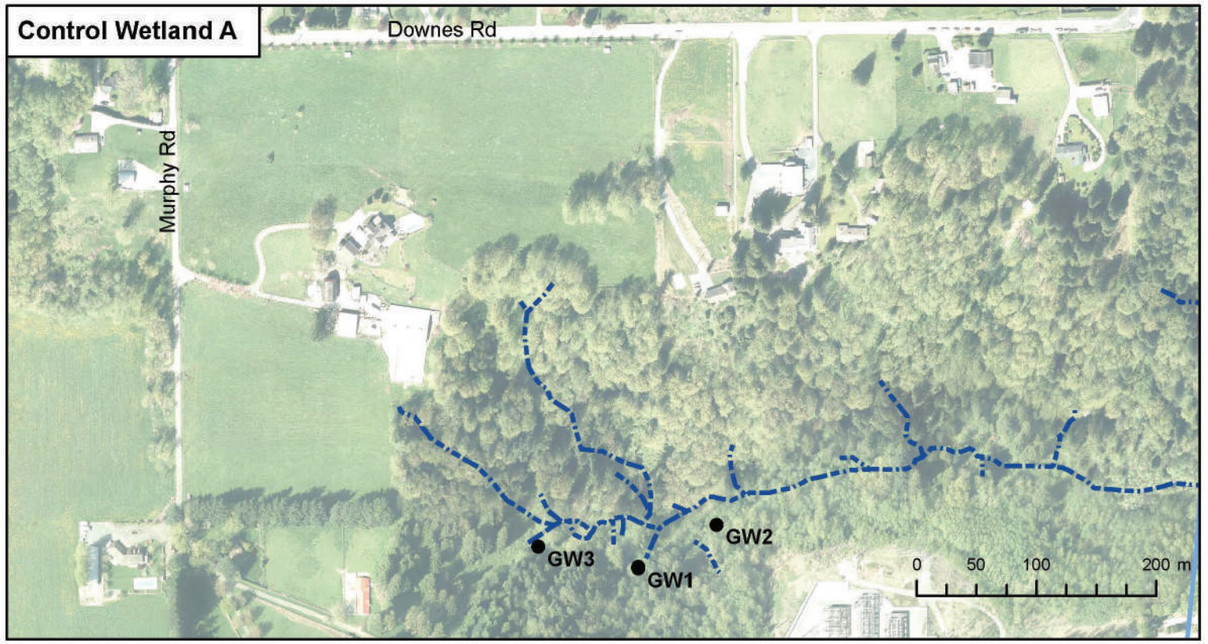
City of Abbotsford

Figure 5-4

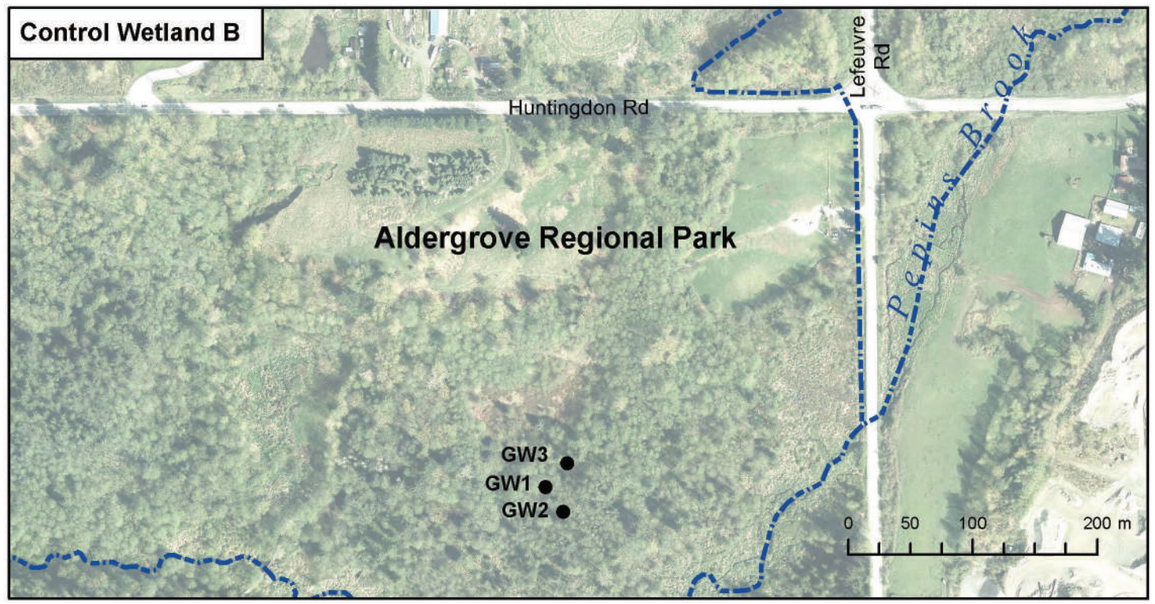
Key Map



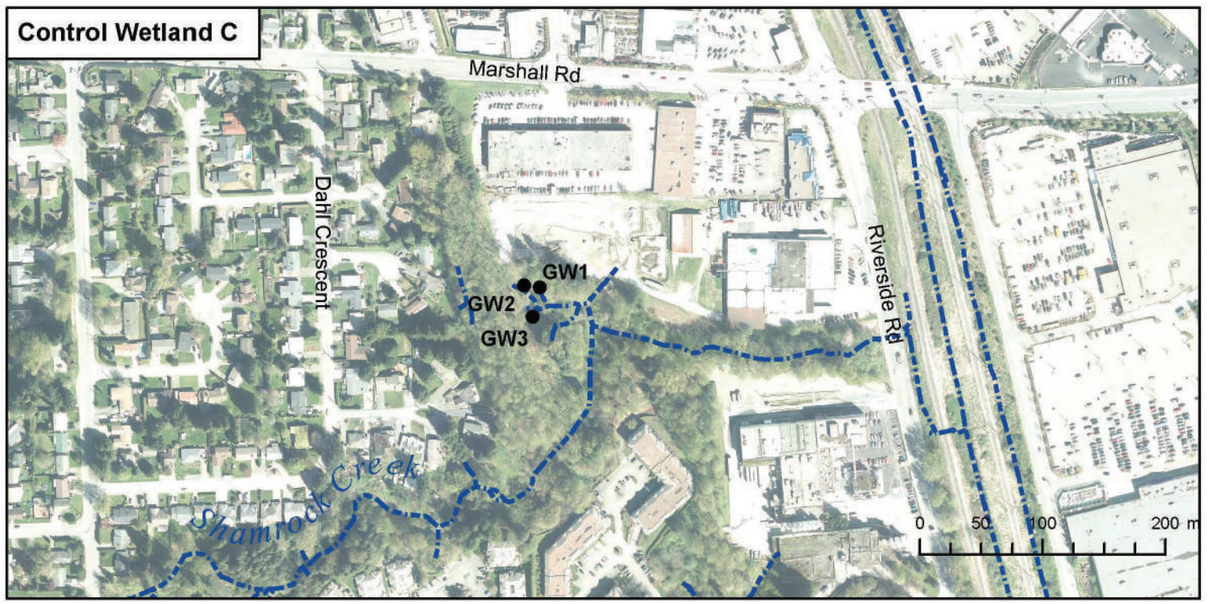
Control Wetland A



Control Wetland B



Control Wetland C



LEGEND

- Shallow groundwater well
- Stream
- Abbotsford-Sumas aquifer
- Abbotsford boundary

N

Prepared by: ENKON Environmental Ltd.

CITY OF ABBOTSFORD
FOR BEVAN WELLS PROJECT

Figure 5-5

Control Wetlands
Shallow Groundwater Well Locations

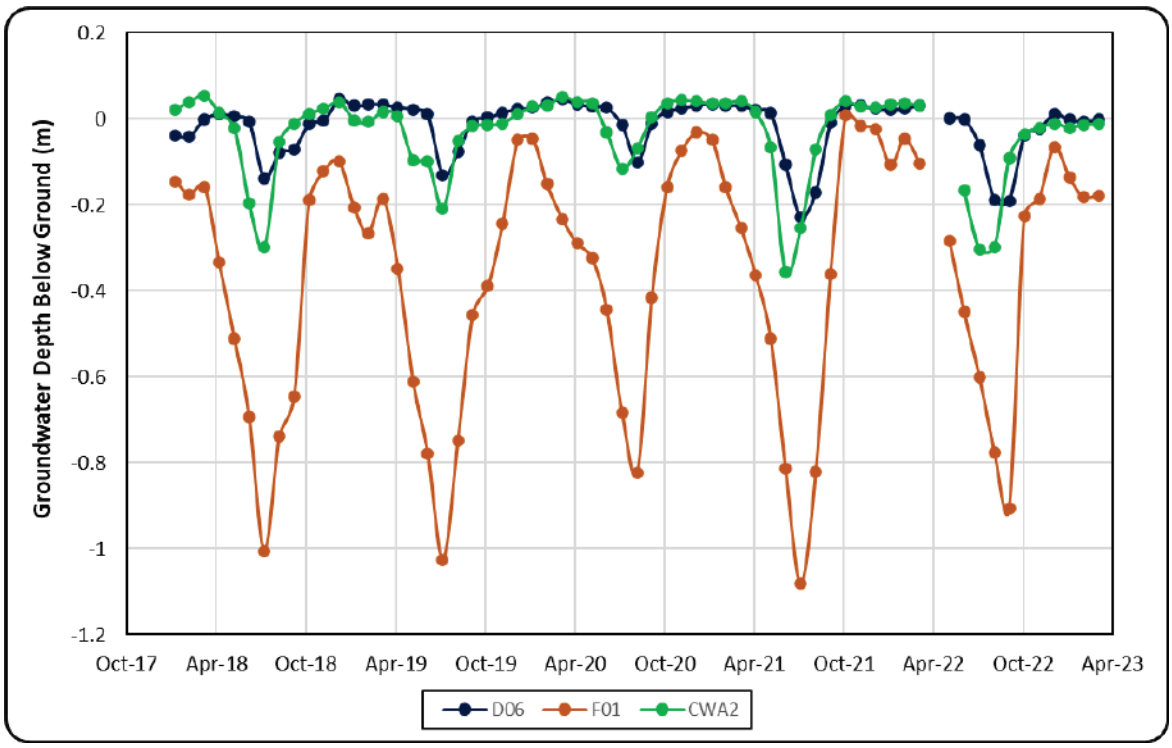
Date: April 2018

N:\GIS_Data\1021013_Data\Arc02_TEM Indicator\Control Wetlands\Figure5 - Control Wetlands AllInOne_EC.mxd

5.3 Results and Discussion

5.3.1 Monitoring Wells

Shallow groundwater data graphs for the 2018 to 2023 monitoring period are attached in Appendix O. Within the Bevan Wells zone of influence and at the control sites, groundwater depths generally declined during the summer. However, the magnitude of change was variable (Figure 5-6). The 2021 summer groundwater levels were lower than in other years at most sites with minimum levels occurring in August or early September. The lower summer groundwater levels in 2021 likely were due to the unusually hot and dry May-July. In the summer of 2022 groundwater levels were not as low as in 2021.



Data plotted are monthly means.

Figure 5-6 Temporal Variations in Groundwater Levels in Selected Wells in the Downes and Fishtrap Creek Watersheds and Control Wetand A

Wells within Fishtrap Creek showed the greatest seasonal differences in groundwater levels, with drops of up to 1.2 m between the winter and summer. In contrast to previous years, flooding did not occur at the F01 well, and water levels were below the top of the pipe. The other two Fishtrap Creek wells experienced data shifts after the October 2021 download that could not be explained by the field measurements, and the data are considered invalid. Of the remaining sites in the Bevan Wells zone of influence, only Boa

Brook showed large fluctuations with a 0.6-m range in water table depth from winter to summer. This location is fed by stormwater run off.

Half of the Downes Creek sites and the single Horn Creek site showed minimal or no seasonal variations in groundwater level. Plot 6 within Downes Creek continued to show greater seasonal variation, while Plots 9 and 10 showed less pronounced seasonal variation.

Seasonal variation was also seen in half of the Control Wetland sites. Site 2 of Control Wetland A and all three sites of Control Wetland B showed seasonal groundwater change. Groundwater levels within the remaining Control Wetland sites showed water level fluctuations up to 0.3m, but these did not appear to be associated with a change from dry season to wet season.

The trends in shallow groundwater levels after five years of monitoring illustrate seasonal changes that occurred within both the control wetlands and the Bevan Wells zone of influence. No downward trends in shallow groundwater levels occurred within the Downes Creek, Fishtrap Creek, or Horn Creek/Boa Brook study areas (e.g., Figure 5-6), nor were any changes attributable to the operation of the Bevan Wells.

5.3.2 Wetland Water Level

Wetland water levels recorded from May 2018 through April 2023 are illustrated in Figure 5-7. This graph shows an overall declining trend in the depth of water within the wetland. The reason for this trend is unclear. It does not appear to be related to the operation of the Bevan Wells as there has been no corresponding increase in water withdrawals.

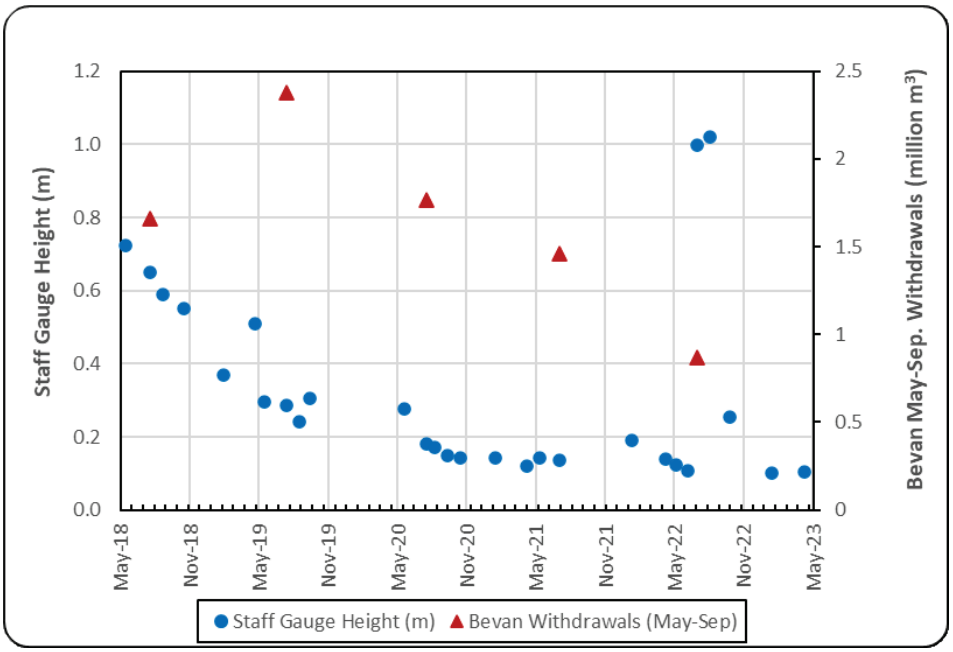


Figure 5-7Water Levels in the Downes Creek Open-Water Wetland, 2018-2023

No similar trends were observed in the flows in Downes Creek (Section 2.4.1), water levels in the (deeper) monitoring wells (Section 4.1.3), or water levels in the shallow groundwater wells (Section 5.2.1). However, a decline is consistent with the drying trend indicated by the CUSUM line on Figure 4-3.

5.4 Successes, Challenges and Suggested Changes

An issue with the water level loggers occurred in Year 12. The problem occurred when the Hobo loggers were downloaded and redeployed in April 2022. A fault in the shuttle caused its internal clock to reset, making all loggers record dates starting in 2010. Hobo technicians were able to correct the dates based on redeployment times, but the loggers had not begun collecting data until early June. Thus, no water levels were recorded in April and May 2022. Furthermore, there were large changes in water levels in D01, D09, and D12 following redeployment, which suggest possible errors in the data. Other shifts in water levels occurred previously and in April 2023; in some cases, these anomalies have been screened out of the graphs in Appendix O.

There were additional data gaps in the spring 2023 download (October 2022 to April 2023 data). The logger at F02 failed to record data during this period. Additionally, the downloaded data from all three wells in Control Wetland B (CWB-GW1, -GW2, and -GW3) could not be corrected for barometric pressure. Thus, the sensor depth and depth to water could not be calculated. Additionally, the October 2022 to April 2023 data points for one well in Control Wetland C (CWC-GW3) appear to be outliers, possibly due to erroneous barometric correction.

6.0 VEGETATION MONITORING

6.1 Terrestrial Ecosystem Mapping

6.1.1 Background

The Bevan Wells Environmental Assessment Certificate Amendment Application (ENKON 2016) provided preliminary terrestrial ecosystem mapping (TEM) results for three study areas where adverse effects to wetland, floodplain or riparian might occur. A Mitigation Plans document (2017) submitted with the 2016 amendment application recommended that the preliminary ecosystem mapping be enhanced to provide detailed vegetation community descriptions and permanent vegetation plots for monitoring species composition change over time. In 2017, TEM was completed for the Fishtrap Creek, Horn Creek and Boa Brook, and Downes Creek watersheds (Figure 5-1) according to the Resources Inventory Committee (RIC) Standards for Terrestrial Ecosystem Mapping in British Columbia (May 1998). The 2017 TEM incorporates the results of two previous TEM projects (ENKON 2016; Hemmera 2010) and provides revised ecosystem boundaries and ecosystem classifications, where appropriate, as well as detailed ecosystem descriptions.

Wetland, floodplain, and riparian areas within the study area are classified down to the site series level. Classifications identify site potential ecosystems as mature seral stages and are based on a site's soil moisture and nutrient regime. Ecosystem information in the TEM is used as a baseline dataset against which vegetation species composition and growing condition (soil moisture and nutrient regime) changes can be measured over time. As such, in 2017 one to three permanent ground inspection plots were established in each significant wetland, floodplain or riparian site series within the study area. Subsequently, three plots were added for a total of 24 permanent ground inspection plots (Figures 5-2, 5-3, and 5-4), seven (7) of which were also used to monitor changes in Oregon forestsnail (*Allogona townsendiana*) critical habitat (Figure 5-4). One additional plot was monitored visually. The ground inspection plots were sampled annually at the end of the dry season, when effects on riparian vegetation from groundwater withdrawal and/or decreased surface water flows should be most apparent. The sixth annual survey was completed in Fall of 2022.

6.1.2 Methods

Ground inspection plots within each terrestrial ecosystem mapping unit were established using data collection methods outlined in the provincial Site Visit (SIVI) Standards (BC Ministry of Environment 2010). Most plots are 20 m by 20 m, but several 10 m x 10 m

plots were created due to terrain restrictions at Fishtrap Creek (all plots aside from FT04), plot B01 at Boa Brook, and plot D14 at Downes Creek. The plots were marked with stakes. In 2018, a reference tree was added to improve the ability to identify each plot. The tree closest to the plot stake was marked and its species recorded along with bearing and distance.

The initial inventory in 2017 collected **site feature data** (slope position, slope, and aspect), **stand attribute data** (age, height, structural stage, and successional status), **soil moisture regime**, **soil nutrient regime**, **rooting zone data** (soil drainage, texture, coarse fragment content, humus form, seepage depth and root restricting layers), and **vegetation species composition data** (percent cover by species and by layer). Vegetation species distribution data was assessed at each canopy layer within each plot; the A layer is the highest layer and is comprised of trees; the B layer is primarily comprised of shrubs, but juvenile trees may also be present in this layer; the C layer refers to herbaceous plants and largely comprises the understory ; the D layer is the lowest layer and comprises the ground layer. For the 2022 annual monitoring, existing ground inspection plots were revisited, and only the vegetation species composition data was collected by ENKON's wetland biologist and vegetation specialist.

The four initial TEM plots documenting Oregon forestsnail habitat characteristics included D05. D06, D14, and D15. At these plots, critical habitat features were observed, including stinging nettle (*Urtica dioica*) presence, presence of coarse woody debris, and factors that assist in maintenance of a moist microclimate, including intact deciduous canopy, dense understory vegetation, and presence of leaf litter. In 2020, three additional 10 m by 10 m Oregon forestsnail plots were added to the survey and designated D16, D17 and D18. All seven (7) plots were assessed as part of the 2022 survey.

6.1.3 Results and Discussion

6.1.3.1 Vegetation Changes

Vegetation cover within the TEM plots has remained relatively consistent over the past six years of monitoring. The ecosystem types that are prevalent in the TEM plots are Ws51 which is characterized by Sitka willow, Pacific willow, and skunk cabbage; Ws52 is a red alder skunk cabbage swamp; Ws53, which is characterized by western redcedar, sword fern and skunk cabbage; and Wm05, which is characterized as cattail marsh. In 2022, substantial changes were noted, such as the appearance of new species within many of the TEM plots (Appendix P). Many of the new species observed in 2022 are not associated with drier plant communities, and instead may signify an increase in plant biodiversity and abundance rather than a response to changes in moisture. For example, in the Ws53 (Western redcedar-sword fern-skunk cabbage) wetland class, Western redcedar (*Thuja plicata*) percent cover did not change, but red alder (*Alnus rubra*) and vine maple (*Acer circinatum*) were observed for the first time; these two species form a component of the plant community that is commonly found in this ecosystem type, and therefore could

represent the earlier stages of increases in species biodiversity. Other notable changes in Ws53 observed in 2022 included the appearance of water parsley (*Oenanthe spp.*), step moss (*Hylocomium splendens*), and common horsetail (*Equisetum arvense*). These plants are also typical of this ecosystem type. Increases in species richness within this ecosystem type are supported by the appearances of the species listed above, as well as the persistence of previously observed species (*i.e.*, lady fern [*Athyrium filix-femina*], spiny wood fern [*Dryopteris expansa*] *etc.*,) in lower or higher canopy layers, such as A through C.

Trailing blackberry (*Rubus ursinus*) was noted in several TEM plots during 2022 where it had not been observed in previous years but was not restricted to a specific ecosystem type (i.e., Ws51, Ws52, Ws53 etc.,). This species was present in plots representative of Ws51 (Sitka willow-Pacific willow-skunk cabbage), Ws53, and Ws52 (red alder-skunk cabbage) ecosystem types. Additional new species outside of the established vegetation subset associated with each ecosystem type (i.e., Ws51, Ws52, Ws53) included mountain ash (*Sorbus stitchensis*), stinging nettle (*Urtica dioica*), piggy-back plant (*Tolmiea menziesii*), devil's club (*Oplopanaax horridus*), common jewelweed (*Impatiens capensis*), sassafras (*Sassafras albidum*), black walnut (*Juglans nigra*), Whitherod (*Viburnum nudum*), and false solomon's seal (*Maianthemim racemosum*). These plants are associated with wetlands/wetted habitats and therefore do not represent a shift to drier plant communities, but instead point to an increase in species diversity and richness.

Invasive species were also newly observed within the TEM plots in 2022. They included Himalayan blackberry (*Rubus armeniacus*), cutleaf blackberry (*Rubus laciniatus*), yellow archangel (*Lamium galeobdolon*), English holly (*Ilex aquifolium*), English ivy (*Hedera helix*), bittersweet nightshade (*Solanum dulcamara*), English laurel (*Prunus* laurocerasus) and rhododendron (*Rhododendron spp.*). Invasive species were present in all plots except for D01, D02, D05 and D06. While percent cover for invasive species remained low in most plots, and occurrences were only apparent in the B and C canopy layers, these species have the potential to spread and drastically change the species composition within each TEM plot, and thus the subsequent ecosystem types. While the invasive species listed above can persist in ecosystems with a wide range of moisture regimes, ideal growth conditions are consistent with moisture conditions found in Ws51, Ws52, and Ws53, which are predominantly moist year-round.

Vegetation cover within the TEM plots has largely remained similar over the past six years of monitoring, although some of the changes are indicative of shifts away from the baseline plant community. As mentioned above, these changes do not represent a shift to drier plant communities but do signify increases in the number of individuals per observed species as well as species richness. Some shrub vegetation. Some shrub vegetation showed fallen leaves or slight decay due to natural seasonal processes (e.g., temperature/light changes into Fall). No signs of drought stress or recent shrub or herb layer mortality due to drought stress were observed at any of the TEM plots. No changes in ecosystem boundaries were observed in traversing the Downes, Horn and Boa, and Fishtrap Creek study areas.

As in previous years, percent cover by the dominant species varied at the sites, but no consistent patterns have been observed over the six years of data collection. Observed differences in vegetation cover were small in most cases (i.e., <10%). Larger shifts in 2022 cover by ecosystem indicator species as compared to 2021 are highlighted in Tables 6-1 (i.e., decreases) and 6-2 (i.e., increases).

Overall, decreases in cover were observed in key indicator species at 15 plots in 2022 (Table 6-1). Two of these plots had some level of decay reported. Leaf fall and decay was observed at some plots even in the earliest days of the inventory (i.e. October 4 and 5), which can be attributed to variability in the timing of leaf fall among years. Variability in weather patterns among years also impacts plant growth. These factors contribute to the variability of cover estimates over time.

Increased cover by some species was observed at 16 plots in 2022 (Table 6-2). In the 2021 report, D15 cover increases were attributed to increased leaf decay (i.e., big leaf maple and salmonberry) at the time of the survey. In 2022, cover increases were due to increases in percent cover for red alder (*Alnus rubra*) and red elderberry (*Sambucus racemosa*), as well as salmonberry (*Rubus spectabilis*), spiny wood fern (*Dryopteris expansa*), and western sword fern (*Polystichum munitum*).

At one of the sites, D15, the cover increases were attributed to vine maple (*Acer circinatum*) expanding into the B1 canopy, as well as overall increases of percent canopy cover by red alder observed in 2021. At another site, D08, a significant upwards shift appeared to be taking place (i.e., plants growing into higher canopy layers) with Western redcedar, vine maple, salmonberry, western hemlock, and black cottonwood extending into the B and A canopy layers.

Measurement error may have impacted cover estimates in 2022. Potential sources of measurement error include insufficiently accounting for gaps within the canopy of a species (overestimate), insufficiently accounting for leaf layering within the canopy (underestimate), and incorrectly projecting plot boundaries for each layer (inconsistent cover estimate).

Table 6-1 Decreases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	Species Name	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
D01	Ws53	C	common horsetail	*Equisetum arvense*	33	7	18	16	38	30	present in B3 layer
D01	Ws53	C	false lily-of-the-valley	*Maianthemum dilatatum*	0.5	0.1	4.5	0.5	2	-	
D01	Ws53	C	fringecup	*Tellima grandiflora*	-	0.1	2.5	2	-	-	
D02	Wm05	B	salmonberry	*Rubus spectabilis*	17	14	22	9	13.5	-	
D02	Wm05	B1	vine maple	*Acer circinatum*	13	11	18	5	18	10	1 plant noted
D02	Wm05	C	Common cattail	*Typha latifolia*	6	7	8	5	3.5	-	
D03	Ws53	B	salmonberry	*Rubus spectabilis*	6	5	4	2	3	-	
D03	Ws53	C1	lady fern	*Athyrium filix-femina*	39	42	49	44	32	30	
D03	Ws53	C1	Western skunk cabbage	*Lysichiton americanus*	42	20	9	22	12	5	2 plants noted at this site
D04	Ws52	C2	common horsetail	*Equisetum arvense*	65	60	80	60	55	25	32 plants counted
D04	Ws52	C	lady fern	*Athyrium filix-femina*	3	3	20	tr	1	-	
D05	Ws53	C	common horsetail	*Equisetum arvense*	25	25	48	55	37.5	30	Dense cover

Table 6-1 Decreases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	Species Name	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
D05	Ws53	B	salmonberry	*Rubus spectabilis*	27	20	24	14	20.25	-	
D06	Ws52	B	salmonberry	*Rubus spectabilis*	27	45	23	40	38	-	
D06	Ws52	B	spiny wood fern	*Dryopteris expansa*	12	12	7	8	8	-	
D06	Ws52	C	piggy-back plant	*Tolmiea menziesii*	47	25	14	8	24	-	
D08	Ws52	B1	vine maple	*Acer circinatum*	11	12	32	33	36.25	15	5 plants counted
D08	Ws52	B1	red alder	*Alnus rubra*	-	10	5	10	6	5	1 planted counted
D08	Ws52	B1	salmonberry	*Rubus spectabilis*	14	9	12	3	0.5	-	more in B2 and C1
D13	Ws51	A	Pacific willow	*Salix lucida ssp. Lasiandra*	8	8	12	2	4	-	not observed in this layer in 2022
D13	Ws51	A3	red alder	*Alnus rubra*	42	40	17	7	15	10	6 plants counted
D14	7	A3	Cascara	*Rhamnus purshiana*	8	20	15	12	17	-	

Table 6-1 Decreases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	Species Name	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
D14	7	C	Western sword fern	*Polystichum munitum*	35	25	30	21	45	5	species cover is dense
D15	7	A1	bigleaf maple	*Acer macrophyllum*	30	50	25	45	65	20	2 plants counted
D15	7	B	salmonberry	*Rubus spectabilis*	68	70	30	34	48.33	20	species cover is dense; trace in C1 layer
D15	7	C	spiny wood fern	*Dryopteris expansa*	9	5	13	8	11	-	none observed in C layer; all in B3 layer
H01	Ws53	A2	paper birch	*Betula papyrifera*	1	10	1.5	8	-	-	
H01	Ws53	B	Western redcedar	*Thuja plicata*	10	5	1	2.5	9	7.5	regeneration evident
H01	Ws53	B2	stink currant	*Ribes bracteosum*	0.5	10.5	0.5	tr	tr	-	
H02	Ws53	A2	paper birch	*Betula papyrifera*	1	10	1.5	8	-	-	
H02	Ws53	A	paper birch	*Betula papyrifera*	7	9	2	4	3	-	

Table 6-1 Decreases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	Species Name	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
FT01	8	B1	red elderberry	*Sambucus racemosa*	40	35	70	33	55	5	2 plants noted
FT01	8	B1	black twinberry	*Lonicera involucrata*	24	20	12	18	12	-	
FT01	8	B1	Cascara	*Rhamnus purshiana*	-	25	20	21	25	-	
FT01	8	C	lady fern	*Athyrium filix-femina*	-	5	0.5	3	1	-	
FT01	8	C	spiny wood fern	*Dryopteris expansa*	27	15	40	14	3.5	-	
FT04	5	A1	Douglas-fir	*Pseudotsuga menziesii*	9	8	14	12	22	-	
FT04	5	B	paper birch	*Betula papyrifera*	-	4	4	1	2	-	none in B layer in 2022
FT06	10	A	black cottonwood	*Populus balsamifera ssp. trichocarpa*	70	60	70	65	-	-	Access restricted; approximate distance from chain link fence = 70m west to plot; inventory based on

Table 6-1 Decreases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	Species Name	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
											visual and aerial estimation
FT06	10	B1	black twinberry	*Lonicera involucrata*	-	11	5	-	-	-	
FT06	10	B1	red-osier dogwood	*Cornus sericea*	42	40	53	65	-	-	
FT06	10	C	common horsetail	*Equisetum arvense*	0.5	2.5	5	1	-	-	
FT07	10	B1	baldhip rose	*Rosa gymnocarpa*	0.5	1	15	5	5	-	

Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	*Species Name*	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
D01	Ws53	A	Western redcedar	*Thuja plicata*	18	13	21	20	20	20	92 cm DBH, 48 cm DBH; 3 trees, trace in A2 layer
D01	Ws53	B1	Red alder	*Alnus rubra*	-	-	-	-	-	5	1 plant noted
D01	Ws53	B2	vine maple	*Acer circinatum*	-	-	-	-	-	25	
D01	Ws53	B2	salmonberry	*Rubus spectabilis*	7	2	13.5	7.5	15	20	
D01	Ws53	B3	common horsetail	*Equisetum arvense*	-	-	-	-	-	60	species cover is dense; present in C layer
D01	Ws53	C	Western skunk cabbage	*Lysichiton americanus*	8	10	10	14	18	25	species cover is dense; tall grasses noted
D01	Ws53	C	Western sword fern	*Polystichum munitum*	-	-	-	-	-	5	
D01	Ws53	C	Lady fern	*Athyrium filix-femina*	-	-	-	-	-	10	

Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	*Species Name*	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
D01	Ws53	C	Step moss	*Hylocomium splendens*	-	-	-	-	-	5	species cover is dense; aquatic vegetation noted
D01	Ws53	C	Water parsley	*Oenanthe spp.*	-	-	-	-	-	5	
D02	Wm05	A2	Western hemlock	*Tsuga heterophylla*	-	-	-	-	-	15	43.5 cm DBH
D02	Wm05	B1	Red alder	*Alnus rubra*	-	-	-	-	-	40	25 cm DBH
D02	Wm05	B2	vine maple	*Acer circinatum*	-	-	-	-	-	55	species cover dense in B2 layer
D02	Wm05	B3	Common horsetail	*Equisetum arvense*	-	-	-	-	-	35	species cover is dense; tall grasses, more than D01
D02	Wm05	B3	lady fern	*Athyrium filix-femina*	-	-	-	-	-	35	
D02	Wm05	C	lady fern	*Athyrium filix-femina*	8	8	16	12	15	10	
D02	Wm05	C	Western skunk cabbage	*Lysichiton americanus*	15	10	8	6	6	10	

Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	*Species Name*	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
D02	Wm05	C2	Lady fern	*Athyrium filix-femina*	-	-	-	-	-	5	
D02	Wm05	C2	water parsley	*Oenanthe spp.*	-	-	-	-	-	15	
D02	Wm05	C2	false lily-of-the-valley	*Maianthemum dilatatum*	-	-	-	-	-	0.8	Dense , though low compared to others.
D03	Ws53	A2	Western red cedar	*Thuja plicata*	-	-	-	-	-	25	8 plants observed
D03	Ws53	A2	Western hemlock	*Tsuga heterophylla*	-	-	-	-	-	10	2 plants observed
D03	Ws53	A3	Red alder	*Alnus rubra*	-	-	-	-	-	1	1 plant observed
D03	Ws53	B1	vine maple	*Acer circinatum*	0.5	4	8	3	5	20	9 plants observed
D03	Ws53	B1	bigleaf maple	*Acer macrophyllum*	-	-	-	-	-	2.5	
D03	Ws53	B1	Western red cedar	*Thuja plicata*	-	-	-	-	-	5	2 plants observed;4 English holly (*Ilex aquifolium*)

Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	*Species Name*	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
D03	Ws53	B2	Vine maple	*Acer circinatum*	-	-	-	-	-	30	12 plants observed
D03	Ws53	B2	salmonberry	*Rubus spectabilis*	-	-	-	-	-	20	9 plants observed
D03	Ws53	B2	mountain ash	*Sorbus sitchensis*	-	-	-	-	-	0.8	1 plant observed
D03	Ws53	C1	English laurel	*Prunus laurocerasus*	-	-	-	-	-	0.7	invasive; 1 plant observed
D03	Ws53	C1	spiny wood fern	*Dryopteris expansa*	11	11	19	12.5	9	30	
D03	Ws53	C1	common horsetail	*Equisetum arvense*	-	-	-	-	-	10	11 plants counted
D03	Ws53	C2	Western skunk cabbage	*Lysichiton americanus*	-	-	-	-	-	5	2 plants counted
D03	Ws53	C2	spiny wood fern	*Dryopteris expansa*	-	-	-	-	-	65	
D03	Ws53	C2	trailing blackberry	*Rubus ursinus*	-	-	-	-	-	10	
D03	Ws53	C2	bittersweet nightshade	*Solanum dulcamara*	-	-	-	-	-	10	

Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	*Species Name*	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
D04	Ws52	A2	black cottonwood	*Populus balsamifera ssp. trichocarpa*	-	-	-	-	-	5	1 plant counted
D04	Ws52	B1	red alder	*Alnus rubra*	-	-	-	-	-	15	5 plants counted
D04	Ws52	B2	vine maple	*Acer circinatum*	-	-	-	-	-	25	
D04	Ws52	C	Western skunk cabbage	*Lysichiton americanus*	31	30	70	35	40	40	
D04	Ws52	C1	salmonberry	*Rubus spectabilis*	-	-	-	-	-	5	
D04	Ws52	C1	nightshade	*Solanum dulcamara*	-	-	-	-	-	2.5	bittersweet nightshade; species cover is dense
D04	Ws52	C1	stink currant	*Ribes bracteosum*	-	-	-	-	-	0.8	
D04	Ws52	C1	honeysuckle	*Lonicera periclymenum*	-	-	-	-	-	2.5	
D04	Ws52	C2	spiny wood fern	*Dryopteris expansa*	-	-	-	-	-	10	
D05	Ws53	A1	black cottonwood	*Populus balsamifera ssp. trichocarpa*	20	20	35	23	18	65	4 plants counted
D05	Ws53	B1	bigleaf maple	*Acer macrophyllum*	-	-	-	-	-	10	

Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	*Species Name*	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
D05	Ws53	B1	vine maple	*Acer circinatum*	-	-	-	-	-	15	
D05	Ws53	B2	twinberry	*Lonicera involucrata*	-	-	-	-	-	35	
D05	Ws53	B2	trailing blackberry	*Rubus ursinus*	-	-	-	-	-	5	
D05	Ws53	B3	lady fern	*Athyrium filix-femina*	-	-	-	-	-	20	
D05	Ws53	C	Western skunk cabbage	*Lysichiton americanus*	22	29	40	28	33.75	75	
D05	Ws53	C	lady fern	*Athyrium filix-femina*	10	7	17	7	10.75	20	
D05	Ws53	C3	water parsley	*Oenanthe spp.*	-	-	-	-	-	5	
D06	Ws52	B1	red alder	*Alnus rubra*	-	-	-	-	-	4.5	1 tree counted; larger trees >50cm DBH surrounding plot
D06	Ws52	B1	vine maple	*Acer circinatum*	-	-	-	-	-	30	5 plants counted
D06	Ws52	B2	vine maple	*Acer circinatum*	-	-	-	-	-	45	
D06	Ws52	B3	common horsetail	*Equisetum arvense*	-	-	-	-	-	35	
D06	Ws52	B3	lady fern	*Athyrium filix-femina*	-	-	-	-	-	25	

Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	*Species Name*	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
D06	Ws52	B3	stinging nettle	*Urtica dioica*	-	-	-	-	-	30	
D06	Ws52	B	red elderberry	*Sambucus racemosa*	10	12	7	8	9.5	10	3 plants counted
D06	Ws52	C	Western skunk cabbage	*Lysichiton americanus*	15	8	15	5	8	25	
D06	Ws52	C	water parsley	*Oenanthe spp.*	-	-	-	-	-	30	
D06	Ws52	C	step moss	*Hylocomium splendens*	-	-	-	-	-	5	
D07	Ws52	A2	Western redcedar	*Thuja plicata*	-	-	-	-	-	5	1 tree counted; pink and blue flagging tape at plot
D07	Ws52	B1	vine maple	*Acer circinatum*	-	-	-	-	-	2.5	1 plant counted
D07	Ws52	B1	red elderberry	*Sambucus racemosa*	-	-	-	-	-	2.5	1 planted counted
D07	Ws52	B2	salmonberry	*Rubus spectabilis*	19	8	29	40	23.75	30	
D07	Ws52	B2	trailing blackberry	*Rubus ursinus*	-	-	-	-	-	10	

Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	*Species Name*	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
D07	Ws52	B2	bittersweet nightshade	*Solanum dulcamara*	-	-	-	-	-	5	invasive species
D07	Ws52	B2	stinging nettle	*Urtica dioica*	-	-	-	-	-	5	
D07	Ws52	C	spiny wood fern	*Dryopteris expansa*	22	14	5	5.5	4.5	5	
D07	Ws52	C	piggy-back plant	*Tolmiea menziesii*	2	1	5	16	9	10	
D07	Ws52	C	lady fern	*Athyrium filix-femina*	1	2	11	2	3	5	
D07	Ws52	C	common horsetail	*Equisetum arvense*	5	18	10	23	35	60	
D07	Ws52	C	Western skunk cabbage	*Lysichiton americanus*	5	16	4	11	14	30	
D07	Ws52	C	stink currant	*Ribes bracteosum*	-	-	-	-	-	5	
D07	Ws52	C2	western sword fern	*Polystichum munitum*	-	-	-	-	-	2.5	
D07	Ws52	C2	Western skunk cabbage	*Lysichiton americanus*	-	-	-	-	-	2.5	
D07	Ws52	C2	salmonberry	*Rubus spectabilis*	-	-	-	-	-	10	
D07	Ws52	C2	bittersweet nightshade	*Solanum dulcamara*	-	-	-	-	-	20	invasive; species cover is dense

Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	*Species Name*	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
D08	Ws52	A2	Western redcedar	*Thuja plicata*	-	-	-	-	-	5	7 trees counted
D08	Ws52	A2	western hemlock	*Tsuga heterophylla*	-	-	-	-	-	10	2 trees counted
D08	Ws52	A2	black cottonwood	*Populus balsamifera ssp. trichocarpa*	-	-	-	-	-	5	1 tree counted
D08	Ws52	B1	Western redcedar	*Thuja plicata*	5	15	6	4	tr	5	2 trees counted
D08	Ws52	B2	Western redcedar	*Thuja plicata*	-	-	-	-	-	15	6 trees counted; 2 English holly bushes in vicinity
D08	Ws52	B2	vine maple	*Acer circinatum*	-	-	-	-	-	25	7 plants counted
D08	Ws52	B2	salmonberry	*Rubus spectabilis*	-	-	-	-	-	25	12 plants counted
D08	Ws52	B2	stinging nettle	*Urtica dioica*	-	-	-	-	-	2.5	1 plant counted
D08	Ws52	B2	devil's club	*Oplopanax horridus*	-	-	-	-	-	2.5	1 plant counted

Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	*Species Name*	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
D08	Ws52	C	lady fern	*Athyrium filix-femina*	7	6	9	5	4.75	5	7 plants counted
D08	Ws52	C	spiny wood fern	*Dryopteris expansa*	11	5	11	7	6.5	55	species cover is dense
D08	Ws52	C	Western sword fern	*Polystichum munitum*	-	-	-	-	-	2.5	1 plant counted; some low density Himalayan blackberry
D08	Ws52	C	Devil's club	*Oplopanax horridus*	-	-	-	-	-	10	10 plants counted
D08	Ws52	C	Western skunk cabbage	*Lysichiton americanus*	-	-	-	-	-	5	3 plants counted
D08	Ws52	C	salmonberry	*Rubus spectabilis*	-	-	-	-	-	2.5	4 plants counted
D08	Ws52	C	lady fern	*Athyrium filix-femina*	-	-	-	-	-	5	7 plants counted
D08	Ws52	C2	Western skunk cabbage	*Lysichiton americanus*	-	-	-	-	-	15	17 plants counted

Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	*Species Name*	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
D08	Ws52	C2	bittersweet nightshade	*Solanum dulcamara*	-	-	-	-	-	35	
D08	Ws52	C2	spiny wood fern	*Dryopteris expansa*	-	-	-	-	-	15	
D08	Ws52	C2	stink currant	*Ribes bracteosum*	-	-	-	-	-	5	
D08	Ws52	C2	Whitherod	*Viburnum nudum*	-	-	-	-	-	0.8	1 plant counted
D13	Ws51	A2	Western hemlock	*Tsuga heterophylla*	-	-	-	-	-	5	1 tree counted; plot is approximately 20 m south from trail/boardwalk and is flagged
D13	Ws51	B1	Pacific willow	*Salix lucida*	-	-	-	-	-	40	species cover is dense
D13	Ws51	B1	vine maple	*Acer circinatum*	-	-	-	-	-	0.7	1 plant counted
D13	Ws51	B2	honeysuckle	*Lonicera periclymenum*	-	-	-	-	-	45	
D13	Ws51	B2	salmonberry	*Rubus spectabilis*	-	-	-	-	-	20	

Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	*Species Name*	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
D13	Ws51	C	western sword fern	*Polystichum munitum*	-	-	-	-	-	0.8	
D13	Ws51	C	spiny wood fern	*Dryopteris expansa*	-	-	-	-	-	10	
D13	Ws51	C	stink currant	*Ribes bracteosum*	-	-	-	-	-	5	
D13	Ws51	C	western skunk cabbage	*Lysichiton americanus*	-	-	-	-	-	20	
D13	Ws51	C	lady fern	*Athyrium filix-femina*	14	4	13	6	7	10	
D13	Ws51	C	stinging nettle	*Urtica dioica*	-	-	-	-	-	25	
D13	Ws51	C	common horsetail	*Equisetum arvense*	12	3	8	4	7.5	25	
D13	Ws51	C2	suicide root	*Cicuta maculata*	-	-	-	-	-	10	poisonous plant
D13	Ws51	C2	piggyback	*Tolmiea menziesii*	-	-	-	-	-	40	
D13	Ws51	C2	spiny wood fern	*Dryopteris expansa*	-	-	-	-	-	15	
D13	Ws51	C2	trailing blackberry	*Rubus ursinus*	-	-	-	-	-	10	
D13	Ws51	C2	Himalayan blackberry	*Rubus armeniacus*	-	-	-	-	-	5	invasive; species cover is dense
D13	Ws51	C3	Duckweed	*Lemnoideae spp.*	-	-	-	-	-	0.8	

Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	*Species Name*	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
D13	Ws51	C3	water parsley	*Oenanthe spp.*	-	-	-	-	-	5	
D14	7	A2	Western hemlock	*Tsuga heterophylla*	-	-	-	-	-	35	1 tree counted
D14	7	A2	bigleaf maple	*Acer macrophyllum*	-	-	-	-	-	25	2 tree counted
D14	7	A2	red alder	*Alnus rubra*	-	-	-	-	-	5	2 plants counted
D14	7	A3	Western redcedar	*Thuja plicata*	-	-	-	-	-	5	2 trees counted
D14	7	A3	vine maple	*Acer circinatum*	-	-	-	-	-	10	5 plants counted: some in B1 layer, trace in B2
D14	7	B	thimbleberry	*Rubus parviflorus*	20	25	18	17	22	25	
D14	7	B	salmonberry	*Rubus spectabilis*	33	25	18	8	18	45	
D14	7	B1	vine maple	*Acer circinatum*	-	-	-	-	-	5	2 plants counted: more A3 layer & trace in B2
D14	7	B1	red alder	*Alnus rubra*	-	-	-	-	-	0.8	1 plant counted

Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	*Species Name*	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
D14	7	B2	vine maple	*Acer circinatum*	-	-	-	-	-	0.8	1 plant counted
D14	7	B3	Western sword fern	*Polystichum munitum*	-	-	-	-	-	10	8 plants counted
D14	7	C1	Lady fern	*Athyrium filix-femina*	-	-	-	-	-	20	
D14	7	C1	spiny wood fern	*Dryopteris expansa*	-	-	-	-	-	30	
D14	7	C1	common horse tail	*Equisetum arvense*	-	-	-	-	-	10	
D14	7	C1	Western skunk cabbage	*Lysichiton americanus*	-	-	-	-	-	15	
D14	7	C1	stinging nettle	*Urtica dioica*	-	-	-	-	-	10	
D14	7	C2	piggyback	*Tolmiea menziesii*	-	-	-	-	-	10	
D14	7	C2	*bittersweet nightshade	*Solanum dulcamara*	-	-	-	-	-	5	invasive; species cover is dense
D14	7	C2	Western skunk cabbage	*Lysichiton americanus*	-	-	-	-	-	15	
D14	7	C3	Piggyback	*Tolmiea menziesii*	-	-	-	-	-	30	

Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	*Species Name*	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
D15	7	A	red alder	*Alnus rubra*	12	20	10	11	5	10	2 plants counted
D15	7	B1	vine maple	*Acer circinatum*	-	-	-	-	-	10	
D15	7	B1	red elderberry	*Sambucus racemosa*	19	15	21	7	23	40	
D15	7	B3	spiny wood fern	*Dryopteris expansa*	-	-	-	-	-	15	
D15	7	C	Western sword fern	*Polystichum munitum*	-	-	-	-	-	10	
D15	7	C1	salmonberry	*Rubus spectabilis*	-	-	-	-	-	5	
B01	Ws52	A2	Western redcedar	*Thuja plicata*	-	-	-	-	-	50	3 trees counted: No flagging tape marking access, but easy access through backyard of 33281 George Ferguson Way
B01	Ws52	A2	red alder	*Alnus rubra*	-	-	-	-	-	30	4 plants counted

Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	*Species Name*	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
B01	Ws52	B1	moutain ash	*Sorbus sitchensis*	-	-	-	-	-	5	1 tree counted
B01	Ws52	B1	rhododendron	*Rhododendron spp.*	-	-	-	-	-	10	1 plant observed
B01	Ws52	B1	red alder	*Alnus rubra*	-	-	-	-	-	15	plants were in a cluster
B01	Ws52	B2	English holly	*Ilex aquifolium*	-	-	-	-	-	5	invasive; 1 plant observed
B01	Ws52	B	salmonberry	*Rubus spectabilis*	95	6	90	65	12	50	species cover is dense
B01	Ws52	B3	*Himalayan blackberry	*Rubus armeniacus*	-	-	-	-	-	30	invasive; species cover is dense
B01	Ws52	B3	*bittersweet nightshade	*Solanum dulcamara*	-	-	-	-	-	5	invasive; species cover is dense
B01	Ws52	C1	lady fern	*Athyrium filix-femina*	-	-	-	-	-	5	
B01	Ws52	C1	common horsetail	*Equisetum arvense*	-	-	-	-	-	0.8	
B01	Ws52	C2	*English ivy	*Hedera helix*	-	-	-	-	-	20	invasive species

Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	*Species Name*	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
B01	Ws52	C2	Lily of the valley	*Convallaria majalis*	-	-	-	-	-	15	
B02	Ws51	A2	black cottonwood	*Populus balsamifera ssp. trichocarpa*	-	-	-	-	-	35	4 trees counted
B02	Ws51	A	Pacific willow	*Salix lucida ssp. Lasiandra*	15	9	4	3	4	10	1 tree counted
B02	Ws51	B1	mountain ash	*Sorbus sitchensis*	-	-	-	-	-	0.8	1 tree counted
B02	Ws51	B1	black twinberry	*Lonicera involucrata*	-	-	-	-	-	45	6 plants counted
B02	Ws51	B1	*English holly	*Ilex aquifolium*	-	-	-	-	-	0.8	invasive; 1 plant counted
B02	Ws51	B1	red alder	*Alnus rubra*	-	-	-	-	-	5	4 plants counted
B02	Ws51	B2	salmonberry	*Rubus spectabilis*	-	-	-	-	-	15	
B02	Ws51	B2	lady fern	*Athyrium filix-femina*	-	-	-	-	-	10	
B02	Ws51	B	Hardhack	*Spiraea douglasii*	8	10	9	2.5	9.5	20	
B02	Ws51	B2	common jewelweed	*Impatiens capensis*	-	-	-	-	-	30	
B02	Ws51	C	lady fern	*Athyrium filix-femina*	5	8	4	12	6	15	

Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	*Species Name*	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
B02	Ws51	C	western skunk cabbage	*Lysichiton americanus*	-	-	-	-	-	20	species cover is dense
H01	Ws53	A	Western redcedar	*Thuja plicata*	60	40	20	24	22	30	Split alder/cedar habitat with swamp throughout
H01	Ws53	A	Western hemlock	*Tsuga heterophylla*	-	-	-	-	-	4.5	
H01	Ws53	A	red alder	*Alnus rubra*	15	10	4	4	5	65	
H01	Ws53	B	red alder	*Alnus rubra*	-	-	-	-	-	7.5	regeneration evident
H01	Ws53	B2	salmonberry	*Rubus spectabilis*	-	-	-	-	-	20	species cover is dense
H01	Ws53	B2	Devil's club	*Oplopanax horridus*	-	-	-	-	-	0.8	1 plant observed
H01	Ws53	C	lady fern	*Athyrium filix-femina*	6	10	8	12	9	45	
H01	Ws53	C	Western skunk cabbage	*Lysichiton americanus*	10	12	6	7	4	5	

Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	*Species Name*	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
H01	Ws53	C1	common jewelweed	*Impatiens capensis*	-	-	-	-	-	20	Mostly in C1 layer, trace in C2; species cover is dense
H01	Ws53	C2	common jewelweed	*Impatiens capensis*	-	-	-	-	-	5	
H01	Ws53	C2	lady fern	*Athyrium filix-femina*	-	-	-	-	-	10	
H01	Ws53	C3	Step moss	*Hylocomium splendens*	-	-	-	-	-	5	mostly water/muck and bare ground; species cover is dense
H01	Ws53	C3	water parsley	*Oenanthe spp.*	-	-	-	-	-	4.5	small to moderate CWD with loose soils noted
H02	Ws53	A	black cottonwood	*Populus balsamifera ssp. trichocarpa*	5	20	8	18	13	15	1 tree counted; 53 DBH

Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	*Species Name*	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
H02	Ws53	A2	red alder	*Alnus rubra*	-	-	-	-	-	55	14 trees counted; 13 - 20 DBH
H02	Ws53	A2	bigleaf maple	*Acer macrophyllum*	-	-	-	-	-	10	1 tree counted; 15 DBH
H02	Ws53	B1	vine maple	*Acer circinatum*	-	-	-	-	-	0.8	1 tree counted
H02	Ws53	B1	black walnut	*Juglans nigra*	-	-	-	-	-	0.8	1 tree counted
H02	Ws53	B1	Western red cedar	*Thuja plicata*	-	-	-	-	-	0.8	1 tree counted
H02	Ws53	B1	red alder	*Alnus rubra*	-	-	-	-	-	5	3 trees counted
H02	Ws53	B2	salmonberry	*Rubus spectabilis*	45	35	25	35	3.5	50	
H02	Ws53	B2	Sassafras	*Sassafras albidum*	-	-	-	-	-	10	
H02	Ws53	C	lady fern	*Athyrium filix-femina*	19	15	6	11	6.25	35	
H02	Ws53	C1	common horsetail	*Equisetum arvense*	-	-	-	-	-	15	
H02	Ws53	C1	Spiny wood fern	*Dryopteris expansa*	-	-	-	-	-	10	
H02	Ws53	C1	Western sword fern	*Polystichum munitum*	-	-	-	-	-	0.8	
H02	Ws53	C2	common jewelweed	*Impatiens capensis*	-	-	-	-	-	5	

Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	*Species Name*	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
H02	Ws53	C2	yellow archangel	*Lamium galeobdolon*	-	-	-	-	-	5	invasive species
FT01	8	A2	Western redcedar	*Thuja plicata*	-	-	-	-	-	15	Access via 1282 Hope Road
FT01	8	A2	red alder	*Alnus rubra*	-	-	-	-	-	20	1 tree noted
FT01	8	B1	vine maple	*Acer circinatum*	-	-	-	-	-	60	
FT01	8	B1	Mountain ash	*Sorbus sitchensis*	-	-	-	-	-	10	1 plant noted
FT01	8	B2	beaked hazelnut	*Corylus cornuta*	-	-	-	-	-	25	
FT01	8	B2	salmonberry	*Rubus spectabilis*	-	-	-	-	-	15	
FT01	8	B2	vine maple	*Acer circinatum*	-	-	-	-	-	10	2 plants observed
FT01	8	B2	Pacific dogwood	*Cornus nuttallii*	-	-	-	-	-	5	1 plant noted
FT01	8	B3	Lady fern	*Athyrium filix-femina*	-	-	-	-	-	10	
FT01	8	B3	red elderberry	*Sambucus racemosa*	-	-	-	-	-	4.5	
FT01	8	C3	lily of the valley	*Convallaria majalis*	-	-	-	-	-	5	
FT01	8	C3	False Solomon's seal	*Maianthemum racemosum*	-	-	-	-	-	5	

Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	*Species Name*	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
FT02	8	A2/A3	red alder	*Alnus rubra*	-	-	-	-	-	20	in-between A2 and A3 layer
FT02	8	A2/A3	Mountain ash	*Sorbus sitchensis*	-	-	-	-	-	5	in-between A2 and A3 layer
FT02	8	B1	red elderberry	*Sambucus racemosa*	-	-	-	-	-	5	edge cluster
FT02	8	B1	beaked hazelnut	*Corylus cornuta*	-	-	-	-	-	0.8	on edge of plot
FT02	8	B2	cutleaf blackberry	*Rubus laciniatus*	-	-	-	-	-	1	invasive; infringing on edge of plot
FT03	10	B	Sitka willow	*Salix sitchensis*	2	15	3	5	1	15	Himalayan blackberry on south side of the plot
FT03	10	B	red elderberry	*Sambucus racemosa*	-	-	-	-	-	5	Mostly reed canary grass in plot, no leaf litter layer
FT03	10	B2	salmonberry	*Rubus spectabilis*	-	-	-	-	-	5	
FT03	10	B2	hardhack	*Spiraea douglasii*	-	-	-	-	-	4.5	

Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	*Species Name*	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
FT03	10	B2	cutleaf blackberry	*Rubus laciniatus*	-	-	-	-	-	4.8	invasive species
FT04	5	A2	red alder	*Alnus rubra*	-	-	-	-	-	20	5 trees observed; located halfway up south slope
FT04	5	A2	vine maple	*Acer circinatum*	-	-	-	-	-	4.5	1 tree observed
FT04	5	A2	paper birch	*Betula papyrifera*	-	-	-	-	-	5	1 tree observed
FT04	5	B1	vine maple	*Acer circinatum*	-	-	-	-	-	5	1 tree observed
FT04	5	B1	mountain ash	*Sorbus sitchensis*	-	-	-	-	-	5	1 tree observed
FT04	5	B1	red elderberry	*Sambucus racemosa*	-	-	-	-	-	5	1 tree counted
FT04	5	B1	Beaked hazelnut	*Corylus cornuta*	-	-	-	-	-	5	1 tree counted
FT04	5	B2	salmonberry	*Rubus spectabilis*	-	-	-	-	-	70	cutleaf blackberry noted
FT04	5	B3	Sitka rose	*Rosa rugosa*	-	-	-	-	-	20	newly observed in 2022

Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2017 and 2022

Plot	Ecosystem Type	Layer	Common Name	*Species Name*	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)	2022 Notes
FT04	5	B3	lady fern	*Athyrium filix-femina*	-	-	-	-	-	10	newly observed in 2022
FT04	5	B3	trailing blackberry	*Rubus ursinus*	-	-	-	-	-	10	bare ground from erosion/game trails throughout plot
FT06	10	A2	red alder	*Alnus rubra*	-	-	-	-	-	10	on the edge of the plot
FT06	10	B1	Pacific dogwood	*Cornus nuttallii*	-	-	-	-	-	70	
FT06	10	B1	red elderberry	*Sambucus racemosa*	-	-	-	-	-	10	
FT06	10	B1	salmonberry	*Rubus spectabilis*	-	-	-	-	-	10	
FT06	10	B2	Hooker's willow	*Salix hookeriana*	-	-	-	-	-	15	
FT06	10	B3	Nootka rose	*Rosa nutkana*	-	-	-	-	-	10	
FT07	10	B3	Hooker's willow	*Salix hookeriana*	-	-	-	-	-	40	

6.1.3.2 Oregon Forestsnail Habitat Features

Increases in deciduous canopy cover were observed at the Oregon forestsnail habitat plots (i.e., D05, D06, D14 to D18). These increases were due to increases in canopy cover from species observed in 2021 (i.e., black cottonwood, vine maple and red alder) as well as observations of new species within the A and B canopy layers (i.e., bigleaf maple, western hemlock, western red cedar). At D05, black cottonwood accounted for 65% of the canopy cover, which is a substantial increase from 18% observed in 2021. Litter leaf volume remained consistently deep and was primarily comprised of bigleaf maple, red alder, and black cottonwood. Plots D05 and D14 through D17 had varied cover of bigleaf maple (10%-80%), which was reflected in the depths of litter observed. Big leaf maple was not observed in D06 or in D18 during the 2022 survey. The A layer in these plots was comprised of red alder (*Alnus rubra*) and black cottonwood (*Populus trichocarpa spp.*).

As noted during the baseline assessment, D06 contains stinging nettle (*Urtica dioica*), which the snails require for breeding. At D06, the cover of stinging nettle had increased in 2022 (30%) from 2021 (16%) and 2020 (7%). The new plots D16, D17, and D18, were selected to contain stinging nettle, allowing additional tracking of nettle cover through time. The quantity of stinging nettle at plots D16, D17 and D18 varied compared to 2021 levels (i.e., D16 increased from 8% to 10%, D17 increased from 7% to 10%, and D18 increased from trace levels to 30%). Variations in stinging nettle cover between 2021 and 2022 may be due to plot locations (e.g., D16, which had the lowest increase in stinging nettle cover, is located farthest away from a mapped water source and in a sloped area, and thus may be drier than the other plots.). The quantities of coarse woody debris at plots D14 and D15 remained similar to that observed previously. The 2022 monitoring showed no overall deterioration in the Oregon forestsnail habitat.

6.1.4 Successes, Challenges and Suggested Changes

After six years of data collection (2017-2022), neither plant mortality nor changes to ecosystem boundaries have been observed. While no major shift in species composition (i.e., >50%) has occurred, an increase in the numbers of individuals of the same species as well species richness within plot was observed. This may represent an increase in species density within each plot and therefore throughout the study area. From an ecosystem perspective, this indicates not only an increase in plant density, but can also signify an increase in plant diversity. This may also indicate a temporal shift in species composition that has been materializing between 2021 and 2022. However, a temporal shift can only be quantified once future datasets are collected and compared to existing datasets.

Annual variability in leaf drop and decay continue to present a challenge for interpreting the data. Additional years of data will provide a better estimate of natural variability and the ability to identify any unusual changes in cover or species assemblages. Completion of future surveys prior to leaf drop will provide more accurate cover metrics for species that

are more sensitive to groundwater changes, such as skunk cabbage and lady fern, and for species that tend to lose their leaves quickly, such as salmonberry, red alder, and vine maple.

6.2 Indicator Plants

6.2.1 Background

Monitoring of hydric indicator plants is identified in the EA Certificate Amendment Application – Mitigation Plans document (2017) as a means to detect effects of potential changes in shallow groundwater and associated soil moisture conditions. Western skunk cabbage (*Lysichiton americanus*) is a hydric soil moisture regime indicator species common to the swamp ecosystems of the Horn Creek and Boa Brook Study Area and the Downes Creek Study Area (Figures 5-3 and 5-4), and both plant density and plant size have been observed to change in with soil moisture (Minore 1969). Indicator plant plots were established in fall 2017 to assess species presence, density, and plant phenology. Comparison of these measures through time will provide a means to assess any observed changes in shallow groundwater dynamics as detected by installed groundwater wells (Section 5). If adverse effects of the Bevan Wells operation occur, shallow ground water elevations are likely to change first, with a vegetation species composition response taking place over a longer time period. Indicator plant plots were to be monitored on an annual basis for the first five years after establishing a "baseline" in 2017 to identify typical vegetation and shallow groundwater conditions. The following constitutes data from fall 2022, the fifth year of monitoring following the 2017 baseline.

6.2.2 Methods

Ten hydric indicator plant plots have been established within the watersheds of interest: 8 plots in the Downes Creek watershed (Figure 5-4) and 2 plots in the Horn Creek and Boa Brook watershed (Figure 5-3). In 2021, D11 (Figure 5-4) was not located and was therefore not included in the data interpretation. However, in 2022, D11 was located and was incorporated into the data interpretation. Plot locations are distributed to capture a range of soil moisture conditions ranging from Wm05 sites in downstream confluence areas to Ws53 sites in watershed headwaters. Candidate plot sites required a minimum skunk cabbage patch size of 15m in diameter. Where possible, these plots were installed adjacent to terrestrial ecosystem mapping plots (Section 6.1.2). At Horn Creek, the terrain within the swamp wetland does not allow for a 15m transect and instead two transects of 10m in length are present.

Field work was conducted between October 4 and October 7, 2022, about two weeks later than the 2021 data collection. The 2022 field work occurred two weeks earlier than the 2017 data collection due to the amount of petiole decay observed in 2017. To adjust for the amount of decay observed in 2017, the 2018 Bevan Avenue Groundwater Supply Development Project Operation Environmental Management Plan (OEMP) (City of

Abbotsford, 2018) specifies that sampling should occur after 1065 growing degree days (or Julian days), which is likely to occur around September 20. It also specifies that all plots must be assessed no later than October 1 each year. As sampling took place after October 1, slight petiole decay was evident in each plot. However, due to the extremely dry weather experienced throughout the growing season in 2022 (April 1 – October 1), decay was minimal and did not present substantial challenges to data collection. Therefore, at the time of the survey, plants had likely reached full maturity.

At each plot, line intercept transects 15 m long (10 m for Horn Creek plots H01 and H02) were marked with labelled PVC posts at the start and finish. An Eslon tape was pulled tight along the transect line. Each mature plant (minimum 6 petioles) intersecting the transect line was included in the plot and its location along the transect (distance from start) and longest petiole length recorded. Rules for determining whether plants petioles that intersect the transect and are included in the plot were developed and applied and are available upon request.

6.2.3 Results and Discussion

Detailed plot data may be found in Appendix Q. Results are summarized in Table 6-3 and Figures 6-1 to 6-6.

In 2022, average petiole length per plot ranged from 9.17 cm to 54.89 cm (Table 6-3), with an average of 38.47 cm for all plots.[6] This average is lower than the 2021, 2020, 2019, 2018, and 2017 data, which had average petiole lengths of 45.41 cm, 40.00 cm, 47.62 cm, 48.11 cm and 48.36 cm respectively. Average petiole lengths have varied throughout the six years at each site, but there have been few consistent year-to-year trends (Figures 6-1 and 6-2). The 2022 mean petiole length was lower than the 2017 measurements at 8 of the 10 sample sites with collected 2022 data, and in 7 cases results were also lower than the 2021 data.

In 2022, the average plant density (as number of plants per metre) was higher than the 2017 density at 7 of the 10 sample sites with the 2022 data (Figures 6-3 and 6-4). The 2022 density was lower than the 2021 value at 7 sites. Site D11 was compared to 2020 data as no data was collected in 2021, and the density was found to be lower than the 2020 value at D11. Sites D05, D08 and D12 had greater plant densities in 2022 than in 2021, while the remainder (B02, D01, D06, D09, D10, D11 and H01-LA2) had lower plant densities. No consistent pattern was apparent in density through time across the sites.

[6] D11 was included in 2022, as it was found successfully. H01-LA1 was not included in 2022 as it was not located.

Table 6-3 Indicator Plant Plot Results 2017 to 2022

Plot #	Average of Petiole Length (cm)						Density (Plants per Metre) *						Total Petiole length per metre (cm)					
	2017	2018	2019	2020	2021	2022	2017	2018	2019	2020	2021	2022	2017	2018	2019	2020	2021	2022
B02-LA1	52.85	49.89	43.76	30.17	38.25	10.28	0.87	3.13	1.67	2.40	2.13	1.60	45.80	156.33	72.93	72.40	81.60	16.44
D01-LA1	63.47	60.95	58.62	51.00	53.07	45.63	2.27	2.87	2.27	2.33	3.00	1.60	143.87	174.73	129.53	119.00	159.20	73.0
D05-LA1	55.15	51.88	54.74	47.83	53.71	51.88	1.33	2.20	1.53	1.20	1.60	1.70	73.53	114.13	83.93	57.40	85.93	88.20
D06-LA1	54.29	50.90	51.35	41.41	43.37	44.78	0.93	2.07	1.73	1.13	2.87	1.80	50.67	105.20	78.73	46.93	124.33	80.6
D08-LA1	35.40	37.11	33.83	33.00	32.23	31.58	0.33	0.60	0.40	0.40	0.47	0.80	11.80	22.27	13.53	13.20	15.04	25.30
D09-LA1	46.58	49.35	51.50	34.00	46.20	45.25	0.80	1.53	2.00	1.93	2.00	1.60	37.27	75.67	103.00	65.73	92.4	72.40
D10-LA1	43.83	43.92	NA**	48.29	52.85	52.11	0.40	0.80	NA**	0.93	0.87	0.30	17.53	35.13	NA**	45.07	45.8	15.60
D11-LA1	38.80	41.55	44.33	34.91	NA***	39.10	0.33	0.67	0.60	0.73	NA***	0.70	12.93	27.70	26.60	25.60	NA***	27.4
D12-LA1	56.98	58.97	56.84	51.93	54.79	54.89	1.73	2.13	1.67	1.73	1.93	2.70	98.77	125.80	94.73	96.93	105.93	148.20
H01-LA1*	41.96	44.96	44.85	31.71	NA***	NA***	0.93	1.53	1.30	0.93	NA***	NA***	39.17	68.93	58.30	44.40	NA***	NA***
H01-LA2*	42.67	39.75	36.35	35.76	31.83	9.17	1.80	2.13	1.70	1.13	0.60	0.50	76.80	84.80	61.80	60.80	19.10	4.58

*Measures are based on a 10m transect, rather than 15m, and the plots are the same site in parallel

**Plot could not be found due to blowdown that occurred after the 2018 sampling period. The plot was found again in 2020.

***Plot could not be found.

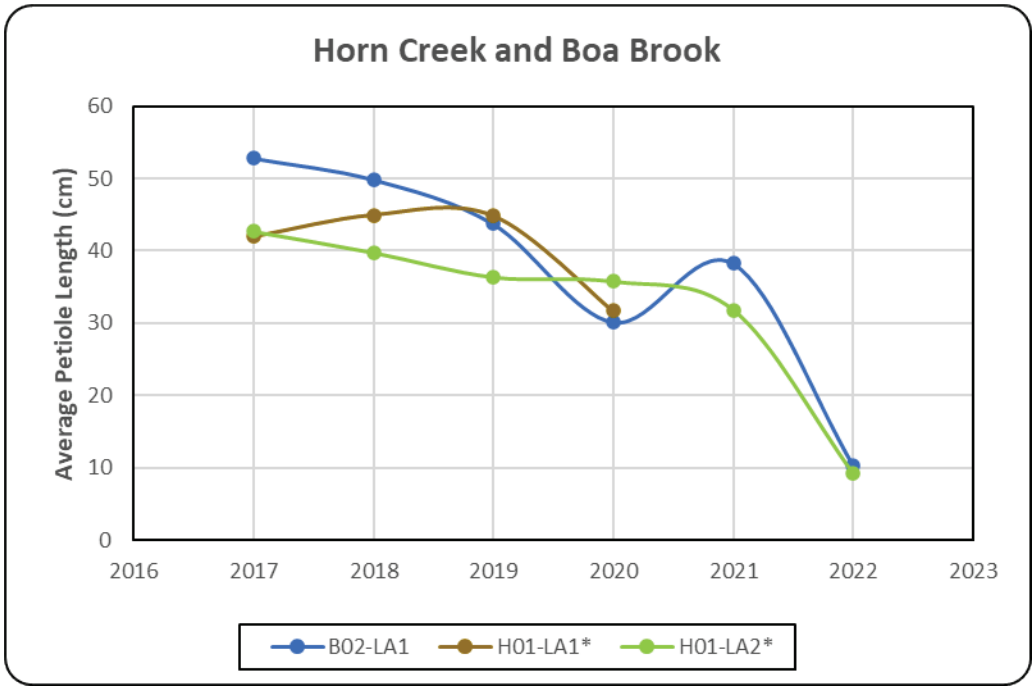


Figure 6-1 Comparison of the Average Petiole Length for the 2017 to 2022 Skunk Cabbage Line Intercepts in the Horn Creek/Boa Brook Watershed

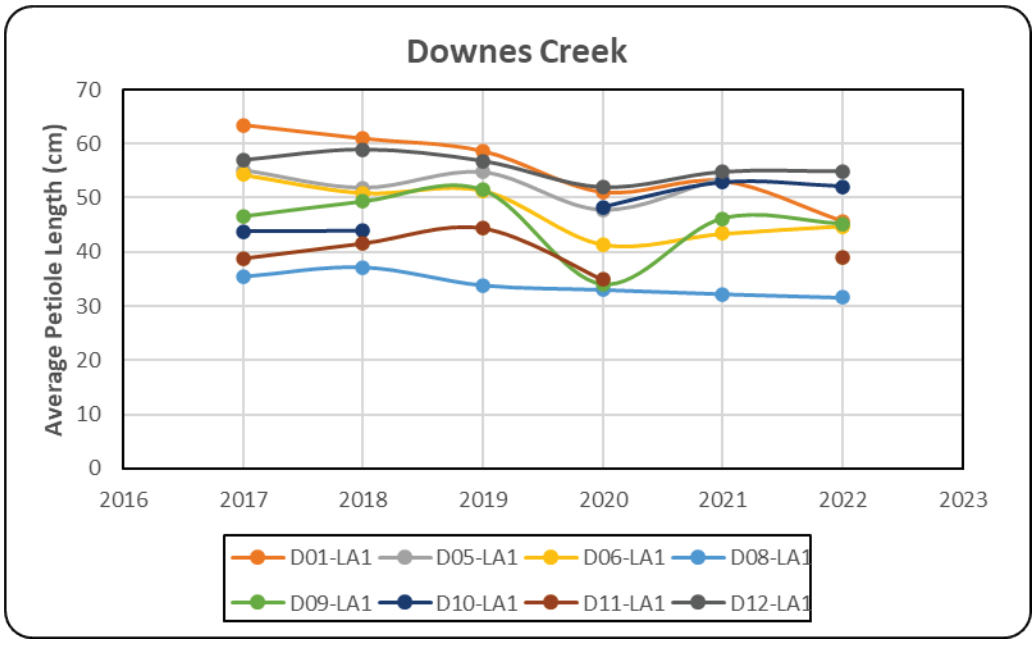


Figure 6-2 Comparison of the Average Petiole Length for the 2017 to 2022 Skunk Cabbage Line Intercepts in the Downes Creek Watershed

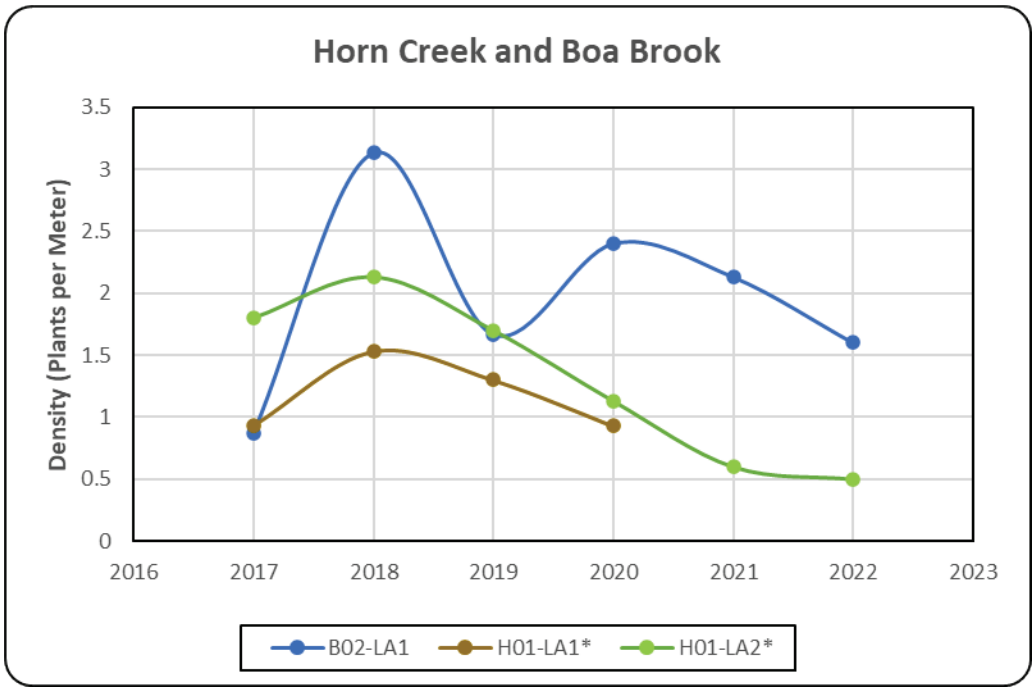


Figure 6-3 Comparison of the Density of Plants Encountered by the 2017 to 2022 Skunk Cabbage Line Intercepts in the Horn Creek/Boa Brook Watershed

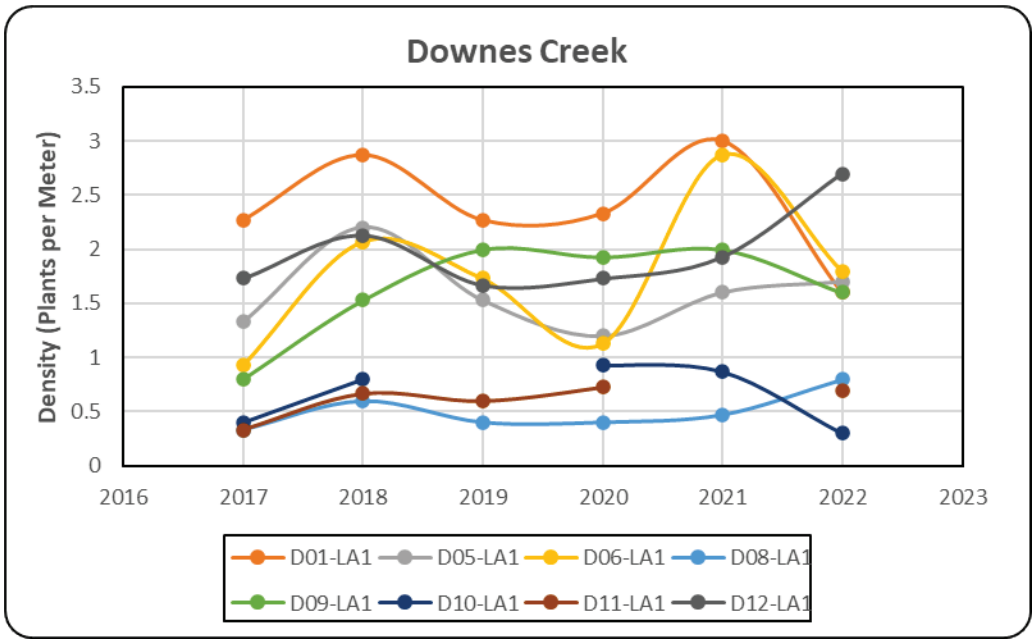


Figure 6-4 Comparison of the Density of Plants Encountered by the 2017 to 2022 Skunk Cabbage Line Intercepts in the Downes Creek Watershed

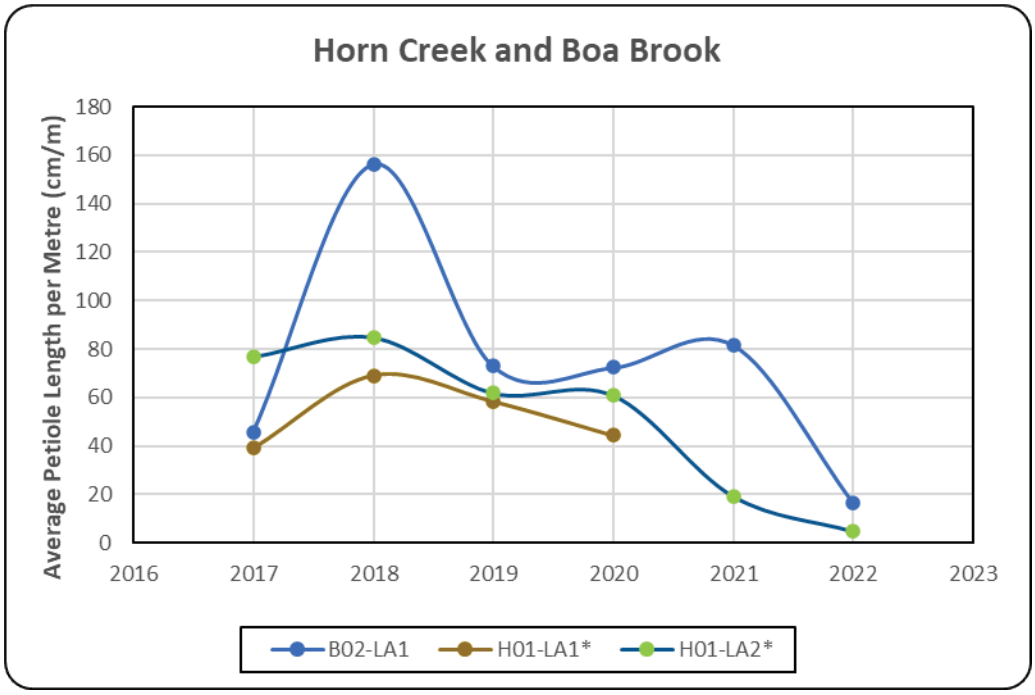


Figure 6-5 Comparison of the Average Petiole Length per Metre for the 2017 to 2022 Skunk Cabbage Line Intercepts in the Horn Creek/Boa Brook Watershed

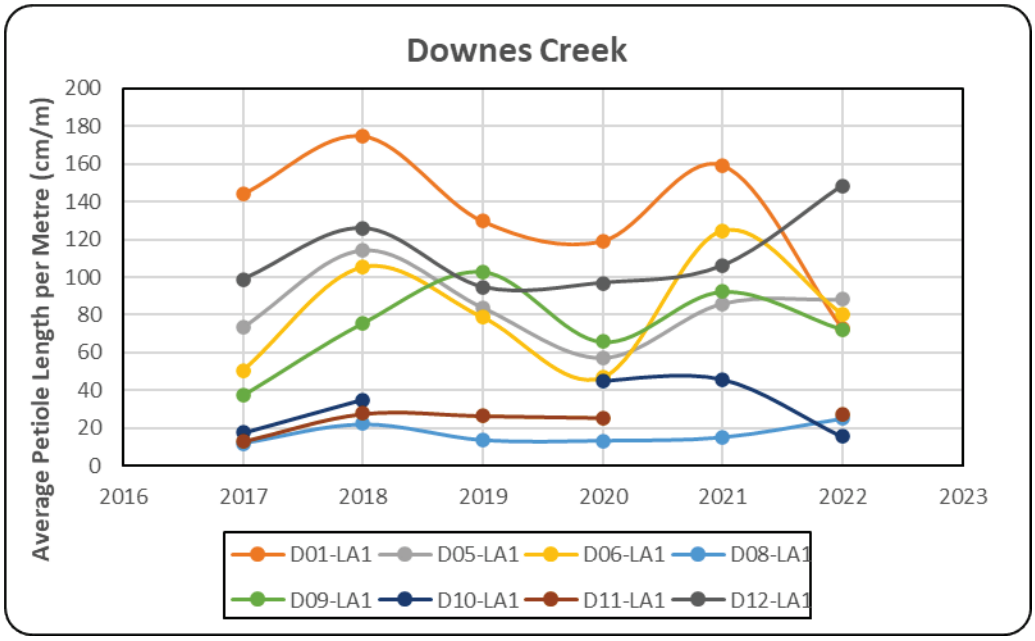


Figure 6-6 Comparison of the Average Petiole Length per Metre for the 2017 to 2022 Skunk Cabbage Line Intercepts in the Downes Creek Watershed

Petiole length per metre values decreased at 8 of the sites in 2022 compared with 2017; however, trends were not consistent across all sites (Figures 6-5 and 6-6). The 2022 average petiole length per metre was 55.17 cm compared to 81.04 cm in 2021, 58.86 cm in 2020, 72.31 cm in 2019, 90.06 cm in 2018, and 55.29 cm in 2017.

Statistical analyses were conducted to provide support for the observed changes in indicator plant parameters. The analyses included linear regressions on average petiole lengths in selected plots (B02-LA1, H01-LA2, D01-LA1, and D08-LA1) and Mann-Kendall non-parametric trend analyses on all indicator parameters. Unlike regression analysis, the Mann-Kendall test considers direction of the trend but makes no assumptions about linearity. This analysis was performed using the MAKESENS application for Excel (Salmi *et al*. 2002). The analyses included separate averages over the monitoring period for plots without missing data and for all plots.

The regression analyses showed a highly significant ($p=0.0028$) decrease in average petiole length at D01-LA1, and significant decreases at B02-LA1 ($p=0.0165$), H01-LA2 ($p = 0.0317$), and D08-LA1 ($p=0.0173$). The decreases noted in average petiole length at plots H01-LA2 and D01-LA1 may be due to their locations and amount of canopy cover present (i.e., skunk cabbage thrive in consistently wet, mucky areas with partial sun to light shade, as excessive heat from strong constant sunlight is not conducive to growth). Plots D01-LA1 and H01-LA2 are in open canopy areas that may experience greater levels of direct sunlight during the growing season. Decreases at B02-LA1 and D08-LA1 are likely not due to lack of shade, as both plots have considerable canopy cover. The decreases may instead be due to prolonged drought conditions experienced throughout the growing season of 2022, in which 37% less precipitation fell from April to October, when compared against a similar year of rainfall; in 2011, 525.40 mm of precipitation fell over the same 7-month period, which is 37% higher than the 386.40 mm that fell in over the growing season in 2022. Decreases in precipitation over the growing season can induce stress in the skunk cabbage, and thus reduce the growing potential of the plants themselves over the course of the growing season.

Based on the Mann-Kendall tests, significant ($p<0.05$) temporal trends occurred at multiple sites (Table 6-5). Significant decreasing trends in average petiole length were noted at B02-LA1, D01-LA1, D08-LA1, and H01-LA2. Decreasing trends in plant density and total petiole length per metre were noted at H01-LA2 with no downward trends at the other sites. The changes in Downes Creek do not signify a downward trend at the watershed level, and there are too few plots in the Horn-Boa study area to provide conclusions about watershed level changes. In all, the indicator plant measurements showed did not appear to show adverse effects attributable to operation of the Bevan Wells. It should be noted, however, that the power of the Mann-Kendall test is low for fewer than eight data points (Holbert 2019). Subsequent years of data collection will provide a more robust assessment of trends.

Table 6-4 Decreases in Skunk Cabbage Petiole Length over Time (2017 – 2022): Regression Results

B02-LA1

Source	df	SS	MS	F	Significance
Regression	1	975.844	975.844	15.76	**0.0165**
Residual	4	247.692	61.923		
Total	5	1223.535			

H01-LA2

Source	df	SS	MS	F	Significance
Regression	1	525.806	525.806	10.50	**0.0317**
Residual	4	200.326	50.082		
Total	5	726.132			

D01-LA1

Source	df	SS	MS	F	Significance
Regression	1	207.294	207.294	43.13	**0.0028**
Residual	4	19.224	4.806		
Total	5	226.518			

D08-LA1

Source	df	SS	MS	F	Significance
Regression	1	17.073	17.073	15.32	**0.0173**
Residual	4	4.457	1.114		
Total	5	21.530			

df – Degrees of Freedom SS – Sum of Squares MS – Mean Squared

Bold indicates statistical significance. Significance set at $p < 0.05$.

Table 6-5 Significance of Mann-Kendall Tests for Trends in Skunk Cabbage Indicator Parameters, 2017 – 2022

Average Petiole Length

Time Series	First Year	Last Year	n	Mann-Kendall S	Significance	Sen's Slope Estimate
B02-LA1	2017	2022	6	-13	p<0.05	-7.56
D01-LA1	2017	2022	6	-13	p<0.05	-2.78
D05-LA1	2017	2022	6	-6		-0.515
D06-LA1	2017	2022	6	-7		-2.19
D08-LA1	2017	2022	6	-13	p<0.05	-0.793
D09-LA1	2017	2022	6	-5		-0.950
D12-LA1	2017	2022	6	-7		-0.65
H01-LA2	2017	2022	6	-15	p<0.01	-3.16
D-Average [a]	2017	2022	6	-11	p<0.05	-1.43
D-Average All [a]	2017	2022	6	-5		-0.732

Plant Density

Time Series	First Year	Last Year	n	Mann-Kendall S	Significance	Sen's Slope Estimate
B02-LA1	2017	2022	6	-1		-0.023
D01-LA1	2017	2022	6	0		0.000
D05-LA1	2017	2022	6	3		0.057
D06-LA1	2017	2022	6	5		0.174
D08-LA1	2017	2022	6	8		0.035
D09-LA1	2017	2022	6	6		0.157
D12-LA1	2017	2022	6	6		0.130
H01-LA2	2017	2022	6	-13	p<0.05	-0.400
D-Average [a]	2017	2022	6	5		0.074
D-Average All [a]	2017	2022	6	3		0.070

Total Petiole Length per Metre (cm)

Time Series	First Year	Last Year	n	Mann-Kendall S	Significance	Sen's Slope Estimate
B02-LA1	2017	2022	6	-3		-5.87
D01-LA1	2017	2022	6	-7		-10.53
D05-LA1	2017	2022	6	3		1.42
D08-LA1	2017	2022	6	7		0.810
D09-LA1	2017	2022	6	3		5.6
D12-LA1	2017	2022	6	5		5.600
H01-LA2	2017	2022	6	-13	p<0.05	-14.5
D-Average [a]	2017	2022	6	-1		-0.88
D-Average All [a]	2017	2022	6	3		1.58

a D-Average is average of all plots having 6 years of data. D-Average All is average of all plots. **Bold** indicates significance. Significance is set at p<0.05. Blank indicates p>0.1.

6.2.4 Successes, Challenges, and Suggested Changes

Due to the assessment timing change included in the OEMP, the 2018 to 2021 fieldwork was completed 4 to 5 weeks earlier than the 2017 baseline, with a goal of viewing plants largely prior to decay. The 2022 fieldwork was completed 2 to 3 weeks earlier than the 2017 baseline. Per the OEMP, all plots must be assessed after approximately 1065 growing degree days (assuming a threshold temperature of 10 degrees Celsius). For planning purposes, surveys should be completed after September 20 but before October 1 annually The 2022 surveys were completed from October 4 to October 7 following the growing degree day threshold. Even though the 2022 inventory was completed after the maturation threshold, only slight decay was observed in all plots, and the data were not adversely affected.

The indicator plant surveys focus on Downes Creek, where potential changes in the shallow groundwater regime are a greater concern than in the Horn-Boa watershed. However, given the loss of an indicator plant plot in Horn Creek and apparent trends in the remaining Horn Creek and Boa Brook plots, ENKON recommends the establishment of replacement/additional plots in this watershed.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

This report summarises the findings from the Year 12 (May 2022 – April 2023) environmental monitoring of the Bevan Wells Groundwater Supply Development Project. Year 12 data have been presented in comparison with previous annual monitoring data, including the Year 2 baseline data, and Year 3 and 4 data when the mitigation wells were augmenting flows to Horn Creek and Boa Brook. The monitoring program has produced the following observations and conclusions.

A maximum daily withdrawal of 25 ML/day is permitted under the EA Certificate. The Bevan Wells were used extensively from Year 3 through Year 12. In 2022, well operation complied water withdrawal limits. The maximum daily withdrawal was 19.394 ML/day, and the total withdrawal was 1,971 ML or 79% of the total allowable groundwater diversion (2,505 ML/year).

Flows measured in the creeks during Year 12 were within range of previous measurements and did not exhibit any long-term declining trends. Although calculated flows for Downes Creek went below the 27.9 L/s threshold during Year 12, all manual measurements during this interval were greater than this trigger value. The occurrence of calculated flow at Downes Creek below the 27.9 L/s threshold likely reflects the high sensitivity of calculated flows to changes in the measured water level in the creek.

Flow measurements at the Fishtrap Creek SCADA station have been challenging. Due to variability in low flow measurements, it has not been possible to develop a rating curve for the site. As a result, the monitoring station will operate as a water level station, and further flow measurements will not be completed. To mitigate potential low-flow periods, it is recommended that the Fishtrap Creek mitigation well continues to be turned on during the summer months.

An apparent shift in the flow pattern Downes Creek hydrometric station occurred on December 24, 2022, triggered by a rainfall event. Although an adjustment was made to the rating curve, all reported discharge data after December 24, 2022 should be considered estimates. An additional five flow measurements encompassing a range of low, medium, and high flows are recommended to allow redevelopment of the rating curve.

Manual flow monitoring at several sites experienced challenges related to high or low water levels. Water levels in Fishtrap Creek at F-02 were too high to allow complete flow

measurements in in June 2022 and October 2022 through April 2023. Likewise, the water at F-04 was too deep for flow measurements in January 2022 .Conversely, the channel was dry at both F-02 and F-04 in September 2022. Waechter Creek at the staff gauge was also dry in September 2022, and in August 2022 the flow at this point was too low to measure accurately. A similar issue occurred in Boa Brook at B-01. The staff gauge was above the water line from July through September/early October 2022.

A programming error in the shuttle for the Hobo loggers resulted in a lack of flow data for April and May 2022. Additionally, the WT-01 and D-04 Hobo loggers failed, and no valid data were recorded at these sites during the summer of 2022.

The expanded flow monitoring stations have continued to be problematic. In addition to the high and low water level issues, the manual stream flow data recorded at B-02, D-02, D-03 and D-04 have been too variable to establish a stage-discharge rating curve.

Although the Bevan Wells have been used extensively in Years 3 through 12, water quality data have remained generally consistent with Year 2 baseline data. The only observed change was a statistically significant decreasing trend in dissolved oxygen concentrations at B-01, H-02 and the Willband Creek reference site (W-01). However, water temperature at H-02 did not show a corresponding increase, which suggests that the trend was unrelated to the operation of the Bevan Wells. Other data for Years 2 to 11 show that the use of the Bevan Wells has not affected water quality.

Six representative sites for the assessment of fish habitat (two on Boa Brook and four on Horn Creek) continued to be assessed as part of the annual monitoring program. There was very little change in physical habitat parameters from the previous annual monitoring results. There were no statistically significant decreasing trends in bankfull width or bankfull depth. At Horn Creek, a significant increasing trend in the average wetted width was observed at site 1A, and a significant decreasing trend occurred at site 3C. No significant trends (increasing or decreasing) were observed at the other Horn Creek or Boa Brook sites. Habitat suitability for coho, cutthroat trout fry and parr, and rainbow trout fry and parr was evaluated as changes in the amount of usable habitat based on depth and velocity across the channel. There were statistically significant changes in habitat suitability for some species and/or life stages at some sites but no overall decrease in availability of suitable habitat in Horn Creek or Boa Brook. The changes over time are attributable to natural variation of physical habitat parameters and do not appear to reflect effects of water withdrawal by the Bevan Wells.

Groundwater levels were measured at seven monitoring well locations. During Year 12 aquifer water level elevations and the magnitude of seasonal variation were generally consistent with trends for the same interval during prior years. There was no evidence of a progressive year-over-year decline in water levels in any of the observation wells.

Year 12 was the fifth full year of the expanded monitoring programs required under the amended EA Certificate, although some data were collected in 2017 during establishment of the additional monitoring stations. No unanticipated adverse effects were identified in Year 12 monitoring. The five years of mesohabitat and shallow groundwater monitoring is not sufficient to draw conclusions, but there were no changes that would suggest an immediate need for a mitigation well for Downes Creek (Condition #25).

Some issues with the water level loggers occurred in Year 12. A fault in the shuttle caused its internal clock to reset, making all loggers record dates erroneous dates from April to October 2022. Although it was possible to correct the date, the loggers did not collect data in April and May 2022, and large shifts in baseline water levels in several wells suggested possible data errors. Additionally, the logger at F02 failed to record data from October 2022 to April 2023, and the downloaded data from all three wells in Control Wetland B could not be corrected for barometric pressure, resulting in no valid data for the wetland during this period.

There was an overall decrease in water level in the Downes Creek wetland from 2018 to 2023. The decrease did not correspond to withdrawals by the Bevan Wells.

After five years of data collection, the vegetation monitoring showed neither a major shift in species composition nor changes to ecosystem boundaries that would suggest a response to drier conditions. Trend analyses of indicator plant (skunk cabbage) parameters showed decreases in average petiole length in four plots, one each in the Horn Creek and Boa Brook watershed and two in the Downes Creek watershed. Decreasing trends in plant density and total petiole length per metre were noted at the Horn Creek plot with no downward trends at the other sites. The changes in Downes Creek do not signify a downward trend at the watershed level. There are too few plots in the Horn-Boa study area to provide conclusions about watershed level changes. In all, the indicator plant measurements showed did not appear to show adverse effects attributable to operation of the Bevan Wells.

7.2 Recommendations

Five years of conducting the expanded monitoring program required by the 2017 Amendment have resulted in some challenges that may require adjustments to the program. Specific issues are related the expanded flow and mesohabitat monitoring stations and the indicator plant monitoring sites in Horn Creek-Boa Brook.

Several expanded flow monitoring stations have continued to be problematic. In addition to high and low water level issues, the manual stream flow data recorded at B-02, D-02, D-03 and D-04 have been too variable to establish a stage-discharge rating curve. ENKON recommends that a qualified professional hydrologist in consultation with a qualified professional fisheries biologist re-evaluate the expanded flow monitoring sites to determine whether:

- monitoring at these sites can provide sufficiently accurate flows to determine temporal trends in summer low flows;
- sufficiently accurate flow monitoring can be achieved without significant channel configuration (e.g., weir installation) and if not, whether the flow data is valuable enough to warrant the disturbance to fish habitat; and
- whether the program objectives (identification of negative effects on fish habitat) can be achieved through seasonal flow monitoring (manual measurements) in conjunction with the current mesohabitat monitoring program.

For several years beavers have been active at F-02 and F-03, changing the site characteristics. It will be difficult to identify effects, if any, of the Bevan Wells on fish habitat at these sites due to the confounding influence of beaver activity. A qualified fisheries biologist should assess the possibility of finding additional or alternate mesohabitat monitoring sites that are unaffected by beavers, although these sites will not likely be available in some reaches.

The indicator plant surveys focus on Downes Creek, where potential changes in the shallow groundwater regime are a greater concern than in the Horn-Boa watershed. Originally three indicator plant plots were established in this watershed, but one Horn Creek plot was lost. Given the apparent trends in the remaining Horn Creek and Boa Brook plots, ENKON recommends the establishment of replacement/additional plots in this watershed.

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