1. ADOPTION OF THE AGENDA

1.1 June 6, 2018 Regular Meeting Agenda
That the Climate Action Committee adopt the agenda for its regular meeting scheduled for June 6, 2018 as circulated.

2. ADOPTION OF THE MINUTES

2.1 April 4, 2018 Regular Meeting Minutes
That the Climate Action Committee adopt the minutes of its regular meeting held April 4, 2018 as circulated.

3. DELEGATIONS

On Table 3.1 Jill Dwyer, Coquitlam River Watershed Roundtable Coordinator, in partnership with the Watershed Watch Salmon Society
Subject: Sponsorship Request for Watershed Outreach Campaign – Striving to Change Behaviour to Achieve Watershed Health

4. INVITED PRESENTATIONS

5. REPORTS FROM COMMITTEE OR STAFF

5.1 Caring for the Air 2018 Report
Designated Speaker: Julie Saxton, Air Quality Planner, Parks, Planning and Environment Department
That the MVRD Board receive for information the report dated May 10, 2018, titled “Caring for the Air 2018 Report”.

1 Note: Recommendation is shown under each item, where applicable.
5.2 **Best Management Practices for Invasive Species in the Metro Vancouver Region**  
*Designated Speakers: Laurie Bates-Frymel, Senior Regional Planner, Parks, Planning and Environment Department and Tasha Murray, Executive Director of the Invasive Species Council of Metro Vancouver*  
That the MVRD Board receive for information the report dated May 11, 2018, titled “Best Management Practices for Invasive Species in the Metro Vancouver Region”.

5.3 **Use of Land Cover Data to Assess Regional Ecosystem Services**  
*Designated Speaker: Josephine Clark, Regional Planner, Parks, Planning and Environment Department*  
That the MVRD Board receive for information the report titled “Use of Land Cover Data to Assess Regional Ecosystem Services” dated May 14, 2018”.

5.4 **Update of the Metro Vancouver Sensitive Ecosystem Inventory (SEI)**  
*Designated Speaker: Josephine Clark, Regional Planner, Parks, Planning and Environment Department*  
That the MVRD Board receive for information the report titled “Update of the Metro Vancouver Sensitive Ecosystem Inventory (SEI)” dated May 7, 2018.

5.5 **Manager’s Report**  
*Designated Speaker: Roger Quan, Director, Air Quality and Climate Change, Parks, Planning and Environment Department*  
That the Climate Action Committee receive for information the report dated May 25, 2018, titled “Manager’s Report”.

6. **INFORMATION ITEMS**

6.1 **Correspondence dated May 2, 2018 from Pembina Institute re: Letter to B.C. Environment Minister George Heyman**

7. **OTHER BUSINESS**

8. **BUSINESS ARISING FROM DELEGATIONS**

9. **RESOLUTION TO CLOSE MEETING**  
*Note: The Committee must state by resolution the basis under section 90 of the Community Charter on which the meeting is being closed. If a member wishes to add an item, the basis must be included below.*

10. **ADJOURNMENT/CONCLUSION**  
That the Climate Action Committee adjourn/conclude its regular meeting of June 6, 2018.

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Membership:
- Corrigan, Derek (C) – Burnaby  
- Reimer, Andrea (VC) – Vancouver  
- Buhr, Karl – Lions Bay  
- Dupont, Laura – Port Coquitlam  
- Gill, Tom – Surrey  
- Harris, Maria – Electoral Area A  
- Jackson, Lois – Delta  
- Masse, Robert – Maple Ridge  
- Steves, Harold – Richmond  
- Storteboom, Rudy – Langley City  
- Villeneuve, Judy – Surrey  
- Williams, Bryce – Tsawwassen

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*Climate Action Committee*
Minutes of the Regular Meeting of the Metro Vancouver Regional District (MVRD) Climate Action Committee held at 1:07 p.m. on Wednesday, April 4, 2018 in the 28th Floor Committee Room, 4730 Kingsway, Burnaby, British Columbia.

MEMBERS PRESENT:
Chair, Mayor Derek Corrigan, Burnaby
Vice Chair, Councillor Andrea Reimer, Vancouver
Mayor Karl Buhr, Lions Bay
Councillor Laura Dupont, Port Coquitlam
Director Maria Harris, Electoral Area A
Mayor Lois Jackson, Delta
Councillor Robert Masse, Maple Ridge (departed at 3:06 p.m.)
Councillor Harold Steves, Richmond (departed at 2:55 p.m.)
Councillor Rudy Storteboom, Langley City
Councillor Judy Villeneuve, Surrey

MEMBERS ABSENT:
Councillor Tom Gill, Surrey
Chief Bryce Williams, Tsawwassen

STAFF PRESENT:
Roger Quan, Air Quality and Climate Change Director, Parks, Planning and Environment
Donna Brown, Acting Chief Administrative Officer
Janis Knaupp, Legislative Services Coordinator, Board and Information Services

1. ADOPTION OF THE AGENDA

1.1 April 4, 2018 Regular Meeting Agenda

It was MOVED and SECONDED That the Climate Action Committee adopt the agenda for its regular meeting scheduled for April 4, 2018 as circulated.

CARRIED

2. ADOPTION OF THE MINUTES

2.1 March 7, 2018 Regular Meeting Minutes

It was MOVED and SECONDED That the Climate Action Committee adopt the minutes of its regular meeting held March 7, 2018 as circulated.

CARRIED
3. **DELEGATIONS**
No items presented.

4. **INVITED PRESENTATIONS**
No items presented.

5. **REPORTS FROM COMMITTEE OR STAFF**

5.1 **Metro Vancouver’s Climate Action Strategy: Climate 2050 Discussion Paper and Stakeholder Education and Engagement Process**

Report dated March 20, 2018 from Jason Emmert, Air Quality Planner, Conor Reynolds, Program Manager, Air Quality and Climate Change Policy Parks, Planning and Environment, and Lucy Duso, Policy Coordinator, External Relations, seeking MVRD Board endorsement of the final Climate 2050 Discussion Paper and direction to staff to initiate stakeholder education and engagement based on the Discussion Paper to inform development of the Climate 2050 Strategic Plan.

Members were provided with a presentation including changes made to the Climate 2050 Discussion Paper based on feedback from the Climate Action Committee at its March 7, 2018 meeting, Issues Areas summaries, climate change data and trends and the education and engagement strategy highlighting public information and dialogues, key interviews, stakeholder meetings and forums, youth engagement, member jurisdictions, and next steps.

In response to questions, members were informed about how consultation will shape strategy development and implementation, timing, climate change trends, and design of the engagement strategy.

In response to a request for feedback on consultation and education, members suggested that consideration be given to:

- identifying opportunities to incorporate public feedback into the strategy
- informing stakeholders about local actions being taken at consultation events
- exploring climate policy and best practices in Washington State
- seeking agencies or groups to endorse Climate 2050 and exploring the creation of an agency or coalition to support efforts
- emphasizing the urgent need to adapt to climate change as part of education
- seeking feedback on actions Metro Vancouver and other agencies can take

In response to a request for feedback on the strategy, members suggested that consideration be given to:

- how to plan for climate change in Metro Vancouver based on projected growth, increased diversion to composting facilities and impacts on host communities, and local implications from combined sewer issues
• identifying local government successes and constraints to achieving GHG targets, examining local and sectoral GHG gains, and how Metro Vancouver can assist others in meeting targets
• numbering categories in the Issues Areas for easy reference in the strategy
• identifying responsibilities and actions that can be taken by all levels of government and communities members
• in the “Scenarios for Getting to 80% GHG Reduction by 2050” graph, representing the current path to show the lack of progress and urgency
• compiling actions being taken by local governments to develop best practices in reducing GHGs

In response to questions, local governments were encouraged to share Metro Vancouver’s social media campaign associated with Climate 2050 consultation, and to participate in dialogues and forums. Members were also informed about reporting requirements under the BC Climate Action Charter, and carbon tax rebates.

Presentation material titled “Climate 2050 Strategy Final Discussion Paper and Engagement Strategy” is retained with the April 4, 2018 Climate Action Committee agenda.

It was MOVED and SECONDED
That the MVRD Board:

a) endorse the Climate 2050 Discussion Paper, and associated Education and Engagement Strategy, as attached to the report dated March 20, 2018, titled “Metro Vancouver’s Climate Action Strategy: Climate 2050 Discussion Paper and Stakeholder Engagement Process”; and

b) direct staff to initiate stakeholder education and engagement based on the Discussion Paper to inform the development of the Climate 2050 Strategic Plan.

CARRIED

5.2 Forecast of 2015 Lower Fraser Valley Air Emissions Inventory and Policy Implications

Report dated March 16, 2018 from Shelina Sidi, Senior Project Engineer, and Derek Jennejohn, Lead Senior Engineer, Parks, Planning and Environment, summarizing the forecast of the 2015 air emissions inventory for the Lower Fraser Valley to 2035 highlighting projected changes in emissions from key regional sources, and potential implications for development of new air quality and climate change plans, policies and programs.

Members were provided with a presentation on the forecast of the 2015 Lower Fraser Valley Air Emissions Inventory and policy implications highlighting geographic scope, timing including historical trends, base year, and forecasts,
pollutants, sources, GHG trends in Metro Vancouver from 1995 to 2035, smog-forming pollutants, policy and regulation emission scenarios, and next steps.

2:55 p.m. Councillor Steves departed the meeting.

Members commented on Metro Vancouver’s advocacy role, specifically around GHG implications and projected population growth, and increasing rail and port activities in Metro Vancouver.

Presentation material titled “Forecast of the 2015 Lower Fraser Valley Air Emissions Inventory and Policy implications” is retained with the April 4, 2018 Climate Action Committee agenda.

It was MOVED and SECONDED
That the MVRD Board receive for information the report dated March 16, 2018, titled “Forecast of 2015 Lower Fraser Valley Air Emissions Inventory and Policy Implications”.

CARRIED

5.3 Proposed Scope Amendment to MVRD Sustainability Innovation Fund Project: Transit-Oriented Affordable Housing Fund Business Case Project
Report dated March 24, 2018 from Raymond Kan, Senior Regional Planner, Parks, Planning and Environment, providing an update on the Transit-Oriented Affordable Housing Fund Business Case Project approved in 2016 under the MVRD Sustainability Innovation Fund, and seeking MVRD Board authorization to amend the scope of work, consistent with and complementary to Phase 2 of the Transit-Oriented Affordable Housing Study.

It was MOVED and SECONDED
That the MVRD Board approve an amendment to the scope of the Transit-Oriented Affordable Housing Fund Business Case Project, which received funding under the MVRD Sustainability Innovation Fund, to include tools identified in the Transit-Oriented Affordable Housing Study.

CARRIED

5.4 Manager’s Report
Report dated March 20, 2018 from Roger Quan, Air Quality and Climate Change Director, Parks, Planning and Environment, updating the Climate Action Committee on the Committee’s 2018 Work Plan, Canadian Ambient Air Quality Standards for Nitrogen Dioxide, environmental impacts of brown lawns during conservation periods, and the launch of EVWorkplace.ca.

In response to questions, members were informed about the status of consultation on the development of a regional odour management strategy and proposed residential wood smoke regulation bylaw.
It was MOVED and SECONDED
That the Climate Action Committee receive for information the report dated March 20, 2018, titled “Manager’s Report”.

CARRIED

3:06 p.m. Councillor Masse departed the meeting.

6. INFORMATION ITEMS

It was MOVED and SECONDED
That the Climate Action Committee receive for information the following Information Items:
6.1 Report dated March 27, 2018 regarding Metro Vancouver’s Public Engagement Policy
6.2 Correspondence dated March 9, 2018 from UBCM to Board Chair Greg Moore, regarding 2017 Resolutions

CARRIED

7. OTHER BUSINESS
No items presented.

8. BUSINESS ARISING FROM DELEGATIONS
No items presented.

9. RESOLUTION TO CLOSE MEETING
No items presented.

10. ADJOURNMENT/CONCLUSION

It was MOVED and SECONDED
That the Climate Action Committee conclude its regular meeting of April 4, 2018.

CARRIED
(Time: 3:06 p.m.)

____________________________   __________________________
Janis Knaupp,      Derek Corrigan, Chair
Legislative Services Coordinator
Request to present to the Metro Vancouver Regional District - Climate Action Committee- June 6, 2018
Re: Sponsorship Request for Watershed Outreach Campaign – Striving to Change Behaviour to Achieve Watershed Health

Sponsorship Request Amount: A contribution of $3,950.00 towards an overall project totaling $22,315. (In-kind: $7,365.00 and Cash: $14,950)

Submitted by: Jill Dwyer, Coquitlam River Watershed Roundtable Coordinator, in partnership with the Watershed Watch Salmon Society

Email: coordinator@coquitlamriverwatershed.ca Phone: 604-505-8676

Background- The Coquitlam River Watershed Roundtable (CRWR) is a unique organization focused on advancing the health and sustainability of the Coquitlam River watershed. In operation since 2011, the CRWR is supported by a multi-sector Core Committee that guides its work, and a financial trustee, the Watershed Watch Salmon Society.

The CRWR Mission Statement says that the CRWR will:

- Facilitate collaborative resolution of urban growth and natural resource use pressures consistent with agreed community objectives and values,
- Inform and educate people about these matters and the watershed and,
- Promote and support conservation of a sustainable, healthy watershed environment.

The Coquitlam River watershed boasts a vast headwater wilderness including Coquitlam Lake Reservoir above the dam, and at least thirty watercourses which flow into a developed lower watershed that drains into the lower Fraser River. The river flows from Metro Vancouver’s Coquitlam Lake Reservoir and BC Hydro’s Coquitlam Dam, through Coquitlam and Port Coquitlam, the reserve lands of the Kwikwetlem First Nation, and Metro Vancouver’s Colony Farms, where the river mouth meets the Lower Fraser River. The Coquitlam Lake Reservoir provides approximately one third of the total system’s supply with drinking water and power generation for Metro Vancouver area residents.

In 2015, the CRWR launched the Lower Coquitlam River Watershed Plan (LCRWP) that involved more than 60 partners and three years in the making. Metro Vancouver was a significant supporting partner in its development. The overarching vision of the LCRWP is a healthy watershed that is enjoyed and supported by the community. Integral to achieving this vision is recognizing the linkages between healthy watersheds and healthy people. The LCRWP includes the integration of natural and human systems, such as land-based resources, social development, economic development, and inclusion of cultural and spiritual values. The LCRWP identifies several pressures that affect watershed health, provides strategies to address them, and initial action plans for implementation. However, implementation of the LCRWP also requires the commitment of key partners to help support the strategies for action. The topmost pressures the CRWR has identified for implementation includes actions that address the pressures from development, water extraction and invasive species on the health of the lower Coquitlam River watershed. The CRWR seeks the endorsement of support by the Climate Action Committee for Metro Vancouver to provide sponsor funding for a year-long initiative aimed to address the impacts of Invasive Species and Water Extraction on the health of the Coquitlam River watershed.
Objective - In partnership with Vancity Shaughnessy Station Community Branch, Fisheries and Oceans Canada, the Real Estate Foundation of BC, the Watershed Watch Salmon Society will provide support to the Coquitlam River Watershed Roundtable to deliver a series of voluntary event-based and hands-on outreach campaigns that will result in a measurable change in community behaviour toward the use of invasive plant species, and the overuse of drinking water. The project location is the lower Coquitlam River watershed, and will be piloted as a program that will be designed to be transferable to other municipalities. The aim of the project is to generate change in the use and sale of invasive plant species throughout the Metro Vancouver area and improve flows for fish through greater drinking water conservation. The CRWR is hopeful that Metro Vancouver can be a supporting funding partner in this work.

Other Funders - Building on our success in accessing funding support from multiple sources, CRWR submitted an application to Vancity Shaughnessy Station Community Branch to provide $10,000 for this initiative in March, 2018. Based on a preliminary meeting with Vancity staff, we have reason to hope that our application will be approved in May. Contribution funding of $1,000 from the Real Estate Foundation of BC and Fisheries and Oceans Canada has been secured, combined with an estimated $7,365 in-kind CRWR partner support. Metro Vancouver’s financial contribution will be an important factor in leveraging these funds.

Project Description - Invasive species and water extraction are pressures that affect ecological and human well-being components – the things the community said they care about in the Lower Coquitlam River Watershed Plan (LCRWP, 2015) and highlighted in the LCRWP Implementation Update 2018 Going Forward. Through a targeted behaviour-based campaign implemented over 10 – 12 months with other community events, as well as standalone events, Tri-City residents will learn about the impacts from invasive species and the overuse of drinking water on watershed health, specifically: riparian and natural areas, the Coquitlam River system and salmon, cultural and spiritual values, human health and safety, recreation and natural resources. These activities align with Metro Vancouver’s Ecological Health Action Plan to secure critical and sensitive habitats and ecological corridors, restore and enhance critical habitats in regional parks and greenways, and build community capacity to undertake stewardship activities, restoration, and species recovery and biodiversity enhancement projects.

The Coquitlam River Watershed Roundtable will organize and lead activities that appeal to families, youth and adults to learn about the impacts of invasive plant species and overuse of our water; hear about the heritage values of native plant species for Kwikwetlem First Nation; participate in traditional Iranian and Asian nature events; demonstrate the importance of flow needs for fish, through various technical research studies; which can lead to the implementation of strategies that will reduce pressure on the things we care about.

Guided by a project team and coordinator, the Outreach Campaign series will include informational outreach sessions, including training and orientation sessions for volunteers assisting in outdoor events, recruiting funding partner staff, members and their families to participate in hands-on “pulls” and riparian native planting opportunities; and a community-based social marketing campaign that includes the cities of Coquitlam and Port Coquitlam, including Kwikwetlem First Nation territory, to assess success in changing community behaviour towards protecting watershed health. The Project Team will coordinate with its funding partners to provide presentations and project updates, a final summary and results-based project report. The two strategies for action will engage a range of sectors of interest and organizations, drinking water/ water conservation and invasive species specialists, staff expertise from the cities of Coquitlam and Port Coquitlam, Metro Vancouver and Kwikwetlem First Nation in the delivery of events and research.

Specific benefits to Metro Vancouver and its member municipalities - The project aligns with Metro Vancouver Parks, Policy and Planning and Water staff that support implementation of the following strategies and plans:

- Metro Vancouver Invasive Species Management Strategy
- Grow Green initiative
- Metro Vancouver Drinking Water Conservation Plan
- Metro Vancouver Ecological Health Plan
- Joint Water Use Plan for Capilano and Seymour watersheds

www.coquitlamriverwatershed.ca
Climate Action Committee
To: Climate Action Committee

From: Julie Saxton, Air Quality Planner
Parks, Planning and Environment Department

Date: May 10, 2018
Meeting Date: June 6, 2018

Subject: Caring for the Air 2018 Report

RECOMMENDATION
That the MVRD Board receive for information the report dated May 10, 2018, titled “Caring for the Air 2018 Report”.

PURPOSE
To present the 2018 edition of the annual Caring for the Air report and provide information about the outreach activity conducted for the previous edition of the report.

The 2018 Caring for the Air report provides an update about climate change and air quality in the Lower Fraser Valley airshed in 2017 including initiatives undertaken by Metro Vancouver and partner agencies to reduce emissions of greenhouse gases and air contaminants, actions that can be pursued by individuals, and summaries of air quality measurements.

BACKGROUND
Metro Vancouver’s “Integrated Air Quality and Greenhouse Gas Management Plan” (IAQGGMP) contains strategies and actions to raise awareness and enhance understanding of the actions being taken to improve air quality, and reduce emissions of greenhouse gases and other air contaminants. “Caring for the Air” was developed and first published in 2012 to provide information about key air quality and climate change initiatives in accessible plain language.

The Board Strategic Plan confirms the IAQGGMP strategies and actions related to outreach and communications. It includes strategic direction to “Improve public understanding of the value of clean air and greenhouse gas reductions, and actions to achieve both”, and more specifically, to:

a) Educate the public about Metro Vancouver’s air quality monitoring and management activities.

b) Publicize tangible actions that individuals and businesses can take to reduce emissions of greenhouse gases and other air contaminants.

c) Publish materials, such as “Caring for the Air”, that present evidence-based findings about air quality in the region in language that is accessible to a broad audience.

“Caring for the Air” is written to be accessible for any reader with a general interest in air quality and climate change and provides annual updates about activities to improve air quality, reduce greenhouse gas emissions and protect against the effects of climate change. It also reports on the performance measures used to monitor progress in these areas. The reports published between 2012 and 2017 included information about air quality, visual air quality and climate change adaptation and mitigation as well as background material to provide context and guidance about technical elements.
of the activities described. Electronic versions add value by providing readers with opportunities to locate additional information through links to background material and references available online.

“CARING FOR THE AIR” 2017 DISTRIBUTION AND PROMOTION
“Caring for the Air” is made widely available in hard copy and electronically with distribution throughout the year to foster wider recognition of Metro Vancouver’s air quality and climate change programs. The publication is provided to other government agencies and organizations as well as on request to members of the public including people who have subscribed to the “Caring for the Air” email distribution list.

Copies of “Caring for the Air” 2017 were circulated to municipal offices and libraries in the region. A rack card was developed to highlight the content of the 2017 edition and more than 3,000 rack cards were distributed to community centres and hospitals in the region and, in cooperation with the BC Lung Association, more broadly to individuals with an interest in health and air quality. Rack cards and copies of the report were also offered at events including Electrafest, Lungs for Life health fairs, Emotive events, public meetings, open houses and Globe 2018 as well as at the Metro Vancouver Information Centre.

Expanded social media promotion for “Caring for the Air”, including regular posts on Metro Vancouver’s Twitter and Facebook channels, was used to reach out to potential audiences about “Caring for the Air” 2017 between July and December, 2017. Posts highlighted the range of topics covered by articles in the report and provided links to the online version of “Caring for the Air” 2017. Social media analytics indicate that “Caring for the Air” posts reached over 30,000 people, resulting in engagement through likes, shares, comments, and residents accessing the electronic version of the report through the hyperlinks provided. At the time of writing, there had been over 3,000 views of the electronic version of the “Caring for the Air” 2017 report.

INSIDE “CARING FOR THE AIR” 2018
The 2018 edition of “Caring for the Air” presents information about progress made on air quality and climate change projects undertaken by Metro Vancouver and partners in the Lower Fraser Valley in 2017 and early 2018. The articles also underscore the relevance of these initiatives to residents of the region. Rationales for action, to improve understanding of project activities aimed at reducing emissions of air contaminants and greenhouse gases and preparing for the impacts of climate change, are shared in the report.

Articles in “Caring for the Air” 2018 describe actions being taken to mitigate climate change including mechanisms to improve the energy efficiency of buildings and reduce associated greenhouse gas emissions, present the results of foundational work to understand residents’ concerns and knowledge about climate change, and highlight the development of the Climate 2050 Strategy, to guide future climate policies and actions. Details about important advances in air quality monitoring and management in the region are also provided with articles about:

- Managing odour impacts in Metro Vancouver.
- Actions that could reduce emissions of air contaminants and greenhouse gases from personal vehicles such as cars and trucks.
- Improvements in the air quality monitoring network to enhance air quality assessments.
- How meteorological data are being used to augment understanding of changes occurring in the region’s climate.
• The results of the 2015 air emissions inventory, including summaries of trends in emissions from key sectors together with projections for future emissions, and how the projections are used to prioritize and inform current or potential future policies.
• The impacts of unprecedented levels of wildfire smoke on air quality in the region in 2017.

A visual presentation of air quality data summaries for 2017 and commentary on air quality trends and exceedances of ambient air quality objectives and updates on incentives available to residents and businesses to reduce wood smoke and diesel particulate matter are also provided. Background material offers insights into the purpose of Health Impact Assessments, how to get involved in providing input on air permit applications, and the development of air emission regulations to improve air quality.

Outreach through traditional media, social media and air quality events will continue in 2018 to increase awareness and readership of “Caring for the Air”. This will build on established audiences for “Caring for the Air” and help publicize the actions Metro Vancouver and partners are taking to reduce greenhouse gas emissions, adapt to climate change and improve air quality to enhance livability in the region.

ALTERNATIVES
This is an information report. No alternatives are presented.

FINANCIAL IMPLICATIONS
The “Caring for the Air” report describes projects and programs that were undertaken within approved program budgets and work plans or by successful application to the GVRD Sustainability Innovation Fund. The report also provides information about collaborative work with external organizations on initiatives supported by their resources as well as relevant initiatives that are entirely the responsibility of external organizations.

SUMMARY / CONCLUSION
The Board Strategic Plan gives direction to improve public awareness of the value of clean air and greenhouse gas reductions, and actions to achieve both. The annual “Caring for the Air” report provides a vehicle for conveying information about air quality and climate change in the region in a manner that is accessible, relevant and of general interest to a wide range of readers. The seventh edition provides updates, news about actions, activities and performance measures related to the work conducted by Metro Vancouver and other organizations in the region in 2017 and 2018, with a focus on climate initiatives.

“Caring for the Air” complements other outreach activities and publications, such as the State of the Air report produced by the BC Lung Association, which describes air quality programs throughout British Columbia, and Metro Vancouver’s annual technical air quality monitoring report, the “Lower Fraser Valley Air Quality Monitoring Report”.

Attachment
1. “Caring for the Air” 2018 (Doc# 25529404)
Caring for the Air
2018
The Lower Fraser Valley airshed

Metro Vancouver is situated within the Lower Fraser Valley. Air pollution can freely cross our borders both from and into the surrounding areas. These include the Fraser Valley Regional District to the east, Whatcom County in the State of Washington to the south, Vancouver Island to the west and Howe Sound and the Sunshine Coast to the north.

Managing air quality successfully requires effective collaboration with our neighbours and other levels of government, and participation from businesses, public institutions, non-government organizations, and residents. Many of the articles in this publication reflect these partnerships.

We would like to acknowledge the contributions made to this publication by:

City of North Vancouver
Climate Action; Public Opinion

In 2017 Metro Vancouver conducted a public opinion survey to understand the attitudes of Metro Vancouver residents towards both climate change and local government responses to climate change. The research explored residents’ opinions on the causes of climate change, the aspects of climate change that are of most concern, people’s perception of the efforts of governments, businesses and individuals to address climate change, and support for future actions to address climate change.

The results of the survey support the development of a regional climate action plan, Climate 2050 (see page 2). Metro Vancouver residents want to see more local action.

- Metro Vancouver residents are highly aware of and concerned about climate change, and the impacts in our region.
- Metro Vancouver residents generally have low awareness of current actions being taken to address climate change, particularly those taken by local government.

Along with goals to protect air quality and public health, Metro Vancouver’s Climate Action Committee provides advice and direction to minimize the region’s contribution to global climate change. This survey shows that there is public support for further regional action on climate change.

The Climate 2050 strategy will be an overarching climate action strategy for Metro Vancouver. It will outline Metro Vancouver’s vision and goals to both reduce greenhouse gas emissions and adapt to climate impacts. It will also establish a framework to develop and implement dynamic roadmaps for future climate action by Metro Vancouver, and facilitate learning and sharing of best practices with our members and others.

LOCAL GOVERNMENTS CAN LEAD INITIATIVES TO ADDRESS CLIMATE CHANGE IN AREAS SUCH AS:

- engage on best practices to reduce GHG emissions
- increase commitments to clean energy
- adhere to building codes to reduce GHG emissions from municipal buildings
- choose lower emissions vehicles for corporate fleets
- protect lands that absorb climate impacts such as floods and droughts
- prioritize energy efficient infrastructure design and the delivery of clean energy
- Climate Action Committee
Climate change is both a global challenge and a local challenge – we are already feeling the impacts of climate change across the planet, including here in Metro Vancouver. Meeting the climate challenge requires bold leadership, creative thinking, and extensive collaboration. Cities and regional governments are at the forefront of global action on climate change. Much of the region’s infrastructure, as well as policies and initiatives that impact our neighbourhoods and daily lives, are managed and coordinated by cities and regions.

For nearly 20 years Metro Vancouver and local cities have been taking action on climate change, embedding effective climate actions into existing management plans. But we need to do more. Everyone stands to benefit from a coordinated and collaborative approach to maximize the benefits of our climate initiatives.

To that end, Metro Vancouver is currently developing the Climate 2050 strategy. Climate 2050 will guide policy and actions across the Metro Vancouver region, using our resources efficiently to reduce carbon emissions and prepare for the unavoidable impacts of global warming. The strategy will apply a ‘climate lens’ to all policies and actions undertaken by Metro Vancouver, to inform climate change adaptation and prevention in coming years.

Metro Vancouver is committed to an open decision-making process, and to setting goals that can be measured, reported, and evaluated. In addition to working closely with its member jurisdictions Metro Vancouver will engage businesses and residents, and coordinate with other orders of government and key agencies who have critical roles in achieving climate goals.

You can find more information at metrovancouver.org, search ‘Climate 2050’.
AirAware – Bringing Air Quality Monitoring Home

Metro Vancouver operates a world class air quality monitoring network with 29 monitoring stations from Horseshoe Bay to Hope. More than ten pollutants are measured throughout the network with high quality equipment that is strictly maintained. These data provide a ‘gold standard’ for accurately measuring air quality.

New sensor technology has led to the development of low-cost air quality monitors that are readily available to anyone and allow you to collect your own data anywhere you want. This is cool, but you might be wondering “how good are the data”? There are several things to consider.

**Location** Air quality is worse the closer you are to sources of air pollutants, so don’t put the sensor next to your BBQ – these data will not represent the air that you breathe most of the time.

**Consistency** Metro Vancouver’s team of qualified technicians calibrate and audit air quality analyzers regularly to check they are performing correctly. Most low-cost sensors don’t let you do this.

**Quality** Instruments costing tens of thousands of dollars offer accurate, precise and reliable measurements. Don’t expect that a sensor costing a few hundred dollars or less will match the performance of more sophisticated equipment.

**Data interpretation** Many of the sensors on the market report instantaneous data collected every second. These measurements should not be compared with longer term (e.g. daily) health-based thresholds as several of the sensor websites do. You have to compare a 24-hour measurement with the 24-hour threshold.

AirAware is a new citizen science outreach project developed by Metro Vancouver to understand how and why people are using these low-cost sensors. Metro Vancouver will be looking for participants this summer (2018) to learn more about their sensors, how they compare to Metro Vancouver’s instruments, and how they can fit in with the regional monitoring network. Through collaboration with residents and other partners, such as Vancouver Coastal Health Authority, this project will help us determine how we can all get the most out of this new technology.

You can access data from the air quality monitoring network at [www.airmap.ca](http://www.airmap.ca).
Where Air Emissions Come From in Metro Vancouver

What is an emissions inventory?

Every five years, Metro Vancouver compiles an inventory of air pollutant and greenhouse gas (GHG) emissions in the Lower Fraser Valley airshed (see map inside front cover). The inventory reports on air emissions from a broad range of sources: industrial facilities; commercial, institutional, residential, agricultural, and naturally occurring sources; and mobile sources, such as cars and trucks, non-road equipment, rail locomotives, aircraft and marine vessels.

Here’s a snapshot of what we found.

1 Modest decrease in GHG emissions

In 2015 we found that GHG emissions in Metro Vancouver had decreased compared to 2010 to about 15 million tonnes, which is a 2% reduction. While a modest decrease is encouraging, more needs to be done to meet regional targets (see page 2).

Heating and cooling of buildings, such as our homes or commercial buildings, require energy and are major contributors of regional GHG emissions. Between 2010 and 2015 emissions from buildings decreased by more than 10%, thanks to reduced natural gas consumption, partly through improved efficiency of equipment.

GHG emissions from industrial sources increased between 2010 and 2015, primarily because of economic growth in the cement and petroleum products sectors. Vehicle traffic emissions also increased due to growth in the region’s population and economy.

A business-as-usual forecast projects that regional GHG emissions will decrease by about one percent in 2035. GHG emissions from cars and trucks are projected to fall by about 35% by 2035, due to emission regulations, but this is offset by increases in GHG emissions from buildings and industry because of regional population and economic growth.

We also looked at the potential effect of a quicker shift from conventional cars and trucks to electric vehicles (EVs) as a way of achieving greater GHG emission reductions in the region. We found that strong EV policies could result in nearly 50% of new vehicle sales being EVs and plug-in EVs, providing a significant drop in GHG emissions. See page 6 for the details.

2 Smog-forming pollutant emissions still decreasing

In 2015, major sources of smog-forming pollutants were chemical products, cars and trucks, marine vessels, non-road engines and industrial sources.

Emissions of smog-forming pollutants, such as nitrogen oxides (NOx) and volatile organic compounds (VOC), have decreased since 1995 thanks to improved engine emissions standards, vehicle repairs required through the former AirCare program, improved fuel and product formulation, and regulation of evaporative sources of VOC. This trend is expected to continue to 2030, although VOC reductions are projected to slow as emissions from chemical products such as paints, industrial solvents and coatings, adhesives, and personal care products increase as the region grows.
How do we use an emissions inventory?

The emissions inventory provides insights into key sources of air emissions in our region, and helps us examine the current state of and our impacts on the region’s air quality and climate.

Emissions inventory forecasts allow us to assess the potential benefits of regulations and policies. Forecasts are also used to evaluate actions in regional climate action and air quality management plans, and to identify areas where emission reductions may be needed.

3 Sulphur oxide emissions have decreased

Sulphur oxide (SOx) emissions dropped more than 70% from 2010 to 2015, largely because of implementation of the North American Emission Control Area (ECA) in 2012. The ECA requires vessels to use cleaner marine fuels, reducing marine vessel SOx emissions by about 95%. However, SOx emissions are expected to increase slightly to 2035, primarily as marine traffic in our region increases.

An article in Caring for the Air 2017 (page 13) shows the benefit of the ECA on our air quality.

4 Fine particulate matter emissions have decreased overall

Fine particulate matter (PM2.5) emissions have been decreasing steadily since 1995, driven by reductions in emissions from the wood products and petroleum refining industries, as well as reduced vehicle emissions. However, significant sources of PM2.5 remain in 2015, including residential wood burning, non-road engines, industrial sources and marine vessels.

In a business-as-usual forecast, transportation emissions are expected to continue decreasing, driven by increasingly stringent emission standards for vehicles, non-road engines and marine vessels, and cleaner fuels.

With the longevity and slow replacement of wood burning appliances, indoor wood burning is expected to be the most significant source of PM2.5 emissions to 2035. However, phasing out conventional fireplaces and uncertified inserts and woodstoves through regulatory and non-regulatory measures could reduce over 90% of PM2.5 emissions from indoor wood burning by 2035 compared to the business-as-usual scenario.
The air quality and greenhouse gas emissions benefits of electric vehicles are often publicized, but what is the cumulative effect in an airshed?

As part of a recent analysis of emissions (the 2015 Lower Fraser Valley Emissions Inventory), Metro Vancouver investigated possible future scenarios for electric vehicle uptake in Metro Vancouver and the Fraser Valley Regional District. Researchers at Simon Fraser University and Navius Research produced three potential future scenarios that reflect different degrees of policy support for the electrification of light-duty vehicles. These included scenarios based on: (1) weak demand, (2) strong demand, and (3) strong supply and demand.

The scenarios were applied against the actual light-duty vehicle fleet for the Metro Vancouver region, taking into account natural turnover, vehicle growth rates and actual vehicle kilometres travelled in this region.

Emissions forecasts were then derived for air pollutants and greenhouse gases (GHGs) from 2015 to 2035.

The results of the study show that a transition to electric vehicles is projected to significantly reduce GHG emissions (10% and 27% by 2035 in Scenarios 2 and 3, respectively) and have a measurable impact on air pollutant emissions. For example, a 7% and 18% reduction for PM$_{2.5}$s by 2035 in Scenarios 2 and 3, respectively.

Electrification is expected to have a greater impact on GHGs than air contaminants because federal standards on the latter are more stringent. Beginning in model year 2017, light-duty vehicles are subject to standards which effectively bring air emissions down to near-zero. Although Canada has adopted GHG standards for light-duty vehicles which tighten between 2017 and 2025, they are far from near-zero.
Individually, new vehicles are much cleaner than 20 years ago, but collectively the personal vehicle fleet remains the dominant source of some pollutants in our region.

Metro Vancouver’s 2015 emissions inventory shows that while there are many sources of emissions in our region, personal vehicles are the largest source of smog-forming pollutants and climate changing greenhouse gases (see page 4). In fact, a relatively small number of older vehicles produce a substantial amount of smog-forming pollutants. Newer vehicles generate less smog-forming pollutants, but due to their large number, produce more greenhouse gases than older vehicles (see page 6).

Metro Vancouver is investigating how to reduce the amount of air pollutants released from personal vehicles such as cars and trucks. Vehicle emissions policies focussed on protecting human health and our environment need to address both air quality and climate change issues.

Vehicle pollution can be reduced using many different approaches, including incentives to reduce emissions from older vehicles, more stringent engine standards for new vehicles, and shifting more travel into other modes such as transit, cycling and walking. Jurisdictions around the world have implemented many approaches to reduce these air contaminants but what works in other jurisdictions may not work as well in Metro Vancouver because of our size and different regulatory structures.

A Metro Vancouver study will help identify benefits and trade-offs between different approaches that could be implemented in our region. The best approach may consider issues such as housing affordability, social equity, feasibility and alignment with related initiatives including the Mobility Pricing Independent Commission and federal Electric Vehicle Strategy. The study will provide important information to support evidence-based policy making that will help us reach air quality and climate goals.
What’s the purpose of an air permit?
Metro Vancouver uses air permits to reduce the impacts of air contaminants emitted from businesses.

Who decides whether a permit is issued?
The District Director, a staff person appointed by the Metro Vancouver Board, decides whether to issue a new permit or amendment after reviewing an application from a business and hearing from concerned persons.

How does the public find out about an application?
When a business applies for major changes or a new permit they must post a copy of the notice (the application summary) at their site, and publish it in local newspapers and the BC Gazette.

Metro Vancouver posts the notice on our website and notifies anyone who has complained about the facility in the past three years or subscribed to our notification list. Metro Vancouver also asks the host municipality, local health authority and other agencies for comments on the application. The District Director may require the applicant to organize meetings to provide information to the public.

Notification provides information to help the public make informed comments about a permit application.

How do I voice my concerns?
Anybody who thinks they may be negatively affected by an air permit application has the right to have their concerns considered by the District Director during the permitting process. A person has at least 30 days after the last public notification to provide comments, in writing. The applicant gets a chance to respond to all comments.

When deciding whether a permit should be issued, the District Director may consider relevant information provided by the applicant, Metro Vancouver staff and any others who have provided comments.

How will I know what has been decided and what if I don’t like the decision?
Once the District Director makes a decision about a permit, the applicant, agencies and comment providers are notified. Any person who may be affected by the decision can appeal to the BC Environmental Appeal Board (www.eab.gov.bc.ca).

Where can I find out more?
More information about Metro Vancouver’s air permitting process is available at metrovancouver.org (search: apply permit).
Wood Changes Make Sense

Many people enjoy the ambience created by a wood fire, but burning wood releases harmful pollutants into the air we breathe. Wood smoke contains fine particulate matter (PM2.5), which is made up of tiny particles suspended in the air that can be inhaled deep into our lungs. Exposure to PM2.5 can aggravate heart and lung conditions and reduce life expectancy. Wood smoke also contains a mixture of chemicals that have other negative impacts on human health (see Toxic Air Pollutants Risk Assessment).

Indoor residential wood burning is the largest source of PM2.5 in the region. To help reduce wood smoke emissions, Metro Vancouver runs an exchange program which allows residents to apply for a rebate when they replace their uncertified wood burning appliance (e.g. fireplace or older wood stove) with a new, lower emission unit. Funding is limited and rebates are offered on a first come, first served basis:

- **$400** if you exchange an uncertified wood-burning appliance for a pellet stove, electric heat pump, or a natural gas or propane appliance.

- **$250** if you exchange an uncertified wood-burning appliance for a CSA or EPA-certified wood-burning appliance or electric insert.

The wood stove exchange program has been in place since 2009 and over 500 exchanges have been made, resulting in ongoing emissions reductions of over 9,000 kilograms of PM2.5 per year. This helps improve air quality in neighbourhoods where people live, work and play.

In 2017 and 2018 Metro Vancouver undertook consultation and engagement on a phased approach to adding regulatory mechanisms to manage indoor residential wood burning emissions.

Replacing a fireplace or old wood-burning appliance with a gas fireplace or new wood-burning appliance will give you more efficient heating and help reduce PM2.5 levels for everybody. To find out more about the exchange program and qualifying appliances, visit: metrovancouver.org (search: 'wood stove exchange').
Benefits From Retiring Your Dirty Diesel Engines

Since 2012, Metro Vancouver’s Bylaw 1161 has regulated the oldest and dirtiest (Tier 0 and Tier 1) non-road diesel engines, such as those found in construction and other heavy-duty equipment, to reduce the impacts of harmful diesel particulate matter on human health and the environment. More than 140 engines have been retired. Assuming each of these was replaced with a Tier 2 or newer engine, the estimated diesel particulate reduction is almost 5,500 kg, which is equivalent to taking 4,600 newer diesel pick-up trucks off the road.

Metro Vancouver estimates that there are more than 600 Tier 0 and Tier 1 engines no longer being used that were registered but never formally retired. This additional unconfirmed reduction in emissions means a combined total of 30 tonnes of diesel particulate matter has been taken out of the air we breathe.

Owners of Tier 0 and Tier 1 engines pay fees to operate in the region. Metro Vancouver currently only charges fees for the most polluting engines, to encourage owners to retire older units and replace them with cleaner engines. When an owner retires an engine, they become eligible to receive a cash refund of up to 80% of the fees paid in the previous three years. Engine retirements also provide a healthier workplace for the operator, as well as a healthier overall environment for everybody in the region.

If you own a ‘not in use’ Tier 0 or Tier 1 engine, apply for a refund as soon as possible. A small amount of paperwork could mean hundreds of dollars in your pocket. You have one year from the date of retirement to apply for a refund.

Our officers routinely inspect worksites so if you haven’t registered your Tier 0 or Tier 1 engine, we encourage you to do so as soon as possible or risk fines. More information is available at metrovancouver.org (search: ‘fee refund’ or ‘register engine’).
Health Impact Assessments: Improving Our Future

When a ‘big project’ (such as a major construction project like a bridge replacement) is being considered in our region, it is common to engage the public to get feedback about issues and concerns. By involving the public, the social impacts of a project can be considered in design alternatives. But what about potential health impacts, which may be less visible and more difficult for residents to anticipate?

A Health Impact Assessment (HIA) provides a standardized way of assessing both the bad and good health impacts a project might have, ranging from risk of injury to health risks associated with air pollution and noise. By identifying potential impacts at an early stage in a project planning process, it is possible to find solutions and reduce long term negative effects.

Metro Vancouver has developed a guidebook and toolkit to help with preparation of a Health Impact Assessment. Several large projects in our region have used this approach successfully in recent years. One example is the Georgia and Dunsmuir viaduct replacement project. This will be a large demolition and construction project with the potential to impact residents for an extended period of time. By using HIA, public health has been assessed throughout a project’s lifecycle.

<table>
<thead>
<tr>
<th>HEALTH INDICATOR</th>
<th>PREDICTED HEALTH EFFECT</th>
<th>REASON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Quality</td>
<td>Neutral</td>
<td>Emissions from the project will be relatively minor compared to other sources in the area, and vehicle traffic is predicted to decrease.</td>
</tr>
<tr>
<td>Noise</td>
<td>Neutral</td>
<td>The project will limit construction at night. Once the project is completed, noise mitigation measures will include earth berms, low-noise pavement, and upgraded sound insulation at a nearby building that has been predicted to be most significantly affected by project noise.</td>
</tr>
<tr>
<td>Active Transportation</td>
<td>Positive</td>
<td>The project includes improved walking and cycling infrastructure.</td>
</tr>
<tr>
<td>Access to Green Spaces</td>
<td>Positive</td>
<td>The project includes an opportunity to expand a nearby park.</td>
</tr>
</tbody>
</table>

Examples of how an HIA is used to look at the potential impacts of factors that can affect health.

From: City of Vancouver Georgia and Dunsmuir viaduct replacement Desktop Health Impact Assessment

Climate Action Committee
Hot and Dry Conditions – A Recipe for Bad Air Quality

Prolonged hot and dry conditions caused extreme fire risk and led to intense wildfire activity in 2017.

In the summer of 2017 wildfires burned aggressively across the province, resulting in the largest burnt area of B.C. ever being recorded in a season. The smoke from these wildfires affected people throughout North America, including in Metro Vancouver and the Fraser Valley Regional District. Metro Vancouver’s air quality expertise was critically important in detecting the arrival of wildfire smoke in the Metro Vancouver and Lower Fraser Valley airshed, and for getting information out to the public and media.

When air quality becomes degraded, Metro Vancouver issues an air quality advisory in partnership with other agencies in the region. Air quality advisories provide information about what is causing air quality degradation, the health effects associated with it, and the actions people can take to protect themselves and others.

Wildfire smoke in the summer of 2017 was more intense and lasted longer than ever previously measured in our airshed. Fine particulate matter in the smoke was detected at monitoring stations from Hope to Horseshoe Bay. Five air quality advisories were issued, totalling an unprecedented 19 days with an advisory in effect. The longest continuous period under an advisory occurred from August 1st to 12th, when levels of fine particulate matter were high due to wildfire smoke. Ground-level ozone also became elevated at times during hot sunny weather.

Metro Vancouver residents generally enjoy clean, clear air, so the wildfire smoke impacts on the region for two of the last three summers is notable. These events may provide a taste of how an increase in the severity and occurrence of wildfires caused by our changing climate could affect us more severely in the future.

Metro Vancouver has a goal of having zero days of air quality advisories. Metro Vancouver has put policies in place, such as the Regional Ground Level Ozone Strategy and the Non-Road Diesel Engine Program, to reduce the occurrence of advisories.
Air Quality in 2017

Although outdoor air quality in Metro Vancouver is generally good most of the time, occasionally air quality objectives are not met. Wildfire smoke had significant impacts on air quality in the region in 2017 (see page 12). Hot, sunny weather also caused levels of ground-level ozone to increase at times. Both of these factors resulted in exceedances of air quality objectives.

Metro Vancouver and other air quality agencies strive for continuous improvement in air quality to protect health and the environment. As additional information becomes available, new, more protective objectives are adopted that require tighter standards to be met. New federal standards for sulphur dioxide (SO2) were added to the Canadian Ambient Air Quality Standards (CAAQS) in 2016. In November 2017, Metro Vancouver adopted more stringent objectives for SO2 of concentrations of 70 ppb measured over one hour and 5 ppb averaged over a year, which replaced the interim objective adopted by Metro Vancouver in 2015.

Air Quality Trends

The regional trends charts (right) illustrate the change in average air quality across the region over time. Measurements from monitoring stations located from Horseshoe Bay to Hope are averaged to represent the ambient (outdoor) air quality typically experienced in the region.

Average trends for the region show that improvements have been made over the last decade for most air contaminants, even while the region’s population has grown. The region’s air quality improvements are a result of many emission reduction actions that have been implemented (see pages 4 and 5).

Peak ground-level ozone levels (not shown), which occur during summertime hot and sunny afternoons, are better now than in the 1980s and early 1990s. However, despite lower levels of pollutants that form ground-level ozone, average levels of ground-level ozone are increasing slightly. This is partly due to an increase in ozone formed outside Canada coming into our region.
The Canadian Ambient Air Quality Standard for fine particulate matter (PM$_{2.5}$) was achieved for 2017 at all monitoring stations with the exception of Hope (see map above). Levels were better than Metro Vancouver’s annual objective at all stations with the exception of the Vancouver near-road monitoring station. Peak levels at all stations were worse than the short-term objective (25 μg/m$^3$ based on an average over 24 hours) in August and September. This was due to wildfire smoke. Additional exceedances of the objective occurred in July at Hope also due to wildfire smoke, in November and December in several locations thought to be caused by local wood burning and two locations in October likely due to Halloween activities.

GROUND-LEVEL OZONE IN 2017

The map above shows that the Canadian Ambient Air Quality Standard for ground-level ozone was achieved at all monitoring stations except Hope in 2017. Monitoring data also showed that peak levels were higher than Metro Vancouver’s 8-hour objective (65 ppb) and 1-hour objective (82 ppb) on a few occasions in Burnaby, Richmond, Pitt Meadows, Maple Ridge, Langley, Abbotsford, Mission, Chilliwack, Agassiz, and Hope in August. It is unusual for ozone exceedances to occur in the west (i.e., Burnaby and Richmond) and it is thought that wildfire smoke enhanced ozone production. Exceedances were also briefly observed in May, June and July at a few stations.
SULPHUR DIOXIDE IN 2017

Average concentrations of sulphur dioxide for 2017 are shown above. All stations were better than Metro Vancouver’s annual objective of 5 ppb. Peak levels were better than Metro Vancouver’s 1-hour objective of 70 ppb at all stations in 2017 except for at Capitol Hill, where exceedances occurred in February, March, October and December for a total of six hours. Peak levels at Capitol Hill are mainly influenced by the nearby oil refinery.

NITROGEN DIOXIDE IN 2017

In 2017, nitrogen dioxide concentrations were better than Metro Vancouver’s 1-hour air quality objective at all monitoring stations. Measurements averaged over the entire year were within Metro Vancouver’s annual objective with the exception of at the near-road monitoring station on Clark Drive in East Vancouver (shown above). The near-road station is heavily influenced by traffic emissions. The highest average nitrogen dioxide concentrations in the region are measured in highly urbanized areas near busy roads.
Embracing new technology, using information about health impacts

Many pollutants, such as fine particulate matter (PM2.5), are measured continuously by the air quality monitoring network’s 29 long-term air quality monitoring stations, with data reported in near-real-time. Other pollutant samples, such as some toxic air pollutants, are collected on a regular schedule for detailed analysis in a laboratory. Here’s how the network is keeping up to date and responding to new priorities and emissions sources.

Case 1: Health research tells us that smaller particles (less than 2.5 micrometres) cause the greatest health effects. Increased monitoring of fine particulate matter (PM2.5) and new instruments providing more complete measurements of PM2.5 have been integrated into the network in recent years.

As interest grows in measuring even smaller particles, known as ultrafine particles, Metro Vancouver is exploring how we can measure these effectively in the region.

Case 2: A new instrument was acquired in 2017 to improve our ability to evaluate air toxics, such as benzene, and to help assess the air quality implications of industrial projects such as the Trans-Mountain Pipeline expansion project.

Staying informed about weather trends

Weather conditions greatly affect air quality and how pollution levels vary throughout the day, from season to season, and across the region. Wind speed, wind direction, temperature, rainfall and humidity measurements improve air quality forecasts, predictions of air quality advisories, environmental and health assessments, and our response to air quality complaints.

The important connection between weather and air quality means that meteorology is measured at most air quality stations in the network. There are also some stations that only measure meteorology. Some of these data are used by the provincial government’s Climate Related Monitoring Program to improve our knowledge about changing weather patterns in our region. Understanding future climate projections and impacts on the region helps when developing the new Metro Vancouver climate action strategy (Climate 2050).

To find weather or air quality data in your community, check out AirMap.ca.
Metro Vancouver is working to clear the air – and reduce human health risks – by tackling air emissions from automotive refinishing facilities (commonly called autobody shops). Automotive refinishing activities release air contaminants into the air, including volatile organic compounds, hazardous air pollutants and particulate matter. These pollutants are associated with adverse health and environmental effects.

Potential changes to the Greater Vancouver Regional District Automotive Refinishing Emission Regulation Bylaw No. 1086, 2008, which regulates emissions from these facilities, have been proposed.

The existing bylaw requires that most vehicles are spray coated in appropriate spray booths using approved paints and cleaners. There are several key potential changes being considered, including modernizing the paint standards to meet or exceed national standards. Another potential change is ensuring that all spray coating operations follow bylaw requirements, since some operations conducting similar work are currently not covered by the bylaw.

The requirements are designed to protect residents’ health and the environment. Other changes also being considered would simplify bylaw enforcement and clarify requirements for businesses who are subject to the regulation.

Metro Vancouver hosted a series of consultation events between November 2017 and March 2018, including three webinars and three stakeholder meetings. The feedback received is being reviewed and will be reported to the Metro Vancouver Board later in 2018.

More information about the proposals and consultation events can be found on Metro Vancouver’s website (search: ‘Potential amendments to Bylaw 1086’).
Odorous air contaminants have the potential to cause everything from nuisance in residential neighbourhoods, to health concerns at elevated levels. Requirements to control emissions from odour-generating facilities can be included in air quality permits and regulations. However, as residential, industrial and commercial density increases in Metro Vancouver, it is anticipated that odour concerns and complaints will continue to rise.

Metro Vancouver is responsible for managing and regulating air quality in our region. With an increasing number of complaints from the public about unpleasant odours emanating from a variety of sources, including compost and food processing facilities, the current approach to odour management needs to be improved to address current and future needs. This has led Metro Vancouver to explore more effective tools to reduce odour emissions across the region.

Metro Vancouver is working with communities, businesses and government partners to revise its framework for managing odorous air contaminants in a responsible manner that respects both community and business values. Approaches being considered to improve how Metro Vancouver deals with odours are:

- Specifying limits on the level of odour occurring at the facility boundary or in the affected community;
- Emission limits for sources at facilities, designed to reduce odour impacts in nearby communities;
- Applying technology requirements to control odour;
- Requiring the use of best management practices for new or existing facilities;
- Employing economic instruments to encourage emissions reductions and allow administrative costs to be recovered from authorized sources of odorous air contaminants; and
- Changing existing bylaws to clarify provisions for managing the impacts of emissions of odorous air contaminants.

These approaches could be applied, individually or in combination, to reduce odour and offer a future odour management framework the flexibility to find effective solutions for existing issues and prevent new issues arising.

More information about the consultation can be found at metrovancouver.org (search: ‘odorous air contaminants’).
NOx, NOx, Whose Air?
New Air Quality Objectives for Nitrogen Dioxide

Nitrogen dioxide (NO₂) and nitric oxide (NO) are known collectively as nitrogen oxides (NOx). NOx are formed when fuel is burned at high temperatures, for example, in an engine or a boiler.

Nitrogen dioxide is a highly-reactive, reddish-brown gas with a pungent and irritating odour. It is sometimes responsible for “brown haze” seen in the air. It is linked to health effects such as decreased lung function and respiratory health problems, particularly for children and adults with asthma. It also plays a major role in ground-level ozone formation and secondary particulate formation, which can affect visual air quality in the region.

Transportation is a key source of NO₂ emissions, so it’s no surprise that areas near busy roads and intersections, such as downtown Vancouver, tend to have the highest concentrations of NO₂. Lower concentrations are often observed where there is less traffic, such as eastern areas of Metro Vancouver.

Metro Vancouver sets outdoor air quality objectives for air pollutants, including NO₂, to protect human health and the environment. NOx emissions in the region have been decreasing since 1995, and concentrations of NO₂ have followed suit. Concentrations are generally better than objectives in the region (see page 15).

The setting of air quality objectives in Metro Vancouver follows a principle of continuous improvement, and in 2017, the Metro Vancouver Board adopted new, more stringent objectives for sulphur dioxide (SO₂), consistent with Canadian Ambient Air Quality Standards (CAAQS) established by the federal government. In 2017, the federal government established new CAAQS for NO₂ when new science indicated that the previous national NO₂ standards were no longer sufficiently protective. The NO₂ CAAQS take effect in 2020, and will be followed by even stricter requirements in 2025. Similar to the process for SO₂, Metro Vancouver is reviewing the new CAAQS for NO₂ for incorporation in the region. It’s expected that the 2020 CAAQS are achievable for the region, but achieving the standards in 2025 will require further reductions in NO₂ emissions.
Stepping Up to Better Building Energy Efficiency

Buildings contribute 27% of the region’s greenhouse gas emissions and 7% of smog forming pollutants, mostly from burning fossil fuels for heating. The BC Energy Step Code is a new voluntary provincial standard that will improve the energy efficiency and carbon footprint of new buildings beyond current minimum standards.

The Energy Step Code has five steps, each step representing a higher standard of energy efficiency. At the highest level (Step 5), a building will be “net-zero ready”. This means that if a renewable energy technology is installed, the building will produce at least as much clean energy as it consumes.

Added benefits of the Step Code are improved health and comfort for building occupants as well as more affordable operating costs and consumer protection. Step Code buildings are:

- Healthier, through better air circulation;
- More comfortable, through better management of ambient temperature; and
- Quieter, through better air sealing and insulation.

Many local governments are adopting the Step Code, recognizing the benefits, and their role in contributing to a growing effort to dramatically reduce building emissions in the Metro Vancouver region. The BC Energy Step Code is a vital tool for governments to achieve greenhouse gas reduction goals.

North Shore Leads the Way

The City of North Vancouver has worked with the development industry to increase energy efficiency in buildings for many years. In December 2017, the City became the first local government in BC to enact the BC Energy Step Code in its zoning and construction regulation bylaws.

The Districts of North and West Vancouver have followed suit, creating an “efficient new home zone” from Horseshoe Bay to Deep Cove. From July 2018, all new low-rise condos, town homes and houses built on the North Shore will be required to meet Step 2 of the Step Code and all new commercial buildings will meet Step 1.

Moving early to adopt the Step Code in a coordinated way across the North Shore has increased certainty for developers and provided time for them to respond to new energy efficiency requirements.

The province has set a goal of achieving net-zero energy ready new construction in BC by 2032.
To: Climate Action Committee

From: Laurie Bates-Frymel, Senior Regional Planner
Parks, Planning and Environment Department

Date: May 11, 2018
Meeting Date: June 6, 2018

Subject: **Best Management Practices for Invasive Species in the Metro Vancouver Region**

**RECOMMENDATION**
That the MVRD Board receive for information the report dated May 11, 2018, titled “Best Management Practices for Invasive Species in the Metro Vancouver Region”.

**PURPOSE**
To provide the Climate Action Committee and the MVRD Board with three invasive species best management practices (BMPs) for information and provide an update on the status of additional BMPs under development.

**BACKGROUND**
Invasive species are non-native plants and animals that have been introduced to an area without the predators and pathogens from their native habitats that keep them in check. Some of these invasive species are highly destructive, competitive and difficult to control. They can threaten property and recreational values, infrastructure, our agricultural base, public health and safety, as well as the ecological health and diversity of our natural environment. Conservation biologists have globally ranked invasive alien species as the second most serious threat to biodiversity after habitat destruction.

This report brings forward best management practices (BMPs) documents on three invasive species, and information on additional BMPs to be developed.

**PROCESS FOR DEVELOPMENT OF BEST MANAGEMENT PRACTICES**
At the request of member jurisdictions and other partners, the Regional Planning Advisory Committee (RPAC) created an Invasive Species Subcommittee to assist with collaboration and coordination of invasive species management efforts within the region. This Subcommittee is composed of environment and parks staff from member jurisdictions, as well as non-voting associates from the provincial and federal government, stewardship groups, right-of-way land managers, businesses and staff from Metro Vancouver Regional Parks and Water Services.

During a work planning session in 2017, RPAC-Invasive Species Subcommittee members raised concern about inconsistent invasive species management practices across the region and a longstanding need for locally-tested guidance. Hence, the Subcommittee requested Metro Vancouver to develop a set of locally-relevant best management practices (BMPs) for priority invasive species in the region. For the first set of BMP species, members chose:

- Knotweed species,
- Giant hogweed,
• European fire ants,
• European chafer beetle,
• Himalayan blackberry, and
• Scotch broom.

BMPs for the first three species are provided for the Committee’s information and comment. European chafer beetle, Himalayan blackberry and Scotch broom BMPs will be ready in the coming months.

BEST MANAGEMENT PRACTICES
To create the BMPs, Metro Vancouver retained the Invasive Species Council of Metro Vancouver, and sub-consultants Diamond Head Consulting and the Invasive Species Council of British Columbia. The target audiences are local government staff, crews, project managers, contractors, consultants, developers, stewardship groups, and others who have a role in invasive species management. The BMPs include recommendations about identification, tracking, reporting, effective prevention and control strategies, disposal, monitoring and restoration, as well as references and additional resources. This guidance is based on the best available science and local experience.

The knotweed, giant hogweed and European fire ant BMPs (see Attachments 1, 2 and 3) have been reviewed by members of RPAC, the RPAC-Invasive Species Subcommittee and many additional local experts. A brief overview of each BMP is provided here.

Knotweed Species
Knotweeds are aggressive plants with strong roots that can cause stream bank erosion and significant damage to building foundations, pavement, bridges and other infrastructure. These roots emit a substance that kills other plants, creating dense monocultures and destroying native habitat. Japanese, giant, bohemian and Himalayan knotweeds are considered ‘noxious weeds’ under the provincial Weed Control Act and must be controlled by land owners or occupiers.

Manual control (e.g., pulling and digging) will not completely eradicate knotweeds and should be used with extreme caution because small fragments of stem or root can regrow into a new plant. Effective control of knotweeds can be achieved using phased application of specific federally-approved herbicides over several years. Provincial regulations must be followed, especially when using herbicides in riparian areas. Sites should be monitored on an annual basis and follow-up treatments applied where needed. Biological control options for knotweeds are currently not available and cultural control (e.g., grazing by animals) is not recommended due to the risk of further spread and constraints in urban areas.

To reduce the risk of spread, the BMPs recommend chemical treatment of knotweeds or deep burial on site. However, if on site disposal is not an option, the BMPs also provide a list of possible disposal facilities. Site managers should contact the disposal facilities beforehand to ensure they can properly handle the material.

Giant Hogweed
Giant hogweed is a high priority species in the region primarily due to the potential health impacts from direct contact with its phototoxic sap. After touching the sap, sunlight exposure can cause blistering, scarring, and recurrent dermatitis for several years. Giant hogweed is considered a toxic
plant by Worksafe BC. It is also a ‘noxious weed’ under the provincial *Weed Control Act* and must be controlled by land owners or occupiers.

The giant hogweed BMPs provide tips on how to identify and report these plants. Proper identification is important because the look-alike native Cow Parsnip is an important nectar source for pollinators.

With proper personal protective equipment, manual control (e.g., flower removal and tap root cutting) of giant hogweed can be effective. In cases where manual control has not been successful or it would pose a safety risk for crews, control with federally-approved herbicides (e.g., spray-on/wipe on or stem injection) may be effective. Provincial regulations must be followed, especially when using herbicides in riparian areas. Sites should be monitored on an annual basis and follow-up treatments applied where needed. Biological control options for giant hogweed are currently not available and cultural control (e.g., grazing by animals) is not recommended due to the risk of animal injury and constraints in urban areas.

Giant hogweed should be double bagged and removed from the site if people may encounter the material. Only the Vancouver Landfill and Metro Vancouver’s Waste-to-Energy Facility accept giant hogweed for disposal at this time.

**European Fire Ants**

European fire ants aggressively defend their territory by swarming and delivering painful, repeated stings to any sort of threat, such as people, pets and wildlife that come in close proximity to their nests. European fire ants are not a regulated pest in BC. They have been detected in many communities in the Metro Vancouver region and elsewhere in BC, and they have the potential to establish in moist coastal and riparian areas further north and east.

The European fire ant BMPs provide tips on how to identify and report these insects, and locate their nests while wearing proper personal protective gear. Control with an insecticide can be effective for small to medium infestations. Sites should be monitored on an annual basis and follow-up treatments applied where needed. Cultural control (e.g., removing rocks, logs or vegetation that serve as nesting habitat) will not completely eradicate European fire ants; however, it will reduce population density and may prevent spread to new areas. Digging and torching infested soil are not recommended because they can be labour intensive and ineffective, but these techniques could be employed if insecticide is not an option. Biological control options for European fire ants are currently not available.

The BMPs recommend leaving infested soil on site due to the high risk of spread during and after transport. Soil infested with European fire ants may be accepted at the Vancouver or Mission Landfills for deep burial, provided they have sufficient capacity.

As with all invasive species, prevention (e.g., maintaining healthy green spaces with non-invasive plants and invasive-free soil) is the most economical and effective way to reduce the risk of spread over the long term.
NEXT STEPS
After receipt by the MVRD Board, these BMPs will be posted on www.metrovancouver.org, and circulated widely through the RPAC-Invasive Species Subcommittee and connections via the Invasive Species Council of Metro Vancouver. Staff expect the BMPs for European chafer beetle, Himalayan blackberry and Scotch broom will be ready in the coming months.

ALTERNATIVES
This is an information report. No alternatives are presented.

FINANCIAL IMPLICATIONS
Funds for all six BMPs were included in the 2017 Regional Planning budget. Additional budget has been allocated for more BMPs in 2018 and those species will be decided by the RPAC-Invasive Species Subcommittee later this spring.

SUMMARY / CONCLUSION
As part of the RPAC-Invasive Species Subcommittee’s 2017 work plan, Metro Vancouver retained the Invasive Species Council of Metro Vancouver to create a set of best management practices (BMPs) for key invasive species found within the Metro Vancouver region. BMPs for knotweeds, giant hogweed and European fire ants have been completed and are attached to this report. After receipt by the MVRD Board, these documents will be posted on www.metrovancouver.org, and shared with local government staff, crews, project managers, contractors, consultants, developers, stewardship groups, and others who have a role in invasive species management in this region. BMPs for European chafer beetle, Himalayan blackberry and Scotch broom will be shared with the Climate Action Committee in the coming months.

Attachments (Doc# 25530891)
1. Best Management Practices for Knotweed Species in the Metro Vancouver Region
2. Best Management Practices for Giant Hogweed in the Metro Vancouver Region
BEST MANAGEMENT PRACTICES FOR Knotweed Species
in the Metro Vancouver Region

Fallopia japonica
Fallopia x bohemica
Fallopia sachalinensis
Polygonum polystachyum/
Persicaria wallichii
Disclaimer

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Created by: Metro Vancouver and the Invasive Species Council of Metro Vancouver

In partnership with: The Invasive Species Council of British Columbia
Diamond Head Consulting

Requested by: Metro Vancouver's Regional Planning Advisory Committee – Invasive Species Subcommittee

4730 Kingsway, Burnaby, BC, V5H 0C6
metrovancouver.org

May 2018

Climate Action Committee
## Contents

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>4</td>
</tr>
<tr>
<td>Regulatory Status</td>
<td>5</td>
</tr>
<tr>
<td>Impacts</td>
<td>5</td>
</tr>
<tr>
<td>Reproduction and Spread</td>
<td>5</td>
</tr>
<tr>
<td>Habitat and Distribution</td>
<td>6</td>
</tr>
<tr>
<td>Identification</td>
<td>7</td>
</tr>
<tr>
<td>Knotweed Species</td>
<td>7</td>
</tr>
<tr>
<td>Similar Species</td>
<td>9</td>
</tr>
<tr>
<td>Tracking</td>
<td>10</td>
</tr>
<tr>
<td>Reporting</td>
<td>10</td>
</tr>
<tr>
<td>Prevention and Control Strategies</td>
<td>11</td>
</tr>
<tr>
<td>Prevention: Imperative</td>
<td>11</td>
</tr>
<tr>
<td>Chemical: Recommended</td>
<td>11</td>
</tr>
<tr>
<td>Manual/Mechanical: Caution</td>
<td>19</td>
</tr>
<tr>
<td>Cultural: Not Recommended</td>
<td>20</td>
</tr>
<tr>
<td>Biological: Not Available</td>
<td>20</td>
</tr>
<tr>
<td>Disposal</td>
<td>21</td>
</tr>
<tr>
<td>On Site Disposal</td>
<td>21</td>
</tr>
<tr>
<td>Off Site Disposal</td>
<td>22</td>
</tr>
<tr>
<td>Cleaning and Disinfection</td>
<td>23</td>
</tr>
<tr>
<td>Follow-Up Monitoring</td>
<td>24</td>
</tr>
<tr>
<td>Restoration</td>
<td>24</td>
</tr>
<tr>
<td>References</td>
<td>25</td>
</tr>
<tr>
<td>Additional Resources</td>
<td>27</td>
</tr>
<tr>
<td>Acknowledgements</td>
<td>27</td>
</tr>
</tbody>
</table>
Introduction

The impacts of invasive species on ecological, human, and economic health are of concern in the Metro Vancouver region. Successful control of invasive species requires concerted and targeted efforts by many players. This document - “Best Management Practices for Knotweed Species in the Metro Vancouver Region” - is one of a series of species-specific guides developed for use by practitioners (e.g., local government staff, crews, project managers, contractors, consultants, developers, stewardship groups, and others who have a role in invasive species management) in the region. Together, these best practices provide a compendium of guidance which has been tested locally by many researchers and operational experts.

Four species of invasive knotweeds are found in the Metro Vancouver region:

- Japanese knotweed (*Fallopia japonica*)
- Bohemian knotweed (*Fallopia x bohemica*)
- Giant knotweed (*Fallopia sachalinensis*)
- Himalayan knotweed (*Polygonum polystachyum, Persicaria wallichii*)

Throughout this document these species are collectively referred to as ‘knotweeds’.

Native to regions in Asia, knotweeds were first introduced to British Columbia in 1901 as a cultivated horticultural specimen (Barney 2006). In the last few decades knotweeds have gained attention as one of the 100 worst invasive species in the world (Lowe, Browne and Boudjelas 2000). They are included as one of the top ten invasive species for control in BC (Invasive Species Council of British Columbia 2017) and they are high priority species for management in the Metro Vancouver region.

In recent years best practices for identifying and managing knotweeds have advanced rapidly. Academic institutions, government, and non-government organizations continue to study these species in British Columbia. As researchers and practitioners learn more about the biology and control of knotweeds, it is anticipated that the recommended best management practices will change overtime and this document will be updated. Please check metrovancouver.org often to ensure you have the most recent version of these best management practices.
REGULATORY STATUS

Japanese, Bohemian, giant and Himalayan knotweeds are classed as noxious weeds within all regions of the province under the BC Weed Control Act, Weed Control Regulation, Schedule A, Part 1 – Provincial Weeds. Under this Act, “an occupier1 must control noxious weeds growing or located on land and premises, and on any other property located on land and premises, occupied by that person”.

Section 2 (1) (b) (iii) of the Community Charter, Spheres of Concurrent Jurisdiction - Environment and Wildlife Regulation, states that “municipalities may regulate, prohibit and impose requirements in relation to control and eradication of alien invasive species” which includes Japanese and giant knotweeds. Other knotweed species are not currently listed.

Under the Forest and Range Practices Act, Invasive Plants Regulation, a “person carrying out a forest practice or a range practice must carry out measures that are: (a) specified in the applicable operational plan, or (b) authorized by the minister, to prevent the introduction or spread of prescribed species of invasive plants.” The list of invasive plants in the Regulation includes Japanese and giant knotweeds, but other knotweed species are not currently listed.

IMPACTS

Knotweeds can have significant social, economic and environmental impacts, including deleterious impacts on local ecosystems (Clements, Larsen and Grenz 2016). They appear to exude allelopathic2 substances that have substantial negative effects on the growth of native plants (Murrell, et al. 2010). Once established, knotweeds displace surrounding vegetation, creating dense monocultures. Concern about knotweeds has been mounting around the world as more and more native habitat is being lost, particularly in riparian areas (Sea to Sky Invasive Species Council 2009).

Knotweeds’ vigorous rhizome growth can damage concrete walls, pavement, bridge and building foundations, drainage works and flood prevention structures (Global Invasive Species Database 2017), and cause erosion of shorelines. Knotweeds can also affect motorist, cyclist, and pedestrian safety by blocking sightlines and signs along roads, highways, trails, and other transportation routes. Dense thickets can increase concerns about personal security in parks (Yong 2017). They can also be a nuisance for aquatic recreationalists frequenting lakes, streams, or rivers as uncontrolled infestations can impede access.

All levels of government and private property owners spend significant resources managing knotweed in the Metro Vancouver region every year. In 2016, local/provincial governments and several right-of-way partners on Metro Vancouver’s Regional Planning Advisory Committee - Invasive Species Subcommittee spent over $660,000 on knotweed control efforts. This figure does not include control costs for private landowners across the region or costs associated with education and awareness activities.

REPRODUCTION AND SPREAD

Knotweeds spread by rhizomes, which can extend up to 3 metres deep and 20 metres wide (BC Ministry of Transportation and Infrastructure 2016). These expansive rhizomes are much larger than expected for a plant of its size, making knotweeds even more challenging to manage.

New plants sprout from fragments of root and stem material. Even very small fragments (0.7 grams or more) of the rhizomes or stems can regenerate (Beerling, Bailey and Conolly 1994), which enables knotweeds to spread very easily and effectively. Buried rhizomes can regenerate from depths of 1 metre or more. One common cause of spread is

---

1 An occupier is a person who (a) is in physical possession of land, premises or property, or (b) is responsible for, and has control over, the condition of, the activities conducted on and the persons allowed to enter or use, land, premises or property.

2 Allelopathy is the suppression of one plant by another through release of biochemicals.
from unauthorized dumping of cut or dug knotweed in green spaces or natural areas.

**Hybridization:** Bohemian knotweed is a hybrid between Japanese and giant knotweed. Hybrid plants can produce large numbers of wind-dispersed viable seeds that germinate at rates approaching 100% in some populations (Gillies, Clements and Grenz 2016).

**Dispersal:** Knotweed fragments can be spread by infested equipment, mowers, improper disposal of removed plant material, wind, wildlife, flooding events, and horticulture activities such as selling, purchasing, trading, or maintaining plants, as well as the movement and use of infested soil. Disturbing the top growth of knotweed may encourage growth, resulting in a larger and denser infestation (Chadburn 2018).

**HABITAT AND DISTRIBUTION**

Knotweeds can tolerate a wide variety of site conditions, including challenging environments such as highly shaded areas, areas with high salinity, high heat, or drought. In the Metro Vancouver region knotweed is commonly found in riparian areas, in or around stockpiled material (e.g., soil, aggregate, mulch), on derelict land, along transportation corridors, and in gardens. Occasionally knotweeds are found growing in the water of shallow streams, waterways, and ditches.

All four knotweed species have been found in the Metro Vancouver region. Until recently it was thought that Japanese knotweed was the most prevalent knotweed species in the region; however recent genetic testing indicates that Bohemian knotweed is the most common taxon across western North America (Gaskin, et al. 2014). This finding is supported by unpublished data collected in the Fraser Valley by S. Gillies (University of the Fraser Valley) and by local mapping and observations of knotweed sites (Watson 2017). Himalayan knotweed is the least common of the knotweed species in the region (Watson 2017).
Identification

**KNOTWEED SPECIES**

Japanese, Bohemian, giant, and Himalayan knotweeds appear very similar in their biological attributes and growth characteristics. They are all perennial species; the above-ground vegetation dies off and the below-ground vegetation lies dormant during the winter. The distinguishing characteristics for these knotweeds are the mid-stem leaf shape, size, and other characteristics (Wilson 2007). The similarities between Japanese and Bohemian knotweed can make it difficult to distinguish between the two species.

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>STEMS</th>
<th>LEAVES</th>
<th>FLOWERS</th>
<th>RHIZOMES</th>
<th>FRUIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common to all species</td>
<td>Hollow, upright, green with reddish-brown speckles</td>
<td>Heart to triangular shaped, 8-10 cm wide, 15 cm long except giant</td>
<td>Showy, plume-like, branched clusters along stem and leaf axils (places on the main stems where buds or branches develop)</td>
<td>Rhizomes up to 7.5 cm diameter, penetrate at least 2 m in suitable soils (although contamination zone is considered up to 3 metres deep and up to 20 metres wide)</td>
<td>Typically dark, glossy, 8-9 mm long, 3-winged; not all are fertile</td>
</tr>
<tr>
<td>Bohemian</td>
<td>1.5-2.5 m in height</td>
<td>Egg-shaped, 5-30 cm, about 2/3 as wide, base variable in shape, from ± straight to moderately curved, leaf tip gradually to sharply tapered</td>
<td>Hairs – few or no hairs on leaf margin, veins on leaf underside have small, stout hairs</td>
<td>White or greenish white to pink</td>
<td>Dry seeds pods are 3-angled, black, smooth, shiny, 2.5-3 mm long</td>
</tr>
<tr>
<td>STEMS</td>
<td>LEAVES</td>
<td>FLOWERS</td>
<td>FRUIT</td>
<td></td>
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<td>------------</td>
<td>------------------------------------------------------------------------</td>
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<td>-----------------------------------------------------------------------</td>
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<td></td>
</tr>
<tr>
<td>Giant</td>
<td>2-4 m in height&lt;br&gt;Egg-shaped, 20–40 cm, about 2/3 as wide, deeply indented at the base (heart-shaped), leaf tip pointed, leaf texture thin and flexible; generally twice the size of the other 3 species&lt;br&gt;Hairs – tiny stiff hairs on leaf margin, veins on leaf underside have long, multicellular hairs</td>
<td>Pale green or greenish-white</td>
<td>Dry seed pods are 3-angled, black, smooth, shiny, 2.5-3 mm long</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Himalayan</td>
<td>1-2 m in height&lt;br&gt;Himalayan knotweed looks most different from the other species broadly lance shaped, up to 20 cm long and less than half that wide&lt;br&gt;Hairs – copious stiff hairs on leaf margin, veins on leaf underside with numerous stiff hairs</td>
<td>White</td>
<td>Dry seed pods are small, 3-sided and have old sepals attached and are smooth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Japanese</td>
<td>1-3 m in height&lt;br&gt;Egg-shaped, 3-10 cm, 2/3 as wide, base straight not curved, leaf tip abruptly pointed, leaf texture thick and leathery; a distinguishing feature for Japanese knotweed is the zigzag pattern in which leaves are arranged along the plant’s arching stems&lt;br&gt;Hairs – no stiff hairs on leaf margin, veins on leaf underside have blunt knobs (sabres), giving them a htry rough, ridged appearance</td>
<td>Whitish or greenish-white</td>
<td>Dry seed pods are 3-angled, black, smooth, shiny, 2.5-3 mm long</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a) Leaves

Knotweed species leaves and leaf hairs
(WILSON 2007)

b) Hairs on the underside veins of leaves
SIMILAR SPECIES

Knotweeds are often referred to incorrectly as “false bamboo” and can be confused with ornamental bamboo. Bamboo (Bambusoideae spp.) has harder stems that cannot be snapped easily like knotweed, and leaves that are very slender and long (varies between species and varieties, but bamboo leaves are usually up to 50 cm long). Bindweed (Convolvulus arvensis) has similar leaves but is a climbing or sprawling vine with thin, solid stems. The native species dogwood (Cornus spp.) and introduced lilac (Syringa vulgaris) have similar leaf shapes to knotweed, however their leaves grow opposite each other along woody stems, whereas knotweed leaves are alternate. Himalayan knotweed can be confused with dock (Rumex species) and several other species of Persicaria. Leaf length, leaf shape, flower structure, and flower colour can be used as distinguishing features.
Tracking

The provincial government maintains the Invasive Alien Plant Program (IAPP) application (BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development 2017), which houses information pertaining to invasive plant surveys, treatments, and monitoring. Many agencies, including local governments, have their own internal invasive species inventory and mapping protocols that are used by staff, contractors and, in some cases, the public. For example, the City of North Vancouver has its own system called AlienMap. Agencies in British Columbia that do not enter data into IAPP are encouraged to check it regularly because it contains public reports and data from other agencies and it is important to consider as much data as possible when making management decisions. The Map Display module of IAPP is publicly accessible.

When carrying out a knotweed inventory, be sure to record the following information as it will later inform your treatment plan:

• Size and density of infestation;
• Location in relation to the high water mark of watercourses; and
• Location in relation to other water sources, such as wells.

Reporting

Please report knotweed occurrences to:

• The Provincial Report-A-Weed program (via online form or smart phone app www.reportaweedbc.ca).
• The Invasive Species Council of Metro Vancouver: 1-604-880-8358 or www.iscmv.ca.
• The municipality where the knotweed was found.
• The landowner directly – Most land managers are keen to be made aware of knotweed sites immediately so control can be arranged as soon as possible. If the landowner is unknown, the Invasive Species Council of Metro Vancouver can provide support to identify the appropriate authority.

Reports submitted through these channels are reviewed by invasive species specialists who coordinate follow-up activities when necessary with the appropriate local authorities. However, some people may be hesitant to report knotweed infestations as their presence may affect property values.
Prevention and Control Strategies

Effective invasive plant management programs may include a variety of control techniques ranging from prevention, chemical, cultural, manual, biological, and/or mechanical methods. Each method is described below in order of effectiveness.

Coordinated management efforts across jurisdictional boundaries are critical. If infestations are shared, it is ideal for the entire infestation to be treated with the same method at the same time. Management efforts will be less successful if only a portion of the infestation is targeted. With herbicide use, partial treatment of the infestation can also contribute to herbicide resistance.

Knotweed can be spread by land owners maintaining, cutting or digging the plant on their properties and dumping the waste into green spaces. Appropriate disposal techniques (see section below) are an essential prevention strategy. Do not purchase, trade, or grow knotweeds. Instead of knotweeds, grow regional native plants that are naturally adapted to the local environment and non-invasive. Consult the Invasive Species Council of BC’s [Grow Me Instead Program](http://www2.gov.bc.ca/gov/content/environment/biodiversity/invasive-species/grow-me-instead-program) or [Metro Vancouver’s Grow Green website](http://www.growgreen.ca) for non-invasive, drought-tolerant plants and garden design ideas. Ensure all materials (e.g., topsoil, gravel, mulch, compost) are knotweed-free. Healthy green spaces are more resistant to invasion by invasive plants, so it is also important to maintain or establish healthy plant communities.

**CHEMICAL: RECOMMENDED**

Due to the extensive rhizome system, chemical control with a systemic herbicide is the most effective treatment method for all four species of knotweeds.

The BC Ministry of Transportation and Infrastructure has trialed the use of several non-systemic chemicals (saltwater, vinegar, borax, foam, etc.) to control knotweed. Treatment efficacy was found to be as poor as some manual control methods; there was no impact on the roots. Authorization from Health Canada’s Pest Management Regulatory Agency is required to test any non-registered pest control products.

When alternative methods to prevent or control invasive plants are unsuccessful, professionals often turn to herbicides. With the exception of substances listed on Schedule 2 of the [BC Integrated Pest Management Regulation](http://www2.gov.bc.ca/gov/content/agriculture/pests/invasive/pest-management-regulation), the use of herbicides is highly regulated in British Columbia. Site characteristics must be considered with herbicide prescribed, based on site goals and objectives and in accordance with legal requirements. [This summary of BC’s Integrated Pest Management Act](http://www.legis.gov.bc.ca/laws/statutes/i/act.html) provides an overview of the provincial legislation.
PESTICIDE LICENCE AND CERTIFICATION

A valid pesticide licence is required to:

• offer a service to apply most pesticides;

• apply most pesticides on public land including local government lands; and

• apply pesticides to landscaped areas on private land, including outside office buildings and other facilities.

Pesticides (e.g., herbicides, insecticides, fungicides) are regulated by the federal and provincial government, and municipal governments often have pesticide bylaws.

• Health Canada evaluates and approves chemical pest control products as per the Pest Control Products Act.

• The BC Integrated Pest Management Act sets out the requirements for the use and sale of pesticides in British Columbia. This Act is administered by the Ministry of Environment.

• Several municipalities have adopted bylaws which prohibit the use of certain pesticides.

Everyone who uses pesticides must be familiar with all relevant laws.

ONLY companies or practitioners with a valid Pesticide Licence and staff who are certified applicators (or working under a certified applicator) may apply herbicide on invasive plants located on public lands in British Columbia. Applicators must be either the land manager/owner or have permission from the land manager/owner prior to herbicide application.

On private property the owner may obtain a Residential Applicators Certificate (for Domestic class products only) or use a qualified company. Residents do not require a Residential Applicator Certificate for certain uses of domestic class glyphosate including treatment of plants that are poisonous for people to touch, invasive plants and noxious weeds listed in legislation, and weeds growing through cracks in hard surfaces such as asphalt or concrete. Refer to the ‘Pesticides & Pest Management’ and ‘Home Pesticide Use’ documents listed in the Additional Resources Section for more information.

Questions? Contact the BC Integrated Pest Management Program:

Telephone: (250) 387-9537
Email: bc.ipm@gov.bc.ca

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3 on up to 50 ha/year by a single organization. Organizations looking to treat over 50 hectares of land per year are also required to submit a Pest Management Plan and obtain a Pesticide Use Notice confirmation.
Pesticide applicator certificates can be obtained under the category ‘Industrial Vegetation Management’ to manage weeds on industrial land, roads, power lines, railways, and pipeline rights-of-way for control of noxious weeds on private or public land. Assistant applicator training is also available and the online course and exam are free.

Although an annual fee and annual reporting are required, it is best practice for personnel supervising or monitoring pesticide contracts to also maintain a pesticide applicator licence so they are familiar with certification requirements.

For more information on how to obtain a licence and the requirements when working under the provincial Integrated Pest Management Act and Regulation, please review the Noxious Weed & Vegetation Management section on this webpage: gov.bc.ca/PestManagement.

PHASED APPROACH

Chemical control plans should always include three phases: 1) control, 2) maintenance, and 3) ecological restoration. For knotweeds, the control phase takes at least two seasons, and often includes at least two treatments in year one, followed by at least one treatment in year two. After initial treatment during active growth, follow-up treatments should occur no sooner than 2 weeks, preferably 4-6 weeks or more (or as stated on the herbicide label), so there is sufficient foliage to absorb adequate quantities of herbicide for translocation to the tips of rhizomes (Ralph 2017). Note that some of the herbicides used for knotweed control are restricted to one application per site per year. After initial control efforts have nearly eliminated the knotweed, the site must be periodically monitored and new growth treated to prevent re-infestation (Gover, et al. 2008). Restoration should also be a priority, especially if there is risk the site will be colonized by other invasive plant species.
HERBICIDE LABELS

Individual herbicide labels must always be reviewed thoroughly prior to use to ensure precautions, application rates, and all use directions, specific site and application directions are strictly followed. Under the federal Pest Control Products Act and the BC Integrated Pest Management Regulation, persons are legally required to use pesticides (including herbicides) only for the use described on the label and in accordance with the instructions on that label. Failure to follow label directions could cause damage to the environment, poor control results, or danger to health. Contravention of laws and regulations may lead to cancellation or suspension of a licence or certification, requirement to obtain a qualified monitor to assess work, additional reporting requirements, a stop work order, or prohibition from acquiring authorization in the future. A conviction of an offence under legislation may also carry a fine or imprisonment.

Herbicide labels include information on both the front and back. The front typically includes trade or product name, formulation, class, purpose, registration number, and precautionary symbols. Instructions on how to use the pesticide and what to do in order to protect the health and safety of both the applicator and public are provided on the back (BC Ministry of Environment 2011).

Labels are also available from the Pest Management Regulatory Agency's online pesticide label search or mobile application as a separate document. These label documents may include booklets or material safety data sheets (MSDS) that provide additional information about a pesticide product. Restrictions on site conditions, soil types, and proximity to water may be listed. If the herbicide label is more restrictive than provincial legislation, the label must be followed.
### HERBICIDE OPTIONS

The following systemic herbicides can be used on knotweeds in British Columbia:

<table>
<thead>
<tr>
<th>ACTIVE INGREDIENT (EXAMPLE BRAND NAMES)+</th>
<th>APPLICATION</th>
<th>PERSISTENCE</th>
<th>GROWTH STAGE++</th>
<th>TYPE+++</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glyphosate (many products)</td>
<td>foliar</td>
<td>non-residual*</td>
<td>actively growing</td>
<td>non-selective</td>
</tr>
<tr>
<td></td>
<td>application</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>stem injection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(only Roundup WeatherMAX® With Transorb 2 Technology)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imazapyr (example: Arsenal™)**</td>
<td>foliar</td>
<td>residual</td>
<td>actively growing</td>
<td>non-selective</td>
</tr>
<tr>
<td></td>
<td>application</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aminopyralid + metsulfuron methyl (example: Clearview™)***</td>
<td>foliar</td>
<td>residual</td>
<td>actively growing</td>
<td>selective, no affect to grasses</td>
</tr>
<tr>
<td>Aminopyralid (example: Milestone™)</td>
<td>foliar</td>
<td>residual</td>
<td>actively growing</td>
<td>selective, no affect to grasses</td>
</tr>
<tr>
<td></td>
<td>application</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triclopyr (example: Garlon™)****</td>
<td>foliar</td>
<td>residual</td>
<td>during growing season</td>
<td>selective, no affect to grasses</td>
</tr>
<tr>
<td></td>
<td>application</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

+ The mention of a specific product or brand name of pesticide in this document is not, and should not be construed as an endorsement or recommendation for the use of that product.

++ Active growing periods vary from year to year depending on weather and other factors. There may be more than one active growing period for a plant in a year. Typically, the active growing period for knotweeds is from the spring until the plants mature and set seeds.

+++ Herbicides that control all vegetation are non-selective, while those that control certain types of vegetation (for example, only grasses or only broadleaf plants) are termed selective.

* Non-residual herbicides are active only on growing plant tissue have little or no persistence in the soil whereas residual herbicides persist in the soil, remaining effective over an extended period of time.

** Only on non-crop areas.

*** Only Japanese knotweed is listed on this label. The federal Pest Management Regulatory Agency is satisfied that long-term control can also be achieved on the other three species (Herbison 2017).

**** Use higher rates for late summer applications when regrowth rates are reduced.

NOTE: Knotweeds are not specifically listed on the Milestone™, Garlon™ or Arsenal™ labels; however, they can be treated under the general application provision for broadleaved plants.

Additional information on products, rates and application methods can be found in 2016 Herbicide Guidelines for Control of Knotweed Species on Crown Lands (see resource section).
APPLYING HERBICIDE IN RIPARIAN AREAS

Provincial legislation prohibits the use of herbicides within 10 metres of natural water courses and 30 metres of domestic or agricultural water sources on public lands. On private lands only herbicide labels need to be followed (which means for glyphosate products and Milestone™, treatment can happen up to the water’s edge). On public lands, glyphosate is the only active ingredient that can be applied within the 10 metre Pesticide-Free Zone (PFZ) in British Columbia in accordance with the BC Integrated Pest Management Act and Regulation and all public land Pesticide Management Plans (PMPs). Glyphosate can only be applied up to 1 metre away from the high water mark (HWM). See the manual/mechanical section below for alternative control techniques that may be used with extreme caution at these sites. The 30 metre no-treatment zone around a water supply intake or well used for domestic or agricultural purposes may be reduced if the licencee or PMP holder is “reasonably satisfied” that a smaller no-treatment zone is sufficient to ensure that pesticide from the use will not enter the intake or well.

When managing knotweeds with herbicide in riparian areas:

- Observe and mark all PFZs while on site.
- The HWM should be determined by careful evaluation by the applicator.
- Distances in PFZs should be measured as horizontal distance.
- Herbicides restricted in a PFZ must not enter these zones by leaching (lateral mobility) through soil or by drift of spray mist or droplets.
- Treatments should be conducted when water levels are low (e.g. summer months) to reduce risk.
- Note that efficacy may be dependent on site conditions, including moisture in the soil. Riparian sites in the City of Burnaby have taken longer to achieve eradication than sites with drier soils when identical treatments were used (Yong 2017).

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4 The Pesticide-Free Zone (PFZ) is an area of land that must not be treated with pesticide and must be protected from pesticide moving into it, under the Integrated Pest Management Act and Regulation.

5 The High Water Mark (HWM) is defined as the visible high water mark of any lake, stream, wetland or other body of water where the presence and action of the water are so common and usual and so long continued in all ordinary years as to mark upon the soil of the bed of the lake, river stream, or other body of water a character distinct from that of the banks, both in vegetation and in the nature of the soil itself. Typical features may include, a natural line or “mark” impressed on the bank or shore, indicated by erosion, shelving, changes in soil characteristics, destruction of terrestrial vegetation, or other distinctive physical characteristics. The area below the high water mark includes the active floodplain (BC Ministry of Environment and Climate Change Strategy 2018).
FOLIAR APPLICATION METHODS

The preferred application methods to minimize non-target damage and applicator exposure are as follows:

• **Spray-on application** uses a backpack or handheld sprayer to completely cover the actively growing plant parts with herbicide, including the underside of the leaves. Spraying the undersides of the leaves maximizes the herbicide contact and uptake by the stomata, most of which are on the underside of the leaves of knotweeds. To access tall foliage and minimize the risk of applicator exposure to herbicide, long wands and wand extensions are recommended. If working in or under a knotweed canopy, applicators should take care to remove plant fragments, soil, and seeds from clothing, footwear, and equipment before leaving the site.

• **Small infestations** (less than 300 stems): Work around the stand perimeter, spraying both the top and underside of the leaves.

• **Large infestations** (300 stems or more): Target the foliage around the perimeter of the infestation first to reduce applicator exposure. After the treated foliage has died back, return to the infestation for a second treatment. Spray foliage that was not treated during the first treatment, and tackle the next “layer” during subsequent treatments. Continue until all foliage has been sprayed.

• **Wipe-on application** involves applying herbicide directly onto leaf surfaces (including the underside) using a simple hand-held wipe-on applicator (e.g., Red WeederTM). Wipe-on application is time-consuming and can be messy due to herbicide drips.

• **Knock down and spray method** is easier with two people. With a blunt end of a machete, a strong stick, or hand, one person knocks the new knotweed stems over (one by one), making sure not to break/cut the stem. With a handheld or backpack sprayer, the second person (applicator) follows the first person and sprays the leaves of the bent over stems, at waist height.

This technique avoids spraying overhead, and provides applicators with easy navigation and the ability to account for what has been sprayed already. With the stems bent over, the undersides of the leaves are also exposed and easily sprayed. This technique is also more effective if done earlier in the season; if the stems become woody and brittle, it’s more likely that the stems will break rather than bend.

The knock down and spray technique has been trialed by the Sea to Sky Invasive Species Council with an average efficacy of 80.6% on 8 sites (Greenberg 2017).

Shrouding or shielding the spray nozzle(s) on the spray wand can minimize herbicide drift into pesticide free zones or other sensitive areas during foliar applications. Tarps or garbage bags can be suspended, wrapped, or draped as a buffer to adjacent sensitive areas including desirable vegetation, waterbodies or structures. This technique can also be used to protect restoration plantings that have become overgrown with knotweeds (BC Ministries of Transportation and Infrastructure 2016).

STEM INJECTION

This technique involves injection of herbicide into single stems using a hand-held tool that delivers a specified amount of product into the hollow stems. Currently in Canada, Roundup WeatherMAX® With Transorb 2 Technology Liquid Herbicide™ (pest control products number 27487) is the only product with stem injection listed the label and therefore the only product that can legally be applied using this method. While it can be used on any sized infestation, this method is useful for patches with few knotweed stems or when stems are growing interspersed between desirable vegetation. This method is more time-consuming as each stem must be injected and marked (some injection tools come with attachments for marking pens).
TREATMENT TIMING

Herbicide should be applied to actively growing plants. Treatment can start either early in the growing season or late summer. For early spring treatments, it is recommended to wait until there is sufficient foliage on the stem (starting when knotweed canes are at least one metre high and when the majority of canes in the infestation have emerged) (Watson 2017). This ensures adequate surface area for absorption. This early season treatment timing requires follow-up on regrowth later in the season. Advantages of early season treatments include avoiding the need for spraying overhead, reducing the risk of breaking canes, preventing flower/seed set from occurring, and using less herbicide. Initial treatments can also start in late summer/early fall when maximum surface area is available to spray because the leaves have all matured. This late season treatment timing requires follow-up the next spring. Both timing methods can be effective, and as with all management techniques, outcomes are site specific.

Knotweed treatment should cease at the end of the growing season once it shows extensive leaf discoloration or defoliation. Treatment efficacy will be reduced during drought periods (BC Ministries of Transportation and Infrastructure 2016).

In order to minimize impact to insects, if possible, treat before the plants flower and avoid treatment during the flowering season. If Himalayan blackberry is present at the treatment site consider treating before the berries form or cutting any blackberry canes with fruit before treatment to eliminate concerns of berry pickers.

MAINTENANCE

Post-chemical treatment monitoring is required for licencees and PMP holders under the Integrated Pest Management Act to ensure that efforts are successful and to allow for adjustments to the management approach as necessary. After initial herbicide treatment, follow-up monitoring and treatment should occur at least once the same year for glyphosate. Note that some of the herbicides used for knotweed control are restricted to one application per site per year. Check the label for application timing and frequency.

Monitoring should continue on at least an annual basis, with follow up treatments occurring as necessary, until the infestation is eradicated. Some knotweed treatment sites may seem eradicated, however new growth has been observed up to three years after the last herbicide treatment or observation of knotweed growth (Watson 2017). Knotweed rhizomes can remain dormant for up to 20 years (Parkinson and Mangold 2010). Monitoring the site for many years is prudent due to knotweed’s extensive rhizome system.
Manual/mechanical control methods (smothering, mowing, pulling, digging, burning, steaming, cutting, and removing by hand or machine) on their own are not effective knotweed control options. These methods may impact the above ground vegetation but do not target the extensive underground rhizome structure, which is essential for successful management. Manual/mechanical control is time-consuming and requires dedicated, frequent removal over numerous years and is likely to yield no change or a growth in the original infestation, at a high risk for spread to other sites.

Although they will not result in successful control or eradication of knotweeds, the following methods may be used to manage knotweed in specific circumstances (for example, in the PFZ or for sight line safety) and should be carried out with extreme caution. For all manual/mechanical methods, if soil is disturbed at a knotweed site, the infestation and a 20 metre radius should be flagged, and care must be taken when working in that “contaminated area” (BC Ministry of Transportation and Infrastructure 2016):

- **Smothering** involves the use of light blocking materials. Many smothering materials are unsuitable – they must be thick and heavy such as recycled conveyor belt. Maintenance visits will be necessary to ensure the cover has not been breached and new shoots do not sprout along edges. Be prepared to expand the covered area over the first few growing seasons as the knotweed spreads beyond the initial area smothered (Clegg 2018). Sites observed in BC where smothering materials were in place for over 10 years have not been successful (Chadburn 2018) (McLean 2018).

- **Cutting flower heads** is used at Bohemian knotweed sites where chemical control is not possible to reduce the seed bank and prevent dispersal (Chadburn 2018). This
must be done before the plants set seed. Care must be taken as described below.

- **Pulling and digging** is used for areas where herbicide is not permitted. Extreme care must be taken at aquatic sites to prevent soil erosion. All plant parts must be prevented from entering the watercourse. The root mass volume is much larger than the aboveground growth so digging will encompass a large area around the infestation. If this technique is used, see Disposal section below to avoid spreading the knotweed.

- **Excavation with heavy equipment** requires all root material to be removed, which requires digging 3 metres deep and up to 20 metres wide (BC Ministry of Transportation and Infrastructure 2016). Great care must be taken when excavating knotweeds as this activity has a high risk of spreading plant fragments. Equipment should be thoroughly washed onsite before transport to reduce risk of spread. Ensure a disposal plan is in place prior to excavating (see Disposal section below). Monitor and treat areas with herbicide after excavation.

- **Mowing** is not recommended as repeated frequent mowing causes an acceleration of new shoot development leading to lateral spread (Drinkwater 2017). It is suspected that plant fragments spread by mowing are one of the main vectors of spread for knotweeds in Metro Vancouver and other regions.

- **Cutting** is not recommended although may be necessary at particular sites. If top growth must be removed, the canes should be carefully handled and allowed to desiccate until completely brown and dead before transport or disposal. If this technique is used, see Disposal section below to avoid spreading the knotweed.

- **Burning and/or heat treatment** is not recommended as the plants contain high water content and all plant tissue, particularly the rhizomes, may not burn. Infrared heat treatment of over 800 degrees Celsius has shown to be time consuming, laborious, and did not affect the centre of large rhizomes (Clegg 2018). In addition, burning is prohibited in many municipalities unless a permit has been obtained from the fire department.

- **Foam, steam and other alternatives** are not recommended as they only act to kill top ground vegetation. Use of these methods have the same challenges as the manual control methods outlined above and do not have long-term evidence to support use.

**CULTURAL: NOT RECOMMENDED**

Although goats and cattle will graze newly emergent shoots right down to ground level in the spring and summer (Centre for Agriculture and Biosciences International 2017) grazing, does not control the rhizome system. Grazing animals may leave behind plant fragments and seeds which will likely regrow. Grazing opportunities are limited in urban areas due to municipal bylaws regulating agriculture animals, the high probability of interface with the public, and the damage animals could cause to riparian areas and other sensitive sites with multiple land uses. Due to these constraints, cultural control is not recommended as a practical management option in the Metro Vancouver region.

**BIOLOGICAL: NOT AVAILABLE**

Biological control or biocontrol is the use of an invasive plant’s natural enemies (chiefly insects, parasites and pathogens) — to reduce its population below a desired level. A sap sucker psyllid, *Aphalara itadori*, has been studied as a potential biological control in the Pacific Northwest (Centre for Agriculture and Biosciences International 2017). *A. itadori* feeds on the sap in the phloem cells of the leaves and stems resulting in twisted and deformed leaves and, more importantly, damage to the meristems and reduced biomass. In 2012, host range screening was completed for *A. itadori* and a permit to import the psyllid into Canada was submitted to the Canadian Food Inspection Agency (CFIA). The psyllid has been approved by CFIA for limited number of releases in Canada. Agriculture and Agri-Food Canada and the BC Ministry of Forests, Lands, Natural
Resource Operations and Rural Development has released the psyllid in BC, Alberta and Ontario and is working on identifying the conditions for establishment and assessing impact (BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development 2017). To date the insect has not established, that is, it has not persisted across multiple years (Bourchier 2018). The BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development and other agencies in North America continue to explore potential biocontrol opportunities for knotweeds. For the current availability of A. itadori, please visit the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development’s Biological Control website.

Disposal

Best practice is to avoid offsite knotweed disposal due to the high risk of spread during transport. If best management practices are followed and chemical control methods are used, treated knotweed canes can be left on site to compost and disposal is not necessary. Canes left to dry and desiccate will not be viable to regrow. Dead canes can be mechanically or manually cut over winter to provide easier access for spring treatments, pedestrian access along paths/sidewalks, or aesthetics (Clegg 2018). Under special circumstances when manual/mechanical control methods are required, follow the recommended disposal procedures described below. Consult individual herbicide labels for information on environmental fate, safety hazards, timing and other considerations if contact of the plants or activities are planned at the site soon after treatment.

HANDLING

When handling or working in or near a knotweed infestation, ensure no plant fragments (or seeds in the case of Bohemian knotweed) fall away or are dropped, as they will likely regrow. When collecting the knotweed cuttings for disposal ensure plant fragments are contained in a bag or container to avoid dropping plant pieces (for green waste - brown paper bags; for garbage - sealed, heavy plastic bags).

ON SITE DISPOSAL

It is best to avoid manual/mechanical control methods to minimize movement of knotweed material or soils infested with plant parts, rhizomes, or seeds. If this control method is necessary, onsite disposal is the best option.

For large operations, such as gravel pits, knotweed plant parts, rhizomes, and seeds can be buried on site to a
minimum depth of 5 metres. Any regrowth should be chemically treated. These sites should be physically marked and records should be kept on file for future referral should re-development of the site occur. Burial sites should be monitored for regrowth on an ongoing basis.

Infested soils can be stock piled, but knotweed growth and stockpiled soil with knotweed growth should be chemically treated and monitored (refer to chemical treatment section). Disposal sites should be far enough away from water and drinking wells to enable herbicide treatment.

Home composting of untreated knotweed is not recommended as it will regrow and infest the composter.

OFF SITE DISPOSAL

If deep burial or stockpiling on site are not options, knotweed plants and soil infested with knotweed foliage, rhizomes, and/or seeds can be disposed at an appropriate facility. To reduce the risk of plant parts, rhizomes, or seeds escaping during transport, all material should be bagged, tarped and strapped securely. Alternatively the material could be placed in a sealed container before transport. The City of Chilliwack performed a one-time trail of deep burial of concentrated rhizome (as well as loose soil contaminated with low levels of rhizome parts) in sealed 200 litre plastic barrels in a municipal landfill with success (Clegg 2018). Most disposal facilities charge a surcharge upon arrival if loads are not secured.

In addition, clothing, vehicles, pets, and equipment should also be inspected for plant material and decontaminated if necessary.

In the Lower Mainland, the following facilities may accept knotweed plants and/or infested soil:

- **Vancouver Landfill**, 5400 72nd Street, Delta, BC. Accepts knotweeds and soil for deep burial only (additional charge). A **Waste Assessment Form** must be completed.
- **BC Earth Exchange**, Corner of Bonson and Fraser Way, Pitt Meadows, BC. May accept soil infested with knotweeds.
- **Fraser Valley Aggregates**, 1080 Bradner Road, Abbotsford, BC. May accept soil infested with knotweeds. This site is under permit by the City of Abbotsford.
- **Mission Landfill**, 32000 Dewdney Trunk Road, Mission, BC. Accepts knotweeds and soil for deep burial only (additional charge). A Waste Assessment Form must be completed.
- **Net Zero Waste**, 5050 Gladwin Road, Abbotsford, BC. Accepts yard waste for industrial composting. This facility does not accept soil.
- **Metro Vancouver’s Waste-to-Energy facility**, 5150 Riverbend Drive, Burnaby, BC. This facility does not accept soil. Accepts loads of knotweeds if customers have:
  - A self-tipping truck;
  - A commercial account; and
  - Pre-approval from the Manager of Solid Waste Services (contact weighscalesystem@metrovancouver.org or 604-451-6185).

Knotweed plant material and small quantities of soil (maximum 0.5 m3 or two wheelbarrows full) are accepted at Metro Vancouver’s Transfer Stations (Langley, Maple Ridge, North Shore, Coquitlam and Surrey). Soil from the Transfer Stations is placed in the garbage stream.

PLEASE CONTACT ALL FACILITIES BEFOREHAND TO CONFIRM THEY CAN PROPERLY HANDLE THE MATERIAL.
CLEANING AND DISINFECTION

Before leaving a site, remove all visible plant parts and soil from vehicles, equipment, and gear, and if possible, rinse these items. When back at a works yard or wash station, vehicles should be cleaned and disinfected using the following steps:

- Wash with 180 °F water at 6 gpm, 2000 psi**, with a contact time of ≥ 10 seconds on all surfaces to remove dirt and organic matter such as vegetation or seeds. Pay special attention to undercarriages, chassis, wheel-wells, radiators, grills, tracks, buckets, chip-boxes, blades, and flail-mowing chains.

- Use compressed air to remove vegetation from grills and radiators.

- Sweep/vacuum interior of vehicles paying special attention to floor mats, pedals, and seats.

- Run air intake fans in reverse where possible.

- Steam clean poor access areas (for example inside trailer tubes) – 200 psi @ 300 °F.

- Fully rinse detergent residue from equipment prior to leaving facility.

** Appropriate self-serve and mobile hot power-wash companies in the Metro Vancouver region include: Mary Hill Truck Wash, Omega Power Washing, Eco Klean Truck Wash, RG Truck Wash, Ravens Mobile Pressure Washing, Hydrotech Powerwashing, Platinum Pressure Washing Inc., and Alblaster Pressure Washing. Wash stations should be monitored regularly for knotweed growth.

Follow-Up Monitoring

Whatever control method is used, follow-up monitoring and maintenance treatments are important components of an integrated management plan or approach. Monitoring should occur around the periphery of the initial infestation as stems can emerge many metres away even when the main portion of the original stand appears dead.

Restoration

Restoration may not be necessary for relatively young and small knotweed infestations. For older, large knotweed infestations, restoration is necessary to suppress colonization by other invasive plant species. Although it is desirable to revegetate with native or non-invasive plant species as soon as possible, restoration activities must be carefully timed. If planting occurs before the knotweed is completely eradicated it will be much harder to manage the remnant knotweed without injuring the restored vegetation (Gover, et al. 2008). Planting broadleaved herbaceous or woody plants after application of a residual herbicide should be delayed until herbicide activity is deactivated in the soils. This will depend on soil type, environmental conditions, and herbicide type. If replanting of broadleaved species is planned soon after herbicide treatment, then a non-residual herbicide (for example, glyphosate) should be used. For glyphosate products, delay preparation of the soils for replanting by at least 7-15 days to ensure complete translocation of herbicide to the root tips (Ralph 2017).

Clearview™ and Milestone™ are safe on established grasses. Grasses may be seeded 10 months following an application. Legume re-establishment may be affected for up to five years. Soil organic matter, rainfall and temperature all affect the rate of degradation (IVM Experts Dow Chemicals Canada 2016).

Revegetation of the site to a domestic or cultured non-native plant species composition may be considered in some circumstances. Often domestic species establish faster and grow more prolifically which aids in resisting knotweed re-invasion.

Local biologists, environmental professionals, agronomists, agrologists, native and domestic forage specialists, seed companies, and plant nurseries are all good sources for localized recommendations for regional native species and regionally adapted domestic species, based on site usage. There are several science-based resources available to guide restoration efforts, such as the South Coast Conservation Program’s Diversity by Design restoration planning toolkit.
References


BC Ministry of Transportation and Infrastructure. 2016. “‘Knot’ on our Highways Poster.”


Chadburn, Crystal, interview by Tasha Murray. 2018. Environmental Roadside Manager, BC Ministry of Transportation and Infrastructure (February 7).

Clegg, Steve, interview by Tasha Murray. 2018. Environmental Services Specialist, City of Chilliwack (February).


Yong, Melinda. 2017. Environmental Technician, City of Burnaby (December).
Additional Resources

For more information please refer to the following resources.


E-Flora BC, an Electronic Atlas of the Plants of BC. www.eflora.bc.ca/


Home Pesticide Use. Province of British Columbia https://www2.gov.bc.ca/gov/content/environment/pesticides-pest-management/pesticide-use/pesticide-certification/certificate-categories/home-pesticide-use


Pesticides and Pest Management. Province of British Columbia https://www2.gov.bc.ca/gov/content/environment/pesticides-pest-management

Acknowledgements

The project team would like to thank the following individuals and groups for their contributions related to the development and review of this document:

Catherine Tarasoff, AgroWest Consulting

Jennifer Grenz, Greener This Side

Metro Vancouver’s Regional Planning Advisory Committee (RPAC) - Invasive Species Subcommittee

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Heracleum mantegazzianum

BEST MANAGEMENT PRACTICES FOR
Giant Hogweed
in the Metro Vancouver Region

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Climate Action Committee
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# Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>4</td>
</tr>
<tr>
<td>Regulatory Status</td>
<td>5</td>
</tr>
<tr>
<td>Impacts</td>
<td>5</td>
</tr>
<tr>
<td>Reproduction and Spread</td>
<td>5</td>
</tr>
<tr>
<td>Habitat and Distribution</td>
<td>5</td>
</tr>
<tr>
<td>Identification</td>
<td>6</td>
</tr>
<tr>
<td>Similar Species</td>
<td>7</td>
</tr>
<tr>
<td>Tracking</td>
<td>9</td>
</tr>
<tr>
<td>Reporting</td>
<td>9</td>
</tr>
<tr>
<td>Prevention and Control Strategies</td>
<td>10</td>
</tr>
<tr>
<td>Handling Giant Hogweed Safely</td>
<td>10</td>
</tr>
<tr>
<td>Prevention: Imperative</td>
<td>11</td>
</tr>
<tr>
<td>Manual: Recommended</td>
<td>11</td>
</tr>
<tr>
<td>Chemical: Recommended</td>
<td>12</td>
</tr>
<tr>
<td>Mechanical: Not Recommended</td>
<td>18</td>
</tr>
<tr>
<td>Cultural: Not Recommended</td>
<td>18</td>
</tr>
<tr>
<td>Biological: Not Available</td>
<td>18</td>
</tr>
<tr>
<td>Disposal</td>
<td>19</td>
</tr>
<tr>
<td>On Site Disposal</td>
<td>19</td>
</tr>
<tr>
<td>Off Site Disposal</td>
<td>19</td>
</tr>
<tr>
<td>Cleaning and Disinfection</td>
<td>19</td>
</tr>
<tr>
<td>Follow-Up Monitoring</td>
<td>20</td>
</tr>
<tr>
<td>Restoration</td>
<td>20</td>
</tr>
<tr>
<td>References</td>
<td>21</td>
</tr>
<tr>
<td>Additional Resources</td>
<td>22</td>
</tr>
<tr>
<td>Acknowledgments</td>
<td>22</td>
</tr>
</tbody>
</table>
Introduction

The impacts of invasive species on ecological, human and economic health are of concern in the Metro Vancouver region. Successful control of invasive species requires concerted and targeted efforts by many players. This document - “Best Management Practices for Giant Hogweed in the Metro Vancouver Region” - is one of a series of species-specific guides developed for use by practitioners (e.g., local government staff, crews, project managers, contractors, consultants, developers, stewardship groups and others who have a role in invasive species management) in the region. Together, these best practices provide a compendium of guidance that has been tested locally by researchers and operational experts.

Giant hogweed is a target for eradication and education in the region due to the health risk associated with direct contact. The Invasive Species Council of Metro Vancouver (ISCMV) has identified giant hogweed as a top-ten invasive species for management in the region.

Academic institutions, government and non-government organizations continue to prioritize and study this species in British Columbia. As researchers and practitioners learn more about the biology and control of giant hogweed in British Columbia, it is anticipated that the recommended best management practices will change over time and this document will be updated. Please check metrovancouver.org regularly to obtain the most recent version of these best management practices.
REGULATORY STATUS

Giant hogweed is classed as a noxious weed within all regions of the province under the BC Weed Control Act, Weed Control Regulation, Schedule A, Part 1 – Provincial Weeds. Under this Act, “an occupier” must control noxious weeds growing or located on land and premises, and on any other property located on land and premises, occupied by that person”.

Section 2 (1) (b) (iii) of the Community Charter, Spheres of Concurrent Jurisdiction, states that “municipalities may regulate, prohibit and impose requirements in relation to control and eradication of alien invasive species” which includes giant hogweed.

IMPACTS

Giant hogweed is a high priority species in the region primarily due to the potential health impacts from direct contact with the plant. The sap in giant hogweed stems and leaves contains furanocoumarins, which upon contact with skin, can result in dermatitis. Furanocoumarins react with sunlight and cause severe burns on the affected skin areas when exposed to sunlight, resulting in blistering and recurrent dermatitis (WorkSafe BC 2006). To reduce the public health risk posed by giant hogweed, all levels of government and private land managers incur management costs in the region every year. In 2016, agencies represented on Metro Vancouver’s Regional Planning Advisory Committee – Invasive Species Subcommittee spent close to $100,000 on giant hogweed control efforts. This figure does not include control costs for private landowners across the region or costs associated with education and awareness activities.

Giant hogweed tends to form monocultures with large standing biomass and extensive litter production. Its early germination allows it to develop seedlings well ahead of native species (Moravcová 2007). Moravcová also noted that the plant may change the composition and species diversity of native plant communities, and in central Europe, investigations have shown a reduction in species richness and densities by up to 50-60% (Hejda, Pysek and Jarosik 2009). Large infestations of giant hogweed can kill grass and other understory plants by shading. When giant hogweed dies back in the winter, the bare soil in the understory is exposed which may result in soil erosion (Moravcová 2007). Increased soil erosion along stream banks, a favourite location for giant hogweed infestations, is a significant concern.

REPRODUCTION AND SPREAD

Giant hogweed reproduces by seed. An average mature plant can produce between 20,000 and 100,000 seeds each year. Since most seeds fall within a few metres of the parent plant, seedlings develop under very crowded conditions and thus seedling mortality is high. The vast majority of seeds (95%) are found within the top 5 cm of the soil layer and within 9 metres from a plant. Seeds may stay viable in the soil for more than five years (New York State Department of Environmental Conservation 2017). The seeds can be dispersed short distances by wind, but travel dramatically longer distances by water, floating for up to 8 hours (Moravcová 2007). Humans also affect dispersal by transporting plants purposefully or accidentally in urban and rural areas.

HABITAT AND DISTRIBUTION

In the Metro Vancouver region, giant hogweed tends to grow in wet areas along streams and rivers, parks, forest edges, on waste ground, near houses, in gardens, in vacant lots, and along transportation corridors. It prefers moist soil.

Giant hogweed is native to the Caucasus region of Eurasia and was introduced into North America in the early 1900s (Michigan State University Extension 2012). In British Columbia, giant hogweed has been detected in the Southwest coastal and island regions, and recently

Identification

Giant hogweed is sometimes referred to as giant cow parsnip or hogweed.

Lifecycle: Biennial (lives for 2 years, flowering in the second) to short-lived perennial (lives for more than 2 years); plant goes dormant in the winter and above-ground leaves and stalks die. Note that identification is easiest when the plant is mature with flowering stalks. However, since the plant only flowers after one or more years, it is important to be able to identify the leaves of young plants.

Stem: Flowering stalk 2.5 m tall, up to 10 cm in diameter, usually with purple blotches; often bristly.

Leaves: Dark green, up to 3 metres long and blades to 2.6 cm wide, divided into two or three deeply-lobed leaflets; coarsely toothed leaf margins and stiff underside hairs. Newly emerged leaves and immature plants will have smaller, basal leaves.

Flowers: Clusters of flowers (compound umbels) 20-50 cm in diameter with rays 50-150 cm in length from central stem; white or pinkish petals; plant flowers only after a year or more of growth.

Seeds: Blunt and rounded toward base (E-Flora 2017); with visible oil tubes that are greater than ¾ the seed length.
Giant hogweed is often confused with wild parsnip (*Pastinaca sativa* L.), Queen Anne’s lace (*Daucus carota* L.), and poison hemlock (*Conium maculatum*) which are introduced species, and palmate coltsfoot (*Petasites frigidus*), devil’s club (*Oplopanax horridus*), cow parsnip (*H. maximum*), and four Angelica species that are native to British Columbia. All are superficially similar in appearance to giant hogweed (E-Flora 2017).

Cow parsnip is the only member of the genus *Heracleum* that is native to North America. This species is an important nectar source for butterflies, bees, and other beneficial insects. The leaves and stems of cow parsnip also contain toxic sap that can cause hypersensitivity to sunlight resulting in burns, blisters, and scarring (ISCBC 2017), however giant hogweed causes a much more severe reaction than cow parsnip (Canadian Council on Invasive Species n.d.). It is easy to distinguish giant hogweed from cow parsnip when they exist in their typical forms, but it becomes difficult when plants are in the early growing stages or when defining characteristics overlap (e.g., small hogweed individuals versus large cow parsnip individuals). Rarely individual plants can share characteristics of both species, making it difficult to visually confirm identity, even for experts. In these cases, experts consult with others and investigate the history of the presence of both species at the site or surrounding area.

<table>
<thead>
<tr>
<th>GIANT HOGWEED</th>
<th>COW PARSNIP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stem</strong></td>
<td></td>
</tr>
<tr>
<td>2 – 5 m tall, rarely taller; up to 10 cm diameter; usually many purple spots, stiff bristles</td>
<td>1-3 m tall, 4.5 to 5 cm diameter, few purple areas, deep ridges, fuzzy hair</td>
</tr>
<tr>
<td><strong>Leaves</strong></td>
<td></td>
</tr>
<tr>
<td>Up to 1.5 m wide, 3m long, compound, lobed (single leaves with lobes that look like a hand and fingers), deeply incised</td>
<td>0.6 – 0.75 m wide, 10-40 cm long; compound, palmate-shaped (looks similar to a maple leaf, or an open palm with fingers outstretched), divided into 3 segments</td>
</tr>
<tr>
<td><strong>Flower</strong></td>
<td></td>
</tr>
<tr>
<td>Umbel-shaped, up to 50 cm across</td>
<td>Umbel-shaped up to 10-20 cm across, rarely larger</td>
</tr>
<tr>
<td><strong>Seeds</strong></td>
<td></td>
</tr>
<tr>
<td>Blunt and rounded toward base; oil tubes &gt;3/4 of seed length</td>
<td>Narrowed toward the base; oil tubes 1/2-3/4 of seed length</td>
</tr>
</tbody>
</table>

Leaves of the mature plant and ripe seeds are reliable features to distinguish giant hogweed from cow parsnip.

Since there are many look-alike plants, it is always advisable to verify identity with an expert, especially prior to any management activity. Due to increased awareness of giant hogweed in the region, there have been many false reports.
Tracking

The provincial government maintains the Invasive Alien Plant Program (IAPP) application (BC Ministry of Forests, Lands and Natural Resource Operations and Rural Development 2017), which houses information pertaining to invasive plant surveys, treatments, and monitoring. Many agencies, including local governments, have their own internal invasive species inventory and mapping protocols that are used by staff, contractors and, in some cases, the public. For example, the City of North Vancouver has its own system called AlienMap. Agencies in British Columbia that do not enter data into IAPP are encouraged to check it regularly because it contains public reports and data from other agencies, and it is important to consider as much data as possible when making management decisions. The “Map Display” module of IAPP is publicly accessible.

When conducting a giant hogweed inventory, the following information should be recorded as it will later inform treatment plans:

- Size and density of infestation;
- Location in relation to the high water mark of watercourses;
- Location in relation to other water sources, such as wells; and
- Public access (whether there is risk of public contact with the plant).

Reporting

Due to the health hazard posed by giant hogweed found in public spaces, it is advisable to report known or suspected giant hogweed infestations as soon as possible. Please report giant hogweed occurrences within Metro Vancouver to:

- The provincial Report-A-Weed program (via online form or smart phone app reportweedbc.ca).
- The Invasive Species Council of Metro Vancouver: 1-604-880-8358 or iscmv.ca.
- The municipality where the giant hogweed was found.
- The landowner directly – Most land managers are keen to be made aware of giant hogweed sites immediately so control can be arranged as soon as possible. If the landowner is unknown, the Invasive Species Council of Metro Vancouver can provide support to identify the appropriate authority.

Reports submitted through these channels are reviewed by invasive species specialists who coordinate follow-up activities when necessary with the appropriate authorities. However, some people may be hesitant to report giant hogweed infestations as their presence may affect property values.
Prevention and Control Strategies

Effective invasive plant management programs may include a variety of control techniques ranging from prevention, chemical, manual, mechanical, biological and/or cultural methods. Each method is described below in order of effectiveness.

HANDLING GIANT HOGWEED SAFELY

Clear, toxic sap is found in all parts of giant hogweed. Contact with sap can occur by brushing against the plant, handling plant material, or even by touching tools or mowing equipment that was used for giant hogweed control (Hallworth 2009). To ensure the necessary precautions are taken, it is best to hire a professional to handle giant hogweed infestations.

Personal protective equipment (PPE) is critical to ensure that sap from plants does not contact workers’ skin (see WorkSafeBC video).

WHEN HANDLING GIANT HOGWEED PLANTS, THE FOLLOWING PPE SHOULD BE WORN:

- Goggles or face shield;
- Sunblock;
- Long pants and long-sleeved shirt under waterproof coveralls or rain gear (pants and jacket with hood);
- Heavy rubber gloves or other waterproof gloves that can be discarded after use (for example, dishwashing gloves);
- Rubber boots; and
- Heavy, waterproof tape can be used to cover seams and gaps between clothing and gear.

BE SURE TO HAVE THE FOLLOWING ON HAND:

- Access to water or portable water source for cleaning gloves and clothes;
- Hand soap;
- A portable eyewash station; and
- A first aid kit.

USE THE FOLLOWING PROTOCOL WHEN HANDLING GIANT HOGWEED:

1. As a preventative measure, apply sunblock to skin,
paying special attention to places that have the potential to be exposed to sap like face, neck, hands and wrists.

2. Put on goggles, waterproof coveralls, rubber gloves and boots and ensure no skin areas will be exposed.

3. Cover seams between clothing and gear by tucking items into one another or using heavy, waterproof tape to seal any gaps.

4. Use one of the recommended control methods (e.g., mechanical or chemical control) described below.

5. After control has been completed, wash gloved hands with soap and water.

6. Rinse gloves, coveralls and boots thoroughly with water, paying special attention to gloves and sleeves.

7. Carefully remove gloves, coveralls and boots by turning protective clothing inside out while ensuring any portions of clothing that were exposed to hogweed sap will not accidentally come into contact with skin.

8. Wash hands, equipment, faucet taps and door handles with soap and water.

9. Remove and wash goggles.

10. Dispose of coveralls and gloves after use. Any non-disposable clothing should be washed carefully with soap and water.

11. If skin accidentally comes in contact with sap, wash thoroughly with soap and water and consult a physician. Avoid sunlight and cover the exposed area immediately. Using sunscreen on the affected skin may minimize or help prevent further reactions from occurring when outside. Sunscreen may also be helpful for several months after contact with the plant sap, due to potential continued sun sensitivity.

12. If sap gets into the eyes, flush with copious amounts of water and use sunglasses, then consult a physician.

(WorkSafe BC 2006).

Adapted from Langley Environmental Partners Society (2017) and New York State Department of Environmental Conservation (2017).

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**STRATEGY COLOUR LEGEND**

| GREEN: RECOMMENDED |
| ORANGE: CAUTION |
| RED: NOT RECOMMENDED OR NOT AVAILABLE |

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**PREVENTION: IMPERATIVE**

Prevention is the most economical and effective way to reduce the spread of giant hogweed over the long term. Be sure to inspect and remove seeds from personal gear, clothing, pets, vehicles, and equipment and ensure soil, gravel, and other fill materials are not contaminated with giant hogweed seeds before leaving an infested area.

Do not purchase, trade, or grow giant hogweed. Instead, grow regional native plants that are naturally adapted to the local environment and are non-invasive. Consult the Invasive Species Council of BC’s ‘Grow Me Instead’ Program or Metro Vancouver’s Grow Green website for non-invasive, drought-tolerant plants and garden design ideas. Ensure all materials (e.g., topsoil, gravel, mulch, compost) are weed-free. Healthy green spaces are more resistant to invasion by invasive plants, so it is also important to maintain or establish healthy plant communities.

**MANUAL: RECOMMENDED**

Manual control, (eg. pulling and digging) can prevent seed production and release of seeds into the soil. To prevent seed production, it is most effective to cut blooms soon after they appear, in May and June. With proper
PPE, hand-pulling or digging can be effective on young seedlings, single plants or small infestations of a few individuals (Watson 2017). Safety risks for workers increases when dealing with large plants and large infestations. Manual control may be impractical in these circumstances. Manual removal is the recommended method when plants need to be removed from a site immediately due to the health concern.

The following methods can be used to manually control giant hogweed:

- **Taproot Cutting - for small groups of plants (<100):**

  Giant hogweed has a large, deep taproot like a carrot that stores energy for annual growth and/or flowering and provides a buffer against damage to the above-ground parts of the plant from mowing or browsing. The taproot can be up to 45 cm long and 12 cm thick. Giant hogweed can re-sprout new leaves after taproot cutting so follow-up is essential (Hallworth 2009).

  Using loppers, cut back the upper portions of larger plants for easier access to cut the stem and taproot. During flowering season, be sure to cut and bag flower heads first for secure disposal. Sever the root about 5 to 15 cm below the soil surface (or further if possible) using a sharp, long-handled narrow shovel or spade (Watson 2017).

  Cut the taproots in early spring (April 1 to May 15) and revisit the site in early-summer (June 15 to July 15) to target any plants that were missed or have re-sprouted. Make sure to target all plants. Above-ground plant parts can be left on-site to decompose, unless there is risk that people will come in contact with them. In this case cut the stem into pieces that will fit into sealed plastic bags (see Disposal).

  - **Flower removal**

    Removal of the flower head (umbel) can be as effective as cutting the whole mature plant in stopping seed spread. However, the timing of cutting is crucial to prevent additional seeds from being produced. Cutting too early may result in the plant regenerating and producing new flowers with viable seeds. It is best to remove the umbels while in flower (usually May to August in Metro Vancouver although seeds can set as early as July) but before they go to seed. If plants are cut in the flowering stage, the site should be checked again a few weeks later to ensure no new flower heads have formed.

    Removal of flower heads only is a short-term, stop-gap method for preventing further seed dispersal (that is, when it is too late in the season to employ other techniques). It does not kill the plant.

    A long reach pruner or any sharp cutting tool which is long enough to avoid touching the plant can be used to cut and hold the flower heads. With a cutting tool, workers can pull the blade towards themselves to cut the stem. A second person can gently hold the stem and direct the fallen umbel into a sturdy plastic bag. If cut later in the season, avoid scattering seeds on the ground; if seeds are mature and shedding, contain them in a plastic bag or on a tarp, or within as small an area as possible. If seeds have scattered around the plant, scrape/rake the soil surface and collect and dispose of as many of the seeds as possible.

**CHEMICAL: RECOMMENDED**

When alternative methods to prevent or control invasive plants are unsuccessful, professionals often turn to herbicides. With the exception of substances listed on Schedule 2 of the Integrated Pest Management Regulation, the use of herbicides is highly regulated in British Columbia. Site characteristics must be considered with each herbicide prescribed, based on site goals and objectives and in accordance with legal requirements. This summary of BC’s Integrated Pest Management Act provides an overview of the provincial legislation.
PESTICIDE LICENCE AND CERTIFICATION

A valid pesticide licence is required to:

• offer a service to apply most pesticides;
• apply most pesticides on public land including local government lands; and
• apply pesticides to landscaped areas on private land, including outside office buildings and other facilities.

Pesticide applicator certificates can be obtained under the category ‘Industrial Vegetation Management’ to manage weeds on industrial land, roads, power lines, railways, and pipeline rights-of-way for control of noxious weeds on private or public land. Assistant applicator training is also available and the online course and exam are free.

Pesticides (e.g., herbicides, insecticides, fungicides) are regulated by the federal and provincial government, and municipal governments often have pesticide bylaws.

• Health Canada evaluates and approves chemical pest control products as per the Pest Control Products Act.
• The BC Integrated Pest Management Act sets out the requirements for the use and sale of pesticides in British Columbia. This Act is administered by the Ministry of Environment and Climate Change Strategy.
• Several municipalities have adopted bylaws that prohibit the use of certain pesticides.

Everyone who uses pesticides must be familiar with all relevant laws.

Although an annual fee and annual reporting are required, it is best practice for personnel supervising or monitoring pesticide contracts to also maintain a pesticide applicator licence so they are familiar with certification requirements.

For more information on how to obtain a licence and the requirements when working under the provincial Integrated Pest Management Act and Regulation, please review the Noxious Weed & Vegetation Management section on this webpage: gov.bc.ca/PestManagement.
ONLY companies or practitioners with a valid Pesticide Licence and staff who are certified applicators (or working under a certified applicator) may apply herbicide on invasive plants located on public lands in British Columbia. Applicators must be either the land manager/owner or have permission from the land manager/owner prior to herbicide application.

On private property the owner may obtain a Residential Applicators Certificate (for Domestic class products only) or use a qualified company. Residents do not require a Residential Applicator Certificate for certain uses of domestic class glyphosate including treatment of plants that are poisonous for people to touch, invasive plants and noxious weeds listed in legislation, and weeds growing through cracks in hard surfaces such as asphalt or concrete. Refer to the ‘Pesticides & Pest Management’ and ‘Home Pesticide Use’ documents listed in the Additional Resources Section for more information.

Questions? Contact the BC Integrated Pest Management Program: Telephone: (250) 387-9537 Email: bc.ipm@gov.bc.ca

HERBICIDE LABELS

Individual herbicide labels must always be reviewed thoroughly prior to use to ensure precautions, application rates, and all use directions, specific site and application directions are strictly followed. Under the federal Pest Control Products Act and the BC Integrated Pest Management Act and Regulation, persons are legally required to use pesticides (including herbicides) only for the use described on the label and in accordance with the instructions on that label. Failure to follow label directions could cause damage to the environment, poor control results, or danger to health. Contravention of laws and regulations may lead to cancellation or suspension of a licence or certification, requirement to obtain a qualified monitor to assess work, additional reporting requirements, a stop work order, or prohibition from acquiring authorization in the future. A conviction of an offence under legislation may also carry a fine or imprisonment.

Herbicide labels include information on both the front and back. The front typically includes trade or product name, formulation, class, purpose, registration number, and precautionary symbols. Instructions on how to use the pesticide and what to do in order to protect the health and safety of both the applicator and public are provided on the back (BC Ministry of Environment 2011).

Labels are also available from the Pest Management Regulatory Agency’s [online pesticide label search](#) or mobile application as a separate document. These label documents may include booklets or material safety data sheets (MSDS) that provide additional information about a pesticide product. Restrictions on site conditions, soil types, and proximity to water may be listed. If the herbicide label is more restrictive than provincial legislation, the label must be followed.
The following herbicides can be used on giant hogweed in British Columbia

* Non-residual herbicides are active only on growing plant tissue have little or no persistence in the soil whereas residual herbicides persist in the soil, remaining effective over an extended period of time.

** Avoid application of this product in areas where the roots of desirable trees and/or shrubs may extend unless injury or loss can be tolerated. Roots of desirable trees or vegetation are affected by local conditions and can extend well beyond the tree canopy.

+ The mention of a specific product or brand name of pesticide in this document is not, and should not be construed as, an endorsement or recommendation for the use of that product.

++ Active growing periods vary from year to year depending on weather and other factors. There may be more than one active growing period for a plant in a year.

+++ Herbicides that control all vegetation are non-selective, while those that control certain types of vegetation (for example, only grasses or only broadleaf plants) are termed selective.

NOTE: Giant hogweed is not specifically listed on these herbicide labels. However, it falls under the general application provision for broadleaved plants.

### HERBICIDE OPTIONS

<table>
<thead>
<tr>
<th>ACTIVE INGREDIENT (EXAMPLE BRAND NAMES)+</th>
<th>APPLICATION</th>
<th>PERSISTENCE</th>
<th>GROWTH STAGE++</th>
<th>TYPE+++</th>
</tr>
</thead>
</table>
| Glyphosate (many products)             | • foliar application  
• stem injection (only Roundup WeatherMAX® With Transorb 2 Technology) | non-residual* | actively growing | non-selective |
| Chlorsulfuron + aminocyclopyrachlor (for example Truvist™)* | foliar application | residual | 4 leaf stage | selective, no affect to grasses |
| Metsulfuron methyl + aminocyclopyrachlor (for example Navius™)** | foliar application | residual | 4 leaf stage | selective, no affect to grasses |
| Aminopyralid (for example Milestone™) | foliar application | residual | new germinants only | selective, no affect to grasses |
APPLYING HERBICIDE IN RIPARIAN AREAS

Provincial legislation prohibits the use of herbicides within 10 metres of natural water courses and 30 metres of domestic or agricultural water sources on public lands. On private lands, only herbicide labels need to be followed (which means for glyphosate products and Milestone™, treatment can happen up to the water’s edge). On public lands, glyphosate is the only active ingredient that can be applied within the 10 metre Pesticide-Free Zone (PFZ)\(^3\) in British Columbia in accordance with the BC *Integrated Pest Management Act* and Regulation and all public land Pesticide Management Plans (PMPs). Glyphosate can only be applied up to 1 metre away from the high water mark (HWM)\(^4\). See the manual/mechanical section above for alternative control techniques that may be used with extreme caution at these sites. The 30 metre no-treatment zone around a water supply intake or well used for domestic or agricultural purposes may be reduced if the licensee or PMP holder is “reasonably satisfied” that a smaller no-treatment zone is sufficient to ensure that pesticide from the use will not enter the intake or well.

When managing giant hogweed with herbicide in riparian areas:

- Observe and mark all PFZs while on site.
- The HWM should be determined by careful evaluation by the applicator.
- Distances in PFZs should be measured as horizontal distance.
- Herbicides restricted in a PFZ must not enter these zones by leaching (lateral mobility) through soil or by drift of spray mist or droplets.
- Treatments should be conducted when water levels are low (e.g. summer months) to reduce risk.
- Note that efficacy may be dependent on site conditions, including moisture in the soil.
FOLIAR APPLICATION METHODS

The preferred application methods to minimize non-target damage and applicator exposure are as follows:

- **Spray-on application** uses a backpack or handheld sprayer to completely cover the actively growing plant parts with herbicide, including the underside of the leaves (plants should be 20 to 50 cm in height). Spraying the undersides of the leaves maximizes the herbicide contact and uptake by the stomata. To access tall foliage and minimize the risk of applicator exposure to herbicide, long wands and wand extensions are recommended.

- **Wipe-on application:** This method is only allowed if using products containing glyphosate. Apply herbicide directly onto leaf surfaces using a simple hand held wipe-on applicator (for example, Red Weeder™). The wipe-on method is only recommended when spraying is not an option. Caution must be taken when using this technique due to the extended time workers would be in close proximity to the plants during application. Wipe-on application is time-consuming and can be messy due to herbicide drips.

Shrouding or shielding the spray nozzle(s) on the spray wand can minimize herbicide drift into pesticide free zones or other sensitive areas during foliar applications. Tarps or garbage bags can be suspended, wrapped or draped as a buffer to adjacent sensitive areas including desirable vegetation, waterbodies or structures.

STEM INJECTION

This technique involves injection of herbicide into single stems using a hand-held tool that delivers a specified amount of product into the hollow stems. Currently in Canada, Roundup WeatherMAX® With Transorb 2 Technology Liquid Herbicide™ (pest control products number 27487) is the only product with stem injection listed the label and therefore the only product that can legally be applied using this method. While it can be used on any sized infestation, this method is useful for patches with few hogweed stems or when stems are growing interspersed between desirable vegetation. This method is more time-consuming and expensive as each stem must be injected and marked (some injection tools come with attachments for marking pens).

TREATMENT TIMING

Herbicide should be applied to actively growing plants. For first treatments in the spring, it is recommended to wait until there is sufficient foliage to ensure adequate surface area for absorption (starting when the hogweed is 20 to 50 cm in height). Early season treatments avoid the need for spraying overhead, reduce the risk of breaking canes, prevent flower/seed set from occurring, and use less herbicide.

In order to minimize impact to insects, if possible, treatment should be avoided during the flowering season. If Himalayan blackberry is also present at the treatment site consider treating before the berries form or cutting any blackberry canes with fruit before treatment to eliminate concerns of berry pickers.

MAINTENANCE

Post-chemical treatment monitoring is required for licencees and PMP holders under the Integrated Pest
Management Act to ensure that efforts are successful and to allow for adjustments to the management approach as necessary.

Monitor the site annually in mid to late spring post-treatment. Identify and remove any new seedlings, including the roots. After no new plants are found, the provincial government recommends monitoring the site after 1, 2, 4, and 6 years (Province of BC 2017).

MECHANICAL: NOT RECOMMENDED

Mechanical control using power equipment (e.g., brush saws or weed wackers) is not recommended because removing giant hogweed in this manner can cause sap to splash out of plants onto the face or other exposed skin. Power equipment can also spread seeds and become contaminated with sap.

CULTURAL: NOT RECOMMENDED

Giant hogweed is not effectively controlled by light grazing, but intensive grazing may provide control. Cattle and sheep find it palatable and can be trained to browse it. Grazing is best done by hairy and dark-pigmented animals to reduce inflammation of any mucus-secreting membranes from the furanocoumarins found in the sap. Grazing animals prefer young and fresh giant hogweed plants, and the most efficient control is obtained by beginning the grazing early in the growing season when the plants are small (Nielson, et al. 2005). Pigs can also be highly effective, rooting out and eating all underground plant vegetation (Tiley, Felicite and Wade 1996).

Within Metro Vancouver, grazing to control giant hogweed is likely only feasible in agricultural or field habitats. Grazing opportunities are limited in urban areas due to municipal bylaws regulating animals, the high probability of interface with the public, and the damage animals would cause to riparian areas and other sensitive sites with multiple land uses. Due to these constraints, cultural control is not recommended as a practical management option in the Metro Vancouver region.

BIOLOGICAL: NOT AVAILABLE

There are currently no biological control agents available in British Columbia for giant hogweed. It is likely that biological control is not a high priority for giant hogweed as it is usually desirable to remove/treat it immediately because of the health risks to the public. Due to these constraints, biological control is not recommended as a practical management option in the Metro Vancouver region.
Disposal

ON SITE DISPOSAL

Cut or chemically-treated stems and leaves can be left on-site to decompose, unless there is any risk that people will encounter them (Hallworth 2009). Viable seeds and roots should not be left onsite due to the risk of spread or re-growth. Do not compost giant hogweed at home or at municipal works yards due to the risk of exposure to the toxic sap.

OFF SITE DISPOSAL

Giant hogweed umbels, stems and other plant parts must be double-bagged in heavy garbage bags for disposal. Bags should be sealed tightly.

In the Metro Vancouver region, the following facilities accept giant hogweed plants and/or soil infested with giant hogweed seeds, provided they have sufficient capacity:

- **Vancouver Landfill**, 5400 72nd St, Delta, BC. Accepts double-bagged giant hogweed and soil for deep burial only (additional charge). A [Waste Assessment Form](#) must be completed.

- **Metro Vancouver’s Waste-to-Energy facility**, 5150 Riverbend Drive, Burnaby, BC. This facility does not accept soil. Accepts loads of double-bagged giant hogweed if customers have:
  - A self-tipping truck;
  - A [commercial account](#); and
  - Pre-approval from the Manager of Solid Waste Services (contact [weighscalesystem@metrovancouver.org](mailto:weighscalesystem@metrovancouver.org) or 604-451-6185).

CLEANING AND DISINFECTION

Before leaving a site, remove all visible plant parts and soil from vehicles, equipment and gear, and if possible, rinse these items. When back at a works yard or wash station, vehicles should be cleaned and disinfected using the following steps:

- Wash with 180 °F water at 6 gpm, 2000 psi*, with a contact time of ≥ 10 seconds on all surfaces to remove dirt and organic matter such as vegetation or seeds. Pay special attention to undercarriages, chassis, wheel-wells, radiators, grills, tracks, buckets, chip-boxes, blades, and flail-mowing chains;

- Use compressed air to remove vegetation from grills and radiators;

- Sweep/vacuum interior of vehicles paying special attention to floor mats, pedals, and seats;

- Steam clean poor access areas (for example, inside trailer tubes) – 200 psi @ 300 °F; and

- Fully rinse detergent residue from equipment prior to leaving facility.

* Appropriate self-serve and mobile hot power-wash companies in the Metro Vancouver region include: Mary Hill Truck Wash, Omega Power Washing, Eco Klean Truck Wash, RG Truck Wash, Ravens Mobile Pressure Washing, Hydrotech Powerwashing, Platinum Pressure Washing Inc., and Alblaster Pressure Washing. Wash stations should be monitored regularly for hogweed growth.

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Follow-Up Monitoring

Whatever control method is used, follow-up monitoring and maintenance treatments are important components of an integrated management plan or approach.

• After umbel removal, new umbels and flowers will often form on lower branches. If umbels were removed during the flowering stage, check the site again in a few weeks to ensure no new flowers have formed. If so, cut and remove.

• If taproots were cut, monitor the site annually in mid to late spring to ensure that new seedlings are identified and removed, including the roots.

• Sites where herbicide application was used must be re-visited to assess efficacy of treatment.
  • After spring glyphosate treatments, a follow-up visit should occur in late spring to early summer, depending on growing conditions. As there is no residual control of new germinants with glyphosate, seeds can germinate at any time after applications and are free to grow. Re-treatment of new plants on the site should occur when the plants are actively growing and there is sufficient foliage for adequate herbicide uptake. Plants should be 20 to 50 cm in height to ensure enough herbicide will be absorbed.
  • For the residual herbicides, monitoring should occur two or more weeks after treatment to evaluate efficacy. If re-growth has occurred, it is best to consult the label before re-treatment to confirm the maximum number of applications per season. In some cases, another product could be considered for use in a second application.

Restoration

Restoration may not be necessary for small giant hogweed infestations. For large infestations, restoration is often necessary to suppress colonization by other invasive plant species. Although it is desirable to revegetate with native or non-invasive plant species as soon as possible, restoration activities must be carefully timed. If planting occurs before the giant hogweed is completely eradicated, it will be much harder to manage re-growth without injuring the restored vegetation and putting workers at risk. Planting broadleaved herbaceous or woody plants after application of a residual herbicide should be delayed until herbicide activity is deactivated in the soils. This will depend on soil type, environmental conditions, and herbicide type. Replanting grass species should be delayed for 12 months after application of a residual herbicide (Ralph 2017). If replanting with broadleaved species is planned soon after herbicide treatment, then a non-residual herbicide (for example, glyphosate) should be used. For glyphosate products, delay preparation of the soils for replanting by at least 7-15 days to ensure complete translocation of herbicide to the root tips (Ralph 2017).

Revegetation of the site to a domestic or non-native, non-invasive plant species composition may be considered in some circumstances. Species must be prescribed based on the ecology of the site and should be determined by a qualified environmental professional.

Local biologists, environmental professionals, agronomists, agrologists, native and domestic forage specialists, seed companies and plant nurseries are all good sources for regional native species and regionally-adapted domestic species recommendations, based on site usage. Several science-based resources are available to guide restoration efforts, such as the South Coast Conservation Program’s Diversity by Design restoration planning toolkit.
References


ISCBC. 2017. “Giant Hogweed Factsheet.”


Acknowledgments

The project team would like to thank the following group for contributions related to the development and review of this document:

- Metro Vancouver’s Regional Planning Advisory Committee (RPAC) – Invasive Species Subcommittee
- Nick Page, Raincoast Applied Ecology

Additional Resources

For more information please refer to the following resources.

- Pesticides and Pest Management. Province of British Columbia https://www2.gov.bc.ca/gov/content/environment/pesticides-pest-management
BEST MANAGEMENT PRACTICES FOR
European Fire Ants
in the Metro Vancouver Region

Climate Action Committee
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May 2018
# Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>4</td>
</tr>
<tr>
<td>Regulatory Status</td>
<td>5</td>
</tr>
<tr>
<td>Impacts</td>
<td>5</td>
</tr>
<tr>
<td>Nests</td>
<td>5</td>
</tr>
<tr>
<td>Reproduction and Spread</td>
<td>5</td>
</tr>
<tr>
<td>Habitat and Distribution</td>
<td>6</td>
</tr>
<tr>
<td>Identification</td>
<td>7</td>
</tr>
<tr>
<td>Physical Characteristics</td>
<td>7</td>
</tr>
<tr>
<td>Confirming Identity</td>
<td>7</td>
</tr>
<tr>
<td>Similar Species</td>
<td>8</td>
</tr>
<tr>
<td>Tracking</td>
<td>8</td>
</tr>
<tr>
<td>Reporting</td>
<td>9</td>
</tr>
<tr>
<td>Prevention and Control Strategies</td>
<td>10</td>
</tr>
<tr>
<td>Prevention: Imperative</td>
<td>11</td>
</tr>
<tr>
<td>Chemical: Recommended</td>
<td>12</td>
</tr>
<tr>
<td>Cultural: Partially Recommended</td>
<td>15</td>
</tr>
<tr>
<td>Manual/Mechanical: Not Recommended</td>
<td>15</td>
</tr>
<tr>
<td>Biological: Not Available</td>
<td>16</td>
</tr>
<tr>
<td>Disposal</td>
<td>16</td>
</tr>
<tr>
<td>Follow-up Monitoring</td>
<td>17</td>
</tr>
<tr>
<td>Restoration</td>
<td>17</td>
</tr>
<tr>
<td>References</td>
<td>19</td>
</tr>
<tr>
<td>Additional Resources</td>
<td>20</td>
</tr>
<tr>
<td>Acknowledgments</td>
<td>20</td>
</tr>
</tbody>
</table>
Introduction

The impacts of invasive species on ecological, human and economic health are of concern in the Metro Vancouver region. Successful control of invasive species requires concerted and targeted efforts by many players. This document – “Best Management Practices for European Fire Ants in the Metro Vancouver Region” – is one of a series of species-specific guides developed for use by practitioners (e.g., local government staff, crews, project managers, contractors, consultants, developers, stewardship groups and others who have a role in invasive species management) in the region. Together, these best practices provide a compendium of guidance that has been tested locally by researchers and operational experts.

The European fire ant was first recorded in British Columbia in 2010. It has impacted many communities in Metro Vancouver, and several other areas in the province. Its distinctive swarming and stinging behaviour has given it high profile as one of the region’s most alarming invasive species.

Since its discovery in British Columbia, best practices for identifying and managing this species (and other invasive ants) have advanced rapidly. Academic institutions, government and non-government organizations continue to study this species in British Columbia, testing a variety of control methods. As researchers and practitioners learn more about the biology and control of European fire ants in British Columbia, it is anticipated that the recommended best management practices will change over time and this document will be updated. Please check metrovancouver.org regularly to obtain the most recent version of these best management practices.
REGULATORY STATUS

The European fire ant is not currently regulated in British Columbia. Hence, land managers are not required to control European fire ants at this time.

IMPACTS

The presence of European fire ants in gardens, yards, parks, golf courses, turf areas and other green spaces renders these areas unusable. European fire ants aggressively defend their territory by swarming and delivering painful, repeated stings to any sort of threat, such as people, pets and wildlife that come in close proximity to their nests. Stings leave venom under the skin, which may swell, become red and painful for 30 to 120 minutes, followed by itchiness that can last for a week (WorkSafe BC 2014). On rare occasions, these stings can cause anaphylactic shock (Saltman 2016).

European fire ants have a number of impacts on native ecosystems. These aggressive ants are able to displace native ant species, which are beneficial for seed dispersal, pollination, and keeping predator-prey relationships in balance (Naumann and Higgins 2015). Although little research has been conducted locally, European fire ant infestations have been found to reduce chick survival in several bird populations elsewhere in North America (Robinson, et al. 2013).

The presence of European fire ants also has economic impacts for governments, businesses, non-profit groups and individuals in Metro Vancouver and across British Columbia. Preliminary damage estimates for British Columbia in 2012 were approximately $100,000,000/year if this species were to spread throughout its potential habitat range. This estimate includes property damage caused by European fire ants to households, schools, municipalities, golf courses, public parks and green spaces (Sayre 2017). In 2016, agencies represented on Metro Vancouver’s Regional Planning Advisory Committee – Invasive Species Subcommittee spent approximately $26,000 on European fire ant control efforts. This figure does not include control costs for private landowners across the region or costs associated with education and awareness activities. This species’ potential to establish in large areas of BC (see Habitat section below) suggests that more widespread impacts are possible.

NESTS

European fire ant nests are typically found in places with high humidity. Favourable nesting areas include soil along roots of trees or shrubs, under rocks, logs or other human or natural debris, and in decaying logs (E. Groden, A. Drummond, et al. 2016). Nests can be very difficult to locate as construction does not result in obvious mounds or disturbances of the soil.

The typical European fire ant nest consists of a series of popcorn-sized chambers along a vertical shaft, barely 15 cm wide and typically no more than 20 cm below ground. In very sandy soils they may reach down to almost a metre. Nests may be located at the surface, just beneath a covering of moss, or within the above-ground crown of clumping perennial grasses and ferns, as well as in rock crevices with little to no soil (Sayre 2017).

An ant colony, called a formicary, is the basic unit around which ants organize their lifecycle. European fire ant colonies are ‘polygynous’ (i.e., many queens) and ‘polydomous’ (i.e., many nests per individual colony), allowing for high densities of the ants in a given area. In North America, colonies have a density of approximately 4 nests per square metre (Higgins 2015). Lateral tunnels connect adjacent colonies but the extent of underground interconnectedness is unknown and is an on-going research topic in British Columbia (Higgins 2017).

REPRODUCTION AND SPREAD

European fire ants predominantly spread by budding - as new colonies grow, some queens will leave the parent colony, accompanied by a group of workers, and establish

Mature colonies can contain a few thousand workers with a new reproductive total (queens or males) of a few to several hundred individuals per year (Higgins 2015). A single colony may have 15-20 queens present (Higgins 2015).

European fire ants are often spread through human activities. They nest in garden and landscaping materials, including potted plants, soil, compost, tree balls and mulch. Entire nests can be inadvertently transplanted along with these materials (Higgins 2015). Some species of fire ants have also been known to cross water bodies by linking together as a colony to form a waterproof raft (Mlot, Tovey and Hu 2011).

**HABITAT AND DISTRIBUTION**

European fire ants prefer moist habitats with a mean annual temperature greater than 6° Celsius. Precipitation in affected areas usually exceeds 1000 mm/year (E. Groden, F. Drummond, et al. 2005). Under these conditions, European fire ants have the potential to establish along the coast from Vancouver to Prince Rupert, as far inland as Hope, and through all of Vancouver Island, the Gulf Islands and Haida Gwaii. In the interior, conditions are appropriate for establishment in a small area in Nelson and from Prince Rupert inland to Terrace (Higgins 2015). Moist riparian areas may be at risk throughout British Columbia.

The European fire ant is native to the Palearctic regions of Europe and Asia and from Ireland to western Siberia (E. Groden, F. Drummond, et al. 2005). In Canada, it has established in Quebec, Ontario, New Brunswick, Nova Scotia, Prince Edward Island and British Columbia (Hicks 2012).

This species of ant was first recorded in British Columbia in 2010 and has been detected in many communities in Metro Vancouver and on Vancouver Island: Burnaby, Chilliwack, Coquitlam, Courtenay, Delta, District of North Vancouver, Maple Ridge, Richmond, Surrey, Pitt Meadows, Vancouver, West Vancouver, Courtenay, Oak Bay, and Victoria. There is one known population in British Columbia’s interior in Naramata (Higgins 2015).
Identification

PHYSICAL CHARACTERISTICS

European fire ants are typically reddish-brown in colour, however their colour varies between colonies. The workers are about 4mm to 5mm in length. Queens can be distinguished from the workers mainly by their size, growing to 9mm in length. The waist has 2 segments, with the last segment of the alitrunk (the thorax) sporting two spines that point backwards. The workers bodies are covered with fine hairs and they have antennae with 12 segments (Arevalo and Groden 2016). It is important to note that there are many species of ants in British Columbia, including other species that are red or that sting. While the swarming and stinging behavior can be characteristic of European fire ants, it is important to confirm the ant’s identity before considering treatment options.

CONFIRMING IDENTITY

Proper identification of ants can be challenging. Several agencies and specialists within British Columbia can assist with ant identification (Inter-Ministry Invasive Species Working Group 2015). Below are the current methods and procedures to collect and submit ant samples for identification (Higgins 2015):

1. Collect a sample on a cool morning, when the ants are less likely to sting. This can be done by:
   a. Laying out apple slices in areas where nests are suspected and checking on the slices within an hour. If the apple is covered in ants, quickly pick it up and place it and the ants into a container and freeze overnight.
   b. Scooping a portion of the nest into a bucket of soapy water and letting it sit for a few minutes until the ants have died.
2. Gently remove 10-20 dead ants and place them in a waterproof container and add alcohol (rubbing or clear consumable alcohol) to preserve the ants.

3. Place the container in a sealed bag and ship.

4. Send samples to one of the following locations for identification. Please include your name and the date and location where the samples were collected.

   **Preferred location:** Plant Health Laboratory, Ministry of Agriculture. Download and complete the necessary form at [http://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/animals-and-crops/plant-health/plant-health-laboratory](http://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/animals-and-crops/plant-health/plant-health-laboratory). Please note that any positive samples will NOT be reported to the Canadian Food Inspection Agency (CFIA) as this species is not a plant pest and is therefore not regulated under the federal Plant Protection Act. Shipping instructions can be found on the back of the form.

   **Alternate location 1:** Dr. Rob Higgins, Department of Biological Sciences, Thompson Rivers University, 805 TRU Way, Kamloops, British Columbia, V2C 0C8.

   **Alternate location 2:** Natural History Section, Entomology Dept, Royal British Columbia Museum, Attn: Claudia Copley, 675 Belleville St, Victoria, British Columbia, V8X 9W2.

The **British Columbia Inter-Ministry Invasive Species Working Group** periodically updates identification procedures based on current research.

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**SIMILAR SPECIES**

A few morphological differences can help to differentiate the European fire ant from the other ants within the same genus. When viewed from above, the frontal lobes of the European fire ant look thin and lamellar (with thin layers of overlapping tissue), laterally developed and do not cover the antennal base. One characteristic that differentiates the genus *Myrmica* from some other ants is the propodeum (the first abdominal segment fused anteriorly to the thorax) has two spines pointing backwards (Arevalo and Groden 2016).

Some ant species found in the coastal region of British Columbia that may be confused with the European fire ant include (Higgins 2015):

- Impressive fire ant (*Myrmica specioides*)
- Rough fire ant (*Myrmica scabrinodis*)
- Manica invidia (no common name)
- Thatching ant (*Formica oreas*)
- Tropical stinging ant (*Hypoponera puntatissima*)

DNA analysis is currently helping experts to distinguish these species from the European fire ant. Ongoing research will help determine whether the management practices in this document are valid for the other invasive ants in the region.

**Tracking**

The **British Columbia Inter-Ministry Invasive Species Working Group** is working in collaboration with various experts, governments and non-government organizations to determine the full extent of the European fire ant invasion in British Columbia.
Reporting

Please report all European fire ant occurrences within Metro Vancouver to:

- The provincial [Report Invasives program](#) (via online form or smart phone app).
- The Invasive Species Council of Metro Vancouver: 1-604-880-8358 or [iscmv.ca](#).
- The municipality where the European fire ant infestation was found.
- The landowner directly – If the infestation is on private property, the municipality should also be notified with as many details as possible about the location and description of the suspected infestation. Most land managers are keen to be made aware of European fire ant sites immediately so control can be arranged as soon as possible. If the landowner is unknown, the [Invasive Species Council of Metro Vancouver](#) can provide support in identifying the appropriate authority.

Reports submitted through these channels are reviewed by invasive species specialists who coordinate follow-up activities when necessary with the appropriate local authorities. However, some people may be hesitant to report European fire ant infestations as their presence may affect property values.
Prevention and Control Strategies

Effective management programs may include a variety of control techniques ranging from prevention, chemical, cultural, manual, biological, and/or mechanical methods. Each method is described below in order of effectiveness.

Coordinated management efforts across jurisdictional boundaries are critical. If infestations are shared, it is ideal for the entire infestation to be treated with the same method at the same time. Management efforts will be less successful if only a portion of the infestation is targeted.

CAUTION: When treating European fire ant infestations, ensure that the appropriate personal protective gear is worn, including closed-toed shoes or rubber boots, pants tucked in, and sealing any other gaps between items of clothing so that no skin is exposed. Gloves are also recommended. Ants that come in contact with skin can be brushed away. Crushing them will only provoke them to sting. WorkSafe BC (2014) provides additional guidelines to prevent stings and recommendations for medical treatment if stings occur.

Eradication of European fire ants in infested areas greater than 200m² is nearly impossible due to challenges around complex nest locations (e.g., under trees roots, edges of parking lots, retaining walls, wood fence posts, valued plantings, etc.) and difficulty finding all of the nests.

For large infestations, the management goal should be controlling and containing the infestation, as opposed to eradicating it (Higgins 2017). Prior to commencing any control activities, the location and extent of the infestation must be understood (see ‘Finding the Nests’ box).

The treatment methods listed below can be carried out any time of year except winter. During the cold winter months, European fire ants tend to ball up in a way that suggests they might be easily targeted and removed; however, within each nest, there are multiple balls at different depths making it difficult to locate and treat all of the balls (Higgins 2017).
**FINDING THE NESTS**

European fire ants forage within a metre or so of their nests and will cluster heavily upon apple slices when they are close to a nest. Hence, one of the best practices for finding nests is to:

1. Lay out apple slices one metre apart, in a rough grid.
2. Check the apple slices within an hour to see if there are any ants on them. If European fire ants are detected on the apple slice, then there is a nest nearby, most likely within a few metres.
3. Put on personal protective gear.
4. To localize the nest, stomp on the ground around the apple; this will disturb the ants and cause them to swarm around a nest entrance (Sayre, 2017) (Wong, 2017).
5. When mapping European fire ant infestations, the outer boundary of the infested area can be defined if ants are not observed within 10m of an apple slice (Higgins, 2017).

Assessments should be carried out when it is warm (< 20 °Celsius), dry and when ants are actively foraging (morning or afternoon).

Wire mesh or small inverted baskets (e.g., mesh fruit baskets) can be secured over the apple slices if removal of the bait by other animals (e.g., squirrels) is a concern.

**STRATEGY COLOUR LEGEND**

- **GREEN**: RECOMMENDED
- **ORANGE**: CAUTION
- **RED**: NOT RECOMMENDED OR NOT AVAILABLE

**PREVENTION: IMPERATIVE**

Prevention is the most economical and effective way to reduce the spread of European fire ants over the long term. Practitioners and the public should be made aware that transporting materials from infested areas increases the risk of spread. Potted plants, soil, mulches, and similar materials should be inspected on site and again before transplanting or use. If ants are found, the materials should not be used until they can be identified by a reliable source (see ‘Confirming Identity’ above) and/or destroyed.
CHEMICAL: RECOMMENDED

With the exception of substances listed on Schedule 2 of the Integrated Pest Management Regulation, the use of pesticides is highly regulated in British Columbia. Site characteristics must be considered with pesticide prescribed, based on site goals and objectives and in accordance with legal requirements. This summary of BC’s Integrated Pest Management Act provides an overview of the provincial legislation.

PESTICIDE LICENCE AND CERTIFICATION

A valid pesticide licence is required to:

• offer a service to apply most pesticides;
• apply most pesticides on public land including local government lands;
• apply pesticides to landscaped areas on private land, including outside office buildings and other facilities.

Pesticide applicator certificates can be obtained under the category ‘Industrial Vegetation Management’ to manage invasive species on industrial land, roads, power lines, railways, and pipeline rights-of-way on private or public land. Assistant applicator certificates are also available and the online course and exam are free.

Pesticides (e.g., insecticides, herbicides, fungicides) are regulated by the federal and provincial government, and municipal governments often have pesticide bylaws.

• Health Canada evaluates and approves chemical pest control products as per the Pest Control Products Act.
• The BC Integrated Pest Management Act sets out the requirements for the use and sale of pesticides in British Columbia. This Act is administered by the Ministry of Environment and Climate Change Strategy.
• Several municipalities have adopted bylaws which prohibit the use of certain pesticides.

Everyone who uses pesticides must be familiar with all relevant laws.

1 on up to 50 ha/year by a single organization. Organizations looking to treat over 50 hectares of land per year are also required to submit a Pest Management Plan and obtain a Pesticide Use Notice confirmation.
ONLY companies or practitioners with a valid Pesticide Licence and staff who are certified applicators (or working under a certified applicator) may apply pesticide on invasive species located on public lands in British Columbia. Applicators must be either the land manager/owner or have permission from the land manager/owner prior to pesticide application.

On private property the owner may obtain a Residential Applicator Certificate (for Domestic class products only) or use a qualified company. Refer to the ‘Pesticides & Pest Management’ and ‘Home Pesticide Use’ documents listed in the Additional Resources Section for more information.

Questions? Contact the BC Integrated Pest Management Program:
Telephone: (250) 387-9537
Email: bc.ipm@gov.bc.ca

Although an annual fee and annual reporting are required, it is best practice for personnel supervising or monitoring pesticide contracts to also maintain a pesticide applicator licence so they are familiar with certification requirements. For more information on how to obtain a licence and the requirements when working under the provincial Integrated Pest Management Act and Regulation, please review the Noxious Weed & Vegetation Management section on this webpage: www.gov.bc.ca/PestManagement.

INSECTICIDE LABELS

Individual insecticide labels must always be reviewed thoroughly prior to use to ensure precautions, application rates, and all use directions, specific site and application directions are strictly followed. Under the federal Pest Control Products Act and the BC Integrated Pest Management Regulation, persons are legally required to use pesticides (including insecticides) only for the use described on the label and in accordance with the instructions on that label. Failure to follow label directions could cause damage to the environment, poor control results, or danger to health. Contravention of laws and regulations may lead to cancellation or suspension of a licence or certification, requirement to obtain a qualified monitor to assess work, additional reporting requirements, a stop work order, or prohibition from acquiring authorization in the future. A conviction of an offence under legislation may also carry a fine or imprisonment.

Insecticide labels include information on both the front and back. The front typically includes trade or product name, formulation, class, purpose, registration number, and precautionary symbols. Instructions on how to use the pesticide and what to do in order to protect the health and safety of both the applicator and public are provided on the back (BC Ministry of Environment and Climate Change Strategy 2011).

Labels are also available from the Pest Management Regulatory Agency’s online pesticide label search or mobile application as a separate document. These label documents may include booklets or material safety data sheets (MSDS) that provide additional information about a pesticide product. Restrictions on site conditions, soil types, and proximity to water may be listed. If the insecticide label is more restrictive than provincial legislation, the label must be followed.

INSECTICIDE OPTIONS

The following insecticide can be used on European fire ants in British Columbia:

PERMETHRIN (ANT OUT© AND OTHER BRANDS)²

This is the most successful insecticide to date; however, for large infestations, the cost will be high and this method...

² The mention of a specific product or brand name of pesticide in this document is not and should not be construed as an endorsement of that product.
may not be effective. Permethrin has low toxicity overall, however it is toxic to fish, pollinating insects, wildlife and domestic animals. Below are the recommended procedures to apply permethrin in different environments (Higgins 2015) (Sayre 2017) (Wong 2017). A 0.25% permethrin solution is recommended for the following permethrin applications:

IN TURF, FLOWER BEDS, OR OPEN AREAS

1. Put on personal protective gear (see ‘Prevention and Control Strategies’ above).
2. If the exact location of the nest is known, disturb the area and watch where the ants start to swarm or use the advice in the ‘Finding the Nests’ box above to locate the nests for treatment.
3. Clear any coarse debris from the surface, but work quickly to ensure no ants are escaping as work is being carried out.
4. Beginning from about 1-2 feet from the nest, start digging and turning over the soil (a hand spade works well), while simultaneously spraying the soil. Work from the outside of the nest inward, honing in on the center. Keep digging down and around the nest until ants or tunnels are no longer observed.
5. Place the treated soil in a mound over the area after treatment.
6. Cover the mound to prevent birds and cats from coming in contact with the treated soil. Permethrin on the surface (exposed to light) will break down in a day or two but beneath the surface it will remain active for up to 40 days.
7. Continue this process until all of the nests have been treated.

IN MOSS

1. Put on personal protective gear (see ‘Prevention and Control Strategies’ above).
2. European fire ant nests in moss tend to be very shallow, just beneath the moss layer, and they can be quite extensive, covering a wide area. When the moss cover is gently pulled back, the ants, including queens and eggs will most likely be visible on the surface.
3. To treat, gently pull away the moss to reveal nests and then treat according to the above method. Be sure to spray the moss as well as treat the infested soil. After treatment, replace the moss back over the soil to keep the permethrin active in the soil.
4. The moss will likely die. However, after successful eradication, the moss can be restored by combining living moss and buttermilk or yogurt, mixing it in a blender and spreading it out to re-establish a mature moss layer over the span of 1-2 years.

IN THE CROWN OF A PLANT OR ROCK CREVICE

1. Put on personal protective gear (see ‘Prevention and Control Strategies’ above).
2. If nests are located in rock crevice, use a digging tool or stick to try to get as many of the ants/eggs out of the crevice for treatment. There may or may not be soil in the crevice; European fire ants are known to nest in rock crevices with little to no soil, or even in the openings of pipes or concrete blocks lying on the ground.
3. Using the stream setting on the nozzle on your sprayer, spray a stream of permethrin into the crevice to get as far into the nest as possible and spray the opening of the crevice. Follow up is required to monitor for activity and ensure that the treatment reached all the ants.

IN THE CROWN OF A FERN OR PERENNIAL GRASS CREVICE

1. Put on personal protective gear (see ‘Prevention and Control Strategies’ above).
2. If you find a nest in the crown of a fern or perennial grass, the ants are likely nesting in both the crown and in the roots.
3. Spray the crown first, then dig out the plant and treat the roots. It may be necessary to cut up the plant or the root mass to access the entire colony for treatment. Spray as much of the infested plant surface as possible, being sure to get into the entire root mass and the crown. The treated plant can be left to decompose in place or can be disposed of according to local bylaws. Infested plants cannot be saved and will have to be replaced.

**BAITING**

Baits have been shown to offer limited to poor control in European fire ant infestations and will not eradicate an infestation but may temporarily reduce the population density and prevent further spread. Baits tend to only kill the workers and not the queens, who determine the colony (Yong 2017).

Baits that contain 2% boric acid in a sugar solution are recommended where other options are not practical. These are commercially available from retailers carrying household pesticides. Ant baits that have a boric acid content of 4-5% should be avoided as these higher concentrations are not effective (Inter-Ministry Invasive Species Working Group 2015). Baits should be replaced each week as they tend to dry out in hot weather or become saturated with water when it rains.

Baits should be used during early to mid-summer, the period during which the queens and ant brood are consuming the most food. Bait should not be placed directly within vegetable gardens and raised beds, rather around the perimeter of these structures (E. Groden, F. Drummond, et al. 2005).

**CULTURAL: PARTIALLY RECOMMENDED**

Cultural control methods include altering the landscape to reduce the quality of their preferred habitat (e.g., removing debris such as rocks and logs and any vegetation that serves as nesting habitat or a food source). Cultural control methods will not lead to eradication of European fire ant infestations; however, they will help reduce population density and may help prevent infestations in new areas.

Infestations can be contained by installing a barrier of crushed rock (course gravel) that is at least 2 feet deep by 6 feet wide along the periphery of the infestation. In theory, the conditions (long distance to travel, hot conditions and minimal food resources) along the rock barrier will deter the ants from crossing it (Higgins 2017) (Sayre 2017). European fire ants cannot establish nests in coarse gravel, though they have been known to nest in pathways composed of compacted fine crushed rock or gravel.

**MANUAL/Mechanical: NOT RECOMMENDED**

Digging and torching (using a propane torch to apply fire to infested soil) infested soil may reduce the number of ants within a colony, but it is unlikely to eliminate the colony. Colonies are likely to return because the heat from the torch may not travel far enough to reach all of the queens in the nest (Higgins 2015). This method is labour intensive, requiring repeated applications and close monitoring. Digging and torching is only recommended if the use of permethrin is not an option. To effectively dig and torch, one person can turn over the infested soil with a shovel to expose the ants, while a second person torches the soil with a propane torch. Repeated monitoring and treatment will likely be required (Sayre 2017).
**BIOLOGICAL: NOT AVAILABLE**

There is currently no known biological control agent available for the European fire ant in British Columbia. The European fire ant appears to be a poor candidate for biological controls. As social animals living in microbe rich soil they have evolved extensive mechanisms to detect infections in colony members and limit their spread. Research has shown that European fire ants are able to identify colony members that have been infected with fungal biological control. Infected members are killed, dismembered and the body parts taken to the hottest location available to sterilize the parts (Higgins 2017).

**Disposal**

Best practice is to avoid off site disposal of European fire ant-infested soil due to the high risk of spread during and after transport. However, if it must be removed, any applicable local area bylaws (e.g., soil removal and deposition bylaws) and protocols must be adhered to.

The following protocol is recommended for disposing of European fire ant-infested soil that has undergone treatment:

1. Roll out a sheet of thick plastic and spread the infested soil onto the sheet.
2. If the soil has not yet been treated with permethrin, apply 0.25% solution of permethrin to the infested soil on the sheet.
3. Roll the infested material up in the plastic and seal the ends.
4. Tape all seams along the plastic roll to ensure it is sealed.
5. Leave the sealed package in the sun during high temperatures (not in winter) for 2 days to ensure the majority of the ants are dead.
6. Open the package and inspect it for ants and/or eggs.
7. If no ants and/or eggs remain, transfer the soil back into the formerly infested area.
8. Although generally not recommended, if the soil must be transferred offsite, reseal the package with tape and transfer it to a vehicle. Ensure the cover is tightly fastened to prevent detachment due to wind turbulence.
9. Carefully transport and dispose of the package at a local landfill (e.g., Vancouver landfill).
10. Thoroughly wash the transport vehicle.

In the Lower Mainland, the following facilities accept European fire ant-infested soil for disposal, provided they have sufficient capacity:

- **Vancouver Landfill**, 5400 72nd St, Delta, BC. Accepts soil for deep burial only (additional charge). A Waste Assessment Form must be completed.
- **Mission Landfill**, 32000 Dewdney Trunk Road, Mission, BC. Accepts soil for deep burial only (additional charge). A Waste Assessment Form must be completed.

Small quantities of soil (maximum 0.5 m$^3$ or two wheelbarrows full) are accepted at Metro Vancouver’s Transfer Stations (Langley, Maple Ridge, North Shore, Coquitlam and Surrey). Soil from the Transfer Stations is placed in the garbage stream.

**PLEASE CONTACT ALL FACILITIES BEFOREHAND TO CONFIRM THEY CAN PROPERLY HANDLE THE MATERIAL.**
Follow-up Monitoring

Whatever control method is used, follow-up monitoring and maintenance treatments are part of an integrated management plan or approach. Monitoring European fire ant treatments will reveal short- and long-term trends that can lead to new knowledge and understanding and subsequently improve site-specific management effectiveness and efficiencies. Regular inspection and monitoring should be part of the site management plan as re-invasion in treated areas is likely.

Treated area(s) should be monitored annually by laying out apple slices in the spring and early summer to identify active colonies and enable quick control.

Restoration

Recommended control strategies (digging and application of permethrin) involve the disturbance and possibly the removal of small patches of turf, plants and/or soil. If turf, plants or soil are removed, the soil should be replaced with clean (invasive-free) top soil, and the area re-seeded or re-planted with native (or at least non-invasive) vegetation and watered thoroughly (Higgins 2017).
References


Additional Resources

For more information please refer to the following resources.

- British Columbia Inter-Ministry Invasive Species Working Group. [https://www.for.gov.bc.ca/hra/invasive-species/fire_ants.htm](https://www.for.gov.bc.ca/hra/invasive-species/fire_ants.htm)
- Controlling European Fire Ants (Myrmica rubra) on Residential Properties - Best Approach to Date (with video). [http://faculty.tru.ca/rhiggins/control_of_myrmica_rubra_2.htm](http://faculty.tru.ca/rhiggins/control_of_myrmica_rubra_2.htm)

Acknowledgments

The project team would like to thank the following individuals and groups for their contributions related to the development and review of this document:

- Cynthia Sayre, Curator of Collections, VanDusen Botanical Garden
- Dr. Robert J. Higgins, Myrmecologist, Department of Biological Sciences, Thompson Rivers University
- Metro Vancouver’s Regional Planning Advisory Committee’s (RPAC)–Invasive Species Subcommittee

To submit edits or additions to this report, contact Laurie Bates-Frymel, Senior Regional Planner at [laurie.bates-frymel@metrovancouver.org](mailto:laurie.bates-frymel@metrovancouver.org).
To: Climate Action Committee

From: Josephine Clark, Regional Planner
Parks, Planning and Environment Department

Date: May 14, 2018

Subject: Use of Land Cover Data to Assess Regional Ecosystem Services

RECOMMENDATION
That the MVRD Board receive for information the report titled “Use of Land Cover Data to Assess Regional Ecosystem Services” dated May 14, 2018.

PURPOSE
This report provides the Climate Action Committee and MVRD Board with an update on the use of high-resolution land cover data to advance regional ecological health through the assessment of ecosystem services. This project focused on two specific topics – regional greenspace connectivity and the use of landscape indicators to investigate stream health.

BACKGROUND
This report provides information on ‘Methods to assess regional ecosystem services’, which is identified on the Climate Action Committee’s 2018 work plan in the second quarter.

In October 2017, staff provided the Climate Action Committee with a presentation on the completion of the Land Cover Classification project, which used satellite imagery and LiDAR (light detection and ranging) to create a high-resolution map of the region divided into broad biophysical classes, such as buildings, paved surfaces, shrub, coniferous and deciduous trees, grass, etc.

Metro Vancouver staff have been working with UBC’s Landscape Ecology Lab and Integrated Remote Sensing Studio to identify methods to quantify, map and understand ecosystem services using the land cover mapping, and have tested methods related to regional greenspace connectivity and stream health, which are the subject of this report. The results support actions and performance measurement of Metro 2040 and the Ecological Health Action Plan, which is currently being updated.

HIGH-RESOLUTION REGIONAL LAND COVER DATA
High-resolution land cover data was obtained for Metro Vancouver in 2017 and has created opportunities to advance the understanding of ecosystem services in the region. Land cover data, which maps the earth’s surface to broad biophysical classes such as buildings, paved surfaces, grass, etc., is key to ecosystem services analysis because it provides information about the entire landscape. Previous land cover data created for the region has not been compiled at high enough resolution to study urban areas, which are complex and highly heterogeneous.
REGионаL ecosystem services asseSSment

Ecosystem services are the essential benefits that nature provides humans for free, and an ecosystem service assessment considers how ecosystem functions generate these services to produce benefits, and how these benefits are distributed to society. This is an evolving field and methods to evaluate ecosystem services need to be tested and calibrated for the Metro Vancouver region. These two initial studies applied methods used successfully elsewhere to investigate greenspace connectivity and linking landscape indicators to stream health. Both studies utilized the new high-resolution land cover, and the work was completed by the Landscape Ecology Lab at UBC, in collaboration with the Integrated Remote Sensing Studio.

Regional Greenspace Connectivity

Connectivity of habitats is a critical issue for conservation and is particularly important in urban areas where remaining greenspace is often fragmented. Reduced connectivity can negatively impact ecosystem services flows, reduce the dispersal ability of plants and animals in the short term, and the viability of populations over longer time frames.

This study looked at three species: Pacific wren, Douglas squirrel and Townsend’s vole. These species were chosen because they have contrasting dispersal abilities and habitat requirements. The study compared habitat connectivity networks for each species and identified habitat patches that are vital for connectivity (i.e. if these patches were lost, the connection would be broken, and the species would not be able to travel along the full extent of the habitat corridor). The study also identified the protection status of habitats for these species.

This study found that of the three species, Pacific wren landscapes are the most connected, with much of the region linked together into a single component. Douglas squirrel landscapes are well-connected where development is low and forest cover is high, such as in the northern part of the region. The Townsend’s vole generally has the least connected landscapes, however, large patches in agricultural areas leads to relatively high connectivity values in the south of the region due to within-patch connectivity.

Using the high-resolution land cover and the Metro Vancouver Sensitive Ecosystem Inventory as inputs, this study provides a range of metrics to quantify how connected landscapes are for each species. Patches important for overall connectivity are mapped, as are patches that play important roles as stepping stones or hubs of connectivity. The protected status of patches critical for connectivity is determined and unprotected patches are highlighted.

Next steps will be determined with staff (including staff from member jurisdictions) and could include testing the results against field data of species presence and absence, as well as expanding the analysis to include a wider range of species. The study results can be used to inform conservation planning and land use decisions.

Linking Landscape Indicators to Stream Health

The second study explored the use of landscape indicators to explain water quality in streams throughout Metro Vancouver. Urban streams are subject to a range of complex stressors associated with nearby impervious surfaces that can increase stream pollution. There is a large body of research demonstrating that the percentages of different land cover types, as well as their spatial arrangement and connectivity, can be important landscape indicators of stream health. The value of landscape...
indicators lies in their ability to complement time-consuming field sampling, provide valuable information at broader spatial scales, and aid comparison among multiple streams in many regions.

Comparative statistical models were used to link a suite of landscape indicators to major water quality parameters – dissolved oxygen, nitrate, turbidity, fecal coliform, and E. Coli – at both the watershed level and immediate riparian zone (30 metres on either side of a stream). Results showed that:

- High-resolution land cover data is essential for accurately deriving landscape indicators;
- Percentage of forest/vegetated areas as well as impervious surfaces were highly correlated with some water chemistry variables (i.e. dissolved oxygen and fecal coliform), but less correlated with others (i.e. turbidity);
- Landscape indicators measured at the watershed level explained a large amount (nearly 50%) of the variability in dissolved oxygen and fecal coliform concentrations; and,
- The configuration of riparian forests and edges was particularly important for explaining the variability in water chemistry.

This work demonstrates that landscape indicators are a promising avenue for monitoring urban water quality. Next steps will be determined with staff (including staff from member jurisdictions) and could include the addition of further water quality parameters, investigating the effect of land use types on water quality, and incorporating sewerage system information and green infrastructure. Green infrastructure is the natural, enhanced, and engineered assets that collectively provide society with ecosystem services required for healthy living. Natural assets (such as forests, wetlands and soil) and enhanced or engineered systems (such as bioswales and green roofs) conserve natural resources and mitigate negative environmental effects, benefiting both people and wildlife. The addition of green infrastructure information would help to evaluate the effectiveness of different green infrastructure options for improving water quality.

**ALTERNATIVES**
This is an information report. No alternatives are presented.

**FINANCIAL IMPLICATIONS**
Costs associated with this project were included in Board approved program budgets. Both the Land Cover Classification project and the landscape indicators study were supported by grants from the Natural Sciences and Engineering Research Council of Canada (NSERC) Engage program.

**SUMMARY / CONCLUSION**
High-resolution land cover data was obtained for Metro Vancouver in 2017 and has created opportunities to advance the understanding of ecosystem services in the region. Ecosystem service assessment is an evolving field and evaluation methods need to be tested and calibrated for the Metro Vancouver region. This project focused on two topics of importance to ecological health – regional greenspace connectivity and the use of landscape indicators to investigate stream health. Habitat connectivity networks were mapped for three different species, and the methods used could be repeated for a broader range of species. Numerous landscape indicators were tested for their links to water quality and the results indicate this is a promising avenue for monitoring urban stream health. Further research topics will be determined with staff, including staff from member jurisdictions, and updates on research progress and outcomes will be shared with the Climate Action Committee and Board as they are available.
Attachments (Doc# 25494038)
1. Executive Summary: High spatial resolution landscape indicators show promise in explaining water quality of urban streams
2. Excerpt of the Greenspace Connectivity Final Report

25081971
EXECUTIVE SUMMARY

High spatial resolution landscape indicators show promise in explaining water quality of urban streams

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Prepared for: Josephine Clark, Metro Vancouver Regional District
Dec 2017
ABSTRACT

The degradation of urban rivers and streams around the world is due in large part to landscape fragmentation induced by rapid urban sprawl. Urban streams are subject to a myriad of complex stressors associated with nearby impervious surfaces that impact delivery of pollutants. The aim of this project was to explain water quality attributes through the use of landscape indicators (e.g. percent impervious surfaces, riparian forest edges) throughout Metro Vancouver, BC, Canada. To do so, first, we compared landscape indicators derived from high spatial resolution land cover (2 and 5 m spatial resolution) with those derived from moderate resolution (30 m) imagery to evaluate their relative efficacy in characterizing impervious surfaces and forest cover in urban watersheds. Second, using a subset of watersheds with water quality monitoring stations, we linked a suite of landscape indicators to major chemical properties and pollutants using a series of comparative statistical models. Our results showed:

- Impervious surfaces measured at 5 m matched estimates from 2 m (LIDAR) information.
- High spatial resolution imagery greatly improved estimates of impervious surfaces as compared to 30 m imagery which overestimated impervious surfaces by a large amount (85% on average).
- Percentage of forest/vegetated areas as well as impervious surfaces were highly correlated with some water chemistry variables (i.e. dissolved oxygen and fecal coliform), but less correlated with other water chemistry variables (i.e. turbidity).
- Landscape indicators measured at the watershed level explained a large amount (nearly 50%) of the variability in dissolved oxygen and fecal coliform concentrations.
- In general, landscape indicators were more useful during the wet season than dry season.
- The configuration of riparian forests and edges was particularly important for explaining the variability in water chemistry.

This work demonstrates that landscape indicators are a promising avenue for monitoring urban water quality especially when using high spatial resolution land cover. Our work provides support for several management directions as well as new avenues worthy of future research. High spatial resolution imagery is capable of detecting very detailed features of the heterogeneous urban environment, especially the spatial arrangement of land cover, within narrow riparian zones. Thus, future investments in imagery are potentially very worthwhile. City planners and managers should also consider the role of complementary strategies for maintaining stream health over different spatial scales (i.e., riparian zone and watershed) depending on the water quality constituent and management objective of concern.

Future research avenues are also numerous. While sewerage system information and Green infrastructure (GI) are likely to be very important, results from our initial analysis were inconclusive due to severe data limitations. A better understanding of the effectiveness of GI would require more systematic collection of GI information, gaining access to existing information at the municipal level, as well as creative use of existing geospatial layers to infer potential locations of GI (e.g., wetland areas). A longer term study of watershed change - using historical aerial photography in a focal watershed - to examine water quality changes in response to GI installation would help evaluate the effectiveness of different GIs options and predict future water quality trends. Outcomes from such a study, and as well as our landscape indicators, could be used to inform future urban planning when linked with urban growth models.
INTRODUCTION

Major changes in the world’s rivers and streams have occurred largely induced by landscape fragmentation. In urban areas, landscape fragmentation is often accompanied by increases in impervious surface and decreases in overall forest, greenspace, and natural vegetation (Faulkner, 2004; Riebsame et al., 1994). Landscape fragmentation amplifies the transport of nutrients and sediment to receiving waters, creates flashier runoff and greater peak discharges and can impact stream status (Allen et al., 2004; Arnold and Gibbons, 1996; Paul and Meyer, 2008). Noting these linkages, a large body of research has demonstrated that the percentages of different land cover types, as well as their spatial arrangement and connectivity, can be important indicators of stream status (Amiri and Nakane, 2009; Carey et al., 2011; Gergel et al., 2002). The value of landscape indicators lies in their ability to complement time-consuming field sampling, provide valuable information at broader spatial scales, and aid comparison among multiple streams in many regions.

Among the dozens of landscape indicators, the percentage of impervious surfaces tends to be the most important in explaining urban stream status (Table 1). Increases in impervious surfaces in urban landscapes contribute to higher runoff volume, faster peak discharge, and increased loading of pollutants and sediments (Amiri et al., 2012; Zhou et al., 2014). Numerous studies demonstrate that percentage impervious surfaces is a good predictor of water quality parameters such as \( E. \text{Coli} \), fecal coliform and nitrate (Table 1). Apart from percent imperviousness, the percentage of other land cover (e.g. forest), and configurational indicators (e.g. forest edge density) have also been strongly associated with water quality in empirical models (Carey et al., 2011).

Table 1. Commonly used landscape indicators and key findings for interpreting urban aquatic system status at different and spatial resolutions. Note: (+) indicates positively related and (-) indicates negatively related.

<table>
<thead>
<tr>
<th>Landscape Indicator</th>
<th>Scale Measured</th>
<th>Dependent Variables</th>
<th>Key Findings</th>
<th>Land Cover Resolution</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>% urban areas, % forest cover</td>
<td>watershed</td>
<td>EC, TDS, TN, DON, NH(^+), NO(_2)-</td>
<td>% urban positively related to EC, TDS, TN, DON, NH(^+), NO(_2)-</td>
<td>1: 50,000 topographical map</td>
<td>Haidary et al. 2013</td>
</tr>
<tr>
<td>% urban, % rural</td>
<td>watershed</td>
<td>TP, TN, NO(_2)-N, NH(^+)-N, Cl(^-)</td>
<td>% urban positively related to Cl(^-), % agriculture positively related to NO(_2)-N</td>
<td>N/A</td>
<td>Raney and Eimers 2014</td>
</tr>
<tr>
<td>% impervious area, patch density/edge/shape, largest patch</td>
<td>sub-basin, canal buffer, site buffers</td>
<td>NO(_x)-N, NH(_x)-N, TP</td>
<td>LPI was the best predictor of NO(_x)-N load; LDI values inversely related to NO(_x)-N; TP loads were better indicated at a smaller spatial extent</td>
<td>1:40,000 &amp; 1:12,000 aerial photography</td>
<td>Carey et al. 2011</td>
</tr>
<tr>
<td>land composition</td>
<td>sub-watershed</td>
<td>pH, TDS, Cl(^-), NO(_2)-, SO(_2)-, coliforms, ( E. \text{coli} ), turbidity, etc.</td>
<td>Total coliforms &amp; ( E. \text{coli} ) positively correlated to % urban</td>
<td>Medium (10-100m)</td>
<td>Pullanikkatil et al. 2015</td>
</tr>
<tr>
<td>% urban/forest/agric/ grassland</td>
<td>sub-watershed</td>
<td>TP</td>
<td>TP negatively related to forested area (&lt; 30%)</td>
<td>Medium (10-100m)</td>
<td>Amiri et al., 2012</td>
</tr>
<tr>
<td>% urban/forest/agricultural/ grassland, patch and edge size and density</td>
<td>watershed and land class levels</td>
<td>BOD, pH, DO, SS, TN, TP</td>
<td>Size-related landscape metrics stronger indicators for TN &amp; SS; 64%, 64% and 32% of total variations in SS, TN, pH could be explained by changes in compositional attributes</td>
<td>Medium (10-100m)</td>
<td>Amiri and Nakane 2009</td>
</tr>
</tbody>
</table>
The explanatory power of landscape indicators for describing variation in water quality is affected by two fundamental components: the spatial resolution and the spatial extent of analysis. Riparian zones and catchments (or watersheds) are two commonly used extents in this type of analysis. Moderate resolution (10-100 m) satellite images have been widely used to map impervious surfaces and land-use change in previous studies (Steuer et al. 2010; Torbick and Corbiere, 2015). However, due to the heterogeneity and complexity of the urban landscape, moderate resolution images lack an appropriate level of detail where intermingled land cover types exist (e.g., roof tiles and paved roads). Consequently, the diversity of land cover types and the fine scale of features in the urban mosaic can result in relatively high rates of misclassification between urban and other land cover classes in maps (Weng 2012; Momeni et al. 2016).

Given the newly-available 2 m resolution LiDAR and 5 m resolution RapidEye imagery analyzed for the Metro Vancouver Regional District as part of our previous work, we thought it important to evaluate the utility of these high spatial resolution data sources for mapping landscape indicators with relevance to urban stream monitoring. Our research is among the first to adopt these high spatial resolution approaches to explore landscape indicators of water quality. Our main objectives are three-fold:

1. Compare estimates of impervious surface cover derived from 2-, 5-, 30 m resolution imagery;
2. Explore the strength of statistical relationships between water quality parameters and landscape indicators measured at two different spatial extents (entire watershed vs. immediate riparian zone);
3. Determine the utility of more detailed landscape indicators which incorporate arrangement and configuration of impervious surfaces, greenspace, and sewerage information.
METHODS

We focused on the Metro Vancouver Regional District in British Columbia, Canada (Figure 1). All of the data used and steps described briefly below are explained in much greater detail in our final report and manuscripts currently under review / in preparation (available upon request).

To answer Objective 1, impervious surface estimates were determined for 91 major watersheds across the region whereby estimates derived from 5 and 30 m resolution imagery were compared. The 5 and 30 m land cover data (from RapidEye and Annual Crop Inventory data layer, respectively), for the year 2014. Also as part of Objective 1, a subset of 28 streams (only those with 2 m LIDAR information) was also examined to compare riparian impervious measures when using 2, 5, and 30m resolution imagery. To answer Objectives 2 and 3, landscape indicators derived from 5 m hybrid map were used for assessment. This hybrid map was a combination of 2 m LiDAR and 5 m RapidEye results. Using this 5 m hybrid map, we evaluated the utility of landscape indicators measured at both the riparian zone scale (for N=53 sampling stations) and watershed level (N=46 sampling stations).

Watershed boundaries were delineated using a 12 m-resolution Digital Elevation Model (DEM) obtained from German Aerospace Centre. Effort was made to adjust or interpolate (“fill-in”) any missing values using the 2 m LiDAR imagery and where it was absent we used the 30 m Shuttle Climate Action Committee
Radar Topography Mission (SRTM) DEM. ArcGIS stream layers were provided by Metro Vancouver as well as individual municipalities. Several streams segments which were incorrectly mapped and/or mismatched to the riparian boundaries in high resolution imagery were redrawn in a time-consuming process using ArcMap.

Five water quality parameters were selected for analysis, including dissolved oxygen (mg/L), nitrate (mg/L), turbidity (NTU), fecal coliform (CFU/100ml) and *Escherichia coli* (*E. Coli*, CFU/100ml). A detailed description of landscape indicators is provided in Table 2.

**Table 2. A summary of explanatory variables used in this research. All landscape indicators were derived from the hybrid 5 m land cover map using FRAGSTATS software.**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Landscape Indicator</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMPERV</td>
<td>% Impervious</td>
<td>% Impervious surfaces, including Buildings, Other_built, Paved, and Barren in 5 m high resolution map</td>
</tr>
<tr>
<td>CONIF</td>
<td>% Coniferous</td>
<td>% Coniferous forest in 5 m high resolution map</td>
</tr>
<tr>
<td>DECI</td>
<td>% Deciduous</td>
<td>% Deciduous forest in 5 m high resolution map</td>
</tr>
<tr>
<td>SHRUB</td>
<td>% Shrub</td>
<td>% Shrubland in 5 m high resolution map</td>
</tr>
<tr>
<td>AGRI</td>
<td>% Agricultural</td>
<td>% Agricultural land use, determined by 30 m crop inventory map</td>
</tr>
<tr>
<td>VEGE</td>
<td>% Other vegetated</td>
<td>% Other vegetated area, including Modified Grass-Herb, Natural Grass-herb, Non-photosynthetic veg in 5 m high resolution map</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Landscape Indicator</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PD</td>
<td>Patch Density</td>
<td>Number of patches within a zone/buffer divided by the area of a zone/buffer, capturing the fragmentation of a land cover class</td>
</tr>
<tr>
<td>PE</td>
<td>Perimeter-Area Ratio</td>
<td>Edge length of patches divided by the area of patches, capturing the shape of patches</td>
</tr>
<tr>
<td>ED</td>
<td>Edge Density</td>
<td>Edge length of patches within a zone/buffer divided by the area of a zone/buffer, capturing both fragmentation and shape of patches</td>
</tr>
</tbody>
</table>

**Statistical Analysis**

Pearson’s correlations between water quality parameters and land cover variables were determined in an exploratory analysis, followed by linear regression to better assess the relationship between water quality and specific landscape indicators. Two model selection procedures were employed: Forward stepwise (adding the best variable) and backward stepwise (removing the weakest variable) in order to determine the best model for each water quality parameter. The best models were evaluated based on those having the lowest Akaike Information Criteria (AIC) value. Partial r-squared values were computed to determine the most important landscape indicator within each best model.
KEY RESULTS AND DISCUSSION

High resolution land cover is essential for accurately assessing impervious surfaces

Imagery at 5 m resolution produced results with little difference from 2 m imagery in terms of impervious cover estimates. Impervious surfaces at watershed scale were generally over-estimated by 85% using 30 m resolution imagery, and the overestimation would be further amplified at 30 m riparian zone scale (see an example in Figure 2). The consistent overestimation of impervious surfaces observed at 30 m resolution is indicative of the limited capacity of medium resolution data to characterize important features of the urban landscape. Conclusively, the utilization of landscape indicators derived from 5 m resolution is an optimal compromise given that 2 m information is currently unavailable for the whole study region.

Links between water quality and landscape indicators at multiple scales

Pearson’s correlations showed that the water quality attributes were typically more correlated with land cover variables measured at the watershed level. Higher IMPERV was associated with lower dissolved oxygen \( (r=-0.30, \ p<0.05) \) and higher fecal coliform \( (r=0.34, \ p<0.05) \). CONIF was positively correlated with dissolved oxygen, and negatively correlated with nitrate, turbidity, and bacterial concentrations.

The explanatory power \( (r^2) \) of landscape indicators at the watershed level was highest for dissolved oxygen, nitrate and fecal coliform; while the explanatory power at the riparian zone level was highest for turbidity and \( E. \ Coli. \) Landscape indicators measured at the watershed level in the best models accounted for nearly 50% of the variability in dissolved oxygen.

Figure 2. From top to bottom, details of land cover near Dear Lake area at 30m, 5m and 2m resolution.
and fecal coliform (Figure 3a-e). The linear models performed generally better in the wet season compared to the dry season (Figure 3f).

**Landscape configuration within the riparian zone is key**
For riparian models, edge density of impervious surfaces (ED_IMPERV) was the most important variable (i.e., highest partial $r^2$) for explaining turbidity and bacteria concentrations (Figure 4a). ED_IMPERV was inversely correlated with dissolved oxygen and edge density of agricultural land use (ED_AGRI) was associated with lower dissolved oxygen. ED_IMPERV alone explained more than 30% of the variability in bacterial concentrations.

For watershed models, the compositional variables (% land cover, not arrangement) were the most important in explaining the changes in water quality (Figure 4b). Our results imply that not only does the increasing proportion of impervious surfaces contributes to the degradation of water quality but also higher edge density of impervious surfaces within the riparian zone is particularly notable.

![Fig. 3 Impact of scale on the performance of landscape indicators in explaining water quality of urban streams. Comparisons show the impact of changing spatial resolution (5 vs 30 m land cover), as well as changing spatial extent (riparian vs. whole watershed) for landscape indicators. R-squared values of best models for five water quality parameters are shown (in wet season except where noted).](image)

**Correlations among land cover variables must be considered**
Our results show that shrubland (SHRUB) and other vegetated area (VEGE) were inversely associated with better water quality, which seems contrary to conventional wisdom at first glance. However, an examination of correlations among different land cover types in the study region indicate that the coniferous class (CONIF) was negatively correlated with SHRUB and VEGE. These findings indicate that maintaining tree canopy cover within watersheds is likely critical for stream protection in urban environments. Increases in lawn and shrub vegetation in residential areas, therefore, are not necessarily good substitutes for the loss of tree canopy.

**Precipitation trends warrant further evaluation**
Trends in precipitation were not taken into consideration in this study. Sporadic and heavy rainfall events are common in the study area, even during the dry season, and could potentially account for the lower explanatory power of dry season models. Thus, the effects of precipitation merit further study in the future. In addition, we excluded upstream monitoring stations (those within the same river/stream system) to ameliorate the issue of spatial autocorrelation. Alternatively, spatial lag model could be a powerful instrument to explicitly take spatial autocorrelation into consideration (Liu et al., 2015) and would enable us to add in additional the deleted monitoring stations. The implementation of such spatial models deserves further investigation.

CONCLUSIONS AND NEXT STEPS

Policy implications
Firstly, high spatial resolution land cover is highly recommended as a baseline for modelling urban expansion, and furthermore, it is likely to be particular helpful in examining urban ecosystem services which depend on configuration (Mitchell et al. 2015). Secondly, the effects of urbanization within the 30 m riparian zone and throughout the entire catchment basin should both be taken into consideration in city planning and management. Overall, our results show the utility of landscape indicators was greatest for nitrate and fecal coliform. Lastly, our results support the idea that different strategies should be developed over differing spatial extents (both riparian and watershed scales) depending on the specific water quality objective of concern. For instance, lower proportions of impervious surfaces at the watershed level were associated with increasing dissolved oxygen. Also, lower edge density of impervious surfaces in the riparian zone was associated with increased dissolved oxygen. Therefore, our results suggest that restoration of even small contiguous areas of riparian buffers could be helpful in supporting water quality.

Utility of sewage information: limited initial results from a pilot study
As part of additional work in a side project, we incorporated sewage information for the City of Surrey who generously shared its sewage information. Using this smaller area, additional models were evaluated using not only percent land cover but also sewage information (density of catch basins and detention ponds) as explanatory variables. The density of detention ponds (within the riparian zone and the entire watershed) was positively associated with turbidity and was the most important factor explaining turbidity. However, catch basin density throughout the entire watershed was positively associated with bacterial concentrations (see Appendix, Figure 5). Confounding factors include a lack of information about the age of catch basins and cleaning schedules. Our results suggest sewerage system information may be potentially important in evaluating stream health and worthy of additional study in other municipalities. It is critical to note however that due to severe sample size limitations, this result is highly inconclusive and warrants additional analysis with a greater sample size before strong conclusions can be made.

Green infrastructure: future questions
For decades, many cities have used green infrastructure (GI) extensively for stormwater management in an attempt to mitigate urban stream problems (Keely et al., 2013). Unfortunately, we were not able to incorporate the impact of green infrastructure on water quality into our current analysis (except as a small pilot in the City of Surrey) as available data were far too limited. A better understanding of the effectiveness of GI throughout the region would require additional systematic collection of GI information throughout the region as well as access to available information (where it exists) at the municipal level. To some extent, existing remote sensing data sources could potentially be used to assist the quantification and mapping of some elements of
urban GI. Along with implementing new systematic mapping programs to catalogue existing GI, some pre-existing datasets could also be used to establish a baseline GI inventory. For example, wetlands and/or riparian areas mapped in the Sensitive Ecosystem Inventory (SEI) could be combined with the new 2014 land cover product to identify riparian vegetation as one component of a GI inventory.

A longer term study of the effectiveness of GI (with comparisons over time) could also be useful in predicting (or bounding) future water quality trends. An ideal candidate for such a future project might be Wagg Creek in the City of North Vancouver, which has abundant water quality data and a long record of historical aerial imagery. As such it is a promising candidate for investigating long term trends in water quality and GI effectiveness. Examination of paired and/or replicated streams and watersheds, before and after implementation of GIs (both natural and engineered), could help in conducting a strategic and useful comparison of water quality changes in response GI implementation and be potentially used to investigate the effectiveness of different GIs. To aid future planning, different urban growth models (e.g. Velma) could also be applied to create and contrast plausible future scenarios utilizing different GI options under future urban expansion.
APPENDIX – ADDITIONAL RESULTS

Figure 4. Variation in water quality parameters explained by landscape indicators in best models found using indicators measured at the riparian zone level (in Panel a) and the watershed level (in Panel b). Comparisons show that landscape configurational factors at riparian zone level are relatively more important (explain more variation in water quality parameters) than configuration of the overall watershed. Better models are those indicated by a higher r² value.

Figure 5. Variation in water quality parameters explained by sewer information in Surrey. Due to an extremely small sample size of N=20 these results are highly suspect but exploratory results are provided nonetheless as they provide a hint of potential additional research which is warranted.
Extract from:

**Application of Geospatial Technologies to Improve Land Cover Assessment and Characterize Ecological Goods and Services across the Metro Vancouver Region**

**December 20, 2017**

**Prepared for:**
Metro Vancouver Regional District

**Prepared by:**
Xiaofeng (Robert) Ruan, Jieying (Jenny) Huang, Sarah Gergel, Dave Williams, Karly Harker, Yuhao Lu, Nicholas Coops

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OBJECTIVE 2: URBAN GREENSPACE CONNECTIVITY ANALYSIS

Abstract

We use a graph theory approach to analyze greenspace connectivity in the Metro Vancouver Regional District (and Abbotsford) from the perspective of three species: the Pacific wren, Douglas squirrel and Townsend’s vole. The first two species are forest dependent, with the Douglas squirrel further restricted to Coniferous patches. The Townsend’s vole is, in contrast, a species that utilizes herbaceous and shrubby patches.

Using a range of metrics we quantify how connected landscapes are for each species. Patches important for overall connectivity are mapped, as are patches that play important roles as stepping stones or hubs of connectivity. The protected status of patches critical for connectivity is determined and unprotected patches are highlighted as having a high conservation priority. Finally, groups of connected patches called components are mapped for each species, with patches linking components across landscapes noted as having a particularly important regional connectivity role.

We find that Pacific wren landscapes are the most connected, with much of the region linked together into a single component. Douglas squirrel landscapes are well-connected where development is low and forest cover is high, such as in the north of the study region. The Townsend’s vole generally has the least connected landscapes, however, large patches in agricultural areas leads to relatively high connectivity values in the south of the study region due to intrapatch connectivity.
Assessing Urban Connectivity Networks

Planners and partner municipalities at Metro Vancouver recognize the importance of greenspace connectivity (Metro Vancouver, 2001; 2013). Connectivity of habitats is a critical issue for conservation and is particularly germane for forested areas and greenspace in urban landscapes. Urban greenspaces often exist in a patchwork of varying levels of fragmentation and connectivity (Cen et al., 2015; Irwin & Bockstael, 2007) that can negatively impact ecosystem services (ES) flows, reduce the dispersal ability of plants and animals in the short term, and the flow of genes and viability of metapopulations over longer time frames (Hanski and Gilpin, 1991; Clergeau and Burel, 1997; Ferreras, 2001; Angelone and Holderegger, 2009; Dixon et al., 2009). However, quantifying the connectivity between parks and protected areas, as well as unprotected urban greenspaces which potentially act as crucial habitat and stepping stones, is challenging and requires new approaches.

Connectivity can be analyzed from structural and functional perspectives (Minor & Urban, 2008). Structural approaches focus on the arrangement of habitat patches alone, without regard to any particularly species. In contrast, functional approaches incorporate the dispersal abilities and specific habitat requirements of a given species to assess landscape connectivity from the standpoint of a particular species (Bélisle, 2005). Functional connectivity approaches are seen as increasingly important, as a number of studies show how landscape connectivity changes considerably depending on the species of interest. Secondly, common umbrella species, such as carnivorous mammals, may not be truly representative of the habitat needs of other species because of their generalist livelihood strategies and long dispersal distances (Billeter et al., 2007; Reviewed in Correa Ayram, Mendoza, Etter, & Salicrup, 2016; Tannier, Foltête, & Girardet, 2012).

Network analysis of connectivity can characterize functional connectivity from the perspective of a focal species in a spatially explicit way (Saura and Torné, 2009). Network analysis enables identification of nodes (i.e. patches) as well as links between them. Links can be defined using distances between nodes, probability of successful dispersal among nodes, and general accessibility (Minor & Urban, 2008; Reviewed in Saura & Torné, 2009) (Figure 1). This approach allows for the identification of key connectivity hubs on the landscape, that is, the locations that function as disproportionately important conduits of organism movement. Graph theory approaches differ from more structural connectivity approaches (e.g., as employed in FRAGSTATS (McGarigal et al., 2002) that produce a single connectivity measure for an entire landscape. Instead, network approaches are often spatially-explicit, meaning that
they can identify specific elements (nodes and links) making the greatest contribution to connectivity (reviewed in Saura and Pascual-Hortal, 2007).

A key feature of using a network analysis approach is that it enables the identification of critical “stepping stone” patches which provide important “thorough-fare” connectivity routes throughout a landscape (Saura & Rubio, 2010; Serret et al., 2014). The loss of stepping stone patches has a greater impact on overall connectivity than their otherwise poor habitat attributes (e.g., potentially small size or poor quality) might suggest. Such an approach can help identify greenspace outside of formally-protected reserves that might be strong candidates for protection or restoration. Such locations might not be identified as “worthy” of protection using habitat quality considerations alone.

Conefor is among the most popular software used for network connectivity analysis (Ayram et al. (2016) and the Probability of Connectivity (PC) metric employed by Conefor is among its most important outputs (Saura and Pascual-Hortal (2007). The PC metric performs extremely well, and has been shown to meaningfully measure the effects of fragmentation and habitat loss and best represent the role of patch configuration – an important driver of landscape connectivity (Laita, Kotiaho, & Mönkkönen, 2011).

Using Conefor and a suite of graph theory metrics, including PC, we assessed greenspace connectivity from the perspective of three contrasting species. We examined 2 mammals and 1 bird species, each with different dispersal capabilities, minimum home range sizes, and habitat requirements, throughout the Metro Vancouver Regional District. Habitat patches were derived from greenspace mapping developed as part of the 5m Hybrid 2014 Metro Vancouver Landcover classification (Ruan et al., 2017;
Williams, Matasci, & Coops, 2018). This high spatial resolution landcover is among the most recent and finest resolution mapping available for the region. It enabled a finer resolution assessment of patch configuration and landscape connectivity than previously possible. Furthermore, wall-to-wall landcover coverage enabled us to produce, to our knowledge, the first-ever connectivity models of the entire metropolitan Vancouver region.

Our analysis had three main objectives:

1. Assess and compare the status of habitat connectivity for the three species with contrasting habitat requirements and dispersal abilities;
2. Locate and highlight patches outside of formally protected areas that may be valuable conservation priorities from the standpoint of connectivity;
3. Identify patches throughout the region critical to greenspace connectivity including components, key nodes, hubs and overlap patches likely responsible for linking subset landscapes together.

Methods

This analysis was performed using a high resolution land cover map (Williams et al., 2018), Sensitive Ecosystem Inventory (SEI) vector data (c. 2013), and Landuse (LU) and Land Designation (LD) vector data of conservation and recreation areas (data c. 2011). The study area included the majority of Metro Vancouver and Abbotsford, which contains some Metro Vancouver parks land (Figure 2). Unpopulated areas in the north of Metro Vancouver (as well as Lion’s Bay) were excluded, as was the northeast corner of Maple Ridge, because these areas’ remoteness and high vegetative connectivity would obscure the results of an analysis of urban greenspace. Conefor 2.6 (Saura and Torne, 2009) and the Conefor Inputs Tool for ArcGIS 10.x 1.0.218 (Jenness, 2016) were used for the analysis, which we conducted in 5 stages:

1. Greenspace Characterization
2. Habitat requirements
3. Conefor link creation, creation of subset landscapes and overlap patches
4. Conefor Metric Selection
5. Addressing Objectives 1-3

The five methods stages are explained in greater detail below.
**1. Greenspace characterization**
As part of our earlier collaboration, a regional landcover product was developed for Metro Vancouver from 2014 RapidEye images and LiDAR data. LiDAR data covered a subset of the region and was collected between 2008 and 2015. A detailed discussion of the creation of the landcover map can be found in Williams, Matasci and Coops (2018), as well as the report prepared by Ruan et al. (2017) for Metro Vancouver. Three different landcover products were created for the 2014 landcover project, with the hybrid landcover – a ‘best-of’ fusion between LiDAR-coverage and RapidEye-only areas – used here. The hybrid landcover is a raster with a spatial resolution of 5m and an overall classification accuracy of 89% (kappa 0.88). Individual user’s and producer’s accuracies for vegetation classes range from 82-99%.

The raster landcover layer was converted to a vector format and vegetation classes (Table 1) were selected. The vegetation polygons were dissolved by their landcover class label to reduce the number of polygons created by vectorization. To minimize the inclusion of tree canopy that overtopped roads and to create more meaningful patches, a buffered a transport line layer was erased from the vegetation polygons. All types of roads, from highways to unpaved resource roads were included.

<table>
<thead>
<tr>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
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<tbody>
<tr>
<td>Built-up</td>
<td>Buildings</td>
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<td></td>
<td>Paved</td>
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<td></td>
<td>Other Built</td>
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<tr>
<td>Bare</td>
<td>Barren</td>
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<td></td>
<td>Soil</td>
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<tr>
<td>Vegetation</td>
<td>Tree canopy</td>
<td>Coniferous</td>
</tr>
<tr>
<td></td>
<td>Broad-leaf</td>
<td>Shrub</td>
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<tr>
<td>Grass-herb</td>
<td>Non-photosynthetic vegetation</td>
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<tr>
<td>Water</td>
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<tr>
<td>Shadow</td>
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<tr>
<td>Clouds/Ice</td>
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Table 11 Landcover classes of the 2014 landcover classification. Vegetative classes (and soil) used for patch selection are bolded.

**2. Habitat requirements**
Three species were selected for connectivity modelling. Two of the species, the Douglas squirrel (*Tamiasciurus douglasii* Audubon and Bachman) and Pacific wren (*Troglodytes pacificus* Baird), are forest dependent and tend to be less abundant in areas of human development (Farwell & Marzluff, 2013; Marzluff et al., 2007; Marzluff, DeLap, Oleyar, Whittaker, & Gardner, 2016; Ransome & Sullivan, 2003). While both species prefer older coniferous forests, the Pacific wren has a wider range of likely habitats including deciduous forest canopy and shrubs (Campbell et al., 1997; National Geographic Society, 2006). The third species, the Townsend’s vole (*Microtus townsendii* Bachman), thrives in natural wetlands and grasslands, but also occupies more modified grass-herb habitats such as airports and agricultural fields (Brylski, Shellhammer, Duke, Harris, & Granholm, 1990; Cornely & Verts, 1988; Lambin, 1994).

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Each species’ unique life history characteristics enabled us to parameterize three very different representations of network connectivity (Table 2). All three species show territorial behaviour, which we used to derive minimum patch size requirements (Carey, 1995; Lambin, 1994, 1997; Marzluff et al., 2016; Ransome & Sullivan, 2003). Douglas squirrel was restricted to Coniferous patches, as such patches are arguably most representative of native vegetation communities. Highways, major roads and water are barriers to Douglas squirrel’s dispersal, however, it also has the longest maximum dispersal distance of the three species modelled. The Pacific wren has a longer median dispersal distance than the other two species, and its dispersal is not limited by roads or water. The wren can also utilize all forest types on the landscape. In contrast, the Townsend’s vole is not reliant on any forest class except shrub for habitat, preferring grass-herb communities. The non-photosynthetic vegetation class from the 2014 landcover, which mostly corresponds to dead grass, was included as vole habitat. So too, was the soil class, which existed on a continuum with non-photosynthetic vegetation and grass-herb, and also corresponded to ploughed agricultural fields that voles could potentially use as habitat. The vole has the shortest dispersal distances of the three species, and though not limited by water, is restricted by major and minor roads (as defined in the Metro Vancouver transport line layer). These different habitat requirements for these three species enabled us to use all the vegetation classes present in the 2014 landcover to model connectivity.

To create habitat patches (a.k.a. nodes) for an individual species, adjacent vegetation polygons sharing relevant habitat characteristics (see Table 2) were dissolved into a single patch. For example, for the Pacific wren, a new forest label was assigned to all polygons corresponding to the coniferous, deciduous and shrub landcovers. These polygons were then dissolved together to create potential habitat patches for the Pacific wren. In this way, polygons that shared a border and were suitable habitat for a species were merged together. After the dissolve operation, the multi-part to single-part tool in ArcMap was used to ensure that resulting polygons had unique IDs. Finally, habitat patches were filtered by area to remove those which were less than the minimum patch size for a given species (Table 2).
Table 12 Species parameters used for patch selection and connectivity modelling in Conefor. Dispersal distances, patch sizes and habitat landcover types were obtained by calculating the weighted means of values found through a literature review. *The calculated minimum patch size for the Townsend’s vole was 0.05 ha, but this value was increased to 0.5 ha to work within processing limitations.

<table>
<thead>
<tr>
<th>Species</th>
<th>Median Dispersal (m)</th>
<th>Max distance (m)</th>
<th>Min patch size (ha)</th>
<th>Land Cover types</th>
<th>Disp. Road limited?</th>
<th>Disp. water limited?</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Douglas squirrel</td>
<td>65</td>
<td>822</td>
<td>0.36</td>
<td>Coniferous</td>
<td>Yes</td>
<td>Yes</td>
<td>(Carey, 1991, 1995; Ransome &amp; Sullivan, 2003; Santini et al., 2013 Table S1; Smith, 1968)</td>
</tr>
<tr>
<td>Pacific wren</td>
<td>102</td>
<td>500</td>
<td>0.4</td>
<td>Coniferous, Deciduous, Shrub</td>
<td>No</td>
<td>No</td>
<td>(De Santo, Willson, Bartecchi, &amp; Weinstein, 2003; Donnelly &amp; Marzluff, 2006; Farwell &amp; Marzluff, 2013; Marzluff et al., 2016)</td>
</tr>
<tr>
<td>Townsend’s Vole</td>
<td>6.4</td>
<td>43</td>
<td>0.5*</td>
<td>Grass-herb, Non-photo vegetation, Shrub, Soil</td>
<td>Yes</td>
<td>No</td>
<td>(Lambin, 1994; Lambin &amp; Krebs, 1991; Taitt &amp; Krebs, 1981)</td>
</tr>
</tbody>
</table>

Area-weighted habitat quality was next assigned to each habitat patch (or node) as follows: First, Habitat Quality was assigned to each patch using the condition values from the Sensitive Ecosystem Inventory (SEI) dated October, 2013. The SEI is a comprehensive, region-wide layer cataloguing a range of ecosystem types including forests, grasslands and wetlands. SEI polygons have a condition value ranging from 1-5 which is a measure of the quality of the polygon independent of its size. This condition attribute provided the basis for creating a new attribute, “area-weighted habitat quality” to each habitat patch as is commonly used in connectivity assessments. Area-weighted habitat quality was calculated as patch area x condition.

Assigning condition values to patches in order to calculate area-weighted habitat quality required some preprocessing. For each habitat layer and species, patches (and parts of patches) falling outside the SEI were assigned a revised minimum condition value of 1. SEI polygons were then assigned condition values equal to one greater than their original value (i.e. 2-6). These two layers were then merged to yield a layer with condition values from 1-6. This new condition layer was used to calculate a weighted average condition value for each habitat patch ranging from 1.0 to 6.0 (using the tabulate intersection tool in ArcMap). For example, a squirrel patch polygon might overtop 3 SEI polygons with condition
values of 2, 4 and 5. The condition polygons each overlap 40%, 35% and 25% of the squirrel patch area, respectively. The squirrel patch would then be assigned the weighted average value of the condition polygons, in this case 3.45.

3. Conefor link creation, creation of subset landscapes and overlap patches
With the patch layers created, Euclidean distance (straight line) links were created among patches up to the maximum dispersal distance for each species (Table 2). Links were created using the Conefor Inputs Tool for ArcGIS 10.x 1.0.218 (Jenness, 2016). Link and patch information for each species was then input into Conefor 2.6 (Saura and Torne, 2009) for the calculation of connectivity metrics. Key parameters were the median and maximum dispersal distance for each species (as per Table 2).

Figure 13 Subset landscapes for each Conefor run. These regions are the landscapes for which connectivity metrics were calculated. Natural water boundaries were used where possible, with the exception of the boundary between the Southwest and Southeast subset landscapes. Here, the border between Surrey and Langley was used. The SW and SE boundary regions were used for the Pacific wren and Townsend’s vole. For the Douglas squirrel the SW and SE subset landscapes were fused into a single southern subset landscape (dark green boundary). Pink polygons highlight where subset landscapes are within 500m of each other, used to create overlap in the patch selection for each subset landscape.

For efficient link creation and Conefor execution the metropolitan region needed to be divided into subset landscapes (Figure 2). Burrard Inlet and the Fraser River were used to separate the North,
Central, Northeast, and South subset landscapes. For the Douglas squirrel a single southern subset landscape was used. For the Pacific wren and Townsend’s vole the number of patches south of the Fraser River was still too large for efficient processing, and so Southwest and Southeast subset landscapes were created at the Surrey-Langley border.

For each species, overlap patches were selected surrounding each subset landscape. These patches were located in a 500m buffer around each subset landscape. 500m was longer than the maximum dispersal distance of any of the species modelled, and allowed for an analysis of the importance of patches that might connect subset landscapes together. Overlap patches were unique for each species because of their different habitat requirements. However, using the metrics detailed below we attempt to identify overlap patches of regional significance and areas of conservation priority.

4. Conefor Metric Selection
Connectivity was measured using the Probability of Connectivity (PC) index and its component metrics (Saura and Pascual-Hortal, 2007), Equivalent Connectivity for PC (EC(PC)) (Saura et al., 2011), as well as the number of links per patch, and the number of components in a network (Table 3). The PC metric describes the amount of reachable habitat within a landscape (here, each subset landscape) both among and within patches. PC uses probabilities of dispersal between patches ($p_{ij}$) and the area-weighted quality of patches ($a$) to determine an overall connectivity measure for a landscape. The probability of successfully moving from one patch to another was set at 0.5 for each mammal’s median dispersal distance. The area-weighted quality for each patch was derived using the SEI, detailed above.

PC can be interpreted as the probability that “…two animals randomly placed within the landscape fall into areas that are reachable from each other…” (Saura & Pascual-Hortal, 2007 p.93). $PC_{num}$, the numerator of the PC equation, is divided by the total habitat area ($A_l$) squared to derive PC. $A_l$ is the area of the entire landscape, including habitat and non-habitat areas – in this case, the area of each subset landscape. Dividing $PC_{num}$ by $A_l$ yields a number between 0 and 1, with 0 representing no habitat patches in the study area and 1 representing an entire landscape occupied by a single patch.

EC(PC) is the Equivalent Connectivity value for the PC index. It measures the amount of habitat resources that are reachable in a landscape (Saura & Fuente, 2011). EC has a number of desirable qualities as a metric, but in general it is useful for “quantifying changes in landscape connectivity and comparing them with the changes in the amount of habitat in the landscape (Saura & Torné, 2012).”
The importance of any given patch in a landscape is $dPC$, calculated as the percent contribution of that patch to overall PC for a landscape (Table 3). $dPC$ itself is the sum of three other node importance metrics: $dPCintra$, which measures within-patch connectivity; $dPCflux$, which measures how connected a patch is to the rest of the network; and $dPCconnector$, which measures how important a patch is for connecting other patches together (i.e. stepping stone importance). These node importance metrics can also be summed for each patch in the landscape (e.g. sum $dPCconnector$) to understand the overall relative importance of, say, stepping stones in a landscape. The sum of these node importance metrics will often be greater than 100.

The number of components in the landscape ($NC$) and the patch degree (the number of links per patch ($e_k$)) are more straightforward metrics. Components are groups of patches that are all connected by at least one link. Single-patch components are also possible. NC allowed us to identify the number of components in a landscape, identify important components based on the sum of node importance metrics, as well as the membership of individual patches in a component.

Table 13 Connectivity metrics calculated using Conefor for animals in Metro Vancouver, adapted from Saura and de la Fuente (2011).

<table>
<thead>
<tr>
<th>Metric Name</th>
<th>Formula/Explanation</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Probability of Connectivity (PC)</td>
<td>$PC = \frac{\sum_{i=1}^{\tau} \sum_{j=1}^{n} a_i \cdot a_j \cdot P_i \cdot \hat{P}_j}{A_L^2}$</td>
<td>$PC$ is the probability that &quot;... two animals randomly placed within the landscape fall into areas that are reachable from each other.&quot; Probabilities between patches are based on median dispersal distances having a probability of 0.5. The patch attribute, $a$, is the area-weighted quality of a patch.</td>
</tr>
<tr>
<td>Equivalent connectivity for PC ($EC(PC)$ or ECA)</td>
<td>$EC(PC) = \sqrt{PCnum}$</td>
<td>$EC(PC)$ measures the amount of habitat resources that are reachable in a landscape. $EC(PC)$ would be highest if all habitat occurred in a single patch. When the node attribute, $a$, is only patch area, $EC(PC)$ is the area a single patch would need to be to have the same connectivity (PC) the network being analyzed.</td>
</tr>
<tr>
<td>$dPC$</td>
<td>$dPC(%) = \frac{PC - PC'}{PC} \times 100$</td>
<td>Measures the effect of node removal on overall network connectivity (PC). $dPC$ is the percent contribution of a node ($k$) to PC. The value of PC after removing node $k$ ($PC'$) is subtracted from the overall value of PC. The difference between the two values is then expressed as a percentage of PC. $dPC$ is composed of three node importance metrics explained below.</td>
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</table>

$dPC = dPCintra + dPCflux + dPCconnector$
### Available habitat provided by a patch (k) itself:

\[ d_{ij} \times d_{kj} \times w \times d_{d\text{d}} = j = k (\alpha_{2}^k). \]

Where \( \alpha \) is area-weighted quality.

- **dPCintra** (Intrapatch Connectivity)
  - The percent contribution of a patch to *intrapatch (within-patch)* connectivity. It is not affected by number of links or link probabilities.
  - **dPCintra** measures how connected a patch is in the network. It depends on the area weighted quality of a patch and its position in the landscape. It differs from **dPCconnector** in that it doesn’t measure how important a given patch is for connecting other nodes together, but rather how connected an individual node is to the rest of the network.

### Area-weighted dispersal flux from a patch (k) to or from all other patches in a landscape:

\[ a_i \times a_j \times p_{ij}. \]

- **dPCflux** (Patch Connectivity)
  - Measures how connected a patch is in the network. It depends on the area weighted quality of a patch and its position in the landscape. It differs from **dPCconnector** in that it doesn’t measure how important a given patch is for connecting other nodes together, but rather how connected an individual node is to the rest of the network.

### Contribution of patch k to the connectivity of neighbouring patches. The sum of \( a_i \times a_j \times p_{ij} \) for any number of pairs of patches, i and j, around a given patch k. Patch k must be part of the best path between i and j.

- **dPCconnector** (Stepping Stone Importance)
  - A measure of how important a patch is for connecting other patches together. It can be thought of as stepping stone importance. **dPCconnector** is independent of a patch’s area-weighted quality, and depends only on a patch being part of the best path for dispersal (i.e. when \( p_i \times p_j \) is highest).

### Number of links (also called edges) of a given patch. Node (patch) degree distributions can help to characterize a landscape into different typologies.

- **Degree**

### The number of components in the landscape (NC). dNC measures the importance of a patch for maintaining component integrity.

- **Number of Components (NC) and dNC**

### Components are groups of connected patches. In a component every patch is connected to every other patch by at least one link. Isolated patches are also components. NC allows for component ID but also individual patch membership in a component. For dNC increasingly negative values denote greater patch importance.

### 5. Addressing Objectives 1-3

We use the metrics in Table 3 to quantify overall landscape connectivity, which patches in each landscape are important (and how), and which patches act as regional connectivity hubs. The LU and LD data outlined above were used to identify which patches were considered already protected and which fell outside protected areas.

**Objective 1: Assess and compare the status of habitat connectivity for the three species with contrasting habitat requirements and dispersal abilities**

To address objective 1 we compared overall connectivity metrics (PC and EC(PC)) and the number of components (NC) for each species and subset landscape. We also measured **sum dPCintra**, **sum dPCflux**, and **sum dPCconnector** for each landscape to compare among the relative importance of intrapatch connectivity, patch connectedness and stepping stones for these three species. In order to address...
Objective 1 we also considered node importance metrics – $d_{PC}$, and its constituents $d_{PCintra}$, $d_{PCflux}$ and $d_{PCconnector}$. These metrics allowed us to see in more detail the roles patches play in connectivity.

**Objective 2: Locate and highlight patches outside of formally protected areas that may be valuable conservation priorities from the standpoint of connectivity**

The role of protected areas for regional connectivity was examined by establishing three classes of protection for habitat patches. We used the 2011 Metro Vancouver Landuse and Land Designation layers to identify protected areas, as well as an Abbotsford land use layer. Patches were assigned a class of protected, partially protected or unprotected based on the percent protected area of a patch. Patches which had areas >90% protected were classified as such. Patches were classified as partially protected if they had between 10% and 90% of their area protected, while patches with less than 10% of their area protected were classified as unprotected.

The relatively conservative threshold of 90% for the protected classification was chosen in order to accurately capture greenspace patches that were more or less contiguously protected, as well as to minimize the inclusion of patches with unprotected edges. Greenspace patches with unprotected edges might have a disproportionate effect on patch connectivity if development produced barriers to animal dispersal. **Key nodes**, the top 20 protected, partially protected and unprotected patches, ranked by $d_{PC}$, were selected for visualization.

**Objective 3: Identify patches throughout the region critical to greenspace connectivity including components, key nodes, hubs and overlap patches**

Using the NC and node importance metrics, we highlight critical **components** in each landscape, and we also visualize important hubs (patches that connect many other patches together) and stepping stone patches and their protected status. **Hubs** are. We determined **hub patches** to be those with a $d_{NC}$ less than zero – indicating their removal would adversely affect (increase) the number of components on the landscape – as well as the top 10 ranked patches for both degree (number of links) and $d_{PCconnector}$.

While some key nodes are also hubs, of particular note are the numerous small patches for all species identified as unprotected hubs. Finally, we assess the role that **overlap patches** play in connecting the subset landscapes together, and which are critical regional hubs.

To identify critical overlap patches, the membership of a patch in components in more than one subset landscape was used, along with patch degree, to identify patches that might be important for connecting the subset landscapes together. If patch degree increased for any patch that existed in multiple subset landscapes, the magnitude of the increase in degree was noted, as was that patch’s potential to connect components across subset landscapes. Patches that connected components across
subset landscapes, especially those components with large cumulative node importance metrics, were identified as critical for regional connectivity.
Objective 1

Pacific wren landscapes most connected, except in the south

The landscapes with the greatest connectivity (PC) and available habitat resources (EC(PC)) were those of the Pacific wren (Figure 3). The Douglas squirrel networks had PC values lower than those of the wren, but still considerably higher than the Townsend’s vole. An exception is in the SW subset landscape where the Townsend’s vole has the highest PC and EC(PC) values. This is in contrast to the number of components in each landscape (NC) which are highest for the vole across the board.

Figure 14 Overall connectivity metrics for each species and subset landscape. Pacific wren landscapes are the most connected, while vole patches are more isolated from each other. A shows nominal PC values while B shows PC on a log scale. For B, the shorter the bar, the higher the value of PC and the higher the connectivity. A and B show that the Pacific wren had the highest PC values in each subset landscape except in the SW. Plot C supports this with slightly more available landscape resources (EC(PC)) for the Townsend’s vole than the Pacific wren in the SW subset landscape. The Douglas squirrel tends to have values closer to that of the Pacific wren than the Townsend’s vole in the C, N, and NE subset landscapes. However, even when comparing the southern subset landscape as a whole PC values are still lower for the squirrel than either the wren or vole, with the squirrel seeing only slightly higher EC(PC) in the S subset than the vole’s SE subset. The number of components, meanwhile is highest for the vole and lowest for the wren, indicating, along with the PC metric, that vole patches tend to be more isolated from each other than either the squirrel or wren patches.
A large number of components relative to the number of patches would generally indicate lower connectivity, however, this can be offset by high intrapatch connectivity, which the Townsend’s vole networks have in abundance (Figure 4). The values of sum dPCintra are lower for the wren and squirrel, despite the large amounts of habitat for these species in the north and northeast subset landscapes. This is because sum dPCflux (i.e. patch interconnectedness), and sum dPCconnector – stepping stone importance – are considerably higher for these two species compared to the Townsend’s vole. It is important to reiterate here that each of these metrics – dPCintra, dPCflux and dPCconnector – are all components of dPC for each patch. The dPCflux metric also incorporates the area-weighted quality of a patch, as well as its maximum product probabilities to other patches. From a connectivity perspective, therefore, higher dPCflux values relative to dPCintra values are desirable because dPCflux considers both patch quality and connectedness, while dPCintra focuses solely on the habitat resources within individual patches. Comparing the metrics side-by-side shows how the relative importance of each measure changes with species and landscape.

Figure 4 also shows that stepping stones are of greater importance in the more connected wren and squirrel landscapes. This has implications for conservation management, as stepping stones in greenspace networks for the Pacific wren and Douglas squirrel need to be better identified and protected to maintain overall network connectivity than for the Townsend’s vole networks.
Figure 15 Node importance plots showing the cumulative importance for each species and subset landscape of (A) intrapatch connectivity, (B) individual patch connectedness, and (C) stepping stone importance. Intrapatch connectivity is the largest component of connectivity for the Townsend’s vole across all subset landscapes (A). Wren patches are the most connected to each other (B), closely followed by the Douglas squirrel in the C, N, and NE subsets. Stepping stone importance (C) is highest for the wren everywhere except the NE subset landscape where it is slightly less than that of Douglas squirrel.

**Large, high quality patches tend to have highest dPC**

Figures 5-7 provide a visualization of dPC values for each species for the entire study region. Though all subset regions are presented simultaneously, the reader is cautioned that dPC values are most relevant for each subset landscape only. Despite this, however, the patches with the highest dPC rankings still likely have high region-wide importance to connectivity. Also, the range of values for dPC is considerable in all subset regions and for all species, with significant variation existing in the lowest two classes shown, especially. For example, though Stanley and Pacific Spirit parks have relatively low dPC values in
Figure 16 Douglas squirrel patch importances. Each patch’s relative contribution to connectivity of each subset area (dPC) is displayed. Subset areas are surrounded by different border colours.

Figure 17 Pacific wren patch importances. Each patch’s relative contribution to connectivity of each subset area (dPC) is displayed. Subset areas are surrounded by different border colours.
the wren and squirrel central subset landscapes, their dPC values are much higher than many neighbouring patches in the city of Vancouver.

For the Pacific wren (Figure 6), large patches tend to be more important than smaller ones, with larger patches in the northern sections of the study region generally the most important. Exceptions are patches in Burn’s Bog, larger patches in Surrey, including Surrey Bend Regional Park and Tynehead Park, and the extensive forest around Sumas Peak in northeast Abbotsford. There are a large number of smaller patches in the southwest and southeast subset landscapes, many of which correspond to riparian areas. The overall pattern indicates that intrapatch connectivity is important, as is area-weighted quality – indicated by the importance of the smaller patches in protected areas. A more detailed treatment of the most important patches in and outside of protected areas is conducted below.

Douglas squirrel landscapes see a similar dPC pattern to the Pacific wren landscapes – with large northern patches the most important. There is, again, a notable exception in the south of the region for coniferous patches around Sumas Peak in northeast Abbotsford. The squirrel landscapes differ from the
wren, however, in that there are far fewer patches outside of the larger coniferous patches, showing the dominance of broad-leaved (or mixed tree) vegetation in more built-up areas of the study region.

The Townsend’s vole landscapes show a different patch distribution across the region, with wetland and agricultural areas best represented. Patch size also drives dPC values here, but so does quality alone, with a number of smaller wetland patches ranked among the most important. For example, Burn’s Bog and the Pitt and Coquitlam River wetlands stand out as important connectivity regions. However, agricultural lands are also important, with southeast Abbotsford seeing some of the highest dPC values.

**Node importances: big patches aren’t always the best stepping stones**

In the wren landscapes (Figure 8) a number of large patches in the north have relatively higher dPCflux than dPCintra values, indicating that high dPC values for some large patches is due to the combination...
of their area-weighted quality and connectivity to other patches, not merely their within-patch connectivity alone.

At the same time, some patches with high dPCflux values, such as those bordering Indian Arm, are relatively less important as stepping stones as indicated by dPCconnector. A number of smaller patches in the southeast subset region, meanwhile do have high dPCconnector values, indicating that they play an important role in connecting other patches together, despite their smaller size and/or lower quality.

A similar pattern can be seen in Douglas squirrel landscapes (Figure 9), where among the large northern patches, some are important for both dPCintra and dPCflux, and others’ importance varies with node importance metric. Patches nestled among other patches tend to have higher dPCflux and dPCconnector values than those on the periphery of a cluster. The lack of large coniferous patches in the more developed areas of the central and south of the region makes individual patch visualization difficult at this scale, however, a similar pattern to that seen in the north of the region is also realized: large, well-connected patches have the highest dPCflux and dPCintra values, while
smaller patches may take on surprisingly large dPCconnector values if they are important stepping stones.

Node importances for Townsend’s vole landscapes (Figure 10) show some of the same characteristics as for the other species, however, due to the vole’s short dispersal distance there is less variability across the three node importance metrics. Those patches that rank as most important for the dPCflux and dPCconnector metrics also have high intrapatch connectivity. At the same time, however, a number of patches that rank highly for dPCintra show lower importance for the other metrics, again indicating that connectivity among patches is generally low.

**Objectives 2 and 3**

*Key nodes and hubs outside of protected areas are conservation priorities*

We address Objective 2 by classifying patches for each species and subset landscape as either protected, partially protected or unprotected using the methodology detailed above (p.69). We then incorporate Objective 3 by mapping key nodes, hubs and components for each species along with their protected status to visualize which patches may be most in need of further conservation.
**Key nodes** in the north of the region (in the north, central and northeast subset landscapes) used by both the Pacific wren and Douglas squirrel are well-protected overall (Figure 11). However, for both species many of these key nodes have unprotected edges which themselves border less protected key nodes (e.g. Maple Ridge).

There are a number of unprotected key nodes for the Wren in the south of the region as well, potentially indicating that important forest patches in agricultural areas are not well protected. Forest patches near Sumas Peak in Abbotsford are also important for both the wren and squirrel, yet these patches are largely unprotected. With few large forest patches in this part of the region, and a high proportion of coniferous patches, those around Sumas Peak may be especially important for conservation.

With exception of some wetland areas, such as Burn’s Bog, and near the Pitt and Coquitlam rivers,
A similar pattern in the north of the region is seen with respect to patches identified as important hubs of connectivity (Figure 12), especially in Maple Ridge, but also North and West Vancouver. The upshot is that the connectivity of the large northern reserve patches to more urbanized areas is not assured. These reserve patches are likely a net source of emigrants for both the wren and squirrel, but it is possible that development near the edges of these reserves could remove patches that act as important stepping stones to more developed parts of the region.

Many of the unprotected hubs occur in the south of the study region, however, there are small
unprotected hubs for all species in the more densely populated sections of the central landscape corresponding to Vancouver, Burnaby and Richmond. These unprotected hubs are potential conservation priorities as they may be important stepping stones benefitting regional connectivity.

**Large groups of connected patches show extent of landscape connectivity:** They can also expand dramatically with overlap patches

Objective 3 is also concerned with **components** and **overlap patches** that are critical for regional connectivity. The extent of connectivity of the Pacific wren landscapes when considering components is shown well in Figure 13. Most subset landscapes are dominated by just one or two components. Furthermore, as shown in Figure 14, once overlap patches are considered, the largest components in the central, northeast, southwest and southeast subset landscapes are actually a single component.

![Wren](image1.png)

![Squirrel](image2.png)

![Vole](image3.png)

Figure 24 The most important components for each species and subset regions, differentiated by colour. A maximum of the top 5 most important components in each subset landscape are shown, chosen by the sum of their patches’ dPC values.
The Douglas squirrel also has large components in the north of the study region, but component coverage is much lower throughout most of the central and southern subset landscapes. Meanwhile, the Townsend’s vole has very little component coverage in the north or central subset landscapes, though the agricultural and wetlands in the northeast subset near the Pitt River are extensive. The majority of the vole components occurs in the agricultural lands in the southwest and southeast subset landscapes.

The extent of Townsend’s vole components would likely change, however, when considering overlap patches along the border of the SE and SW subset landscapes. Though it was not possible at the time of writing to visualize new components that would be created as a result of the overlap patches bridging the subset landscapes, it is likely that further analysis would should a number of new, large vole components in the south of the subset region.

No Squirrel subset landscapes contained overlap patches that were important for connecting subset landscapes together. This is due to Squirrel dispersal being restricted by water, as well as a single
southern subset landscape used for modelling squirrel connectivity.

Figure 26 Townsend’s vole overlap patches and major components. Overlap patches are shown in yellow if they are a member of only 1 component across subset landscapes and orange if they are a member in 2 components.
Summary of priority conservation areas
Unprotected key nodes and hubs, as shown in Figures 11 and 12 are likely to be high conservation priorities. Specific attention should be given to unprotected wren (all forest) and squirrel (coniferous) key nodes and hubs, especially in built-up areas and in the south of study region.

Overlap patches with more than one component membership – especially those on Barnston Island, and nearby riverside patches in Pitt Meadows and Port Coquitlam), are also high conservation priorities. Similarly, riverside patches in Maple Ridge, Surrey and Langley should be assessed for protected status and conservation possibility. Finally, unprotected overlap patches at the Surrey Langley border, should be identified and targeted for conservation if possible.

Caveats and limitations of the study
Caution should be used when deriving species-specific conclusions from these connectivity results. Assumptions about landcover type usage were taken from a literature review but may not be reflective of actual species behaviour. For example, Surrey’s Biodiversity Conservation Strategy notes that both the Douglas squirrel and Pacific wren use all forest types present in the landcover, which may be more realistic than the assumptions used here (City of Surrey, 2014). Also, the patches used in this connectivity analysis are not informed by presence or absence data for any species. Patches included as potentially useable by a species may, in fact, not be suitable and vice versa, and a species may not actually exist there even if a patch is suitable. For example, though Pacific wrens can move through a variety of forest types, they prefer larger coniferous forest patches and tend to avoid even moderately built-up areas (Farwell & Marzluff, 2013). Interspecific interactions also affect how each species uses the landscape – something especially true for territorial and development-sensitive species such as the Douglas squirrel and Pacific wren, with Farwell and Marzluff (2013) showing that declining Pacific wren populations in developing areas were exacerbated by aggressive interactions with Bewick’s wrens.

As noted above, carnivorous mammals have been shown to be imperfect umbrella species for connectivity studies precisely because of their generalist life histories and long dispersal distances. In our study, we had initially planned to use the coyote as one of our focal species. This generalist species has been shown to be quite commensal with human settlement, adeptly traversing the urban matrix. However, because coyotes are so adaptable it made modelling functional connectivity for this species unfeasible given our methodology. Based on a literature review and the expert opinion of urban coyote scholars, we found that coyotes could make use of all vegetation types present in the 2014 landcover layer at highly variable sizes down to less than 1ha. At the same time, maximum dispersal distances
were very long, as supported by telemetry and minimum home range size analyses. The combination of coyotes’ ability to use quite small patches of variable type and quality, as well as their ability to travel large distances led to computational challenges – there were too many patches with too many links to other patches for Conefor to evaluate efficiently. Indeed, we could only generate links for the smallest subset area, the NE subset, and we found the area fully connected – i.e. all patches were connected to all other patches via tens of thousands of links. A landscape that is so hyper-connected for a species does give us some information, however, it makes prioritizing conservation efforts difficult and obscures the role of greenspace patches for other species.

The patch size chosen for the vole was a compromise between ecological representativeness and processing efficiency. Through a literature review we approximated an individual vole’s average home range to be 0.05ha. Selecting non-forested vegetation patches of this size, however, yielded far too many patches to process given the methods and computing power at our disposal. Voles do not tend to live in isolation, either, but in quite large colonies covering extensive agricultural and wetland areas. We therefore chose a minimum patch size for the vole of 0.5ha. This significantly reduced the number of potential habitat patches, allowing us to run a connectivity model. The result is, however, that by removing some of the smallest vole patches, we have likely removed potential stepping stones between larger patches. The result of this is to build a model of connectivity for the vole that is less connected than is otherwise conceivable. However, with the bulk of likely vole habitat captured at a finer scale than previously possible for the region, we believe that our model is still representative of vole habitat and its connectivity. Furthermore, the smaller the patch size included in the model, the more uncertainty surrounding its correct classification in the landcover from which it is derived. Therefore, we feel that our conservative approach here is the best one given the circumstances.

Artificial boundaries are almost always placed around landscapes in connectivity analyses, and this study was no exception. This issue was exacerbated here, however, because of our need to create subset landscapes of Metro Vancouver in order to create our connectivity models. One important fallout of this was our inability to assign accurate PC metric values to overlap patches. Though we still identified patches in 500m overlap areas that may be critical for regional connectivity, we could not fully quantify their contribution to connectivity for the region. A less important, but related, issue was that our calculation of $A_c$ did not include patches that are part of the 500m overlap into the next subset area. This means that resultant PC values for each landscape were slightly larger than if the area of overlap patches was included. However, we feel that this doesn’t prevent comparison among the subset areas.
for two reasons: (1) the area of overlap patches was generally small compared to total landscape area, and (2) where more substantial overlap did exist between the SW and SE subset, the area of overlap was of a similar magnitude, allowing for comparison among subset landscapes.

Another limitation of our analysis is that links are represented using Euclidean (straight line) distances between patches. More complex analyses have used software such as Linkage Mapper (McRae & Kavanagh, 2011) to generate least cost path distances between patches before using graph theory methods. Least cost paths are generated through a ‘cost’ raster, with pixels given values according to their degree of resistance to an animal’s movement. The least cost path between two patches minimizes the cumulative resistance of a path through the cost raster. The result would be links among patches that take a more ‘realistic’ route, often avoiding areas of high resistance, though it should be noted that cost rasters are often quite subjective approximations.

Conefor can also calculate more sophisticated link metrics, however, they are computationally intensive, and were not feasible for use in this analysis. Combined with a least cost path approach to links among patches, link metrics may further enhance a future study by moving beyond patch prioritization to an assessment of the most important routes among patches in a landscape.

**Recommendations for further study**

Despite these limitations, the results do provide insight into regional connectivity for the three species investigated. We have highlighted important patches inside and outside of protected areas for each species, as well as greenspace in the region that might be important for all three species. We recommend further study using a larger suite of species that also addresses some of the limitations laid out above. Namely,

- Connectivity modelling for a wider range of species
- The incorporation of species presence/absence data
- The use of least cost paths as links among patches
- Incorporation of link importance metrics
- Finer-scale analysis of the role of small patches in landscape connectivity
- The inclusion of overlap patches into the total landscape area ($A_l$) for each subset landscape
- And the use of computing resources that would enable the entire region to be modelled as a single landscape.
References


City of Surrey. (2014). *Biodiversity Conservation strategy.*


Saura, S., & Torné, J. (2012). CONEFOR 2.6 User manual (pp. 1–19).


Climate Action Committee
To: Climate Action Committee

From: Josephine Clark, Regional Planner
Parks, Planning and Environment Department

Date: May 7, 2018
Meeting Date: June 6, 2018

Subject: Update of the Metro Vancouver Sensitive Ecosystem Inventory (SEI)

RECOMMENDATION
That the MVRD Board receive for information the report titled “Update of the Metro Vancouver Sensitive Ecosystem Inventory (SEI)” dated May 7, 2018.

PURPOSE
This report provides the Climate Action Committee and MVRD Board with the results from the first 5-year update of the Metro Vancouver Sensitive Ecosystem Inventory.

BACKGROUND
This report provides the results of the ‘Update of the Metro Vancouver Sensitive Ecosystem Inventory (SEI)’, which is identified on the Climate Action Committee’s 2018 work plan in the second quarter.

The Metro Vancouver SEI was originally completed in 2013 and was the first GIS inventory of ecologically significant lands for the region. This 5-year update documents changes to mapped ecosystems and quantifies the amount, rate and type of ecosystem loss. Results are summarized for the entire region and regional core (primarily developed area).

METRO VANCOUVER’S SENSITIVE ECOSYSTEM INVENTORY
The Metro Vancouver SEI was initiated in response to the need for up-to-date, standardized ecological information for the region to facilitate conservation of important ecological areas through informed land use and conservation planning, and increased awareness of ecosystem presence and declines. The ecologically important areas mapped in the SEI provide key ecosystem services to the region including carbon storage, local climate control, and flood absorption, and contribute to our resilience to climate change. They also provide vital habitat and connectivity for biodiversity, including species at risk.

The SEI was conducted according to Provincial standards for mapping ecologically significant ‘Sensitive Ecosystems’, including wetlands, older forests and woodlands. In addition, ‘Modified Ecosystems’ such as old fields and young forest were also mapped. Modified Ecosystems are younger and more human modified but still have ecological value and importance to biodiversity. The majority of mapped ecosystems, particularly in the more urbanized areas of the region, show evidence of disturbance which is also documented in the inventory. The SEI classification system is provided as Attachment 1.
Use of the Sensitive Ecosystem Inventory Data
Multiple Metro Vancouver plans and projects have used the SEI data to incorporate ecological considerations into their work, including the regional growth strategy, the Ecological Health Action Plan, environmental assessments of utilities projects, and most recently, the Regional Parks Land Acquisition Strategy. The SEI has been extensively requested by other levels of government, industry, non-profits and academia, and over 80 data sharing agreements have been established over the last 5 years to provide access. In 2019, the SEI will be made available via Metro Vancouver’s open data portal to reduce barriers to its use and maximize accessibility.

UPDATING THE SENSITIVE ECOSYSTEM INVENTORY
To ensure the Metro Vancouver SEI continues to be an effective and relevant land use and conservation planning tool, it must be kept up to date. Updates document changes to Sensitive and Modified Ecosystems after 5 years and quantifies the amount, rate and type of ecosystem loss.

Using 2014 regional orthophotos, ecosystem polygons were reviewed, and any loss or disturbance was documented. Improvements to the original mapping were also made through error correction and additional field work to confirm and inform mapping decisions.

RESULTS
Region and Regional Core
Tables 1 and 2 below depict ecosystem losses summarized for the region and the regional core (see Map 1). The regional core is the more urbanized southern part of the region and excludes the large parks and estuaries under Provincial management, watersheds and other higher elevation areas. The regional core is most relevant to policy and planning and is where municipal decisions and actions will have the most impact.

Overall, total loss of sensitive and modified ecosystems over 5 years was 1,640 hectares (ha) (0.9%) for the region, and 1,190 ha (3.4%) within the regional core.

<table>
<thead>
<tr>
<th>Sensitive Ecosystems (SE)</th>
<th>Modified Ecosystems (ME)</th>
<th>Totals – SE and ME</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Original SEI (Ha)</strong></td>
<td><strong>Loss (Ha)</strong></td>
<td><strong>% Loss</strong></td>
</tr>
<tr>
<td>Region</td>
<td>150,435</td>
<td>661</td>
</tr>
<tr>
<td>Regional Core</td>
<td>24,958</td>
<td>426</td>
</tr>
</tbody>
</table>

Table 1 – Sensitive and Modified Ecosystem Loss for the Region and Regional Core
As shown in Table 2 below, at both the region and regional core scale, losses for the 5-year period were highest for mature forest, young forest, old field, wetlands and riparian ecosystems.

<table>
<thead>
<tr>
<th>Ecosystem Type</th>
<th>Region Original SEI (Ha)</th>
<th>Region Loss (Ha)</th>
<th>Region % Loss</th>
<th>Regional Core Original SEI (Ha)</th>
<th>Regional Core Loss (Ha)</th>
<th>Regional Core % Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensitive Ecosystems</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alpine</td>
<td>14,536</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Estuarine</td>
<td>8,636</td>
<td>1</td>
<td>0.0%</td>
<td>1,245</td>
<td>1</td>
<td>0.1%</td>
</tr>
<tr>
<td>Freshwater (SE)¹</td>
<td>7,119</td>
<td>1</td>
<td>0.0%</td>
<td>425</td>
<td>1</td>
<td>0.3%</td>
</tr>
<tr>
<td>Herbaceous</td>
<td>114</td>
<td>0</td>
<td>0.2%</td>
<td>89</td>
<td>0</td>
<td>0.3%</td>
</tr>
<tr>
<td>Intertidal</td>
<td>8,129</td>
<td>1</td>
<td>0.0%</td>
<td>153</td>
<td>0</td>
<td>0.2%</td>
</tr>
<tr>
<td>Mature Forest (SE)²</td>
<td>22,030</td>
<td>424</td>
<td>1.9%</td>
<td>7,646</td>
<td>223</td>
<td>2.9%</td>
</tr>
<tr>
<td>Old Forest</td>
<td>34,343</td>
<td>10</td>
<td>0.0%</td>
<td>118</td>
<td>0</td>
<td>0.1%</td>
</tr>
<tr>
<td>Riparian</td>
<td>30,705</td>
<td>97</td>
<td>0.3%</td>
<td>7,971</td>
<td>74</td>
<td>0.9%</td>
</tr>
<tr>
<td>Sparsely Vegetated</td>
<td>9,187</td>
<td>1</td>
<td>0.0%</td>
<td>96</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Wetland</td>
<td>9,973</td>
<td>122</td>
<td>1.2%</td>
<td>6,899</td>
<td>122</td>
<td>1.8%</td>
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<tr>
<td>Woodland</td>
<td>5,663</td>
<td>4</td>
<td>0.1%</td>
<td>316</td>
<td>4</td>
<td>1.1%</td>
</tr>
<tr>
<td><strong>Total - Sensitive Ecosystems (SE)</strong></td>
<td>150,435</td>
<td>661</td>
<td>0.4%</td>
<td>24,958</td>
<td>426</td>
<td>1.7%</td>
</tr>
</tbody>
</table>

| Modified Ecosystems          |                          |                  |               |                                |                        |                     |
| Freshwater (ME)¹             | 142                      | 0                | 0.0%          | 139                            | 0                      | 0.0%                |
| Mature Forest (ME)²          | 4,576                    | 93               | 2.0%          | 2,266                          | 80                     | 3.5%                |
| Young Forest                 | 21,385                   | 459              | 2.1%          | 5,495                          | 258                    | 4.7%                |
| Old Field                    | 2,134                    | 426              | 20.0%         | 2,134                          | 426                    | 20.0%               |
| **Total – Modified Ecosystems (ME)** | 28,237             | 979             | 3.5%          | 10,038                          | 764                    | 7.6%                |
| **Total – SE and ME**        | **178,672**              | **1,640**        | **0.9%**      | **34,996**                      | **1,190**              | **3.4%**            |

*Table 2 – Loss by Ecosystem Type for the Region and Regional Core*

**Characterizing Ecosystem Loss**

The nature of ecosystem loss observed over the last five years ranges widely, from clearing of large, high quality ecosystems, to small, disturbed remnant patches. This loss often involved the removal of relatively small pieces from the edges of a larger area of vegetation, best described as ‘nibbling’. Further analysis into the loss of high versus lower quality sites, as well as the size of lost areas will help to better understand the nature of ecosystem loss. This will enable policymakers to make better informed conservation and land use planning decisions. Preliminary analysis is provided below for ecosystem classes that experienced the most loss.

¹ Freshwater ponds and lakes are considered Sensitive Ecosystems. Freshwater reservoirs are Modified Ecosystems.
² Mature Forests are considered a Sensitive Ecosystem class if they are coniferous or mixed and over 5 ha in size. Coniferous or mixed Mature Forests of less than 5 ha, and broadleaf of any size, are considered Modified Ecosystems.
Mature and Young Forests
The large Provincial parks and protected watersheds in the northern part of the region are home to large amounts of old forest (>250 years old), but outside of these areas, remaining forests are mature (80-250 years old) or young (30-80 years old). Between 2009 and 2014, mature and young forests saw the greatest declines of all ecosystem classes. Only patches of young forest greater than 5 ha are considered to be ‘Modified Ecosystems’ within the SEI; therefore, actual loss of young forest is larger than reported in Table 2. However, because smaller patches of young forest are still important, particularly given the rate and extent of forest loss across the region, smaller patches of young forest were mapped as part of the SEI process and are included in Table 3 below to provide a more complete picture of regional forest loss.

As summarized in Table 3, 1,162 ha (2.2%), of the region’s mature and young forests were converted to other land uses over the 5-year period. For the regional core, these losses were 730 ha (3.9%).

<table>
<thead>
<tr>
<th>Region</th>
<th>Original SEI (Ha)</th>
<th>Loss (Ha)</th>
<th>% Loss</th>
<th>Original SEI (Ha)</th>
<th>Loss (Ha)</th>
<th>% Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mature Forest (SE and ME)</td>
<td>26,606</td>
<td>518</td>
<td>1.9%</td>
<td>9,912</td>
<td>303</td>
<td>3.1%</td>
</tr>
<tr>
<td>Young Forest (ME)</td>
<td>21,385</td>
<td>459</td>
<td>2.1%</td>
<td>5,495</td>
<td>258</td>
<td>4.7%</td>
</tr>
<tr>
<td>Small Young Forest (non SE or ME)</td>
<td>5,410</td>
<td>185</td>
<td>2.2%</td>
<td>3,186</td>
<td>169</td>
<td>5.3%</td>
</tr>
<tr>
<td>Total</td>
<td>53,401</td>
<td>1,162</td>
<td>2.2%</td>
<td>18,593</td>
<td>730</td>
<td>3.9%</td>
</tr>
</tbody>
</table>

Table 3 – Loss of Mature and Young Forests

Old Field
Old field sites were often formerly cultivated or grazed but later abandoned. As an intermediate stage in succession, without management they will eventually become forest. The figures in Table 2 show that 426 ha of old field were lost due to mowing or development. However, those that were mowed rather than developed may be allowed to return to an old field state over time.

Wetland
All losses to freshwater wetland ecosystems occurred in the regional core and totaled 122 ha (1.8%). Loss was largely for wetland swamp (82 ha) and bog (35 ha) that was drained or cleared.

Riparian
A total of 97 ha of riparian ecosystems were lost and of this, 75 ha was riparian fringe (i.e. vegetation along water bodies where there is no floodplain). The majority of riparian fringe ecosystems lost was forested.

Ecosystem Loss and Metro 2040
Preliminary analysis looked at how much loss took place within each of the Metro 2040 land use designations. The results show that 37% of the losses occurred on lands designated as Agricultural, and 29% on Conservation and Recreation lands. Most old field loss was found within the Agricultural designation and further analysis will be completed to ascertain how much loss was due to mowing,
which may not be a permanent loss. Loss within the Conservation and Recreation designation was surprisingly high, but over half was accounted for by harvesting within academic research forests and woodlots. Further analysis will be undertaken to understand other reasons for observed losses.

**Understanding Loss Implications and Future Analysis**

This update is the first time loss has been quantified at the regional level. It establishes a baseline understanding against which future rates of change can be compared, while recognizing that considerable loss and degradation of ecosystems occurred in the preceding approximately 150 years as the region’s urban and agricultural areas grew.

*Metro 2040* contains policies intended to ‘Protect Conservation and Recreation Lands’ (Strategy 3.1) and ‘Protect and enhance natural features and their connectivity’ (Strategy 3.2). Given these policies were adopted in 2011, the speed and scale of loss observed in the SEI update are concerning and suggest a need to assess and strengthen protection efforts.

To inform this assessment and better understand the loss observed, further analysis of the SEI dataset will be undertaken, including:

- an assessment of the proportion of high quality and relatively undisturbed areas lost versus more disturbed areas, and the proportion of larger versus smaller areas lost;
- which sensitive ecosystems are protected and which are not;
- 5-year changes in ecosystem quality (e.g. condition, size, etc.) at the regional and regional core levels;
- Sub-regional breakdowns of ecosystem loss and changes in ecosystem quality;
• Loss quantified by disturbance type (e.g. agricultural, residential, industrial, etc.); and,
• Ecosystem loss in each Metro 2040 land use designation.

The data and information produced from the SEI update will be disseminated to staff from member jurisdictions, among others.

**ALTERNATIVES**
This is an information report. No alternatives are presented.

**FINANCIAL IMPLICATIONS**
Costs associated with the Metro Vancouver Sensitive Ecosystem Inventory update were included in approved program budgets and work plans.

**SUMMARY / CONCLUSION**
The Metro Vancouver Sensitive Ecosystem Inventory (SEI) update provides key insights into the state of the region’s most important ecological areas and changes over a 5-year period. The amount, rate and type of ecosystem loss was quantified at both the regional and regional core (i.e. primarily developed parts of the region) scales. Total loss of sensitive and modified ecosystems over 5 years was 1,640 ha (0.9%) for the region, and 1,190 ha (3.4%) for the regional core. Losses were highest for mature forest, young forest, old field, wetland, and riparian ecosystems. Over 1,162 ha (2.2%) of the region’s mature and young forests were converted to other land uses over the 5-year period. For the regional core, these losses were 730 ha (3.9%).

Given the policies in place in Metro 2040 to preserve natural areas and connectivity, the speed and scale of loss observed in the SEI update are concerning and suggest a need to assess and strengthen protection efforts. Further analysis of the SEI dataset will be completed, including to characterize loss in more detail, assess the protection status of sensitive ecosystems, and quantify loss by disturbance type. This analysis will help Metro Vancouver and its member jurisdictions understand the state of the region’s environment and inform future policies and actions. Updating the SEI will ensure it continues to be an effective and relevant land use and conservation planning tool for the many users across the region.

**Attachment**
1. Metro Vancouver Sensitive Ecosystem Inventory Classification System

25352959
### SENSITIVE ECOSYSTEMS

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<th>SUBCLASS</th>
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<td>Avalanche tracks</td>
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### MODIFIED ECOSYSTEMS

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To: Climate Action Committee

From: Roger Quan, Director, Air Quality and Climate Change
Parks, Planning and Environment Department

Date: May 25, 2018

Subject: Manager’s Report

RECOMMENDATION
That the Climate Action Committee receive for information the report dated May 25, 2018, titled “Manager’s Report”.

Climate Action Committee 2018 Work Plan
Attachment 1 to this report sets out the Committee’s Workplan for 2018. The status of work program elements is indicated as pending, in progress, or complete. The listing is updated as needed to include new issues that arise, items requested by the Committee, and changes to the schedule.

International Airshed Strategy Meeting
The Georgia Basin Puget Sound International Airshed Strategy Coordinating Committee brings together air quality staff from jurisdictions in the Pacific Northwest, at the national, provincial/state, and regional levels. Membership from the US includes US Environmental Protection Agency Region 10, Washington State Department of Ecology, the local clean air agencies of Puget Sound, Northwest Washington, Olympic Region, and the Whatcom Conservation District. Canadian representatives include Environment and Climate Change Canada, Health Canada, BC Ministry of Environment and Climate Change Strategy, Fraser Valley Regional District, and Metro Vancouver. Other health and agricultural agency representatives also participate from time to time.

This group meets twice per year to coordinate on air quality policy and regulation development, monitoring, compliance and enforcement, education and outreach, technological developments, and best practices. The 2018 meeting will be hosted by Metro Vancouver, and will be held on June 4 – 5. Agenda topics include updates from all agencies, climate change actions, residential wood combustion initiatives, emerging developments in monitoring (including citizen science monitors), a session on health impacts, coordination on wildfire smoke management and messaging, and other education and outreach initiatives.

Revisions to Liquid Waste Heat Recovery Policy to Clarify Carbon Credit Allocation
At its May 25, 2018 meeting, the GVS&DD Board approved the revised Liquid Waste Heat Recovery Policy as presented in the report dated May 4, 2018, titled “Revisions to Liquid Waste Heat Recovery Policy to Clarify Carbon Credit Allocation. The revisions address the allocation of carbon credits to project proponents, including the host jurisdiction, for heat recovery projects undertaken by GVS&DD that achieve GHG emission reductions, and subsequent distribution of excess credits among member jurisdictions. The following clauses were added to the policy for effluent heat recovery projects:

Carbon credits will be allocated to the host jurisdiction as a project proponent for contributions to the project that can be financially valued (other than Tier 1 and 2 cost apportionments). In recognition of the important role of the host and of impacts that

Climate Action Committee
cannot be valued financially, the host jurisdiction will receive 5% of the credits allocated to GVS&DD, for the initial term of the agreement for the sale of heat.

Carbon credits from GVS&DD emissions reduction projects that have been allocated to GVS&DD as a project proponent will be retained by GVS&DD, up to the amount needed for GVS&DD to be carbon neutral in a given year. If GVS&DD achieves carbon neutrality in a given year, excess carbon credits will be transferred to member jurisdictions.

The distribution of excess carbon credits among member jurisdictions will be calculated based on capital contribution to the portfolio of GVS&DD liquid waste heat recovery emissions reduction projects. Calculated excess carbon credit distributions less than one tonne will not be transferred, but will instead be redistributed among the other member jurisdictions.

The report dated May 4, 2018, titled “Revisions to Liquid Waste Heat Recovery Policy to Clarify Carbon Credit Allocation” is item E2.2 in the GVS&DD Board Meeting Agenda - May 25, 2018.

New Continuous VOC Monitoring
A new air quality monitoring instrument was acquired this year to improve Metro Vancouver’s ability to measure a number of volatile organic compounds (VOC), such as benzene, toluene, ethylbenzene, xylene and 1-3 butadiene. Some of these pollutants are referred to as toxic air pollutants with potential health effects including cancer and a variety of non-cancer effects. With this new instrument they can now be monitored continuously, which augments the ongoing program of measuring VOC at several stations in the monitoring network by collecting air samples over a 24-hour period for later analysis in a federal laboratory. This instrument will help assess the air quality implications of emissions from transportation, home heating and industrial operations, including petroleum refining and distribution. Once testing is completed, this new instrument can be set up in existing air quality monitoring network stations or in Metro Vancouver’s mobile air monitoring unit (MAMU).

Improving Information Available During Wildfire Smoke Events
In advance of the summer of 2018, Metro Vancouver has led an initiative to develop more effective communication about wildfire smoke for residents in the Lower Fraser Valley. A working group involving staff from Metro Vancouver, Environment and Climate Change Canada, Health Canada, BC Ministry of Environment and Climate Change Strategy, Fraser Valley Regional District, Northwest Clean Air Agency, Vancouver Coastal Health, Fraser Health, BC Lung Association and BC Centre for Disease Control, has reviewed the information provided to the public from agencies in the summer of 2017, assessed gaps that may have exacerbated public concern during wildfire events, and is working on mechanisms to ensure that the public receives consistent messaging from credible sources when wildfire smoke causes air quality degradation in the airshed.

A resource package is being created that contains material about priority topics including the impacts of wildfire smoke on human health and air quality, advice about how to mitigate exposure to wildfire smoke, and information about how to get updates about smoke forecasts and air quality measurements, and how to reduce emissions. BC Centre for Disease Control is developing information related to health protection during wildfire smoke events, with input from health agencies. Air quality agencies are collaborating on guidance to help people find relevant air quality information while the airshed is being impacted by wildfire smoke. Agreement on content is being
sought from all agencies participating in the working group to allow timely proactive outreach to be conducted and efficient responses to be provided to the public.

**City of Langley Urban Agriculture Demonstration**
At its May 25th meeting, the MVRD Board received an information report on the status of projects that had received funding from the Regional District Sustainability Innovation Fund (SIF). One of the updates pertained to the City of Langley Urban Agriculture Demonstration project. The project had received $50,000 from SIF in 2016, and staff have provided additional clarification that the funding was used to support development of a concept plan, business plan, engagement activities, and preparation of a report conveying lessons learned from the project. The funding did not include any allocation for construction.

**Attachment**
1. Climate Action Committee 2018 Work Plan

25376485
## Priorities

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<td>Update on DC Fast Charger project at Metro Tower III (SIF project)</td>
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<td>Results of first phase of consultation on development of a regional odour management strategy</td>
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<td>Framework for update to Air Quality Management Plan, including discussion paper</td>
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<td>Metro Vancouver’s climate actions and carbon neutral progress for 2017</td>
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From: Karen Tam Wu [mailto:karentw@pembina.org]
Sent: May-02-18 3:14 PM
To: Mayor
Subject: Letter to B.C. Environment Minister George Heyman

Dear Mayor Corrigan,

As a member of B.C.’s Climate Solutions and Clean Growth Advisory Council, I wanted to share this news with you.

Last week, the council sent a letter to B.C. Minister of Environment and Climate Change Strategy George Heyman, regarding the government’s commitment to release a climate solutions and clean growth strategy in the fall.

As we wrote in our letter, this strategy should be as much an economic plan as an environmental plan. It must cut carbon pollution, while at the same time clearly signalling that B.C. is open for business in the low-carbon economy.

Read the full letter.

The council will be advising the government on the strategy, and I’ll endeavor to keep you informed about this important process.

Sincerely,
Karen

Karen Tam Wu, RPF
B.C. Director (acting) | Pembina Institute
karentw@pembina.org | c: 778-846-5647
Suite 610, 55 Water Street, Vancouver, BC, V6B 1A1
www.pembina.org

Manage emails.
April 25, 2018

The Honourable George Heyman  
Minister of Environment and Climate Change Strategy  
Province of British Columbia  
Legislative Buildings  
Victoria, British Columbia V8W 9E2

Dear Minister Heyman,

Thank you for the opportunity to contribute to British Columbia’s actions on climate change and clean growth. Given the critical importance of these issues, we are honoured to advise you and your government.

We welcome the government’s commitment to release a *Climate Solutions and Clean Growth Strategy* in fall 2018. In our view, this strategy should signal a steady, committed and iterative approach to climate action that consistently drives down emissions and increases economic opportunities for all British Columbians, while strengthening community and household resilience.

The *Climate Solutions and Clean Growth Strategy* should be as much an economic plan as an environmental plan. It must cut carbon pollution, while at the same time enabling low-carbon innovation and supporting just transitions for workers and communities. The *Climate Solutions and Clean Growth Strategy* should clearly signal that British Columbia is open for business in the low-carbon economy as a competitive and leading jurisdiction for investors.

The Climate Solutions and Clean Growth Advisory Council (the Council) supports the government’s carbon tax increase which provides an incentive to invest in clean energy and promotes clean growth while providing resources to support household affordability. We also support the steps government is taking towards competitiveness for the industrial sector.

We recommend the *Climate Solutions and Clean Growth Strategy* be integrated with other developing provincial strategies, particularly the energy roadmap and the economic development strategy. We feel that creating a single integrated strategy, as other jurisdictions have successfully done, will best position British Columbia for long-term success.
Climate Solutions and Clean Growth Advisory Council

Our Principles

Since being formed, the Council has been focused on providing a foundation for the work ahead. We have identified a set of principles to guide our work. Our advice will respect Indigenous perspectives and the goal of reconciliation, and will be designed with the following principles in mind:

1. Demonstrating Ambitious Leadership
2. Ensuring Credible, Durable, and Cost-Effective Policies
3. Creating Prosperity and Jobs
4. Supporting a Just Transition
5. Enabling Industry Competitiveness
6. Increasing Community Resilience
7. Respecting Diversity and Ensuring Equity
8. Committing to Meaningful Engagement

We include additional detail on these principles in the attachment.

The Council is aware of the debate surrounding industrial projects. In our Principles, the Council emphasizes the importance of an integrated, balanced and ambitious approach that reconciles credible and effective climate action that delivers significant emission reductions in line with targets, and the active pursuit of economic development across British Columbia that includes industrial projects.

The Climate Solutions and Clean Growth Strategy

The Council understands that the government’s Climate Solutions and Clean Growth Strategy will include a vision for climate action and clean growth, updated legislated targets, and certain foundational actions and sectoral plans for transportation; buildings and communities; and industry to meet the sectoral targets.

Government has proposed a workplan that is structured, measured and deliberate which we support. It is important that government move forward with concrete actions that set us on a path towards our targets and demonstrates sincerity and credibility regarding our collective commitment to meeting these targets. We recognize the context within which the strategy is implemented will change over time. The constraints and opportunities that will present themselves in future decades cannot be easily predicted. Plans will evolve over time and will need to be evaluated and updated on a regular basis.

As you develop the Climate Solutions and Clean Growth Strategy, we recommend the following as it relates to reduction targets.
Climate Solutions and Clean Growth Advisory Council

Updated Reduction Targets

Greenhouse gas (GHG) reduction targets drive governments to reduce carbon and create goal-oriented climate action policies. We know British Columbia will not meet its existing 2020 target. However, the province can meet its target to reduce emissions by 80 per cent below 2007 levels by 2050. We must reach this long-range target and do our part to keep global warming well below two degrees.

To help achieve the 2050 target, we support government’s intention to repeal the 2020 target and your proposal to introduce a new legislated target of reducing emissions by 40 per cent below 2007 levels by 2030. In addition, we recommend government establish and legislate a 2040 target. We also recommend government adopt targets for 2025 and 2035, to help ensure that we are on track for the 2030 and 2040 targets.

We also support your commitment to implement sector-specific targets for three sectors: transportation; industry; and, buildings and communities. These targets help focus efforts on early action to change the existing GHG emissions curve. There is already a substantial body of work and consultation that has been undertaken on targets, including a recommendation from the 2015 Climate Leadership Team. In light of this, we recommend you update the sectoral targets previously recommended by the Climate Leadership Team. We support targets that are the most cost effective option with the information available on technologies and trends at this time. We understand this is a 30 percent reduction by 2030 for industry, 30 percent for transportation, and a 60 percent reduction for buildings and communities.

We understand government will consult on these matters and we will provide additional advice after the consultation has been completed.

2015 Climate Leadership Team Recommendations

Further to your request, we have reviewed the 2015 Climate Leadership Team’s recommendations and have prioritized the following as input to the upcoming sectoral plans:

**Low Carbon Fuel Standard:** The transportation sector produces approximately 39 per cent of British Columbia’s total greenhouse gas emissions. We can significantly reduce emissions in this sector via British Columbia’s existing Renewable and Low Carbon Fuel Standard. The Government of Canada has also begun consultations to develop a Clean Fuel Standard that can reduce Canada’s carbon emissions by increasing the use of lower carbon fuels, energy sources, and technologies. British Columbia’s Renewable and Low Carbon Fuel Standard requires a 10 per cent reduction in the average carbon intensity of transportation fuels by 2020 and we recommend investigating the strengthening of the fuel standard beyond 2020.

**Zero Emissions Vehicles (ZEVs):** In 2015, British Columbia joined 13 other jurisdictions under the International ZEV Alliance, which is working to ensure all new passenger vehicles will produce zero emissions by the year 2050. Many jurisdictions have already taken action to get there. We support government’s commitment and advise that British Columbia’s *Climate Solutions and Clean Growth Strategy* will need to define clear actions to reach this goal in keeping with our Principles.
Building Emissions: Buildings contribute approximately 11 per cent of British Columbia’s greenhouse gas emissions. Existing buildings present a considerable challenge to reaching our emissions reduction goals, as they will continue to stand beyond our 2050 reduction target. We recommend the province adopt a suite of policies to target new and existing buildings.

Incentivizing Clean Growth and Addressing Competitiveness: Industrial sectors provide well-paying jobs for thousands of British Columbians and produce approximately 39 per cent of our province’s carbon emissions. We support government’s proposed clean growth incentive program, which would set a global标准 as a basis for redirecting incremental carbon pricing revenue back into the industrial sector and also providing resources to all industries to continue to improve technology and reduce emissions. We look forward to the opportunity to provide further advice on the development of the program and other potential solutions to ensure concerns for industry competitiveness are adequately addressed.

Engagement and Communications

Engaging British Columbians in the opportunities presented by the new Climate Solutions and Clean Growth Strategy will be central to its success. We urge the government to demonstrate steady, committed leadership on this file, both as the Climate Solutions and Clean Growth Strategy takes shape and as it is implemented. Clear, inspiring communication that articulates the future opportunity, the progress being achieved and the meaningful role British Columbians can play in the transition to a clean economy will create positive momentum and durable change.

Next Steps

As they are developed, the Council will consider sectoral plans on transportation, buildings and communities, and industry, as well as the opportunities and challenges of clean growth, and will provide further advice to you.

We also look forward to providing advice on the Climate Solutions and Clean Growth Strategy and the supporting actions as we continue to work with you on this challenging and incredibly important task.

Sincerely,

The Climate Solutions and Clean Growth Advisory Council

[signature page follows]

Attachment
Climate Solutions and Clean Growth Advisory Council – Operating Principles

The Climate Solutions and Clean Growth Advisory Council believes that British Columbia must adopt effective climate policies that build on our province’s strengths while maximizing clean-growth opportunities. Policies and actions recommended by the Climate Solutions and Clean Growth Advisory Council will respect Indigenous perspectives and the principles and values of reconciliation. To this end, we have identified the following eight shared principles to guide our work and inform our advice to government.

1. Demonstrating Ambitious Leadership

We strive to sustain a strong economy, meet our legislated targets and contribute to global climate action by sharing our policy successes and solutions with other jurisdictions, while learning from the experiences of others.

2. Ensuring Credible, Durable, and Cost-Effective Policies

British Columbia needs a suite of credible, durable and cost-effective climate policies and regulations to reduce carbon emissions. Policies need to be designed to support multiple benefits including social, environmental and economic goals.

3. Creating Prosperity and Jobs

Our recommendations will seek to build a strong, sustainable economy that is steadily reducing greenhouse gas emissions and growing investments, while creating and maintaining jobs.

4. Supporting a Just Transition

We support a just economic transition, meaningful employment, secure jobs, and fair wages, including, for example, the education and retraining of workers and support for communities.

5. Enabling Industry Competitiveness

We support actions to enable industrial competitiveness so that companies can continue to thrive and innovate while reducing emissions.

6. Increasing Community Resilience

We support mitigation policies and actions that concurrently strengthen community resilience to climate impacts.

7. Respecting Diversity and Ensuring Equity

We respect British Columbia’s diverse cultures, regions, sectors, and income levels and support fairly distributing benefits while minimizing impacts.

8. Committing to Meaningful Engagement

We support meaningful government engagement with British Columbians to ensure the Climate and Clean Growth Strategy resonates with their communities, work, and way of life.