Greenwood and Kealy Woods Park Urban Forest Environmental Assessment Report

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Submitted to:

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1.0 Introduction

Greenwood and Kealy Woods Park are large (~16.5ha) natural urban forest parks within the upper Grand Boulevard neighborhood of the City of North Vancouver (the City). These parks support recreation trails but are otherwise relatively undeveloped for recreation or other park purposes. The City intends to undertake improvements to these parks to develop their recreation potential while protecting the natural ecosystems that they support.

This environmental assessment identifies existing natural values associated with these areas, provides and inventory of existing sanctioned and non sanctioned recreation features and discusses opportunities and constraints to consider for future park development. The assessment area includes Greenwood Park, Kealy Woods Park and a section of the new Green Necklace Multi-Use Greenway what has been recently constructed.

Photo 1 – View of forest condition in eastern Greenwood Park

2.0 Existing Conditions

2.1 Topography

The topography is variable across these two parks which provides the diversity of ecosystem and features of interest within them. The height of land in the neighborhood is adjacent to Greenwood at the existing water tank. Small bluffs and steep slopes with bedrock outcrops extend off from this height of land leading to gentler slopes below. There is an old quarry that exists in Greenwood with 2 levels of steep bluffs. It is unconfirmed but appears that two other small quarries were created along the western edge of the park. Kealy Woods consist of a bedrock outcrop with a series of surrounding bluffs to the south and west.

A watercourse/wetland complex exists in the northeastern edge of Greenwood carrying runoff from the Highway #1 and drainage from Tempe Heights park to the north. There is also a small wetland and watercourse that drains southeast of the main quarry in Greenwood.

Figure 1: Site location, topographic lines, bluffs and watercourses within the project area.

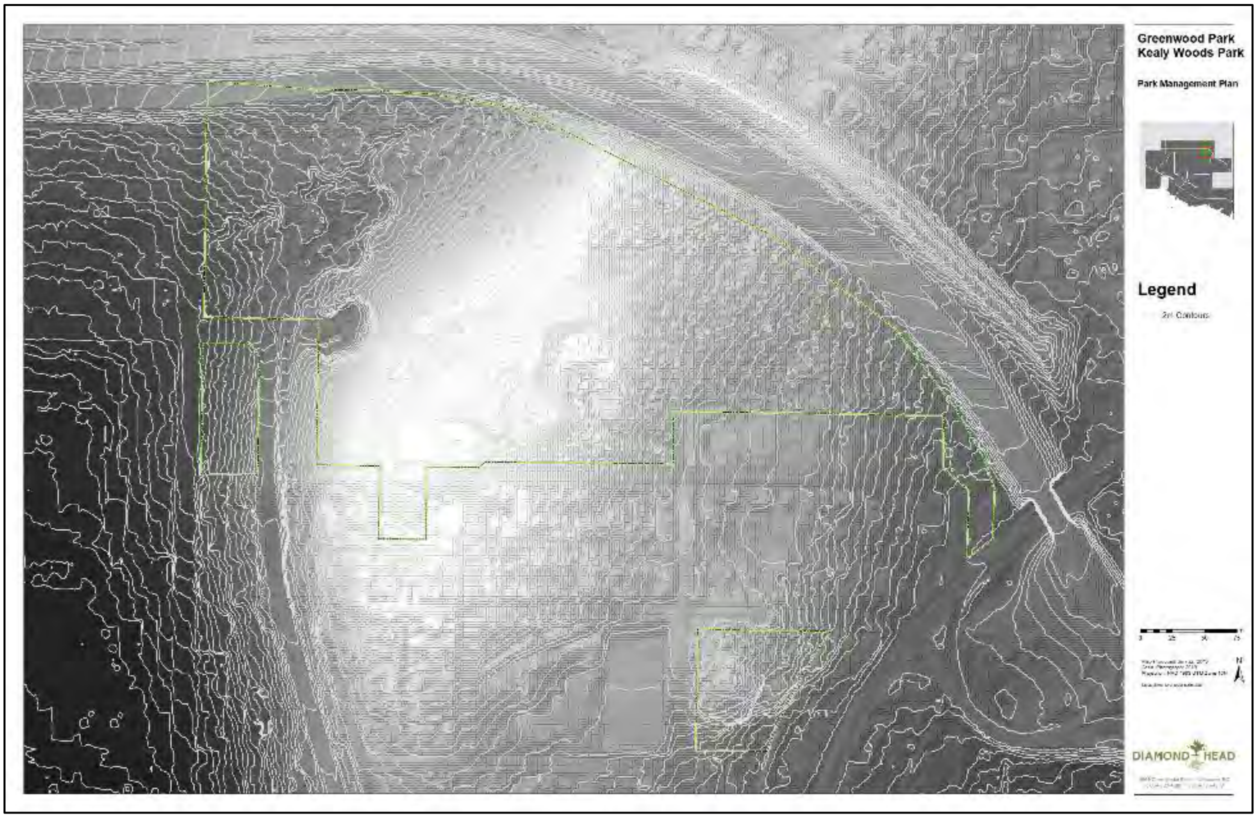


Figure 2: LiDAR relief map of the project area. Lighter areas are higher in elevation while darker areas are lower in elevation.

Photos: Terrain in this study area varies from rocky outcrops to lowland wetlands.

2.2 Biogeoclimatic Classification

The project site is located within the Coastal Western Hemlock Dry Maritime Subzone (CWHdm) of the Biogeoclimatic Ecosystem Classification (BEC) System of BC. This subzone is associated with warm, relatively dry summers and moist, mild winters with little snowfall.

Parent materials are generally morainal and well as some small colluvial areas associated with the bedrock outcrops and bluffs. Soils are generally sandy, coarse and well drained. They are thin when associated with bedrock areas to deeper soils below.

Site level classification (Site Series) is defined by soil moisture and nutrient availability and describes the late seral or climax plant community that will develop through natural succession. The variety of topographic features creates range of ecosystems types. On bedrock outcrops, soils are generally poor and dry represented by site series (ss) 02 and 03. In lowland areas there are rich and moist areas represented by site series 05 and 07. The natural areas on site were classified based on water content and nutrients (Figure 3).

Figure 3: Ecology and leading site series classification

2.3 Forest Stands

The natural plant communities that exist in these parks develop naturally after logging of the original old growth forests at the turn of the last century. Since then there have been quarry operations that have caused more recent disturbances as well as natural events including windthrow and mortality from drought and disease. The park has been divided into polygons with similar plant communities, called ecotypes (Figure 4). A summary of the inventory data collected for each ecotype is provided in 3.8.

A large part of the forest consists of mature, second growth coniferous forests that regenerated naturally after logging. In these areas the dominant tree species include western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata*) and Douglas-fir (*Pseudotsuga menziesii*). These trees are generally 35-40m tall and 40-70cm in diameter. The stands are moderately dense with an average density of 250 stems/ha with openings that have been created by windthrow and disease. Many of the older trees in these stands are over 100 years old. In many areas of Greenwood Park, these stands have an even aged single story canopy which is dense. It restricts sunlight from reaching the forest floor. This, along with human impacts have prevented the establishment of understory plants in some areas.

Photo: Stand condition of even aged mature conifer stands

Wetter areas and areas that have been more recently impacted include more deciduous species, predominantly red alder (*Alnus rubra*) with scattered bigleaf maple (*Acer macrophyllum*), cherry (*Prunus emarginata*) and black cottonwood (Populus balsamifera trichocarpa). Trees in these stands are generally smaller ranging in height from 20-30m tall and 20-50cm in diameter. Average stand density is approximately 600 stems per hectare.

Photo: Stand condition of young deciduous dominated stand on wetter sites

There are many blowdown areas in both Kealy Woods and Greenwood parks that are now regenerating with a mix of young tree species. These young dense stands are dominated by western hemlock but include a mix of other conifer and deciduous species as well. In some areas there has been restoration planting which has enhanced the species diversity. There is one notable Arbutus (*Arbutus menzeisii*) tree that is growing in Kealy Woods park.

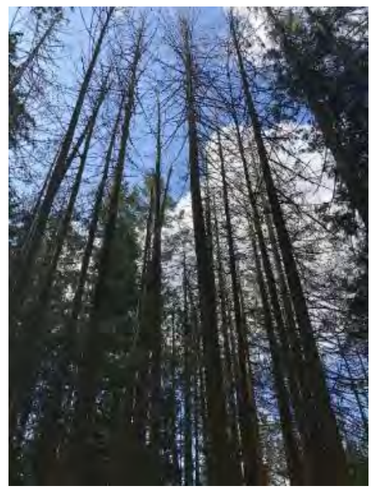
Photo: Blowdown area in Kealy Woods with a healthy arbutus tree

Figure 4: Ecotype polygons described within the study area

2.3.1 Forest Health

Impacts to these natural areas have included pests and diseases as well as abiotic agents (drought and windthrow). Hemlock mistletoe has infected many of the western hemlock resulting in the onset of decay. There has been impacts from windstorms in both parks. A large area in Kealy Woods blew down. This area includes trees growing with shallow rooting over bedrock that were highly exposure on a topographical crest. There are three significant blowdown areas in Greenwood park. These have created stand openings which are now regenerating with young trees and dense shrub communities.

Climate change and two years with very dry summers have caused many trees in the Lower Mainland to suffer drought stress. Many of the western hemlocks and western redcedars in Kealy Woods and some in Greenwood around the quarry have recently died or are currently showing signs of dieback as a result. These are concentrated in areas that are dry due to shallow soils over bedrock limiting soil moisture to the trees that have established there. In Kealy Woods, the historic blowdown as well as this dieback has left the park with large openings with little canopy cover. These forest health concerns cause risk to park users and adjacent values, including roads, sidewalks, houses, and hydro lines.



Photos: Signs of drought stress in western hemlock and western redcedar trees growing on thin soils over rock in Kealy Woods and Greenwood.

Photos: Hemlock Mistletoe is common in hemlock trees throughout Greenwood

Figure 5: Blowdown areas and stands with recent mortality expected to be a result of drought stress.

2.4 Understory Vegetation

Understory vegetation associated with the site is varied. In many areas of Greenwood Park, the forests have an even aged single story canopy which is dense and restricts sunlight from reaching the forest floor. This, along with human impacts have prevented the establishment of understory plants. In conifer dominated areas the predominant vegetation cover consists of sword fern (*Polystichum munitum*), vine maple (*Acer circinatum*), salal (*Gaultheria shallon*) and red huckleberry (*Vaccinium parvifolium*). In areas where stand openings allow light to reach the forest floor the ground cover is denser and includes more diversity of species.

In wetter areas, the understory vegetation can be very dense and consists of species more adapted to rich and wetter growing conditions including salmonberry (*Rubus spectabilis),* red-osier dogwood *(Cornus stolonifera)* and hardhack *(Spirea douglasii).* A detailed list of plants is included in Appendix A.

Photos: Typical ground vegetation in conifer stands. Rattlesnake plantain is an orchid found growing in Greenwood park.

2.5 Invasive plant species

Invasive plant species are found growing throughout the parks but are concentrated around the perimeter of the park areas where there has been historic human activity. The greatest concentrations are found along the Green Necklace trail, the historic extension of Grand Boulevard towards highway #1 as well as the area north of the residents in eastern Greenwood where garden dumping has introduced invasives.

The most common species include: Himalayan blackberry (*Rubus armeniacus*), English ivy (*Hedera helix*), English holly (*Ilex aquifolium*), lamium (*Lamiastrum galeobdolon*), scotch broom (*Cytisus scoparius)* and spurge laurel (*Daphne laureola*). There was historically Japanese knotweed and giant hogweed found growing in the park however these have been mostly eradicated. There are remaining small areas of Japanese knotweed (*Fallopia japonica*) that have been found and are a priority for eradication.

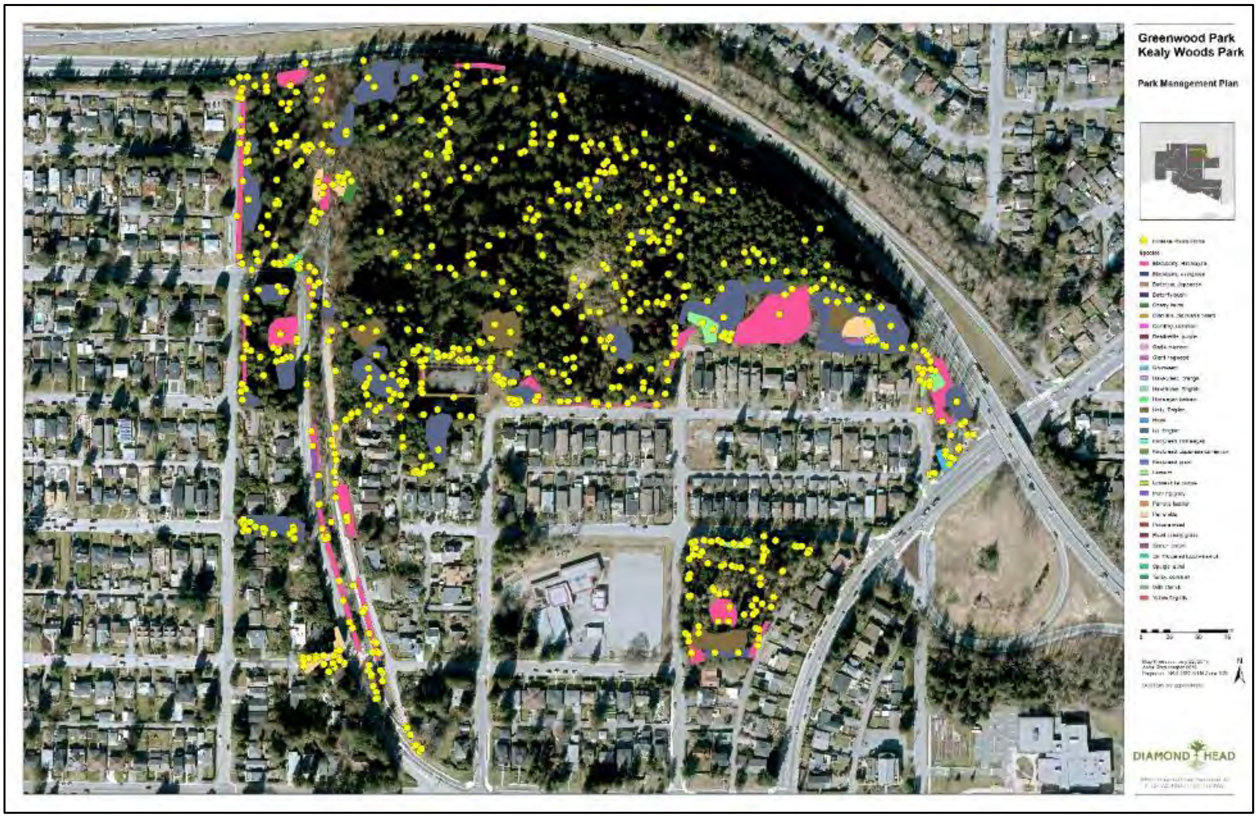


Figure 6: Location of invasive plant species found in the study area

Photos: Invasive lamium and English ivy

2.6 Watercourses

There are two main drainage systems in the study area, both within Greenwood park. The first includes two reaches that drain runoff from the Hwy 1 as well as Tempe Heights Park to the north. There is another ditch that extends east from the height of land along highway 1. These converge in the north west corner of Greenwood at an old quarry area that is now a wetland. The water from these features run west through a culvert under and old roadway and drain into a roadside ditch along Ridgeway Ave. The ditch that extends along the south side of Highway 1 drains to the west and east from a height of land mid way along it. The western part of this ditch drains into the systems that connects with Ridgeway Ave. The eastern half drains along Highway #1 to the east to a stormwater intake near Lynn Valley Road. A smaller drainage system starts at the flat base of the main quarry site in Greenwood and drains down an old gravel roadway that extends southeast and draining into stormwater outlets along Queensbury Ave. There is a large water storage tank adjacent to the south edge of Greenwood. This infrastructure is not associated with any surface waterflow that can be considered natural.

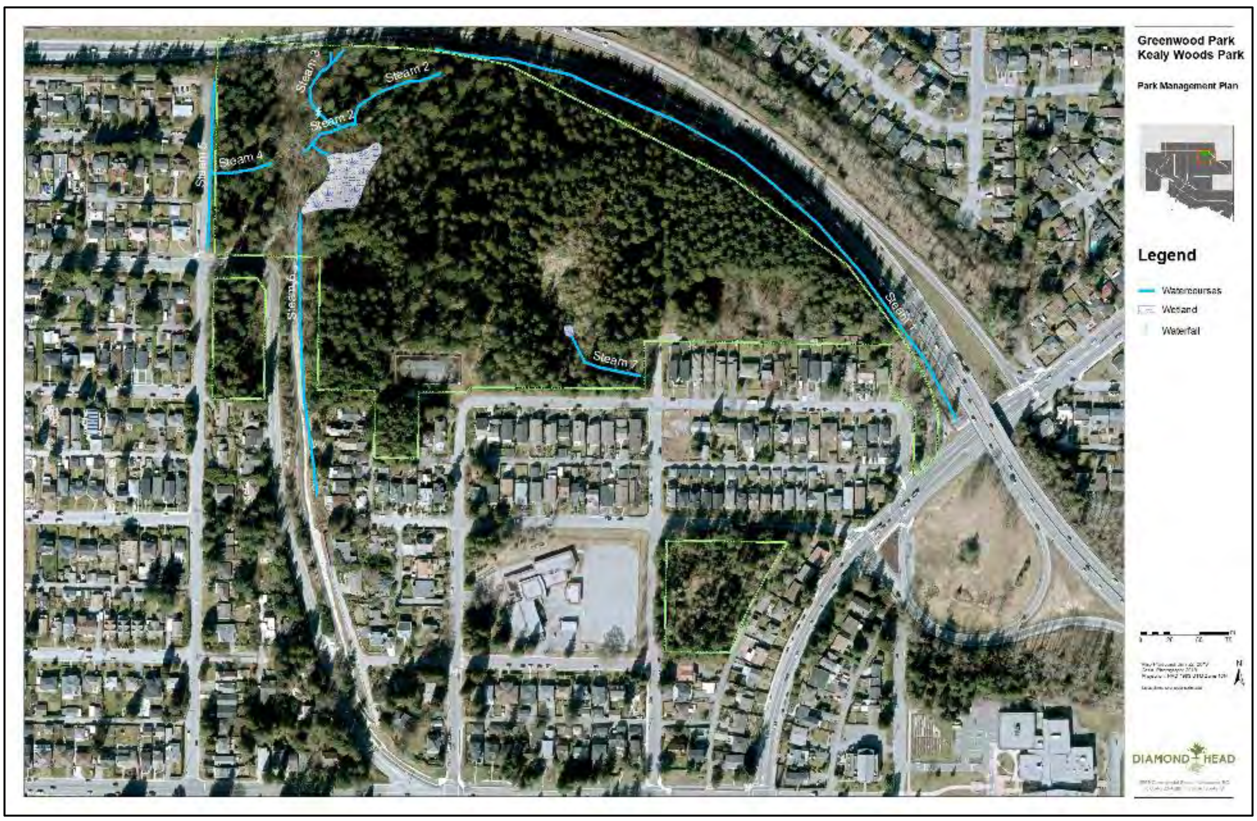


Figure 7: Location of watercourses and wetlands in the park.

2.6.1 Stream 1

Stream 1 is a constructed ditch that runs along the south side of Highway 1. It runs east and west from a height of land around the middle of Greenwood park. It has an average width of 1 m but runs through a deep constructed channel. It was 15 cm deep at the time of the assessment but is expected to carry a large volume of water during high rainfall events. It has an average slope of 5%. The channel bottom consists of 90% mineral soil and organics and 10% gravels. It collected water from the highway as well as a culvert which drains water from the Tempe park stormwater pond to the north. It drains into a culvert which extends west for ~75 m to the start of stream #3. The eastern part of this ditch drains to the east to a stormwater intake near Lynn Valley Road. This ditch is a class B (non-fish bearing) stream.

Photo: Stream 1 is a ditch along highway #1.

2.6.2 Stream 2

Stream 2 is a natural stream/wetland complex that extends through the forested area in the northwest corner of the park converging with Stream 3 and the wetland and draining into stream 4. It is an average of 90 cm in width and 5 cm deep at the time of the assessment. It has an average slope of 5% and is slow draining. It flows below ground at times and has small wetland areas. The channel bottom consists of 100% mineral soil and organics. At the west end it becomes more established as it collects water from stream 3 and the wetland. This is a class B (non-fish bearing) stream.

Photo: Stream 2

2.6.3 Stream 3

Stream 3 collects water from the culvert under Highway 1 which drains water from Tempe park as well as Stream 1. It extends south and drains into stream 2. It is an average of 50 cm in width and 5 cm deep at the time of the assessment. It has an average slope of 3%. The channel bottom consists of 80% mineral soil and organics, 10% gravel and 10% cobble. This stream may have been constructed historically. There is a 3 m tall water fall along this stream. This is a class B (non-fish bearing) stream.

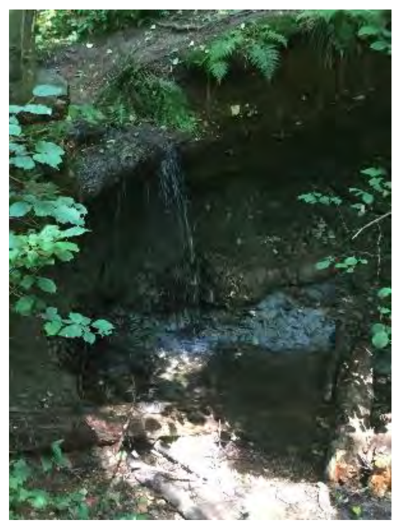


Photo: Stream 3 and its waterfall

2.6.4 Stream 4

Stream 4 is a natural steam that collects water streams 1,2, and 3 out of a culvert under an old road. It drains into a ditch (stream 5) along Ridgeway Ave. It is an average of 110 cm in width and 15 cm deep at the time of the assessment. It has an average slope of 8%. The channel bottom consists of 40% mineral soil and organics, 30% gravel and 20% cobble and 10% boulders. This is a class B (non-fish bearing) stream.

Photo: Stream 4

2.6.5 Stream 5

Stream 5 is a constructed roadside ditch that runs along the east side of Ridgeway Ave. It drains south into a stormwater inlet. It has an average width of 1.2 m. It was 10 cm deep at the time of the assessment but is expected to carry a large volume of water during high rainfall events. It has an average slope of 8%. The channel bottom consists of 20% gavels, 70% cobbles and 10% boulders. This ditch is a class B (non-fish bearing) stream.

2.6.6 Stream 6

Stream 6 is a ditch that was recently constructed along the north side of the Green Necklace trail for drainage. It extends north to connect with the wetland. It is lined with gravels and cobbles. Observations from City staff indicate that during high rainfall events that this ditch is not large enough and there have been overflows along the Green Necklace trail.

2.6.7 Stream 7

Stream 7 drains water from a small wetland that has formed at the bottom of the quarry. It is ephemeral and appears to flow only at rainfall events. It flows down an old road that was built to access the quarry. It is an average of 40 cm in width and 3 cm deep at the time of the assessment. It has an average slope of 20%. The channel bottom consists of 90% gravel and 10% cobble. This is a class B (non-fish bearing) stream.

Photo: Stream 6

Photo: Stream 7

2.6.8 Wetland 1

This wetland exists in what is suspected to be an old quarry area. It is a flat lowland area that supports a younger stand of deciduous trees. The soils are compacted with poor drainage. It drains slowly from a short channel which connects with Stream 2.

2.6.9 Wetland 2

This wetland exists at the base of the quarry. It is a flat lowland area that is relatively small and supports shallow water with wetland species. The soils are compacted with poor drainage.

Photo: Wetland 1

Photo: Wetland 2

2.7 Wildlife

Greenwood Park is disconnected from other large natural areas and plays an important role as a habitat hub within the north part of the City. It provides a wide range of habitat for wildlife, from streams and wetlands, dry rocky outcrops, dense shrub plant communities, and a diversity of forest types. These natural areas provide protected interior habitat that is valuable as a refuge area for species that are less tolerant of human activity

Bedrock outcrops and natural bluffs can support sensitive plant communities and are unique within the region and sensitive to human traffic. These include small rock bluffs with cervices and overhangs suitable for bats. There are vertical cut rock walls associated with the former quarry within Greenwood Park. These are not naturally formed but do provide some unique habitat features.

Photos: Rock outcrops and bluffs provide unique habitat

Areas where there has been blowdown and disease outbreaks provide stand openings with dense ground shrub cover. These areas provide valuable forage and cover areas for small mammals and songbirds. Downed trees provide ground cover corridors for smaller mammals. Standing dead trees develop into high value wildlife trees used for forage, roosting and nesting.

Photo: Large dead standing trees provide valuable wildlife habitat

A detailed wildlife survey was not completed for this site. Professional biologists however did visit the park in the morning for 6 days in the spring of 2020. A list of the species that were heard or seen during this survey is provided in Appendix B. This list also identifies the species that may not have been detected during these field assessments but are expected to inhabit the park based on the habitat that exists.

2.7.1 Birds

There is a diversity of bird species that inhabit this park area. The combination of watercourse, wetlands, forest and dense shrub communities provides habitat for resident and migratory bird families including hawks, owls, doves, hummingbirds, woodpeckers, flycatchers, crows, chickadees, bushtits, nuthatches, creepers, wrens, kinglets, thrushes, starling, kingfishers, swallows, waxwings, warblers, tanagers, sparrows and finches.

There are high value nesting areas for songbirds in the variety of live trees, dead standing wildlife trees as well as the dense shrub communities. There are some large and mature Douglas-fir trees that provide roosting areas and suitable nesting sites for raptors. It is expected that raptors hunt throughout this natural area for prey. Red tailed hawks are known to roost in this park and hunt over the open boulevard areas along highway 1. Pellets of Barred owl (*Strix varia)* were found during the field assessment.

The greatest diversity and number of birds were observed along forest edges and in forest types that are more structurally diverse and open. These areas provide greater cover types extending from the forest floor up to the upper canopy. While a complete list is provided in Appendix B, the following bird species were found to be most abundant and observed during most sit visits.: American robin (*Turdus migratorius*), song sparrow (*Melospiza melodia*), white crowned sparrow (*Zonotrichia leucophrys*) spotted towhee (*Pipilo maculatus*), Swainson's Thrush (*Catharus ustulatus*), Winter Wren (*Trogolodytes trogolodytes*) Black-capped Chickadee (*Parus atricapillus*), Northern flicker (*Colaptes auratus*), dark-eyed junco (*Junco hyemalis*), brown creeper (*Certhia Americana*), Red-breasted nuthatch (*Sitta canadensis*), Northwestern Crow (*Corvus caurinus*), Pacific-slope Flycatcher (*Empidonax difficilis*), Anna's Hummingbird (*Calypte anna*), Rufous Hummingbird (*Selasphorus rufus*), Golden crowned Kinglet (Regulus satrapa), Ruby-crowned Kinglet (Regulus calendula), Black-throated Gray Warbler (*Dendroica nigrescens*), Pine Siskin (*Carduelis pinus*), Purple finch (*Carpodacus purpureus*), House finch (*Carpodacus mexicanus*) and House sparrow (*Passer domesticus*).

Owl pellet found in Greenwood park

Woodpecker feeding on dead hemlock tree

2.7.2 Mammals

The park is large enough and has enough diversity in habitat to support a number of mammals. These include those that are smaller and do not require large home ranges as well as species that are more tolerant of human presence. These include skunk, racoon, squirrel, rats, mouse, shrews and voles. There is suitable habitat to support a number of bat species. Natural roosts present include cliffs, rock crevices and dead standing trees.

Racoon prints

Although this area is disconnected directly from other natural areas, larger mammals are know to travel through the parks as part of their home range. Coyote are known to inhabit the natural area parks in this area. Scat was found in the western edge of Greenwood and numerous park users that were interviewed indicated that they had seen coyote in the park. It is likely that coyote may den in this park. Black bear and cougar are also seen periodically in the parks in this area. Bear scat was found in the western end of Greenwood park. These species are not residents in the park but likely use the park as part of a large home range on the north shore mountains.

Bear scat (left photo) and coyote scat (right photo) found in the west edge of Greenwood park

2.7.3 Amphibians and Reptiles

No formal survey for reptiles and amphibians was conducted. There are no waterbodies observed that provide standing water for long enough to allow for successful rearing of aquatic amphibians. The steams and wetlands do provide habitat for amphibians through the summer. Terrestrial amphibians likely to inhabit this park include Ensinata salamander (*Ensanita eschscholtzii*) and western redback salamander (*Plethodon vehiculum*). Reptiles that could inhabit the park include western garter snake (*Thamnophis elegans vagrans*) and common garter snake (*Thamnophis sirtalis*). Rocky outcrops have the potential to support the northern alligator lizard (*Elgaria coerulea*).

2.8 Species and Ecological Communities at Risk

The BC Conservation Data Centre (CDC) records BC's most vulnerable vertebrate animals and vascular plants, each of which is assigned to a provincial Red or Blue list according to their provincial conservation status rank. Species or populations at high risk of extinction or extirpation are placed on the Red list and are candidates for formal endangered species status. Blue-listed species are considered vulnerable to human activity and natural events.

No species at risk were identified at the site during the field visit. Listed species identified by the CDC within a 3 km radius are summarized in Table 1. The closest recorded occurrence of a species at risk includes Pacific Water Shrew which was trapped north of the study area in 1955[1]. There are occurrences of Red legged frog (Blue listed) and Johnson's Hairstreak however they are within the Lower Seymour Conservation Reserve ~3.5km to the east.

Table 1 Red and Blue-listed species within 3 kilometers of project site

Common Name	Scientific Name	Provincial Status	Habitat	Comments
Pacific water shrew	*Sorex bendirii*	Red	Aquatic riparian areas	Record from 1955. Approximate coordinates are north of Highway #1 and west of Lynn valley road.

[1] https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/conservation-data-centre

There are numerous other wildlife species at risk could potentially inhabit the study area, or the adjacent natural area. An unconfirmed list of these species can be found in Table 2.

Table 2: Species at Risk that could potentially inhabit the areas in and adjacent to the study area.

Common Name	Scientific Name	B.C. Status
Pacific water shrew	*Sorex bendirii*	Red
Keen's long-eared myotis	*Myotis keenii*	Blue
Townsend's big-eared bat	*Corynorhinus townsendii*	Blue
Red-legged frog	*Rana aurora*	Blue
Olive-sided flycatcher	*Contopus cooperi*	Blue
Barn swallow	*Hirundo rustica*	Blue
Western screech-owl, kennicottii subspecies	*Megascops kennicottii kennicottii*	Blue
Band-tailed pigeon	*Patagioenas fasciata*	Blue
Trowbridge's shrew	*Sorex trowbridgii*	Blue

2.8.1 Plant Communities at Risk

All rare and endangered plant communities are mapped based on data retrieved from the Conservation Data Centre (CDC). Rare and endangered plant communities that occur within the study area are identified in Table 3.

Table 3 CDC ranked plant communities located within the study area

Scientific Name	Common Name	BEC Unit	BC Status
Thuja plicata / Polystichum munitum Dry Maritime	Western redcedar / sword fern Dry Maritime	CWHdm/05	Blue
Pseudotsuga menziesii - Tsuga heterophylla / Gaultheria shallon Dry Maritime	Douglas-fir - western hemlock / salal Dry Maritime	CWHdm/03	Blue
Thuja plicata / Tiarella trifoliata Dry Maritime	Western redcedar / three-leaved foamflower Dry Maritime	CWHdm/07	Blue
Tsuga heterophylla / Buckiella undulata	Western hemlock / flat-moss	CWHdm/01	Blue
Pseudotsuga menziesii - Pinus contorta / Holodiscus discolor / Cladina spp.	Douglas-fir - lodgepole pine / oceanspray / reindeer lichens	CWHdm/02	Yellow

Most plant communities identified in the natural areas are Blue-listed. These ecological communities are of Special Concern (formerly Vulnerable) in British Columbia; they have characteristics that make them particularly sensitive or vulnerable to human activities or natural events. This ranking applies to most natural areas in the lower mainland that have been impacted by timber harvesting and urban development. The sensitivity of this park area is similar to other nearby second growth natural areas.

2.8.2 Notable Trees

During the field visit, trees with high wildlife potential or existing use were identified. These include dead standing larger stems that have signs of wildlife use including feeding and cavities. Additionally, notable trees that are of interest for park visitors were mapped. These includes large and dominant trees that are larger in size than most trees in the park as well as trees that have interesting structure. Many trees of interest include Douglas-fir that are growing on rock outcrops or bluffs with interesting root structures. There area also many significant heritage stumps that remain from the initial clearing of old growth. Some of the most interesting have been identified and are shown in Figure 8.

Figure 8: Trees and heritage stumps of significance

Photos: There are numerous trees of interest and heritage stumps in the parks

2.9 Recreational Facilities

2.9.1 Trails

The park contains a network of formal and informal trails used by walkers, runners, and mountain bikers. Trails surfaces are mostly soil and organics. Sections of the most used formal trails have been covered in gravel. Some trails have been identified as a mountain biking trails in the web application "Trailforks" (Figure 10). The Green Necklace Trail is a newly constructed urban greenway that is paved and designed for multi-use. It extends through the south east corner of Greenwood park.

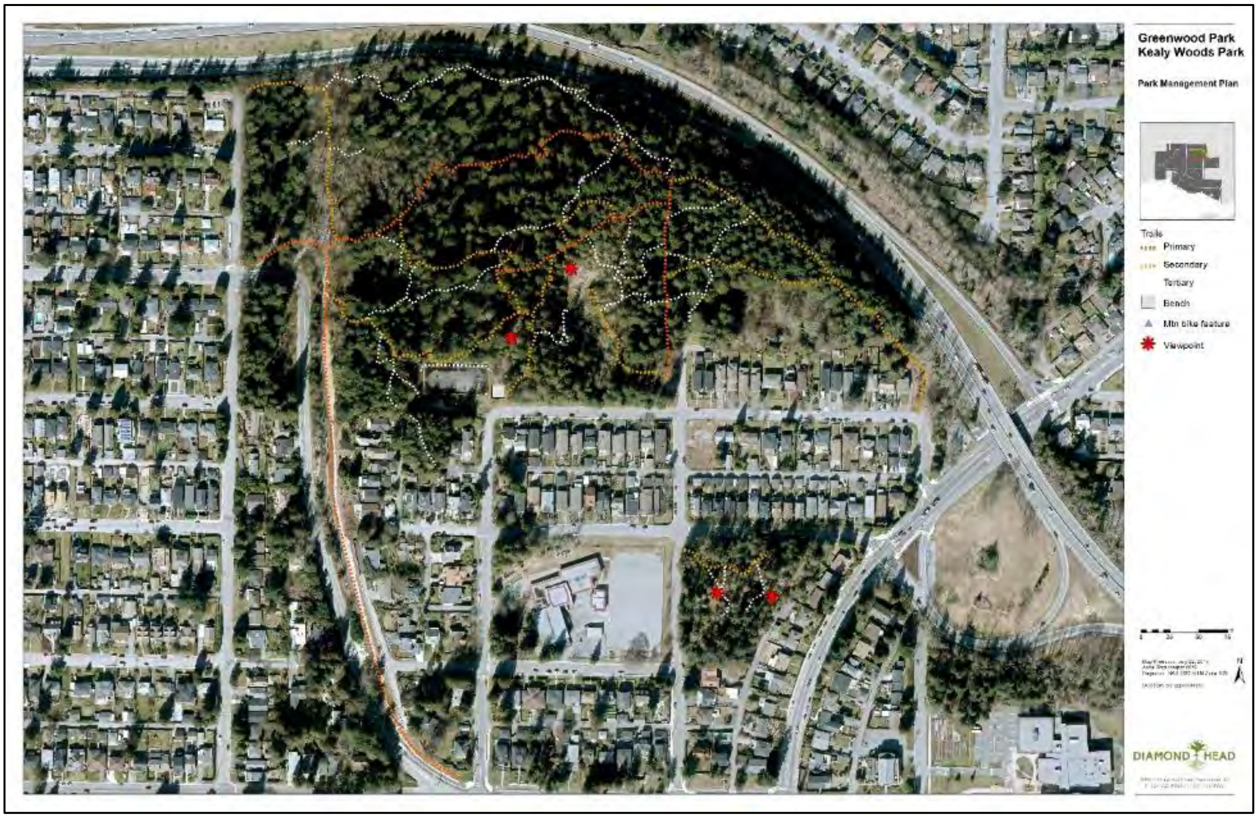


Figure 9: Existing recreational trails

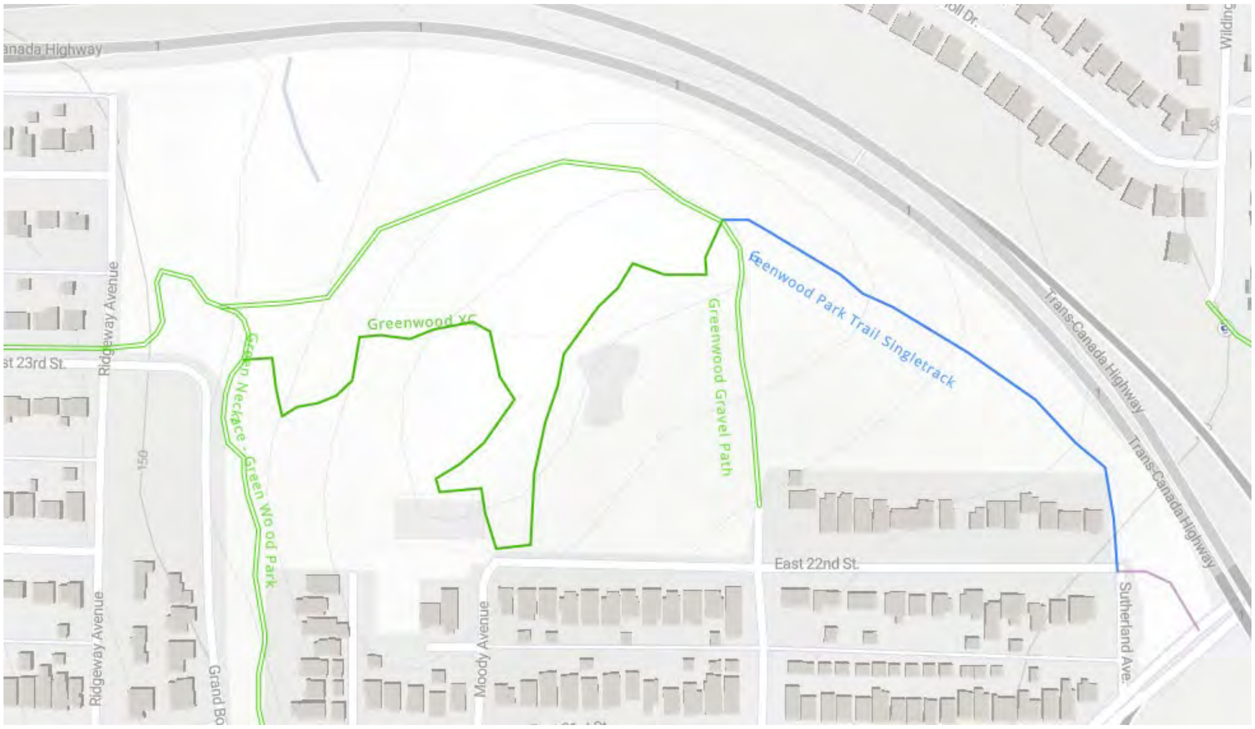


Figure 10: Mountain biking trails identified on Trailforks – Greenwood Gravel Path, Greenwood XC and Greenwood Park Singletrack

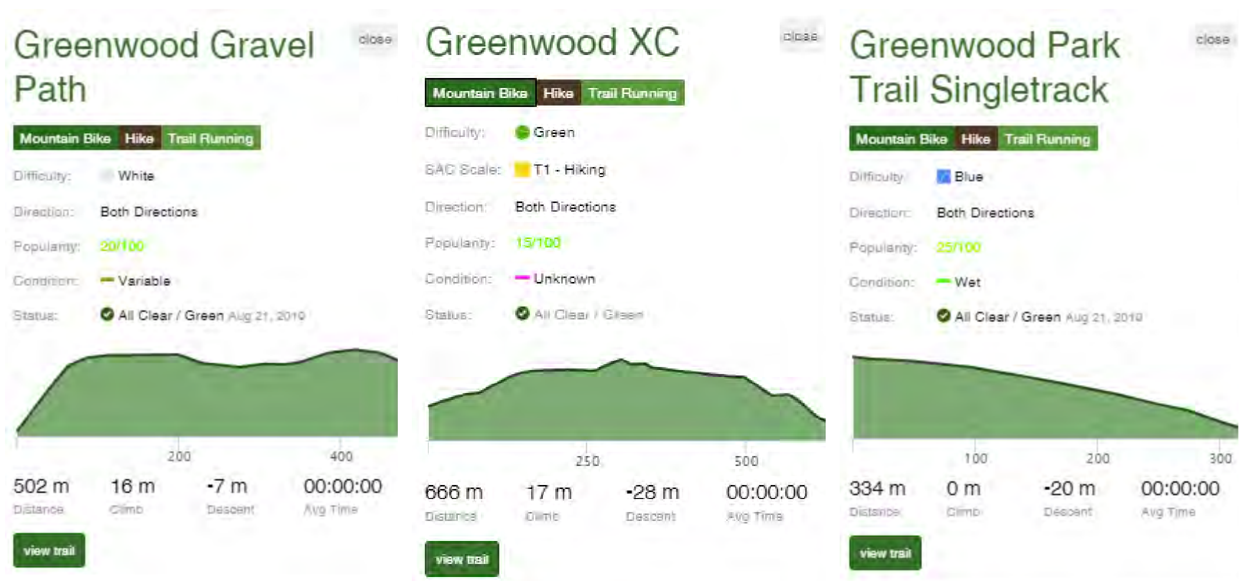
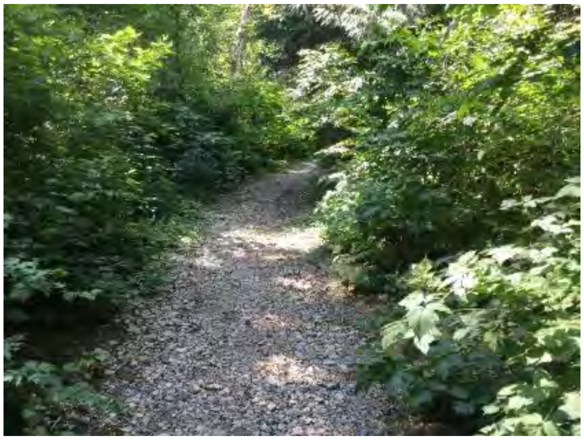


Figure 11: Mountain biking trail descriptions on Trailforks



Photos: There are a variety of trails types found in the parks

2.9.2 Frisbee Golf Course

There is a frisbee golf course in Greenwood Park. It includes 18 holes with identified tee off locations. Trees are used as targets for each hole. Currently the trees are identified with aluminum tags and many have been recently spray painted. It is uncertain how long this course has been active. There are unsanctioned trails that have formed along these holes as a result of its use. Tee off boxes have disturbance from traffic including compaction and lack of ground vegetation. This course appears to still be used occasionally.

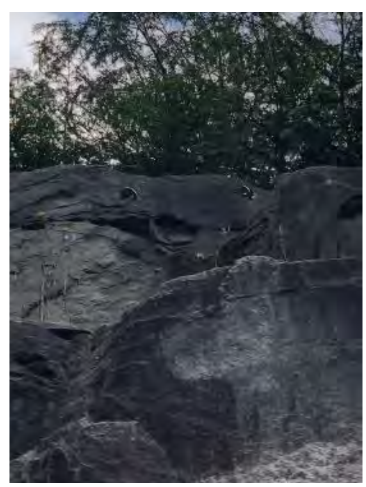
Figure 12: Disc Golf Course

Photos: Spray paint and tags indicate disc golf features

2.9.3 Rock Climbing

There are a number of natural and created rock bluffs in the study area. In Greenwood, there is evidence of active rock climbing. Two routes designed for roped climbing were found that have bolts as anchors. There was also chalk marks found on some of the shorter bluffs indicating that they are used for bouldering.

Figure 13: Areas used for rock climbing



Photos: Rock bluffs have evidence of use for rock climbing

2.9.4 Unsanctioned activity

There is evidence of unsanctioned activities in the quarry area, including partying and campfires. This area is difficult to police as it is set down in the terrain, out of sight and earshot. There is often garbage left in this area. The evidence of campfires is concerning based on the risk of fire in the adjacent forest. There is an established camp with a tent as well as areas that have chairs and benches. Remains of old tree house structures were found. Graffiti is found on some of the rock bluffs. Around the parks at the interface with residential lots there is evidence of dumping of garden waste.

Figure 14: Unsanctioned activity and impacts

Photos: Impacts and unsanctioned activities

2.10 Degraded areas

There are several areas that have little to no understory vegetation, typically under dense stands of conifers that have extensive traffic. The lack of light in these areas has prevented the successfully regeneration of vegetation and trees.

Figure 15: Areas for restoration with low understory cover

Photos: Disturbed understory

2.10.1 Wildfire Risk

With drier summers and climate change trends, the risk from wildfire is increasing in urban park areas. Fuel characteristics vary through the assessment area. Generally, the areas dominated by deciduous trees pose a low risk. These trees have a low flammability and are found growing on naturally wet ecotypes. Conifer dominated stands pose a moderate to high risk depending on the amount and structural nature of fuels present. In some areas the crown fuels are well above the forest floor reducing the risk of a crown fire. In these areas a ground fire may spread but would need to be very intense to produce a flame length high enough to ignite the upper crowns.

In other areas of the parks there has been high fuel-loading on the ground from blowdown and many of the mature trees have retained their lower branches. These areas pose a high risk of a ground fire starting and spreading into the crowns of the trees. The forests in Kealy woods are a good example of this type of fuel condition.

Photos: The forest along the eastern part of Greenwood (polygon 17) is a good example of an area where there is low ground fuel loading and few ladder fuels. A ground fire would be unlikely to spread to the crowns of the trees unless under extreme weather conditions.

The grade of the terrain also plays a large role in determining the fire behavior potential. The risk of wildfire increases dramatically with the steepness of the slope which promotes the spread of a fire uphill. Due to the complexities of wildfire behavior and risk, it is recommended that a more detailed analysis be completed as part of a City wide Community Wildfire Protection Plan to determine what detailed measures will mitigate the risk and execute the City's due diligence.

In general, the greatest risk exists where residents are located up against conifer dominate forest types with no break in the fuels to help slow or defend against a wildfire. Figure 16 illustrates a 30 m zone from residents within conifer dominated forest types. Fuel mitigation in these areas will reduce the wildfire risk to these residents.

Figure 16: Wildfire interface areas of concern. These include conifer dominated drier stands that are adjacent to residents with no fuel break.

2.10.2 Environmental Sensitivity and Value

Ecosystems are dynamic and complicated which can make rating their value very difficult. Some areas provide habitat to support a high number of species while others support species that may be considered rare or sensitive to human impacts. Other areas may be valuable as movement corridors between two natural areas. For this assessment the biologists that completed the field work have rated areas in the park for environmental value considering the following:

Biodiversity: The forests that are more open, with multistoried canopies and dense diverse understory vegetation provide the greatest habitat for the highest number of species. Most of these area also have large diameter trees, high value dead standing wildlife trees as well as an abundance of downed woody debris. These areas also have dense and diverse surface vegetation communities.

Water/Riparian Areas: Areas that are close the water features are also highly important as they provide access to water which is essential to the survivability of most species. These areas also tend to support high levels of biodiversity.

Isolation: Natural areas located away from urban areas provide interior refuge habitat that is important for certain species that are less tolerant of human presence. Refuge areas are typically greater than 100m from interface areas.

Sensitivity: Some areas are highly sensitive to degradation from human traffic. There are some areas on rock outcrops that provide habitat that is not common in this region. Many of the plant communities that grow in these types of areas are highly sensitive to human impacts.

Areas in Greenwood and Kealy Woods have been rated from very high to low based on these considerations. These ratings should be considered when planning for park amenities and infrastructure.

Figure 17: Ecological value/sensitivity rating

3.0 Opportunities for Enhancement

Greenwood and Kealy Woods Park are highly diverse and valuable natural areas within a developed residential area of the City. It is large with natural areas that are isolated away from human influences providing a range of habitat features. There are some opportunities to enhance, restore previous disturbances, and protect them from the influences of human development. The following sections include recommendations to be considered during the design phase of the park. These have been developed with the protection of the environment being a foremost priority. It is understood that other values will be considered for the planning of recreation opportunities in the park.

3.1 Trails

There is one well used trail that extends through Greenwood park from Queensbury Ave to the Green Necklace trail at 23rd St and Grand Boulevard. This provides a logical loop through the park. There are numerous other trails through Greenwood and Kealy Woods that range in condition and use. An authorised and maintained trail system should be identified to prevent ecological degradation from the numerous braided trails that now exist. Once an official trail system is recognized, it can be maintained, and the other trails can be blocked off and restored back to a natural state.

The permitted usages of this trail system should be determined through stakeholder consultation. Currently there are no restrictions on usage. Biking in particular can cause conflicts with other user groups. There is an opportunity to provide a designated mountain biking route designed for novice bikers in the eastern part of Greenwood park.

Recommended connections are illustrated in Figure 18. These are currently relatively well used trails that provide access from perimeter access points to areas of interest in the park and provide for logical routes. There are numerous trails recommended around and upslope from the quarry area. This indicates a desire for visitors to explore the rock bluffs in this area. Making some trails official will allow for the restoration of adjacent areas that have been impacted by foot traffic.

There are currently numerous trails and degraded areas throughout the east side of Greenwood Park from the frisbee golf course and due to the low ground vegetation cover. There is some construction of mountain biking features in this area, which should be formalized. The trails in this eastern part of Greenwood would connect to a park entrance near Lynn Valley Road.

In Kealy Woods park there are two access points that connect to each other and a short trail leading a lookout point at the peak of the rock outcrop. Small bluffs prevent trails through the eastern and southern portions of the park.

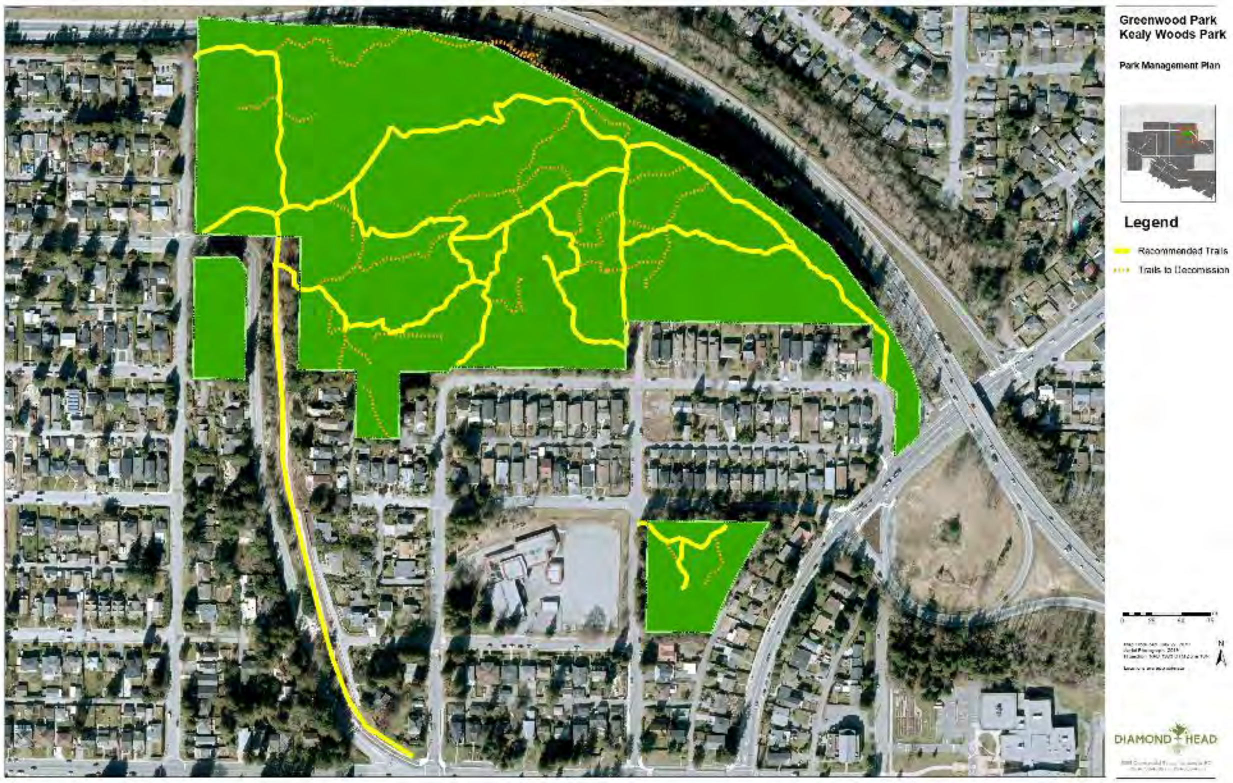


Figure 18: Recommended trail network.

The following are recommended trail classes to define use and character.

1. **Urban Paved Trail – The Green Necklace** - Wide paved trail that accommodates low-speed activities, and is suitable for strollers and mobility impaired individuals.
2. **Multi-Use Trail – Connecting Queensbury Ave to Ridgeway Ave** - Wide surfaced trail suitable for a range of low-intensity recreational pursuits, including walking, jogging, cycling.
3. **Nature Trail** – Narrow natural surface trails with obstacles, steep sections and some stairs. Intended mostly for walking.
4. **Novice Off road Biking Trail** – A loop trail of gentle grade and natural surfacing. Includes a number of natural technical features intended for learning to mountain bike.

3.2 Disk Golf Course

The disk golf course is causing environmental degradation in the park. The tee off and hole areas are trampled by foot traffic, causing soil compaction and preventing vegetation from establishing. There is spray paint on the trees and logs to direct the location of fairways. This area of Greenwood has low understory vegetation cover allowing players to walk off trail along the fairways. It is recommended that the course be dismantled and that the degraded areas restored back to native plant community.

3.3 Rock Climbing

The Quarry area provides short bluffs that are suitable for novice rock climbing. There are currently two routes. It is possible that 5-10 more routes could be established. A partnership is recommended with local rock climbing groups to establish and maintain these routes. The shorter bluffs are suitable for a range of skill levels of bouldering. The routes and bouldering area could be made official, mapped and promoted.

Figure 19: Suitable rock climbing areas

3.4 Managing invasive species

Invasive plant species should be managed to protect natural biodiversity and prevent further spread and encroachment to and from adjacent areas. These should be treated using the current best management practices for each species. Manual removal is recommended wherever possible in order to minimize the introduction of chemical herbicides into sensitive environmental areas. Exact treatment and control methods are dependent on site conditions and the species encountered and may require adapted and site-specific control plans. Chemical treatments are not advisable in riparian areas; particularly adjacent to closed watercourses.

Some areas of the park are infested to a point where eradication will be very difficult. These areas include the western edge of Greenwood and the residential interface north of 22nd and east of Queensbury. In these areas it is recommended that an approach of risk mitigation and containment be adopted. Invasive species should be contained to within natural or man made boundaries and the impacts to the ecology mitigated through measures such as removal of climbing Ivy on trees.

Other areas of the park that are mostly natural should aim to eradicate invasive species. It is cost effective to remove invasive plants when they are small and at the establishment stages. Species of concern to focus on include English ivy, lamium and blackberry.

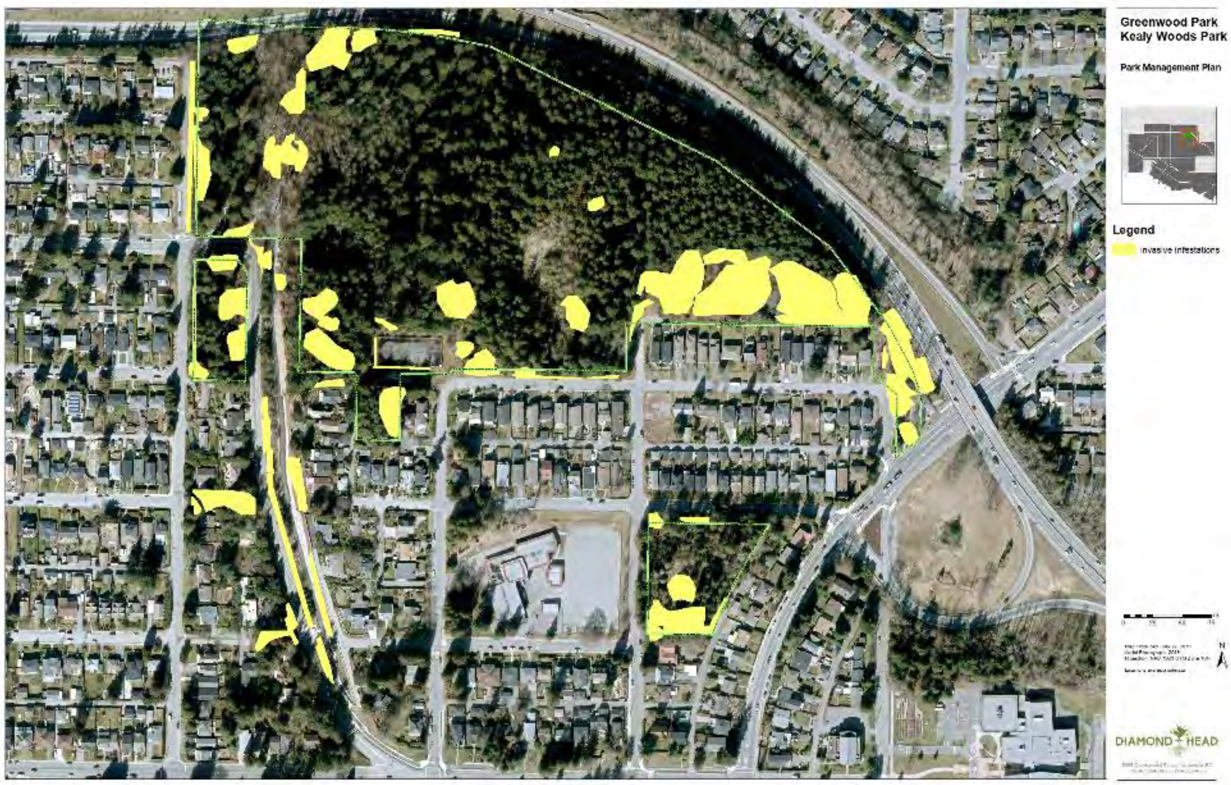


Figure 20: large invasive species infestations

3.5 Wildlife Habitat

Creation of additional natural habitat features wherever possible will improve overall biodiversity in the park. Historic windthrow has created a mosaic of closed stands to open shrub communities as well as large woody debris cover on the ground. There are a moderate number of well used dead standing trees. However additional wildlife trees will further increase habitat for cavity nesters. When trees are mitigated for risk it is recommended that wildlife trees be created if safe to do so. This includes cutting the tree at a height that is equal to or less than the closest trail of target.

Increasing plant and tree species diversity throughout the parks will enhance wildlife habitat. Recommendations for specific areas should be developed by a professional biologist. Preliminary recommendations are provided in section 3.8.

3.6 Mitigation of tree risk

There are a number of areas with dead standing trees. In addition, there are openings in the forest canopy created from windthrow which have destabilized some trees. These trees may pose a threat to park users or targets around the edge of the park. However, these trees do provide valuable habitat diversity and should only be removed if they meet the criteria of a high risk tree following the Tree Risk Assessment Procedures published by the International Society of Arboriculture.

Priorities for mitigation should be based on the targets that are at risk if tree did fail. The highest risk areas include the residents around the perimeter of the park and highway 1. Secondary targets include roads and the Green Necklace trail. The lowest priority targets include the trail system.

Many dead standing cedar trees that have died from drought stress can be stable and remain standing for many years due to the natural decay resistance of this wood. These trees can provide high value habitat and should be retained if possible.

3.7 Mitigation of fire risk

There are well used fire pits present in the quarry area as well as on three rock outcrops areas. These should be removed, and signage installed with information about the high risk of wildfires that could start as a result of unauthorised fires in the park. These fire pits are the greatest risk of ignition in the park.

Further risk from wildfire exists where residents are up against conifer dominated forest areas. These are illustrated in Figure 16. In these areas it is recommended that forests be treated to reduce the ground and ladder fuel loading. This includes removing dead wood accumulations and pruning up branches of the standing trees to 3m in height. This work should be completed under the direction of a professional forester.

3.8 Restoration of degraded areas

There are several areas that have little to no understory vegetation. These are typically under dense stands of conifers and have extensive traffic. The lack of light in these areas has prevented the successful regeneration of vegetation and trees. Table 4 provides recommended plants and trees that should be considered when restoring these areas. Suitability is provided for rich and wetter ecosystems types as well as drier more moderate sites. This list also includes some species that are more adapted to expected climate change conditions. Planting sites for each species should be site specific and directed by a professional with knowledge of these characteristics.

Table 4: Species List for Restoration

Scientific Name	Common Name	Rich wetter sites	Moderate drier sites	Comments
Trees				
Alnus rubra	*Red alder*	*X*	*X*	*Nitrogen fixing and suitable for poor soils. Shade intollerant*
Beltula papyrifera	*Paper birch*	*X*	*X*	
Thuja plicata	*Western redcedar*	*X*	*X*	
Abies grandis	*Grand fir*	*X*		*Climate adaptation species*
Acer macrophyllum	*Bigleaf maple*	*X*		
Picea stichensis	*Sitka spruce*	*X*		
Populus balsamifera	*Black cottonwood*	*X*		*Shade intollerant*
Prunus emarginata	*Bitter cherry*	*X*		
Tsuga heterophylla	*Western hemlock*	*X*		
Arbutus menziesii	*Arbutus*		*X*	*Climate adaptation species. Plant on open rocky sites*
Pseudotsuga menziesii	*Douglas-fir*		*X*	*Shade intollerant*
Shrubs				
Acer circinatum	*Vine maple*	*X*	*X*	
Oemleria cerasiformis	*Indian plum*	*X*	*X*	
Ribes sanguineum	*Red-flowering currant*	*X*	*X*	
Cornus stolonifera	*Red-osier dogwood*	*X*		*Plant in clusters*
Crataegus douglasii	*Black hawthorn*	*X*		
Lonicera involucrata	*Black twinberry*	*X*		
Physocarpus capitatus	*Pacific ninebark*	*X*		
Ribes bracteosum	*Stink currant*	*X*		
Rubus spectabilis	*Salmonberry*	*X*		
Rubus parviflorus	*Thimbleberry*	*X*		
Salix Sp	*Willow (Pacific, Scouler, Sitka)*	*X*		
Sambucus racemosa	*Red elderberry*	*X*		
Spiraea douglasii	*Hardhack*	*X*		*Plant in clusters*
Amelanchier alnifolia	*Saskatoon*		*X*	*Climate adaptation species*
Corylus cornuta	*Beaked hazelnut*		*X*	
Gaultheria shallon	*Salal*		*X*	*Plant in clusters*
Holodiscus discolor	*Oceanspray*		*X*	*Climate adaptation species*
Mahonia nervosa	*Dull Oregon-grape*		*X*	
Rosa gymnocarpa	*Baldhip Rose*		*X*	
Rosa nutkana	*Nootka rose*		*X*	
Symphocarpos albus	*Snowberry*		*X*	
Vaccinium parvifolium	*Red Huckleberry*		*X*	*Plant in organic substrates*
Rubus ursinus	*Trailing Blackberry*	*X*	*X*	
Herbs				
Athyrium filix-femina	*Lady Fern*	*X*		
Blechnum spicant	*Deer Fern*	*X*	*X*	
Dryopteris expansa	*Spiny Wood Fern*		*X*	
Polystichum munitum	*Sword Fern*	*X*	*X*	

3.9 Channelizing of stream 7

Stream 7 currently runs down the old access road for the Quarry and drains onto Queensbury Ave. This area is also used as a trail. When water runs down this trail it likely results in poor water quality. It is recommended that this trail be adopted as a sanctioned trail and that a trailside ditch be constructed to channelize this water. A small ditch can be dug along the side of this trail with a target width of 50cm.

4.0 Proposed park amenity improvements and impact assessment

Following the environmental assessment and initial public consultation, a number of improvements have been proposed to improve the parks infrastructure and ecological integrity. An environmental impact assessment has been completed for each. This assessment considers potential changes to the biophysical environment caused by the proposed activity by identifying Valued Ecosystem Components (VECs). VECs are selected to facilitate an appropriate, focused assessment of the potential direct and indirect effects of a project. These VECs include wildlife species diversity, understory vegetation, significant trees, species and communities at risk and changes to hydrology and water quality.

4.1 Formalization of a trail system and restoration of unauthorised trails

A recognized trail network will be adopted that includes well used trails that provide access to areas of interest in the park. These will include a multi-use trail that connects Queensbury Ave to Ridgeway Ave. This will be a wide surfaced trail suitable for a range of low-intensity recreational pursuits, including walking, jogging, cycling. There is one 35 m section with a steep grade and stairs at the north end of Greenwood which will be realigned.

In the eastern part of Greenwood Park, a mountain biking circuit will be established. This will be a loop trail of gentle grade and natural surfacing. It will include natural technical features intended for learning to mountain bike. This circuit is currently being used by bikers and some technical trail features have been constructed. The remaining trails including those in Kealy Woods will be designated as nature trails. These will have natural surfaces with some low obstacles, steep sections, and some stairs. These trails will be intended mostly for walking. All other existing trails in the parks will be blocked off with natural debris to discourage access and restored to natural plant communities.

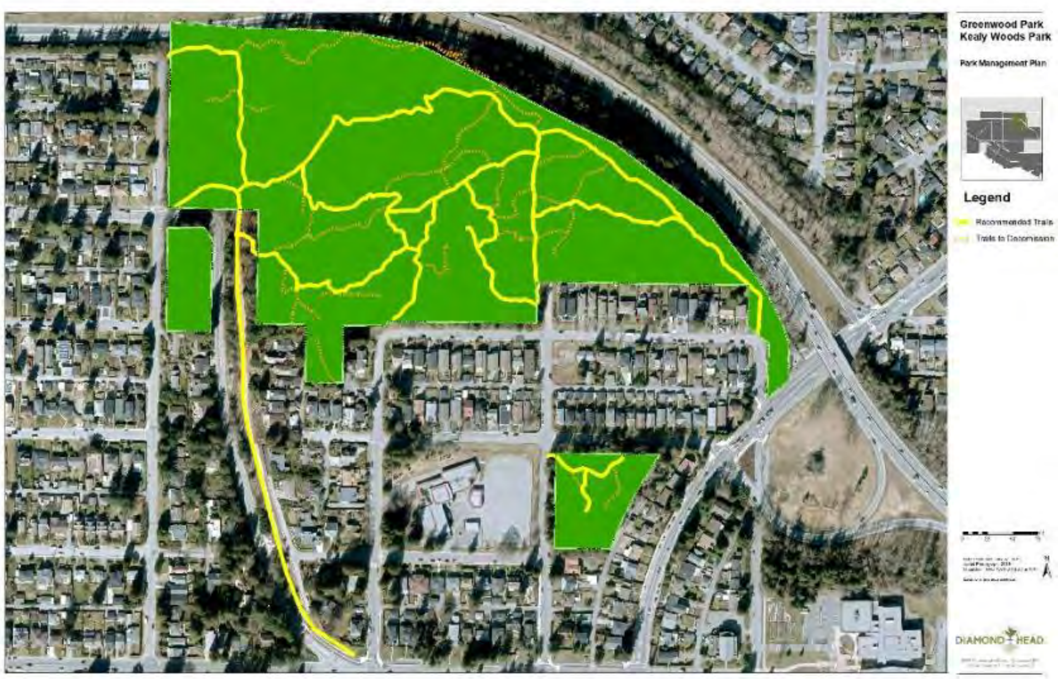


Figure 21: Proposed trail network.

Multi-use trail that connects Queensbury Ave to Ridgeway Ave.

Nature trails will include some stairs and obstacles

Techical features are being constructed allong the proposed mountian bike circuit

Unauthoriosed trails will be blocked off and restored

Table 5 Impact Assessment of the proposed trail system

Valued Ecosystem Components	Concern/Significance			Comment
	Low	Medium	High	
Wildlife Species Diversity		✓		Formalizing the trails and deactivating unauthorized trials will reduce the fragmentation of the forest and reduce access to many areas of the park for people and dogs. User frequency may increase on authorized trails as they are upgraded and maintained. The most significant impacts include disturbances and conflicts from dogs and people.
Understory Vegetation	✓			Some loss of understory vegetation is expected where trails are widened and along the realignment of one section in north Greenwood. This will cause the loss of some understory vegetation. However, this loss will be small in relation to the existing disturbed areas and offset by the restoration of unauthorized trails.
Significant Trees	✓			All trail work will be designed to avoid the impacts to mature trees. Some minor impacts to structural roots are expected where trails are realigned or widened.
Species and Communities at Risk	✓			The trails will generally follow existing routes. These works will not impact any habitat that is required by any species at risk within the park.
Hydrology and Water Quality	✓			Formalizing the trail network will include improvements to trail drainage. This will help to prevent surface erosion and negative impacts to downstream water quality.

4.1.1 Recommendations for mitigation:

- Trails should follow existing alignments wherever possible.
- Nature trails should be narrow with a target width of 1.5m.
- Install drainage features to restore natural hydrology and prevent surface erosion of trail surfaces.
- Complete all trail upgrades during periods of dry weather.
- Where tree roots are exposed on trail surfaces, protect them with geofabric on top of the roots followed by gravel and cobbles to a target depth of 200 mm.
- Restore all unauthorised trails to natural plant communities (see Section 4.1.2).

4.1.2 Deactivation of unauthorised trails

As part of the recognition of a trail system, efforts will be made to block access and restore all unauthorised trails to a natural condition. Efforts and strategies for deactivation will vary depending on the popularity of the trail, hydrological impacts, and productivity of the understory vegetation. The following efforts are recommended.

1. **Post signage and place large woody debris across the trail.** Larger stems are more effective at blocking access to the trails, as they are more difficult for the public to move. Efforts should focus on the first 10m of the trail entrances.
2. **Replant with native vegetation**. Trails surface should be de-compacted with pickaxes and shovels and planted with native species. Plants which grow aggressively, reach tall heights, and have thorns are most effective at dissuading travel. Recommended species are provided in Table 6.

Table 6 Species list for restoring deactivated trails

Botanical Name	Common Name
Picea sitchensis	Sitka Spruce
Crataegus douglasii	Black Hawthorn
Rosa gymnocarpa	Baldhip rose
Rosa nutkana	Nootka rose
Rubus spectabilis	Salmonberry
Rubus ursinus	Trailing blackberry
Acer circinatum	Vine maple
Symphocarpos albus	Snowberry
Corylus cornuta	Beaked hazelnut
Oemleria cerasiformis	Indian plum

3. If deactivated trail use persists, **install wood fencing** (ie. split rail) across the trail entrance with "restoration area" signage.

4.2 Drainage improvement works at the northwest corner of Greenwood Park

Drainage improvement works have been partially completed in the northwest corner of Greenwood Park. These include improvement to the grades of the Green Necklace trail ditch to ensure water drains into a wetland, as well as upgrades to the ditch that extends along Ridgeway Ave. Most of the impacts from machinery will be in areas that are already disturbed or infested with invasive plant species. All works along Ridgeway Ave will be completed from the roadway and outside of the park.

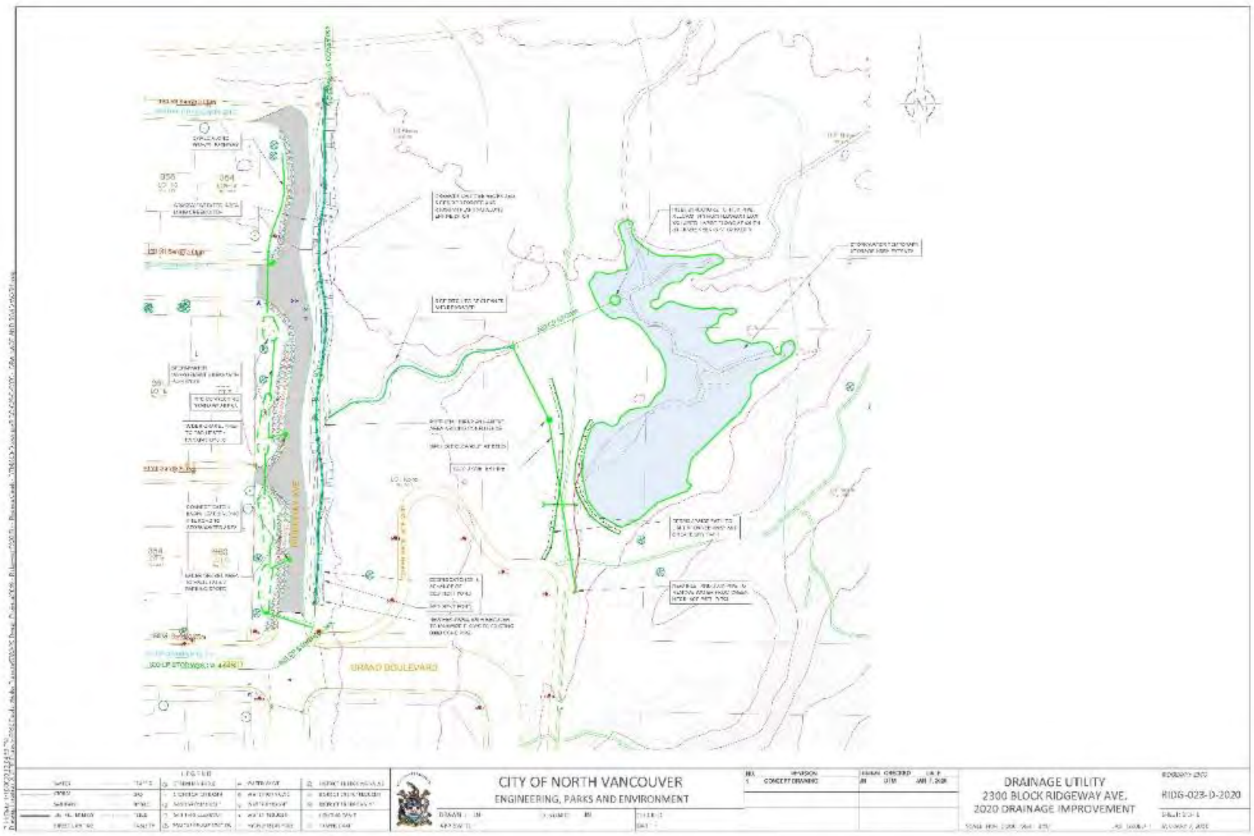


Figure 22: Proposed stormwater improvements

Table 7 Impact Assessment of stormwater improvements

Valued Ecosystem Components	Concern/Significance			Comment
	Low	Medium	High	
Wildlife species diversity	✓			The changes to water flow and impacts from construction will not cause the loss of any existing high value wildlife habitat. Upon completion these upgrades will improve the condition of the in-stream habitat and water quality in the wetland and roadside ditch.
Understory Vegetation	✓			Some loss of understory vegetation is expected for machinery access. In most cases, these areas are already disturbed or infested with invasive species. All disturbed areas will be restored back to a native plant community.
Significant trees		✓		There are no mature trees close to the improvements to the Green Necklace ditch. There are mature conifer trees adjacent to the Ridgeway Ave ditch improvements that may be impacted during excavation works for the ditch. No mature trees will be removed for these works.
Species and Communities at Risk	✓			These works will not detrimentally impact any habitat that is specifically required by any species at risk in Greenwood Park. This work has the potential to improve habitat for some species at risk by increasing water flow to the wetland area.
Hydrology and Water Quality	✓			This work will improve the long-term hydrology and water quality and reduce flood risk and erosion.

4.2.1 Recommendations for mitigation:

- Contractor should take care with heavy machinery to avoid unnecessary disturbance to native understory vegetation
- An arborist should supervise any excavation works for the Ridgeway ditch within 5 m of any mature trees.
- All disturbed areas should be restored following the species recommended in Section 3.8.

4.3 Establishment of an outdoor classroom

An outdoor classroom is proposed west of the quarry. This will include placement of logs and cut rounds for seating arranged in a circular pattern and around an area designated for a teacher to speak from. There is currently very little understory vegetation in this area. Some restoration works with native plants, bird nest boxes and bat houses should occur nearby to showcase native ecology. Fencing will be installed adjacent to the edge of the quarry and bluffs as safety measures.

View of the area proposed for the outdoor classroom

Table 8 Impact Assessment of establishing an outdoor classroom

Valued Ecosystem Components	Concern/Significance			Comment
	Low	Medium	High	
Wildlife species diversity	✓			The area proposed currently has very low understory vegetation coverage. The classroom will be located away from one significant dead standing tree with numerous cavities that provides high value to wildlife. The presence of classes will dissuade some wildlife from this area when the classroom is active, though this is expected to be infrequent. Any habitat features within this area are abundant in adjacent areas of the park.
Understory Vegetation	✓			The installation of features and trampling from class attendance will impact ground vegetation. Currently there is very little existing understory vegetation. There will be restoration efforts to replant this area which will be protected and integrated into the class programing. There will be a net gain of understory vegetation compared to current conditions.
Significant trees	✓			This area is forested with mature and young conifer trees. No trees will be removed for the classroom. The class attendees may cause some compaction of the trees rooting zones when in session, though this is expected to be infrequent.
Species and Communities at Risk	✓			There are no unique habitat features found in this area required by species at risk.
Hydrology and Water Quality	✓			There are no water features nearby this classroom area.

4.3.1 Recommendations for mitigation:

- All seating features to be installed should be made of native conifer trees.
- The classroom should include a program to restore the understory vegetation in this area which would be fenced and can be used for education.
- Install bird boxes and bat boxes to be maintained by the classes.
- There is one significant dead standing trees of high value for wildlife. Located the classroom as far away as possible from this tree.

Monitoring and Ecological Indicators

Planning for these parks aims to protect and enhance the integrity of these natural areas. Monitoring the success of these measures and keeping track of the condition of the park and allows the City to detect changes and impacts from recreation use as well as climate change. Ecological indicators are used to understand the condition of natural areas and can include physical attributes of natural areas or the presence of certain species. For an ecological indicator to be effective it must be easy to measure and be an attribute that reflects the overall ecological health of an area. The following are indicators that are recommended to be assessed periodically.

Invasive Plant Species Cover: The presence of invasive species provides an indication of the impacts the urban environmental is having on a natural area. Planned mitigation works will reduce the cover of invasive species. Completing an inventory of invasive species every 5 years will provide a good indication of the overall ecological integrity of the parks.

Indicator Wildlife Species: Population health of other species and quality of habitat may be inferred based on management information collected for ecological indicator species. A list of potential indicator species to monitor biodiversity and environmental change in the park is outlined in Table 9. These species are easily monitored and are typical of the habitat found on the north shore. The health of these populations indicate the ecological health of a natural area. Birds are particularly valuable due to ease of observation, responsiveness to change, and abundant research to support their use as indicators. Species to monitor the health of habitat types in the parks are recommended in Table 9.

Table 9 Indicator species and monitoring methods

Habitat Type	Indicator species	Survey Method
Open Shrub	Spotted Towhee (*Pipilo maculatus*)	Singing birds
	Anise Swallowtail (*Papilio zelicaon Lucas*)	Visual survey for adults
Deciduous Forests	Black-throated Gray Warbler (*Dendroica nigrenscens*)	Singing birds
	Swainson’s Thrush (*Catharus ustulatus)*	Singing birds
Coniferous Forests	Brown Creeper (*Certhia Americana*)	Singing birds
	Barred owl (*Strix varia*)	Call back surveys
Mixed Forests	Pileated Woodpecker (*Dryocopus pileatus*)	Evidence of foraging
	Douglas Squirrel (*Tamiasciurus douglasii*)	Woodlands Investigate methods

5.0 Ecosystem Services Analysis

5.1 I-Tree methods

The modelling package i-Tree Eco was used to estimate ecosystem services that are provided by the natural areas in Greenwood and Kealy Woods. This model derives outputs using measurements on individual trees (diameter at breast height, tree height, crown missing, crown height, crown diameters) in plots scattered randomly through the study area. Ecosystem services estimates were generated for trees within the study area for:

- Avoided stormwater runoff (the amount of rainwater intercepted by tree canopy and infiltrated into the soil),
- Carbon sequestration and storage for global climate regulation (the carbon stored in the tree and the amount sequestered each year based on estimated annual growth),
- Air pollution removal (removal of ozone, sulfer dioxide, nitrogen dioxide, carbon monoxide and particulate matter less than 2.5 microns),
- Tree bioemissions (isoprene and monoterpenes, precursors to ozone formation) and,
- Leaf area and leaf biomass (key inputs for various ecosystem services calculations).

For individual trees in the inventory, estimates were made for:

- Leaf area (m3) and dry leaf biomass (kg) were attributed with i-Tree Eco's results (based on Nowak [1996] and the Beer-Lambert law).
- Total dry biomass (kg) was calculated using Canadian national biomass equations for BC (Ung 2008).
- Total above ground carbon (kg) was calculated by multiplying biomass by 0.5.
- Tree volumes (m3) were calculated using volume equations for common tree species in BC (Nigh, 2016)
- Surface saturation storage capacity (m3), the amount of water stored on tree surfaces before through-flow begins, was estimated using the method in Xiao and McPherson (2016).

5.2 Summary of I-Tree findings

The detailed outputs from this analysis are provided in Appendix B. A summary of the ecosystem services provided by Greenwood and Kealy Woods parks are as follows:

- Number of trees: 7,988
- Tree Cover: 58.3 %
- Most common species of trees: western hemlock, vine maple, western redcedar
- Percentage of trees less than 6" (15.2 cm) diameter: 56.4%
- Pollution Removal: 470.7 kilograms/year (Can$17.7 thousand/year)
- Carbon Storage: 1.634 thousand metric tons (Can$188 thousand)
- Carbon Sequestration: 39.98 metric tons (Can$4.59 thousand/year)

- Oxygen Production: 31.99 metric tons/year
- Avoided Runoff: 2.377 thousand cubic meters/year (Can$5.53 thousand/year)

Appendix A - Ecological Data Forms

Figure 23: Ecotype polygons

Polygon #1

ECOLOGICAL CHARACTERISTICS			
Soil Texture/Coarse Fragment Content	Soil Moisture/ Soil Nutrient	Humus Type/ Depth (cm)	BEC Site Series
Sandy Loam/45	4/D	Mor/10	SS05

STAND CHARACTERISTICS					
Canopy Layer	Dominant Trees	Co-Dominant Trees	Intermediate Trees	Suppressed Trees	Regeneration
Species[1] (% by volume; + denotes <10%)	-	$Hw_8Fd_1Cw_1$	$Cw_5Hw_4Dr_1$	Hw_8Cw_2	Hw_8Cw_2
Density (stems/ha)	-	150	50	20	40
Tree diameter at breast height (cm)	-	60	20	5	
Tree height (m)	-	38	22	3	
Crown closure (%)	35				
Age (years)	85				

[1] Species codes: Dr (red alder), Hw (western hemlock), Fd (Douglas fir), Cw (western redcedar).

UNDERSTORY VEGETATION – Total Cover -70%		
Species		Avg % Cover
Sword fern	*Polystichum munitum*	26-50
Red huckleberry	*Vaccinium parvifolium*	26-50
Beaked Hazelnut	*Corylus cornuta*	11-25
Vine maple	*Acer circinatum*	11-25
Bracken fern	*Pteridium aquilinum*	11-25
Deer Fern	*Blechnum spicant*	6-10
Spiny Wood Fern	*Dryopteris expansa*	6-10
Red Elderberry	*Sambucus racemosa*	6-10
Sitka mountain-ash	*Sorbus sitchensis*	6-10
Goatsbeard	*Aruncus dioicus*	1-5
Salmonberry	*Rubus spectabilis*	1-5

Polygon #2

ECOLOGICAL CHARACTERISTICS			
Soil Texture/Coarse Fragment Content	Soil Moisture/ Soil Nutrient	Humus Type/ Depth (cm)	BEC Site Series
Sandy Loam/45	4;5/C;D	Mor/13	$SS05_7SS07_3$

STAND CHARACTERISTICS					
Canopy Layer	Dominant Trees	Co-Dominant Trees	Intermediate Trees	Suppressed Trees	Regeneration
Species[1] (% by volume; + denotes <10%)	-	$Hw_6Cw_3Fd_1$	$Hw_5Cw_3Dr_2Vb+$	Hw_7Cw_3	$Hw_5Cw_5Ss_1$
1Density (stems/ha)	-	60	30	60	30
Tree diameter at breast height (cm)	-	60	25	5	
Tree height (m)	-	37	17	4	
Crown closure (%)	30				
Age (years)	70				

[1] Species codes: Dr (red alder), Vb (bitter cherry), Hw (western hemlock), Fd (Douglas fir), Cw (western redcedar), Ss (Sitka spruce).

UNDERSTORY VEGETATION – Total Cover - 80%		
Species		Avg % Cover
Vine maple	*Acer circinatum*	26-50
Spiny wood fern	*Dryopteris expansa*	26-50
Salal	*Gaultheria shallon*	26-50
Deer Fern	*Blechnum spicant*	11-25
Sword fern	*Polystichum munitum*	11-25
Bracken fern	*Pteridium aquilinum*	6-10
Thimbleberry	*Rubus parviflorus*	6-10
Salmonberry	*Rubus spectabilis*	6-10
Red huckleberry	*Vaccinium parvifolium*	6-10
Broad-Leaved Starflower	*Trientalis latifolia*	6-10
Beaked Hazelnut	*Corylus cornuta*	6-10
Grass Sp.		6-10

Polygon #3

ECOLOGICAL CHARACTERISTICS			
Soil Texture/Coarse Fragment Content	Soil Moisture/ Soil Nutrient	Humus Type/ Depth (cm)	BEC Site Series
Sandy Loam/35	5;6;7/D	Moder/4	$SS07_9SS012_1$

STAND CHARACTERISTICS					
Canopy Layer	Dominant Trees	Co-Dominant Trees	Intermediate Trees	Suppressed Trees	Regeneration
Species[1] (% by volume; + denotes <10%)	$Act_{10}Act+$	Dr	Dr_9Hw_1	Cw_7Hw_3	Hw
1Density (stems/ha)	25	200	50	10	10
Tree diameter at breast height (cm)	75	30	15	3	
Tree height (m)	38	24	14	4	
Crown closure (%)	60				
Age (years)	45				

[1] Species codes: Act (black cottonwood), Dr (red ader), Hw (western hemlock), Cw (western redcedar).

UNDERSTORY VEGETATION – Total Cover -90%		
Species		Avg % Cover
Salmonberry	*Rubus spectabilis*	>50
Sword fern	*Polystichum munitum*	11-25
Red elderberry	*Sambucus racemosa*	11-25
Beaked hazelnut	*Corylus cornuta*	11-25
Vine maple	*Acer circinatum*	11-25
Lady Fern	*Athyrium filix-femina*	6-10
Skunk cabbage	*Lysichiton americanum*	6-10
Baldhip rose	*Rosa Gymnocarpa*	6-10
Willow sp.	*Salix sp.*	6-10
Sitka mountain-ash	*Sorbus sitchensis*	6-10
Common horsetail	*Equisetum arvense*	6-10
Creeping buttercup	*Ranunculus repens*	6-10

Polygon #4

ECOLOGICAL CHARACTERISTICS			
Soil Texture/Coarse Fragment Content	Soil Moisture/ Soil Nutrient	Humus Type/ Depth (cm)	BEC Site Series
Sandy Loam/35	6-7/D	Moder/2	$SS12_{70}07_{30}$

STAND CHARACTERISTICS					
Canopy Layer	Dominant Trees	Co-Dominant Trees	Intermediate Trees	Suppressed Trees	Regeneration
Species[1] (% by volume; + denotes <10%)	-	Dr	Hw	Hw_5Dr_5	Hw
1Density (stems/ha)	-	250	10	25	25
Tree diameter at breast height (cm)	-	35	20	5	
Tree height (m)	-	27	18	4	
Crown closure (%)	50				
Age (years)	25				

[1] Species codes: Dr (red ader), Hw (western hemlock)

UNDERSTORY VEGETATION – Total Cover -95%		
Species		Avg % Cover
Salmonberry	*Rubus spectabilis*	26-50
Black twinberry	*Lonicera involucrata*	11-25
Red elderberry	*Sambucus racemosa*	6-10
Skunk cabbage	*Lystichitum americanum*	6-10
Hardhack	*Spirea douglasii*	6-10

Polygon #5

ECOLOGICAL CHARACTERISTICS			
Soil Texture/Coarse Fragment Content	Soil Moisture/ Soil Nutrient	Humus Type/ Depth (cm)	BEC Site Series
Sandy Loam/35	5/D	Moder/4	$SS07_7SS05_3$

STAND CHARACTERISTICS					
Canopy Layer	Dominant Trees	Co-Dominant Trees	Intermediate Trees	Suppressed Trees	Regeneration
Species[1] (% by volume; + denotes <10%)	Cw_6Hw_4	Hw_7Cw_3	Hw_9Cw_1Vb+	Cw_6Hw_4	Cw_6Hw_4
1Density (stems/ha)	15	50	25	25	15
Tree diameter at breast height (cm)	95	48	15	8	
Tree height (m)	37	28	8	3	
Crown closure (%)	35				
Age (years)	130				

[1] Species codes: Vb (bitter cherry), Hw (western hemlock), Cw (western redcedar).

UNDERSTORY VEGETATION – Total Cover -90%		
Species		Avg % Cover
Salmonberry	*Rubus spectabilis*	26-50
Vine maple	*Acer circinatum*	11-25
Sword fern	*Polystichum munitum*	11-25
Red elderberry	*Sambucus racemosa*	6-10
One-Leaved Foamflower	*Tiarella trifoliata*	6-10
Deer Fern	*Blechnum spicant*	6-10
Beaked hazelnut	*Corylus cornuta*	6-10
Red huckleberry	*Vaccinium parvifolium*	6-10
Lady Fern	*Athyrium filix-femina*	1-5
Spiny wood fern	*Dryopteris expansa*	1-5

Polygon #6

ECOLOGICAL CHARACTERISTICS			
Soil Texture/Coarse Fragment Content	Soil Moisture/ Soil Nutrient	Humus Type/ Depth (cm)	BEC Site Series
Sandy Loam/35	3/C	Mor/8	$SS01_6SS03_3SS02_1$

STAND CHARACTERISTICS					
Canopy Layer	Dominant Trees	Co-Dominant Trees	Intermediate Trees	Suppressed Trees	Regeneration
Species[1] (% by volume; + denotes <10%)	Fd_7Hw_3	Hw_7Fd_3	Cw_7Hw_3	Cw_8Hw_2	-
1Density (stems/ha)	50	100	100	25	-
Tree diameter at breast height (cm)	48	40	30	15	
Tree height (m)	27	24	18	5	
Crown closure (%)	50				
Age (years)	84				

[1] Species codes: Fd (Douglas fir), Hw (western hemlock), Cw (western redcedar).

UNDERSTORY VEGETATION – Total Cover -90%		
Species		Avg % Cover
Red huckleberry	*Vaccinium parvifolium*	11-25
Lady Fern	*Athyrium filix-femina*	6-10
Salal	*Gaultheria shallon*	6-10
Sword fern	*Polystichum munitum*	6-10

Polygon #7

ECOLOGICAL CHARACTERISTICS			
Soil Texture/Coarse Fragment Content	Soil Moisture/ Soil Nutrient	Humus Type/ Depth (cm)	BEC Site Series
Sandy Loam/40	4/C;D	Mor/8	$SS05_7SS01_3$

STAND CHARACTERISTICS					
Canopy Layer	Dominant Trees	Co-Dominant Trees	Intermediate Trees	Suppressed Trees	Regeneration
Species[1] (% by volume; + denotes <10%)	-	$Hw_6Cw_3Fd_1Dr+$	Hw_8Cw_2	Hw_7Cw_3	Cw_7Hw_3
1Density (stems/ha)	-	250	200	50	50
Tree diameter at breast height (cm)	-	60	25	3	
Tree height (m)	-	34	18	4	
Crown closure (%)	70				
Age (years)	95				

[1] Species codes: Dr (red alder), Hw (western hemlock), Fd (Douglas fir), Cw (western redcedar).

UNDERSTORY VEGETATION – Total Cover - 60%		
Species		Avg % Cover
Sword fern	*Polystichum munitum*	26-50
Red huckleberry	*Vaccinium parvifolium*	11-25
Salal	*Gaultheria shallon*	6-10
Bracken fern	*Pteridium aquilinum*	6-10
Salmonberry	*Rubus spectabilis*	6-10
Red elderberry	*Sambucus racemosa*	6-10
Rosy twistedstalk	*Streptopus roseus*	6-10
Aslaskan blueberry	*Vaccinium alaskaense*	6-10
Beaked Hazelnut	*Corylus cornuta*	6-10
Sitka mountain-ash	*Sorbus sitchensis*	6-10
Vine maple	*Acer circinatum*	1-5

Polygon #8

ECOLOGICAL CHARACTERISTICS			
Soil Texture/Coarse Fragment Content	Soil Moisture/ Soil Nutrient	Humus Type/ Depth (cm)	BEC Site Series
Sandy Loam/40	4/D	Moder/5	SS05

STAND CHARACTERISTICS					
Canopy Layer	Dominant Trees	Co-Dominant Trees	Intermediate Trees	Suppressed Trees	Regeneration
Species[1] (% by volume; + denotes <10%)	-	Hw_8Fd_2	$Cw_{10}Pl_+$	Mb_6Vb_4	-
Density (stems/ha)	-	50	25	25	-
Tree diameter at breast height (cm)	-	60	30	15	
Tree height (m)	-	31	18	10	
Crown closure (%)	40				
Age (years)	55				

[1] Species codes: Hw (western hemlock), Fd (Douglas fir), Cw (western redcedar), Pl (lodgepole pine), Vb (bitter cherry),

UNDERSTORY VEGETATION – Total Cover - 35%		
Species		Avg % Cover
Vine maple	*Acer circinatum*	6-10
Sword fern	*Polystichum munitum*	6-10
Red huckleberry	*Vaccinium parvifolium*	1-5
Beaked Hazelnut	*Corylus cornuta*	1-5
Salal	*Gaultheria shallon*	1-5

Polygon #9

ECOLOGICAL CHARACTERISTICS			
Soil Texture/Coarse Fragment Content	Soil Moisture/ Soil Nutrient	Humus Type/ Depth (cm)	BEC Site Series
Sandy Loam/40	3/C	Mor/9	$SS01_6SS03_3SS02_1$

STAND CHARACTERISTICS					
Canopy Layer	Dominant Trees	Co-Dominant Trees	Intermediate Trees	Suppressed Trees	Regeneration
Species[1] (% by volume; + denotes <10%)	Fd	$Fd_7Hw_2Cw_1$	Cw_7Hw_3	Hw_8Cw_2	-
1Density (stems/ha)	25	100	75	150	-
Tree diameter at breast height (cm)	85	55	25	15	
Tree height (m)	38	31	15	8	
Crown closure (%)	60				
Age (years)	138				

[1] Species codes: Hw (western hemlock), Fd (Douglas fir), Cw (western redcedar).

UNDERSTORY VEGETATION – Total Cover -40%		
Species		Avg % Cover
Red huckleberry	*Vaccinium parvifolium*	>50
Oregon beaked moss	*Kindbergia oregana*	>50
Wavy-leaved cotton moss	*Plagiothecium undulatum*	26-50
Salal	*Gaultheria shallon*	11-25
Sword fern	*Polystichum munitum*	11-25
False Lily-Of-The-Valley	*Maianthemum dilatatum*	11-25
Step moss	*Hylocomium splendens*	11-25
Bracken fern	*Pteridium aquilinum*	11-25
False azalea	*Menziesia ferruginea*	6-10

Scattered windthrow. Many hemlock have mistletoe

Polygon #10

ECOLOGICAL CHARACTERISTICS			
Soil Texture/Coarse Fragment Content	Soil Moisture/ Soil Nutrient	Humus Type/ Depth (cm)	BEC Site Series
Sandy Loam/65	1;2/B	Mor/8	$SS02_8SS03_2$

STAND CHARACTERISTICS					
Canopy Layer	Dominant Trees	Co-Dominant Trees	Intermediate Trees	Suppressed Trees	Regeneration
Species[1] (% by volume; + denotes <10%)	-	Fd_8Cw_2		$Cw_7Fd_2Ep_1$	Cw_7Od_3
1Density (stems/ha)	-	10		25	5
Tree diameter at breast height (cm)	-	65		8	
Tree height (m)	-	28		7	
Crown closure (%)	10				
Age (years)	110				

[1] Species codes: Ep (Paper birch), Fd (Douglas fir), Cw (western redcedar), Od (Mountain Ash)

UNDERSTORY VEGETATION – Total Cover -60%		
Species		Avg % Cover
Grasses		10-25
Salal	*Gaultheria shallon*	6-10
Saskatoon	*Amelanchier alnifolia*	1-5
Hazelnut	*Corylus cornuta*	1-5
Red huckleberry	*Vaccinium parvifolium*	1-5
Sitka mountain-ash	*Sorbus sitchensis*	1-5
Sword fern	*Polystichum munitum*	1-5
Bracken fern	*Pteridium aquilinum*	1-5
Rattlesnake-plantain	*Goodyera oblongifolia*	1-5
Spiny wood fern	*Dryopteris expansa*	1-5

Polygon #11

ECOLOGICAL CHARACTERISTICS			
Soil Texture/Coarse Fragment Content	Soil Moisture/ Soil Nutrient	Humus Type/ Depth (cm)	BEC Site Series
Sandy Loam/45	2;3/C	Mor/8	$SS03_7SS02_3$

STAND CHARACTERISTICS					
Canopy Layer	Dominant Trees	Co-Dominant Trees	Intermediate Trees	Suppressed Trees	Regeneration
Species[1] (% by volume; + denotes <10%)	-	Hw_8Cw_2	Cw_5Hw_4	Hw_7Cw_3	Hw_9Cw_1
1Density (stems/ha)	-	200	100	100	250
Tree diameter at breast height (cm)	-	40	25	4	
Tree height (m)	-	29	20	4	
Crown closure (%)	30				
Age (years)	125				

[1] Species codes: Hw (western hemlock, Cw (western redcedar).

UNDERSTORY VEGETATION – Total Cover -20%		
Species		Avg % Cover
Sword fern	*Polystichum munitum*	6-10
Red huckleberry	*Vaccinium parvifolium*	6-10
Vine maple	*Acer circinatum*	1-5
Salal	*Gaultheria shallon*	6-10

<u>Polygon #12 – Quarry</u>

ECOLOGICAL CHARACTERISTICS			
Soil Texture/Coarse Fragment Content	Soil Moisture/ Soil Nutrient	Humus Type/ Depth (cm)	BEC Site Series
Sandy Loam/70	2/B	Mor/1	$SS02_{100}$

STAND CHARACTERISTICS					
Canopy Layer	Dominant Trees	Co-Dominant Trees	Intermediate Trees	Suppressed Trees	Regeneration
Species[1] (% by volume; + denotes <10%)	-	$Hw_8Cw_6Ep_1Vb_{r1}$			
1Density (stems/ha)	-	20			
Tree diameter at breast height (cm)	-	5			
Tree height (m)	-	4			
Crown closure (%)	30				
Age (years)	125				

[1] Species codes: Hw (western hemlock, Cw (western redcedar), Vb (Bitter cherry) Ep (Paper birch)

UNDERSTORY VEGETATION – Total Cover -30%		
Species		Avg % Cover
Hardhack	*Spirea douglasii*	1-6
Salal	*Gaultheria shallon*	1-6
Sitka mountain-ash	*Sorbus sitchensis*	1-6
Willow	*Salix sp*	1-6
Grass sp.		1-5

Highly disturbed quarry. Some dying cedar around quarry edges.

Polygon #13

ECOLOGICAL CHARACTERISTICS			
Soil Texture/Coarse Fragment Content	Soil Moisture/ Soil Nutrient	Humus Type/ Depth (cm)	BEC Site Series
Sandy Loam/50	2;3/B	Mor/8	$SS03_{70}SS02_{30}$

STAND CHARACTERISTICS					
Canopy Layer	Dominant Trees	Co-Dominant Trees	Intermediate Trees	Suppressed Trees	Regeneration
Species[1] (% by volume; + denotes <10%)	-	Cw_9Hw_1	Cw_{10}	Cw10	$Hw_8Cw_1Od_1Cs_+$
1Density (stems/ha)	-	25	25	50	100
Tree diameter at breast height (cm)	-	35	20	10	
Tree height (m)	-	21	17	6	
Crown closure (%)	15				
Age (years)	110				

[1] Species codes: Hw (western hemlock, Cw (western redcedar), Cs (Cascara), Od (Mountain Ash)

UNDERSTORY VEGETATION – Total Cover -25%		
Species		Avg % Cover
Sword fern	*Polystichum munitum*	6-10
Red Elderberry	*Sambucus racemosa*	<1
Salal	*Gaultheria shallon*	6-10
Trailing blackberry	*Rubus ursinus*	6-10
Sitka mountain-ash	*Sorbus sitchensis*	6-10
Large leaved avens	*Geum macrophyllum*	6-10
Grass sp.		1-5
Red huckleberry	*Vaccinium parvifolium*	1-5
Bunchberry	*Cornus canadensis*	<1

80% of cedar have recently died from drought stress. 800 Stems/ha of dead standing cedar 15-25cm diameter and 16-22m tall. Compacted from foot traffic with low veg cover.

Polygon #14

ECOLOGICAL CHARACTERISTICS			
Soil Texture/Coarse Fragment Content	Soil Moisture/ Soil Nutrient	Humus Type/ Depth (cm)	BEC Site Series
Sandy Loam/65	5:6/D	Moder/4	SS07

STAND CHARACTERISTICS					
Canopy Layer	Dominant Trees	Co-Dominant Trees	Intermediate Trees	Suppressed Trees	Regeneration
Species[1] (% by volume; + denotes <10%)	-	$Dr_8Vb_1Act_1$	$Dr_7Cw_2Vb_1$	Cw	
1Density (stems/ha)	-	200	75	100	
Tree diameter at breast height (cm)	-	25	20	5	
Tree height (m)	-	25	17	4	
Crown closure (%)	50				
Age (years)	70				

[1] Species codes: Act (black cottonwood), Dr (red ader), Vb (bitter cherry), Cw (western redcedar).

UNDERSTORY VEGETATION – Total Cover -90%		
Species		Avg % Cover
Salmonberry	*Rubus spectabilis*	>50
Vine maple	*Acer circinatum*	26-50
Red Elderberry	*Sambucus racemosa*	26-50
Sword fern	*Polystichum munitum*	11-25
Herb-robert	*Geranium robertanium*	11-25
Lady Fern	*Athyrium filix-femina*	6-10
Spiny wood fern	*Dryopteris expansa*	6-10
Bigleaf maple	*Acer Macrophyllum*	6-10
Common horsetail	*Equisetum arvense*	6-10
One-Leaved Foamflower	*Tiarella trifoliata*	6-10
Grass sp.		6-10
Creeping buttercup	*Ranunculus repens*	6-10
Large-Leaved Avens	*Geum macrophyllum*	6-10
Willow sp.	*Salix sp.*	1-5
Hardhack	*Spiraea douglasii*	1-5

Polygon #15

ECOLOGICAL CHARACTERISTICS			
Soil Texture/Coarse Fragment Content	Soil Moisture/ Soil Nutrient	Humus Type/ Depth (cm)	BEC Site Series
Sandy Loam/40	4/D	Moder/8	$SS05_6SS01_3SS03_1$

STAND CHARACTERISTICS					
Canopy Layer	Dominant Trees	Co-Dominant Trees	Intermediate Trees	Suppressed Trees	Regeneration
Species[1] (% by volume; + denotes <10%)	$Cw_9Hw_1Fd_{0.1}$	Hw_6Cw_4	Cw_6Hw_4	Hw_8Cw_2	-
1Density (stems/ha)	25	150	200	100	-
Tree diameter at breast height (cm)	70	40	28	25	
Tree height (m)	30	25	20	9	
Crown closure (%)	80				
Age (years)	40				

[1] Species codes: Hw (western hemlock), Fd (Douglas fir), Cw (western redcedar).

UNDERSTORY VEGETATION – Total Cover - 70%		
Species		Avg % Cover
Sword fern	*Polystichum munitum*	11-25
Red huckleberry	*Vaccinium parvifolium*	11-25
Vine maple	*Acer circinatum*	6-10
Lady Fern	*Athyrium filix-femina*	1-5
Bracken fern	*Pteridium aquilinum*	1-5
Red Elderberry	*Sambucus racemosa*	1-5
Salal	*Gaultheria shallon*	1-5
Hazelnut	*Corylus cornuta*	1-5
Spiny wood fern	*Dryopteris expansa*	1-5
Broad-Leaved Starflower	*Trientalis latifolia*	<1

Mistletoe infection in hemlock trees

Polygon #16

ECOLOGICAL CHARACTERISTICS			
Soil Texture/Coarse Fragment Content	Soil Moisture/ Soil Nutrient	Humus Type/ Depth (cm)	BEC Site Series
Sandy Loam/40	4/D	Mor/10	$SS05_{10}$

STAND CHARACTERISTICS					
Canopy Layer	Dominant Trees	Co-Dominant Trees	Intermediate Trees	Suppressed Trees	Regeneration
Species[1] (% by volume; + denotes <10%)	-	Hw_9Cw_1	Hw	Hw_{10}	$Hw_9Mb_1Fd_+$
1Density (stems/ha)	-	50	25	400	500
Tree diameter at breast height (cm)	-	50	30	5	
Tree height (m)	-	37	28	3	
Crown closure (%)	25				
Age (years)	85				

[1] Species codes: Hw (western hemlock), Fd (Douglas fir), Cw (western redcedar), Mb (bigleaf maple).

UNDERSTORY VEGETATION – Total Cover -70%		
Species		Avg % Cover
Salal	*Gaultheria Shallon*	1-5
Salmonberry	*Rubus spectabilis*	1-5
Deer Fern	*Blechnum spicant*	1-5
Red elderberry	*Sambucus racemosa*	6-10
Spiny wood fern	*Dryopteris expansa*	6-10
Sword fern	*Polystichum munitum*	6-10
Vine Maple	*Acer circinatum*	6-10
Red huckleberry	*Vaccinium parvifolium*	10-25

This area has been impacted by blowdown and hemlock mistletoe infection. It has an open canopy with a dense understory establishing. Trees and shrubs have been planted in this area.

Polygon #17

ECOLOGICAL CHARACTERISTICS			
Soil Texture/Coarse Fragment Content	Soil Moisture/ Soil Nutrient	Humus Type/ Depth (cm)	BEC Site Series
Sandy Loam/50	4;5/D	Mor/13	$SS05_9SS07_1$

STAND CHARACTERISTICS					
Canopy Layer	Dominant Trees	Co-Dominant Trees	Intermediate Trees	Suppressed Trees	Regeneration
Species[1] (% by volume; + denotes <10%)	-	$Hw_7Cw_2Fd_1$	Cw_5Hw_5	Cw_7Hw_3	-
1Density (stems/ha)	-	350	100	10	-
Tree diameter at breast height (cm)	-	45	30	8	
Tree height (m)	-	34	26	7	
Crown closure (%)	70				
Age (years)	80				

[1] Species codes: Hw (western hemlock), Fd (Douglas fir), Cw (western redcedar).

UNDERSTORY VEGETATION – Total Cover - 35%		
Species		Avg % Cover
Sword fern	*Polystichum munitum*	11-25
Red huckleberry	*Vaccinium parvifolium*	11-25
Red elderberry	*Sambucus racemosa*	6-10
Lady Fern	*Athyrium filix-femina*	1-5
Deer Fern	*Blechnum spicant*	1-5
Spiny wood fern	*Dryopteris expansa*	1-5
Dull Oregon-grape	*Mahonia nervosa*	1-5
Broad-Leaved Starflower	*Trientalis latifolia*	1-5
False azalea	*Menziesia ferruginea*	1-5
Bracken fern	*Pteridium aquilinum*	1-5
Salmonberry	*Rubus spectabilis*	1-5
Vine maple	*Acer circinatum*	1-5
Salal	*Gaultheria shallon*	1-5
False azalea	*Menziesia ferruginea*	<1

Polygon #18

ECOLOGICAL CHARACTERISTICS			
Soil Texture/Coarse Fragment Content	Soil Moisture/ Soil Nutrient	Humus Type/ Depth (cm)	BEC Site Series
Sandy Loam/35	4/D	Moder/4	SS05

STAND CHARACTERISTICS					
Canopy Layer	Dominant Trees	Co-Dominant Trees	Intermediate Trees	Suppressed Trees	Regeneration
Species[1] (% by volume; + denotes <10%)	Act	$Vb_8Dr_1Cs_1$	-	-	-
1Density (stems/ha)	1	150	-	-	-
Tree diameter at breast height (cm)	70	35	-	-	
Tree height (m)	35	18	-	-	
Live crown ratio					
Crown closure (%)	25				
Age (years)	40				

[1] Species codes: Act (black cottonwood), Vb (Bitter cherry), Dr (red alder), Cs (Cascara)

UNDERSTORY VEGETATION – Total Cover -90%		
Species		Avg % Cover
Vine maple	*Acer circinatum*	>50
Sword fern	*Polystichum munitum*	11-25
Salmonberry	*Rubus spectabilis*	11-25
Bracken fern	*Pteridium aquilinum*	6-10
Red elderberry	*Sambucus racemosa*	6-10
Red huckleberry	*Vaccinium parvifolium*	6-10
Mountain sweet-cicely	*Osmoriza chilensis*	6-10
Lady Fern	*Athyrium filix-femina*	6-10
Salal	*Gaultheria shallon*	6-10
Broad-Leaved Starflower	*Trientalis latifolia*	6-10
Trailing blackberry	*Rubus ursinus*	6-10

Polygon #19

ECOLOGICAL CHARACTERISTICS			
Soil Texture/Coarse Fragment Content	Soil Moisture/ Soil Nutrient	Humus Type/ Depth (cm)	BEC Site Series
Sandy Loam/50	3:4/C	Mor/12	SS01

STAND CHARACTERISTICS					
Canopy Layer	Dominant Trees	Co-Dominant Trees	Intermediate Trees	Suppressed Trees	Regeneration
Species[1] (% by volume; + denotes <10%)	Fd	Hw_7Cw_3	Hw_6Cw_4	Cw	Cw_9Fd_1
Density (stems/ha)	10	400	50	20	
Tree diameter at breast height (cm)	60	40	18	5	
Tree height (m)	32	26	20	5	
Crown closure (%)	60				
Age (years)	75				

[1] Species codes: Hw (western hemlock), Fd (Douglas fir), Cw (western redcedar).

UNDERSTORY VEGETATION – Total Cover - 20%		
Species		Avg % Cover
Red huckleberry	*Vaccinium parvifolium*	6-10
Bracken fern	*Pteridium aquilinum*	1-5
Sitka mountain-ash	*Sorbus sitchensis*	<1

Polygon #20

ECOLOGICAL CHARACTERISTICS			
Soil Texture/Coarse Fragment Content	Soil Moisture/ Soil Nutrient	Humus Type/ Depth (cm)	BEC Site Series
Sandy Loam/45	2;3/c	Moder/3	$SS03_7SS02_3$

STAND CHARACTERISTICS					
Canopy Layer	Dominant Trees	Co-Dominant Trees	Intermediate Trees	Suppressed Trees	Regeneration
Species[1] (% by volume; + denotes <10%)	-	Hw_8Cw_2	Cw_7Hw_3	$Hw_6Cw_3Vb_1$	Hw_8 $Fd_1Cw_1A_+$
1Density (stems/ha)	-	25	25	100	600
Tree diameter at breast height (cm)	-	40	25	4	
Tree height (m)	-	29	20	4	
Crown closure (%)	30				
Age (years)	125				

[1] Species codes: Hw (western hemlock), Cw (western redcedar), A (Arbutus), Vb (Bitter cherry), Fd (Douglas fir)

UNDERSTORY VEGETATION – Total Cover -90%		
Species		Avg % Cover
Sword fern	*Polystichum munitum*	11-25
Salal	*Gaultheria shallon*	11-25
Red huckleberry	*Vaccinium parvifolium*	11-25
Bracken fern	*Pteridium aquilinum*	6-10
Vine maple	*Acer circinatum*	1-5
Spiny wood fern	*Dryopteris expansa*	1-5
False Lily-Of-The-Valley	*Maianthemum dilatatum*	1-5
Common snowberry	*Symphoricarpos albus*	1-5
Sitka mountain-ash	*Sorbus sitchensis*	1-5
Broad-Leaved Starflower	*Trientalis latifolia*	1-5
Grass sp.		1-5
Western trumpet honeysuckle	*Lonicera ciliosa*	1-5

Polygon #21

ECOLOGICAL CHARACTERISTICS			
Soil Texture/Coarse Fragment Content	Soil Moisture/ Soil Nutrient	Humus Type/ Depth (cm)	BEC Site Series
Sandy Loam/45	2;3;4/c;d	Moder/8	$SS01_6SS05_4$

STAND CHARACTERISTICS					
Canopy Layer	Dominant Trees	Co-Dominant Trees	Intermediate Trees	Suppressed Trees	Regeneration
Species[1] (% by volume; + denotes <10%)	-	$Fd_1Hw_7Cw_2$	Cw_7Hw_3	$Hw_6Cw_3Vb_1$	Hw_9Cw_1
1Density (stems/ha)	-	150	100	100	250
Tree diameter at breast height (cm)	-	40	25	4	
Tree height (m)	-	29	20	4	
Crown closure (%)	30				
Age (years)	125				

[1] Species codes: Hw (western hemlock), Cw (western redcedar), Fd (Douglas fir), Vb (Bitter cherry)

UNDERSTORY VEGETATION – Total Cover -90%		
Species		Avg % Cover
Sword fern	*Polystichum munitum*	26-50
Bracken fern	*Pteridium aquilinum*	11-25
Red elderberry	*Sambucus racemosa*	11-25
Red huckleberry	*Vaccinium parvifolium*	11-25
Vine maple	*Acer circinatum*	5-10
Spiny wood fern	*Dryopteris expansa*	5-10
Salal	*Gaultheria shallon*	5-10
False Lily-Of-The-Valley	*Maianthemum dilatatum*	5-10
Salmonberry	*Rubus spectabilis*	5-10
Common snowberry	*Symphoricarpos albus*	5-10
Sitka mountain-ash	*Sorbus sitchensis*	5-10
Broad-Leaved Starflower	*Trientalis latifolia*	1-5
Hazelnut	*Corylus cornuta*	1-5

Polygon #22 – Green Necklace Trail

ECOLOGICAL CHARACTERISTICS			
Soil Texture/Coarse Fragment Content	Soil Moisture/ Soil Nutrient	Humus Type/ Depth (cm)	BEC Site Series
Sandy Loam/45	3;4/c	Moder/3	SS01

STAND CHARACTERISTICS					
Canopy Layer	Dominant Trees	Co-Dominant Trees	Intermediate Trees	Suppressed Trees	Regeneration
Species[1] (% by volume; + denotes <10%)	Act_6Fd_4	$Dr_5Fd_1Cw_1Act_1Vb_1$		$Dr_7Cw_2Fd_1Cw_1$	Cw
1Density (stems/ha)	25	200		100	25
Tree diameter at breast height (cm)	35	15		10	
Tree height (m)	25	15		6	
Crown closure (%)	20				
Age (years)	15				

[1] Species codes: Dr (red alder), Fd (Douglas fir), Cw (western redcedar), Vb (bitter cherry), Act (black cottonwood)

UNDERSTORY VEGETATION – Total Cover -70%		
Species		Avg % Cover
Salmonberry	*Rubus spectabilis*	11-25
Vine maple	*Acer circinatum*	11-25
Hazelnut	*Corylus cornuta*	1-5
Hardhack	*Spiraea douglasii*	1-5
Sword fern	*Polystichum munitum*	1-5
Bracken fern	*pteridium aquilinum*	1-5

Notes:

- Most vegetation cover is invasive species (blackberry, English ivy, Cherry laurel, lamium, holly)
- Three mature western redcedar trees have recently died
- Historically a disturbed site with compacted soils
- South end disturbed for recent Metro Vancouver infrastructure
- One large White poplar with numerous suckers growing nearby

Polygon #23

ECOLOGICAL CHARACTERISTICS			
Soil Texture/Coarse Fragment Content	Soil Moisture/ Soil Nutrient	Humus Type/ Depth (cm)	BEC Site Series
Sandy Loam/40 (compacted)	5-6/C-D	Moder/3	SS07

STAND CHARACTERISTICS					
Canopy Layer	Dominant Trees	Co-Dominant Trees	Intermediate Trees	Suppressed Trees	Regeneration
Species[1] (% by volume; + denotes <10%)		$Act_7Dr_2(Cw_1)$	$Act_4Dr_4(Cw_1W_1Aw_1)$	$Cw_6W_3\ Aw_1$	
1Density (stems/ha)		150	100	100	
Tree diameter at breast height (cm)		50	30	10	
Tree height (m)		34	18	6	
Crown closure (%)	35				
Age (years)	40				

[1] Species codes: Act (black cottonwood), Cw (western redcedar), W (Willow), Aw (White poplar)

UNDERSTORY VEGETATION – Total Cover -90%		
Species		Avg % Cover
Hazelnut	*Corylus cornuta*	1-5
Hardhack	*Spiraea douglasii*	1-5
Salmonberry	*Rubus spectabilis*	6-10
Vine maple	*Acer circinatum*	1-5
Sword fern	*Polystichum munitum*	1-5
Red osier dogwood	*Cornus stolonifera*	1-5
Common snowberry	*Symphoricarpos albus*	1-5

Notes:

- Trees are mostly on lower side of trail
- Most vegetation cover is invasive species
- Planted area above trail consists of a mix of native and non native species

Appendix B – Wildlife Inventory

Table 10 - Birds

Common Name	Scientific Name	Status	Confirmed in Study Area	Likely but not Confirmed	Season			
					Spring	Summer	Fall	Winter
ORDER ANSERIFORMES: Swans, Geese and Ducks **FAMILY ANATIDAE: Swans, Geese and Ducks**								
Tundra Swan	*Cygnus columbianus*	Blue						x
Trumpeter Swan	*Cygnus buccinator*	Yellow						x
Mute Swan	*Cygnus olor*	Non Native			x		x	x
Greater White-fronted Goose	*Anser albifrons*	Yellow			x		x	x
Snow Goose	*Anser caerulescens*	Yellow			x		x	x
Canada Goose	*Branta canadensis*	Yellow			x	x	x	x
Cackling Goose	*Branta hutchinsii*	Yellow			x	x	x	x
Wood Duck	*Aix sponsa*	Yellow			x	x	x	x
Green-winged Teal	*Anas crecca*	Yellow			x	x	x	x
Mallard	*Anas platyrhynchos*	Yellow			x	x	x	x
Northern Pintail	*Anas acuta*	Yellow			x	x	x	x
Blue-winged Teal	*Spatula discors*	Yellow			x	x	x	
Cinnamon Teal	*Spatula cyanoptera*	Yellow			x	x	x	
Northern Shoveler	*Spatula clypeata*	Yellow			x	x	x	x
Gadwall	*Mareca strepera*	Yellow			x	x	x	x
Eurasian Wigeon	*Mareca penelope*				x		x	x
American Wigeon	*Mareca americana*	Yellow			x	x	x	x
Canvasback	*Aythya valisineria*	Yellow			x		x	x
Redhead	*Aythya americana*	Yellow				x	x	
Ring-necked Duck	*Aythya collaris*	Yellow			x	x	x	x
Greater Scaup	*Aythya marila*	Yellow			x		x	x
Lesser Scaup	*Aythya affinis*	Yellow			x		x	x
Surf Scoter	*Melanitta perspicillata*	Blue			x			x
White-winged Scoter	*Melanitta deglandi*				x			x
Black Scoter	*Melanitta americana*	Blue					x	x
Harlequin Duck	*Histrionicus histrionicus*				x			x
Long-tailed Duck	*Clangula hyemalis*	Blue			x			x
Common Goldeneye	*Bucephala clangula*	Yellow			x			x
Barrow's Goldeneye	*Bucephala islandica*	Yellow			x			x

Common Name	Scientific Name	Status	Confirmed in Study Area	Likely but not Confirmed	Season			
					Spring	Summer	Fall	Winter
Bufflehead	*Bucephala albeola*	Yellow			x			x
Hooded Merganser	*Lophodytes cucullatus*	Yellow			x	x	x	x
Common Merganser	*Mergus merganser*	Yellow			x		x	x
Red-breasted Merganser	*Mergus serrator*	Yellow			x			x
Ruddy Duck	*Oxyura jamaicensis*	Yellow					x	x
Ring-necked Pheasant	*Phasianus colchicus*	Exotic			x	x	x	x
Ruffed Grouse	*Bonasa umbellus*	Yellow			x	x	x	x
ORDER GAVIIFORMES: Loons FAMILY GAVIIDAE: Loons								
Red-throated Loon	*Gavia stellata*	Yellow			x		x	x
Pacific Loon	*Gavia pacifica*	Yellow			x		x	
Common Loon	*Gavia immer*	Yellow					x	
ORDER PODICIPEDIFORMES : Grebes FAMILY PODICIPEDIDAE: Grebes								
Pied-billed Grebe	*Podilymus podiceps*	Yellow			x		x	x
Horned Grebe	*Podiceps auritus*	Yellow			x		x	x
Western Grebe	*Aechmophorus occidentalis*	Red (1-SC)			x	x	x	x
Clark's Grebe	*Aechmophorus clarkii*	Red			x	x		
ORDER PELECANIFORMES: Totipalmate Swimmers FAMILY PHALACROCORACIDAE: Cormorants								
Double-crested Cormorant	*Phalacrocorax auritus*	Blue			x	x	x	x
ORDER CICONIIFORMES: Bitterns, Herons, Egrets, Ibises, Storks and Vultures FAMILY ARDEIDAE: Bitterns, Herons and Egrets								
American Bittern	*Botaurus lentiginosus*	Blue			x	x	x	x
Great Blue Heron *ssp. fannini*	*Ardea herodias fannini*	Blue (1)			x	x	x	x
Green Heron	*Butorides virescens*	Blue				x		
Black Crowned Night Heron	*Nycticorax nycticorax*	Red			x	x	x	x
FALCONIFORMES: Diurnal Birds of Prey FAMILY ACCIPITRIDAE: Osprey, Eagles and Hawks								
Turkey Vulture	*Cathartes aura*	Yellow			x	x	x	
Osprey	*Pandion haliaetus*	Yellow				x	x	
Bald Eagle	*Haliaeetus leucocephalus*	Yellow			x	x	x	x
Northern Harrier	*Circus hudsonius*	Yellow			x	x	x	x
Cooper's Hawk	*Acccipiter cooperii*	Yellow		x	x	x	x	x

Common Name	Scientific Name	Status	Confirmed in Study Area	Likely but not Confirmed	Season			
					Spring	Summer	Fall	Winter
Northern Goshawk *ssp. laingi*	*Accipiter gentilis laingi*	Red (1-T)			x			x
Sharp-shinned Hawk	*Accipiter striatus*	Yellow			x		x	x
Red-tailed Hawk	*Buteo jamaicensis*	Yellow	x		x	x	x	x
Rough-legged Hawk	*Buteo lagopus*	Blue			x	x	x	x
Common Nighthawk	*Chordeiles minor*	Yellow (1)			x	x		
ORDER FALCONIFORMES: Diurnal Birds of Prey FFAMILY FALCONIDAE: Falcons								
American Kestrel	*Falco sparverius*	Yellow			x	x		
Merlin	*Falco columbarius*	Yellow			x	x	x	x
Peregrine Falcon *ssp. pealei*	*Falco peregrinus pealei*	Blue (1-SC)				x	x	
Peregrine Falcon *ssp. Anatum*	*Falco peregrinus anatum*	Red (1-SC)			x	x	x	x
Gyrfalcon	*Falco rusticolus*	Blue			x	x	x	x
ORDER GRUIFORMES: Cranes, Rails and Allies FAMILY RALLIDAE: Rails, Gallinules and Coots								
Sora Rail	*Porzana carolina*	Yellow				x	x	
Virginia Rail	*Rallus limicola*	Yellow			x	x	x	x
American Coot	*Fulica americana*	Yellow			x	x	x	x
ORDER CHARADRIIFORMES: Shorebirds,Gulls, Auks and Allies FAMILY CHARADRIIDAE: Plovers								
Sandhill Crane	*Antigone canadensis*	Yellow			x	x	x	x
Semipalmated Plover	*Charadrius semipalmatus*	Yellow				x	x	
Marbled Murrelet	*Brachyramphus marmoratus*	Blue (1)			x	x	x	
Killdeer	*Charadrius vociferus*	Yellow			x	x	x	x
FAMILY SCOLOPACIDAE: Sandpipers, Phalaropes and Allies								
Dunlin	*Calidris alpina*	Yellow			x		x	x
Spotted Sandpiper	*Actitis macularius*	Yellow				x		
Solitary Sandpiper	*Tringa solitaria*	Yellow				x	x	
Stilt Sandpiper	*Caldris himantopus*	Unknown				x		
Sharp-tailed Sandpiper	*Calidris acuminata*	Yellow					x	
Baird's Sandpiper	*Calidris bairdii*	Unknown				x	x	
Western Sandpiper	*Calidris mauri*	Yellow			x	x	x	
Least Sandpiper	*Calidris minutillla*	Yellow				x	x	
Semipalmated Sandpiper	*Calidris pusilla*	Unknown			x	x	x	
Hudsonian Godwit	*Limosa haemastica*	Red					x	
Marbled Godwit	*Limosa fedoa*	Unknown				x		
Short-billed Dowitcher	*Limnodromus griseus*	Blue			x	x	x	

Common Name	Scientific Name	Status	Confirmed in Study Area	Likely but not Confirmed	Season			
					Spring	Summer	Fall	Winter
Long-billed Dowitcher	*Limnodromus scolopacous*	Yellow			x	x	x	x
Greater Yellowlegs	*Tringa melanoleuca*	Yellow			x	x	x	x
Lesser Yellowlegs	*Tringa flavipes*	Yellow			x	x	x	
Wilson's Snipe	*Gallinago delicata*	Yellow			x	x	x	x
Wilson's Phalarope	*Phalaropus tricolor*	Yellow			x	x	x	
Red-necked Phalarope	*Phalaropus lobatus*	Blue				x	x	
FAMILY LARIDAE: Jaegers, Skua, Gulls and Terns								
Bonaparte's Gull	*Chroicocephalus philadelphia*	Yellow				x	x	
Herring Gull	*Larus argentatus*	Yellow						x
Ring-billed Gull	*Larus delawarensis*	Yellow			x	x	x	x
California Gull	*Larus californicus*	Blue					x	
Mew Gull	*Larus canus*	Yellow			x	x	x	x
Glaucous-winged Gull	*Larus glaucenscens*	Yellow			x	x	x	x
Caspian Tern	*Hydroprogne caspia*	Blue			x	x	x	
ORDER COLUMBIDAE: Pigeons and Doves **FAMILY COLUMBIDAE: Pigeons and Doves**								
Band-tailed Pigeon	*Columba fasciata*	Blue (1-SC)				x	x	
Rock Dove	*Columba livia*	Non-native	x		x	x	x	x
Mourning Dove	*Zenaida macroura*	Yellow			x	x	x	
ORDER STRIGIFORMES: Owls **FAMILY STRIGIDAE: Typical Owls**								
Barn Owl	*Tyto alba*	Red (1-T)			x	x	x	x
Western Screech Owl *ssp. kennicottii*	*Megascops kennicottii kennicottii*	Blue (1-T)		x				
Great Horned Owl	*Bubo virginanus*	Yellow			x	x	x	x
Barred Owl	*Strix varia*	Yellow	x		x	x	x	x
Spotted Owl	*Strix occidentalis*	Red (1-E)			x	x	x	x
Short-eared Owl	*Asio flammeus*	Blue (1)			x	x	x	x
Long-eared Owl	*Asio otus*	Yellow			x		x	x
Northern Saw-whet Owl	*Aegolius acadicus*	Yellow		x	x		x	x
ORDER STRIGIFORMES: **FAMILY :**								
Black Swift	*Cypseloides niger*	Blue (1-E)			x	x		
Vaux's Swift	*Chaetura vauxi*	Yellow			x	x		
FAMILY TROCHILIDAE: hummingbirds								

Common Name	Scientific Name	Status	Confirmed in Study Area	Likely but not Confirmed	Season			
					Spring	Summer	Fall	Winter
Anna's Humminbird	*Calypte anna*	Yellow	x		x	x	x	x
Rufous Hummingbird	*Selasphorus rufus*	Yellow	x		x	x		
ORDER CORACIIFORMES: Kingfisher FAMILY ALCEDINIDAE: Kingfishers								
Belted Kingfisher	*Megaceryle alcyon*	Yellow			x	x	x	x
ORDER PICIFORMES: Woodpeckers and Allies FAMILY PICIDAE: Woodpeckers								
Downy Woodpecker	*Dryobates pubescens*	Yellow	x		x	x	x	x
Hairy Woodpecker	*Dryobates pubescens*	Yellow		x	x		x	
Northern Flicker	*Colaptes auratus*	Yellow	x		x	x	x	x
Pileated Woodpecker	*Dryocopus pileatus*	Yellow	x		x		x	x
Red-breasted Sapsucker	*Sphyrapicus ruber*	Yellow		x			x	x
ORDER PASSERIFORMES: Passerine Birds FAMILY TYRANNIDAE: Tyrant Flycatchers								
Olive-sided Flycatcher	*Contopus cooperi*	Blue (1-T)	x		x	x		
Western Wood-pewee	*Contopus sordidulus*	Yellow		x		x		
Willow Flycatcher	*Empidonax trailii*	Yellow				x	x	
Hammond's Flycatcher	*Empidonax hammondii*	Yellow		x	x		x	
Pacific-slope Flycatcher	*Empidonax difficilis*	Yellow	x		x	x		
Eastern Kingbird	*Tyrannus tyrannus*	Yellow				x		
FAMILY LANIIDAE: Shrikes								
Northern Shrike	*Lanius borealis*	Yellow			x		x	x
FAMILY VEREONIDAE: Vireos								
Cassin's Vireo	*Vireo cassinii*	Yellow		x	x	x	x	
Hutton's Vireo	*Vireo huttoni*	Yellow			x	x	x	
Warbling Vireo	*Vireo gilvus*	Yellow		x	x	x	x	
Red-eyed Vireo	*Vireo olivaceus*	Yellow			x	x		
FAMILY CORVIDAE: Jays, Magpies and Crows								
Steller's Jay	*Cyanocittta stelleri*	Yellow		x			x	
Northwestern Crow	*Corvus caurinus*	Yellow	x		x	x	x	x
Common Raven	*Corvus corax*	Yellow		x	x	x	x	x
FAMILY HIRUNDINIDAE: Swallows								
Purple Martin	*Progne subis*	Blue			x	x		
Tree Swallow	*Tachycineta bicolor*	Yellow		x	x	x	x	

Common Name	Scientific Name	Status	Confirmed in Study Area	Likely but not Confirmed	Season			
					Spring	Summer	Fall	Winter
Violet-green Swallow	*Tachycineta thalassina*	Yellow		x	x	x	x	
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	Yellow			x	x		
Bank Swallow	*Riparia riparia*	Yellow (1-T)				x	x	
Cliff Swallow	*Petrochelidon pyrrhonota*	Yellow			x	x	x	
Barn Swallow	*Hirundo rustica*	Blue (1-T)		x	x	x	x	
FAMILY PARIDAE: Chickadees								
Black-capped Chickadee	*Poecile atricapilla*	Yellow	x		x	x	x	x
Chestnut-backed Chickadee	*Poecile rufescens*	Yellow						x
FAMILY AEGITHALIDAE: Bushtits								
Bushtit	*Psaltriparus minimus*	Yellow	x		x	x	x	x
FAMILY SITTIDAE: Nuthatches								
Red-breasted Nuthatch	*Sitta canadensis*	Yellow	x		x	x	x	x
FAMILY CERTHIIDAE: Creepers								
Brown Creeper	*Certhia americana*	Yellow	x		x	x	x	x
FAMILY TROGLODYTIDAE: Wrens								
Bewick's Wren	*Thryomanes bewickii*	Yellow			x	x	x	x
Pacific Wren	*Troglodytes pacificus*	Yellow	x		x	x	x	x
Marsh Wren	*Cistothorus palustris*	Yellow			x	x	x	x
FAMILY REGULIDAE: Kinglets								
American Dipper	*Cinclus mexicanus*	Yellow						
Golden-crowned Kinglet	*Regulus satrapa*	Yellow	x		x	x	x	x
Ruby-crowned Kinglet	*Regulus calendula*	Yellow	x		x		x	x
FAMILY TURDIDAE: Bluebirds, Thrushes and Allies								
Swainson's Thrush	*Catharus ustulatus*	Yellow	x		x	x	x	
Hermit Thrush	*Catharus guttatus*	Yellow			x	x	x	x
American Robin	*Turdus migratorius*	Yellow	x		x	x	x	x
Varied Thrush	*Ixoreus naevius*	Yellow	x		x		x	x

Common Name	Scientific Name	Status	Confirmed in Study Area	Likely but not Confirmed	Season			
					Spring	Summer	Fall	Winter
FAMILY STURNIDAE: Starlings and Allies								
European Starling	*Sturnus vulgaris*	Non-native	x		x	x	x	x
FAMILY MOTACILLIDAE: Wagtails and Pipits								
American Pipit	*Anthus rubescens*	Yellow			x		x	x
FAMILY BOMBYCILLIDAE: Waxwings								
Bohemian Waxwing	*Bombycilla garrulus*							x
Cedar Waxwing	*Bombycilla cedrorum*			x	x	x	x	x
Northern Waterthrush	*Parkesia noveboracensis*	Yellow					x	
FAMILY PARULIDAE: Wood-Warblers, Sparrows, Blackbirds and Allies								
Orange-crowned Warbler	*Vermivora celata*		x		x	x	x	
Yellow Warbler	*Dendroica petechia*			x	x	x	x	
Yellow-rumped Warbler	*Dendroica coronata*			x	x	x	x	
Black-throated Gray Warbler	*Dendroica nigrescens*		x		x		x	
Townsend's Warbler	*Setophaga townsendi*			x	x		x	
MacGillivray's Warbler	*Oporornis tolmiei*			x		x		
Common Yellowthroat	*Geothlypis trichas*			x	x	x	x	
Wilson's Warbler	*Wilsonia pusilla*			x	x	x	x	
FAMILY THRAUPIDAE: Tanagers								
Western Tanager	*Piranga ludoviciana*		x		x	x		
FAMILY EMBERIZIDAE: Towhees, Sparrows, Longspurs and Allies								
Spotted Towhee	*Pipilo maculatus*		x		x	x	x	x
Savannah Sparrow	*Passerculus sandwichensis*				x	x	x	
Fox Sparrow	*Passerella iliaca*			x	x		x	x
Song Sparrow	*Melospiza melodia*		x		x	x	x	x
Lincoln's Sparrow	*Melospiza lincolnii*				x		x	x
Swamp Sparrow	*Melospiza georgiana*						x	x
White-throated Sparrow	*Zonotrichia albicollis*	Yellow					x	

Common Name	Scientific Name	Status	Confirmed in Study Area	Likely but not Confirmed	Season			
					Spring	Summer	Fall	Winter
White-crowned Sparrow	*Zonotrichia leucophrys*		x		x	x	x	x
Golden-crowned Sparrow	*Zonotrichia atricapilla*				x	x	x	x
Dark-eyed Junco	*Junco hyemalis*		x		x	x	x	x
FAMILY CARDINALIDAE: Cardinals, Grosbeaks and Allies								
Black-headed Grosbeak	*Pheucticus melanocephalus*			x	x	x		
Red-winged Blackbird	*Agelaius phoeniceus*				x	x	x	x
Western Meadowlark	*Sturnella neglecta*				x		x	
FAMILY ICTERIDAE: Blackbirds, Orioles and Allies								
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*	Yellow			x			
Brewer's Blackbird	*Euphagus cyanocephalus*							x
Brown-headed Cowbird	*Molothrus ater*					x	x	x
Bullock's Oriole	*Icterus bullockii*				x	x		
FAMILY FRINGILLIDAE: Cardueline Finches and Allies								
Purple Finch	*Carpodacus purpureus*		x		x	x	x	x
House Finch	*Carpodacus mexicanus*		x		x	x	x	x
Red Crossbill	*Loxia curvirostra*				x			x
Common Redpoll	*Acanthis flammea*				x			x
Pine Siskin	*Carduelis pinus*		x		x	x	x	x
American Goldfinch	*Carduelis tristis*			x	x	x	x	x
Evening Grosbeak	*Coccothraustes vespertinus*	Yellow (1)		x			x	x
FAMILY PASSERIDAE: Old World Sparrows								
House Sparrow	*Passer domesticus*	Non-native	x		x	x	x	x

Table 11 - Mammals

Common Name	Scientifc Name	BC Status (SARA)	Confirmed in Study Area	Likely but not Confirmed
Western Long-eared Myotis	*Myotis evotis*			
Keen's Long-eared Myotis	*Myotis keenii*			
Little Brown Myotis	*Myotis lucifugus*	Yellow (1-E)		x
California Myotis	*Myotis californicus*			
Long-legged Myotis	*Myotis volans*			
Yuma Myotis	*Myotis yumanensis*			x
Hoary Bat	*Lasiurus cinereus*			
Townsend's Big-eared Bat	*Plecotus townsendii*	Blue		x
Silver-haried Bat	*Lasionycteris noctivagans*			
Big Brown Bat	*Eptesicus fuscus*			x
Virginia Opossum	*Didelphis virginiana*	Non-native		
Pacific Water Shrew	*Sorex bendirii*	Red (1-E)		
Trowbridge's Shrew	*Sorex trowbridgii*	Blue		
Olympic Shrew	*Sorex rohweri*	Red		
Cinereus (Common) Shrew	*Sorex cinereus*			x
Dusky Shrew	*Sorex monticolus*			
Vagrant Shrew	*Sorex vagrans*			
Shrew-mole	*Neurotrichus gibbsii*			
Eastern Cottontail	*Sylvilagus floridanus*			
Snowshoe Hare ssp. Washingtonian	*Lupus americans washingtonian*	Red		
North American Deer Mouse	*Peromyscus maniculatus*			x
Southern Red-backed Vole ssp. occidentalis	*Myodes gapperi occidentalis*	Red		
Long-tailed Vole	*Microtus longicaudus*			
Creeping Vole	*Microtus oregoni*			x
Townsend's Vole	*Microtus townsendii*	Red (1-E)		
Muskrat	*Ondatra zibethica*			
Beaver	*Castor canadensis*			
Northern Flying Squirrel	*Glaucomys sabrinus*	Yellow		
Easter Gray Squirrel	*Sciurus carolinensis*	Non-native	x	
Douglas Squirrel	*Tamiasciurus douglasii*			x
Townsend's Chipmunk	*Neotamias townsendii*			
Pacific Jumping Mouse	*Zapus trinotatus*			x
House Mouse	*Mus musculus*			x
Norway Rat	*Rattusnorvegicus*			x
Roof Rat/Black Rat	*Rattus rattus*			x

Common Name	Scientifc Name	BC Status (SARA)	Confirmed in Study Area	Likely but not Confirmed
Coyote	*Canis latrans*		x	
River Otter	*Lontra canadensis*			
Marten	*Martes americana*			
Fisher	*Martes pennanti*	Yellow		
Striped Skunk	*Mephitis mephitis*			x
Spotted Skunk	*Spilogale putorius*			
Ermine ssp. Fallenda	*Mustela erminea fallenda*			
Long-tailed Weasel ssp. Altifrontalis	*Mustela frenata altifrontalis*	Red		
Mink	*Mustela vison*			
Raccoon	*Procyon lotor*		x	
Black bear	*Ursus americanus*		x	
Mule deer ssp. Columbianus	*Odocoileus hemionus*			
Mountain Beaver	*Aplondtia rufa*	Yellow (1)		
Roosevelt Elk	*Cervus elaphus roosevelti*	Blue		
Steller Sea Lion	*Eumetopias jubatus*	Blue (1-SC)		
Wolverine ssp. Luscus	*Gulo gulo luscus*	N/A (1-SC)		
Mountain Goat	*Oreamnos americanus*	Blue		

Table 12 - Amphibians and Reptiles

Common Name	Scientifc Name	BC Status (SARA)	Confirmed in Study Area	Likely but not Confirmed
Western Pond Turtle	*Actinemys marmorata*	Red (1)		
Western Toad	*Anaxyrus boreas*	Yellow (1)		
Coastal Tailed Frog	*Ascaphus truei*	Yellow (1)		
Northern Rubber Boa	*Charina bottae*	Yellow (1)		
Painted Turtle - Pacific Coast Population	*Chrysemys picta* pop. 1	Red (1)		
Sharp-tailed Snake	*Contia tenuis*	Red (1-E)		
Coastal (Pacific) Giant Salamander	*Dicamptodon tenebrosus*	Blue (1-T)		
Gopher Snake *ssp. Catenifer*	*Pituophis catenifer catenifer*	Red (1-Ext)		
Northern Red-legged Frog	*Rana aurora*	Yellow (1-SC)		
Oregon Spotted Frog	*Rana pretiosa*	Red (1-E)		
Rough-skinned newt	*Taricha granulosa*	Yellow		
Northwest Salamander	*Ambystoma gracile*	Yellow		
Long toed salamander	*Ambystoma macrodactylum*	Yellow		

Common Name	Scientifc Name	BC Status (SARA)	Confirmed in Study Area	Likely but not Confirmed
Ensatina Salamander	*Ensatina eschscholtzii*	Yellow		x
Western red-backed salamander	*Plethodon vehiculum*	Yellow		x
Western toad	*Anaxyrus boreas*	Yellow		
Tailed frog	*Ascaphus truei*	Blue		
Pacific Treefrog	*Pseudacris regilla*	Yellow		
Red legged frog	*Rana aurora*	Blue		
American Bullfrog	*Lithobates catesbeiana*	Non native		
Northern alligator lizard	*Elgaria coerulea principis*	Yellow		x
Western garter snake	*Thamnophis elegans vagrans*	Yellow		x
Common garter snake	*Thamnophis sirtalis*	Yellow		x

Appendix C – I-Tree Ecosytem Analysis Report

i-Tree
Ecosystem Analysis

Kealy-Greenwood iTree Eco Assessment

Urban Forest Effects and Values
September 2019

Summary

Understanding an urban forest's structure, function and value can promote management decisions that will improve human health and environmental quality. An assessment of the vegetation structure, function, and value of the Kealy-Greenwood iTree Eco Assessment urban forest was conducted during 2019. Data from 20 field plots located throughout Kealy-Greenwood iTree Eco Assessment were analyzed using the i-Tree Eco model developed by the U.S. Forest Service, Northern Research Station.

- Number of trees: 7,988
- Tree Cover: 58.3 %
- Most common species of trees: Western hemlock, Vine maple, Western redcedar
- Percentage of trees less than 6" (15.2 cm) diameter: 56.4%
- Pollution Removal: 470.7 kilograms/year (Can$17.7 thousand/year)
- Carbon Storage: 1.634 thousand metric tons (Can$188 thousand)
- Carbon Sequestration: 39.98 metric tons (Can$4.59 thousand/year)
- Oxygen Production: 31.99 metric tons/year
- Avoided Runoff: 2.377 thousand cubic meters/year (Can$5.53 thousand/year)
- Building energy savings: N/A – data not collected
- Avoided carbon emissions: N/A – data not collected
- Structural values: Can$13.4 million

Metric ton: 1000 kilograms
Monetary values Can$ are reported in Canadian Dollars throughout the report except where noted.
Ecosystem service estimates are reported for trees.

For an overview of i-Tree Eco methodology, see Appendix I. Data collection quality is determined by the local data collectors, over which i-Tree has no control. Additionally, some of the plot and tree information may not have been collected, so not all of the analyses may have been conducted for this report.

Table of Contents

I. Tree Characteristics of the Urban Forest

The urban forest of Kealy-Greenwood iTree Eco Assessment has an estimated 7,988 trees with a tree cover of 58.3 percent. The three most common species are Western hemlock (35.4 percent), Vine maple (31.8 percent), and Western redcedar (16.0 percent).

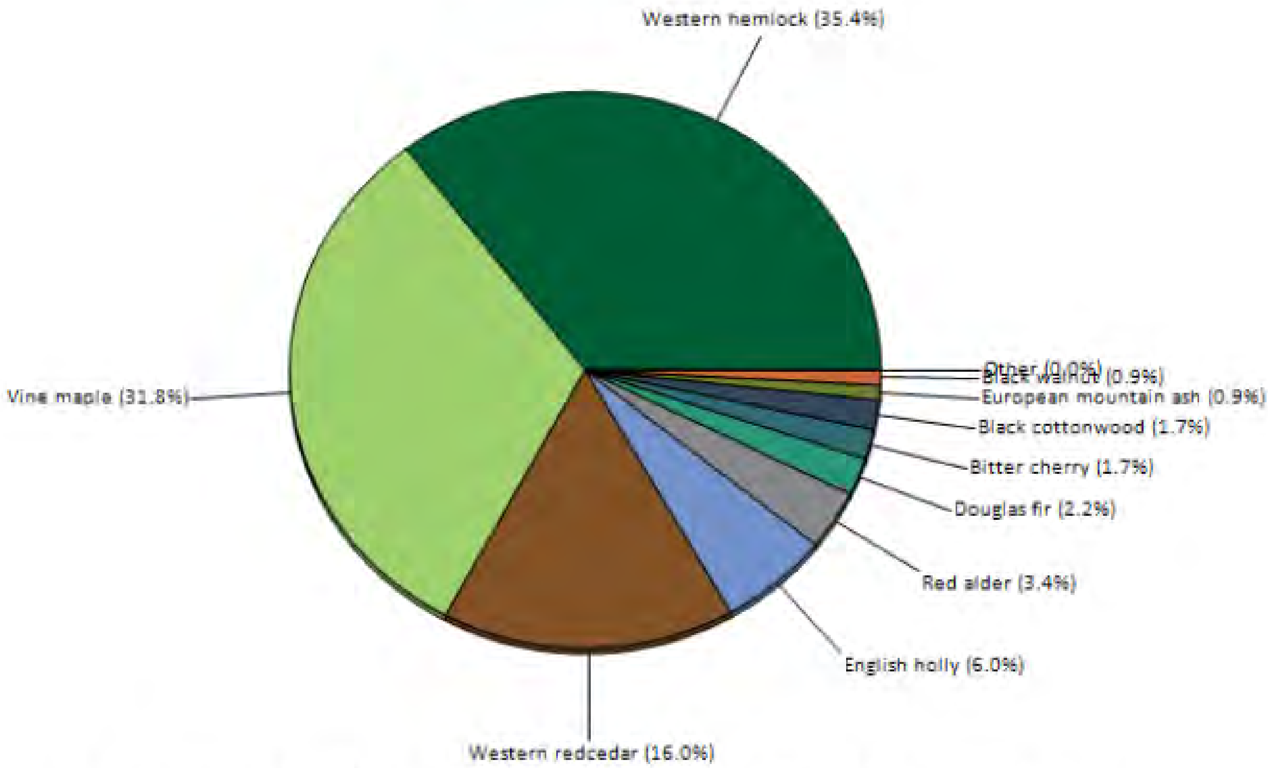


Figure 1. Tree species composition in Kealy-Greenwood iTree Eco Assessment

The overall tree density in Kealy-Greenwood iTree Eco Assessment is 610 trees/hectare (see Appendix III for comparable values from other cities). For stratified projects, the highest tree densities in Kealy-Greenwood iTree Eco Assessment occur in Greenwood Park followed by Kealy Woods Park.

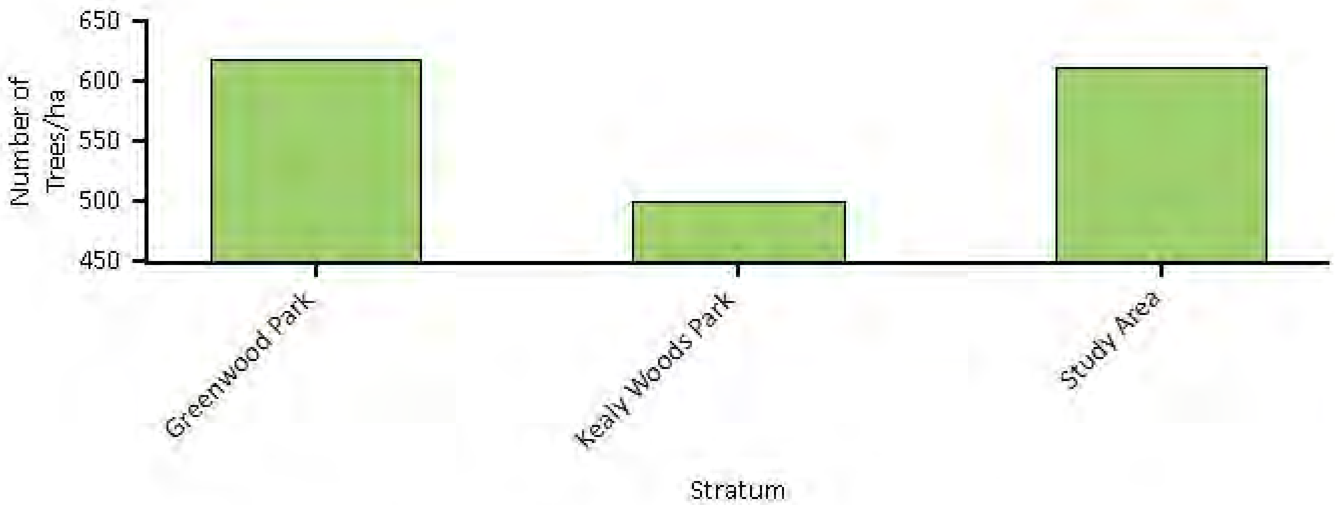


Figure 2. Number of trees/ha in Kealy-Greenwood iTree Eco Assessment by stratum

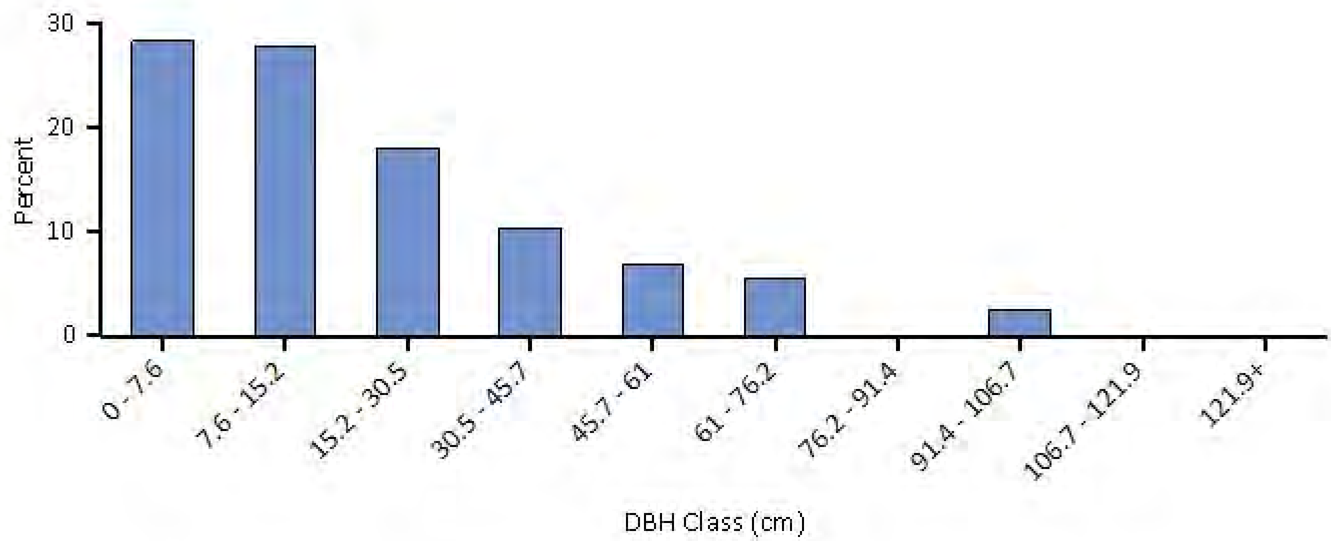


Figure 3. Percent of tree population by diameter class (DBH - stem diameter at 1.37 meters)

Urban forests are composed of a mix of native and exotic tree species. Thus, urban forests often have a tree diversity that is higher than surrounding native landscapes. Increased tree diversity can minimize the overall impact or destruction by a species-specific insect or disease, but it can also pose a risk to native plants if some of the exotic species are invasive plants that can potentially out-compete and displace native species. In Kealy-Greenwood iTree Eco Assessment, about 91 percent of the trees are species native to North America. Most trees have an origin from Europe & Asia (9 percent of the trees).

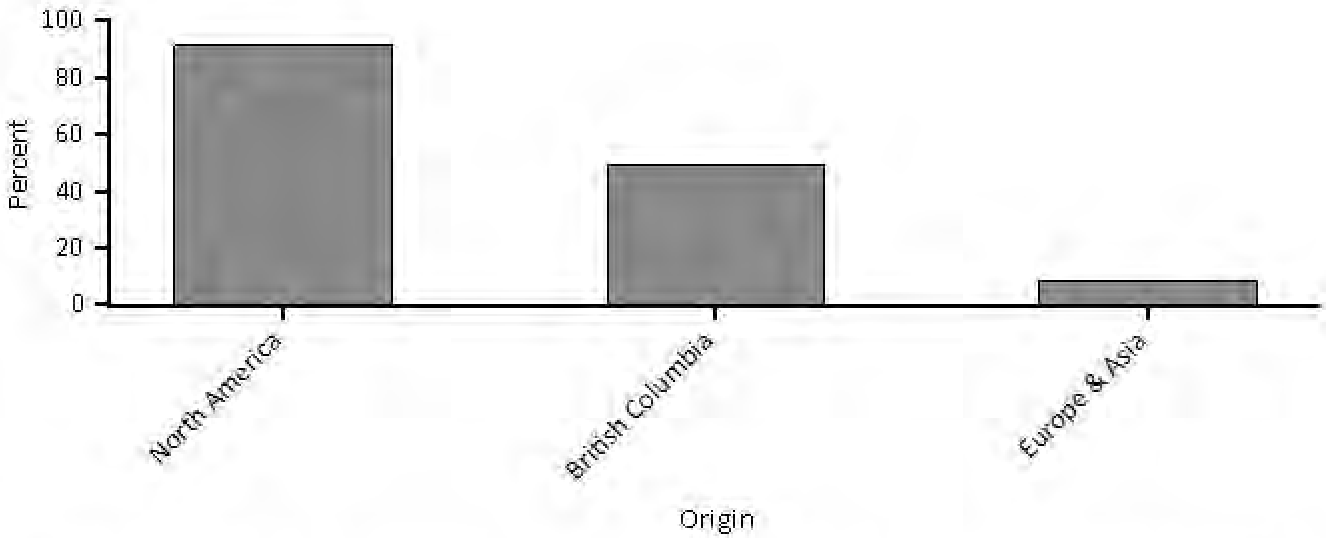


Figure 4. Percent of live tree population by area of native origin, Kealy-Greenwood iTree Eco Assessment

Invasive plant species are often characterized by their vigor, ability to adapt, reproductive capacity, and general lack of natural enemies. These abilities enable them to displace native plants and make them a threat to natural areas.

II. Urban Forest Cover and Leaf Area

Many tree benefits equate directly to the amount of healthy leaf surface area of the plant. Trees cover about 58 percent of Kealy-Greenwood iTree Eco Assessment and provide 79.21 hectares of leaf area. Total leaf area is greatest in Greenwood Park followed by Kealy Woods Park.

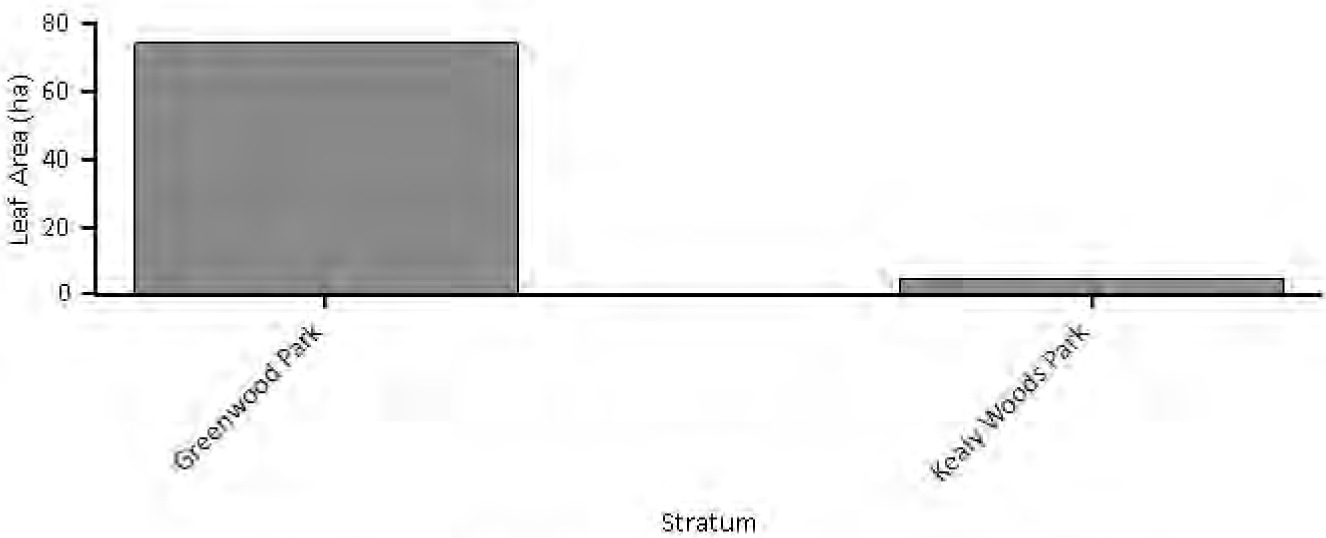


Figure 5. Leaf area by stratum, Kealy-Greenwood iTree Eco Assessment

In Kealy-Greenwood iTree Eco Assessment, the most dominant species in terms of leaf area are Western hemlock, Western redcedar, and Vine maple. The 10 species with the greatest importance values are listed in Table 1. Importance values (IV) are calculated as the sum of percent population and percent leaf area. High importance values do not mean that these trees should necessarily be encouraged in the future; rather these species currently dominate the urban forest structure.

Table 1. Most important species in Kealy-Greenwood iTree Eco Assessment

Species Name	*Percent Population*	*Percent Leaf Area*	*IV*
Western hemlock	35.4	68.2	103.5
Vine maple	31.8	7.2	39.0
Western redcedar	16.0	20.3	36.3
English holly	6.0	0.7	6.7
Red alder	3.4	1.7	5.1
Douglas fir	2.2	0.2	2.3
Black cottonwood	1.7	0.4	2.1
Bitter cherry	1.7	0.2	1.9
Black walnut	0.9	1.0	1.9
European mountain ash	0.9	0.2	1.0

Common ground cover classes (including cover types beneath trees and shrubs) in Kealy-Greenwood iTree Eco Assessment include duff/mulch, bare soil, unmaintained grass, rock, other impervious, water, and buildings, impervious covers such as tar, and cement, and herbaceous covers such as herbs, and grass (Figure 6). The most dominant ground cover types are Duff/Mulch (61.3 percent) and Herbs (30.8 percent).

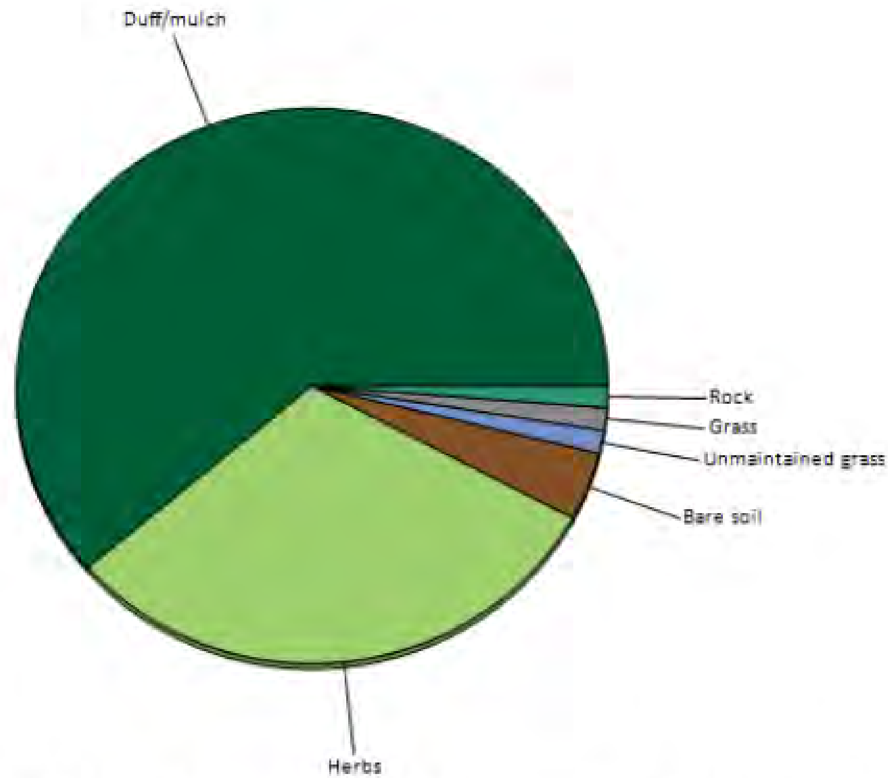


Figure 6. Percent of land by ground cover classes, Kealy-Greenwood iTree Eco Assessment

III. Air Pollution Removal by Urban Trees

Poor air quality is a common problem in many urban areas. It can lead to decreased human health, damage to landscape materials and ecosystem processes, and reduced visibility. The urban forest can help improve air quality by reducing air temperature, directly removing pollutants from the air, and reducing energy consumption in buildings, which consequently reduces air pollutant emissions from the power sources. Trees also emit volatile organic compounds that can contribute to ozone formation. However, integrative studies have revealed that an increase in tree cover leads to reduced ozone formation (Nowak and Dwyer 2000).

Pollution removal[1] by trees and shrubs in Kealy-Greenwood iTree Eco Assessment was estimated using field data and recent available pollution and weather data available. Pollution removal was greatest for ozone (Figure 7). It is estimated that trees and shrubs remove 470.7 kilograms of air pollution (ozone (O3), carbon monoxide (CO), nitrogen dioxide (NO2), particulate matter less than 2.5 microns (PM2.5)[2], and sulfur dioxide (SO2)) per year with an associated value of Can$17.7 thousand (see Appendix I for more details).

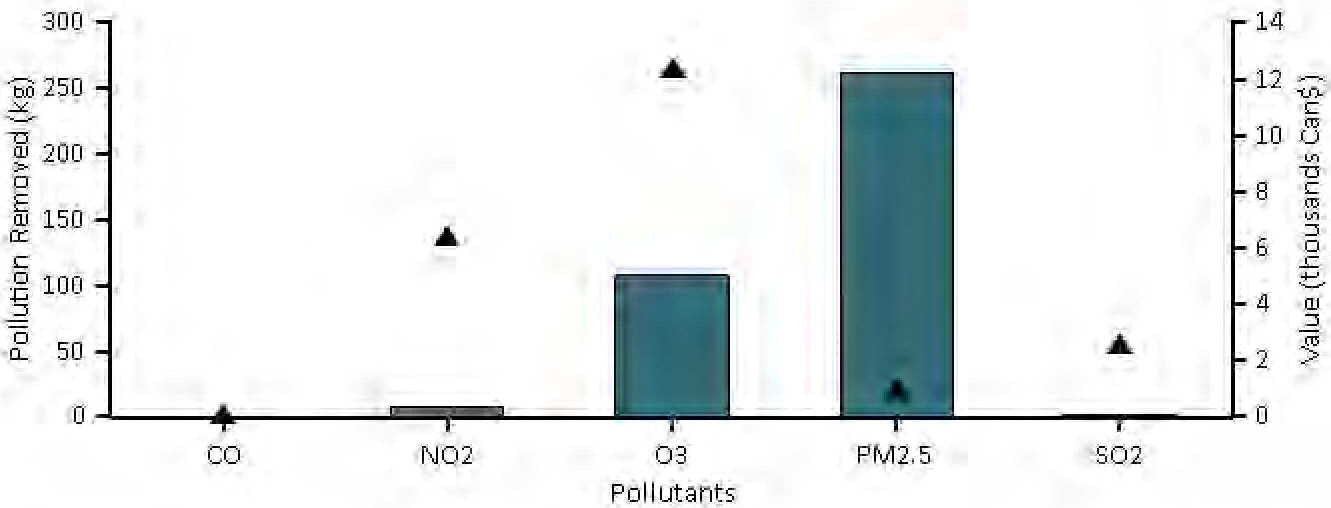


Figure 7. Annual pollution removal (points) and value (bars) by urban trees, Kealy-Greenwood iTree Eco Assessment

[1] Particulate matter less than 10 microns is a significant air pollutant. Given that i-Tree Eco analyzes particulate matter less than 2.5 microns (PM2.5) which is a subset of PM10, PM10 has not been included in this analysis. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

[2] Trees remove PM2.5 when particulate matter is deposited on leaf surfaces. This deposited PM2.5 can be resuspended to the atmosphere or removed during rain events and dissolved or transferred to the soil. This combination of events can lead to positive or negative pollution removal and value depending on various atmospheric factors (see Appendix I for more details).

In 2019, trees in Kealy-Greenwood iTree Eco Assessment emitted an estimated 62.35 kilograms of volatile organic compounds (VOCs) (1.87 kilograms of isoprene and 60.48 kilograms of monoterpenes). Emissions vary among species based on species characteristics (e.g. some genera such as oaks are high isoprene emitters) and amount of leaf biomass. Eighty- two percent of the urban forest's VOC emissions were from Western redcedar and Western hemlock. These VOCs are precursor chemicals to ozone formation.[3]

General recommendations for improving air quality with trees are given in Appendix VIII.

[3] Some economic studies have estimated VOC emission costs. These costs are not included here as there is a tendency to add positive dollar estimates of ozone removal effects with negative dollar values of VOC emission effects to determine whether tree effects are positive or negative in relation to ozone. This combining of dollar values to determine tree effects should not be done, rather estimates of VOC effects on ozone formation (e.g., via photochemical models) should be conducted and directly contrasted with ozone removal by trees (i.e., ozone effects should be directly compared, not dollar estimates). In addition, air temperature reductions by trees have been shown to significantly reduce ozone concentrations (Cardelino and Chameides 1990; Nowak et al 2000), but are not considered in this analysis. Photochemical modeling that integrates tree effects on air temperature, pollution removal, VOC emissions, and emissions from power plants can be used to determine the overall effect of trees on ozone concentrations.

IV. Carbon Storage and Sequestration

Climate change is an issue of global concern. Urban trees can help mitigate climate change by sequestering atmospheric carbon (from carbon dioxide) in tissue and by altering energy use in buildings, and consequently altering carbon dioxide emissions from fossil-fuel based power sources (Abdollahi et al 2000).

Trees reduce the amount of carbon in the atmosphere by sequestering carbon in new growth every year. The amount of carbon annually sequestered is increased with the size and health of the trees. The gross sequestration of Kealy-Greenwood iTree Eco Assessment trees is about 39.98 metric tons of carbon per year with an associated value of Can$4.59 thousand. Net carbon sequestration in the urban forest is about 11.99 metric tons. See Appendix I for more details on methods.

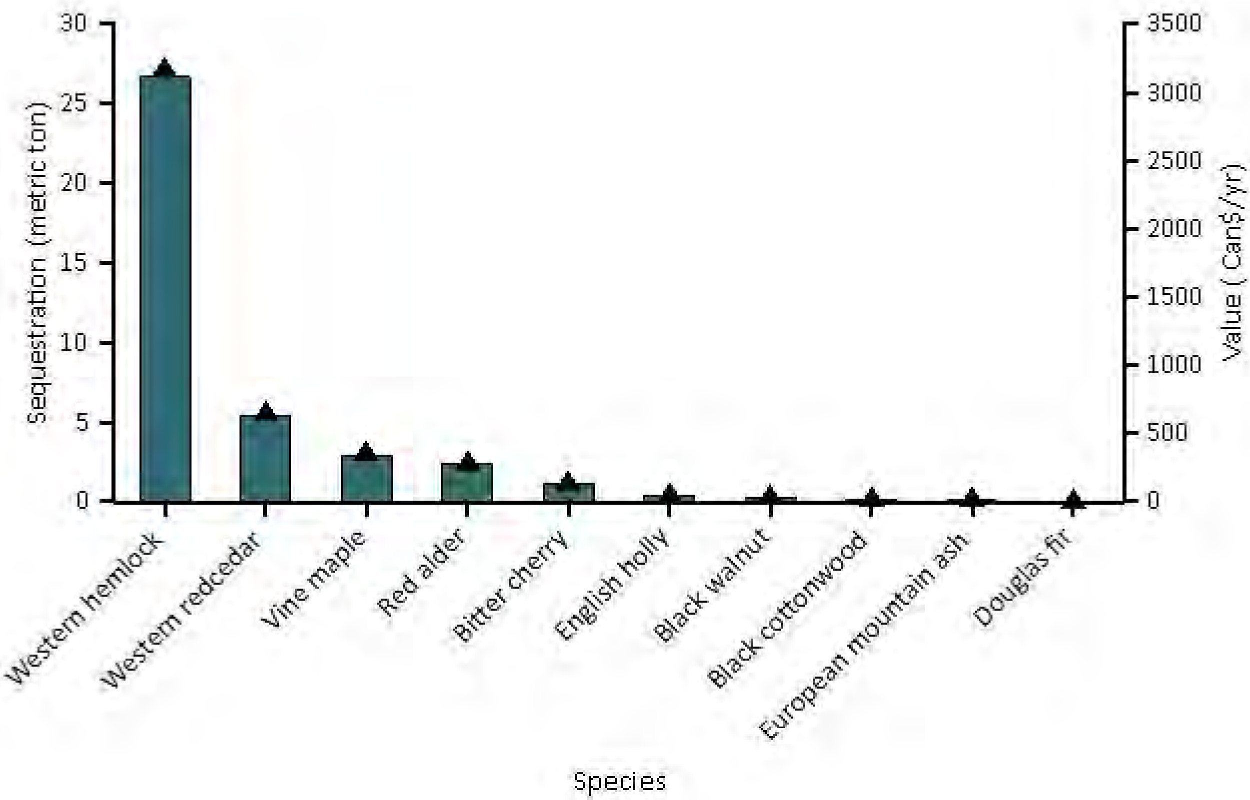


Figure 8. Estimated annual gross carbon sequestration (points) and value (bars) for urban tree species with the greatest sequestration, Kealy-Greenwood iTree Eco Assessment

Carbon storage is another way trees can influence global climate change. As a tree grows, it stores more carbon by holding it in its accumulated tissue. As a tree dies and decays, it releases much of the stored carbon back into the atmosphere. Thus, carbon storage is an indication of the amount of carbon that can be released if trees are allowed to die and decompose. Maintaining healthy trees will keep the carbon stored in trees, but tree maintenance can contribute to carbon emissions (Nowak et al 2002c). When a tree dies, using the wood in long-term wood products, to heat buildings, or to produce energy will help reduce carbon emissions from wood decomposition or from fossil-fuel or wood-based power plants.

Trees in Kealy-Greenwood iTree Eco Assessment are estimated to store 1630 metric tons of carbon (Can$188 thousand). Of the species sampled, Western hemlock stores and sequesters the most carbon (approximately 61.6% of the total carbon stored and 67.8% of all sequestered carbon.)

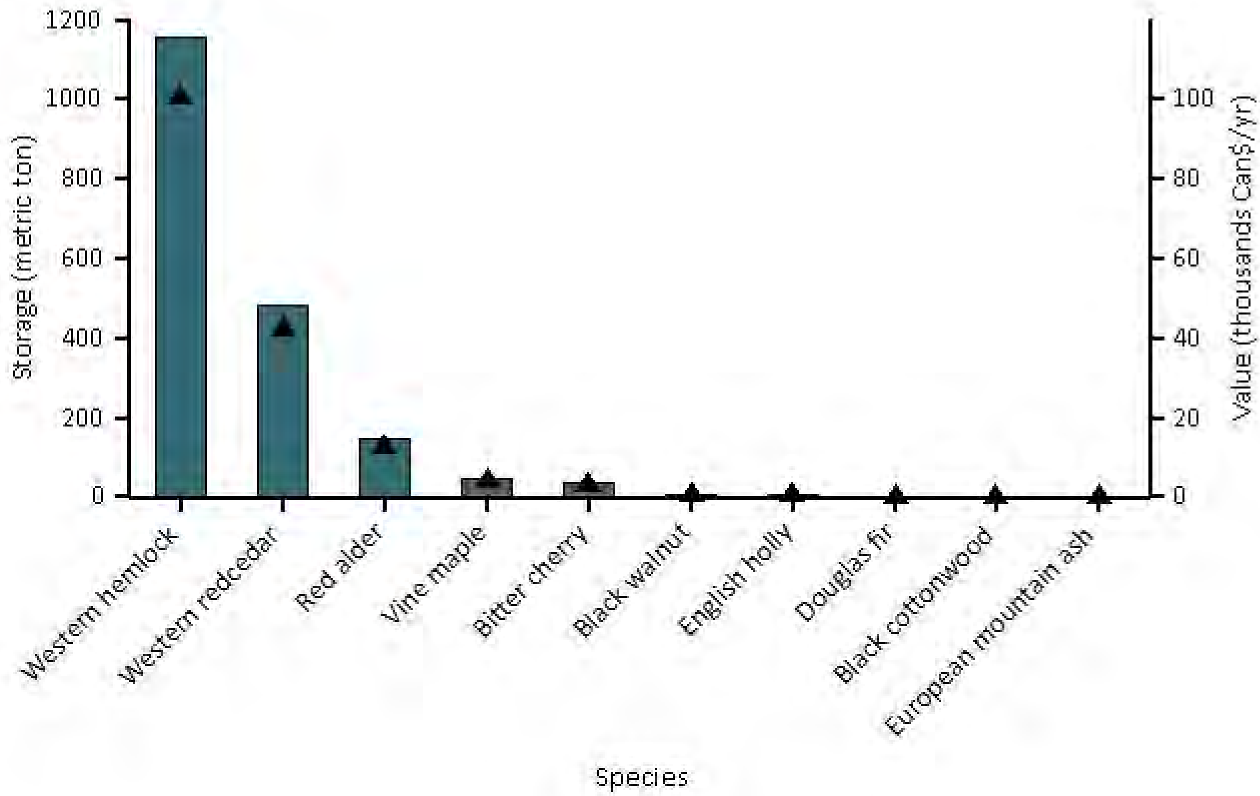


Figure 9. Estimated carbon storage (points) and values (bars) for urban tree species with the greatest storage, Kealy-Greenwood iTree Eco Assessment

V. Oxygen Production

Oxygen production is one of the most commonly cited benefits of urban trees. The net annual oxygen production of a tree is directly related to the amount of carbon sequestered by the tree, which is tied to the accumulation of tree biomass.

Trees in Kealy-Greenwood iTree Eco Assessment are estimated to produce 31.99 metric tons of oxygen per year.[4] However, this tree benefit is relatively insignificant because of the large and relatively stable amount of oxygen in the atmosphere and extensive production by aquatic systems. Our atmosphere has an enormous reserve of oxygen. If all fossil fuel reserves, all trees, and all organic matter in soils were burned, atmospheric oxygen would only drop a few percent (Broecker 1970).

Table 2. The top 20 oxygen production species.

Species	*Oxygen (metric ton)*	*Net Carbon Sequestration (metric ton/yr)*	*Number of Trees*	*Leaf Area (hectare)*
Western hemlock	51.08	19.16	2,824	54.01
Vine maple	6.10	2.29	2,541	5.72
Bitter cherry	2.85	1.07	137	0.18
Western redcedar	1.35	0.51	1,281	16.06
English holly	1.00	0.37	481	0.53
Black walnut	0.59	0.22	69	0.82
Black cottonwood	0.40	0.15	137	0.29
European mountain ash	0.17	0.06	69	0.14
Douglas fir	-0.72	-0.27	174	0.13
Red alder	-30.85	-11.57	275	1.32

[4] A negative estimate, or oxygen deficit, indicates that trees are decomposing faster than they are producing oxygen. This would be the case in an area that has a large proportion of dead trees.

VI. Avoided Runoff

Surface runoff can be a cause for concern in many urban areas as it can contribute pollution to streams, wetlands, rivers, lakes, and oceans. During precipitation events, some portion of the precipitation is intercepted by vegetation (trees and shrubs) while the other portion reaches the ground. The portion of the precipitation that reaches the ground and does not infiltrate into the soil becomes surface runoff (Hirabayashi 2012). In urban areas, the large extent of impervious surfaces increases the amount of surface runoff.

Urban trees and shrubs, however, are beneficial in reducing surface runoff. Trees and shrubs intercept precipitation, while their root systems promote infiltration and storage in the soil. The trees and shrubs of Kealy-Greenwood iTree Eco Assessment help to reduce runoff by an estimated 2.38 thousand cubic meters a year with an associated value of Can$5.5 thousand (see Appendix I for more details). Avoided runoff is estimated based on local weather from the user-designated weather station. In Kealy-Greenwood iTree Eco Assessment, the total annual precipitation in 2010 was 117.8 centimeters.

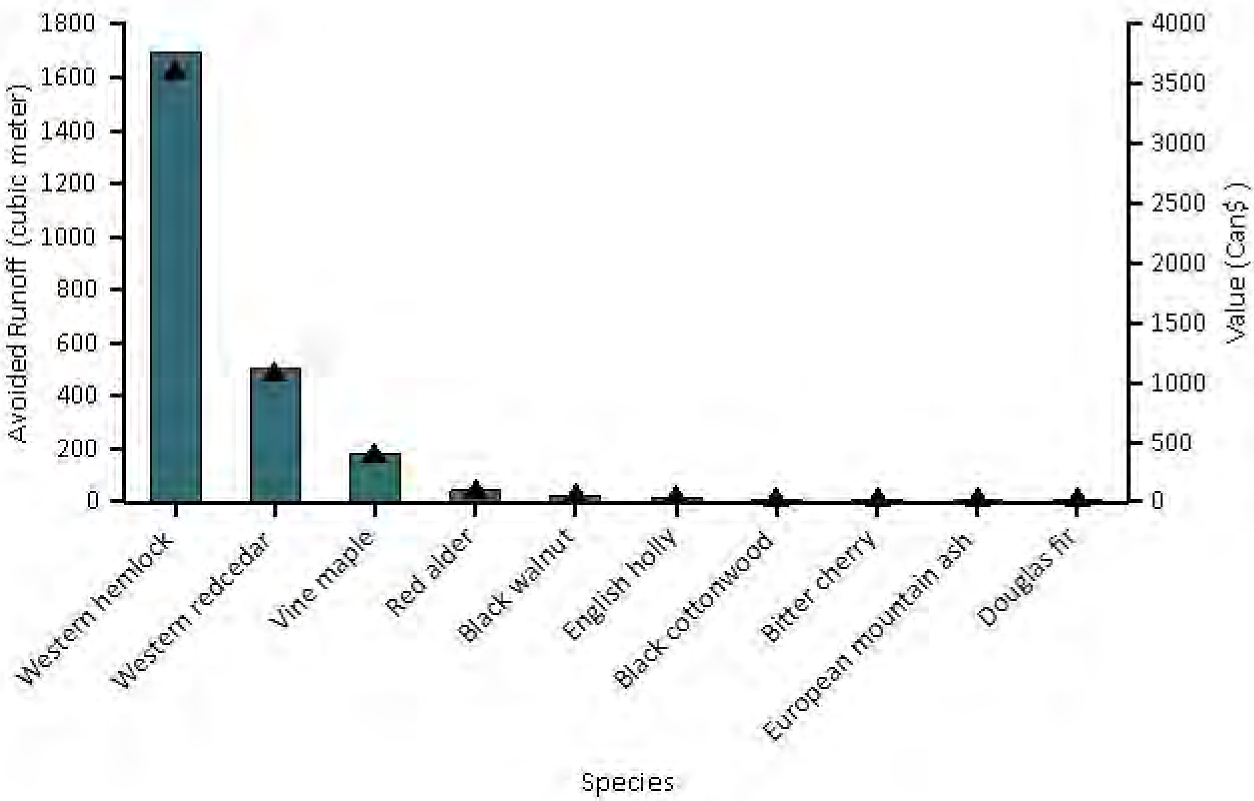


Figure 10. Avoided runoff (points) and value (bars) for species with greatest overall impact on runoff, Kealy-Greenwood iTree Eco Assessment

VII. Trees and Building Energy Use

Trees affect energy consumption by shading buildings, providing evaporative cooling, and blocking winter winds. Trees tend to reduce building energy consumption in the summer months and can either increase or decrease building energy use in the winter months, depending on the location of trees around the building. Estimates of tree effects on energy use are based on field measurements of tree distance and direction to space conditioned residential buildings (McPherson and Simpson 1999).

Because energy-related data were not collected, energy savings and carbon avoided cannot be calculated.

Table 3. Annual energy savings due to trees near residential buildings, Kealy-Greenwood iTree Eco Assessment

	Heating	*Cooling*	*Total*
MBTU[a]	0	N/A	0
MWH[b]	0	0	0
Carbon Avoided (kilograms)	0	0	0

[a]MBTU - one million British Thermal Units

[b]MWH - megawatt-hour

Table 4. Annual savings [a](Can$) in residential energy expenditure during heating and cooling seasons, Kealy-Greenwood iTree Eco Assessment

	Heating	*Cooling*	*Total*
MBTU[b]	0	N/A	0
MWH[c]	0	0	0
Carbon Avoided	0	0	0

[b]Based on the prices of Can$95.9883333333333 per MWH and Can$17.8878017585382 per MBTU (see Appendix I for more details)

[c]MBTU - one million British Thermal Units

[c]MWH - megawatt-hour

[5] Trees modify climate, produce shade, and reduce wind speeds. Increased energy use or costs are likely due to these tree-building interactions creating a cooling effect during the winter season. For example, a tree (particularly evergreen species) located on the southern side of a residential building may produce a shading effect that causes increases in heating requirements.

VIII. Structural and Functional Values

Urban forests have a structural value based on the trees themselves (e.g., the cost of having to replace a tree with a similar tree); they also have functional values (either positive or negative) based on the functions the trees perform.

The structural value of an urban forest tends to increase with a rise in the number and size of healthy trees (Nowak et al 2002a). Annual functional values also tend to increase with increased number and size of healthy trees. Through proper management, urban forest values can be increased; however, the values and benefits also can decrease as the amount of healthy tree cover declines.

Urban trees in Kealy-Greenwood iTree Eco Assessment have the following structural values:

- Structural value: Can$13.4 million
- Carbon storage: Can$188 thousand

Urban trees in Kealy-Greenwood iTree Eco Assessment have the following annual functional values:

- Carbon sequestration: Can$4.59 thousand
- Avoided runoff: Can$5.53 thousand
- Pollution removal: Can$17.7 thousand
- Energy costs and carbon emission values: Can$0

(Note: negative value indicates increased energy cost and carbon emission value)

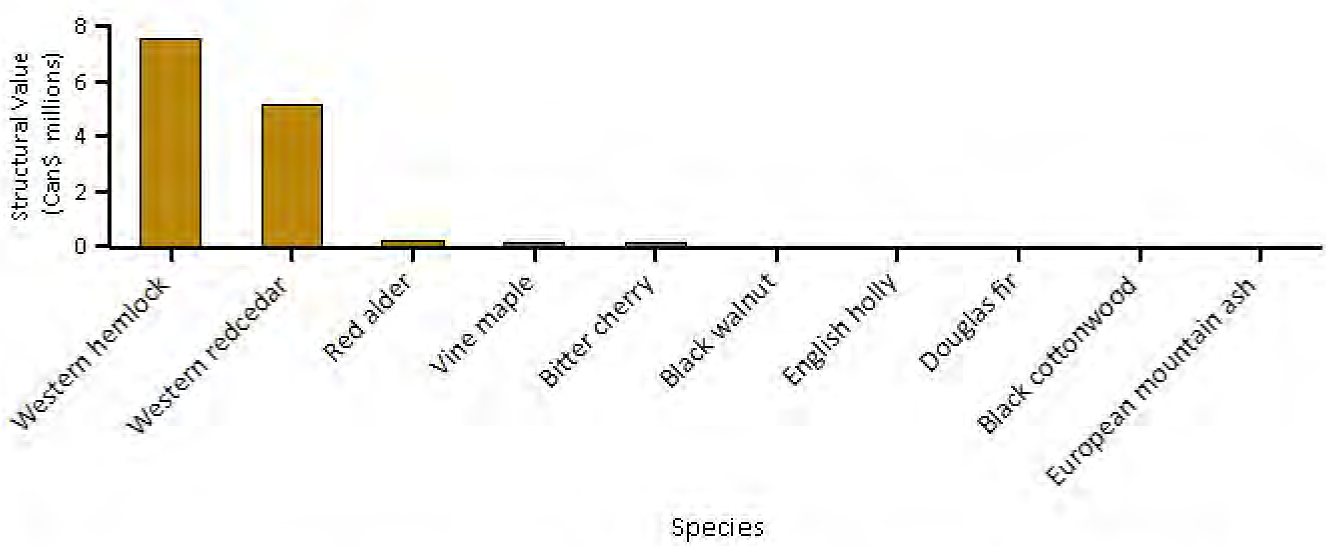


Figure 11. Tree species with the greatest structural value, Kealy-Greenwood iTree Eco Assessment

[1] Structural value in Canada is calculated using the same procedure as the U.S. (Nowak et al 2002a). Base costs and species values are derived from the International Society of Arboriculture Ontario Chapter and applied to all Canadian provinces and territories.

IX. Potential Pest Impacts

Various insects and diseases can infest urban forests, potentially killing trees and reducing the health, structural value and sustainability of the urban forest. As pests tend to have differing tree hosts, the potential damage or risk of each pest will differ among cities.Thirty-six pests were analyzed for their potential impact.

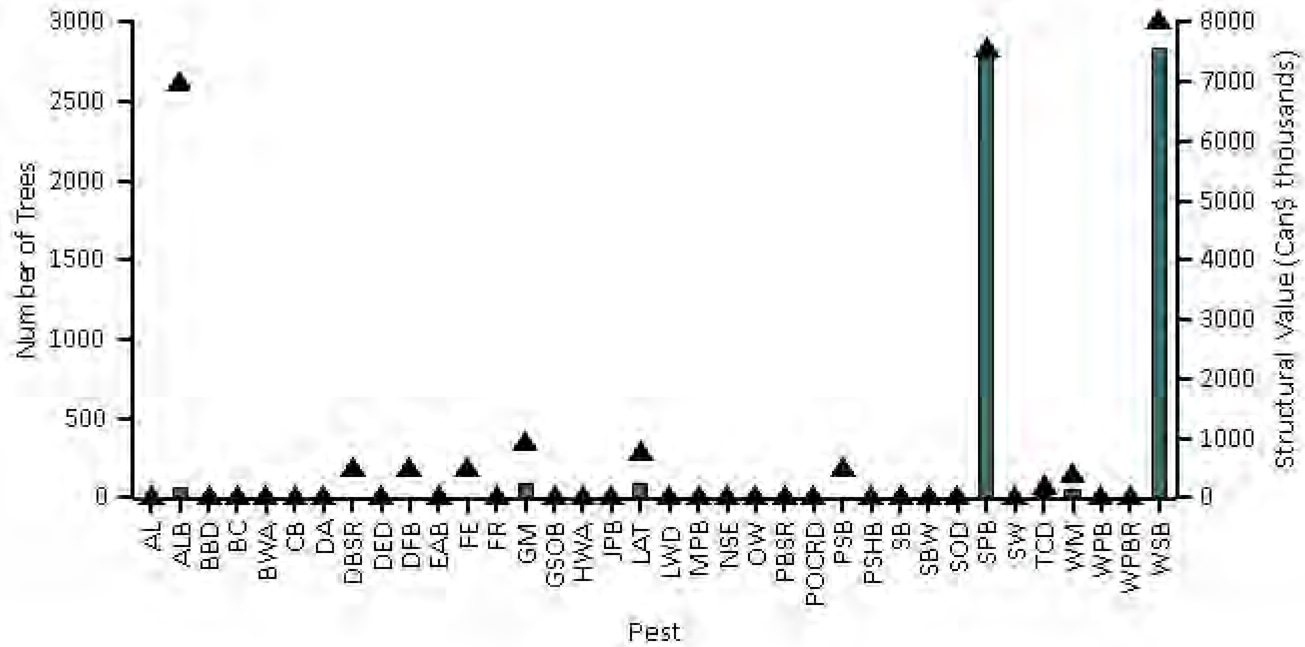


Figure 12. Number of trees at risk (points) and associated compensatory value (bars) by potential pests, Kealy-Greenwood iTree Eco Assessment

Aspen leafminer (AL) (Kruse et al 2007) is an insect that causes damage primarily to trembling or small tooth aspen by larval feeding of leaf tissue. AL has the potential to affect 0.0 percent of the population (Can$0 in structural value).

Asian longhorned beetle (ALB) (Animal and Plant Health Inspection Service 2010) is an insect that bores into and kills a wide range of hardwood species. ALB poses a threat to 32.7 percent of the Kealy-Greenwood iTree Eco Assessment urban forest, which represents a potential loss of Can$176 thousand in structural value.

Beech bark disease (BBD) (Houston and O'Brien 1983) is an insect-disease complex that primarily impacts American beech. This disease threatens 0.0 percent of the population, which represents a potential loss of Can$0 in structural value.

Butternut canker (BC) (Ostry et al 1996) is caused by a fungus that infects butternut trees. The disease has since caused significant declines in butternut populations in the United States. Potential loss of trees from BC is 0.0 percent (Can$0 in structural value).

Balsam woolly adelgid (BWA) (Ragenovich and Mitchell 2006) is an insect that has caused significant damage to the true firs of North America. Kealy-Greenwood iTree Eco Assessment could possibly lose 0.0 percent of its trees to this pest (Can$0 in structural value).

The most common hosts of the fungus that cause chestnut blight (CB) (Diller 1965) are American and European chestnut. CB has the potential to affect 0.0 percent of the population (Can$0 in structural value).

Dogwood anthracnose (DA) (Mielke and Daughtrey) is a disease that affects dogwood species, specifically flowering and Pacific dogwood. This disease threatens 0.0 percent of the population, which represents a potential loss of Can$0 in structural value.

Douglas-fir black stain root disease (DBSR) (Hessburg et al 1995) is a variety of the black stain fungus that attacks Douglas-firs. Kealy-Greenwood iTree Eco Assessment could possibly lose 2.2 percent of its trees to this pest (Can$5.52 thousand in structural value).

American elm, one of the most important street trees in the twentieth century, has been devastated by the Dutch elm disease (DED) (Northeastern Area State and Private Forestry 1998). Since first reported in the 1930s, it has killed over 50 percent of the native elm population in the United States. Although some elm species have shown varying degrees of resistance, Kealy-Greenwood iTree Eco Assessment could possibly lose 0.0 percent of its trees to this pest (Can$0 in structural value).

Douglas-fir beetle (DFB) (Schmitz and Gibson 1996) is a bark beetle that infests Douglas-fir trees throughout the western United States, British Columbia, and Mexico. Potential loss of trees from DFB is 2.2 percent (Can$5.52 thousand in structural value).

Emerald ash borer (EAB) (Michigan State University 2010) has killed thousands of ash trees in parts of the United States. EAB has the potential to affect 0.0 percent of the population (Can$0 in structural value).

One common pest of white fir, grand fir, and red fir trees is the fir engraver (FE) (Ferrell 1986). FE poses a threat to 2.2 percent of the Kealy-Greenwood iTree Eco Assessment urban forest, which represents a potential loss of Can$5.52 thousand in structural value.

Fusiform rust (FR) (Phelps and Czabator 1978) is a fungal disease that is distributed in the southern United States. It is particularly damaging to slash pine and loblolly pine. FR has the potential to affect 0.0 percent of the population (Can$0 in structural value).

The gypsy moth (GM) (Northeastern Area State and Private Forestry 2005) is a defoliator that feeds on many species causing widespread defoliation and tree death if outbreak conditions last several years. This pest threatens 4.3 percent of the population, which represents a potential loss of Can$237 thousand in structural value.

Infestations of the goldspotted oak borer (GSOB) (Society of American Foresters 2011) have been a growing problem in southern California. Potential loss of trees from GSOB is 0.0 percent (Can$0 in structural value).

As one of the most damaging pests to eastern hemlock and Carolina hemlock, hemlock woolly adelgid (HWA) (U.S. Forest Service 2005) has played a large role in hemlock mortality in the United States. HWA has the potential to affect 0.0 percent of the population (Can$0 in structural value).

The Jeffrey pine beetle (JPB) (Smith et al 2009) is native to North America and is distributed across California, Nevada, and Oregon where its only host, Jeffrey pine, also occurs. This pest threatens 0.0 percent of the population, which represents a potential loss of Can$0 in structural value.

Quaking aspen is a principal host for the defoliator, large aspen tortrix (LAT) (Ciesla and Kruse 2009). LAT poses a threat to 3.4 percent of the Kealy-Greenwood iTree Eco Assessment urban forest, which represents a potential loss of Can$234 thousand in structural value.

Laurel wilt (LWD) (U.S. Forest Service 2011) is a fungal disease that is introduced to host trees by the redbay ambrosia beetle. This pest threatens 0.0 percent of the population, which represents a potential loss of Can$0 in structural value.

Mountain pine beetle (MPB) (Gibson et al 2009) is a bark beetle that primarily attacks pine species in the western United States. MPB has the potential to affect 0.0 percent of the population (Can$0 in structural value).

The northern spruce engraver (NSE) (Burnside et al 2011) has had a significant impact on the boreal and sub-boreal forests of North America where the pest's distribution overlaps with the range of its major hosts. Potential loss of trees from NSE is 0.0 percent (Can$0 in structural value).

Oak wilt (OW) (Rexrode and Brown 1983), which is caused by a fungus, is a prominent disease among oak trees. OW poses a threat to 0.0 percent of the Kealy-Greenwood iTree Eco Assessment urban forest, which represents a potential loss of Can$0 in structural value.

Pine black stain root disease (PBSR) (Hessburg et al 1995) is a variety of the black stain fungus that attacks hard pines, including lodgepole pine, Jeffrey pine, and ponderosa pine. Kealy-Greenwood iTree Eco Assessment could possibly lose 0.0 percent of its trees to this pest (Can$0 in structural value).

Port-Orford-cedar root disease (POCRD) (Liebhold 2010) is a root disease that is caused by a fungus. POCRD threatens 0.0 percent of the population, which represents a potential loss of Can$0 in structural value.

The pine shoot beetle (PSB) (Ciesla 2001) is a wood borer that attacks various pine species, though Scotch pine is the preferred host in North America. PSB has the potential to affect 2.2 percent of the population (Can$5.52 thousand in structural value).

Polyphagous shot hole borer (PSHB) (University of California 2014) is a boring beetle that was first detected in California. Kealy-Greenwood iTree Eco Assessment could possibly lose 0.0 percent of its trees to this pest (Can$0 in structural value).

Spruce beetle (SB) (Holsten et al 1999) is a bark beetle that causes significant mortality to spruce species within its range. Potential loss of trees from SB is 0.0 percent (Can$0 in structural value).

Spruce budworm (SBW) (Kucera and Orr 1981) is an insect that causes severe damage to balsam fir. SBW poses a threat to 0.0 percent of the Kealy-Greenwood iTree Eco Assessment urban forest, which represents a potential loss of Can$0 in structural value.

Sudden oak death (SOD) (Kliejunas 2005) is a disease that is caused by a fungus. Potential loss of trees from SOD is 0.0 percent (Can$0 in structural value).

Although the southern pine beetle (SPB) (Clarke and Nowak 2009) will attack most pine species, its preferred hosts are loblolly, Virginia, pond, spruce, shortleaf, and sand pines. This pest threatens 35.4 percent of the population, which represents a potential loss of Can$7.55 million in structural value.

The sirex woodwasp (SW) (Haugen and Hoebeke 2005) is a wood borer that primarily attacks pine species. SW poses a threat to 0.0 percent of the Kealy-Greenwood iTree Eco Assessment urban forest, which represents a potential loss of Can$0 in structural value.

Thousand canker disease (TCD) (Cranshaw and Tisserat 2009; Seybold et al 2010) is an insect-disease complex that kills several species of walnuts, including black walnut. Potential loss of trees from TCD is 0.9 percent (Can$23.7

thousand in structural value).

Winter moth (WM) (Childs 2011) is a pest with a wide range of host species. WM causes the highest levels of injury to its hosts when it is in its caterpillar stage. Kealy-Greenwood iTree Eco Assessment could possibly lose 1.7 percent of its trees to this pest (Can$151 thousand in structural value).

The western pine beetle (WPB) (DeMars and Roettgering 1982) is a bark beetle and aggressive attacker of ponderosa and Coulter pines. This pest threatens 0.0 percent of the population, which represents a potential loss of Can$0 in structural value.

Since its introduction to the United States in 1900, white pine blister rust (Eastern U.S.) (WPBR) (Nicholls and Anderson 1977) has had a detrimental effect on white pines, particularly in the Lake States. WPBR has the potential to affect 0.0 percent of the population (Can$0 in structural value).

Western spruce budworm (WSB) (Fellin and Dewey 1986) is an insect that causes defoliation in western conifers. This pest threatens 37.5 percent of the population, which represents a potential loss of Can$7.55 million in structural value.

Appendix I. i-Tree Eco Model and Field Measurements

i-Tree Eco is designed to use standardized field data from randomly located plots and local hourly air pollution and meteorological data to quantify urban forest structure and its numerous effects (Nowak and Crane 2000), including:

- Urban forest structure (e.g., species composition, tree health, leaf area, etc.).
- Amount of pollution removed hourly by the urban forest, and its associated percent air quality improvement throughout a year.
- Total carbon stored and net carbon annually sequestered by the urban forest.
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power sources.
- Structural value of the forest, as well as the value for air pollution removal and carbon storage and sequestration.
- Potential impact of infestations by pests, such as Asian longhorned beetle, emerald ash borer, gypsy moth, and Dutch elm disease.

Typically, all field data are collected during the leaf-on season to properly assess tree canopies. Typical data collection (actual data collection may vary depending upon the user) includes land use, ground and tree cover, individual tree attributes of species, stem diameter, height, crown width, crown canopy missing and dieback, and distance and direction to residential buildings (Nowak et al 2005; Nowak et al 2008).

During data collection, trees are identified to the most specific taxonomic classification possible. Trees that are not classified to the species level may be classified by genus (e.g., ash) or species groups (e.g., hardwood). In this report, tree species, genera, or species groups are collectively referred to as tree species.

Tree Characteristics:

Leaf area of trees was assessed using measurements of crown dimensions and percentage of crown canopy missing. In the event that these data variables were not collected, they are estimated by the model.

An analysis of invasive species is not available for studies outside of the United States. For the U.S., invasive species are identified using an invasive species list for the state in which the urban forest is located. These lists are not exhaustive and they cover invasive species of varying degrees of invasiveness and distribution. In instances where a state did not have an invasive species list, a list was created based on the lists of the adjacent states. Tree species that are identified as invasive by the state invasive species list are cross-referenced with native range data. This helps eliminate species that are on the state invasive species list, but are native to the study area.

Air Pollution Removal:

Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide and particulate matter less than 2.5 microns. Particulate matter less than 10 microns (PM10) is another significant air pollutant. Given that i-Tree Eco analyzes particulate matter less than 2.5 microns (PM2.5) which is a subset of PM10, PM10 has not been included in this analysis. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

Air pollution removal estimates are derived from calculated hourly tree-canopy resistances for ozone, and sulfur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models (Baldocchi 1988; Baldocchi et al 1987). As the removal of carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal rates (deposition velocities) for these pollutants were based on average measured values from the literature (Bidwell and Fraser 1972; Lovett 1994) that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere (Zinke 1967).

Recent updates (2011) to air quality modeling are based on improved leaf area index simulations, weather and pollution processing and interpolation, and updated pollutant monetary values (Hirabayashi et al 2011; Hirabayashi et al 2012; Hirabayashi 2011).

Trees remove PM2.5 when particulate matter is deposited on leaf surfaces (Nowak et al 2013). This deposited PM2.5 can be resuspended to the atmosphere or removed during rain events and dissolved or transferred to the soil. This combination of events can lead to positive or negative pollution removal and value depending on various atmospheric factors. Generally, PM2.5 removal is positive with positive benefits. However, there are some cases when net removal is negative or resuspended particles lead to increased pollution concentrations and negative values. During some months (e.g., with no rain), trees resuspend more particles than they remove. Resuspension can also lead to increased overall PM2.5 concentrations if the boundary layer conditions are lower during net resuspension periods than during net removal periods. Since the pollution removal value is based on the change in pollution concentration, it is possible to have situations when trees remove PM2.5 but increase concentrations and thus have negative values during periods of positive overall removal. These events are not common, but can happen.

For reports in the United States, default air pollution removal value is calculated based on local incidence of adverse health effects and national median externality costs. The number of adverse health effects and associated economic value is calculated for ozone, sulfur dioxide, nitrogen dioxide, and particulate matter less than 2.5 microns using data from the U.S. Environmental Protection Agency's Environmental Benefits Mapping and Analysis Program (BenMAP) (Nowak et al 2014). The model uses a damage-function approach that is based on the local change in pollution concentration and population. National median externality costs were used to calculate the value of carbon monoxide removal (Murray et al 1994).

For international reports, user-defined local pollution values are used. For international reports that do not have local values, estimates are based on either European median externality values (van Essen et al 2011) or BenMAP regression equations (Nowak et al 2014) that incorporate user-defined population estimates. Values are then converted to local currency with user-defined exchange rates.

For this analysis, pollution removal value is calculated based on the prices of Can$1,486 per metric ton (carbon monoxide), Can$18,975 per metric ton (ozone), Can$2,834 per metric ton (nitrogen dioxide), Can$1,032 per metric ton (sulfur dioxide), Can$658,697 per metric ton (particulate matter less than 2.5 microns).

Carbon Storage and Sequestration:

Carbon storage is the amount of carbon bound up in the above-ground and below-ground parts of woody vegetation. To calculate current carbon storage, biomass for each tree was calculated using equations from the literature and measured tree data. Open-grown, maintained trees tend to have less biomass than predicted by forest-derived biomass equations (Nowak 1994). To adjust for this difference, biomass results for open-grown urban trees were multiplied by 0.8. No adjustment was made for trees found in natural stand conditions. Tree dry-weight biomass was converted to stored carbon by multiplying by 0.5.

Carbon sequestration is the removal of carbon dioxide from the air by plants. To estimate the gross amount of carbon sequestered annually, average diameter growth from the appropriate genera and diameter class and tree condition was added to the existing tree diameter (year x) to estimate tree diameter and carbon storage in year x+1.

Carbon storage and carbon sequestration values are based on estimated or customized local carbon values. For international reports that do not have local values, estimates are based on the carbon value for the United States (U.S. Environmental Protection Agency 2015, Interagency Working Group on Social Cost of Carbon 2015) and converted to local currency with user-defined exchange rates.

For this analysis, carbon storage and carbon sequestration values are calculated based on Can$115 per metric ton.

Oxygen Production:

The amount of oxygen produced is estimated from carbon sequestration based on atomic weights: net O2 release (kg/yr) = net C sequestration (kg/yr) × 32/12. To estimate the net carbon sequestration rate, the amount of carbon sequestered as a result of tree growth is reduced by the amount lost resulting from tree mortality. Thus, net carbon sequestration and net annual oxygen production of the urban forest account for decomposition (Nowak et al 2007). For complete inventory projects, oxygen production is estimated from gross carbon sequestration and does not account for decomposition.

Avoided Runoff:

Annual avoided surface runoff is calculated based on rainfall interception by vegetation, specifically the difference between annual runoff with and without vegetation. Although tree leaves, branches, and bark may intercept precipitation and thus mitigate surface runoff, only the precipitation intercepted by leaves is accounted for in this analysis.

The value of avoided runoff is based on estimated or user-defined local values. For international reports that do not have local values, the national average value for the United States is utilized and converted to local currency with user-defined exchange rates. The U.S. value of avoided runoff is based on the U.S. Forest Service's Community Tree Guide Series (McPherson et al 1999; 2000; 2001; 2002; 2003; 2004; 2006a; 2006b; 2006c; 2007; 2010; Peper et al 2009; 2010; Vargas et al 2007a; 2007b; 2008).

For this analysis, avoided runoff value is calculated based on the price of Can$2.32 per m³.

Building Energy Use:

If appropriate field data were collected, seasonal effects of trees on residential building energy use were calculated based on procedures described in the literature (McPherson and Simpson 1999) using distance and direction of trees from residential structures, tree height and tree condition data. To calculate the monetary value of energy savings, local or custom prices per MWH or MBTU are utilized.

For this analysis, energy saving value is calculated based on the prices of Can$95.99 per MWH and Can$17.89 per MBTU.

Structural Values:

Structural value is the value of a tree based on the physical resource itself (e.g., the cost of having to replace a tree with a similar tree). Structural values were based on valuation procedures of the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition, and location information (Nowak et al 2002a; 2002b). Structural value may not be included for international projects if there is insufficient local data to complete the valuation procedures.

Potential Pest Impacts:

The complete potential pest risk analysis is not available for studies outside of the United States. The number of trees at risk to the pests analyzed is reported, though the list of pests is based on known insects and disease in the United States.

For the U.S., potential pest risk is based on pest range maps and the known pest host species that are likely to experience mortality. Pest range maps for 2012 from the Forest Health Technology Enterprise Team (FHTET) (Forest

Health Technology Enterprise Team 2014) were used to determine the proximity of each pest to the county in which the urban forest is located. For the county, it was established whether the insect/disease occurs within the county, is within 400 kilometers of the county edge, is between 400 and 1210 kilometers away, or is greater than 1210 kilometers away. FHTET did not have pest range maps for Dutch elm disease and chestnut blight. The range of these pests was based on known occurrence and the host range, respectively (Eastern Forest Environmental Threat Assessment Center; Worrall 2007).

Relative Tree Effects:

The relative value of tree benefits reported in Appendix II is calculated to show what carbon storage and sequestration, and air pollutant removal equate to in amounts of municipal carbon emissions, passenger automobile emissions, and house emissions.

Municipal carbon emissions are based on 2010 U.S. per capita carbon emissions (Carbon Dioxide Information Analysis Center 2010). Per capita emissions were multiplied by city population to estimate total city carbon emissions.

Light duty vehicle emission rates (g/mi) for CO, NOx, VOCs, PM10, SO2 for 2010 (Bureau of Transportation Statistics 2010; Heirigs et al 2004), PM2.5 for 2011-2015 (California Air Resources Board 2013), and CO2 for 2011 (U.S. Environmental Protection Agency 2010) were multiplied by average miles driven per vehicle in 2011 (Federal Highway Administration 2013) to determine average emissions per vehicle.

Household emissions are based on average electricity kWh usage, natural gas Btu usage, fuel oil Btu usage, kerosene Btu usage, LPG Btu usage, and wood Btu usage per household in 2009 (Energy Information Administration 2013; Energy Information Administration 2014)

- CO2, SO2, and NOx power plant emission per KWh are from Leonardo Academy 2011. CO emission per kWh assumes 1/3 of one percent of C emissions is CO based on Energy Information Administration 1994. PM10 emission per kWh from Layton 2004.
- CO2, NOx, SO2, and CO emission per Btu for natural gas, propane and butane (average used to represent LPG), Fuel #4 and #6 (average used to represent fuel oil and kerosene) from Leonardo Academy 2011.
- CO2 emissions per Btu of wood from Energy Information Administration 2014.
- CO, NOx and SOx emission per Btu based on total emissions and wood burning (tons) from (British Columbia Ministry 2005; Georgia Forestry Commission 2009).

Appendix II. Relative Tree Effects

The urban forest in Kealy-Greenwood iTree Eco Assessment provides benefits that include carbon storage and sequestration, and air pollutant removal. To estimate the relative value of these benefits, tree benefits were compared to estimates of average municipal carbon emissions, average passenger automobile emissions, and average household emissions. See Appendix I for methodology.

Carbon storage is equivalent to:

- Amount of carbon emitted in Kealy-Greenwood iTree Eco Assessment in 3 days
- Annual carbon (C) emissions from 1,270 automobiles
- Annual C emissions from 522 single-family houses

Carbon monoxide removal is equivalent to:

- Annual carbon monoxide emissions from 0 automobiles
- Annual carbon monoxide emissions from 0 single-family houses

Nitrogen dioxide removal is equivalent to:

- Annual nitrogen dioxide emissions from 21 automobiles
- Annual nitrogen dioxide emissions from 10 single-family houses

Sulfur dioxide removal is equivalent to:

- Annual sulfur dioxide emissions from 626 automobiles
- Annual sulfur dioxide emissions from 2 single-family houses

Annual carbon sequestration is equivalent to:

- Amount of carbon emitted in Kealy-Greenwood iTree Eco Assessment in 0.1 days
- Annual C emissions from 0 automobiles
- Annual C emissions from 0 single-family houses

Appendix III. Comparison of Urban Forests

A common question asked is, "How does this city compare to other cities?" Although comparison among cities should be made with caution as there are many attributes of a city that affect urban forest structure and functions, summary data are provided from other cities analyzed using the i-Tree Eco model.

I. City totals for trees

City	*% Tree Cover*	*Number of Trees*	*Carbon Storage (metric tons)*	*Carbon Sequestration (metric tons/yr)*	*Pollution Removal (metric tons/yr)*
Toronto, ON, Canada	26.6	10,220,000	1,108,000	46,700	1,905
Atlanta, GA	36.7	9,415,000	1,220,000	42,100	1,509
Los Angeles, CA	11.1	5,993,000	1,151,000	69,800	1,792
New York, NY	20.9	5,212,000	1,225,000	38,400	1,521
London, ON, Canada	24.7	4,376,000	360,000	12,500	370
Chicago, IL	17.2	3,585,000	649,000	22,800	806
Baltimore, MD	21.0	2,479,000	517,000	16,700	390
Philadelphia, PA	15.7	2,113,000	481,000	14,600	522
Washington, DC	28.6	1,928,000	477,000	14,700	379
Oakville, ON , Canada	29.1	1,908,000	133,000	6,000	172
Boston, MA	22.3	1,183,000	290,000	9,500	257
Syracuse, NY	26.9	1,088,000	166,000	5,300	99
Woodbridge, NJ	29.5	986,000	145,000	5,000	191
Minneapolis, MN	26.4	979,000	227,000	8,100	277
San Francisco, CA	11.9	668,000	176,000	4,600	128
Morgantown, WV	35.5	658,000	84,000	2,600	65
Moorestown, NJ	28.0	583,000	106,000	3,400	107
Hartford, CT	25.9	568,000	130,000	3,900	52
Jersey City, NJ	11.5	136,000	19,000	800	37
Casper, WY	8.9	123,000	34,000	1,100	34
Freehold, NJ	34.4	48,000	18,000	500	20

II. Totals per hectare of land area

City	*Number of Trees/ha*	*Carbon Storage (metric tons/ha)*	*Carbon Sequestration (metric tons/ha/yr)*	*Pollution Removal (kg/ha/yr)*
Toronto, ON, Canada	160.4	17.4	0.73	29.9
Atlanta, GA	275.8	35.7	1.23	44.2
Los Angeles, CA	48.4	9.4	0.36	14.7
New York, NY	65.2	15.3	0.48	19.0
London, ON, Canada	185.5	15.3	0.53	15.7
Chicago, IL	59.9	10.9	0.38	13.5
Baltimore, MD	118.5	25.0	0.80	18.6
Philadelphia, PA	61.9	14.1	0.43	15.3
Washington, DC	121.1	29.8	0.92	23.8
Oakville, ON , Canada	192.9	13.4	0.61	12.4
Boston, MA	82.9	20.3	0.67	18.0
Syracuse, NY	167.4	23.1	0.77	15.2
Woodbridge, NJ	164.4	24.2	0.84	31.9
Minneapolis, MN	64.8	15.0	0.53	18.3
San Francisco, CA	55.7	14.7	0.39	10.7
Morgantown, WV	294.5	37.7	1.17	29.2
Moorestown, NJ	153.4	27.9	0.90	28.1
Hartford, CT	124.6	28.5	0.86	11.5
Jersey City, NJ	35.5	5.0	0.21	9.6
Casper, WY	22.5	6.2	0.20	6.2
Freehold, NJ	94.6	35.9	0.98	39.6

Appendix IV. General Recommendations for Air Quality Improvement

Urban vegetation can directly and indirectly affect local and regional air quality by altering the urban atmosphere environment. Four main ways that urban trees affect air quality are (Nowak 1995):

- Temperature reduction and other microclimate effects
- Removal of air pollutants
- Emission of volatile organic compounds (VOC) and tree maintenance emissions
- Energy effects on buildings

The cumulative and interactive effects of trees on climate, pollution removal, and VOC and power plant emissions determine the impact of trees on air pollution. Cumulative studies involving urban tree impacts on ozone have revealed that increased urban canopy cover, particularly with low VOC emitting species, leads to reduced ozone concentrations in cities (Nowak 2000). Local urban management decisions also can help improve air quality.

Urban forest management strategies to help improve air quality include (Nowak 2000):

Strategy	*Result*
Increase the number of healthy trees	Increase pollution removal
Sustain existing tree cover	Maintain pollution removal levels
Maximize use of low VOC-emitting trees	Reduces ozone and carbon monoxide formation
Sustain large, healthy trees	Large trees have greatest per-tree effects
Use long-lived trees	Reduce long-term pollutant emissions from planting and removal
Use low maintenance trees	Reduce pollutants emissions from maintenance activities
Reduce fossil fuel use in maintaining vegetation	Reduce pollutant emissions
Plant trees in energy conserving locations	Reduce pollutant emissions from power plants
Plant trees to shade parked cars	Reduce vehicular VOC emissions
Supply ample water to vegetation	Enhance pollution removal and temperature reduction
Plant trees in polluted or heavily populated areas	Maximizes tree air quality benefits
Avoid pollutant-sensitive species	Improve tree health
Utilize evergreen trees for particulate matter	Year-round removal of particles

Appendix V. Invasive Species of the Urban Forest

Invasive species data is only available for the United States. This analysis cannot be completed for international studies because of a lack of necessary data.

Appendix VI. Potential Risk of Pests

Pest range data is only available for the United States. This analysis cannot be completed for international studies because of a lack of necessary data.

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Benefits Summary of Trees by Stratum and Species

Location: North Vancouver, Greater Vancouver, British Columbia, Canada
Project: Kealy-Greenwood iTree Eco Assessment, Series: CNV-KG, Year: 2019
Generated: 2019-09-27

Stratum	Species	Trees		Carbon Storage			Gross Carbon Sequestration			Avoided Runoff	
		Number	SE	(metric ton)	SE	(Can$)	(metric ton/yr)	SE	(Can$/yr)	(m^3/yr)	(Can$/yr)
Greenwood Park	Vine maple	2,541	±944	40.25	±16.60	4,623.98	2.95	±1.16	338.98	171.80	399.38
	Red alder	275	±159	125.45	±91.20	14,409.90	2.41	±2.31	276.43	39.73	92.35
	English holly	481	±300	2.89	±1.88	332.45	0.38	±0.24	44.03	15.94	37.05
	Black walnut	69	±68	4.17	±4.14	479.42	0.23	±0.23	26.64	24.58	57.14
	Black cottonwood	137	±136	1.47	±1.45	168.34	0.15	±0.15	17.69	8.66	20.12
	Bitter cherry	137	±136	30.10	±29.88	3,457.98	1.14	±1.13	130.77	5.31	12.35
	Douglas fir	137	±94	1.78	±1.73	204.14	0.01	±0.01	0.88	0.34	0.78
	European mountain ash	69	±68	0.47	±0.47	54.19	0.07	±0.06	7.49	4.21	9.80
	Western redcedar	1,099	±327	403.27	±169.94	46,323.13	5.14	±2.04	590.26	424.16	986.04
	Western hemlock	2,679	±527	932.54	±229.56	107,120.95	25.01	±5.94	2,873.43	1,540.76	3,581.83
	Total	**7,623**	**±1,013**	**1,542.39**	**±261.46**	**177,174.49**	**37.49**	**±6.30**	**4,306.60**	**2,235.48**	**5,196.84**
Kealy Woods Park	Douglas fir	36	±36	0.15	±0.15	17.49	0.01	±0.01	0.74	3.62	8.43
	Western redcedar	182	±108	17.74	±17.42	2,037.44	0.38	±0.37	44.12	57.92	134.65
	Western hemlock	146	±144	73.90	±72.88	8,488.82	2.10	±2.07	240.75	80.26	186.58
	Total	**364**	**±0**	**91.79**	**±55.31**	**10,543.75**	**2.49**	**±1.69**	**285.62**	**141.81**	**329.66**
Study Area		**7,988**	**±1,013**	**1,634.18**	**±267.25**	**187,718.24**	**39.98**	**±6.52**	**4,592.21**	**2,377.28**	**5,526.50**

Carbon storage and gross carbon sequestration value is calculated based on the price of Can$114.87 per metric ton.
Avoided runoff value is calculated by the price Can$2.325/$m^3$. The user-designated weather station reported 117.8 centimeters of total annual precipitation.
Pollution removal value is calculated based on the prices of Can$1,485.80 per metric ton (CO), Can$18,974.53 per metric ton (O3), Can$2,833.73 per metric ton (NO2), Can$1,032.35 per metric ton (SO2), Can$658,697.20 per metric ton (PM2.5).
Structural value is the compensatory value calculated based on the local cost of having to replace a tree with a similar tree.
A value of zero may indicate that ancillary data (pollution, weather, energy, etc.) may not available for this location or that the reported amounts are too small to be shown.

Benefits Summary of Trees by Stratum and Species

Location: North Vancouver, Greater Vancouver, British Columbia, Canada
Project: Kealy-Greenwood iTree Eco Assessment, Series: CNV-KG, Year: 2019
Generated: 2019-09-27

Pollution Removal		Structural Value	
(metric ton/yr)	(Can$/yr)	(Can$)	SE
0.03	1,276.68	173,093.96	±70,034.85
0.01	295.22	234,107.40	±229,703.92
0.00	118.43	23,183.01	±14,463.46
0.00	182.65	23,669.08	±23,496.13
0.00	64.32	4,271.11	±4,239.91
0.00	39.48	150,670.64	±149,569.71
0.00	2.49	3,605.69	±3,579.35
0.00	31.31	3,090.60	±3,068.01
0.08	3,152.02	4,933,258.74	±2,110,779.35
0.31	11,449.82	6,900,464.04	±1,737,053.95
0.44	**16,612.41**	**12,449,414.27**	**±2,263,686.23**
0.00	26.94	1,911.52	±1,885.09
0.01	430.42	265,415.44	±257,975.07
0.02	596.43	647,531.17	±638,577.05
0.03	**1,053.79**	**914,858.14**	**±378,716.89**
0.47	**17,666.20**	**13,364,272.41**	**±2,295,147.46**

Structure Summary by Stratum and Species

Location: North Vancouver, Greater Vancouver, British Columbia, Canada
Project: Kealy-Greenwood iTree Eco Assessment, Series: CNV-KG, Year: 2019
Generated: 2019-09-27

Stratum	Species	Trees		Leaf Area		Leaf Biomass		Tree Dry Weight Biomass		Average Condition
		Number	SE	(ha)	SE	(metric ton)	SE	(metric ton)	SE	(%)
Greenwood Park	Vine maple	2,541	±944	5.724	±2.841	3.222	±1.599	80.508	±33.202	81.42
	Red alder	275	±159	1.324	±1.195	0.965	±0.871	250.891	±182.397	72.13
	English holly	481	±300	0.531	±0.357	0.710	±0.478	5.788	±3.754	99.50
	Black walnut	69	±68	0.819	±0.813	0.656	±0.652	8.347	±8.286	99.50
	Black cottonwood	137	±136	0.288	±0.286	0.208	±0.207	2.931	±2.910	99.50
	Bitter cherry	137	±136	0.177	±0.176	0.137	±0.136	60.207	±59.767	97.00
	Douglas fir	137	±94	0.011	±0.011	0.017	±0.017	3.554	±3.454	49.75
	European mountain ash	69	±68	0.140	±0.139	0.111	±0.111	0.944	±0.937	99.50
	Western redcedar	1,099	±327	14.132	±5.585	27.177	±10.741	806.531	±339.879	61.88
	Western hemlock	2,679	±527	51.336	±10.716	28.362	±5.921	1,865.081	±459.115	71.18
	Total	**7,623**	**±1,013**	**74.483**	**±11.425**	**61.567**	**±10.874**	**3,084.783**	**±522.926**	**76.17**
Kealy Woods Park	Douglas fir	36	±36	0.121	±0.119	0.189	±0.187	0.304	±0.300	99.50
	Western redcedar	182	±108	1.930	±1.846	3.711	±3.550	35.474	±34.838	62.30
	Western hemlock	146	±144	2.674	±2.637	1.477	±1.457	147.799	±145.755	80.25
	Total	**364**	**±0**	**4.725**	**±0.672**	**5.378**	**±2.280**	**183.577**	**±110.616**	**73.20**
Study Area		**7,988**	**±1,013**	**79.207**	**±11.445**	**66.944**	**±11.110**	**3,268.360**	**±534.497**	**76.04**