# City of Victoria

## Vegetation Canopy Change Detection Analysis
## 2007-2023
## Phase 03 Project

March 25, 2025

Submitted to:
City of Victoria
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terra remote sensing

# Contents

# Above Ground Vegetation Change Assessment Using Multiple LiDAR Datasets, 2013 – 2023

Terra Remote Sensing, March 25, 2025

## EXECUTIVE SUMMARY

In 2019 and 2020, and 2024, Terra Remote Sensing (Terra) compared four LiDAR datasets collected over the City of Victoria with the goal of quantifying changes in above ground vegetation in the city. The first LiDAR dataset is from 2007, the second dataset from 2013, the third from 2019 and the fourth from 2023. The goal of the study was to quantify the change in vegetation area and volume between the two datasets over each interval period (2007-2013, 2013-2019 and 2019-2023). Change was observed and characterized by comparing the measured area of vegetation coverage by subtracting the two different years and by using image (raster) processing techniques to detect vegetation object removal as well as the introduction of new vegetation objects.

The overall project was undertaken in three phases. The first phase of the project had the goal of assessing change between 2007 and 2013, as the 2019 dataset was not yet available at the time of the first study, and there was good value in assessing a baseline year for ongoing change detection work. A finding in Phase 01 was, due to the sampling differences between the 2007 and 2013 LiDAR datasets, meaningful comparisons were difficult to make as uncertainties existed around the accuracy of using a 1m pixel size for both years of data. Therefore, it was concluded that 2013 would serve as the most reliable baseline dataset to use going forward. One encouraging aspect of this report is that the measured change between 2013 to 2019 were similar to what was observed between 2007 to 2013. It should also be noted that a comparison of the Habitat Acquisition Trust (HAT) analysis was not undertaken in the second project phase and therefore has not been referenced in this report. Similar trends in vegetation change were observed in the third phase of the project comparing 2019 and 2023 LiDAR data.

Between 2019 and 2023 there was a 1.26% net increase of above ground vegetation (*table 2*). Consistent with the findings of the Phase 02 report, the horizontal growth of existing vegetation offsets the effect of vegetation loss from urban development or die off. Vegetation gain from new plantings was present in several locations, which did not represent a significant contribution to vegetation fill in between 2019-2023.

This Phase 03 Project Report summarizes the datasets used, the methodology used to determine the area and volume of vegetation, results in terms of area and volume of vegetation change.

# INTRODUCTION

The City of Victoria's Urban Forest Master Plan (UFMP) was approved by Council in 2013, following extensive consultation with community members, staff and industry experts. The plan provides guidance on the long-term management and enhancement of the urban forest, with 26 recommendations relating to trees on public and private lands to be completed over the next few decades. At present, the City has direct control over roughly one-third (33,000ha) of the urban forest inventory. The other two-thirds consists of trees on private land. The City's overall tree canopy coverage when last measured from 2019 LiDAR data was assessed to be 28.83% (Phase 02 Project, 2021 Terra Remote Sensing).

The City's plan for the results provided in this report, as well as the associated data deliverables, is to:

- Establish an accurate baseline assessment of tree canopy and impervious surface across the entire City from which to benchmark changes over time
- Assess above ground vegetation cover across the entire City
- Identify areas of the City with significant changes in tree canopy
- Establish a robust program to assess tree canopy and impervious surface change on an ongoing and regular basis
- Inform the City's management of the urban forest

This report is the third phase of the overall project that was completed for the City of Victoria. The first project phase compared LiDAR data from 2007 and 2013, which had highly different LiDAR densities due to sensor advancements during that period of time. The 2007 dataset was not dense enough to support a 1m pixel size for vegetation cover, so various techniques (which were not required for this report) were employed in order to investigate changes to vegetation between the 2007 and 2013 datasets as the 2019 LiDAR data was not available at the time of the first phase of the project. The focus of this Phase 03 project was to assess the change in vegetation between 2019 and 2023. The results from the Phase 02 project provide confidence to the results reached in the Phase 03 project as the observed increases and loss of vegetation is relatively similar between the four datasets covering 2007 – 2023.

# DESCRIPTION OF LIDAR DATASETS

LiDAR is an active remote sensing technology that emits laser pulses at a high sampling rate (current sensors sample up to 2 million pulses/second) and measures the range to target from the sensor of the returned laser pulses based on the speed of light. Based on range to target, the 3D position, time, and orientation of the sensor, the 3D position of each laser return can be determined and contribute to a "point cloud" representing objects scanned by the sensor. Each of these points are georeferenced and generally accurate within 20cm of the object's real-world position. In 2019 and 2023, LiDAR sensors were deployed on aircraft and flown over the City of Victoria by different vendors and for different purposes.

The 2019 LiDAR dataset was flown under the National Disaster Mitigation Program (NDMP) for sea level rise and tsunami studies around the circumference of Vancouver Island with a targeted pulse density of 8 pulses/m². The 2023 LiDAR dataset was flown for the Capital Regional District, with a targeted pulse density of 8 pulses/m². All LiDAR datasets were classified into ground, vegetation ≥2m from ground elevation, buildings, and a 'catch all' non-vegetation class, which includes distribution wires, signs, traffic lights, and other above ground features that are not vegetation or buildings. Vegetation ≥2m above ground elevation was only considered in this analysis, which allowed low 'clutter' to be ignored as potentially false vegetation. Objects under 2m in height from ground elevation such as mailboxes, cars, umbrellas, trampolines, barbeques, etc. are difficult and time consuming to accurately distinguish from vegetation in the same height class. Distribution lines, lamp standards, high trucks, shipping containers etc. were removed from the ≥2m vegetation class through manual classification methods in order to achieve a high level of classification accuracy of a 'clean' vegetation class.

As the data was provided to Terra pre-classified, a quality control (QC) process that involved reviewing the classified points overlaid on orthophotos was conducted to ensure significant vegetation wasn't missing from vegetation class, or significant non-vegetation features were included in the vegetation class. After the LiDAR classification QC, the LiDAR vegetation class was rasterized (vector to image process), and each year was compared using the three methods to summarize different aspects of change (gain and loss of vegetation area, and change in volume). In order to test the quality of the data classification, 154 random points were placed on vegetation, solely identified using the 2023 CRD orthophotos, and then these points were overlaid on the vegetation raster image created from the classified LiDAR and assessed if the LiDAR was classified as vegetation. The assessment passed at 97.40%. These validation points were provided to the City as part of the project deliverables, and the tabulated results have been included in Appendix A of this report.

The 2019 and 2023 datasets were rasterized at 1m grid size, which was used to determine the area of 2019 and 2023 above ground vegetation cover. As an initial measure of change, the area of vegetation between two datasets was measured and summarized (Table 1). These numbers do not provide a measure of how much vegetation has been lost or gained, rather are the total area of the classified vegetation cover for each year's dataset.

To gain a better idea of where the changes have occurred, the datasets were compared to assess vegetation loss and gain areas. It can be asserted that horizontal vegetation growth between 2019-2023 again offset the effect of vegetation removal, as was the case between 2013-2019. It should be noted that there is an imbalance between added vegetation (new plantings or vegetation increasing in height above the ≥2m classification threshold) versus removed vegetation (removed vegetation is far greater than the added vegetation), however the overall losses are offset by the effect of horizontal vegetation growth.

## Vegetation Area Calculation

**Table 1**

| Year | 2m+ Vegetation Area (ha) | % of City Area | Comment |
|---|---|---|---|
| 2007 | **512** | **26.41%** | Measured at 2m cell size |
| 2013 | **513** | **26.46%** | Measured at 1m cell size |
| 2019 | **559** | **28.83%** | Measured at 1m cell size |
| 2023 | **582** | **30.01%** | Measured at 1m cell size |

## Vegetation Area Change Calculation

Table 2

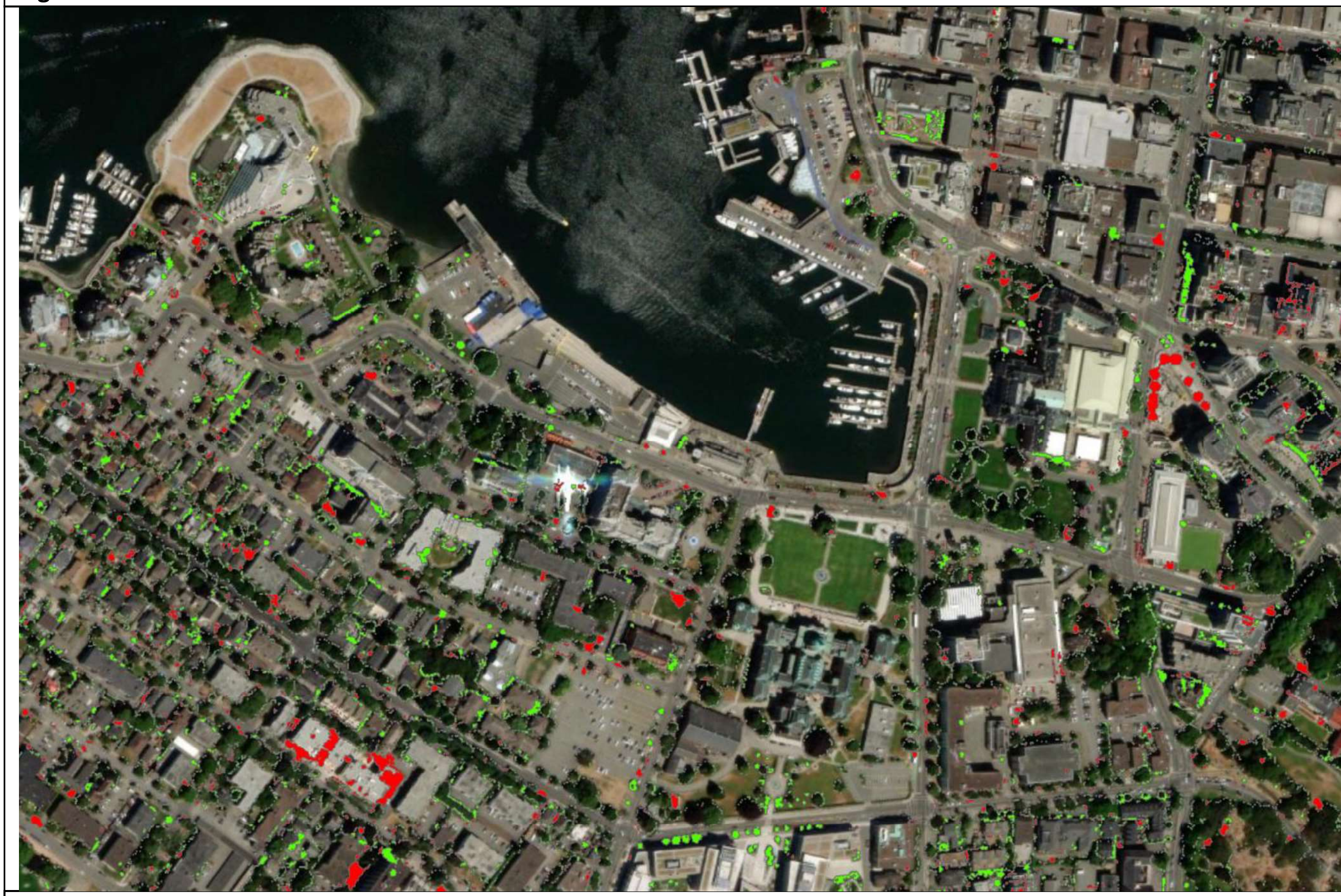
| Description | Area (ha) | % of City-Wide Vegetation Area | Comment |
|---|---|---|---|
| Vegetation Added between 2007-2013 | **53.4** | **10.43%** | Based on 2007 vegetation area of 512ha |
| Vegetation Loss Between 2007-2013 | **-52.38** | **-10.23%** | Based on 2007 vegetation area of 512ha |
| Vegetation Added between 2013-2019 | **113.1** | **22.14%** | Based on 2013 vegetation area of 513ha |
| Vegetation Loss Between 2013-2019 | **-65.7** | **-12.81%** | Based on 2013 vegetation area of 513ha |
| Vegetation Added Between 2019-2023 | **82** | **14.67%** | Based on 2019 Vegetation area of 559 ha |
| Vegetation Lost Between 2019-2023 | **-57.52** | **-10.29%** | Based on 2019 Vegetation area of 559 ha |
| Net Vegetation Area Change 2007-2013 | **0.19%** | | Based on the city area of 1,939 ha |
| Net Vegetation Area Change 2013-2019 | **2.37%** | | Based on the city area of 1,939 ha |
| Net Vegetation Area Change 2019-2023 | **1.26%** | | Based on the city area of 1,939 ha |

Vegetation area coverage was also broken down by neighborhood areas (table 3).

**Table 3**

| Neighbourhood | Vegetation Cover 2013 (ha) | Vegetation Cover 2019(ha) | Vegetation Cover 2023 (ha) | % Difference from 2013-2019 | % Difference from 2019-2023 |
|---|---|---|---|---|---|
| Burnside | 31.24 | 34.48 | 36.85 | 10.37% | 6.87% |
| Downtown | 5.76 | 7.10 | 7.48 | 23.78% | 5.35% |
| Fairfield | 87.78 | 92.06 | 96.87 | 4.88% | 5.22% |
| Fernwood | 51.4 | 55.92 | 57.1 | 8.79% | 2.11% |
| Gonzales | 50.28 | 53.25 | 54.27 | 5.95% | 1.92% |
| Harris Green | 3.91 | 4.16 | 4.3 | 6.39% | 3.37% |
| Hillside Quadra | 50.45 | 57.14 | 59.43 | 13.28% | 4.01% |
| James Bay | 55.19 | 62.88 | 66.97 | 13.93% | 6.50% |
| North Jubilee | 17.11 | 18.89 | 19.63 | 10.46% | 3.92% |
| North Park | 10.58 | 11.56 | 12.41 | 9.26% | 7.35% |
| Oaklands | 49.29 | 53.79 | 56.58 | 9.19% | 5.19% |
| Rockland | 57.49 | 60.02 | 60.47 | 4.40% | 0.75% |
| South Jubilee | 9.87 | 10.68 | 11.23 | 8.21% | 5.15% |
| Victoria West | 30.49 | 36.17 | 39.1 | 18.79% | 8.10% |
| **Total** | **510.82** | **558.10** | **582.69** | **9.28%** | **4.41%** |

**Figure 1**

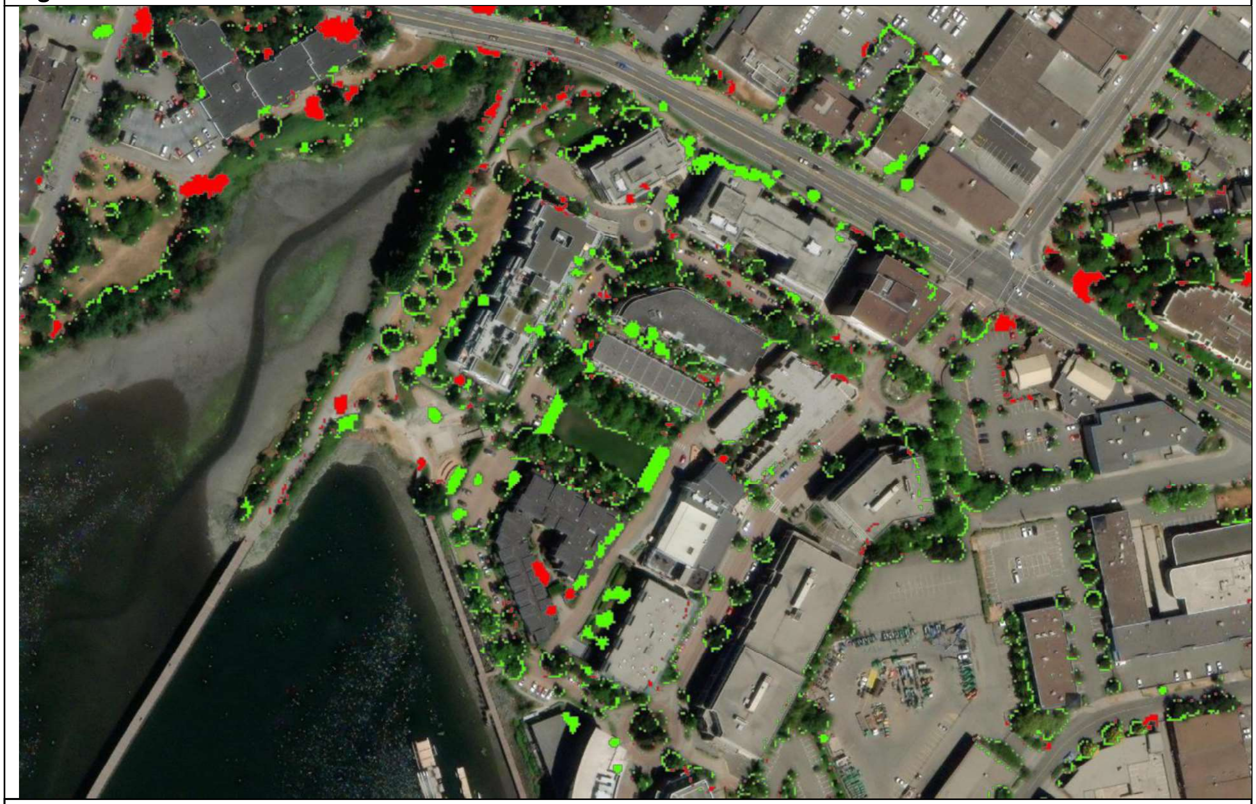


Vegetation gain (green) and vegetation loss (red) around the inner harbour (2019-2023)

**Figure 2**

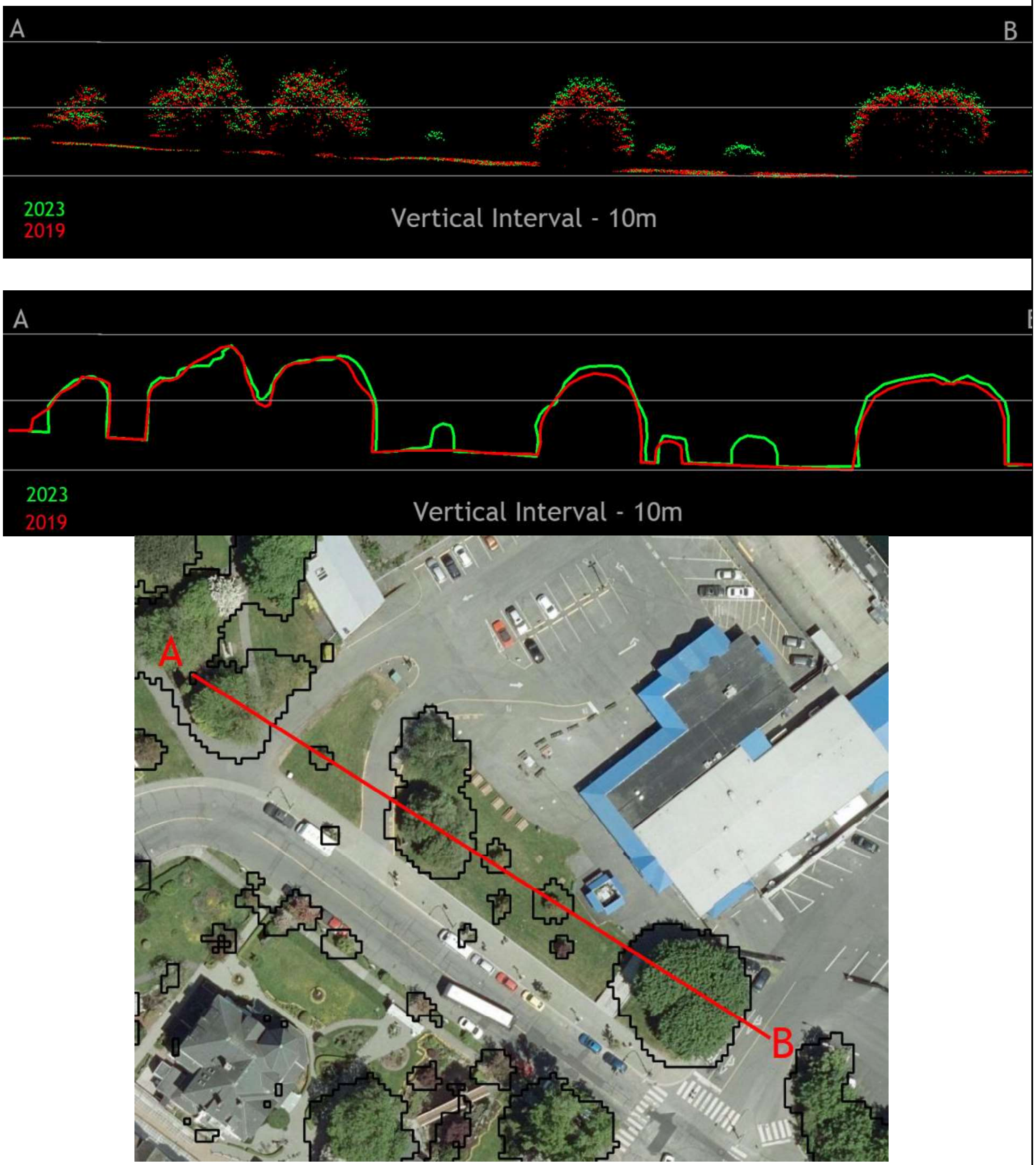
Vegetation growth and removal at Topaz Park (intersection of Blanshard and Finlayson) after renovations. Gains in green and losses in red for 2019 to 2023.

**Figure 3**



New vegetation at the development properties on Jutland and Gorge Road. Gains in green and losses in red between the years 2019 and 2023.

**Figure 4**




Sample 2m cross section profile(s) and plan view showing transect of the LiDAR cross section images showing vertical vegetation change between 2019 - 2023, near the Clipper Terminal Building, Red points in top image are 2019 LiDAR data and Green points are 2023 LiDAR. Middle image shows profile of Digital Surface Model (DSM) comparing 2019 (Red) and 2023 (Green).

# CONCLUSION

The results from the Phase 03 project (2019-2023) generally supported the overall trends of vegetation gain/loss area, which were observed in the Phase 01 Project (2007-2013) and Phase 02 Project (2013-2019). Assessing the accuracy of either dataset with actual measurements on the position and height of above ground vegetation is not possible without having field verifications conducted at or near the time of each survey. However, the inherent accuracy of LiDAR data, in terms of being able to measure spatial objects above ground surface, lends a high degree of confidence in the measurement of the position and height of vegetation. Additionally, as previously mentioned the LiDAR classification accuracy was assessed at 97.4% (see appendix A).

Assessing whether the horizontal and vertical vegetation growth detected in this study is on 'trend' with what is 'normal' is a complex question. Victoria, BC, is situated in the Pacific Northwest (PNW), a broad geographic region whose nominal boundaries are the Pacific Ocean to the West and the Rocky Mountains to the East. Due to its geographic extension and diversity, the PNW is home to many different types of forests, in particular the costal temperate rainforest, subalpine and montane forest. The predominant species in the coastal temperate rainforest are Douglas-fir, Western redcedar and Western hemlock. There are a number of factors affecting the growth of natural forests, which can be summarized in site conditions, age class, climatic conditions, and forest disturbances. Landscapes and ecosystems are dynamic both in space and time, therefore it is very difficult to obtain reliable data about yearly growth that can be generalized to a small region, especially an urban area where there are abundant non-native species of trees, site-specific pollution, areas of intense irrigation and vegetation management, and areas of unnatural shade from buildings. Coniferous trees typical of the coastal PNW region also have growth rates that vary according to age. In ideal conditions, seedlings and young Douglas-fir and Western redcedar can grow at 2 to 4 inches per year, while at the age of 8 to 10 years, the growth rate can be close to 2-3 feet/year. Climate change is expected to be a primary driver in change of structure and composition of plant species.

Vegetation across an urban environment plays an important role by providing many ecosystem services, so gaining an understanding of the asset in terms of how much exists, where, and how it changes over time, is extremely valuable. Based on the three phases of the project, multi-temporal LiDAR data represents an important tool that is helping to facilitate informed policy and management decisions regarding the City's vegetation assets. The results of the comparison between the 2019 and 2023 LiDAR datasets verify the trends of vegetation growth identified in the Phase 01 and 02 Project Reports, which lends credibility to the observed trends in vegetation change over time. As the four datasets (2007, 2013, 2019 and 2023) span approximately 16 years, the actual time of vegetation removal or new plantings can't be precisely determined. It will be of importance to monitor the continual changes in the city's vegetation canopy to assess whether the fill in growth of existing and new plantings will continue to outstrip the vegetation loss. Further to on-going monitoring, determining age class, distribution, and species composition will help to forecast vegetation growth trends and potentially predict when vegetation growth will cease to offset observed losses.

# APPENDIX A – CLASSIFICATION ACCURACY ASSESSMENT

| Easting | Northing | Vegetation Point ID | Test Result |
|---|---|---|---|
| 471706.86 | 5362521.39 | 1 | Pass |
| 472180.69 | 5362768.45 | 2 | Pass |
| 472253.71 | 5362031.46 | 3 | Pass |
| 471839.83 | 5363025.75 | 4 | Pass |
| 472557.11 | 5363102.23 | 5 | Pass |
| 472343.56 | 5363246.36 | 6 | Pass |
| 471950.40 | 5363176.05 | 7 | Pass |
| 471527.17 | 5362946.17 | 8 | Pass |
| 472930.49 | 5362327.80 | 9 | Pass |
| 472704.09 | 5361910.35 | 10 | Pass |
| 472482.14 | 5362073.09 | 11 | Pass |
| 472407.34 | 5362240.28 | 12 | Pass |
| 472998.21 | 5363083.33 | 13 | Pass |
| 472769.09 | 5363335.61 | 14 | Pass |
| 472649.17 | 5363440.80 | 15 | Pass |
| 472991.26 | 5363611.92 | 16 | Pass |
| 472925.15 | 5363772.51 | 17 | Pass |
| 473251.99 | 5363941.34 | 18 | Pass |
| 473163.95 | 5363961.11 | 19 | Pass |
| 472989.88 | 5364010.78 | 20 | Pass |
| 472751.79 | 5364204.53 | 21 | Pass |
| 472649.59 | 5363932.93 | 22 | Pass |
| 472294.25 | 5363881.84 | 23 | Pass |
| 471991.32 | 5363869.93 | 24 | Pass |
| 471520.40 | 5364200.39 | 25 | Pass |
| 471740.18 | 5364472.25 | 26 | Pass |
| 471947.02 | 5364494.55 | 27 | Pass |
| 471790.57 | 5364927.96 | 28 | Pass |
| 471659.36 | 5365038.44 | 29 | Pass |
| 471518.13 | 5364935.76 | 30 | Pass |
| 471354.59 | 5365013.43 | 31 | Pass |
| 471049.47 | 5364903.26 | 32 | Pass |
| 470987.81 | 5364664.96 | 33 | Pass |
| 471872.46 | 5365455.52 | 34 | Pass |
| 472143.01 | 5365424.45 | 35 | Pass |
| 472007.30 | 5365893.90 | 36 | Pass |
| 472443.42 | 5365553.53 | 37 | Pass |
| 472545.28 | 5365895.89 | 38 | Pass |
| 471470.24 | 5365958.31 | 39 | Pass |
| 473032.57 | 5365236.50 | 40 | Pass |
| 472716.25 | 5365186.90 | 41 | Pass |
| 472538.43 | 5364830.97 | 42 | Pass |
| 473176.36 | 5364654.50 | 43 | Pass |
| 472847.63 | 5364573.13 | 44 | Pass |
| 473564.02 | 5363471.25 | 46 | Pass |
| 473508.60 | 5363585.33 | 47 | Pass |
| 473406.14 | 5363692.93 | 48 | Pass |

| | | | |
|---|---|---|---|
| 473453.61 | 5363767.01 | 49 | Pass |
| 473455.95 | 5363852.22 | 50 | Pass |
| 473636.31 | 5363850.53 | 51 | Pass |
| 473712.70 | 5363616.69 | 52 | Pass |
| 473765.09 | 5363437.35 | 53 | Pass |
| 473822.88 | 5363565.73 | 54 | Pass |
| 473737.93 | 5363735.80 | 55 | Pass |
| 473361.93 | 5364078.26 | 56 | Pass |
| 473454.83 | 5364160.98 | 57 | Pass |
| 473505.65 | 5363934.87 | 58 | Pass |
| 473890.71 | 5364286.92 | 59 | Pass |
| 473758.27 | 5364427.64 | 60 | Pass |
| 473651.82 | 5364577.81 | 61 | Pass |
| 473565.20 | 5364688.78 | 62 | Pass |
| 473334.33 | 5364752.81 | 63 | Pass |
| 473311.43 | 5364602.61 | 64 | Pass |
| 473343.16 | 5364415.38 | 65 | Pass |
| 473436.31 | 5364349.59 | 66 | Pass |
| 473277.36 | 5364842.39 | 67 | Pass |
| 473408.71 | 5364984.70 | 68 | Pass |
| 473770.85 | 5364988.99 | 69 | Pass |
| 473890.83 | 5365239.42 | 70 | Pass |
| 473939.78 | 5365520.50 | 71 | Pass |
| 473488.24 | 5365576.67 | 72 | Pass |
| 473180.73 | 5365787.80 | 73 | Pass |
| 473167.82 | 5365671.13 | 74 | Pass |
| 473209.05 | 5366125.16 | 75 | Pass |
| 473667.82 | 5366129.27 | 76 | Pass |
| 474063.03 | 5365820.13 | 77 | Pass |
| 473754.06 | 5365722.80 | 78 | Pass |
| 474271.73 | 5364919.69 | 79 | Pass |
| 474065.45 | 5365124.54 | 80 | Pass |
| 474162.67 | 5365455.65 | 81 | Pass |
| 474329.55 | 5365885.89 | 82 | Pass |
| 474661.20 | 5366007.23 | 83 | Pass |
| 475096.24 | 5365960.24 | 84 | Pass |
| 475253.79 | 5366081.43 | 85 | Pass |
| 475278.14 | 5365721.92 | 86 | Pass |
| 475056.53 | 5365360.18 | 87 | Pass |
| 474662.76 | 5365083.14 | 88 | Pass |
| 474885.23 | 5364934.20 | 89 | Fail |
| 475289.95 | 5365233.51 | 90 | Fail |
| 475382.11 | 5365245.50 | 91 | Pass |
| 475378.81 | 5365506.62 | 92 | Pass |
| 475397.38 | 5365803.35 | 93 | Pass |
| 475425.57 | 5365072.22 | 94 | Pass |
| 475414.31 | 5364863.23 | 95 | Pass |
| 475643.80 | 5364855.72 | 96 | Fail |

| | | | |
|---|---|---|---|
| 475607.17 | 5364599.19 | 97 | Pass |
| 475366.04 | 5364657.55 | 98 | Pass |
| 475485.90 | 5364421.39 | 99 | Pass |
| 475700.28 | 5364336.38 | 100 | Pass |
| 475382.50 | 5364103.14 | 101 | Pass |
| 476125.99 | 5364339.55 | 102 | Pass |
| 475921.44 | 5364283.72 | 103 | Pass |
| 476024.81 | 5363972.86 | 104 | Pass |
| 475967.40 | 5363872.39 | 105 | Pass |
| 475786.07 | 5364167.74 | 107 | Pass |
| 475677.49 | 5364074.20 | 108 | Pass |
| 475522.01 | 5364044.05 | 109 | Pass |
| 475484.36 | 5363824.91 | 110 | Pass |
| 475362.10 | 5363866.66 | 111 | Pass |
| 475235.15 | 5363838.37 | 112 | Pass |
| 474304.37 | 5363480.46 | 113 | Pass |
| 474150.27 | 5363654.18 | 114 | Pass |
| 473899.47 | 5363587.94 | 115 | Pass |
| 474103.27 | 5363950.08 | 116 | Pass |
| 474038.32 | 5364345.10 | 117 | Pass |
| 474145.61 | 5364397.08 | 118 | Pass |
| 474690.87 | 5364626.90 | 119 | Pass |
| 474976.50 | 5364464.22 | 120 | Pass |
| 474933.28 | 5364199.89 | 121 | Pass |
| 474655.96 | 5363778.33 | 122 | Pass |
| 474509.70 | 5363891.35 | 123 | Pass |
| 475153.14 | 5363744.79 | 124 | Pass |
| 474973.45 | 5363590.21 | 125 | Pass |
| 475497.34 | 5363458.61 | 126 | Pass |
| 475150.23 | 5363368.40 | 127 | Pass |
| 475251.39 | 5363183.20 | 128 | Pass |
| 475037.36 | 5363148.76 | 129 | Pass |
| 474812.12 | 5362811.09 | 130 | Pass |
| 474651.11 | 5363140.26 | 131 | Pass |
| 474374.91 | 5363392.26 | 132 | Fail |
| 474209.36 | 5363222.96 | 133 | Pass |
| 474257.65 | 5363015.55 | 134 | Pass |
| 475642.41 | 5363598.27 | 135 | Pass |
| 475978.83 | 5363487.86 | 136 | Pass |
| 475831.25 | 5363443.75 | 137 | Pass |
| 475639.23 | 5363349.06 | 138 | Pass |
| 475984.35 | 5363078.14 | 139 | Pass |
| 475570.94 | 5363026.20 | 140 | Pass |
| 475461.97 | 5363089.73 | 141 | Pass |
| 475379.82 | 5362580.08 | 142 | Pass |
| 475854.28 | 5362469.02 | 143 | Pass |
| 475529.01 | 5362169.23 | 144 | Pass |
| 475242.40 | 5362094.46 | 145 | Pass |

| | | | |
|---|---|---|---|
| 473518.79 | 5361839.48 | 146 | Pass |
| 473867.46 | 5361709.90 | 147 | Pass |
| 474544.49 | 5362036.71 | 148 | Pass |
| 474889.55 | 5362379.56 | 149 | Pass |
| 473369.42 | 5362216.70 | 150 | Pass |
| 473332.21 | 5362520.43 | 151 | Pass |
| 473281.92 | 5362928.18 | 152 | Pass |
| 473675.72 | 5363207.28 | 153 | Pass |
| 473885.11 | 5362773.10 | 154 | Pass |
| **Test Result** | | **150/154 Passed** | **97.40%** |