Assessment of the Ecological Impacts of Non-Native Trees In and Around the Town of Newhalem, WA

June 5, 2015

ENSC 15.2
Science and Engineering Project Center
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June 5, 2015

Seattle City Light
700 5th Ave Suite 3200
Seattle, Washington 98104

Attention: Scott Luchessa and Colleen McShane

Re: Newhalem, WA Non-Native Trees Project

Dear Mr. Luchessa and Ms. McShane:

The ENSC 15.2 project team of Seattle University is pleased to present this final report addressing the scope of the spread of non-native trees along the Upper Skagit River near Newhalem, WA. Our report covers the following topics:

- History of the landscaping in the town of Newhalem
- Data collected within the riparian corridor and in the town
- Analysis of the spread of non-native species, with possible seed sources
- Maps showing densities of native and non-native trees based on results
- A literature review of successful remediation plans
- A list of possible remedial actions
- A recommended remediation plan to address the spread of non-native species

It has been a pleasure working with Seattle City Light on evaluating Newhalem's riparian ecosystem and developing non-native management plans. Thank you.

Sincerely,

Aaron Cleborne　　　Polly Lentz　　　Katie Stick

CC: Dr. J. Wesley Lauer, Dr. Lyn Gualtieri, Seattle University Project Center

Assessment of the Ecological Impacts of Non-Native Trees

In and Around the Town of Newhalem, WA

Project Sponsor

Seattle City Light

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June 5, 2015

Executive Summary

This report addresses the request from Seattle City Light for Seattle University Team ENSC 15.2 to identify, map, and assess the ecological impacts of the spread of non-native trees along the Skagit River near the town of Newhalem, WA. Non-native trees planted for landscaping purposes in the 1920s in Newhalem have spread into the adjacent riparian corridor and also into downstream areas of the riparian zone within the Ross Lake National Recreation Area. Team ENSC 15.2 presents possible management practices and controls to address the spread of non-native trees, in particular sycamore maple (*Acer pseudoplatanus*) and European beech (*Fagus sylvatica*), in various habitat types near Newhalem.

Belt transects were used to characterize the populations of non-native species within the study area, which consisted of the riparian corridor along the north bank of the Skagit River through Newhalem. Data recorded for each transect included length, width, and location (GPS coordinates). Within each transect all trees were identified by species and classified by diameter-at-breast-height (DBH). GPS coordinates of mature European beech and sycamore maple present in the city landscaping were mapped. Stem densities of non-native trees were calculated for the entire study area and helped to characterize the forest composition of the riparian corridor. Additional work at downstream locations southwest of the primary study area was conducted specifically to map the spread of European beech outside city limits.

Sycamore maple, European beech, one-seeded hawthorn, and Norway maple were the most abundant and widespread non-native species in the riparian corridor. The stem density of sycamore maple (0.22 stems/m^2) was far greater than the most abundant native species, Western red cedar (0.11 stems/m^2). European beech was most prevalent beyond city limits at a location downstream of Newhalem. The overall stem density of native species (0.52 stems/m^2) was only slightly higher than the stem density of non-native species (0.48 stems/m^2) in Newhalem, suggesting that non-native species already have a strong foothold within the riparian area.

Four management options aimed at controlling European beech and sycamore maple at all life stages were developed by ENSC 15.2. Management options take into account aesthetics, ecosystem health, estimated cost, effectiveness of removing seed source, and support from literature.

The proposed management option for controlling sycamore maple and European beech involves tree girdling, removal of some stems, application of herbicide, and continual management of seedlings every two years. Landscaped trees are not removed, thus preserving aesthetics within the town. However, landscaped trees will continue to contribute to the seed bank, thus continuing to produce seedlings. To work towards eradicating these two species within the riparian corridor, all female sycamore maples with a DBH above 3 inches and all European beech with a DBH above 8 inches will be cut and removed. Herbicide such as glyphosate will be applied to the stumps to prevent re-sprouting. Seedlings will be manually removed during the early spring when the soil is moist, once every two years. Saplings (approximately 2-6 inches DBH) will be girdled to provide canopy cover and habitat. Once girdled individuals are felled, stumps will also be treated with glyphosate. The proposed management option effectively controls the two species by removing seed source within the riparian corridor while keeping cost low and keeping aesthetics within Newhalem in mind.

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I. Introduction

This report addresses the request from Seattle City Light for Seattle University Team ENSC 15.2 to identify, map, and assess the ecological impacts of the spread of non-native trees along the Skagit River near the town of Newhalem, WA. Non-native trees planted for landscaping purposes in the 1920s in Newhalem have spread into the adjacent riparian corridor and possibly also into downstream areas of the riparian zone within the Ross Lake National Recreation Area. Team ENSC 15.2 presents possible management practices and controls to address the spread of non-native trees, in particular sycamore maple (*Acer pseudoplatanus*) and European beech (*Fagus sylvatica*), in various habitat types near Newhalem.

A. Background

1. Region

The town of Newhalem is located in northwest Washington (Figure 1), along the Skagit River and State Route 20, which links western and eastern Washington (Figure 2, see next page). The town is within the North Cascades, a landscape which is largely undisturbed, protected by wilderness, recreational area, and national park designations. The largest of these are the north and south units of the North Cascades National Park (Figure 2, see next page). The town of Newhalem is located within the Ross Lake National Recreation Area. For visitors to the area, Newhalem is the last stop before crossing the North Cascades Mountains, and is one of the few developed areas within the surrounding national park.

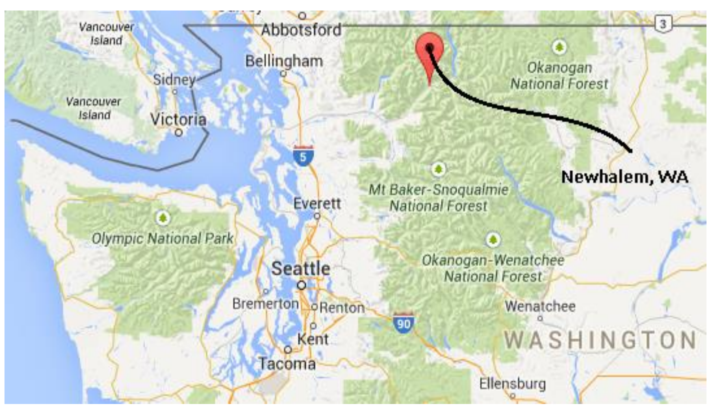

Figure 1. Google Map of Newhalem in relation to Washington State.

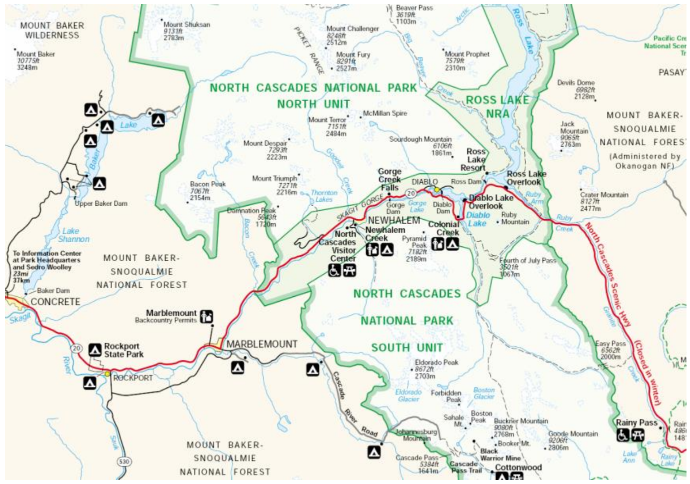

Figure 2. Map of North Cascades National Park. Newhalem is located within the Ross Lake National Recreation Area and the North Cascades National Park. Image obtained from Stanton Studio.

Newhalem is located inland from Puget Sound by approximately 150 miles and is within the North Pacific Maritime Dry-Mesic Douglas-fir Western Hemlock Ecological System, as defined by the Washington Natural Heritage Program (WNHP) (Rocchio and Crawford 2009). This ecological system is typical of interior western Washington lowlands (<2,000 ft elevation) and has a mild, moist maritime climate, with more precipitation falling as rain than as snow. Vegetation is dominated by Douglas-fir, with western hemlock co-dominant or occasional in the canopy; sword fern is usually a major component of the understory (Rocchio and Crawford 2009). Large areas of old-growth and second-growth coniferous forests dominate the landscape. Common native tree species present in the riparian habitat near Newhalem include big-leaf maple (*Acer macrophyllum*), black cottonwood (*Populous balsamifera*), Douglas-fir (*Pseudotsuga menziesii*), paper-birch (*Betula papyrifera*), rocky mountain maple (*Acer glabrum*), red alder (*Alnus rubra*), vine maple (*Acer circinatum*), and western red cedar (*Thuja plicata*). Common understory plants within this habitat are salmonberry (*Rubus spectabilis*), salal (*Gaultheria shallon*), and sword fern (*Polystichum munitum*).

2. History

Construction of Seattle City Light's Skagit River Hydroelectric Project began in 1918. The Gorge Dam was the first to be built and was functioning by 1924, followed by the Diablo (1936) and Ross (1961) dams. To build and operate the hydroelectric project, a small construction camp was built by Seattle City Light at the mouth of the Newhalem Creek. The population of the camp quickly grew to over 1,000 residents and eventually became known as the town of Newhalem (Figure 3, see next page).

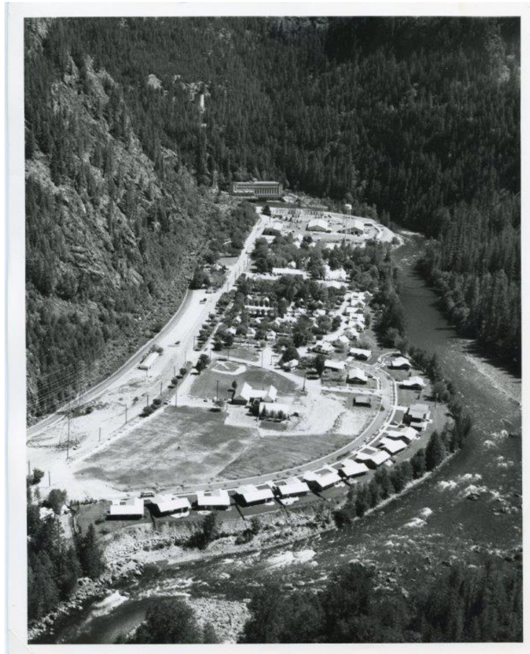

Figure 3. Seattle City Light Newhalem 1971
Gorge switchyard 266.

Over time, Newhalem was landscaped, which involved planting a variety of non-native trees typically used for horticultural purposes in towns and parks throughout the United States. Trees present in the Newhalem landscaping include: American chestnut (*Castanea dentata*), black walnut (*Juglans nigra*), box elder (*Acer negundo*), European beech (*Fagus sylvatica*), golden chain tree (*Laburnum anagyroides*), horse-chestnut (*Aesculus hippocastanum*), northern red oak (*Quercus rubra*), Norway maple (*Acer platanoides*), and sycamore maple (*Acer pseudoplatanus*). Many of these non-native trees were planted along the main street of Newhalem, as well as in residential yards.

The Skagit River Hydroelectric Project was completed in the early 1960s, and in 1968 the North Cascades National Park was established. To comply with federal regulations for national parks, the Skagit River Hydroelectric Project and the surrounding City Light-owned lands were administratively excluded and designated as the Ross Lake National Recreation Area.

3. Research Area

The primary focal area for this study, titled "primary study area," was the riparian zone along the north bank of the Skagit River through Newhalem. This area is approximately 1400 meters long, bound at the upstream end by the Ladder Creek Pedestrian Bridge and by the National Park Service Bridge to Newhalem Campground at the downstream end (Figure 4, see next page). Quantitative data were collected in this area. The width of the riparian corridor varies depending on the distance of the high bank from the river's edge (Figures 4 and 5, see next page).

Additional observations and qualitative data were collected as needed within the landscaped area in Newhalem, the transmission line corridor and downstream locations (Figure 5, see next page) as needed to characterize the distribution, structure and relative abundance of populations of non-native trees within a larger context. This was titled the secondary study area.

Figure 4: Primary study area, with an approximate area of 3 acres.

Figure 5: Secondary study area, with an approximate area of 182 acres.

4. Potential Impacts of Non-Native Species

The term *non-native species* refers to a species that has extended their distributional range by either natural or anthropogenic means (Selge and Fischer 2011). Non-native species cause changes to the environment into which they are introduced, often excluding native species through competition for space and resources and reducing biodiversity (Jeschke et al. 2014). Invasive species are defined as a species with a detrimental impact on nature, the economy and/or human health and well-being, and often spread prolifically into alien environments (Selge and Fischer 2011). Invasive non-native species sometimes displace native flora that have co-evolved with native fauna. The influx of non-native plants may affect habitat for wildlife species that rely on native species for food and cover. Some of the non-native species planted along the streets of Newhalem have spread into the riparian zone could potentially be or become invasive. Non-native species in the riparian zone near Newhalem could have a variety of potential impacts, including:

- Outcompeting native species for available resources
- Decreasing native tree population
- Decreasing overall biodiversity
- Spreading and colonizing into habitats adjacent to the riparian zone

Non-native tree species can establish in areas near roads, river beds, and in disturbed areas due to a variety of factors, including the ability to disperse across longer distances, reach reproductive age faster (Wangen 2006), and germinate under harsh conditions. The ability of certain non-native species to re-sprout, as well as reproduce at a low DBH or at a relatively young age, allows them to produce a large number of trees and out-compete native species (Martin 2010). The cost of controlling increases dramatically once a non-native species has become established. Damages from invasive species cost the United States over $120 billion annually (“The Cost of Invasive Species” 2012). If proper removal is not addressed, the cost of controlling the species is likely to increase (Squirrell 2012).

4.1 Sycamore Maple

Seattle City Light expressed concern about multiple non-native species, especially sycamore maple, and their colonization within the riparian corridor. Sycamore maple can be invasive outside its native range due to its rapid growth and maturation (Hein et al. 2009), prolific seed production, and readily wind-dispersed seeds. Tree species that rely on wind dispersal are both distance- and density-dependent (Pigot and Leather 2008), meaning that one individual can spread its seed easily into the surrounding riparian environment. Seed dispersal is on average 30 to 80 meters from the landscaped tree. However, during severe storms seeds can travel up to several thousand meters. Sycamore maple seedlings are shade-resistant, contributing to their ability to spread even in densely forested areas, though disturbances causing canopy openings are required for the species to advance in the canopy layer (Helliwell and Harrison 2015).

Sycamore maple usually begins flowering at 6-7 years old (Binggeli 1992) but does not reach sexual maturity around until age 30 (Hein et al. 2009), meaning the flowers are not yet fertile. Trees that reach sexual maturity cast dense shade and can thus affect the richness and abundance of ground flora (Nesom 2002). Sycamore maple may support fewer herbivorous insects and may cause Sooty Bark Disease (Squirrell 2012).

The species regenerates prolifically due to high germination rates (Jones 1945). The ability to reproduce quickly makes sycamore maple a potentially invasive non-native species. Sycamore seedling mortality is the limiting stage in sycamore recruitment (Pigot et al. 2008) and due to mass germination in the spring there is little to no seed bank (Binggeli 1994). Sycamore maple is most common and reaches its largest size on alluvial soils along streams. The species grows best with a steady supply of water but is intolerant of flooding ("Silvics Manual").

Sycamore maple is monoecious, meaning that mature trees generally contain both female and male reproductive organs (Binggeli 1994). Yet some plants only produce male flowers (Binggeli 1992). Usually inflorescences start flowering with a sequence of male (protandrous) or female (protogynous) flowers and then switch to the other sex (Binggeli 1992). The male flowering sequence is usually much longer (10 days) than the female flowering sequence (6 days) (Binggeli 1992). Self-pollination is possible but unlikely due to the differences in flowering sequences (Binggeli 1992). The sex of sycamore maple can be determined from flowers, buds, and infructescence (see Appendix C). The control of sycamore maple can be achieved by removal of seed producers, i.e. morphologically hermaphrodite but functionally female trees. Thus, male flowering individuals may be retained since they do not produce seeds (Binggeli 1992).

4.2 European Beech

European beech saplings present within the riparian corridor have the potential to become invasive within the Skagit Hydroelectric Project study area as well. The establishment of natural tree regeneration requires several conditions, such as a sufficient number of appropriately spaced landscaped trees, suitable soil, and favorable precipitation and temperatures (Korpe et al. 1991; Saniga 2007). European beech seedlings can survive deep shade for a long period and then respond rapidly to canopy openings (Watt 1923), which makes them competitive with other species (Collet et al. 2001). European beech occurrence is not restrained by soil acidity or soil nutrition (Bolte et al. 2006) which makes it a stress tolerant competitor capable of eliminating plants growing beneath it (Packham et al. 2012). The species prefers a maritime climate (Bolte et al. 2006) and is limited by drought and spring frost (Packham et al. 2012).

European beech is known for its masting patterns (periodic synchronous production of very large seed crops) that occur biennially. However, in Europe mast years may tend to be four to eight years apart. European beech mast generally drop close to the landscaped tree (Packham et al. 2012) but birds and small animals play a key role in increasing the seed dispersal distance of the species (Milleron et al. 2013). Small animals, primarily squirrels and blue jays are the greatest contributor to seed dispersal (Packham et al. 2012). European beech seeds can be dispersed by both gravity and water (ibid), meaning that the Skagit River could in part be responsible for the dispersal of European beech seeds to downstream locations.

European beech reaches maturity at a DBH >7 cm (Szymura, et al. 2010; Fichtner, et al. 2012). Beech seeds germinate from early spring to early summer (Bolte et al. 2006, Packham et al. 2012) and an adequate supply of water as well as a chilling period is necessary for seeds to break dormancy (Packham et al. 2012). Seedlings are readily killed by drought and freezing temperatures. The species is monoecious, protogynous (female flowers mature before male flowers), and female and male flowers appear on the same branches (Packham et al. 2012). Pollination occurs via wind and self-pollination is generally incompatible. Therefore, isolated trees often produce a high proportion of empty nuts (Packham et al. 2012).

The species has no persistent seedbank and the seeds germinate in the spring following their seed dispersal (Packham et al. 2012). The vast majority of European beech trees develop from seed. European beech sprouts can develop their own root systems by producing suckers from the root of a tree and by developing from the trunk of a broken or uprooted landscaped tree (Packham et al. 2012). Thus, management plans should include the treatment of stumps with herbicide to prevent trees from re-sprouting.

4.3 Norway Maple

Norway maple is listed as an invasive species in the northeastern U.S. and planting is prohibited in Massachusetts (Swearingen 2010). In Montana, the species out-competes local riparian trees and encourages the growth of con-specifics and thus reduces biodiversity (Meiners 2005). Recent research has shown that forests invaded by Norway maple have less wildflower diversity compared with forests dominated by native sugar maple ("Norway Maple" 2004).

The species have a rapid growth rate in comparison to native species and their ability to create a dense canopy prevents the regeneration of native seedlings (Swearingen 2010). Seedlings are particularly shade tolerant (Reinhart et al. 2005) and the possibility of multiple lag phases during the expansion phase allows the species to invade relatively undisturbed forests (Wangen and Webster 2006). A lag phase species, such as Norway maple release multiple generations of seedlings that can survive until germination conditions are favorable (Wangen and Webster 2006). Norway maple is less likely to be preyed upon by native predators than native species such as sugar maple, thus contributing to its spread and proliferation in native forests (Meiners 2005; Martin and Canham 2010).

Norway maple produce seeds at a relatively low DBH of 7.9 cm (Martin and Canham 2010) but does not produce viable seeds until 25-30 years of age (Wangen and Webster 2006). A 30cm DBH Norway maple was estimated to have produced over 26,350 seedlings (Martin and Canham 2010). Norway maple spreads by vegetative reproduction and by seed. The species flowers in the spring and fruits mature during summer into paired winged samaras (Swearingen 2010) which are wind dispersed ("Norway Maple" 2004).

Germination is enhanced by soil disturbance, although exposure to mineral soil is not a prerequisite for germination (Munger 2013). Norway maple grows best on moist well drained soils but can reportedly tolerate flooding for up to four months (Munger 2013). The species maintains a continuously recruited "seedling-bank" of persistent, multi-aged seedlings, given a seed source (Munger 2013). Since Norway maple is similar to sycamore maple, management plans used to control the species in the northeastern U.S. can be adapted and used to control sycamore maple ("Norway Maple" 2004).

4.4 One-seeded Hawthorn

Although one-seeded hawthorn was not present in the original landscaping of Newhalem, the species is present within the riparian corridor and is a non-native species of concern. One-seeded hawthorn is listed as an invasive species in California and typically inhabits riparian areas, grasslands, and woodlands throughout the North Coast Ranges ("Crataegus Monogyna"). Seeds are produced around 10 years of age and are primarily dispersed via birds and other animals. The seeds may also be dispersed by humans and/or water. Control of the species in California has been successful by manually removing seedlings, cutting down trees and either removing their roots or applying herbicides to the trunk ("Crataegus Monogyna"). Additional information regarding the life history of the species was not readily available.

B. Summary of Problem

Non-native trees that were planted in the Newhalem landscape have spread into and colonized the riparian corridor adjacent to the town, and the surrounding area. Seattle City Light is concerned about this trend, particularly with sycamore maple and European beech species, as both trees have the potential to extend elsewhere into the Ross Lake National Recreation Area and beyond, potentially altering the structure and natural functions of native forest ecosystems. Therefore, understanding the nature of the existing population structure and size through data collection—including a survey of the riparian corridor within the city limits and an assessment of the riparian corridor downstream— was necessary to identify management recommendations and priorities. Following identification of invasive plant population structure and distribution, management recommendations were made to facilitate control and the spread of non-native tree species and to begin to restore the area to a natural ecosystem.

II. Methods

Team ENSC 15.2 established belt transects within the primary study area (Figure 4) to map the spread of non-native trees within the riparian corridor. A stratified random approach was used to determine the location of transects to sample along 1400 meters of the riverbank within the city limits Newhalem, which comprised the study area. The entire area was separated into 100-meter lengths, then a random number generator was used to select the location of each 5-meter transect. Data recorded for each transect included length, width, and location using GPS coordinates. Within each transect all trees were identified to species and the number of trees counted within four DBH size classes (<2, 2 to 4, 4 to 6, and >6 inches); additionally, all trees with a DBH >6 inches were measured with a diameter tape.

Stem densities of both non-native and native species present within each of the 14 belt transects were calculated. Species specific stem densities were used to calculate the percentage of non-native species for each transect. Average stem densities of all species were calculated to provide species specific stem densities for the entire study area. Average species stem densities were normalized by dividing through by the sum of the stem densities of all species. Normalized average stem densities were used to calculate the percentage of non-native and native species present within the entire study area.

GPS coordinates (NAD 83 HARN WA State Plane) of the randomly selected belt transects were input into to the ArcGIS Geographic Information System (GIS) and displayed over a satellite image of Newhalem, obtained using Topcon GR-3 surveying equipment. Calculated stem densities and percentages of non-native species per transect were displayed using GIS to spatially analyze the relative abundance and distribution of non-native species.

Additional locations peripheral to the primary study site were assessed for the presence of non-native species, particularly European beech. A downstream location (see Figure 5, page 4), directly south-west of the Newhalem Campground bridge, was surveyed for the presence of European beech. North and South boundaries were determined to be the river's edge and the service road. Start and end points were assigned when fewer than five European beech trees were observed within eyesight. GPS coordinates were recorded at the indicated start and end points, along the river's edge, and along an area where European beech was present.

Locations (GPS coordinates) and DBH measurements of mature sycamore maple and European beech listed in the 1998 Arborist Report (Appendix B) were verified and recorded. Locations (GPS coordinates) and DBH measurements of mature sycamore maple and European beech absent from the Arborist Report but clearly a part of the city landscaping were recorded as well.

These data were used to describe the condition of the riparian area, and thus aid in recommending management practices to control the spread of non-native trees.

III. Results

Team ENSC 15.2 established 14 transects in the primary study area (Figure 6).

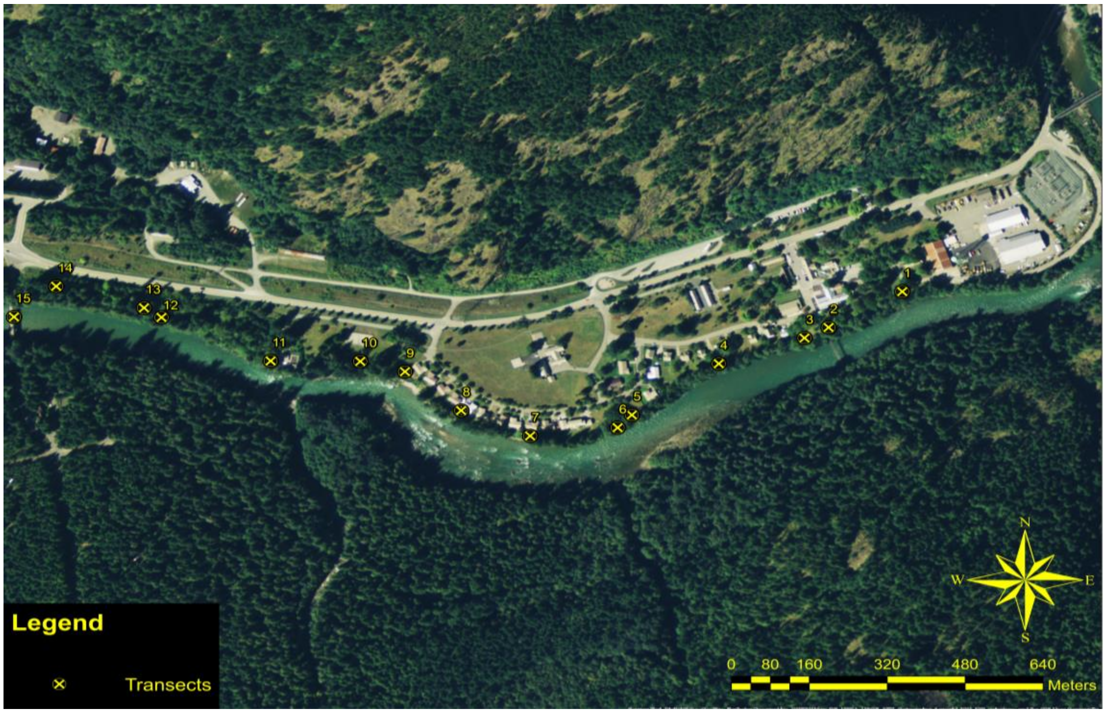

Figure 6. Locations of 14 randomly selected belt transects within the riparian corridor.

GPS coordinates of the randomly-selected belt transects were displayed over a satellite image of Newhalem. Stem densities and percentages of non-native species were calculated for each transect, and then used to spatially analyze the relative abundance and distribution of non-native species. Within these transects 7 non-native species were recorded. Non-native species with high stem densities and general traits that make them suitable for invasion were selected as species of concern (see Table 1).

Table 1. Most abundant non-native tree species recorded within riparian corridor.

Common Name	Scientific Name
Sycamore Maple	*Acer pseudoplatanus*
European Beech	*Fagus sylvatica*
One-seeded Hawthorn	*Crataegus monogyna*
Norway Maple	*Acer platanoides*

The ratio of non-native species to total species present was calculated for the entire riparian corridor study area using normalized stem densities for non-native and native tree species (see Figure 7, next page). Stem densities of non-native and native species were normalized by the total stem density of all accounted trees. The normalized stem density of native species (0.52 stems/m^2) is only slightly higher than the combined stem density of non-native species (0.48 stems/m^2) as shown in Table 1, suggesting that non-native trees already have a strong foothold within the native forest (Figure 7). The abundance of non-native species also suggests that non-natives are having a significant impact on stand structure over most of the primary study area.

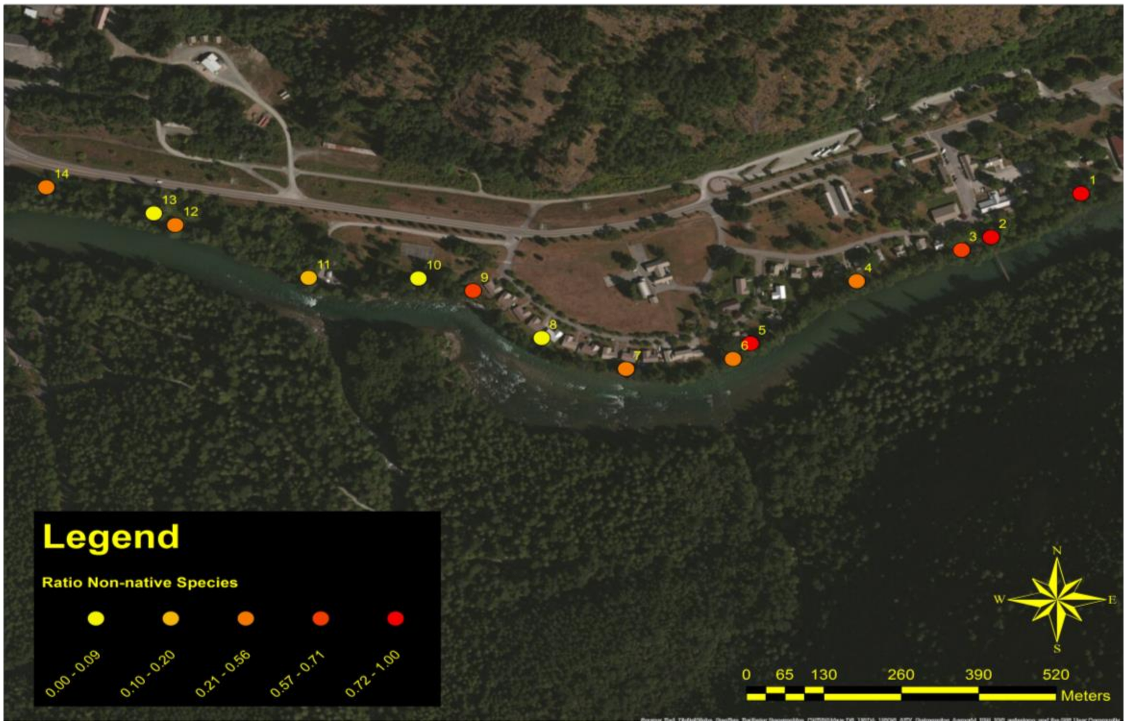

Figure 7. Stem density ratio of non-native species to native species in the study area belt transects, normalized by total stem density of non-native and native species amongst all 14 transects. Red indicate the highest stem density for non-native species.

The most prevalent non-native tree recorded within the riparian corridor is sycamore maple (Figure 8, see next page). This species is the greatest contributor to the combined high stem density of non-native species within the riparian corridor (Figure 7).

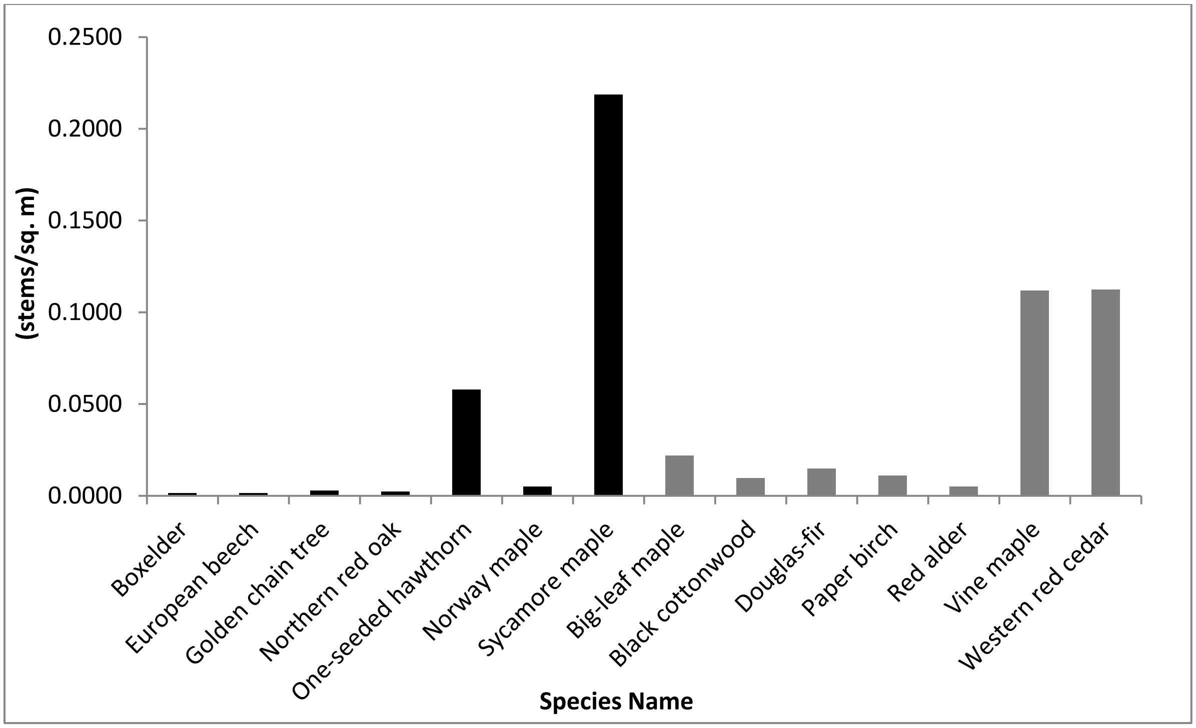

Figure 8. Average stem densities of species present within 14 randomly selected belt transects (black = non-native species, light gray = native species).

Average stem densities of other non-native species including boxelder (0.001 stems/m^2), golden chain tree (0.003 stems/m^2), and northern red oak (0.002 stems/m^2) were far less than the average stem density of sycamore maple (0.22 stems/m^2) (Figure 8). As indicated in Figure 9, the population of sycamore maple in the riparian corridor largely consists of small saplings (<2 in.). However, all size classes of sycamore maple are represented (Figure 9), indicating that sycamore maple is successfully outcompeting native species.

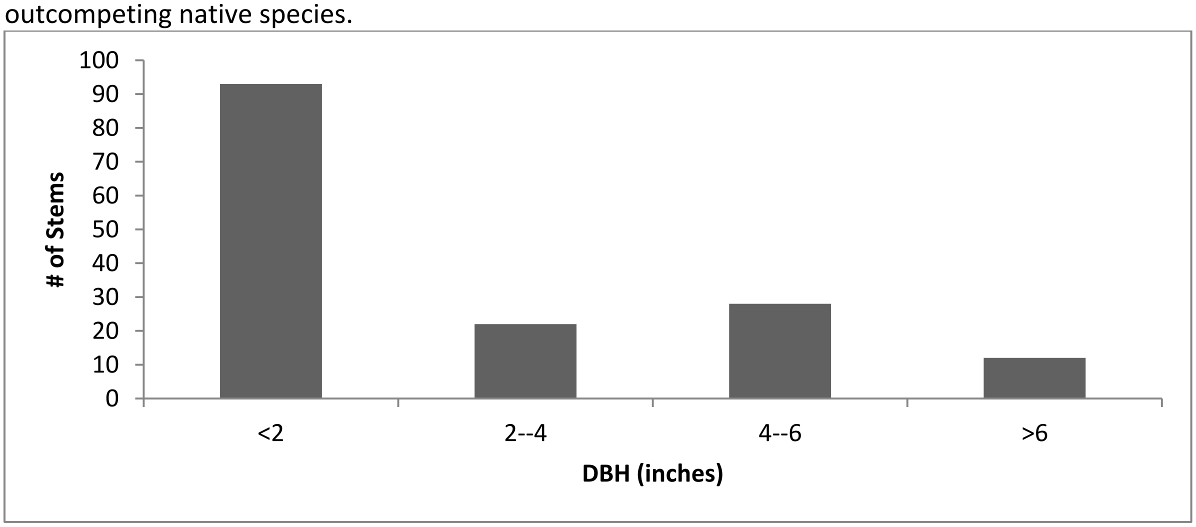

Figure 9. Number of sycamore maples within each of the DBH size classes within 14 belt transects.

Transects 2-6 that are downwind in a southwesterly direction of three landscaped sycamore maple in the center of town have the greatest stem densities of sycamore maple (Figure 10). Locations of landscaped trees were provided in the 1998 Arborist Report (Appendix B). Identification of the tree species were verified in the field and cross referenced with the 1998 Arborist Report map (Appendix B). In addition, mature trees not noted in the 1998 Arborist Report, but that were likely a part of the landscaping in Newhalem, were identified and mapped. Transects with high stem densities of sycamore maple (Figure 10) had the largest ratio of non-native species to native species present (Figure 7, see page 11). Sycamore maple is the greatest contributor to non-native species within the riparian corridor.

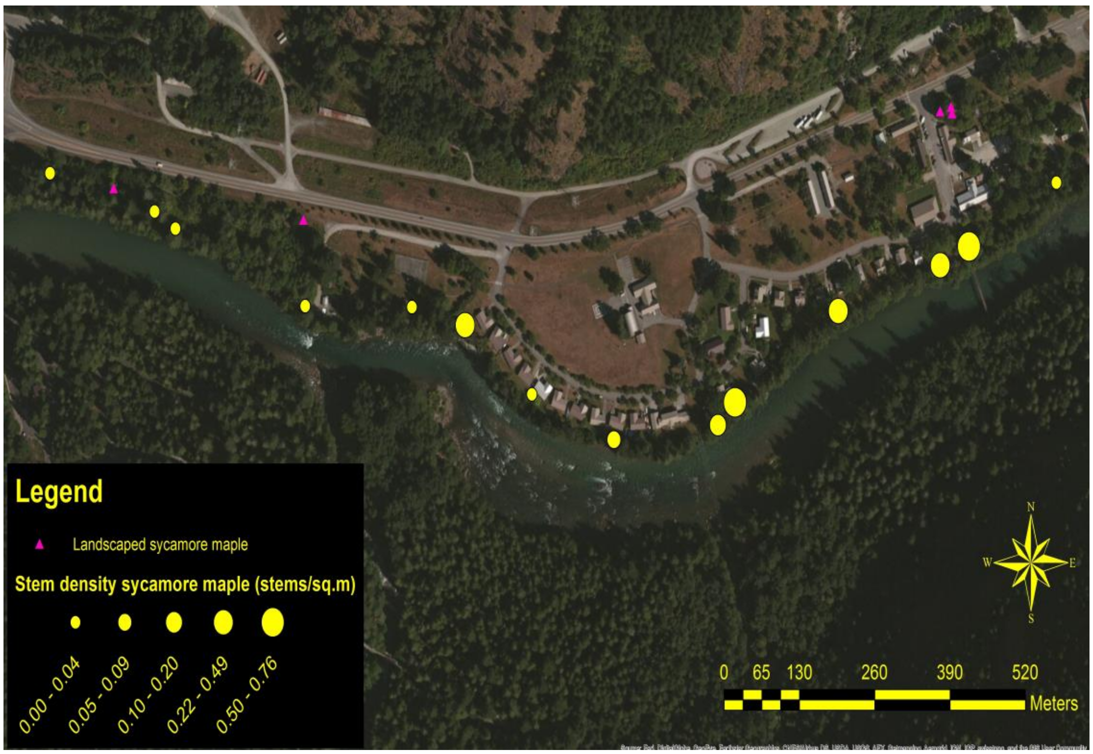

Figure 10: Landscaped mature sycamore maple trees and stem a density of sycamore maple throughout 14 transects in the study area.

Stem density of sycamore maple per transect is positively correlated to the distance from the farthest landscaped tree (R^2=0.4861, Figure 11, see next page).

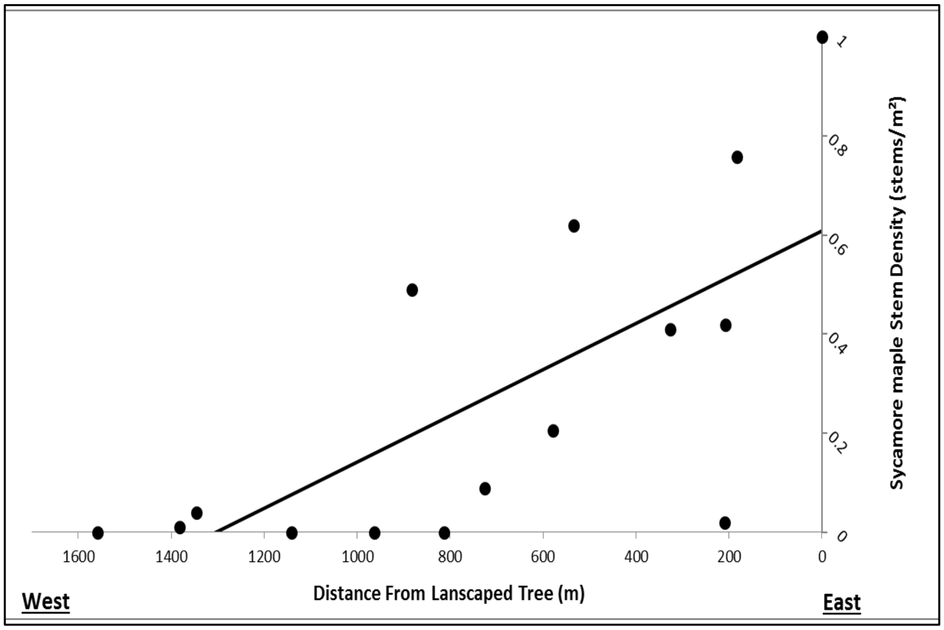

Figure 11. Stem density of Sycamore maple, and their distance from landscaped sycamore maple trees. data with an R^2 value of 0.4861 shows a correlation of 48%, implying that the farthest east landscaped sycamore maple may be contributing to stem density within each of the transects.

Mature European beech present in the landscaping and the area of European beech presence at the secondary study area is shown in Figure 12. Beech nuts are spread by small animals and possibly the river. Although only presence was noted in the downstream location and not abundance or size of each tree, this information is useful in demonstrating the prevalence of European beech where there are fewer competitor species, such as sycamore maple, even though the seed source may be far upstream. Thus, consideration of European beech control is required in management options.

Figure 12. Locations of landscaped European beech trees and presence of beech in secondary study area.

IV. Discussion

The data collected and analyzed by Team ENSC 15.2 indicate that the structure and composition of the riparian forest throughout Newhalem has been significantly affected by non-native trees. 48% of the forest is now comprised of non-native species, primarily sycamore maple. DBH size classes of sycamore maple also indicate the presence of multiple age classes of sycamore maple which clearly suggests that they are outcompeting native species (Figure 9). This indicates that conditions are favorable for the sexual reproduction of this species in particular. In fact, sycamore maple containing seeds and flowers were identified within the riparian corridor during the fall. Without control sycamore maple and European beech will continue to reproduce and likely spread.

Transects 1, 2, and 5 had the greatest stem densities of sycamore maple (Figure 10), while transects 2, 4, 5, and 9 had the greatest percentage of non-native species (Figure 7). The sycamore maple and non-native trees in transects 1—5 are adjacent to the area of Newhalem with the greatest number of mature non-native trees in the city landscaping, which represent the source population for the non-native trees in the riparian corridor (Figure 10). The correlation between landscaped tree location and presence and prevalence of non-native trees within the riparian corridor is demonstrated in Figure 11. Transects 6—14, which are farther from the majority of the mature landscaping trees, have fewer non-native and sycamore maple species present, with the exception of transect 9. Perhaps mature non-native trees in transects 1—5 are responsible for the spread of seeds westward near transect 9. Alternatively, a single mature non-native tree in close proximity could also be responsible for the high percentage of non-native trees in transect 9. Additionally, sexually mature sycamore maples recorded within the riparian corridor (Figure 10) could be contributing to the spread of the species in conjunction with the mature non-native landscaping trees (Figure 11).

One-seeded hawthorn and Norway maple are the second and third most abundant non-native species recorded within the study area (Figure 8). Although the stem density of European beech (0.002 stems/m^2) is less than the stem density of golden chain tree (0.003 stems/m^2), and northern red oak (0.002 stems/m^2) in the primary study area, the species may be of greater concern given greater observed dispersal distances in the secondary study site (Figure 12). The stem density of sycamore maple (0.2186 stems/m^2) is far greater than the stem densities of one-seeded hawthorn (0.038 stems/m^2) and Norway maple (0.0050 stems/m^2). Although control is easiest when populations are low, Seattle City Light asked that the management plans focus on sycamore maple and European beech. Therefore, the management plans proposed are tailored to control the spread of only those two species.

V. Management Alternatives

Five recommended management options for limiting the spread and controlling non-native trees within the riparian corridor were created (Table 2, see page 19). Each option takes into account the main management goals:

- limiting the spread of non-native tree species within the riparian corridor by removing seed sources
- creating healthy natural ecosystems by promoting native plant associations
- limiting cost and labor for Seattle City Light

All proposed management options stay away from extremes; for instance, clear-cutting the riparian corridor would be cost-effective and time-efficient (Hartley and Han 2007), but would likely be unpopular with visitors to and residents of Newhalem, and could contribute to erosion and sedimentation problems without rapid restoration of native riparian plant assemblages. On the other end of the spectrum, continuing with Seattle City Light's current practice of managing sycamore maple and other invasive plants will not address the issues of the spread of non-native tree species identified in this report. Thus, each of the five management plans presented lie somewhere between these two extreme options.

All management options involve integrated pest management, incorporating multiple strategies for control and eradication of non-native trees. Simply cutting down mature non-native trees does not adequately eliminate non-natives from the riparian corridor since sycamore maples and European beech re-sprout from stumps. Re-sprouted stumps can mature and contribute the seed bank, and thus the seed source is not effectively eliminated (Burch and Zedaker 2003, Nesom 2002, Binggeli 1992, Smallidge and Nyland 2009). Thus, herbicides must be applied to prevent re-sprouting of these two species. In order to economically and ecologically manage the ecosystem ("Integrated Pest Management" 2014), integrated pest management will be used in conjunction with herbicide application. Therefore, each option takes into account multiple strategies of controlling non-native populations of sycamore maple and European beech.

Every option includes replanting with native tree and shrub species using stock from a nearby nursery once the non-native trees are removed to facilitate restoration of native riparian plant associations. Since lost genetic diversity cannot be recreated, it is important to preserve pre-adapted genotypes for restoration purposes (Johnson, et al. 2010). These trees should be replanted to mimic the density of a natural *Pseudotsuga menziesii*-dominated forest: Douglas fir to dominate the canopy, western hemlock (*Tsuga heterophylla*) and red alder (*Alnus rubra*) pioneering underneath, and an understory with the fern *Polystichum munitum*. Traditional silviculture replanting practices typically includes planting only Douglas fir and relies on the natural successional processes of the surrounding seed source to fill in the rest of the natural forest makeup (Halpern and Spies 1995). However, planting a more diverse number of species allows the ecosystem to restore more quickly, and lessens the need to thin out non-native trees in the area in the future (Halpern and Spies 1995). Thus, every remediation option suggests replanting with multiple species.

Little literature is available on management options for sycamore maple and European beech. Existing studies on Norway maple (Webb et al. 2001; Reinhart et al. 2005) and American beech (Smallidge and Nyland 2009), respectively, were used in developing the following management options. In addition, little literature is available on the cost of each management option. We expect that each option will have a high upfront cost due to either the removal or girdling of trees. Herbicide application and maintenance of seedlings is foreseen as an ongoing cost, which is variable for each option as described below and in Table 2 (see page 19).

Note that one-seeded hawthorn, Norway maple, and other non-native species identified in Table 1 are not considered in the management options. These species are not nearly as prolific and problematic as sycamore maple and European beech, and therefore are not of concern to Seattle City Light.

Option 1

Option 1 aims to remove the existing seed sources (landscaped trees) of the two most abundant non-native tree species, sycamore maple and European beech. Option 1 includes removing all morphologically hermaphrodite but functionally female landscaped sycamore maples (Binggeli 1992) and all European beech to remove the original seed source. All mature sycamore maples at age 25—30, or above 3 inches DBH (Hein, et. al 2009; "Platanus Occidentalis" 1990), will be cut for removal, and herbicide such as glyphosate will be applied to stumps to prevent re-sprouting. A guide for determining the sex of sycamore maple can be found in Appendix C. In addition, all sexually mature European beech above 7 centimeters DBH (Szymura, et al. 2010; Fichtner, et al. 2012) within the riparian corridor would be removed and stumps treated with glyphosate, repeated every ten years as younger trees reach sexual maturity (Smallidge and Nyland 2009), until all growing individuals have been removed. Viable maple seeds in the soil will be sprayed annually in the spring.

Since the secondary seed source is removed through cutting and applying herbicide, the potential of continued spread of sycamore maple and European beech within the riparian corridor is greatly decreased. Only the riparian corridor within city limits will be targeted, thus limiting labor involved in maintenance. However, this option has the largest negative impact of all proposed management options on the aesthetics of the town and of the riparian corridor, because it calls for the removal of the original female landscaped trees in town, as well as all mature trees of the two species along the river.

Option 2

Option 2 aims to fix the current problem of sycamore maple and European beech spreading. This option does not involve removing landscaped trees, so aesthetics will be maintained. This method suggests cutting to remove the trees and applying herbicide to the stumps of all mature sycamore maple individuals in the riparian corridor within Newhalem over 3 inches ("Platanus Occidentalis" 1990; Burch and Zedaker 2003), and cutting every European beech over 8 inches DBH once, applying herbicide at that time and again 3 months later (Smallidge and Nyland 2009). This option addresses only the riparian corridor in town to limit the scope of the crew's work, and thus the labor and cost involved with management.

Continual management is required for this option, consisting of removing and spraying sycamore maple saplings every two years, and spraying European beech saplings every two years (Smallidge and Nyland 2009), due to the remaining landscaped trees in town contributing seeds to the riparian corridor. This management option goes the furthest to fix current problems and prevent future problems with non-native spread in the riparian corridor, thus limiting the ecological impacts of the landscaping in town, while not physically removing the landscaped trees to maintain aesthetics.

Option 3

Option 3 suggests removing only the seedlings of sycamore maple and European beech. A crew would remove every seedling of those species once per year, then apply herbicide such as glyphosate to stems using a foliar spray method (Smallidge and Nyland 2009), including European beech less than two inches DBH. Eventually, the mature trees would die off naturally, thereby exhausting the seed source for both species (Burch and Zedaker 2003). This option targets the riparian corridor both within Newhalem and downstream. This will be costly and likely take the longest to successfully remove the seed source of any management option. But, it is the only option that maintains aesthetics in the riparian corridor by leaving mature trees. By doing so, this plan also leaves canopy cover and habitat for species in the area (Nesom 2002), therefore making it a better option for ecosystem health, despite possibly continuing the colonization of the species downstream. Although glyphosate has environmental concerns, it is generally considered to have low toxicity to non-target organisms (Nakamura et al. 2008).

Option 4

Option 4 focuses on removing the seed source by girdling trees, but leaving the stems to decompose naturally. Tree girdling involves removing a strip of bark around a tree's trunk in order to inhibit growth (De Schepper and Steppe 2011). This option proposes cutting all mature female sycamore maple and all European beech within the riparian corridor in order to stop the spread of non-natives. Seedlings will be manually removed during the early spring when the soil is moist ("Sycamore Maple") once every two years. Trees falling in between these two categories (approximately 2-6 inches DBH) will be girdled, in order to maintain canopy cover and habitat for ecosystem health (De Schepper and Steppe 2011). Each individual will be cut with two 3-inch bands completely encircling the stem, six or more inches apart (Smallidge and Nyland 2009), during the spring ("Norway Maple" 2004). Tree girdling acts as a phased approach to tree removal, as it can take years for a tree to perish from girdling ("Norway Maple" 2004). However, the method is not 100% guaranteed to kill the tree; the tree stump may also re-sprout if untreated, so stumps will be treated with glyphosate (Burch and Zedaker 2003). This option would be implemented within city limits as well as downstream, late in the growing season when chances of re-sprouting are lower (De Schepper and Steppe 2011). This option is the best for removing the seed source while maintaining the health of the ecosystem. It is also a less labor-intensive option for removing trees, as it is the only option not requiring the complete removal of trees from the forest, but instead leaving them as snags and logs for rebuilding habitat.

Table 2. Management plan option details. Focus areas listed include landscaped trees (L), riparian corridor within city limits (R), and/or downstream riparian corridor (D). Removal methods are stratified by tree size: seedling, sapling (immature tree up to 3 inches DBH for sycamore maple, 7 centimeters for European beech), or mature (including mature trees within riparian corridor, and landscaped trees). SYMA represents sycamore maple, and EUBE represents European beech.

Option	**Goal**	**Focus Area**	**Removal Method, Herbicide**			**Replant**	**Relative Cost**	**Key Citations**
			seedling	**sapling**	**mature**			
1: Remove landscaped trees	remove seed source	L, R	Sprayed 1x/year in spring	-	Cut, apply glyphosate every 10 years	yes	low	Binggeli 1992; Hein, et. al 2009; "Platanus Occidentalis" 1990; Szymura, et al. 2010, Fichtner, et al. 2012; Smallidge and Nyland 2009
2: Remove seeds of SYMA and EUBE only	remove seed source, maintain aesthetics	R	Cut and apply herbicide every 2 years	Cut, apply herbicide once	-	yes	low	"Platanus Occidentalis" 1990; Burch and Zedaker 2003; Smallidge and Nyland 2009
3: Ecosystem Health	gradually limit spread of non-natives, ecosystem health	R, D	Cut and apply glyphosate 1x/year	-	-	yes	medium	Smallidge and Nyland 2009; Burch and Zedaker 2003; Nesom 2002; Nakamura et al. 2008
4: Girdle	remove seed source quickly while maintaining ecosystem health	R, D	Manually remove every 2 years in spring	Girdle, apply glyphosate	Cut female SYMA and all EUBE, apply glyphosate in late spring	yes	medium	De Schepper and Steppe 2011; Smallidge and Nyland 2009; "Sycamore Maple"; "Norway Maple" 2004; Burch and Zedaker 2003

VI. Recommendation and Conclusion

Based on the goals of Seattle City Light, we propose option 4 for addressing the concerns of controlling the spread of the sycamore maple and European beech, working towards eradicating those species within the riparian corridor, and promoting the long-term restoration of native plant associations. This option features the removal of mature sycamore maple and European beech within the riparian corridor in town and downstream to remove the seed source and control the spread of those species, as well as periodic maintenance of non-native seedlings. Tree girdling of saplings allows for continuing habitat and canopy cover for animal and plant species in the riparian corridor, as tree girdling takes much longer to fell a tree than traditional cut-and-remove methods featured in other management options. By addressing every life history stage of the target species and applying herbicide at every step, team ENSC 15.2 believes option 4 is the best management plan for Seattle City Light to implement along the Skagit River in and around Newhalem.

VI. References

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Appendix A: Annotated Bibliography

1. General Seed Dispersal

Gómez-Aparicio, Lorena, Jose M. Gómez, and Regino Zamora. "Spatiotemporal Patterns of Seed Dispersal in a Wind-dispersed Mediterranean Tree (Acer Opalus Subsp. Granatense): Implications for Regeneration." *Ecography* 30.1 (2007): 13-22. Web.

The authors studied seed dispersal of the rare Mediterranean tree over a two-year period in Sierra Nevada and Sierra de Baza stony slope and forested areas by placing seed traps at set distances away from the mother tree. They found that seed dispersal distances had a mean of 2-4 meters in every study area, with a maximum distance of 7-12.5 meters. In this study, seed limitation was almost completely due to dispersal limitation; in other words, an already forested area inhibited the success of a new sapling growing from a seed, rather than mother trees not producing adequate seed numbers. Seed mass was unrelated to dispersal distance. However, source height did increase seed dispersal distance; with this in mind, trees to focus on in Newhalem might be the tallest individuals first.

Imbert, Eric, and Francois Lefevre. "Dispersal and Gene Flow Of Populus Nigra (Salicaceae) Along A Dynamic River System." *Journal of Ecology* 91.3 (2003): 447-456. Web.

This study was conducted with the Black poplar (*Populus nigra* L.) in the riparian zone along the Drome River in France. This species in particular is known to utilize both wind and the river for seed dispersal. By tracking the gene flow along the riparian zone, the authors found that gene flow was not asymmetrical; in other words, seed dispersal occurred both in the downstream direction as expected, as well as upstream. It is important to note that this species produces seeds in catkins, dissimilar from the European beech, which are much heavier and therefore are not as easily dispersed by wind. This study did suggest a strong correlation between upstream and downstream populations, meaning that rivers are a very valid means of seed dispersal.

Squirrell, Jane. "Sycamore, *Acer pseudoplatanus* Fact Sheet." NNSS GB non-native species secretariat (2012). Department for Environment Food & Rural Affairs. Web 5 Apr. 2015.

The government agency posted this sheet to help inform the public of invasion, ecology, and impact of Sycamore maple. The dispersal mechanism allows its seeds to reach distances from 30 to 80 meters. But in high wind storms seeds may be dispersed up to several kilometers. This species is considered to support fewer herbivorous insects, and is prone to Sooty Bark Disease, which may cause pneumonia to humans. Forestry commission in Scotland put an estimated cost of removal of £ 300 per hectare, double the cost of standard tree thinning.

2. Maple Species

2.1 *Acer pseudoplatanus*

Helliwell, D.R., and A.F. Harrison. "Effects of Light and Weed Competition on the Growth of Seedlings of Four Tree Species on a Range of Soils." Quarterly Journal of Forestry (1979): 160-71. Google Scholar. Web. 19 Feb. 2015.

The growth of sycamore maple seedlings was studied by planting individuals over two seasons, on five different soils, under a range of light intensities, with and without competition from weeds. Over the two year period, seedlings showed a smaller increase in dry weight over the range of light intensities employed than did either birch or larch species. This is expected since sycamore maple seedlings are shade tolerant, and thus are relatively unaffected by light intensity. The height growth maximum of the sycamore maple seedlings occurred at 43% light intensity rather than at the maximum light intensity of 82%. While this study indicates that sycamore seedlings are able to germinate and establish under deep shade, canopy opening is required if they are to are to advance to the canopy layer.

Morecroft, Michael D., Victoria J. Stokes, Michele E. Taylor, and James I.L Morison. "Effects of Climate and Management History on the Distribution and Growth of Sycamore (*Acer pseudoplatanus* L.) in a Southern British Woodland in Comparison to Native Competitors." *Forestry* 81.1 (2008): 59-74. Web. 19 Feb. 2015.

This article compares the variability of growth, photosynthesis, and phenology of sycamore maple and ash, a species with invasive characteristics similar to that of sycamore maple. Between 1993 and 2005, the mean diameter growth as well as the height growth was lower in sycamore than in ash. Sycamore maple did not produce significantly more seeds than the ash nor did it colonize a greater area than the ash in that time. There was no evidence given that sycamore maple was out performing ash, either among mature trees or seedlings, meaning that species with similar traits could out-compete sycamore maple in Newhalem. Furthermore, the growth of sycamore maple was the smallest in the driest year. Conversely, the growth was greatest during the years with the greatest rainfall, indicating that the sycamore maple is less drought resistant than the ash. Increased frequency of droughts could inhibit the growth of sycamore maple.

Hazandy, Abdul-Hamid, and Mencuccini Maurizio. "Age- and Size-Related Changes In Physiological Characteristics and Chemical Composition of *Acer pseudoplatanus* and *Fraxinus excelsior* Trees." *Tree Physiology* 29.1 (2009): 27-38. Web.

This study was conducted at Cramond, Almond Valley, west of Edinburgh. The authors found that a Sycamore maple is mature at about 5.2 years, with a DBH of 2 cm. Ages were determined by bud scars on the stem surface, or through tree coring.

Hein, Sebastian, Catherine Collet, Christian Ammer, Noel Le Goff, Jens Peter Skovsgaard, and Peter Savill. "A Review of Growth and Stand Dynamics of *Acer pseudoplatanus* L. in Europe: Implications for Silviculture." *Forestry* 82.4 (2009): 361-85. Institute of Chartered Foresters. Web. 19 Feb. 2015.

Although the primary purpose of this article is to better understand Sycamore maple for silvicultural purposes, it provides a great comprehensive review of the life history and growth of *Acer pseudoplatanus* L.

Pigot, Alex L., and Simon R. Leather. "Invertebrate Predators Drive Distance-dependent Patterns of Seedling Mortality in a Temperate Tree *Acer pseudoplatanus*." *Oikos* 117 (2008): 521-30. Web. 19 Feb. 2015.

This article investigates the patterns of seedling mortality for Sycamore maple to better understand the dynamics of Sycamore invasion and to inform appropriate strategies for its management. Sycamore seedling mortality has been identified as the limiting stage in Sycamore recruitment due to a variety of known factors such as light availability, soil moisture levels, soil compactness, and herbivory. In this study, the majority of newly emerged seedlings died during weeks 2 and 3, and nearest to the landscaped tree. By manipulating predator access to seedlings, this study demonstrated that invertebrates, in particular slugs, were responsible for generating the distance-and biomass-dependent patterns of recruitment rather than the factors such as light availability, soil moisture levels, soil compactness, and vertebrate herbivory.

2.2 *Acer rubrum*

Snell, Rebecca S. "Simulating Long-distance Seed Dispersal in a Dynamic Vegetation Model." *Global Ecology and Biogeography* 23.1 (2014): 89-98. Web.

This study, involving the Red maple (*Acer rubrum*), found that the early maturation of maples results in the quick spread of the species. The age of maturation for this species of Maple is 8 years, and the reported migration rate for the genus *Acer* is 80-200 meters per year.

2.3 *Acer platanoides*

Martin, Patrick H., and Charles D. Canham. "Dispersal and Recruitment Limitation in Native versus Exotic Tree Species: Life-History Strategies and Janzen-Connell Effects." *Oikos* 119 (2010): 807-24. Web. 19 Feb. 2015.

This article discusses the life history traits of invasive and native trees in the northeastern United States. Shade-tolerant *Acer platanoides* produce seeds at a relatively low DBH (7.9 cm) and has a rapid growth rate in comparison to native species. A 30cm DBH *Acer platanoides* was estimated to have produced over 26350 seedlings less than 3 years old. This combination along with the high fecundity of *Acer platanoides* allows for the species to invade forest understories even though its mean seed dispersal distance and seed production is comparable to native species. Most importantly, this article confirms that secondary dispersal and post-dispersal seed predation can significantly alter the shape and pattern of dispersed seeds.

Webb, Sara L., and Pendergast IV, Thomas H., and Dwyer, Marc E. "Response of Native and Exotic Maple Seedling Banks to Removal of the Exotic, Invasive Norway Maple (*Acer platanoides*)." *Journal of the Torrey Botanical Society.* Vol. 128, No. 2, pp. 141-149, (Apr. - Jun., 2001). Web. 2, Feb. 2015.

This article discusses the successes and failures of seed and mature tree removal of Norway maple over a two year period. Trees over 1.5m tall were removed, showing that the removal of the exotic species caused an increase in the native species seedling densities, as well as a decrease in *Acer platanoides* recruitment. However, the study also found that removal of seedlings less than 1.5m allowed for the new arrival of far more *Acer platanoides* than *Acer saccharum* seedlings. Another key point from this article was that even though removal of the tree canopy was a better restoration method, complete canopy removal allowed exotic species to become more prevalent. The article went into discussion saying that to properly eliminate the exotic species, both removal of the tree canopy and continual removal of seedlings is necessary for successful eradication.

Reinhart, Kurt O., Erick Greene, and Ragan M. Callaway. "Effects of Acer Platanoides Invasion On Understory Plant Communities and Tree Regeneration In The Northern Rocky Mountains." *Ecography* 28.5 (2005): 573-582. Web.

This study was conducted on the Norway maple in a riparian zone in Missoula, Montana. The authors investigated the question of whether this non-native species is increasing local biodiversity, or choking out native species and thus decreasing biodiversity. They found that the Norway maple does out-compete local riparian tree species, and encourages the growth of conspecifics. This may be due to the shade produced by the species, in that useful sunlight was reduced 95% under Norway maple canopies, and that seedlings are incredibly shade-tolerant unlike native species in the study site as well as in Newhalem. Therefore, the Norway maple is a key species to look after in our study.

Meiners, Scott J. Seed and Seedling Ecology of Acer *saccharum* and Acer *platanoides*: A Contrast between Native and Exotic Congeners. *Northeastern Naturalist.* Vol. 12, No. 1, pp. 23-32, (2005). Web. 25, Jan. 2015.

This article compares seed predation and growth rates of two maple species: Acer saccharum (sugar maple, native to the northeastern United States) and Acer platanoides (Norway maple, native to Europe). This study found that the successful colonization of Acer platanoides is positively correlated to seed mass. The biomass of seeds affects the dispersal distance and pattern of Acer platanoides more so than growth rates. Additionally, Acer platanoides are less likely to be preyed upon by native predators than Acer saccharum, thus contributing to its spread and proliferation in native forests.

Gómez-Aparicio, Lorena, Charles D. Canham, and Patrick H. Martin. "Neighbourhood Models of the Effects of The Invasive Acer *platanoides* On Tree Seedling Dynamics: Linking Impacts on Communities and Ecosystems." *Journal Of Ecology* 96.1 (2008): 78-90. *Academic Search Complete*. Web. 8 Apr. 2015.

The objective of this study was to analyze the impacts of *Acer platanoides* trees on survival and growth of conspecific and native tree seedlings and to analyze the impacts of *Acer platanoides* on ecosystem processes, specifically on soil resources and light levels. The highly significant correlations between seedling relative height and DBH and soil resources suggested that growth of *Acer platanoides* could be the consequence of an increase in soil fertility caused by the invader. The differences in use of soil resources were the cause of the species-specific responses observed in the study rather than light intensity. The invasion of forests by *Acer platanoides* can drastically change the native forest composition. Furthermore, the invasion of *Acer platanoides* may benefit the native species that are more competitive under nutrient-rich conditions.

Reinhart, Kurt O., and Rachel VandeVoort. "Effect of Native and Exotic Leaf Litter on Macroinvertebrate Communities And Decomposition In A Western Montana Stream." Diversity & Distributions 12.6 (2006): 776-781. Academic Search Complete. Web. 8 Apr. 2015.

Decompostition rates and invertebrate assemblages associated with leaf litter of the non-native *Acer platanoides* and the dominant native *Populus trichocarpa tres* were studied in the riparian habitat along Clark River near Missoula, Montana. The amount of leaf litter as well as the macroinvertebrate community varied depending on the leaf species. Although there was no effect of leaf species on taxon richness, evenness, and diversity, the most common family of predatory macroinvertebrates (Rhyacophilidae) as well as stonefly and caddisfly populations was significantly different among non-native and native leaf species. Changes in their densities are likely to have cascading effects on higher trophic levels (i.e. predatory invertebrates and vertebrates). Furthermore, exotic trees that invade riparian habitats may have an effect that is broadcasted away from the points of invasion to downstream locations.

Wangen, Steven R., and Christopher R. Webster. "Potential for Multiple Lag Phases during Biotic Invasions: Reconstructing an Invasion of the Exotic Tree Acer platanoides." Journal of Applied Ecology 43 (2006): 258-68. JSTOR. Web. 3 Apr. 2015.

This article discusses the long establishment phase and the possibility of multiple lag phases during the expansion phase of *Acer platanoides* invading relatively undisturbed forest ecosystems. Lag phases as well as dispersal pathways can impact the spread of the species. Canopy gaps close to landscaped tree populations or probable long-distance dispersal sites may be an important determinant of lag behavior because it influences the time needed for individuals to reach reproductive maturity. The study found that road corridors appear to facilitate the dispersal of this species at least in forested landscapes by acting as a wind tunnel. This could pertain to the spread of non-native species along the powerline row section in Newhalem that is adjacent to the road. This study also cites that *Acer platanoides* usually does not produce viable seeds until 25– 30 years of age.

3. European Beech

Millerón, M., U. Lopez De Heredia, Z. Lorenzo, J. Alonso, A. Dounavi, L. Gil, and N. Nanos. "Assessment of Spatial Discordance of Primary and Effective Seed Dispersal of European Beech (*Fagus sylvatica* L.) by Ecological and Genetic Methods." *Molecular Ecology* 22 (2013): 1531-545. Web.

This study examines the direct versus indirect methods of dispersal, ie. wind and gravity, versus animal-carried spread of seeds. The indirect dispersal distance for European beech is estimated to be 30-40 meters from the landscaped tree. On average, a seed travels only 6.5-11 meters due to primary dispersal, according to this study. These results take into consideration only wind and gravity, not water, so they cannot be applied to our study, in which this species utilizes the river as a means of seed dispersal. This study also suggests that birds play a key role in increasing seed dispersal distance.

Szymura, Tomasz H., Marta Buszczak, and Magdalena Szymura. "Structure and Dynamics Of A Mature Tree Stand In Submontane Alluvial Forest Of Carici Ramotae-Fraxinetum In The Sudety Mts Foothills (Lower Silesia, Poland)." Dendrobiology 63 (2010): 43-51. Web.

Although there is no literature available detailing the DBH of a mature European beech individual, there are multiple studies that only measured individuals of this species if they were greater than 7 cm. Therefore, a similar method to account for trees might be used in Newhalem.

Fichtner, A., et al. "Competition Response of European Beech *Fagus sylvatica* L. Varies With Tree Size and Abiotic Stress: Minimizing Anthropogenic Disturbances In Forests." Journal of Applied Ecology 49.6 (2012): 1306-1315. Web.

Another source which used >7cm to classify European beech individuals.

4. Girdling

Zarnoch, Stanley J, Mark A. Vukovich, John C. Kilgo, and John I. Blake. "Snag Characteristics And Dynamics Following Natural And Artificially Induced Mortality in a Managed Loblolly Pine Forest." Canadian Journal of Forest Research 43.9 (2013): 817-825.

This study focused on loblolly pine stands in South Carolina. They researched three treatments: trees thinned and removed (keeping consistent canopy cover), trees felled and not removed (leaving woody debris), and artificial snags produced by girdling trees and injecting herbicide. The artificial snags lived longer than natural snags, possibly due to natural snags beginning to decay before falling.

De Schepper, Veerle, and Kathy Steppe. "Tree Girdling Responses Simulated By A Water and Carbon Transport Model." Annals of Botany 108.6 (2011): 1147-1154.

This paper articulates the vast uses of girdling, as well as explains exactly what girdling is. Tree girdling is the removal of a strip of bark around a tree's trunk. It can be used to study a tree's xylem or phloem flow, to examine the wood's hydraulic properties, bark regeneration, and more. Girdling also leads to improved fruit growth, decrease in photosynthesis, increase in starch and sugars in the foliage, and promote stem growth above the cut (and inhibit stem growth below). This demonstrates the importance of applying herbicide after girdling, so as to kill the tree slowly, instead of promoting its growth.

Annighofer, Peter, Peter Schall, Heike Kawaletz, Inga Molder, Andre Terwei, Stefan Zerbe, and Christian Ammer. "Vegetative Growth Response of Black Cherry (Prunus serotina) to Different Mechanical Control Methods in a Biosphere Reserve." Canadian Journal of Forest Research 42.12 (2012): 2037-2051.

This of the four treatment plans (control, felling to industry standards, snapping at 80 cm height, and 20-25 cm girdle at 80 cm height), girdling was the most effective mechanical control method. Re-sprouting occurs in the species studied, and results showed that 100% of felled trees re-sprouted, even if they were treated with an herbicide. Given that Norway and Sycamore maple species both re-sprout, this article suggests that girdling may be part of the best mitigation plan. The article also mentions that height of felling can increase the chance of successfully killing the individual, and cutting closer to the ground increases chance of tree survival. Girdling might be most successful late in the growing season, as opposed to early in the spring when chances of re-sprouting are highest.

5. Clear Cut and Selective Cut

Hartley, Damon S., and Han-Sup Han. "Effects of Alternative Silvicultural Treatments on Cable Harvesting Productivity and Cost in Western Washington." ***Western Journal of Applied Forestry*** **22.3 (2007): 204-12. Web.**

This article notes the benefits and drawbacks of four types of forest management methods in the Pacific Northwest: clear-cut, two-age, patch cut and thin, and group selection. The study found that clearcutting is the most cost-effective and time-efficient, because there are no trees left standing to work around. Overall, the more care required in the management process, the more costly and time-consuming the method proved to be. The article notes cost and time estimates, which can be used in our study. Although it was written from a forestry point of view, the methods will be very similar if implemented in Newhalem.

Halpern, Charles B., and Thomas A. Spies. "Plant Species Diversity in Natural and Managed Forests of the Pacific Northwest." ***Ecological Applications*** **5.4 (1995): 913. Web.**

This article suggests that clear-cut Douglas-fir forests in the Pacific Northwest eventually recover to natural ecosystems, despite initial invasion of non-native plants. It suggests silvicultural practices that promote diverse spatial and temporal conditions foster the greatest species diversity during the recovery period. It is most important to allow old-growth aspects to come back before removing trees in a selective-cut situation.

Jerabkova, Lucie, Cindy E. Prescott, Brian D. Titus, Graeme D. Hope, and Michael B. Walters. "A Meta-analysis of the Effects of Clearcut and Variable-retention Harvesting on Soil Nitrogen Fluxes in Boreal and Temperate Forests." ***Canadian Journal of Forest Research*** **41.9 (2011): 1852-870. Web.**

This study found that clear-cutting a forest significantly increases soil nitrogen. Further, selectively-cut forestry leads to a much lower increase in soil nitrogen. Coniferous forests take over five years to re-equilibrate to pre-disturbance nitrogen levels. Additionally, needle litter remains on the forest floor in clear-cut forests longer than in undisturbed spaces; leaf litter decomposed faster than in undisturbed forest. Nitrogen content in soil directly relates to the recovery time for a forest after disturbance, and therefore will be an important factor when replanting the riparian zone in Newhalem.

Cameron, Donald S., Donald J. Leopold, and Dudley J. Raynal. "Effect of Landscape Position on Plant Diversity and Richness on Electric Transmission Rights-of-way in New York State."***Canadian Journal of Botany*** **75.2 (1997): 242-51. Web.**

Non-native trees growing in a power line row, much like in Newhalem, have the potential to increase species diversity, or lower it as non-natives choke out native species. This study found that power line rows are more susceptible to invasion. They found changing control methods (switching between selective- and clear-cut, for example) leads to even greater species diversity in power line rows, which could be negative in Newhalem. This article suggests for our study that we should consider more seriously the risk of invasion of non-native trees into the power line row.

Moser, W. K., et al. Impacts of Nonnative Invasive Species on US Forests and Recommendations for Policy and Management. ***Journal of Forestry*** **107.6, pp 320-7 (2009).** ***ProQuest.*** **Web. 17 Feb. 2015.**

This article addresses the implications of using proper control methods to effectively remove invasive species. The effects of invasive on forest composition, structure, productivity, and patterns of carbon sequestration can have detrimental effects. The article gives examples of tree diseases and infestations of pests due to non-native species. The only way to properly address the problem is through, listed in order of importance, education and awareness, expanding early detection and active management efforts, improving inventory and monitoring efforts, increasing forest health curriculum, and increasing cross-agency collaboration and support investment in agency resources. If the problem is not properly addressed we could see tremendous adverse impacts on commercial and urban forest resources.

6. Pesticides

Swearingen, J., and Slattery B., and Reshetiloff K., and Zwicker S. Plant Invaders of Mid-Atlantic Natural Areas, 4th ed. *National Park Service and U.S. Fish and Wildlife Service* (2010). Washington, DC. 168pp. Web. 2 Feb. 2015

This source discussed the potential pesticides (Triclopyr amine, Glyphosate, Imazapyr) used for controlling the growth of trees and invasive plants in the Mid-Atlantic region of the United States. Application methods such as the basal bark method, cut stem method, hack-squirt/inject method, and the foliar method were noted. In addition, the report identified the hazards associated with applying pesticides and suggested applying dye to pesticides to ensure precise application to the targeted species.

Burch, Patrick L., and Shepard M. Zedaker. "Removing the Invasive Tree *Ailanthus altissima* and Restoring Natural Cover." *Journal of Arboriculture* 29.1 (2003): 18-24. Web. 6 Feb. 2015.

In this study, eight herbicides were applied to *Ailanthus altissima* (Tree of Heaven) using the basal bark method: spraying the entire circumference of the stem, ensuring the chemical enters underground storage organs wholly and slowly. Manual cutting was used as an alternative control method. Manual cutting stimulated re-sprouting and increased overall stand density, whereas chemical control removed existing trees and also prevented re-sprouting. This experiment proved that herbicide control is more effective than manual control because it prevents the proliferation of pests.

Rosen, Nancy. Omaha, NE 21, May 2012. http://www.prweb.com/pdfdownload/9524136.pdf PrWeb e-books. EZ-Ject Inc. Web. 13, Feb. 2015

The EZ-Ject is an herbicide applicator that uses a long rod attached to an injector that uses gravity to inject poison or other applications with relative ease into the base or stump of invasive trees. This application process is cost effective and has little effect on surrounding habitat.

7. Other Considerations

Mallik, A. U. "Conifer Regeneration Problems in Boreal and Temperate Forests with Ericaceous Understory: Role of Disturbance, Seedbed Limitation, and Keystone Species Change." *Critical Reviews in Plant Sciences* 22.3-4 (2003): 341-66. Web.

This article suggests that vegetative understory may outcompete native trees in a conifer forest. Specifically, ericaceous understory can easily spread into selectively-cut or clear-cut spaces, when the trees are unable to reproduce (when they require fire to spread their seeds). The implications of this are that understory control may be a necessary component of site remediation in Newhalem, more intensive than the ivy control that already happens there.

Löf, Magnus, Daniel C. Dey, Rafael M. Navarro, and Douglass F. Jacobs. "Mechanical Site Preparation for Forest Restoration." *New Forests* 43.5-6 (2012): 825-48. Web.

This literature synthesis examines the impact of mechanical site preparation on conifer seedling survival in replanted forests. Successful re-forestry requires improvement of soil conditions, and control of competing vegetation (especially non-native species) and animal damage. Herbicides are the favored method to control growth of unwanted plants. Mechanical site preparation (including scarification, mounding, sub-soiling of the soil) often requires big machinery, and thus is best suited for clear-cut, as opposed to selectively cut, areas.

Liu, Shuang, Terry Walshe, Graham Long, and David Cook. "Evaluation of Potential Responses to Invasive Non-Native Species With Structured Decision Making." *Conservation Biology* 26.3 (2012): 539-546. Web.

This article is useful twofold: first, the authors discuss a "do nothing" approach to invasive species management; second, the authors outline their decision-making process, which our group can follow in our own development of remediation plans. In the "do nothing" scenario, it is assumed the invasive species (Australian myrtle rust) cannot be controlled. This plan results in the lowest action required of any plan. Other plans were live-with-it (mitigate the effects of invasion, which in Newhalem might look like replanting native trees that were outcompeted), slow-the-spread (through intensive surveillance of infected area borders), partial eradication, and full eradication. This article highlights the consequences of each management plan, as well as the effectiveness of their decision-making model.

Johnson, R, et al. "What are the best seed sources for ecosystem restoration on BLM and USFS lands?" Native plants. USDA NRCS. (2010)

This article discusses how genetic diversity can be maintained in the northwest through preserving and planting seeds of native tree species. Genetic variation within a tree species is important to decrease susceptibility to environmental stress or change; this importance increases with elevation. Lost genetic diversity cannot be recreated, thus it is important to preserve pre-adapted genotypes for restoration purposes. This can be done through the creation of a "tree farm." Seed sources should be selected close to site to ensure optimal performance; in Newhalem, seeds can be taken from the native forest across the river, as these are already adapted to the microclimate of Newhalem.

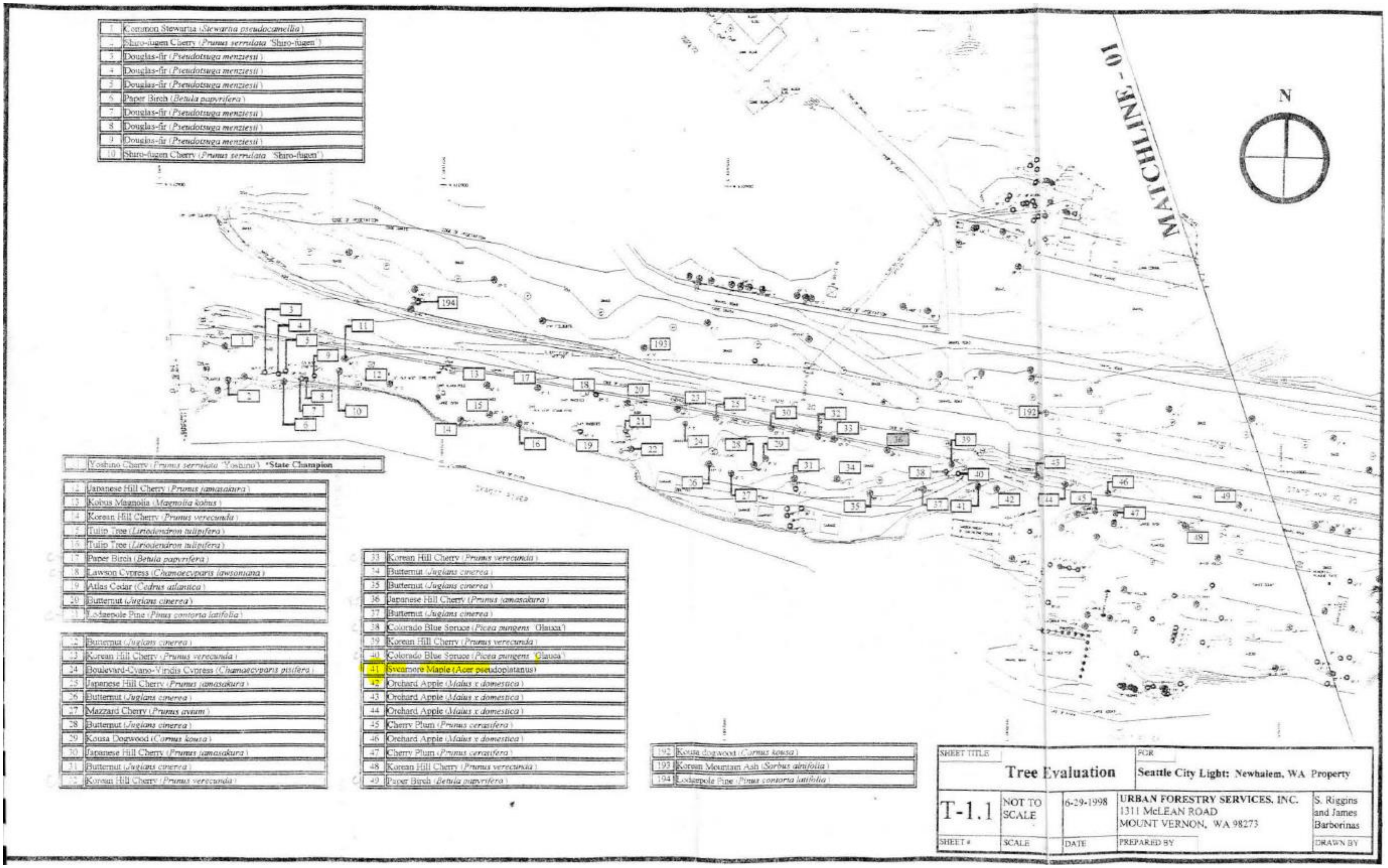
Binggeli, Pierre. "A Taxonomic, Biogeographical and Ecological Overview of Invasive Woody Plants." Journal of Vegetation Science 7.1 (1996): 121-24. JSTOR. Web. 3 Apr. 2015.

This article provides a clear definition for an invasive woody plant as well as categorizes the invasive potential of a variety of woody plants. Although this article does not discuss maple species, it does mention that the relative importance of wind-dispersed species decreases with the degree of invasiveness. Furthermore, this article discusses that forests, both disturbed and undisturbed, appear to be the natural habitats most susceptible to invasions by woody plants.

Bostan, C., et al. "Spread Species Ailanthus Altissima In New Areal And Impacts On Biodiversity." *Research Journal Of Agricultural Science* 46.1 (2014): 104-108. *Academic Search Complete*. Web. 8 Apr. 2015.

This study focuses on the consequences associated with the spread of the invasive tree *Ailanthus altissima* (tree of heaven) in native forests throughout Romania. *Ailanthus altissima* and other common non-native species have become more prevalent as a result of anthropogenic activity. In 2008, an initial estimate assessed costs generated by invasive species in Europe 9600-12700 million per year. Although *Ailanthus altissima* is not a target species in Newhalem, this article is a good reference that discusses the cost associated with controlling invasive species.

Appendix B: 1998 Arborist Report Map



1	Common Stewartia (*Stewartia pseudocamellia*)
2	Shiro-fugen Cherry (*Prunus serrulata* 'Shiro-fugen')
3	Douglas-fir (*Pseudotsuga menziesii*)
4	Douglas-fir (*Pseudotsuga menziesii*)
5	Douglas-fir (*Pseudotsuga menziesii*)
6	Paper Birch (*Betula papyrifera*)
7	Douglas-fir (*Pseudotsuga menziesii*)
8	Douglas-fir (*Pseudotsuga menziesii*)
9	Douglas-fir (*Pseudotsuga menziesii*)
10	Shiro-fugen Cherry (*Prunus serrulata* 'Shiro-fugen')

11	Yoshino Cherry (*Prunus serrulata* 'Yoshino') ***State Champion**

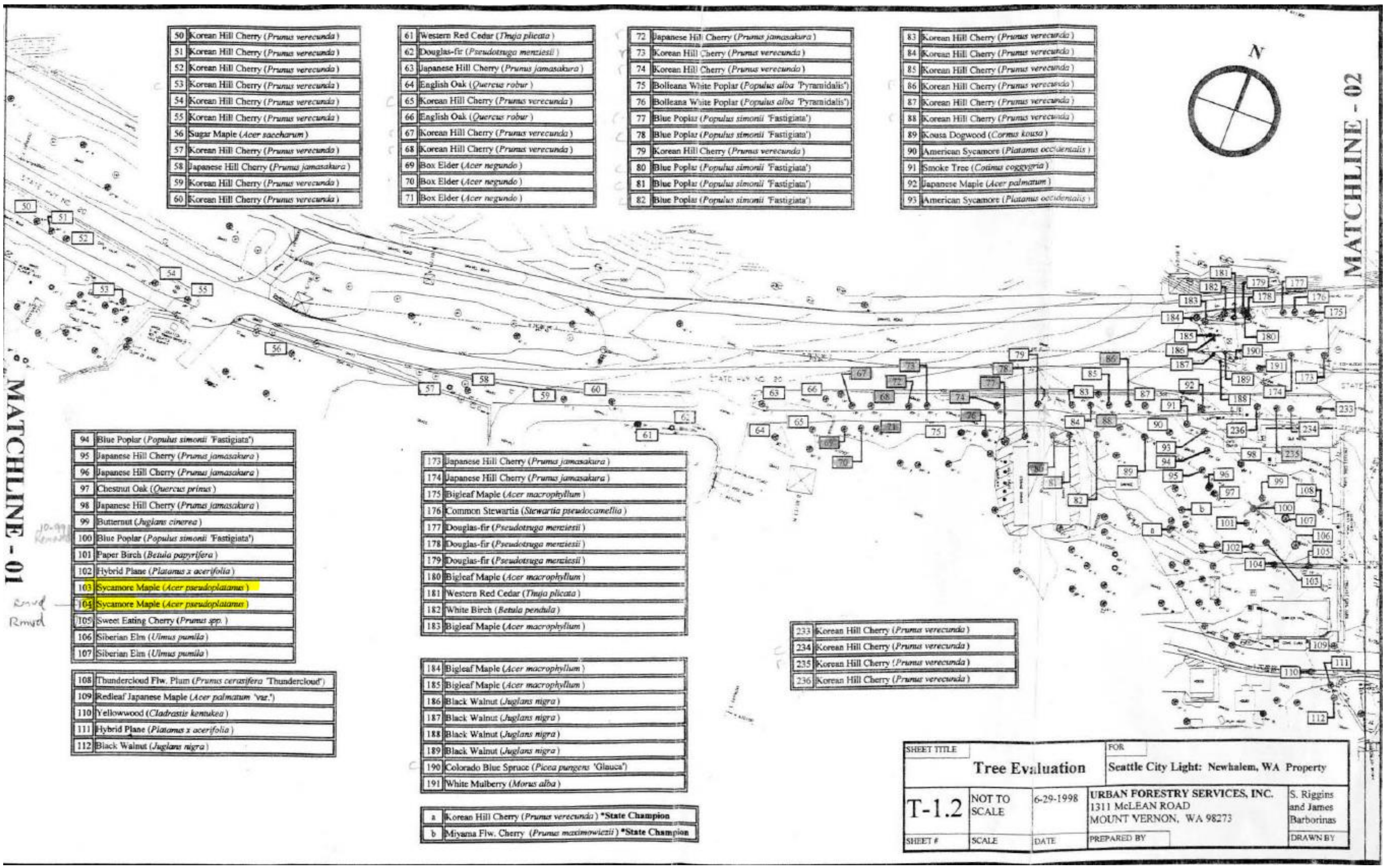
12	Japanese Hill Cherry (*Prunus jamasakura*)
13	Kobus Magnolia (*Magnolia kobus*)
14	Korean Hill Cherry (*Prunus verecunda*)
15	Tulip Tree (*Liriodendron tulipifera*)
16	Tulip Tree (*Liriodendron tulipifera*)
17	Paper Birch (*Betula papyrifera*)
18	Lawson Cypress (*Chamaecyparis lawsoniana*)
19	Atlas Cedar (*Cedrus atlantica*)
20	Butternut (*Juglans cinerea*)
21	Lodgepole Pine (*Pinus contorta latifolia*)

22	Butternut (*Juglans cinerea*)
23	Korean Hill Cherry (*Prunus verecunda*)
24	Boulevard-Cyano-Viridis Cypress (*Chamaecyparis pisifera*)
25	Japanese Hill Cherry (*Prunus jamasakura*)
26	Butternut (*Juglans cinerea*)
27	Mazzard Cherry (*Prunus avium*)
28	Butternut (*Juglans cinerea*)
29	Kousa Dogwood (*Cornus kousa*)
30	Japanese Hill Cherry (*Prunus jamasakura*)
31	Butternut (*Juglans cinerea*)
32	Korean Hill Cherry (*Prunus verecunda*)

33	Korean Hill Cherry (*Prunus verecunda*)
34	Butternut (*Juglans cinerea*)
35	Butternut (*Juglans cinerea*)
36	Japanese Hill Cherry (*Prunus jamasakura*)
37	Butternut (*Juglans cinerea*)
38	Colorado Blue Spruce (*Picea pungens* 'Glauca')
39	Korean Hill Cherry (*Prunus verecunda*)
40	Colorado Blue Spruce (*Picea pungens* 'Glauca')
41	Sycamore Maple (Acer pseudoplatanus)
42	Orchard Apple (*Malus x domestica*)
43	Orchard Apple (*Malus x domestica*)
44	Orchard Apple (*Malus x domestica*)
45	Cherry Plum (*Prunus cerasifera*)
46	Orchard Apple (*Malus x domestica*)
47	Cherry Plum (*Prunus cerasifera*)
48	Korean Hill Cherry (*Prunus verecunda*)
49	Paper Birch (*Betula papyrifera*)

192	Kousa dogwood (*Cornus kousa*)
193	Korean Mountain Ash (*Sorbus alnifolia*)
194	Lodgepole Pine (*Pinus contorta latifolia*)

SHEET TITLE			FOR	
Tree Evaluation			Seattle City Light: Newhalem, WA Property	
T-1.1	NOT TO SCALE	6-29-1998	URBAN FORESTRY SERVICES, INC. 1311 McLEAN ROAD MOUNT VERNON, WA 98273	S. Riggins and James Barborinas
SHEET #	SCALE	DATE	PREPARED BY	DRAWN BY


MATCHLINE - 01
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50 Korean Hill Cherry (Prunus verecunda)
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54 Korean Hill Cherry (Prunus verecunda)
55 Korean Hill Cherry (Prunus verecunda)
56 Sugar Maple (Acer saccharum)
57 Korean Hill Cherry (Prunus verecunda)
58 Japanese Hill Cherry (Prunus jamasakura)
59 Korean Hill Cherry (Prunus verecunda)
60 Korean Hill Cherry (Prunus verecunda)
61 Western Red Cedar (Thuja plicata)
62 Douglas-fir (Pseudotsuga menziesii)
63 Japanese Hill Cherry (Prunus jamasakura)
64 English Oak (Quercus robur)
65 Korean Hill Cherry (Prunus verecunda)
66 English Oak (Quercus robur)
67 Korean Hill Cherry (Prunus verecunda)
68 Korean Hill Cherry (Prunus verecunda)
69 Box Elder (Acer negundo)
70 Box Elder (Acer negundo)
71 Box Elder (Acer negundo)
72 Japanese Hill Cherry (Prunus jamasakura)
73 Korean Hill Cherry (Prunus verecunda)
74 Korean Hill Cherry (Prunus verecunda)
75 Bolleana White Poplar (Populus alba 'Pyramidalis')
76 Bolleana White Poplar (Populus alba 'Pyramidalis')
77 Blue Poplar (Populus simonii 'Fastigiata')
78 Blue Poplar (Populus simonii 'Fastigiata')
79 Korean Hill Cherry (Prunus verecunda)
80 Blue Poplar (Populus simonii 'Fastigiata')
81 Blue Poplar (Populus simonii 'Fastigiata')
82 Blue Poplar (Populus simonii 'Fastigiata')
83 Korean Hill Cherry (Prunus verecunda)
84 Korean Hill Cherry (Prunus verecunda)
85 Korean Hill Cherry (Prunus verecunda)
86 Korean Hill Cherry (Prunus verecunda)
87 Korean Hill Cherry (Prunus verecunda)
88 Korean Hill Cherry (Prunus verecunda)
89 Kousa Dogwood (Cornus kousa)
90 American Sycamore (Platanus occidentalis)
91 Smoke Tree (Cotinus coggygria)
92 Japanese Maple (Acer palmatum)
93 American Sycamore (Platanus occidentalis)
94 Blue Poplar (Populus simonii 'Fastigiata')
95 Japanese Hill Cherry (Prunus jamasakura)
96 Japanese Hill Cherry (Prunus jamasakura)
97 Chestnut Oak (Quercus prinus)
98 Japanese Hill Cherry (Prunus jamasakura)
99 Butternut (Juglans cinerea)
100 Blue Poplar (Populus simonii 'Fastigiata')
101 Paper Birch (Betula papyrifera)
102 Hybrid Plane (Platanus x acerifolia)
103 Sycamore Maple (Acer pseudoplatanus)
104 Sycamore Maple (Acer pseudoplatanus)
105 Sweet Eating Cherry (Prunus spp.)
106 Siberian Elm (Ulmus pumila)
107 Siberian Elm (Ulmus pumila)
108 Thundercloud Flw. Plum (Prunus cerasifera 'Thundercloud')
109 Redleaf Japanese Maple (Acer palmatum 'var.')
110 Yellowwood (Cladrastis kentukea)
111 Hybrid Plane (Platanus x acerifolia)
112 Black Walnut (Juglans nigra)
173 Japanese Hill Cherry (Prunus jamasakura)
174 Japanese Hill Cherry (Prunus jamasakura)
175 Bigleaf Maple (Acer macrophyllum)
176 Common Stewartia (Stewartia pseudocamellia)
177 Douglas-fir (Pseudotsuga menziesii)
178 Douglas-fir (Pseudotsuga menziesii)
179 Douglas-fir (Pseudotsuga menziesii)
180 Bigleaf Maple (Acer macrophyllum)
181 Western Red Cedar (Thuja plicata)
182 White Birch (Betula pendula)
183 Bigleaf Maple (Acer macrophyllum)
184 Bigleaf Maple (Acer macrophyllum)
185 Bigleaf Maple (Acer macrophyllum)
186 Black Walnut (Juglans nigra)
187 Black Walnut (Juglans nigra)
188 Black Walnut (Juglans nigra)
189 Black Walnut (Juglans nigra)
190 Colorado Blue Spruce (Picea pungens 'Glauca')
191 White Mulberry (Morus alba)
a Korean Hill Cherry (Prunus verecunda) *State Champion
b Miyama Flw. Cherry (Prunus maximowiczii) *State Champion
233 Korean Hill Cherry (Prunus verecunda)
234 Korean Hill Cherry (Prunus verecunda)
235 Korean Hill Cherry (Prunus verecunda)
236 Korean Hill Cherry (Prunus verecunda)
SHEET TITLE
Tree Evaluation
FOR
Seattle City Light: Newhalem, WA Property
T-1.2
NOT TO SCALE
6-29-1998
URBAN FORESTRY SERVICES, INC.
1311 McLEAN ROAD
MOUNT VERNON, WA 98273
S. Riggins and James Barborinas
SHEET #
SCALE
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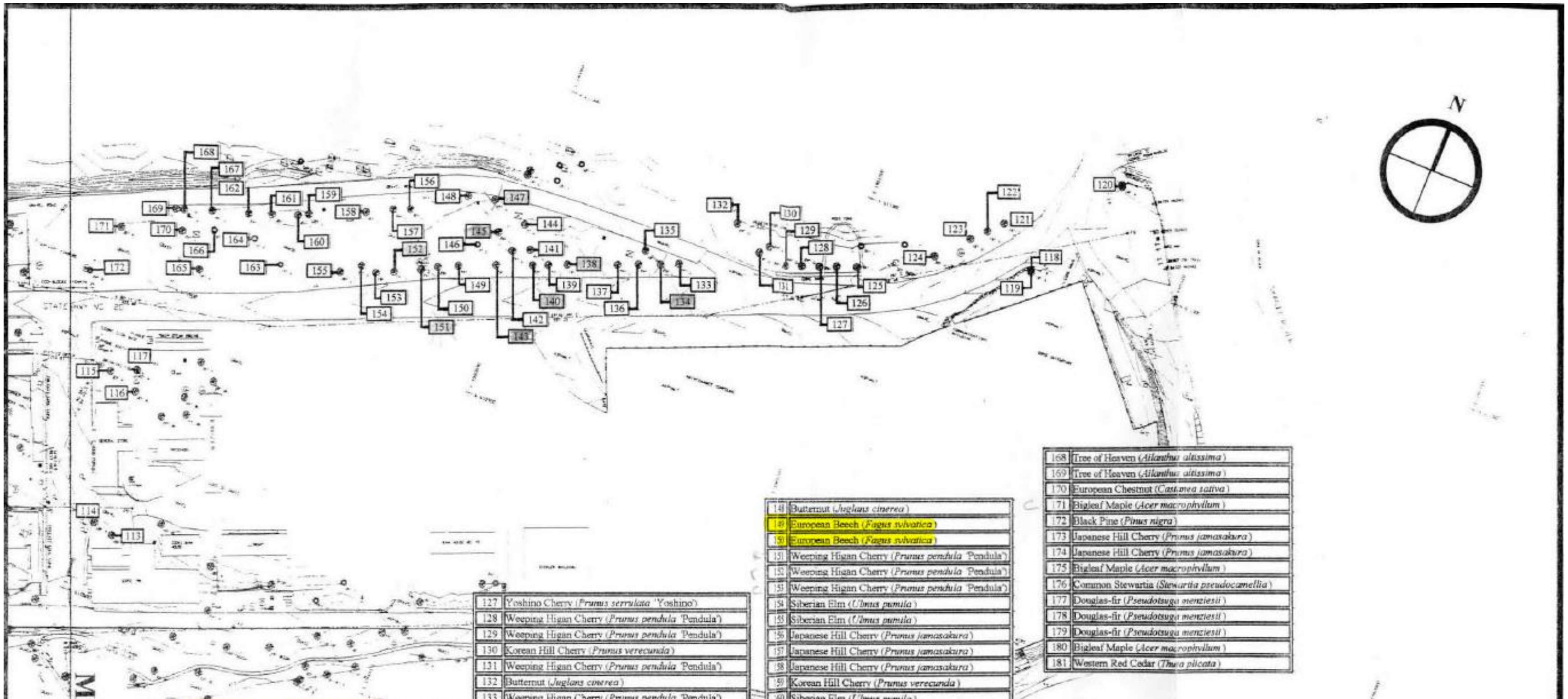


113	Sycamore Maple (*Acer pseudoplatanus*)
114	Sycamore Maple (*Acer pseudoplatanus*)
115	Sycamore Maple (*Acer pseudoplatanus*)
116	Sycamore Maple (*Acer pseudoplatanus*)
117	Sycamore Maple (*Acer pseudoplatanus*)
118	Paper Birch (*Betula papyrifera*)
119	Paper Birch (*Betula papyrifera*)
120	Bigleaf maple (*Acer macrophyllum*)
121	Weeping Higan Cherry (*Prunus pendula* 'Pendula')
122	Weeping Higan Cherry (*Prunus pendula* 'Pendula')
121	Weeping Higan Cherry (*Prunus pendula* 'Pendula')
122	Weeping Higan Cherry (*Prunus pendula* 'Pendula')
123	Yoshino Cherry (*Prunus serrulata* 'Yoshino')
126	Yoshino Cherry (*Prunus serrulata* 'Yoshino')

127	Yoshino Cherry (*Prunus serrulata* 'Yoshino')
128	Weeping Higan Cherry (*Prunus pendula* 'Pendula')
129	Weeping Higan Cherry (*Prunus pendula* 'Pendula')
130	Korean Hill Cherry (*Prunus verecunda*)
131	Weeping Higan Cherry (*Prunus pendula* 'Pendula')
132	Butternut (*Juglans cinerea*)
133	Weeping Higan Cherry (*Prunus pendula* 'Pendula')
134	Weeping Higan Cherry (*Prunus pendula* 'Pendula')
135	Black Walnut (*Juglans nigra*)
136	Weeping Higan Cherry (*Prunus pendula* 'Pendula')
137	European Beech (*Fagus sylvatica*)
138	Weeping Higan Cherry (*Prunus pendula* 'Pendula')
139	European Beech (*Fagus sylvatica*)
140	Weeping Higan Cherry (*Prunus pendula* 'Pendula')
141	Korean Hill Cherry (*Prunus verecunda*)
142	Black Walnut (*Juglans nigra*)
143	Weeping Higan Cherry (*Prunus pendula* 'Pendula')
144	Copper Beech (*Fagus sylvatica f. purpurea*)
145	Japanese Hill Cherry (*Prunus jamasakura*)
146	Noble Fir (Abies procera)
147	Butternut (*Juglans cinerea*)

148	Butternut (*Juglans cinerea*)
149	European Beech (*Fagus sylvatica*)
150	European Beech (*Fagus sylvatica*)
151	Weeping Higan Cherry (*Prunus pendula* 'Pendula')
152	Weeping Higan Cherry (*Prunus pendula* 'Pendula')
153	Weeping Higan Cherry (*Prunus pendula* 'Pendula')
154	Siberian Elm (*Ulmus pumila*)
155	Siberian Elm (*Ulmus pumila*)
156	Japanese Hill Cherry (*Prunus jamasakura*)
157	Japanese Hill Cherry (*Prunus jamasakura*)
158	Japanese Hill Cherry (*Prunus jamasakura*)
159	Korean Hill Cherry (*Prunus verecunda*)
160	Siberian Elm (*Ulmus pumila*)
161	Siberian Elm (*Ulmus pumila*)
162	Siberian Elm (*Ulmus pumila*)
163	Alaska Cedar (*Chamaecyparis nootkatensis*)
164	Concolor Fir (*Abies concolor*)
165	Saucer Magnolia (*Magnolia xSoulangeana*)
166	Noble Fir (*Abies procera*)
167	European Chestnut (*Castanea sativa*)

168	Tree of Heaven (*Ailanthus altissima*)
169	Tree of Heaven (*Ailanthus altissima*)
170	European Chestnut (*Castanea sativa*)
171	Bigleaf Maple (*Acer macrophyllum*)
172	Black Pine (*Pinus nigra*)
173	Japanese Hill Cherry (*Prunus jamasakura*)
174	Japanese Hill Cherry (*Prunus jamasakura*)
175	Bigleaf Maple (*Acer macrophyllum*)
176	Common Stewartia (*Stewartia pseudocamellia*)
177	Douglas-fir (*Pseudotsuga menziesii*)
178	Douglas-fir (*Pseudotsuga menziesii*)
179	Douglas-fir (*Pseudotsuga menziesii*)
180	Bigleaf Maple (*Acer macrophyllum*)
181	Western Red Cedar (*Thuja plicata*)

SHEET TITLE			FOR	
Tree Evaluation			**Seattle City Light: Newhalem, WA Property**	
T-1.3	NOT TO SCALE	6-29-1998	**URBAN FORESTRY SERVICES, INC.** 1311 McLEAN ROAD MOUNT VERNON, WA 98273	S. Riggins and James Barborinas
SHEET #	SCALE	DATE	PREPARED BY	DRAWN BY

Appendix C: Sycamore Maple Identification Guide

Binggeli, P. (1992) Patterns of invasion of sycamore (*Acer pseudoplatanus* L.) in relation to species and ecosystem attributes. D.Phil. thesis, The University of Ulster.

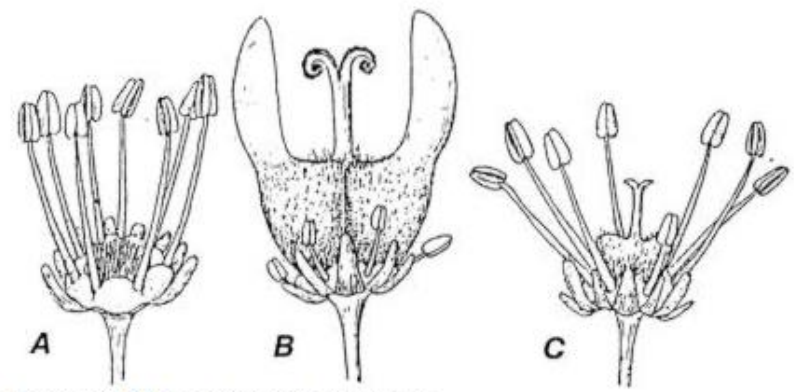
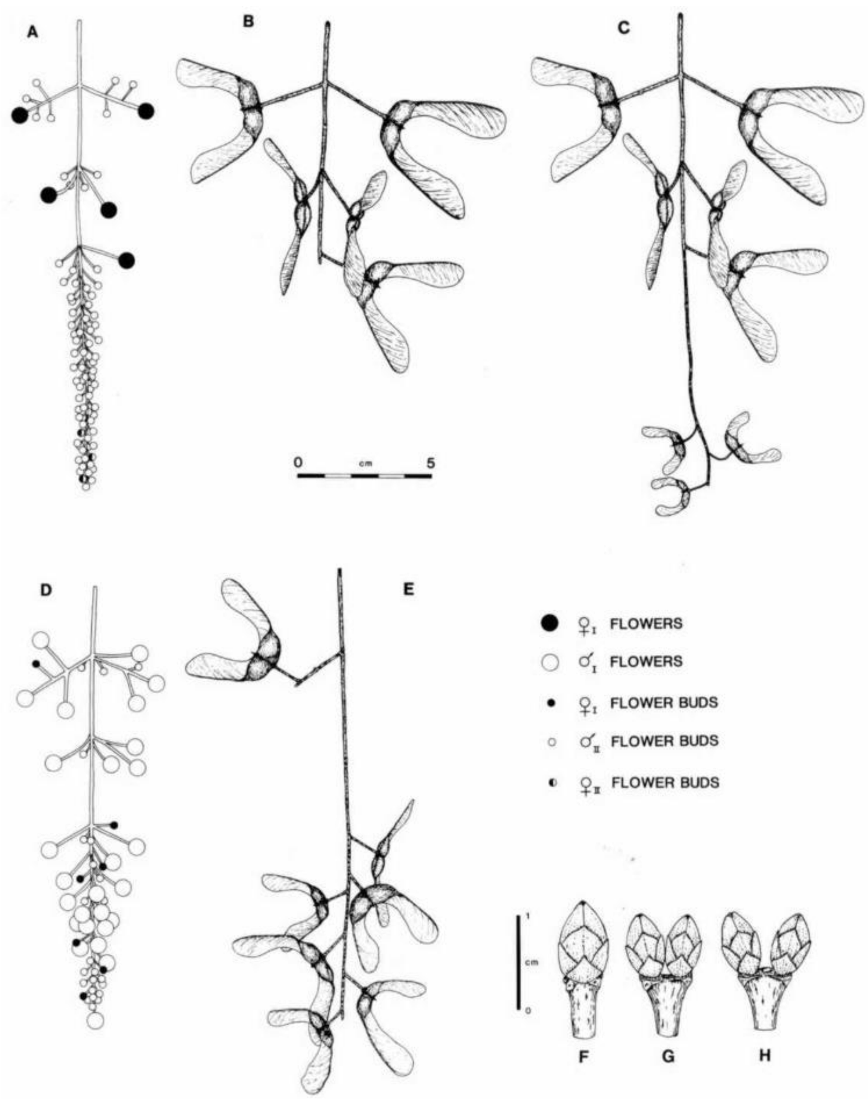


Figure 1. Flower types in sycamore.
A. ♂I flowers: morphologically and functionally male,
B. ♀I flowers: morphologically hermaphrodite but functionally female,
C. ♂II flowers: morphologically hermaphrodite but functionally male (drawings from de Jong 1976.)

Figure 2. Modes of sex expression observed on sycamore inflorescences in the north of Ireland (modes of sex expression after Wittrock 1886).

Figure 1. Architectural differences between protandrous and protogynous inflorescences and infructescences (see Table 1 for other diagnostic features) and shoot morphology after leaf and infructescence fall in Sycamore.
A. Protogynous inflorescence (♀ II flowers of Mode G are ♂ II in Mode B).
B. Protogynous infructescence, Mode B.
C. Protogynous infructescence, Mode G.
D. Protandrous inflorescence.
E. Protandrous infructescence.
F. Vegetative shoot,
G. Flowering shoot (Mode E).
H. Fruiting shoot (Flowering Modes B,C,D & G).



Appendix D: Request for Proposal

SCIENCE AND ENGINEERING PROJECT
CENTER MASTER PROJECT AGREEMENT

EXHIBIT A: COMMITMENT AND SCOPE OF PROJECT AGREEMENT

This agreement is entered into by and between Seattle University, a Washington nonprofit corporation ("SU"), and the undersigned ("Sponsor").

1. Scope of Project. SU and Sponsor agree that the following Project will be jointly supervised by an SU faculty member and the Sponsor Liaison.

Sponsor Name: Seattle City Light

Sponsor Address: 700 5th Ave Suite 3200
Seattle, WA 98104

Sponsor Liaison: Scott Luchessa
Colleen McShane

Project Title: Identifying and Mapping Non-Native Trees Near Newhalem, WA

Project Description:

This project seeks to identify the trees along the riparian corridor along a 1500m stretch near the town of Newhalem, WA on the Upper Skagit River. The purpose of identifying the trees is to identify the non-native trees and create a GIS map of the area. The diameter at breast height (DBH) of the non-native trees will be measured to determine the age, in order to know how many trees have reached sexual maturity. The potential impacts of the non-native trees will be determined through an extensive literature review and a list of possible remediation actions with a cost benefit analysis will be created.

Project Term: October 2014-June 2015

2. Commitment

Sponsor hereby commits the amount of $_______ to the Science and Engineering Project Center of Seattle University, for use in connection with the Project defined in Section 1. This fee will be paid in accordance with one of the following selected payment schedules:

______1) In three payments:
Payment One: $__________ by ______________
Payment Two: $_________ by _______________
Payment Three: $___________ by _______________

______2) In two Payments:
Payment One: $___________ by _____________
Payment Two: $___________ by ______________

______3) In one lump sum of $_________ by______________

SPONSOR	SEATTLE UNIVERSITY
Sponsor Name: _____________________	
By: _______________________________	By: ____________________________
Title: _____________________________	Title: __________________________
Date: _____________________________	Date: ___________________________

Checks payable to: Seattle University

Mail checks to: Attn:

Science and Engineering Project Center
Seattle University
901 12th Ave
PO Box 222000
Seattle, WA 98122

Appendix E: Student Resumes

Aaron Cleborne

2112 N 54^{th} St. Apt. #9, Seattle, WA, 98103
cleborne@seattleu.edu
(360) 941-1508

SUMMARY OF QUALIFICATIONS

- Experience with salmon restoration and water budget calculations
- Strong work ethic and the ability to succeed no matter the difficulties
- Punctual and well organized allows me to stay up on tasks and access available information when needed

EDUCATION

Seattle University, Seattle, WA — Dec. 2013—Present

Bachelor of Science in Environmental Science, Minor in Environmental Engineering

- Geographic Information System (GIS), developing skills in mapping, spatial analysis, displaying vector and raster data
  -Undergraduate project entailing the relationship of salmon hatcheries and point-source pollution sites and how these contribute to limits in genetic diversity
- Environmental Law and Impact, brief cases and better understanding how conflicts get resolved
- Water Resources, develop water budgets and water calculations to properly address inventory.
  -Project entailing the compare and contrast of the Cedar River urban watershed, showing peak flow and annual discharge over time

Whatcom Community College, Bellingham, WA — Sept. 2011-June 2013

Associate's Degree in Arts and Sciences

WORK EXPERIENCE

York Neighborhood Association, Bellingham, WA — Jan. 2012—Aug. 2012

Volunteer

- Public park restoration, planting native plants, drainage, and manual labor
- Established a community pea garden
- Worked closely with the community to properly provide for their needs as well as protecting native ecosystem within the neighborhood

Cascade Cuts, Bellingham, WA (360) 671-6310 — Jan. 2012—Oct. 2012

Horticulturist and Farm Laborer/Landscaper

- Obtained my agriculture safety card with dealing with pesticides
- This greenhouse uses environmentally responsible manners, Self-sustainable greenhouse
  -Beneficial insects, soil recycle

Issacson Farm, Bellingham, WA (360) 671-5300 — July 2011—Oct. 2013

- Self-Sustainable Farm

COMPUTER SKILLS

- Adept knowledge in Google Maps, Microsoft Word , PowerPoint, Excel, SPSS, and Arc GIS

Polly Lentz

lentzp@seattleu.edu
(206) 947-6323

SUMMARY OF QUALIFICATIONS

- Punctual, organized, with a strong and enthusiastic work ethic
- Diverse background in lab and field work relevant to environmental science
- Strong experience with project management and demonstrated interpersonal skills

EDUCATION

Seattle University, Seattle, WA — September 2011—June 2015

Bachelor of Science in Environmental Science, minor in Biology

- Udall Foundation scholarship honorable mention, 2014
- Dean's List, College of Science and Engineering, Winter and Fall 2012, Fall 2014, Winter 2015
- Relevant coursework includes environmental engineering, conservation biology, general and aquatic ecology, plant taxonomy, field methods, statistics, environmental law, water quality monitoring, general and organic chemistry with labs, green engineering, grant writing

WORK EXPERIENCE

ReNUWIt Urban Water ERC, New Mexico State University — June 2013—August 2013

Research Intern

- Examined growth effects and groundwater contamination resulting from the irrigation of Bermudagrass using treated effluent water during the establishment phase of growth
- Conducted individual and team field and lab research, gave presentations, and wrote a report on the study to be published

Center for Environmental Justice at Seattle University, Seattle, WA — April 2013—January 2014

Lab Assistant

- Tested COD, BOD, dissolved oxygen, nitrogen, and pH of effluent water from the Bullitt Center's on-site wetland water treatment system to meet Department of Health standards

Pacific Science Center, Seattle, WA — June 2014—Present

Early Childhood Educator, Summer Camps Teacher, Interpretive Science Educator

- Taught groups of up to 20 children ages 3-12 a range of science topics including biology, engineering, chemistry, and physics
- Engaged enthusiastically with students and participants while also practicing classroom management and conflict resolution
- Assisted with daily museum operations by working in varying floor positions, demonstrating flexibility and initiative

College of Science and Engineering at Seattle University, Seattle, WA — September 2013—June 2015

Peer Mentor

- Counseled STEM students on the academic and social adjustments required to excel through regular meetings, skill-building, and problem-solving

SKILLS

- Mastery of Microsoft programs (Word, PowerPoint, Excel), Google programs, SPSS and R Studio
- Relevant field methods include tree coring, plant identification, stream water sampling

Katie Stick

1402 E Alder, Seattle, WA, 98226
stickk@seattleu.edu
(360) 305-2015

SUMMARY OF QUALIFICATIONS

- Experience with project management and strong interpersonal skills
- Knowledge of field methods and data analysis
- Ability to think critically and multi task

EDUCATION

Seattle University, Seattle, WA — Sept. 2011—Present

Bachelor of Science in Environmental Science, Minor in Spanish — **3.59 GPA**

- Presidential scholarship recipient
- Dean's list of College of Science and Engineering
- Coursework includes organic chemistry, quantitative analysis, statistics, ecology, geology, environmental law, environmental engineering, and field methods

PROJECT/FIELD EXPERIENCE

Seattle University and Minnesota Department of Natural Resources — August 2013

- Intensive field research of jumping spiders in Midwest Minnesota
- Assisted in collecting and identifying species in the field

Engineers without Borders, Chang Mai, Thailand — December 2014

- Participated in a site assessment and water monitoring trip to rural villages

WORK EXPERIENCE

Puget Consumer Cooperative, Seattle, WA — May 2014—Oct. 2014

Courtesy Clerk

- Educated customers about natural foods, sustainable agriculture, and nutrition

Seattle Tilth, Seattle, WA — March 2011—June, 2013

Youth Mentor

- Mentored at-risk and homeless youth in an agricultural employment program
- Assisted with planting, harvesting, and overall garden maintenance

Washington Middle School, Seattle, WA — Jan. 2012—March 2012

Waste Crusaders Leader

- Created and led an afterschool compost program for middle school students
- Organized project structure and produced long term goals

SKILLS

- Proficient in GIS, Microsoft Word, Powerpoint, Excel, and SPSS
- Proficient in Spanish (writing and conversation)