Spanning the Gaps: Integrating Site, Stakeholders, and Context to Enhance Vegetation Management at Seattle City Light

Dylan Marcus

A thesis
submitted in partial fulfillment of the
requirements for the degrees of

Master of Landscape Architecture
Master of Urban Planning

University of Washington
2020

Committee:
Ken Yocom (Co-chair)
Bob Freitag (Co-chair)

Programs authorized to offer degrees:
College of Built Environments

Abstract

Spanning the Gaps: Integrating Site, Stakeholders, and Context to Enhance Vegetation Management at Seattle City Light

Dylan Marcus

Committee:

Ken Yocom (Co-chair)
Department of Landscape Architecture

Bob Freitag (Co-chair)
Department of Urban Design and Planning

Management of vegetation on transmission line right of ways depends on a multitude of factors. Vegetation managemrs must respond not only to the physical parameters of a site - such as topography and line height - but also they must maintain good relationships with easement property owners and other stakeholders throughout the length of a transmission corridor. Socio-ecological context surrounding a transmission right of way further complicates the situation, as a range of habitats and human uses may occur beneath a utility's transmission lines. Seattle City Light owns and manages many miles of transmission right of ways within Seattle and leading up to the Skagit Hydroelectric Project in the North Cascades. Vegetation managers at the large public utility implement management strategies that respond to the many stakeholders along City Light's transmission corridors. This thesis explores the latest efforts of Seattle City Light to maximize multi-functionality on the transmission right of way while minimizing long term monetary and non-monetary costs. A series of case studies - viewed from the perspective of a Seattle City Light intern - spanning the urban-to-rural gradient illustrate the array of stakeholders City Light hopes to engage to initiate collaborative vegetation management strategies. Conclusions are drawn by way of reflection on the case studies investigated, and recommendations are made for future efforts in vegetation management at Seattle City Light.

Acknowledgements

First and foremost, I would like to thank my advisors, Bob Freitag and Ken Yocom. They have provided essential guidance throughout a tumultuous year, and were always willing to take time out of their day to discuss aspects of my project (regardless of how much or little sense I might have made at the time).

I would also like to thank everyone at Seattle City Light who exposed me to this field of study, and provided me with much-appreciated flexibility as a student intern. My experience working with members of the Environment, Land, and Licensing Business Unit; the Vegetation Management Division; and the Engineering Division was invaluable.

Members of the Sauk-Suiattle Tribe of Indians and Stillaguamish Tribe of Indians have taken the time to meet remotely and in-person with representatives of Seattle City Light to express their thoughts, priorities, concerns, and hopes relating to right of way management. I would like to thank them for their continued openness and input.

My fellow students in Landscape Architecture and Urban Planning cannot go unnoticed, as I learned as much from them as I have from any course I have ever taken.

Finally, I would like to acknowledge the endless support and positive encouragement provided by my brother and parents, who are always there when I need them. And, of course, thank you Allison, for keeping me fed, confident, and [reasonably] well-rested.

Contents

List of Tables

List of Figures

Abbreviations

CA = Corridor A

CB = Corridor B

CC = Corridor C

City Light = Seattle City Light

DNR = Washington Department of Natural Resources

EJI = Seattle Environmental Justice Initiative

ELLBU = Environment, Land, and Licensing Business Unit (within Seattle City Light)

EPA = United States Environmental Protection Agency

ESRI = Environmental Systems Research Institute

GIS = Geographic Information System(s)

GPS = Global Positioning System

I5 = United States Interstate 5

IPM = Integrated Pest Management

IVM = Integrated Vegetation Management

LiDAR = Light Detection and Ranging

MWBZ = Modified Wire Border Zone

ORV = Off-road vehicle

ROW = Right of way

RSJI = Seattle Race and Social Justice Initiative

SCL = Seattle City Light

SPI = Sierra Pacific Industries

SR530 = Washington State Route 530

SSIT = Sauk-Suiattle Indian Tribe

USFS = United States Forest Service

VMCS = Vegetation Management Compliance System

VMD = Vegetation Management Division (within Seattle City Light)

WBZ = Wire Border Zone

WCC = Washington Conservation Corp

Abandoned vehicle near Spearhead Lake
Photo Credit: Dylan Marcus

Introduction

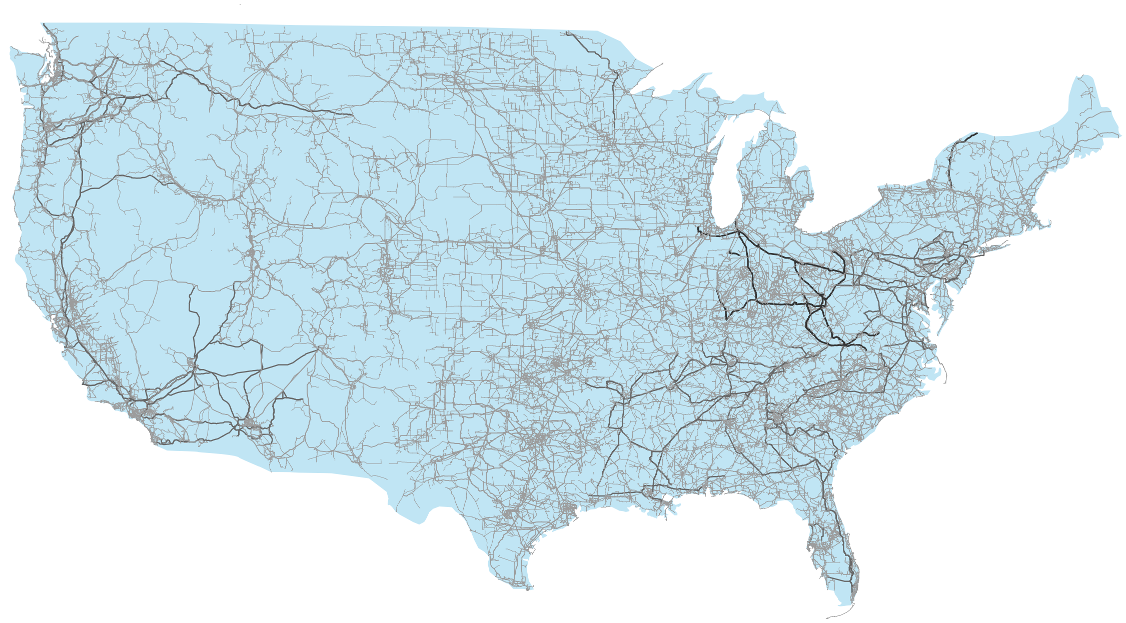
It is difficult to ignore the vehicles shown above: two of them looked like they were dropped from the sky, but for the black remnants of an explosion on the ground that flipped them over. The last car is a half mile north of the others, parked next to a transmission tower and gradually stripped of its wheels, doors, and anything usable, then used for target practice. The right of way on which the cars lie is near Darrington, Washington and is owned by Seattle City Light, which is Seattle's electric utility. I've visited this site and many others as an intern for the utility over the past year, and in that time alone have witnessed changes in the transmission right of way landscape - such as the arrival and continued demolition of abandoned vehicles, or other milder signs of human use like trash or shotgun shells. An expansive network of roads and trails have made this area attractive for motorized recreation, foraging, shooting, and general revelry for decades. While Seattle City Light ("City Light" or SCL) requires some access for maintenance of transmission towers and vegetation, the cumulative use of the land by the public is clearly depleting functionality in this remote and wooded context.

SCL's transmission right of way (ROW) in the southern part of Seattle tells a different story: the ROW passes through industrial, residential, and commercial zones of the city, and it boasts a 4-mile-long multi-use recreation path, multiple community gardens, and areas undergoing restoration planting or mowing efforts to cultivate functional greenspace and opportunities for community engagement. Multi-modal transportation and recreation, stormwater management, heat island mitigation, food, and habitat are all products of ROW management and use here. Additionally, organizations like The Common Acre and EarthCorps coordinate with SCL to steward the land to maximize that same functionality, building social and ecological capital simultaneously. The uses and functions exhibited in the transmission ROW examples above represent two extremes from a single electric utility, but the socio-ecological conditions traversed just by City Light's transmission lines make the right of way condition more variable yet.

Transmission lines are a key component of the electric grid throughout the United States (see Figure 1) and the world, carrying electricity from generating sources – frequently found in rural settings – to population centers, where it can be bought and consumed by residential and commercial customers. Safe, uninterrupted delivery of electricity requires continuous maintenance of transmission ROWs after their routing and construction. In this case "maintenance" primarily means cyclical management of ROW vegetation. Management of transmission line ROW vegetation has been a mainstay for electric utilities since the proliferation of electricity in the late 1800s and early 1900s (Nowak, n.d.).

The methods employed by ROW vegetation managers have evolved along with technology, and their list of objectives has shifted as well: safety and delivery of electricity are still the main purpose of the infrastructure, but utility industry professionals are increasingly focused on the capacity of transmission ROWs to provide ecological and social benefits as well. As a result, compatible ROW vegetation does not just refer to low- or slow-growing plants: compatible ROW vegetation refers to the plant community that is both low-growing and functional for wildlife, insects, and humans alike. To maximize multi-functionality, vegetation managers must cater their approach to the surrounding landscape and the ROW itself: community gardens and lowland prairies may be a compatible and beneficial use of ROW area in South Seattle, but they are neither ecologically suitable

Figure 1. Transmission lines throughout the United States



The above map is solely for diagrammatic purposes. Thicker, darker lines represent transmission lines carrying higher voltrages of electricity, thereby necessitating a wider right of way.

nor are they functional on remote and rural ROWs surrounded by working forests, agriculture, and rural communities.

The City of Seattle – of which SCL is a department – has been recognized nationally and internationally for its commitment to the environment and social justice, a commitment that is acted on across all city departments through an urban forestry program, the Race and Social Justice Initiative, the Environmental Equity Initiative, and other city-wide efforts (Initiatives, Referenda, & Charter Amendments Guides - CityClerk | Seattle.Gov, n.d.). Infrastructure improvements to manage stormwater and to cultivate habitat corridors using roadside ROWs in Seattle are a model for other cities. Programs like RainWise have made such improvements more accessible to underserved communities (RainWise | 700 Million Gallons | Rebates For Rain Gardens & Cisterns, n.d.). While the COVID-19 pandemic has refocused the attention of planners and designers on the multi-functionality of roadway ROWs, professionals in Seattle have worked to accommodate and encourage multi-funcitonal ROW design and use for many years.

Transmission ROW corridors, however, are not primarily located within Seattle, nor have they been a focal point for planners and designers. Consequently, the objectives of these city initiatives must be translated into a framework that is geared specifically towards transmission ROW management. More attention must be paid to the design and management of the linear landscapes transmission lines create. City Light's Vegetation Management Division (VMD) and Environment, Land, and Licensing Business Unit (ELLBU) have identified that need, and are in the process of re-working their platforms for geospatial data collection, monitoring, and analysis to be more accessible and usable for vegetation managers and their crews. Even so, increased capacity for geospatial analysis alone does not translate directly to achieving environmental and equity goals: a new framework is needed to align the management strategies for SCL's transmission ROWs with the ecologically- and socially-oriented values of the City of Seattle as a whole.

To that end, this thesis explores how City Light can implement industry-recognized best practices for vegetation management, while at the same time fostering multi-functionality in the utility's transmission ROWs in a way that responds to the surrounding socio-ecological communities. The following central questions guide my research:

> How can spatial analysis tools be used to inform ROW planning, design, and management decisions so that they can better respond to the adjacent socio-ecological communities?
>
> What combination of technologies, approaches, vegetation controls, and metrics can be used to cultivate, monitor, and adaptively manage multi-functional spaces on City Light's transmission ROWs?

This thesis uses literature, interviews, and a series of case studies – with which I am directly involved as an intern at SCL – to demonstrate that City Light is on the cusp of a major transition into a new arena of right of way vegetation management, in which the typical 2-year cycle of cutting and mowing may be phased out for portions of the ROW. I argue that SCL's internal stakeholders – vegetation managers, engineers, ecologists, GIS analysts, archaeologists, and more – must coordinate to map socio-ecological conditions of identifiable segments of the transmission ROW. The same employees must then map and implement an array of management strategies that cultivate context-responsive functions. Doing so is especially important in areas that are under-utilized or have experienced direct negative impacts. It is not necessarily the case that every one of SCL's transmission ROWs should be growing food or managing stormwater, but none of SCL's transmission ROWs should be used primarily for illicit dumping and experimentation with explosives.

While the physical limitations imposed by transmission lines will always guide the ways in which City Light manages ROW vegetation, input from non-SCL ROW stakeholders should be significant in defining compatible uses and plant communities, especially when outside stakeholders are actively engaged with and interested in contributing to ROW vegetation management. Mapping and engagement efforts may be costly up front, and establishing more stable, diverse, and functional ROW ecosystems will be a gradual process. However, the long-term financial savings combined with the social and ecological benefits resulting from this iterative, location-specific approach outweigh the costs. Those benefits can be maximized when they are directed at ROW stakeholders, and when they are embraced utility-wide. As the case studies in this thesis from South Seattle, Darrington, and elsewhere illustrate, identifying these opportunities is possible, and capitalizing on them can help to develop long-term management strategies that benefit communities for years to come.

Finally, in addition to increasing the consideration given to ROW context and stakeholders, the impacts of site conditions on opportunities for multi-functionality were evaluated. Changing topography and transmission line height can pose both challenges and opportunities. Vegetation managers can opt to manage for one or more target heights for vegetation - the latter option requires far more in-depth analysis, but each method has its own advantages and disadvantages. By creating and iterating a height analysis workflow in some case studies, a comparison can be drawn between them and case studies that take a more unilateral approach.

Literature Review

Looking north towards Mount Higgins from Boulder River's shore on the ROW

Photo Credit: Dylan Marcus

More than "The Greenest Utility"

Lighting Seattle

Seattle has a reputation for its innovative culture, and Seattle City Light is no exception: the first electric lights west of the Rocky Mountains were turned on in Seattle as a result of efforts by Sidney Mitchell and F.H. Sparling, who worked with Thomas Edison himself. Mitchell and Sparling brought light to Seattle in 1886 through the establishment of the privately-owned Seattle Electric Light Company (The Free Online Encyclopedia of Washington State History - HistoryLink.Org, n.d.). The need for electric power rose through the turn of the century, and although the private electric utilities around the Puget Sound all expanded their operations to meet demand, the citizens of Seattle decided through a vote in 1902 to fund the construction of a publicly-owned hydroelectric dam on the Cedar River (Seattle City Light History, n.d.). The generation at Cedar Falls was supervised by the City Water Department from 1905 to 1910, at which point the continuous rise in demand for public power resulted in the creation of Seattle City Light (Seattle City Light History, n.d.).

J.D. Ross – "The Father of Seattle City Light"

James Delmage Ross – more commonly known as J.D. Ross – was a consummate innovator. Ross became superintendent of City Light in 1911 after overseeing the design and construction of the Cedar River power plant (Seattle City Light History, n.d.; The Free Online Encyclopedia of Washington State History - HistoryLink.Org, n.d.). The Skagit River Hydroelectric Project (the Skagit Project) became Ross' most notable legacy: he envisioned three dams along the fast-moving river located in the North Cascades that would provide abundant and affordable energy to residents of Seattle. Ross did not live to see the completion of the third and final dam in 1940, originally named the Ruby Dam but renamed the Ross Dam in his honor (Upper Skagit River Hydroelectric Project, n.d.). However, during his tenure Ross did oversee the construction of the Gorge and Diablo dams, the latter of which was the tallest in the world at the time of completion (Skagit Hydro Project Relicensing | North Cascades Conservation Council, n.d.).

In addition to expanding City Light's generating capacity, Ross helped to solidify the utility's status as a public entity. The Seattle Electric Light Company was formed by private investors before the City of Seattle created City Light, and was later purchased by Stone & Webster – an east coast-based energy company. Stone & Webster held permits to construct generating stations along the Skagit River before City Light did, and it was only the expiration of those permits that presented Ross with the opportunity to realize his vision for the three dams that followed. The affordable energy the dams provided made City Light more than a strong competitor against any iteration of a Stone & Webster subsidiary, and allowed Ross to easily weather being fired by a mayor suspected of being friendly with corporate interests in the electric industry (Ross, James Delmage (J. D.) (1872-1939), n.d.). That mayor was recalled for his firing of Ross, and the next mayor reinstated him as superintendent of City Light.

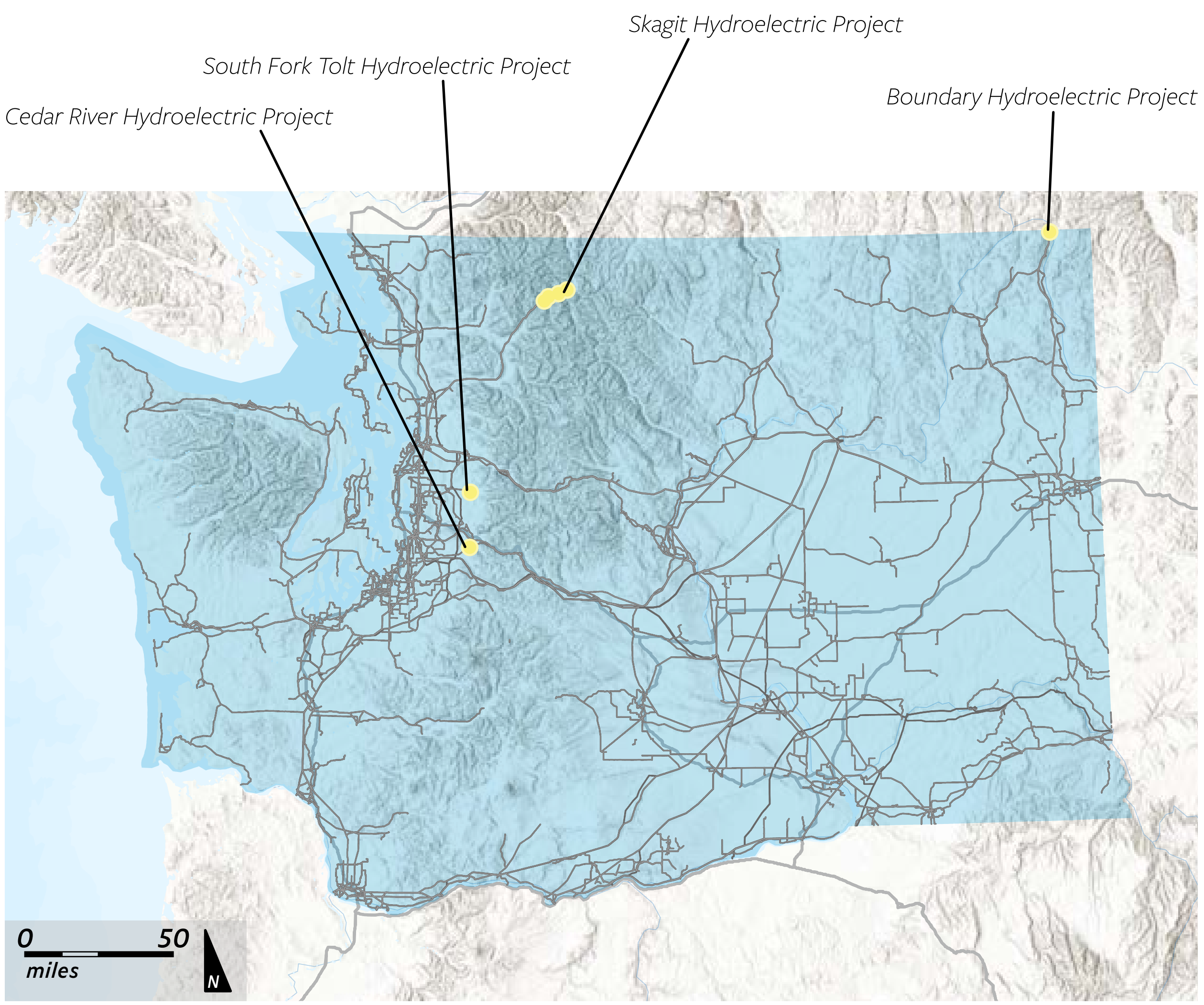
Green public power

City Light continued to compete with the Stone & Webster subsidiary Puget Power (later Puget Sound Energy) after Ross left the utility, and in 1950 Seattle residents approved a measure that allowed City Light to buy up all private utility assets within the city limits (Seattle City Light History, n.d.; Seattle Voters Approve City Light Purchase of Puget Power Assets within City Limits on November 7, 1950., n.d.). City Light's expansion via the Boundary Dam – located in northeastern Washington – has allowed the public utility to provide some of the lowest electricity rates in the United States (Seattle City Light History, n.d.). However, the provision of those rates to urbanites through large-scale modifications to remote and rural landscapes has and continues to upset conservationists and tribes in the region ('The Life-Giving Skagit Has Been Purposely Dewatered by the City of Seattle, and Why?, n.d.). City Light's desire to raise the Ross Dam in the 1970s led to enormous controversy, ending in a lengthy negotiation between City Light and multiple tribes and state and federal departments (Skagit Hydro Project Relicensing | North Cascades Conservation Council, n.d.). City Light has made significant strides in mitigating the cumulative environmental impacts of the dams, and in 1978 created a precursor to the Environment, Land, and Licensing Business Unit – or ELLBU – to monitor progress on meeting environmental goals and to manage licensing. ELLBU continues to work to implement programs and policies relating to the environment, climate change, and land management (Seattle City Light History, n.d.). Around 2010 City Light began using the moniker "The Nation's Greenest Utility" (Skagit Hydro Project Relicensing | North Cascades Conservation Council, n.d.).

Generation to consumption

Another landscape change resulting from Seattle's thirst for cheap electricity generated far from the city was the construction of miles of transmission lines – and ROWs to accommodate them. This situation is typical: producing energy in larger quantities allows for the transmission of electricity at higher voltages, which in turn reduces the total amount of energy lost through transmission (Electrical Grid | Student Energy, 2020). The locations of City Light's hydroelectric projects are shown in Figure 2. While the Boundary Project produces 35-45% of Seattle's electricity, its remote location makes it more practical for that electricity to be transmitted on lines owned by Bonneville Power Administration. Meanwhile, the Skagit Project (which produces about 20% of Seattle's electricity) and City Light's other hydroelectric operations close to Seattle (which produce a small portion of Seattle's electricity) generally use lines owned by City Light (Seattle City Light History, n.d.). Since City Light is only responsible for managing vegetation under transmission lines it owns, this thesis focuses on those sites, namely the latter area (meaning lines running west of the Cascade Mountains). One must ask: how does this public utility live up to its self-appointed position as "The Nation's Greenest Utility" regarding mitigating not only the clear impacts of its generating stations, but also the impacts stemming from the construction and maintenance of their transmission infrastructure.

Figure 2. Transmission Lines of Washington State and SCL Hydroelectric Projects



In the above map, thicker and/or darker lines represent transmission lines carrying higher voltages of electricity, thereby necessitating a wider right of way associated with them.

Cut, spray, both, or neither?

Why and how is ROW vegetation managed?

For general safety and prevention of power outages and wildfires, electric utilities must maintain vegetation that might otherwise come into contact with transmission lines. Precise prescriptions for vegetation clearances are made for electric utilities by the Federal Energy Regulatory Commission for transmission lines, and by state or local agencies for distribution lines (Gilstrap et al., 2015). Safe clearances vary – primarily depending on line voltage and site elevation – but are typically no less than eight feet (NERC Vegetation Management Standard Drafting Team, 2009). However, transmission lines are prone to both sag and sway due to air temperature, wind, span length (the distance between two transmission towers), and electric load (the amount of current travelling through the line). As a result, vegetation managers must consider all locations in which a line could be located under the most extreme conditions when maintaining vegetation (Hooper & Baily, 2004). To insure safety, and as ROWs could be inspected by regulators at any time, it is crucial that considerable buffers be maintained between vegetation and transmission lines.

Because of the distances transmission lines typically traverse, utilities must either buy land on which to route the lines, or establish agreements with public and private landowners along their line's route. Such agreements – known as right of way easements – allow the utility to access the private property for maintenance of the lines, towers, and vegetation. The exact width of a transmission ROW will vary depending on the voltage transmitted through the lines: lines carrying higher voltages require a wider ROW to provide a safe buffer zone of low vegetation surrounding the lines; lower voltage lines do not need to be as wide. City Light's transmission ROWs are managed to maintain a ROW width of approximately 100-150 feet.

Managing vegetation for such long and wide swaths of land varies in difficulty and approach depending on the context. Table 1 summarizes the most common vegetation controls used by electric utilities to manage ROW vegetation. These controls can be used in tandem or not, yielding a range of short- and long-term conditions (National Grid, 2010; NERC Vegetation Management Standard Drafting Team, 2009; Nowak et al., 1992). Manual and mechanical controls are widely employed by utilities as they offer a straight-forward, standardizable, and scalable approach that keeps vegetation at a safe distance from transmission lines. The same stigma surrounding the use of chemical controls does not apply to manual and mechanical controls in the same way (Myers et al., 2016). The widespread acceptance of mown lawns as a symbol of socio-economic status must be considered a factor in American's similar acceptance of the mechanical vegetation controls used to maintain them ("The Great American Lawn," 2019). Additionally, the thousands of acres

Table 1. Types of vegetation controls in right of way vegetation management	
Control Type	*Examples*
Biological	Beneficial predators/insects (Integrated Pest Management); compatible plant community cultivation (Integrated Vegetation Management)
Chemical	Herbicide treatment (selective or broadcast)
Cultural	Mulch/compost application; native species cultivation; weed barriers; prescribed burning
Manual/Mechanical	Mowing/brush-cutting (with tractors, mowers, or chainsaws); hand-pulling or hand-cutting; tilling

of agricultural land crossed by transmission lines across the country are largely managed through manual and mechanical means.

City Light's vegetation management approach evolved similarly to country-wide trends until the 1990s, as can be seen in Figure 3. Manual controls like hand-cutting were used early on; and chemical controls (herbicides) became widespread after World War II due to the proliferation of new chemicals and petroleum-based products (Nowak, 2020). Between the 1970s and the 1990s, though, pressure from the environmental movement pushed SCL to revert to manual and mechanical controls, as the chemical-heavy approach – referred to as "nuking" by managers familiar with the practice at the time – was indiscriminate in its application (D. Mutchler & S. Barnard, personal communication, August 6, 2020). A 2-year mow cycle has become relatively standard for much of SCL's transmission line ROWs, and herbicides are used sparingly for select invasive plant infestations (D. Mutchler et al., personal communication, October 9, 2020).

Which controls?

As the right-hand side of Figure 3 illustrates, a transition away from a single control as a best practice to ROW vegetation management began to be replaced by more holistic approaches starting around 1960. It was around this time that W.C Bramble and W.R. Byrnes initiated what stands as the longest term study on ROW vegetation management and ecology in the United States at Pennsylvania State Game Lands 33 (Ballard et al., 2007; NERC Vegetation Management Standard Drafting Team, 2009; Nowak, n.d.). Bramble and Byrnes (later joined by Yahner) looked extensively at the effects of mechanical and chemical vegetation controls on ROW plant diversity, wildlife habitat, and pollinator populations ("50 Years of Biodiversity Research", 2003). A summary of some notable findings of the Pennsylvania-based research team can be seen in Table 2 (W. C. Bramble

Figure 3. Overview of historic developments for Seattle City Light and for ROW Vegetation management

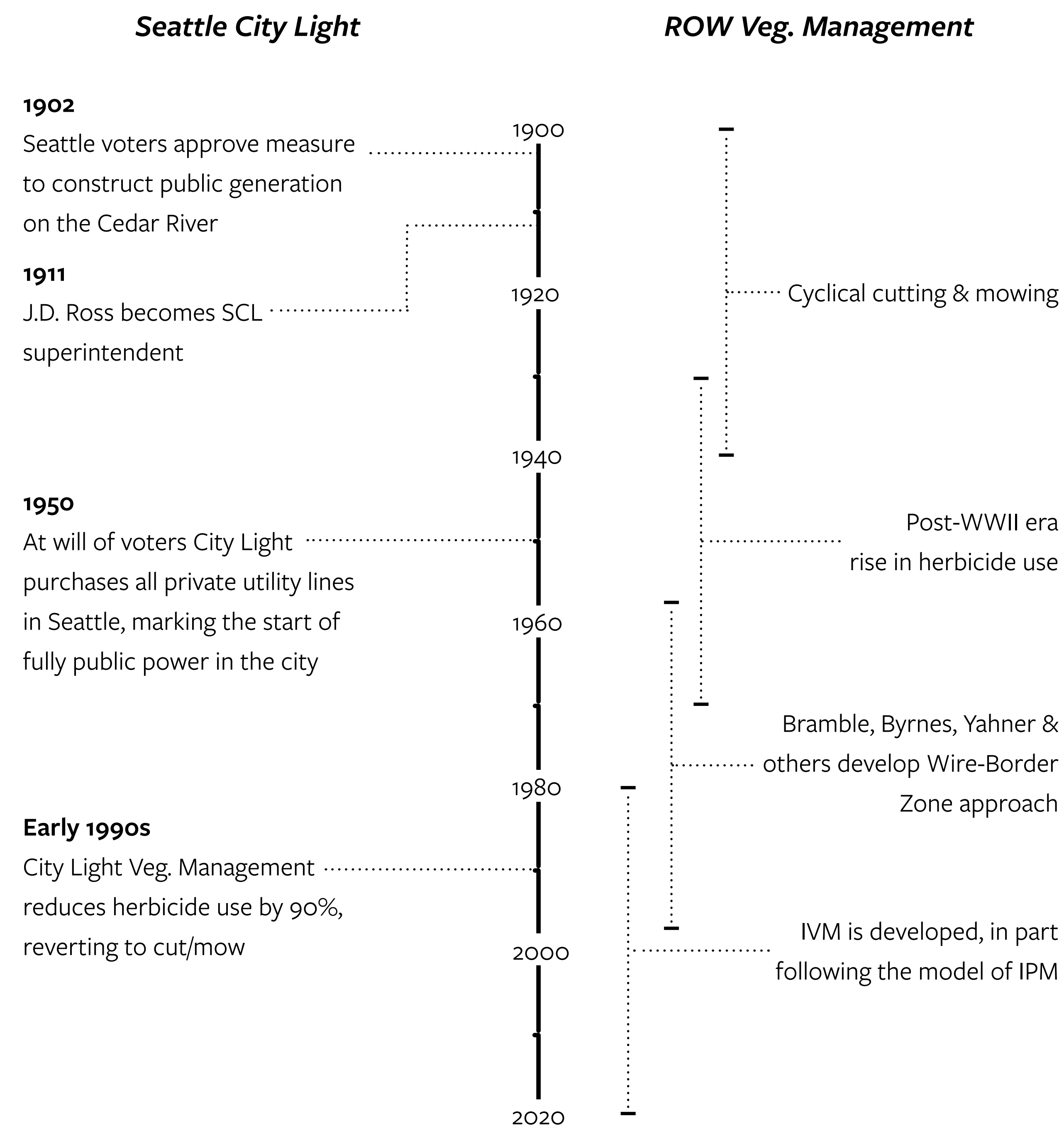


Table 2. Sample of significant findings from the research of Bramble, Byrnes, and Yahner at Pennsylvania State Game Lands 33

Article Title	*Year Published*	*Main Takeaways*
Evaluation of the Wildlife Habitat Values of Rights-of-Way	1979	Researchers developed a weighted habitat scoring system centered on native white-tailed deer that could be applied to ROW ecosystems. The final scores were compared to known desirable conditions for deer habitat, and were found to reflect valuable conditions for white-tailed deer
Resistance of plant cover types to tree seedling invasion on an electric transmission right-of-way	1990	Researchers looked at how resistant different plant communities were to encroachment by tree seedlings (incompatible plant species) Areas found to have abundant grasses and herbs were found to be more resistant to tree seedling encroachment than shrub communities
Effect of herbicide maintenance of an electric transmission line right-of-way on butterfly populations	1999	Researchers compared the effects of different vegetation treatments on butterfly populations Findings showed that the selective and proper use of herbicide actually resulted in increases in butterfly populations It is posited that the proper use of herbicides cultivated a more valuable ROW ecology, containing more native plant species.
Response of amphibian and reptile populations to vegetation maintenance of an electric transmission line right-of-way	2001	Researchers investiaged the diversity and relative abundance of reptiles and amphibians on a transmission ROW and in the surrounding forest Treatments varied across research areas after initial herbicide/mowing phase (treatments included handcutting, mowing, mowing & herbicide, stem-foliar spray, and foliar spray) Findings revealed larger and more diverse populations of amphibians on the ROW, with more species found in wire zones than border zones

& Byrnes, 1979; "Prediction of Cover Type on Rights-of-Way after Maintenance Treatments," 1992; William C. Bramble & Byrnes, 1996; W. Bramble et al., 1999; Yahner et al., 2001).

A notable product of the research at State Game Lands 33 was the development of the "Wire-Border Zone" approach to transmission ROW vegetation management. As shown in Figure 4, the area directly beneath and closest to transmission lines is the "wire zone", which is maintained with a focus on safety and access. Wire zone plant communities are ideally composed of species reaching no more than 3 feet in height (NERC Vegetation Management Standard Drafting Team, 2009). In the "border zones" on either side of the transmission lines, plant communities of a moderate height are cultivated. Plants in the border zone are typically those that are no more than 25 feet tall at maturity (NERC Vegetation Management Standard Drafting Team, 2009). Foliar and basal herbicide treatments are often used to discourage undesirable plant growth in both the Wire and Border Zones (Penn State, n.d.). The results of Bramble and Byrnes' research indicates that when applied properly and appropriately, the WBZ methodology can provide beneficial habitat for wildlife and pollinators while simultaneously accommodating the needs (and budgets) of electric utilities.

Currently Seattle City Light is interested in applying the "Modified Wire-Border Zone" (MWBZ) approach to ROW vegetation management. This variation on the WBZ approach – shown in Figure 5 – goes a step further in maximizing allowable plant height and diversity by considering a lengthwise sectional view and a plan view of the transmission line ROW. Consequently, variations in topography that increase or decrease the ground-to-powerline gap can be incorporated into management

Figure 4. Wire-Border Zone

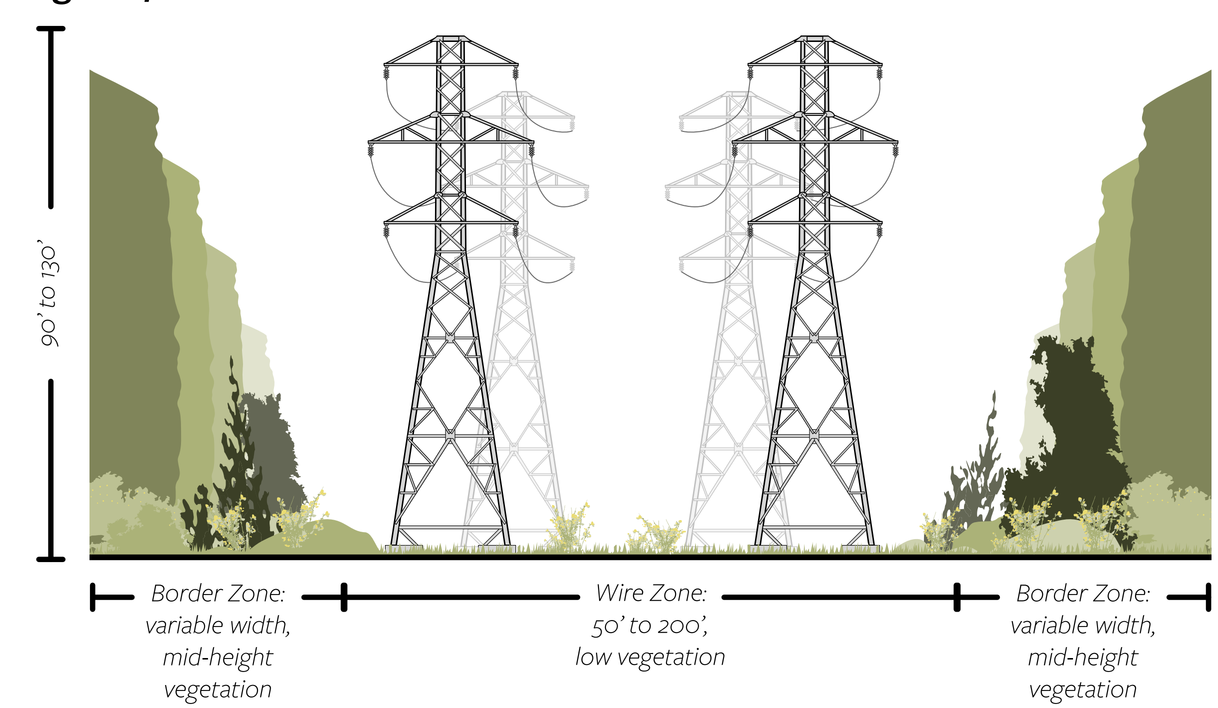
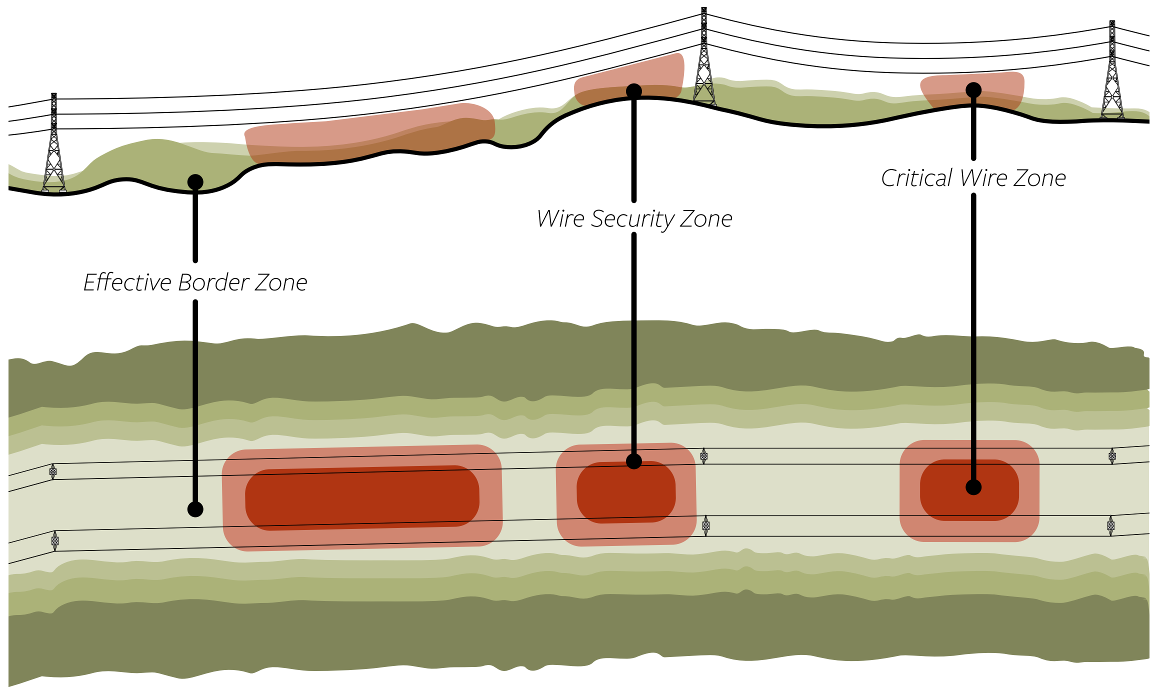


Figure 5. Modified Wire-Border Zone



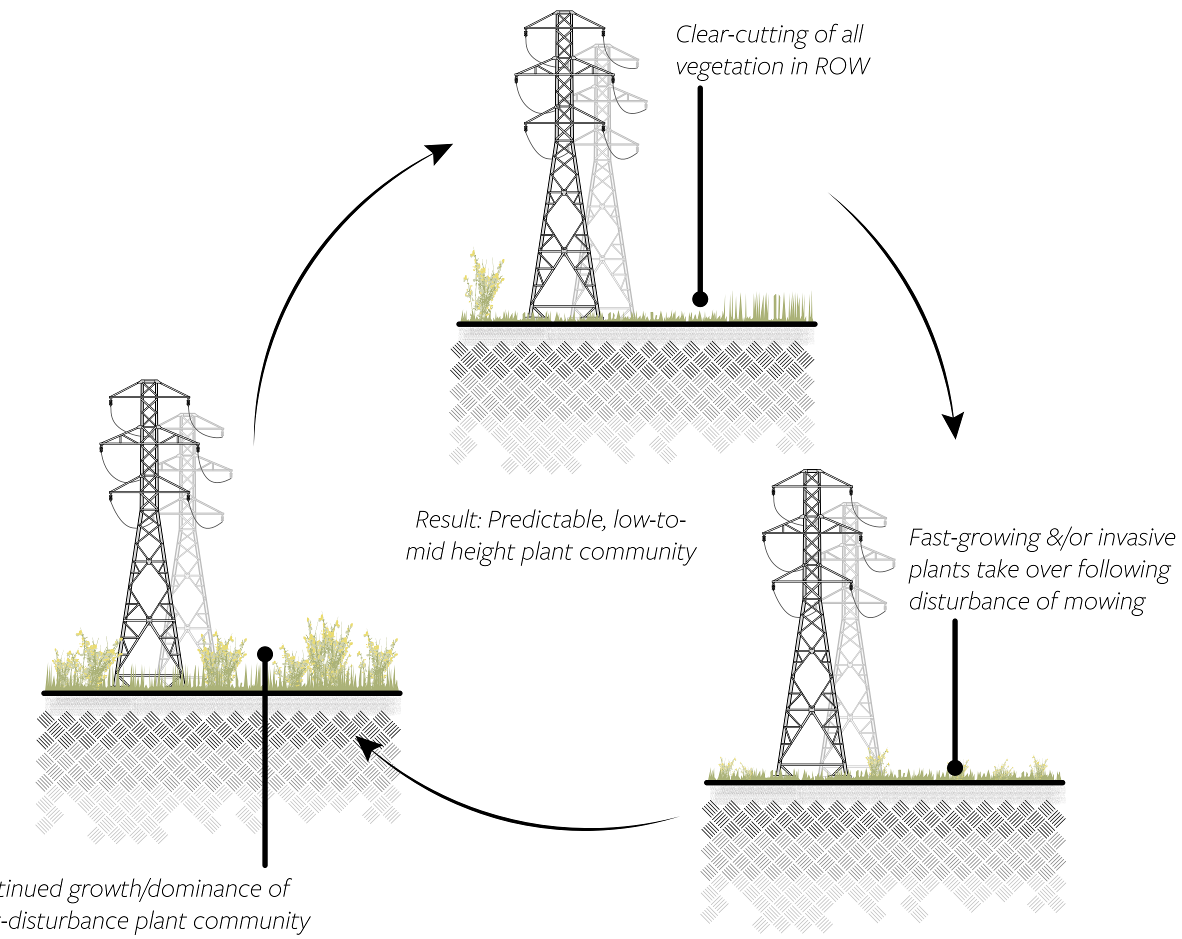
decisions, and wire or border zones are able to take less linear forms through the right of way. Ideally, plant and animal diversity and safety are both maximized through use of the MWBZ approach.

Another result of the work at State Game Lands 33 was the development of the Integrated Vegetation Management (IVM) framework. The U.S. Environmental Protection Agency (EPA) defines IVM in the following fashion:

> "Integrated Vegetation Management (IVM) is generally defined as the practice of promoting desirable, stable, low-growing tree species through the use of appropriate, environmentally-sound, and cost-effective control methods. These methods can include a combination of chemical, biological, cultural, mechanical, or manual treatments." (OCSPP US EPA, 2016)

IVM considers existing site conditions, seed banks, and native ecology. Undesirable plant species – those that either reach heights within the spark zone of transmission lines, or invade and diminish plant diversity – are eradicated over time using the practices that are most appropriate for the site. Conversely, desirable plant species – those that are low-growing and conducive to high quality habitat – are allowed to grow and reproduce, leading to relatively stable ROW ecosystems composed of a diversity of compatible plant species (L. Payne, personal communication, March 18, 2020; J. Steelman, personal communication, April 1, 2020; S. Vera-Art, personal communication, March 18, 2020). Figures 6 and 7 provide a comparison of a typical maintenance cycle under non-IVM (usually cut & mow) and IVM regimes.

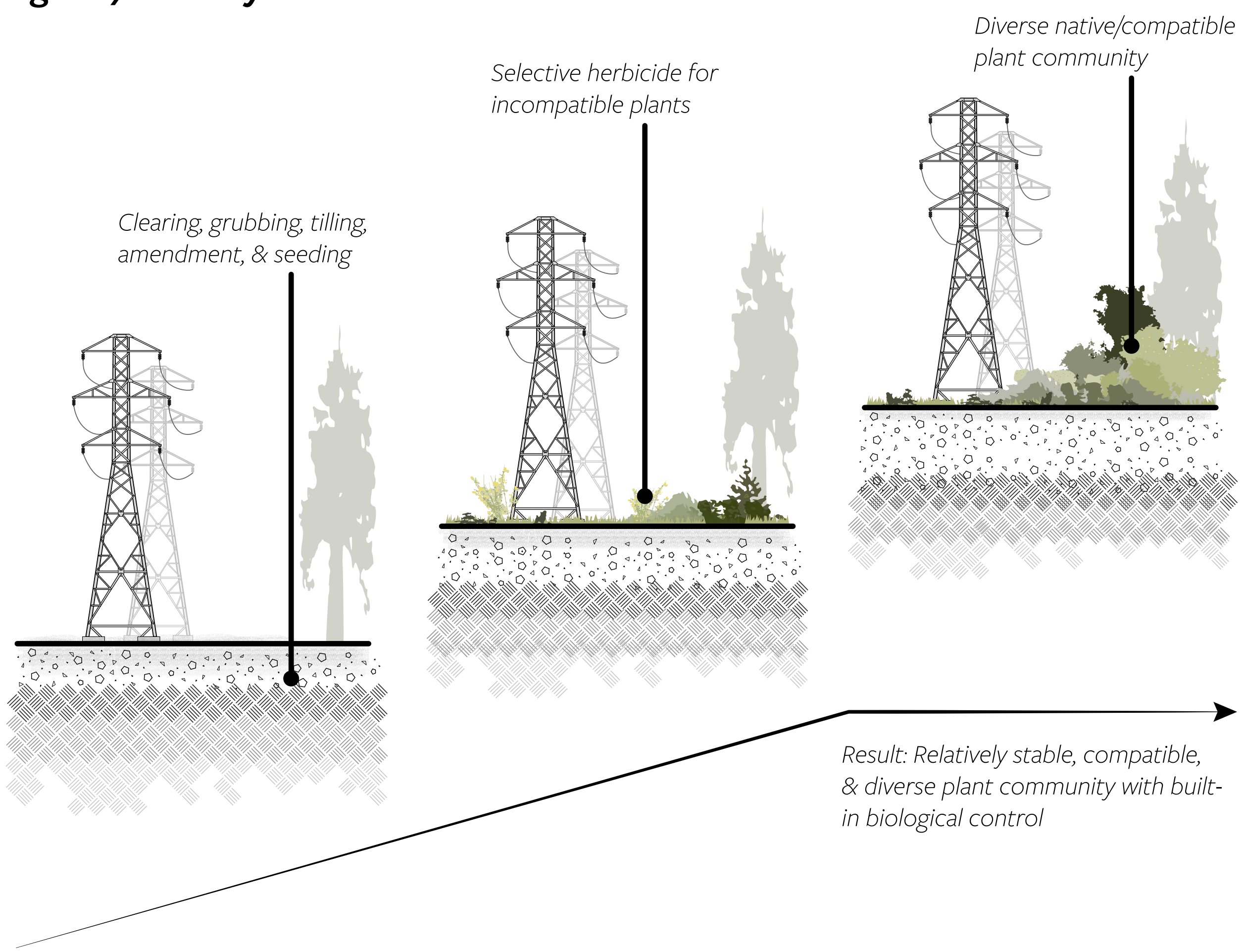
Figure 6. Non-IVM (Cut & Mow) Cycle



The relatively stable ROW plant communities that an IVM regime seeks to grow are documented as having higher upfront costs to a utility. Table 3 draws from two cost analyses and personal communications to illustrate a rough cost-benefit analysis of IVM versus Non-IVM management approaches. The Goodfellow study – on which the graphs in Table 3 are based – is particularly in-depth, comparing the use of solely mechanical and manual controls against an IVM approach that selectively uses herbicides and other controls over a 20-year period. By incorporating findings of Bramble, Byrnes, and Yahner, Goodfellow's project estimates the financial savings and efficiency of both methods; demonstrates that IVM imposes around half the cost of mechanical mowing over time; and finds that IVM creates more stable, maintainable, ecologically-beneficial, and compatible (shorter) plant communities on transmission ROWs (2018).

A major point that was reiterated through articles and personal communications alike is that the biological controls fostered by IVM – albeit costly in both time and money to cultivate – pay

__Figure 7. IVM Cycle__

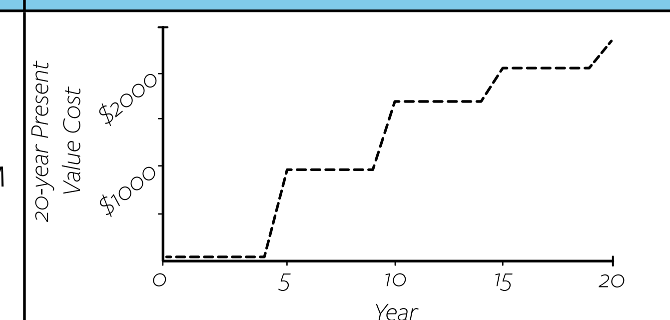
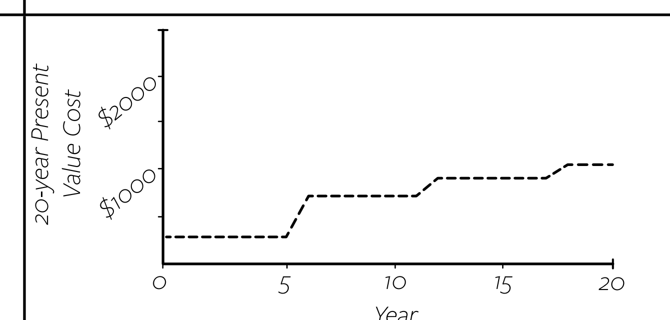


dividends not only in the form of increased social and ecological benefits, but also in the form of predictably and consistently suppressing undesirable vegetation in the ROW at a progressively lower cost as time goes on (Goodfellow, 2018; Nowak, n.d.; Nowak et al., 1992; L. Payne, personal communication, March 18, 2020; J. Steelman, personal communication, April 1, 2020; The Cost-Effectiveness of Integrated Vegetation Management – TREE Fund, n.d.; S. Vera-Art, personal communication, March 18, 2020).

While the State Game Lands 33 project is highly regarded and frequently referenced in the field of vegetation management (A Pacific Gas and Electric Company "Right Tree Right Place" Publication, 2014; Baggett, 2019; L. Payne, personal communication, March 18, 2020; J. Steelman, personal communication, April 1, 2020; S. Vera-Art, personal communication, March 18, 2020), there is a large body of recent literature that reinforces the findings of Bramble, Byrnes, and Yahner. In 2017, researchers in Winnipeg had similar findings relating to butterfly populations, demonstrating that ROWs in urban areas provided valuable butterfly habitat when "appropriate resource plants" were present (Leston & Koper, 2017). A 2016 study by Hill and Bartomeus took place on Swedish transmission line corridors, and found that while the corridors did not increase the diversity of bumblebees in the surrounding areas, the transmission ROWs themselves hosted diverse populations of bumblebees reminiscent of grasslands (Hill & Bartomeus, 2016). Only three years prior, a team of researchers in Connecticut surveyed a transmission ROW for wild bee habitat, finding that the corridors contained more than twice as many bee species – including two particularly rare ones – as the forested areas surrounding the ROW (Wagner et al., 2014). Additionally, a literature review from 2012 investigating 34 published articles on ROW vegetation management noted the high potential of roadside and utility corridors to provide migration pathways for insects, bats, and birds. That literature did, however, indicate the need for further research and testing of alternate methods, particularly those based on herbicide use (Wojcik & Buchmann, 2012).

There are few examples discovered by this researcher of IVM being implemented on a large scale throughout North America. The New York Power Authority's ROWs stand out: Lewis Payne has been a practitioner of IVM at the NYPA for nearly 20 years, and has spearheaded the integration of IVM with GPS tools, GIS analysis, and effective vegetation maintenance and monitoring (L. Payne, personal communication, March 18, 2020; S. Vera-Art, personal communication, March 18, 2020). State Game Lands 33 in Pennsylvania – the study site of Bramble and Byrnes – was mentioned above, and is another excellent precedent (William C. Bramble & Byrnes, 1996). Seattle City Light

Table 3. Costs and benefits of IVM versus Non-IVM vegetation management approaches

Approach	*Cost over time*	*Other Costs*	*Benefits*
Non-IVM		*Vehicle/equipment purchase* *Fuel & maintenance* *Labor* *Emissions* *Loss of habitat/biodiversity/ecosystem services*	*Consistent & predictable vegetation control* *[Relatively] Predictable costs* *Open space* *[Subjective] Aesthetic value*
IVM		*Vehicle/equipment purchase* *Fuel & maintenance* *Labor* *Emissions* *Herbicide*	*Enhanced habitat quality & connectivity* *[Relative] ecological stability (as opposed to a disturbance regime)* *Increased biodiversity & ecosystem services*

**Cost comparison analysis from Goodfellow & Biocompliance Consulting* also has initiatives in place to move in an IVM-oriented direction, namely its restoration program on the Greenline and conservation mowing program along the Chief Sealth Trail, mentioned in the introduction of this thesis.

A newer project that focuses on a more urban landscape is the Meadoway. The Meadoway is a runs through Toronto, Ontario, and it capitalizes on the presence of continuous transmission line ROWs to connect neighborhoods, parks, and other green spaces with a biodiverse linear park. The project is underway, and has entailed a large planning and design effort which has looked not only at the ecological values that will be provided by the space, but also at the ability of this corridor to provide easier, more equitable transportation for underprivileged residents. While there are a few examples of sustainable transmission line right of way management, this is the most comprehensive one in existence by far (The Meadoway - Community Powered Green Spaces, n.d.).

New tools for ROWs

Over the last 20 years geospatial technologies have become ubiquitous in their use not only by utilities, but also by land use planners, designers, and natural or social scientists. Although not exhaustive, Table 4 provides an overview of four common aspects of geospatial technologies, all of which are currently used by City Light in some capacity. The Global Position System (GPS), Remote Sensing, and Light Detection and Ranging (LiDAR) each function as tools within a larger Geographic Information System (GIS).

Environmental Systems Research Institute (ESRI) software is employed by many departments or business units at City Light, the exact needs of each user vary, resulting in a decentralized system that maximizes user flexibility. City Light is in the process of developing its own custom Vegetation Management & Compliance System (VMCS) that will integrate the mapping systems for multiple departments at the utility (namely those involved in vegetation management, engineering, and environmental compliance). The VMCS will provide on-the-ground GPS capabilities for vegetation and line managers, allowing for better viewing of LiDAR data to monitor concerning ROW areas. However, the way in which the VMCS might be used to prioritize projects based on their socio-ecological context; to apply alternative metrics of success; and to facilitate cross-stakeholder collaboration have not yet been explored.

A look at available literature reveals a broad body of knowledge that has developed around applying remote sensing technologies to powerline routing, construction, and modeling. Researchers in Brazil in 2007 used LiDAR scanners, videography, and classification of remotely-sensed satellite imagery to transmission ROWs in an effort to capture potential threats to electric transmission by vegetation. Their findings indicated that LiDAR was not yet able to capture high enough resolutions to show the locations of powerlines themselves, and should therefore be used in conjunction

Table 4. Applicability of available geospatial technologies to ROW vegetation management

Technology	*Description*	*Advantages*	*Disadvantages*
Geospatial Analysis & Geographic Information Systems (GIS)	Incorporates geospatial raster and vector data on computer-based software platforms, allowing for in-depth viewing, analysis, and map creation	Widely-used across City of Seattle Departments Provides for integration of multiple types of data from multiple time periods Allows for dissemination of geospatial data in formats suitable for users/viewers	Requires integration not only of data, but data collection standards for multiple divisions and departments Analysts require high level of training Software is expensive, and software needs vary depending on division/department using the platform
Global Positioning System (GPS)	Satellite-based navigation system that can be utilized by phones and designated units to collect geo-referenced data on-site	Widely-used across City of Seattle Departments Can be used via phones or tablets as well as designated units	Requires standardization of data collection processes for maximum benefit Data collection requires training that not all workers possess Designated units - which provide higher degree of accuracy than mobile devices - are expensive
Remote Sensing	Uses sensors mounted on satellites or airborne vessels to collect geospatial data at multiple wavelengths and resolutions	Can be used to provide detailed information on landcover and vegetation by collecting data in multiple wavelengths (red, green, blue, & infrared primarily) Can show changes in the landscape over time	Data collection is expensive Does not allow for high frequencies of data collection due to cost and difficulty of collection in cloudy conditions Not yet useful for plant species identification on a large scale
Light Detection and Ranging (LiDAR)	Uses the repeated beaming of lasers to and from a sensing platform - often on a plane - to collect both topographic and height data of a landscape in great detail. Technically falls under the category of Remote Sensing.	Can be used to analyze heights of vegetation, buildings, and landforms under varied conditions Provides high level of detail for large swaths of land Can show changes in the landscape over time	Data collection is expensive Does not allow for high frequencies of data collection due to cost Does not adequately capture line height, sag, or sway

with other technologies. Remotely-sensed imagery from satellites was classified by vegetation type with some success, but it was determined that more satellites with the same sensing capabilities would be needed to provide high enough temporal resolution to be useful to vegetation managers (Jardini, Jacobsen, et al., 2007; Jardini, Jardini, et al., 2007). Videography - which captures moving images from airborne scanners - was thought to be promising for this application, and was utilized as early as 1980 (Hakenholz, 1980; Jardini, Jacobsen, et al., 2007; Jardini, Jardini, et al., 2007). However, the practice has fallen out of favor in recent years with the further development of remote sensing and LiDAR scanners.

The findings of Jardini et al. are supported by an extensive literature review of over 140 articles - largely published since 2007 - on data collection methods from satellite, airborne, and terrain-based sources (Matikainen et al., 2016). Researchers found that more emphasis has been placed on modeling the location of conductors, transmission towers, and transmission lines than on modeling the heights and types of vegetation present on or around the ROW. In addition, each method of data collection came with serious advantages and disadvantages. Satellite imagery is readily available at this point, but its low temporal resolution is not conducive to monitoring changes in the landscape. Airborne remote sensing allows for easier monitoring of changes, but flying frequently enough can be cost-prohibitive. It seems clear that a combination of approaches will be the most useful to utility professionals (Matikainen et al., 2016). For vegetation managers, land-based and airborne remote sensing platforms are likely to be promising, although the technologies are still being developed. Better automation of workflows for data analysis is also key to making them cost-effective (Li et al., 2010; Matikainen et al., 2016).

As has been noted, City Light has systems in place for collecting and monitoring environmental data, and is in the process of expanding those systems to be used by vegetation managers. However, the fact that City Light is a public utility owned by a large American city is somewhat unique. As a result, the implementation of any new GIS not only must consider the usual challenges faced by vegetation managers as well as utility engineers, but also must keep costs low while providing for some level of integration with other City departments' GIS.

It is impractical for City Light to adopt new technologies like airborne remote sensing on a broader scale than is absolutely necessary. Such technologies are only used every few years - hardly enough frequency to allow for substantive monitoring of landscape changes. City Light's new VMCS will offer the ability for integration of GPS via the mobile devices of crew members with environmental monitoring data, which will help to identify challenges; prioritize projects; and track short- and long-term costs of vegetation management. The VMCS should also allow for new technologies to be more easily used by ROW vegetation managers once they have been further developed. Even so, software that allows for engineers to model transmission lines and towers as they exist in the landscape - namely PLS-CADD, which is used at SCL - must also be integrated with digital vegetation management tools if more accurate determinations of height limitations are to be recognized (Hooper & Baily, 2004).

Other ROW allies

City Light's Environment, Land, and Licensing Business Unit (ELLBU) interacts frequently with the utility's Vegetation Management Department (VMD). The members of ELLBU manage terrestrial and aquatic restoration projects; wildlife and habitat monitoring; and real estate purchasing and management for City Light, and employees in ELLBU use GIS frequently to document and monitor projects.

ELLBU also ensures City Light's compliance with its License and Settlement Agreements for each of its hydroelectric projects, including those associated with the Skagit Hydroelectric Project. That license agreement is of note, as its Aesthetic Settlement Agreement prescribes the use of a MWBZ approach on certain portions of the transmission lines leading from Seattle to City Light's North Cascade dams. Aesthetic values themselves as they relate to transmission lines have received a large amount of attention over the years through other academic papers (Townsend et al., 1975; Navrud et al., 2008; Slusser, 2012), and are consequently not the focus of this thesis.

However, the prescription of MWBZ management necessitates the involvement of terrestrial ecologists, plant ecologists, and wildlife biologists from ELLBU in transmission ROW vegetation management. Because of more urgent license obligations City Light has been slow to implement these prescriptions to the transmission ROW, but has started to catch up. Some might say the shift is just in time: the literature on managing ROW vegetation for pollinator conservation runs deep, with numerous papers building on the seminary work of Bramble and Byrnes over the last 20-30 years. The low-growing plant communities compatible with transmission lines not only have been found to provide year-round food sources for pollinators, but also have been identified as potentially valuable edge habitat area. As a result, transmission ROWs that might otherwise separate habitat patches can serve to provide seasonal forage for insects, pollinators, and mammals that are not typically found in agricultural or forested landscapes (Baggett et al., 2019; Wagner et al., 2014, 2019).

Cultivating multiple functions

What functions, and why?

As has been stated, the primary function of transmission ROWs is to accommodate infrastructure that conveys electricity from generator to consumer. The secondary function of a transmission ROW may be to preserve or enhance habitat - particularly for pollinating birds and insects - through the cultivation of compatible vegetation. Additional functions might include food production if a ROW cross agricultural landscapes; or recreation when a ROW provides opportunities for trail construction or birding, for example.

A large body of literature exists on the functions provided by the landscape, although ROW vegetation managers have not yet wholeheartedly embraced the frameworks articulated in academia and elsewhere. The Millenium Assessment described four types of "ecosystem services" that might be provided by a landscape: provisioning, cultural, supporting, and regulating services. The functions described above can be easily sorted into these categories: food production is a provisioning service; recreation is a cultural service; and pollinator habitat is a supporting service (World Resources Institute, 2005).

The list hardly stops there, though, when one looks into the writings on ecosystem services theory. Nutrient cycling and climate regulation are increasingly important regulating services offered by forest ecosystems in the face of climate change. Similarly, flood management is a supporting service that is essential to making all communities more resilient to extreme weather events. Of course, community and individual resilience can be further increased through cultural services, whether they are the presence of recreational space or culturally significant landscapes. And while food production might be the first provisioning service to come to mind, the provision of textiles and building materials are also of utmost importance (World Resources Institute, 2005).

Of particular note in this case is the significance of biodiversity to the provision of ecosystem services (Harrison et al., 2014). Biodiversity is being depleted around the world as humans expand their footprint into relatively undisturbed areas, destroying stores local diversity within species; the connections between patches of habitat for a variety of species; and the abundance of individuals of a given species that make a local population viable (Harrison et al., 2014). It is also the case that the invasions of non-native plants pose an enormous threat to ecosystem services, as they disrupt biodiverse ecosystems that have taken years to develop, creating less diverse or less functional ecosystems in their stead (Vilà & Hulme, 2017). Transmission ROWs are a leverage point in this equation, where habitat connections and biodiversity can either be restored through IVM or similar approaches; or can be further depleted through repetitive disturbance management regimes.

In order to facilitate vegetation management strategies that combat biodiverse loss, indicators and metrics must be employed to measure depletion and gain of ecosystem services and/or biodiversity. The methods for measuring ecosystem services are highly debated: those working at a large scale wish to implement standardized systems for measuring ecosystem services so that their degradation can be incorporated into economies as a cost (for instance, ecologically harmful companies might pay a fee for degradation of ecosystem services that might not be encompassed by the global economy otherwise) (Crossman et al., 2012; Paulin et al., 2020). However, others who work at a smaller, localized scale may be disposed to measure ecosystem service production based on indicators or metrics articulated by the local community itself (Feld et al., 2009; Brown et al., 2014). This method requires dialogue between stakeholders in a communitiy to determine what services they deem worthy of measurement, and what aspects of those services can be monitored to demonstrate any gain or loss of functionality.

It seems logical that in considering the services that might be provided by transmission ROWs, City Light would benefit from a combination of the two approaches described above. On one hand, standardization of metrics offers a way to directly compare the functions provided by different segments of SCL's ROWs. On the other hand, the range of stakeholders associated with SCL's ROWs likely have different priorities and levels of interest in vegetation management. As such, it is also important for City Light to acknowledge both their interests and what they see as necessary functions given the socio-ecological context of their community. By engaging interested stakeholders, City Light can determine when additional stakeholder-defined metrics are appropriate for assessing the success of ROW vegetation management.

Stakeholder engagement

There is documented evidence to suggest that the routing of transmission lines is a hot-button issue for members of the public around the world. While ecologists and subscribers to geodesign theory have attempted to develop ways for routing powerlines in more ecologically- and socially-conscious ways (Araneo et al., 2015; Moreno Marimbaldo et al., 2018), homeowners have actively opposed the routing of transmission corridors through or adjacent to their communities (Mueller et al., 2017; Nelson et al., 2018).

A study in California found that while public opposition did not prevent a transmission line project from being constructed, it did play a large part in eroding trust of government officials and the utility, all as a result of the perceived risks of transmission lines (Cain & Nelson, 2013). The same researchers produced findings that have been echoed by other international studies: if community members believe they reside close to the route of a to-be-built transmission line, their perceived risk and opposition to such projects is likely to be higher (Cotton & Devine-Wright, 2013; Mueller et al., 2017; Nelson et al., 2018). Despite public sentiment, there is no conclusive evidence connecting transmission lines to negative health impacts (Jauchem, 1997; OAR US EPA, 2018); and concerns about decreased property values for those residing near corridors to be invalid (Jackson & Pitts, 2010).

The building of trust between utilities and those who hold a stake in their transmission ROWs is essential from the outset (Woolley, 2008), but must also continue throughout the lifespan of a transmission corridor. SCL's vegetation management crews must interact with the public on a daily basis, and communicate with landowners ahead of enacting controls on easement ROW properties. Maintaining good relationships with landowners is an essential aspect of what City Light does, both within and outside of Seattle (D. Mutchler et al., personal communication, October 9, 2020).

Who pays? Who benefits?

As the case studies in this thesis will illustrate, a diverse array of stakeholders are currently involved with SCL's vegetation management activites, including Native American tribes whose historic lands transmission lines traverse; urban tenants and homeowners; public and private natural resource managers; recreationalists; community gardeners; and more. City Light's transmission lines have been around for decades, so opposition to their routing is no longer a concern of the utility. However, it is important to apply an environmental justice lens to the management of transmission ROWs going forward. Seattle's Race and Social Justice Initiative as well as its Environmental Justice Initiative mandate that all City departments substantively engage stakeholders from diverse backgrounds when they are effected by or could benefit from City projects or activities (Initiatives, Referenda, & Charter Amendments Guides - CityClerk | Seattle.Gov, n.d.).

The City's initiatives relating to environmental and social justice are supported by the findings of the Millenium Assessment, which notes the increased effects climate change will have on the world's marginalized and underprivileged communities (2005). Those on the upper rungs of the socio-economic ladder are somewhat insulated from the loss of essential provisioning, cultural, and supporting functions provided by biodiversity and ecosystem services. Conversely, communities who have been oppressed or marginalized historically may rely on those functions for their well-being (food production via community agriculture; open space provision via public parks), or may be severely effected by the loss of those functions (loss of clean air due to lack of tree canopy; loss of sense of place and identity due to eradication of culturally-significant plants and wildlife).

The goal of engaging stakeholders interested in vegetation management on SCL's ROWs must be to direct and maximize functionality generally, and those who have the most to lose from the loss of functionality also have the most to gain. Because of this dynamic, and because of the City's progressive initiatives, City Light must look for opportunities to listen to, collaborate with, and learn from indigenous or marginalized communities in an actionable fashion (Westin et al., 2012).

Methods

Mono-towers at French Creek, looking east
Photo Credit: Dylan Marcus

Review of Central Questions & Hypothesis

A brief re-stating of the central questions that the project will address:

> How can spatial analysis tools be used to inform ROW planning, design, and management decisions so that they can better respond to the adjacent socio-ecological communities?
>
> What combination of technologies, approaches, vegetation controls, and metrics can be used to cultivate, monitor, and adaptively manage multi-functional spaces on City Light's transmission ROWs?

To answer the research questions, three case studies specific to SCL's transmission ROWs in Western Washington were selected and analyzed. A pragmatic and iterative mixed-methods approach provided the flexibility needed to draw from a wide array of data sources at different points during the research process.

This choice is driven by the position of the researcher as a student intern with SCL, and his consequent direct involvement in or experience with the sites and projects inspected. Drawing to some extent from action research theory, this research design acknowledges and allows for the inherent biases of the researcher; their involvement as a participant in their own research; and their intention to draw from an array of source types in an attempt to facilitate positive change in a real way (Stringer, 2007; Westin et al., 2012). To be clear: the main objective of this thesis is to apply systems thinking to improve processes at SCL associated with vegetation management in order to identify and increase the multi-functionality of underutilized ROW spaces.

Case Selection

Because the primary research questions are oriented towards improving work processes at SCL, it was appropriate that the constant among case studies be that each is based on a corridor underneath transmission lines owned by SCL. While SCL does own and operate the Boundary Hydroelectric Project in Northeastern Washington, electricity produced by that dam is transmitted largely on transmission lines owned by the Bonneville Power Administration. Since SCL does own and operate many miles of transmission lines throughout Western Washington, the scope of this project is limited to ROWs associated with lines in the western part of the state.

Each case study looked at a portion – or "corridor" – of the transmission line ROW already undergoing or slated to undergo modifications to their vegetation management regimes. Corridors are between roughly three and six miles in length and are defined for the purposes of this project as continuous areas of the ROW with similar contextual conditions throughout their length. A corridor might be bounded by a road or highway on either end; or by the start or end of a land use type. Transmission corridors were identified by SCL as needing attention for one or more of the following reasons:

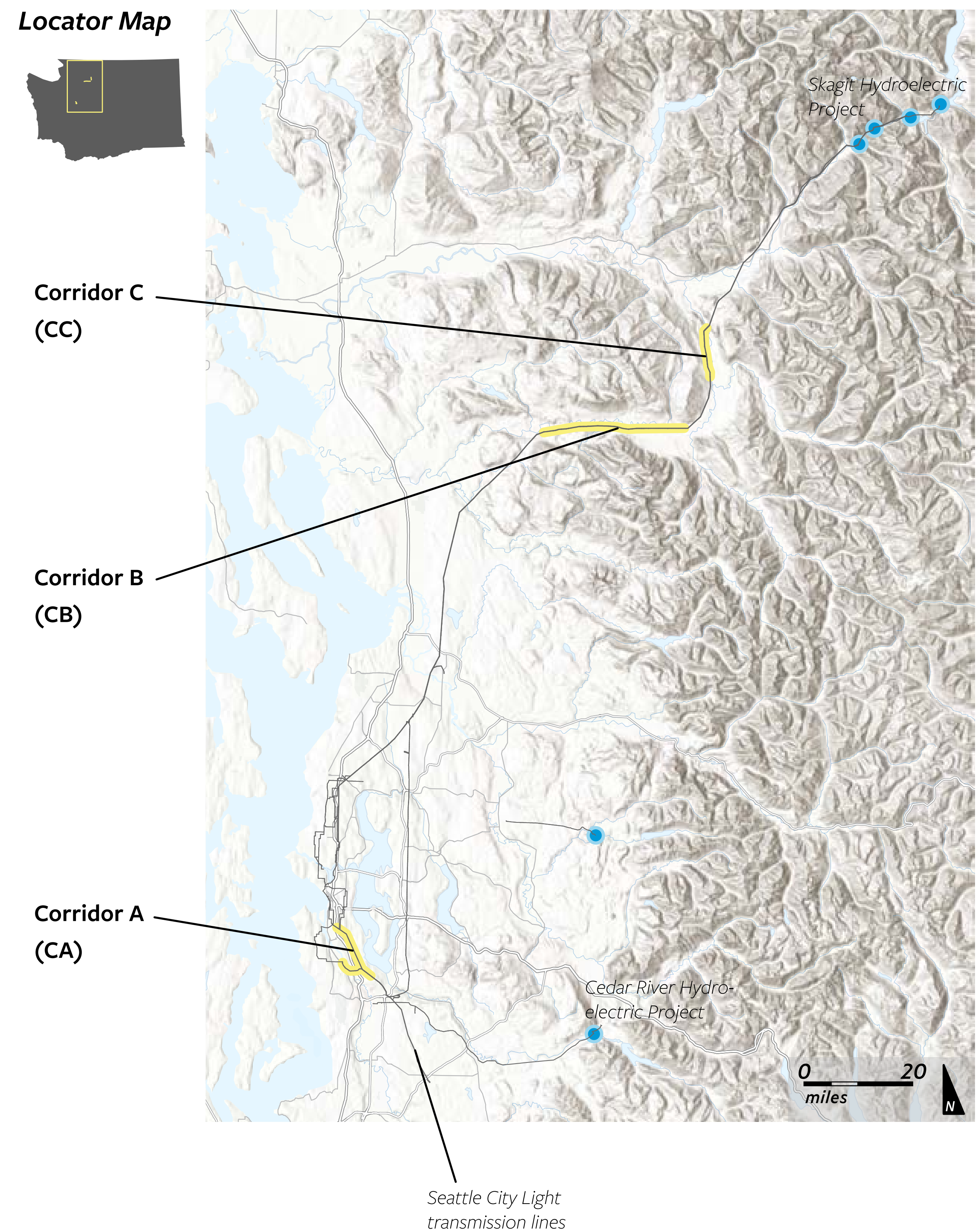
- Concerns expressed by landowners or community members (more generally referred to here as "stakeholders") about current uses of the ROW
- Concerns expressed by stakeholders about the current vegetation management strategies [perceived to be] employed on the ROW
- Concerns expressed by the Federal Energy Regulatory Commission (FERC) about SCL's current vegetation management strategy for parts of the Skagit line ROW
- Concern within SCL about the presence of invasive or noxious plants on the ROW, particularly those that might provide fuel for wildfires; could spread seeds into adjacent properties; and that diminish biodiversity and habitat value
- Concern within SCL about natural hazards that might effect ROW serviceability, namely erosion adjacent to transmission towers
- Concern within SCL about the overall workload and safety of vegetation management crews performing work on the ROW
- Desire within SCL to work collaboratively with stakeholders to find long-term solutions for any issues relating to ROW use and vegetation management

To balance a thorough illustration of the varied conditions crossed by SCL's Western Washington transmission lines against the time and logistical constraints associated with internships and global pandemics, the following criteria were used to select corridors:

- **Socio-ecological Context:** The case study sites investigated illustrate conditions throughout an urban-to-rural gradient, thereby encompassing a representative assortment of contextual conditions traversed by SCL's ROWs. This contextual variation allows for comparison between sites not only of socio-ecological context, but also of interventions, management strategies, methods used for stakeholder engagement, and potential metrics for success.
- **Stakeholder Engagement:** The case study sites investigated each have different levels and types of stakeholder engagement efforts. Having variation in the level and type of stakeholder engagement – some of which are on-going at the time of writing – provides insight not only into a range of successful engagement strategies – particularly during a global pandemic – but also into the relationships between stakeholders, developing management strategies, and context; and the amount and type of information gained through different engagement strategies or stages in the process.
- **Land Ownership & Parcel Size:** The case study sites investigated are parcels owned in fee by SCL, or are easement properties owned by a large public, private, or tribal entity. Easement agreements limit what SCL can legally do on a property to manage vegetation, typically such that cutting or mowing for safety are the primary activities allowed without owner permission or a permit (herbicide often requires landowner permission or notification). Coordination between landowners in a patchwork of parcels is inherently more complex, more costly, and provides the smallest returns on investment when compared with the simpler – albeit still complex – task of engaging and collaborating with fewer landowners of larger parcels to make more widespread positive changes occur.

Figure 8 shows the locations of the corridors used in case studies.

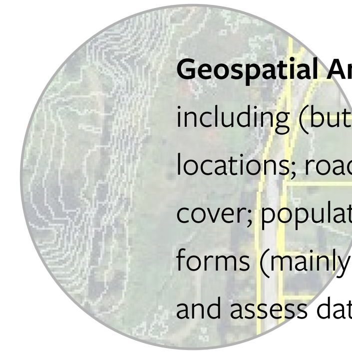
__Figure 8. Map of case study corridor locations__



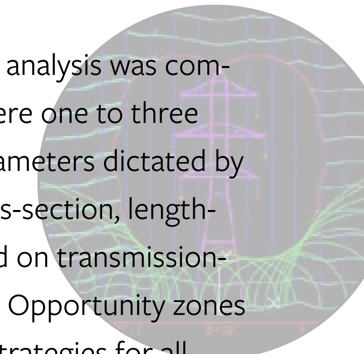
Data Collection

Projects associated with case study corridors were all at different stages of inception or implementation throughout the research period. Consequently, the methods employed for data collection and the types of sources used for each case study varied as well. Due to the process-improvement orientation of this project and to time constraints, this degree of flexibility was necessary to provide sufficient data on each case study for analysis. For example: two of the case studies feature pilot study projects that are currently being implemented on sites within the two corridors, and each of those case studies discuss stakeholder engagement efforts that are on-going as of the time of writing. In-person interactions and on-site observations are drawn upon heavily to inform those cases. Conversely, another case study features a large corridor that has already seen the implementation of pilot projects or new vegetation management prescriptions that have been documented in some capacity. In that case study data was collected more from geospatial and archival sources. Regardless of which methods were used in the course of a case study, the goal of data collection was to identify key points or factors related to each case or pilot, and was not meant to be exhaustive in scope.

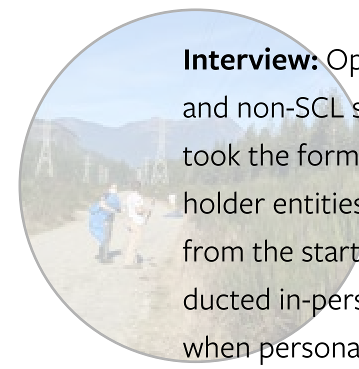
The methods used for data collection are discussed in more detail on the the following page.



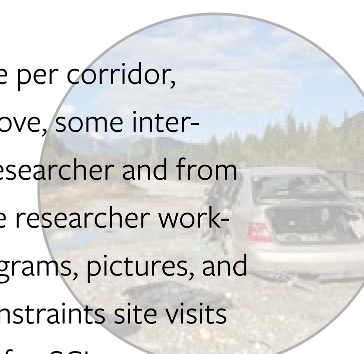
Geospatial Analysis: Datasets available within SCL's archives were viewed using ESRI ArcMap, including (but not limited to) datasets relating to property ownership; transmission tower and line locations; roads; municipal boundaries; tribal landholdings; demographics, and distribution; landcover; population density; water bodies; wildlife; and topography. Publicly available online platforms (mainly from local, county, or state governments) and Google Earth were also used to view and assess data.



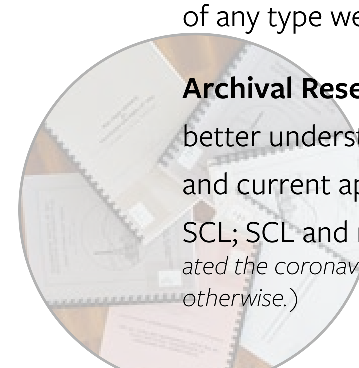
Spatial Analysis: A second, more fine-grained and site-specific round of spatial analysis was completed only on pilot study sites using ArcMap and AutoCAD. Pilot study sites were one to three "spans" in size (a span is the swath of ROW between two towers). Physical parameters dictated by topography and transmission line heights were assessed remotely through cross-section, lengthwise-section, and plan views. In turn, management zones were delineated based on transmission-line-to-ground gap in accordance with a Modified Wire-Border Zone approach. Opportunity zones and critical zones were identified, and compatible plant lists and management strategies for all zones were compiled with stakeholder interests in mind whenever possible.



Interview: Open-ended individual or group interviews were used to gather data from both SCL and non-SCL stakeholders, and from non-SCL ROW vegetation management experts. Interviews took the form of one-on-one or group meetings, or of listening sessions with employees of stakeholder entities (a native tribe, for example). During any meeting, the researcher was transparent from the start about their positionality as a student intern and researcher. Meetings were conducted in-person and on-site when possible, or over Microsoft Teams, Zoom, or Cisco Webex when personal schedules did not permit. *(Note: Because the unit of analysis in this project is an entire case as opposed to individual people, it was determined that assessment by a university Institutional Review Board (IRB) was not required.)*



On-Site Observation: Site visits and on-site observation occurred at least once per corridor, during which general site analysis and impressions were recorded. As noted above, some interviews took place on-site, allowing notes and reflections to be drawn from the researcher and from other meeting participants. Other on-site observations were undertaken by the researcher working alone. Information was collected on field visits through notes, sketches, diagrams, pictures, and GPS points (using a Trimble GeoExplorer device). Due to time and resource constraints site visits of any type were only conducted for corridors that were of the highest priority for SCL



Archival Research: Existing plans or other documents relating to case studies were examined to better understand the natural and human history of specific corridors, and to grasp SCL's historical and current approaches to vegetation management. Documents came from physical archives at SCL; SCL and non-SCL stakeholders; and from online databases. *(Note: As a result of constraints associated the coronavirus pandemic, it was more difficult to access physical archives at SCL than would have been the case otherwise.)*

Data Analysis

Data was analyzed with the following assumed SCL objectives in mind:

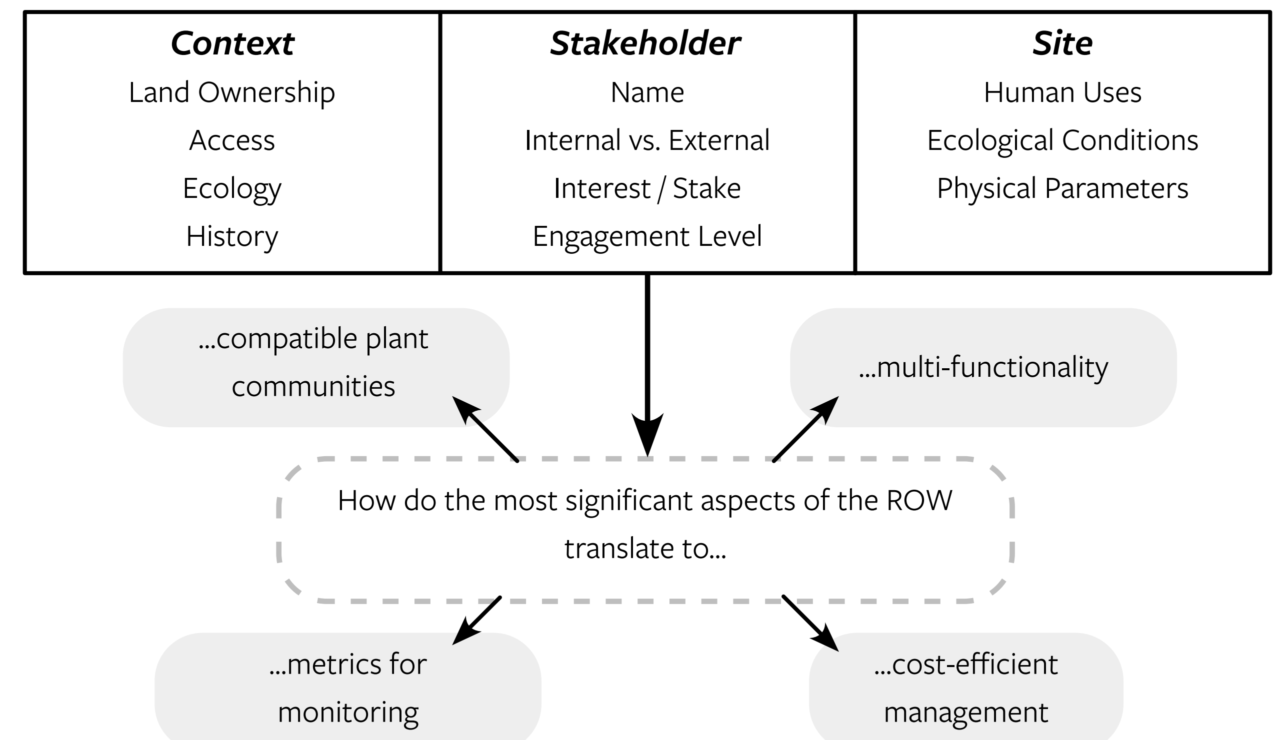
- Maintain serviceability, reliability, and safety of SCL's transmission line ROWs
- Increase multi-functionality on ROW corridors

The recent wildfires in California caused by PG&E highlight the need for excellent vegetation management and line maintenance practices. Such events are likely to intensify as the climate changes (World Resources Institute, 2005). Similarly, cultivating biodiversity, pollinator habitat, and other services that will be reduced by climate change will become increasingly important (World Resources Institute, 2005), and in this arena ROW vegetation managers can assist. As GIS, LiDAR, and drone technologies continue to be refined, utilities will have an even wider array of tools at their disposal to monitor ROW vegetation more easily, less impactfully, and at a lower long-term maintenance cost.

To that end, it was discovered during research that on top of piloting new processes for vegetation management, SCL is also in the process of developing a custom GIS designed specifically for vegetation management of ROWs. Therefore, the purpose of this project would not be to develop a GIS for SCL. It was determined that this project could intead use this series of case studies to provide a menu of options for ROW vegetation managers to use as templates, either for immediate application or as inspiration for more alternatives yet. It was hoped that trends or differences among the case studies would highlight not only strengths and weaknesses for the strategies employed currently, but also the opportunities for and threats to the effective use of the utility's custom GIS.

Analysis of data for each case study focused on ROW context, stakeholders, and site conditions, respectively. Each case study concludes with a brief discussion of the sub-cases or pilot study sites investigated, and following the series of case studies there are reflections diving into themes and connections that were observed. These connections indicate potential areas of leverage or opportunity, which might then be used to infer management prescriptions or metrics. The conceptual workflow is visually depicted in Figures 9. The cyclical, iterative nature of this process resulted in the use of reflection for analysis (Stringer, 2007; Westin et al., 2012).

Figure 9. Conceptual Framework



Costs and benefits discussed are of the financial, ecological, social, or cultural variety. Potential metrics of success were developed for monitoring, or for cost-effectiveness/cost-benefit assessments based on the overlapping goals of stakeholders. In creating a profile of each case, stakeholders are listed in table format where they are rated one through four based on the following descriptions:

- **1** = No direct engagement, only a potential stakeholder.
- **2** = Intermittent and/or indirect contact with stakeholder via email, phone, videochat, or through another stakeholder. Stakeholder has expressed interest in collaboration/coordination of vegetation management activities OR has expressed concerns about the ROW.
- **3** = Active and ongoing engagement with stakeholder. Representatives of stakeholder have participated in a site visit. All conditions of #2 have been met.
- **4** = Stakeholder is directly involved with ROW vegetation management activities on a regular and repeating basis. All conditions of #3 have been met.

Certain stakeholders within SCL that remain constant for all case studies are summarized in Table 5. Otherwise, stakeholders and their respective levels of engagement thus far are summarized using the same format as Table 5 within the corresponding case study section.

To provide a degree of standardization, the questioning of each case study is profiled using the sections below. This structure then allows for more seamless comparison of the wide range of conditions, strategies, processes, and sources that were investigated.

- Context
- Stakeholders
- Site
- Management, Functionality, & Monitoring

Table 5. Constant SCL Stakeholders

Stakeholder	*Engagement Level*	*Interest/Stake*
Vegetation Management (VM) Division	4	Responsible for managing vegetation on SCL's transmission ROWs to ensure safe transmission of electricity in accordance with FERC guidelines Interested in continued improvement and implementation of best management practices to maximize benefits and minimize costs associated with ROW vegetation management Responsible for implementation of the RSJI and EJI
Environment Land & Licensing Business Unit (ELLBU)	4	Responsible for ensuring compliance of ROW vegetation management by SCL with all license obligations and state/federal environmental regulations Responsible for planning and implementation of mitigation and enhancement measures generally Responsible for implementation of the RSJI and EJI
Engineering Division	3	Responsible for ensuring structural integrity of transmission lines and towers Responsible for design and implementation of erosion mitigation/stability control measures Responsible for implementation of the RSJI and EJI

Corridor A: The Green Line & The Chief Sealth Trail

Snoqualmie P-Patch Community Garden
Photo Credit: https://www.seattle.gov/neighborhoods/programs-and-services/p-patch-community-gardening/p-patch-list/snoqualmie

Context

City Light's ROW management strategy in South Seattle - through which Corridor A (CA) runs - has been recognized through Utility Arborist Association publications, webinars, and even a brief documentary titled "Lifelines," available for free online. The *Stewardship Strategy for the Creston-Duwamish "Green Line"* was written in 2012 to usher in a more holistic approach to vegetation management in a part of Seattle with a higher levels of adverse health outcomes than other parts of Seattle, primarily due to the concentration of industrial land use in the area. City Light's accommodation of multi-functionality in the transmission ROW along both the Green Line and the Chief Sealth Trail (locations shown in Figure 10) represent the pinnacle of the utility's efforts to pivot towards holistic vegetation management strategies.

Locator Map ***Figure 10. Context Map of Corridor A (CA)***

Access

CA runs across and between Interstate 5 (I5) and Martin Luther King Jr. Way S in its roughly 6 mile length, cutting through the Industrial District, Beacon Hill, and Rainier Beach. A number of streets cross the corridor, allowing vehicles to pass under the transmission lines throughout CA's length. The Chief Sealth Trail curves through the ROW for about 4 miles, providing one of the substantial greenspaces for walking, running, and biking in this part of Seattle. However, towards the south end of the Chief Sealth Trail the Creston-Duwamish Green Line branches west, crossing I5, the Duwamish River, and State Route 99 before reaching SCL's Duwamish Substation. While vehicular access to the ROW remains good throughout the Green Line, ROW habitat is fragmented here due to the highway crossings and industry - not ideal given both the lack of greenspace and the proximity to the Duwamish River.

Land Ownership

The area surrounding the ROW is made up primarily of privately-owned residential or multifamily properties, as well as a handful of parks, a golf course, and a number of schools. Commercial activity is centered along Martin Luther King Jr. Way S, and industrial activity is restricted to the area west of I5 along the Duwamish River.

Terrestrial and Aquatic Ecology

Because the dominant surrounding zones are industrial and residential, greenspace and habitat can be found primarily in the form of yards and a few parks. The corridor sits up a steep but vegetated slope which I5 parallels, while industrial activities take place along the Duwamish River. The Duwamish used to meander and braid through a wide floodplain (Waterlines: The Waterlines Project Map, 2014). However, the damming of tributary rivers upstream in the Duwamish-Green Watershed as well as channelizing of the lowest-lying parts of its floodplain to allow for industry and port activities led to the reduction of most of the Duwamish River's flow (HistoryLink). Years of pollution and runoff into the river have made the Duwamish a notable superfund site. In fact, the neighborhoods at the northern end of CA have a higher rate of asthma and lower life expectancy than is the average for Seattle (Gould & Cummings, 2013).

Historical and Current Uses

The part of the Duwamish Valley in which CA is located has been home to the Duwamish people "since time immemorial" (Gould & Cummings, 2013). Historically, areas immediately adjacent to the river were primarily mudflats (coastal wetlands), while the upland areas were a mixture of prairie – maintained through controlled burning – and forest. While movement of people was common for seasonal hunting, fishing, gathering, and trade, villages on the banks of the Duwamish River developed to provide gathering places for sheltering in the winter.

After the arrival of non-native people, and as is noted above, the banks of the Duwamish River were built up and industrialized, while the rivers braids were filled in in place of a long, deep channel. SCL's South Substation sits at the north terminus of CA within the old floodplain, while the Georgetown neighborhood and Boeing Field lie to the south. Again, the area immediately surrounding CA is more residential, but neighborhoods are bisected at multiple points by the highway, major roads, and the transmission line itself. The population in this part of Seattle is among the most vulnerable to displacement, and this population is made up of a much larger percentage of people of color than in other parts of the city. When the connection is made between the racial composition of the area, the higher vulnerability to displacement, the pollution and poor air quality, and the lack of the same substantial tree canopy compared to wealthier neighborhoods, it becomes abundantly clear that environmental justice is a major concern throughout the length of CA.

Stakeholders

In addition to SCL's typical internal stakeholders, a number of non-SCL stakeholders are actively engaged with ROW stewardship along the Creston-Duwamish Green Line; fewer are actively involved in vegetation management along the Chief Sealth Trail. Table 6 summarizes CA's primary stakeholders and their site associations.

Site

Chief Sealth Trail

The Chief Sealth Trail is used by walkers, runners, cyclists, and other nearby residents looking for outdoor green space. As highlighted in both Figure 10 and Table 6, the Chief Sealth Trail ROW also hosts three of Seattle's P-Patch community gardens. Although the gardens were established in the '70s and '80s, they continue to thrive to this day, and have plot waitlists estimated at six months to two years long.

Topographically, the Chief Sealth Trail weaves through berms and flat land, making its way gradually downhill as one moves north-to-south. Aside from the P-Patches, the vegetation is largely composed of grass and forbs. Consequently, even though the locations of critical and effective wire zones may vary depending on the distrubtion of pathways, berms, and transmission lines within

Table 6. Corridor A (CA) - Green Line and Chief Sealth Trail Stakeholders

Stakeholder	*Engagement Level*	*Interest/Stake*	*Site Associations*
Non-Profit Organizations (The Common Acre, Green Tukwila Partnership, Earthcorps, etc.)	4	Coordinate with community volunteers and City Light to lead or support restoration efforts Assist City Light with additional vegetation management efforts at select sites as needed Provide support for community outreach efforts	Creston-Duwamish Green Line
Community Volunteers	4	Contribute to restoration and stewardship efforts on the ROW	Creston-Duwamish Green Line Chief Sealth Trail
P-Patch Gardens (Snoqualmie, Maa Nyei Lai Ndeic, and Thistle)	4	The P-patch community gardens in CA were established in 1970's and 1980's, and serve diverse populations living in South Seattle Community gardeners maintain vegetation at low heights, growing food for themselves and to donate to food shelves	Chief Sealth Trail
Recreationalists & Residents (walkers, runners, cyclists, commuters, etc.)	2	Recreate in and enjoy the open space provided by the transmission ROW	Chief Sealth Trail

the ROW, there is little concern for physical limitations throughout the trail's length since the vegetation is managed to such a low height.

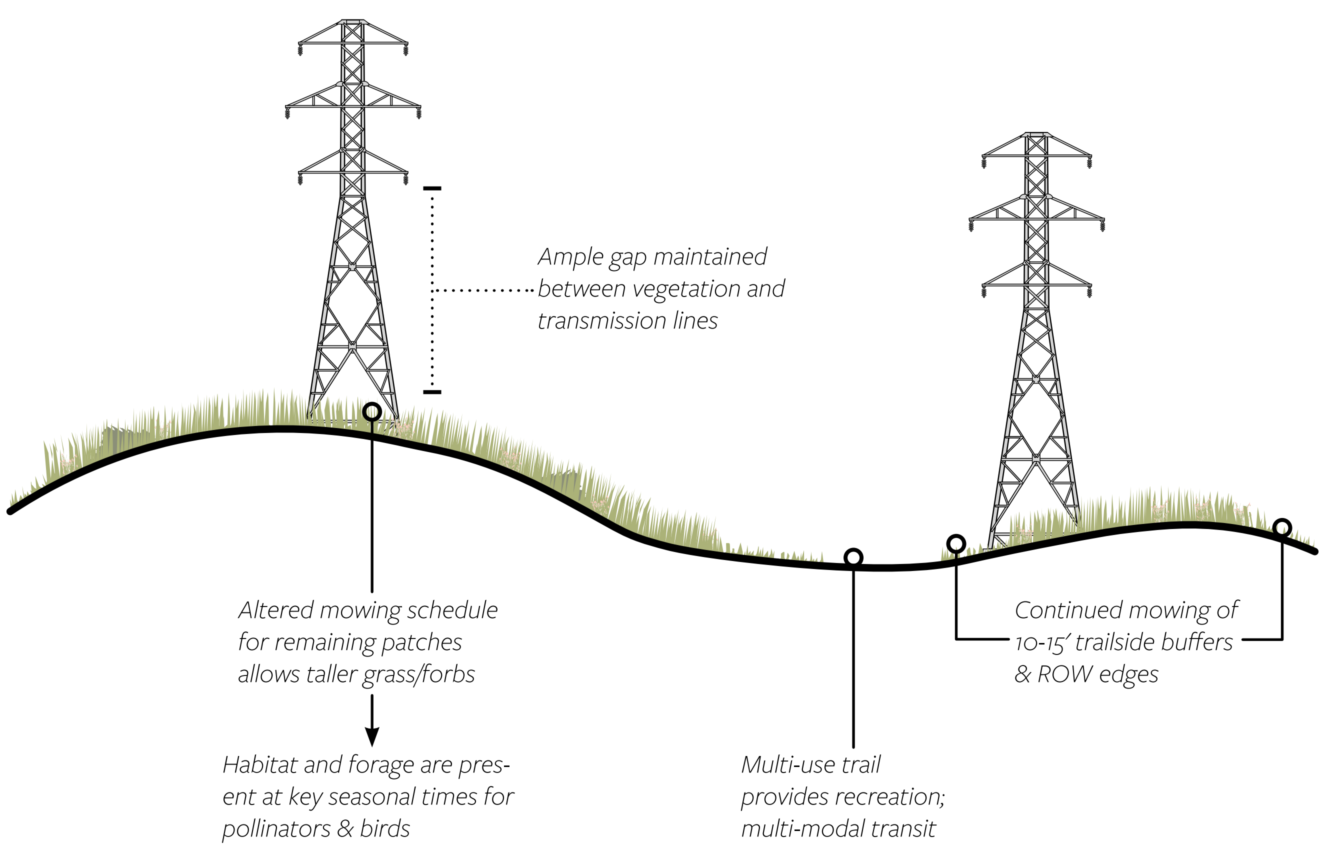
Creston-Duwamish Green Line

Prior to the implementation of a Stewardship Strategy in 2012, the Creston-Duwamish Green Line had an overabundance of invasive plant species. Implementation of the Stewardship Strategy has included a number of community members of the non-profits involved in ROW stewardship. Given the urban context, the Green Line hosts a mix of light recreational uses in addition to stewardship efforts: hillier sections on the east end can accommodate sledders (if or when it snows in Seattle), while other areas can be accessed for walking or running. The topography throughout the Green Line is varied, with flatter sections at the Duwamish Valley floor (where the ROW is primarily surrounded by industry) and slopes at the east and west ends. Similar to Chief Sealth Trail, the overall approach to more holistic vegetation management on the Green Line is more focused on cultivating low-growing plants that crowd out and biologically control incompatible species. It follows once again that a modified wire-border zone strategy is not uniformly applied, nor is it strictly necessary given the Green Line's approach.

Management, Functionality, & Monitoring

With some generalization, Figures 11, 12, and 13 illustrate the most notable and consciously multi-functional vegetation management approaches used on the Chief Sealth Trail and the Green Line, respectively. Functions produced and monitoring methods used are also depicted.

Figure 11. Management, functionality, & monitoring for conservation mowing on the Chief Sealth Trail



Note: above diagram is an approximation of actual scale based on typical patterns for this portion of the transmission ROW.

Figure 12. Management, functionality, & monitoring for community gardening on the Chief Sealth Trail

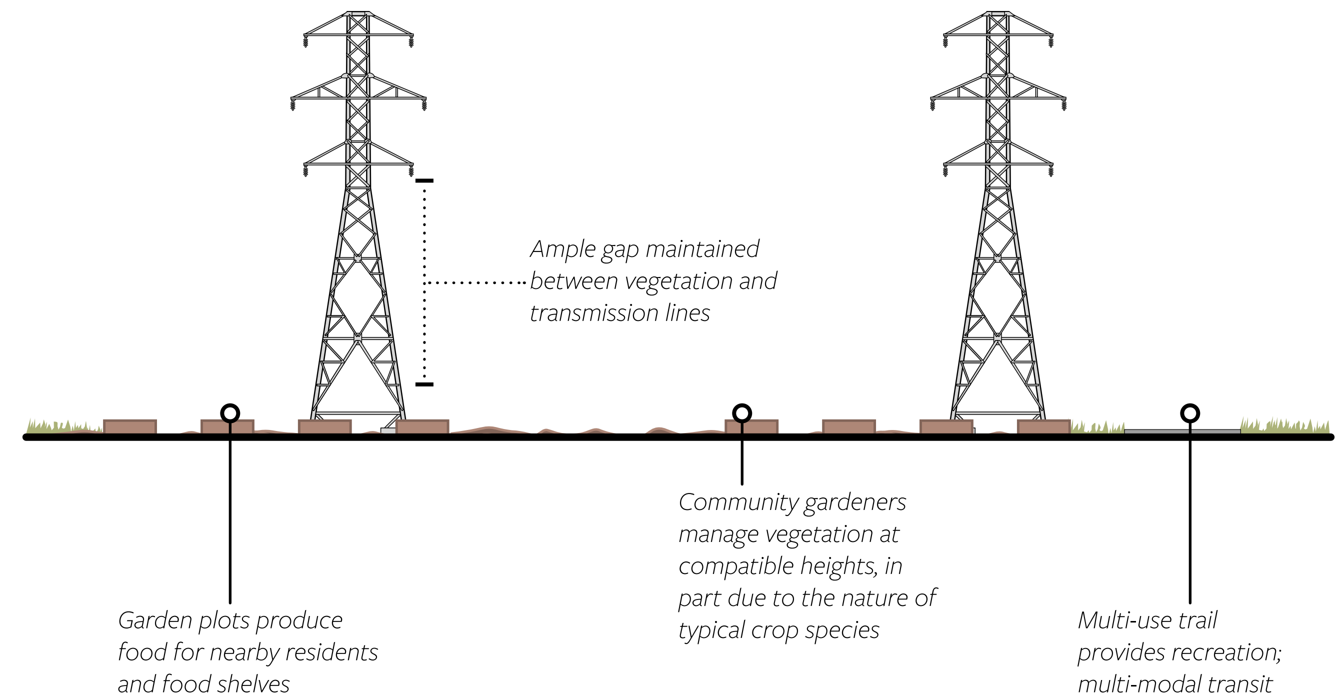
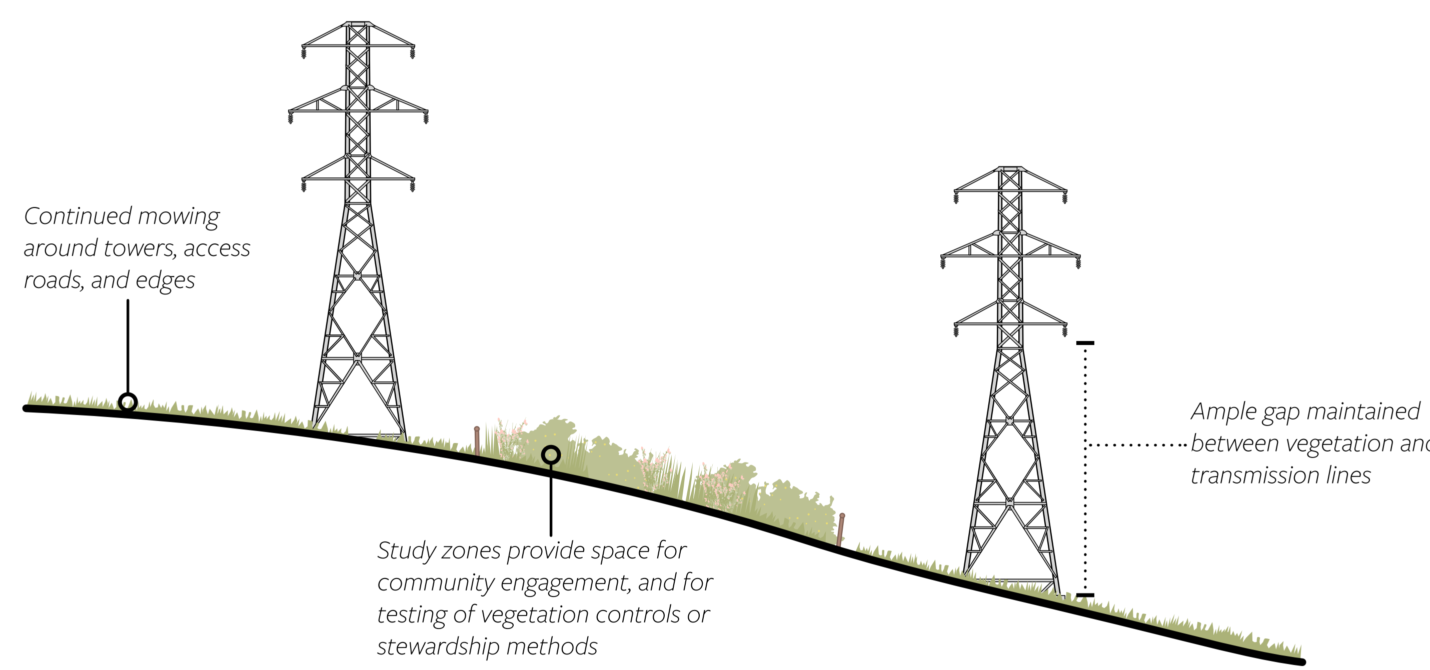


Figure 13. Management, functionality, & monitoring for pollinator-oriented IVM on the Creston-Duwamish Green Line



Note: above diagrams is an approximation of actual scale based on typical patterns for this portion of the transmission ROW.

Discussion

It should be reiterated that the cases included in CA are representative of existing efforts at SCL to move towards holistic ROW vegetation management. They are precedents which were implemented before this researcher was hired as an intern, and the researcher has no direct exposure to these ROW areas through work at City Light. The investigation completed for this thesis was based primarily on articles, management plans, GIS data, and interviews, and no new management strategies are recommended up to this point. Instead, the Chief Sealth Trail and the Green Line provide an urban baseline to which the ensuing case studies can be compared.

With that said, City Light can and should continue to expand and replicate its successful stewardship efforts to more areas - where appropriate - in CA. On the Green Line in particular, the success of pilot studies in biological control of incompatible plant species should be recognized. Ideally the pollinator-oriented IVM practices taking place there could be expanded beyond the confines of specified treatment zones, but the size and potential of a volunteer workforce limits the scope of controls that can be used (chemical controls are off the table) and of the total area that can be reasonably maintained and monitored. At some point, SCL's VMD crews or outside contractors will likely have to step in to remove invasive plants, control incompatible ones, and target those that are most desirable. That transition will be financially costly up front, and will likely be met with resistance from some who favor the efficiency of mowers. However, non-profit organizations have now done the preliminary work of engaging with SCL, articulating their values and needs, and actually managing and monitoring plots to increase their desired functionalities. City Light can apply the lessons learned from the utility's collaborations with these non-profits both to engage with other potential stakeholders, and to modify their vegetation management strategies based on the results of the Green Line pilot studies.

Conservation mowing on the Chief Sealth Trail presents a differenct scenario, with different lessons. There is virtually no cultural shift within the utility that needs to take place to implement the practice, just a modification of the typical mowing cycle. Additionally, this modification has made an opening for implementing IVM practices in select locations along CA, which should serve to create higher quality and more connected habitat for pollinators and birds. However, even though residents in the area have are now on board with the change. VMD worked with City Light's Communications and Marketing team to inform residents of the new management strategy, and hopefully the program will continue to expand after receiving positive feedback from the community.

Community gardens offer yet another picture of urban ROW multi-functionality. The gains are substantial: hundreds of pounds of food, vegetation managed to a compatible height, and immense social capital built through the relationships formed between neighbors at P-Patches. It is imperative to note the difficulty involved in initiating and sustaining any community garden: grassroots organization of community members is generally a prerequisite, and this researcher found no utilities going out of their way to build and fill new community gardens in their transmission ROWs. So while P-Patches may be an extremely multi-functional way to control vegetation, they are clearly not suitable for every setting. A viable population of gardeners is needed, as is their sincere and sustained interest.

Below: *Conservation mowing layout and schedule for Chief Sealth Trail*

Above: *Conservation mowing results on the Chief Sealth Trail*

With that said, it is not outlandish to sieze on the theme of food production as inspiration for new methods of vegetation control and function provision. Pollinator- and avian-oriented IVM pairs well with community-based agriculture - why not expand the opportunities for agriculture beyond the community garden model? Seattle already hosts the Beacon Hill Food Forest, a permaculture-based and community-run operation not far from the northern end of the Chief Sealth Trail. If the right stakeholders were present and interested, select locations could transition to low-growing food forests, crop rotation, or grazing. Significant outreach would be required, and the recipients of food or material products would have to be identified such that this food and other products are accounted for as public resources. Still, there is clearly interest in community agriculture not just in Seattle, but in the part of Seattle CA runs through.

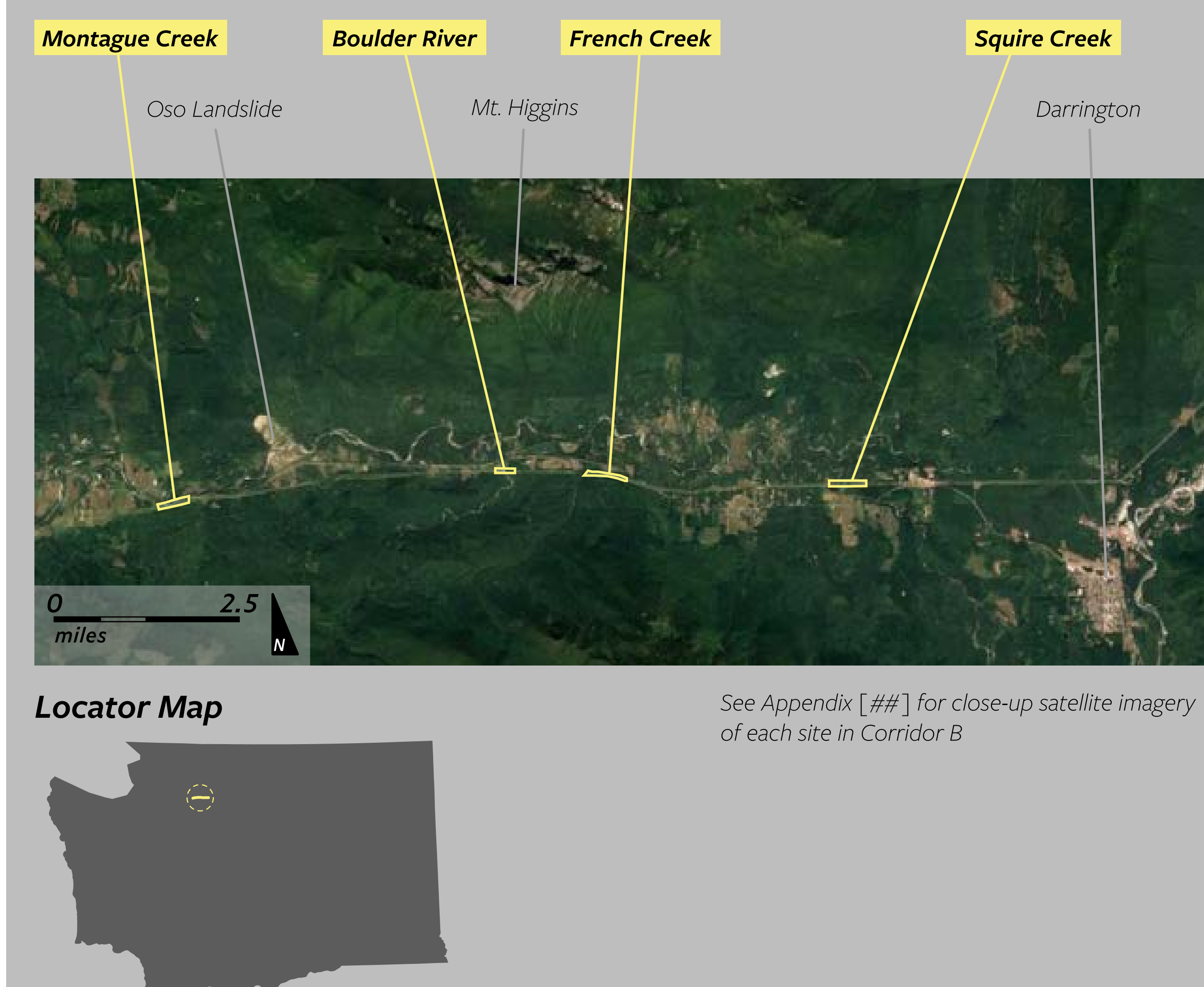
Corridor B: French Creek & Stillaguamish Valley

Mono-towers at French Creek, looking west
Photo Credit: Dylan Marcus

Context

There are two cases discussed in Corridor B (CB), both of which differ greatly from the cases described in CA. The Stillaguamish Valley case refers not to the valley in its entirety - including French Creek - but instead to a series of sites in which the Stillaguamish Tribe of Indians has expressed interest. No pilot projects have yet been implemented in collaboration with the Stillaguamish Tribe, but the collaboration itself has yielded interesting results and reflections. In contrast, the case of French Creek includes only SCL stakeholders and focuses on restoration, invasive species control, and analysis of historical imagery. The researcher does have direct experience with both of these projects through his work at City Light, although less directly in the case of French Creek, as the project was initiated prior to his tenure.

Figure 14. Context Map of Corridor B (CB)



See Appendix [##] for close-up satellite imagery of each site in Corridor B

Access

CB runs east-west parallel to State Route 530 (SR 530). This corridor has numerous access points from the highway, most of which are gated and not accessible to the public. French Creek Road/ NF 2010 and Fortson Mill Road are two of a handful that cross the Corridor and provide public access to USFS and Snohomish County lands, respectively. While it does not provide access to the ROW itself, the Whitehorse Trail – a multi-use trail for hikers, bikers, and equestrians – runs along SR 530 between Arlington and Darrington.

Land Ownership

Ownership of the ROW is mixed throughout this area. Properties immediately adjacent to SR 530 are largely privately-owned, while properties further north or south of the highway are a mix of recreational and productive forest lands owned by the state, county, or federal government; or by one of the many timber companies active in the area. Mt. Higgins lies in Skagit County to the north of SR 530 and the Stillaguamish River, while most of the valley – and the transmission corridor – lies in Snohomish County to the south, creating a braid with SR 530 from west to east.

Terrestrial and Aquatic Ecology

This corridor is located upland and south of the Stillaguamish River. The ROW's southern border is composed almost entirely of continuous forest (as noted above). In contrast, the northern border passes along or through a more varied matrix of forest patches, wetlands, and agricultural or semi-agricultural land. While the forest to the south is dominated by coniferous trees, the patches to the north of the corridor are slightly more varied, and include alder, maple, and other deciduous species often found in younger stands (Pojar & MacKinnon, 2004). Boulder River, French Creek, and others (shown in Figure 14 flow north across the corridor into the Stillaguamish River.

Although many river valleys in the Pacific Northwest are prone to landslides, the Stillaguamish Valley experienced one within the last decade: the Oso landslide occurred on March 22nd, 2014, and covered an entire rural neighborhood just north of the ROW corridor, killing 49 people. This event is notable because it highlights the instability of soil in the area, and the consequent need for erosion control when appropriate.

Historical and Current Uses

The Stillaguamish Tribe of Indians has resided in this area for generations, and was a party to the Treaty of Point Elliot, ensuring their continued access to those lands (Treaty of Point Elliott, 1855, 1855).

Logging, agriculture, and private residences occupy most of the area immediately surrounding the corridor. Small towns are found intermittently along the highway, recognizable by a cross-roads with a gas station, hardware store, and/or convenience store. Residences are concentrated in patches along SR 530, and the Whitehorse Trail provides a non-motorized recreation corridor through the length of the valley. Trails along Boulder River, up Mt. Higgins, and around Fortson Ponds all provide ample opportunity for non-motorized recreation. Parking areas along the high-way also provide access to the river for fishing.

Stakeholders

At the present time, the Stillaguamish Tribe is the most relevant non-SCL stakeholder in CB. Representatives from the Stillaguamish Tribe reached out to members of ELLBU and VMD to discuss the possibility of collaborating on ROW vegetation management in this area. The sites with which the Stillaguamish Tribe is assocated in Table 7 lie on a mix of ROW easement and fee simple properties, making other landowners potential stakeholders in future collaborations with the Tribe. While DNR is the property owner for one of the pilot study sites in Corridor B, they were not contacted for this project. Work at French Creek occurred in 2017 on both DNR and private easement properties.

Site

French Creek

From French Creek's east bank moving eastward, the land slopes steeply upwards, plateaus, and dips into a ravine, then rises back up to the mono-towers that were constructed in 2017. The mono-towers - pictured at the start of this case study - were installed to replace a pair of traditional lattice towers. The height provided by the mono-towers allows them to be located much farther away from the steep bank of French Creek than was the case with the lattice towers, thereby creating considerable defensible space from the threat of erosion. With no lattice towers above the bank of French Creek, there was no longer a need for an access road to run through the ravine, so the area of the road along with other areas disturbed by access and construction were restored to a more natural state. The newly-raised transmission lines combined with the dips and rises in the landscape can now accommodate some woody species in low areas, so forbs, seeds, shrubs and trees were disbursed strategically. A number of notable native plant species were found throughout the site during a single field visit, which can be found in Appendix D. But the presence of Scots broom (*Cytisus scoparius*) is hard to miss. Scots broom is an easily-identifiable, Class B noxious

Table 7. Corridor B (CB) - French Creek & Stillaguamish Valley Stakeholders

Stakeholder	*Engagement Level*	*Interest/Stake*	*Site Associations*
Stillaguamish Tribe of Indians	4	Based in Arlington, Washington, the Stillaguamish have lived, worked, hunted, and foraged throughout this area for generations Owns ROW easement properties within CB Interested in collaborating on ROW improvements through vegetation management Interested in creating opportunities for native youth education and development, which could include ROW stewardship efforts	All
Washington State Department of Natural Resources (DNR)	1	Owns ROW easement properties within and extending south from CB	French Creek
Snohomish County	1	Owns ROW easement properties within CB, as well as properties adjacent to the ROW and to Stillaguamish properties	Fortson Mill Road
Assorted Private Landowners	2	A number of private landowners own ROW easement properties within CB, many of which include riparian areas of interest to the Stillaguamish Tribe Vegetation management crews have cyclical contact with all private landowners on ROW to notify them of management activities	Montague Creek, Boulder River, Squire Creek

weed based on the rating of the Washington State Noxious Weed Control Board (Washington State Noxious Weed Control Board, n.d.), and is shown in the picture below. The plant is difficult to control; is known to suppress biodiversity, and has seeds that can remain in the soil for years after invading, even if thought to be eradicated.

Stillaguamish Valley

As has been mentioned, the Stillaguamish Tribe has entered discussions with City Light about collaborating on ROW vegetation management. Listening sessions were held twice online and once in-person (in a safe and socially-distanced fashion) with members of ELLBU, VMD, and the Stillaguamish Tribe between October and December of 2020. At the time of writing, a second in-person field visit is set to occur in January to work towards site prioritization and selection, but currently no projects have been initiated. However, representatives of the Stillaguamish Tribe asked questions about chemical control usage and its reduction, and about the potential for cultivating culturally-significant plants in the transmission ROW.

***Below**: Looking east and downhill from the mono-towers access road towards the edge of the French Creek restoration area. Note the dark green patches near the transmission tower - these are Scots broom.*

Photo Credit: Dylan Marcus

***Right**: Access road west of mono-towers following restoration planting and seeding in 2017*

***Below**: Scots broom (Cytisus scoparius)*

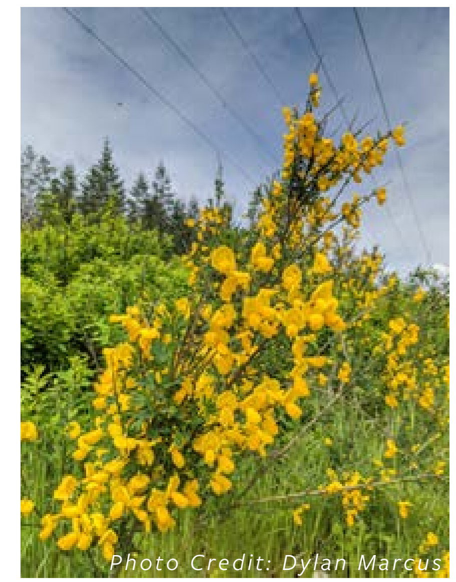


Photo Credit: Dylan Marcus

Photo Credit: Dylan Marcus

During the in-person meeting it became clear that priority areas for potential wildlife habitat should be identified. Creeks and rivers - particularly those paralleling the transmission lines - were places of particular interest given the need for intact riparian buffers, the potential for aquatic habitat enhancements, and the height restriction that prevents many wet-footed plant species that favor watersides from being compatible. The desire to control invasive plant species was also discussed. The sites of interest to the Tribe are highlighted in Figure 14, and include French Creek, Montague Creek, Squire Creek, and Boulder River.

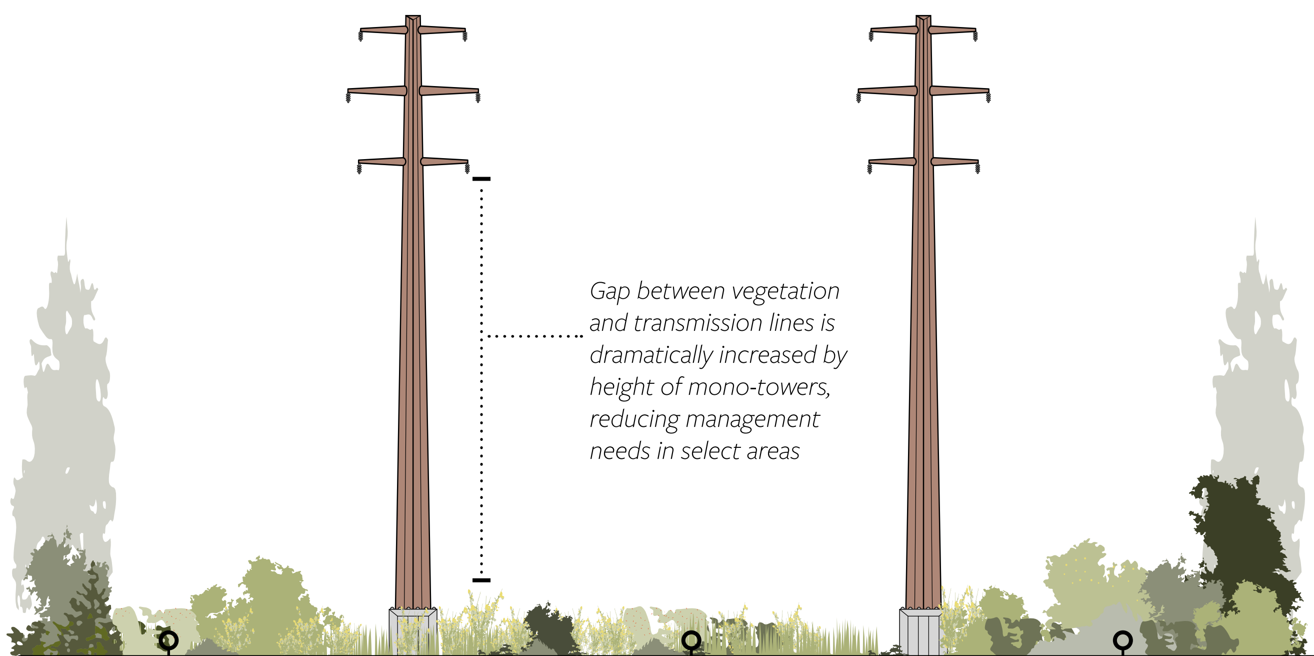
Management, Functionality, & Monitoring

French Creek is the only case study within CB that has received direct and recent stewardship attention, and Figure 15 depicts the management strategy, functionality, and monitoring efforts in place there. Additionally, Appendix A contains a series of maps that were created following an analysis of historical imagery of the French Creek restoration area. The analysis looked at the predicted presence of Scots broom for each year based on the appearance of its characteristic yellow blooms. Since vegetation management efforts have not yet been initiated with the Stillaguamish Tribe, no parallel diagram was produced, but likely management strategies for those areas of interest are presented in the case studies for Corridor C.

Discussion

At the outset, the context of CB necessitates a markedly different approach than CA. Frequent mowing is neither a necessity nor a viable option: the entirety of City Light's transmission ROW between the Bothell Substation and Spearhead Lake is predominantly managed by a 2-year cutting and mowing cycle. Some easement landowners do manage their own ROW vegetation in the corridor. But aside from a few smaller, private parcels, the majority of CB crosses larger easement properties or is owned by City Light. Because of the variation in ownership, topography, ecology, and land use, City Light is far more limited in its ability to unilaterally apply management strategies to its transmission ROW, as can be done in most of CA.

Figure 15. Management, functionality, & monitoring for mono-towers at French Creek ROW



Note: above diagrams is an approximation of actual scale based on typical patterns for this portion of the transmission ROW.

The approach taken to ROW management at French Creek is notable in that the mono-towers present an incredible opportunity for relieving vegetation management crews of some amount of work. The high line heights provided by the towers create a major opportunity zone that is clearly being utilitized to its fullest: the trees are able to grow to upwards of 30 feet on the west side of the creek, and low-lying areas on the east side have been planted out as well. The finished effect should be a matrix alternating between valleys and creeksides vegetated with taller, woody species; and flatter areas with less clearance vegetated with pollinator- and bird-friendly natives that hold the soil in place. The main challenge to this vision is controlling the spread of Scots broom within the site, which is the focus of experiments that are currently underway: 10 foot by 10 foot study plots have been set up throughout the site (shown in Appendix A), and are undergoing treatments for Scots broom removal to test their efficacy. On one hand, French Creek is a promising example

***Below**: Looking east towards a large Scots broom patch near the mono-towers at French Creek*

***Below**: Looking north towards Mount Higgins from the engineered ROW log jam on Boulder River*


Photo Credit: Dylan Marcus

of strategic restoration planting, mulching, and seeding in the ROW. On the other hand, the site has become a laboratory for Scots broom control, which will provide much-needed maintenance and increased biodiversity in the long-term.

Although discussions with the Stillaguamish Tribe are on-going, there are promising results already. First, the next case study on Corridor CC presents approaches to vegetation management that will be relevant to the riparian sites that are of particular interest to the Tribe, as well as to other non-riparian sites when they are identified. Second, Stillaguamish Tribe representatives have already articulated their desire to include native youth in ROW stewardship efforts to provide an opportunity for education and fostering important connections to culturally-significant landscapes and landscape functions. This prospect is exciting: not only for the benefits to native youth, but also it creates a positive long-term relationship with a stakeholder that holds compatible long-term goals regarding environmental stewardship.

Additionally, the sites the Stillaguamish Tribe are a blend of areas that have received recent attention from SCL (French Creek and Boulder River) and areas that had not yet received the same focus (Squire Creek and Montague Creek). French Creek has been discussed extensively in this paper. Lying just west of French Creek, the western shore of Boulder River was solidified using a large engineered log jam, on which restoration plantings were installed. 2020's hot summer was

a challenge for the year-old restoration area, making establishment difficult or impossible for a number of plants. The disturbance created by the log jam construction also made way for Scots broom and reed canary grass (*Phalaris arundinacea*) - a Class C noxious weed in Washington State - to sprout and begin to take hold (Washington State Noxious Weed Control Board, n.d.). So while new projects will hopefully come online at Squire and Montague Creeks, the control of invasives at already-established restoration sites near French Creek and Boulder River may require more immediate attention.

Corridor C: Lyle Creek to Spearhead Lake

Looking north from Rinker Creek's ROW crossing
Photo Credit: Dylan Marcus

Context

The location of Corridor C (CC) can be seen in Figure 16, running from its southern end just north of Darrington to its northern end just before SCL's transmission lines cross the Sauk River towards the Skagit Hydroelectric Project. The area is rural and is used by outdoor enthusiasts, as logging roads, mountain or dirt bike trails, and dispersed campsites are scattered across both sides of North Mountain (just west of CC). A repeating sequence of creek ravines, vegetated slopes and plateaus, and eroded pits used for storage or for off-road Vehicle (ORV) users can be seen moving south to north along the corridor - a contrast to CA and CB.

Locator Map

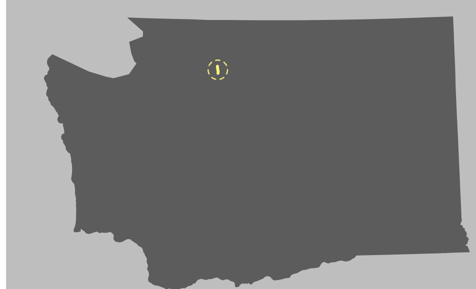


Figure 16. Context Map of Corridor C (CC)

Imagery from Google Earth

Access

CC can be accessed from State Route 530 – east of the corridor – towards its south and north terminals; and can be accessed from unpaved county roads to the west. Figure 16 highlights the primary access points for SCL vegetation management crews completing routine maintenance. Figure 16 also makes note of the unmapped and sprawling network of forest roads and ORV trails along and between Christian Camp Road and Concrete Sauk Valley Road – two Skagit County roads which cross the south and north ends of the corridor, respectively.

Land Ownership

The Sauk-Suiattle Indian Tribe's main property is located on the east side of State Route 530 at the southern end of this corridor. The Tribe also owns Spearhead Lake, located just west of the ROW at the corridor's north end. The majority of the land surrounding the ROW is working forest, owned by the Washington State Department of Natural Resources (DNR), or by Sierra Pacific Industries (SPI) – one of the largest lumber companies in the US, based in California (Sierra Pacific Industries - Our Business, n.d.). The US Forest Service (USFS) also owns land just east of the corridor's north end on Concrete Sauk Valley Road where there is a public boat launch.

Ecology

Multiple creeks run through sections of the corridor down towards the Sauk River, namely Lyle Creek, which runs across on the southernmost parcel; and Rinker Creek, located at the approximate midpoint of the corridor. The Sauk River undulates towards and away from the corridor, and in two locations the top of its steep western bank intersects the ROW. There is also a large bog downhill and east of the corridor towards its north end; and – again – Spearhead Lake is located at the north end. The working forest surrounding Corridor A is composed of a typical assortment of native species such as Douglas fir (*Pseudotsuga menziesii*), sword fern (*Polystichum munitum*), and salal (*Gaultheria shallon*).

Historical and Current Uses

The Sauk-Suiattle Indian Tribe (SSIT) have lived in the area this corridor runs through for generations, and the Treaty of Point Elliot ensures that the SSIT will continue to have access to their ancestral lands for hunting and gathering (Sauk-Suiattle - Index, n.d.; Treaty of Point Elliott, 1855, 1855). SSIT continues to use the area for those purposes and others, and certain sites are sacred.

Over the past few decades management of the forests surrounding CC has required the construction and continued maintenance of logging roads, accessible from Concrete Sauk Valley Road and Christian Camp Road. Public access is currently allowed on the two main roads and a handful of roads without signage. The level of access provided by the forest road network has resulted in the proliferation of ORV use throughout the forests, often without consent of the landowners and with disregard to any aquatic resources. Camping, dumping, shooting, and even meth labs are all activities that have and continue to occur in and around the corridor, causing degradation of habitat as well as unwanted erosion. In fact, it is well-known among SCL crew members and representatives of the SSIT that ORVs frequent both the ROW adjacent to Rinker Creek as well as the Creek itself: while riding up the creek is incredibly damaging to the environment, it presents an interesting obstacle for determined recreationalists.

Top Left: *Erosion by the transmission tower footings above Rinker Creek resulting from excessive ORV use*

Bottom Left: *One intact example of the many often-ignored signs on access roads near CC*

Bottom Right: *Dumped refrigerator, couch, and other miscellaneous items close to Spearhead Lake*

Table 8. Corridor C (CC) - Lyle Creek to Spearhead Lake Stakeholders

Stakeholder	*Engagement Level*	*Interest/Stake*	*Site Associations*
Sauk-Suiattle Indian Tribe (SSIT)	3	Based at south end of CC, and has lived worked, hunted, and foraged in this area for generations Owns land adjacent to the ROW at the south and north ends of CC Concerned with perpetual damage done to their property and the surrounding area by ORV users and other recreationalists Signatory on petition to Skagit County to gate off main roads to CC	Lyle Creek Spearhead Lake
Washington State Department of Natural Resources (DNR)	2	Owns land within and adjacent to the ROW throughout CC Concerned with perpetual damage done to their property and the surrounding area by ORV users and other recreationalists Signatory on petition to Skagit County to gate off main roads to CC	Lyle Creek Spearhead Lake
Sierra Pacific Industries (SPI)	2	Owns land within and adjacent to the ROW throughout CC Concerned with perpetual damage done to their property and the surrounding area by ORV users and other recreationalists Signatory on petition to Skagit County to gate off main roads to CC	Spearhead Lake
Skagit County	2	Owns and is responsible for maintenance of Christian Camp Rd. and Concrete Sauk Valley Rd. Target of petition to gate off main roads to CC to prevent/curb encroachment and damages to property and ecology	CC (entire corridor)
Off-Road Vehicle (ORV) Users/ Recreationalists	1	Users of the expansive network of trails, roads, and natural obstacles running through and around CC While not an organized or formal group, unidentifiable individuals in this group are responsible for the ecological and social damages caused by excessive (and often illegal) ORV use	CC (entire corridor)
Washington Conservation Corps (WCC)	4	Contracted by SCL to complete removal and monitoring of Scots broom (*C. scoparius*) on SCL's fee-owned property near Spearhead Lake May be contracted by SCL for assistance on other ROW VM activities in the future	Spearhead Lake

Stakeholders

The large number of separate entities with a stake in Corridor C is indicative of the complexity of addressing challenges there. Over the last year SSIT has led an effort to bring together the main landowning stakeholders – the SSIT, SCL, DNR, and SPI – to petition Skagit County to allow for the installation of locking gates at strategic locations along Concrete Sauk Valley Road and Christian Camp Road. It is widely acknowledged by VM crew members, engineers, members of ELLBU, and representatives of the SSIT in the course of in-person meetings that gates might only do so much to prevent ORV users from accessing the sprawling network of roads and trails that have been built. Even so, it has become increasingly clear that some action must be taken to reduce ORV and camping activities, as the cumulative damage they have done to ecological and cultural resources is considerable.

Clearly the issue of ORV use and public access to the area in general is a major challenge to be addressed. However, it has become apparent over the course of research that addressing that challenge has a timeline longer than that of this project, and is outside of this project's scope (while still providing relevant information about the social climate surrounding Corridor C).

An on-site listening session and a number of email exchanges have taken place between City Light and the SSIT, and another in-person, on-site listening session took place between members of ELLBU and VMD - this researcher has been present for all of those listening sessions. These discussions made clear that while Rinker Creek remains a concern for both SCL and the SSIT due to erosion occurring there as a result of ORV use, Lyle Creek and Spearhead Lake were identified as areas that can and should be prioritized for immediate action.

The SSIT has also reached out to SCL to discuss collaborating on ecological enhancement projects on Corridor C: Lyle Creek and Mile 56 (near Spearhead Lake) are properties owned by DNR or SCL, so there is a higher degree of flexibility for SCL to implement alternative management strategies or to apply herbicides selectively. The properties are also adjacent to areas owned by and holding significance to the SSIT.

Site

Lyle Creek

Lyle Creek runs beneath SCL's transmission lines as they cross a DNR property at the south end of Corridor C. The southern portion of the site – which Lyle Creek runs through – includes a gated

Right: *Looking North towards Lyle Creek*

Below: *Overturned vehicles south of Spearhead Lake*

access road for SCL, a bridge across the creek, and dense patches of European cutleaf and Himalayan blackberry (*Rubus lacinatus* and *Rubus armeniacus*, respectively). There is a preponderance of native shrubs and trees as well, the former being shaded out in many cases by blackberries. In fact, Himalayan blackberry frequently grows right up to the edge of Lyle Creek, resulting in less shade for the creek than would be favorable to for supporting native fish populations.

The land slopes up substantially towards the transmission towers at the north end of the site. The slope is also vegetated, but is comprised of more native species than is the case in the parts of the site at lower elevations.

Spearhead Lake / Mile 56

SCL owns the parcel just north of where Concrete Sauk Valley Road crosses Corridor C, which is about a half-mile long and encompasses almost three spans. The imagery in Figure 16 shows a number of side roads extend past the ROW edges, one of which provides access to Spearhead Lake. While Spearhead Lake is an important area to SSIT, its banks have hosted large gatherings of campers and partiers not associated with the Tribe, and litter has accumulated as a result. Because

Above: *Looking north from the south shore of Spearhead Lake. The tree on the left has been used for target practice.*

Below: *Spearhead Lake ROW, following Scots broom treatment by WCC crews*

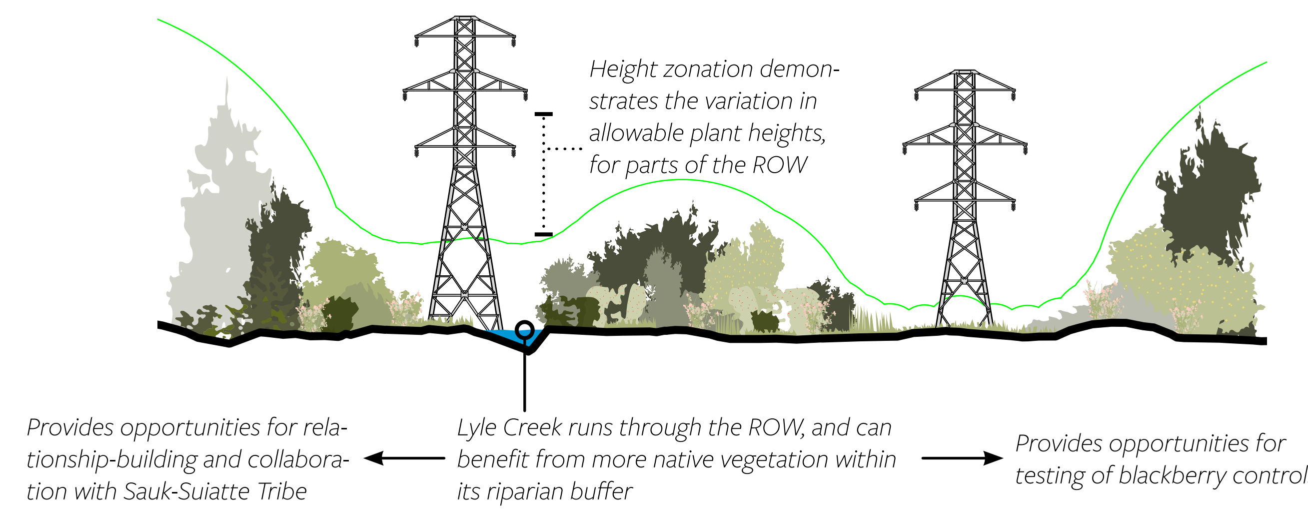
of the significance of Spearhead Lake to the SSIT, as well as the value of the surrounding areas for cultural practices, representatives from the Tribe have reached out to SCL in hopes of enhancing habitat under the transmission lines, with an eye toward attracting elk. It is hoped that the potential reduction of vehicular traffic in this area resulting from gates going up would dramatically increase the attractiveness of the area to elk, so ecological enhancements would be timely.

The landscape along this portion of Corridor C is flat when compared to other parts of the corridor. With that said, there are a number of gradual hills and dips, often rising up from the access road's edges and dipping down towards the edge of the ROW. Vegetation here consists of species listed in Appendix D, with a variety of native species present and a considerable abundance of Scots broom and common tansy (*Tanacetum vulgare*). Vine maple (*Acer circinatum*) and cascara (*Rhamnus purshiana*) can be seen poking up above the lower shrubs, but not (yet) encroaching on the 20 feet of clearance needed for the transmission lines. Vegetation management crew members have stated that maintaining good visibility for easily estimating line clearance during inspections - which could occur at any hour of day or night, anywhere on the transmission line - is essential to making their work safer and more efficient.

Management, Functionality, & Monitoring

ROW stewardship efforts at Lyle Creek and Spearhead Lake have progressed quickly over the six months leading up to the writing of this thesis. While Figures 17 and 18 illustrate the management, functionality, and monitoring measures that are slated for implementation or have been implemented at the two sites, additional discussion of those measures is merited.

Figure 17. Management, functionality, & monitoring for ROW riparian buffer around Lyle Creek



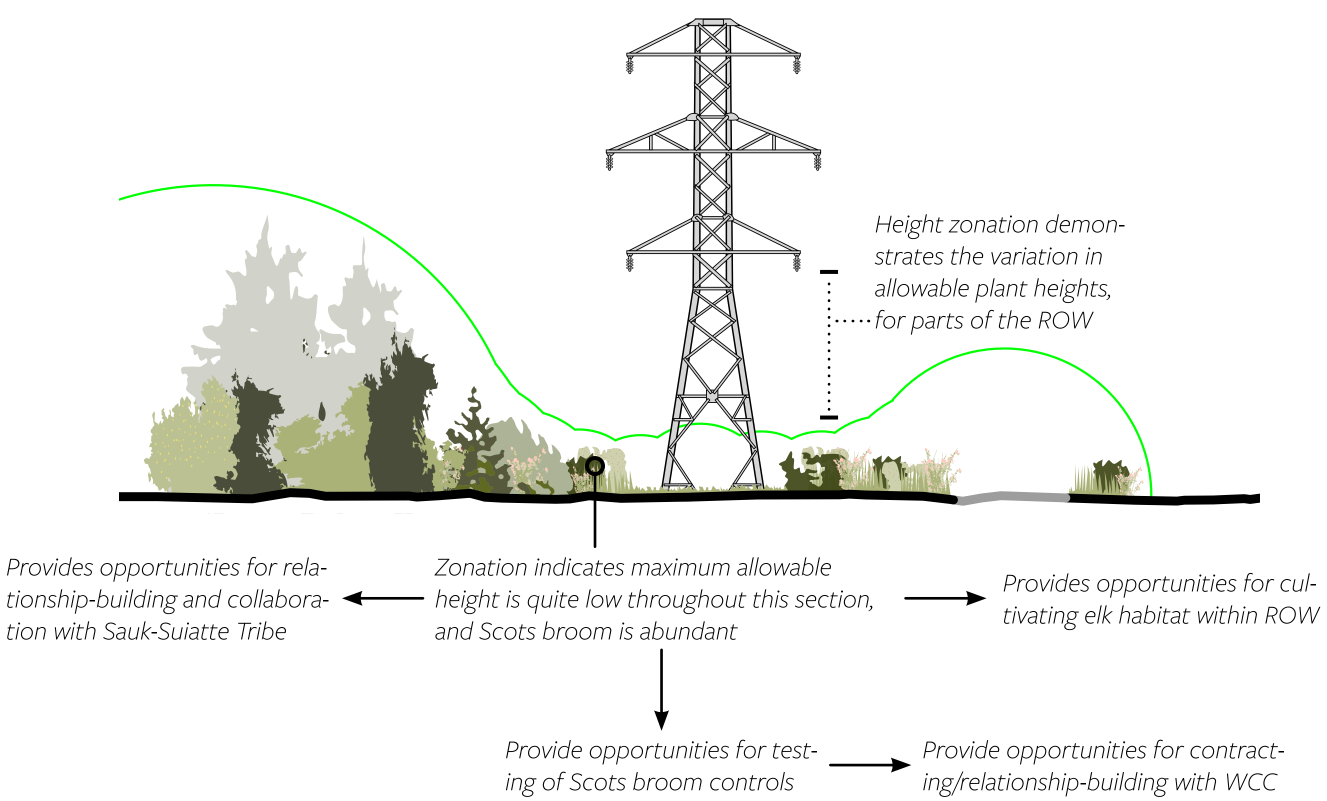
Lyle Creek

The main objectives of collaboration between SCL and the SSIT at Lyle Creek are to eradicate and/or control blackberry infestations, to cultivate native and culturally significant plants, and to maximize vegetative cover of the creek itself. To this end, the SSIT has already contracted with the Skagit River System Cooperative to create a riparian planting plan. Vegetation management crews have expressed concerns about certain fast-growing native species, like red alder (*Alnus rubra*) and black cottonwood (*Populus balsamifera* ssp. *trichocarpa*), that can spread quickly and require fast removal, thereby causing more work for crews. However, the restoration plans for the area around Lyle Creek should, over time, suppress faster-growing species through the cultivation of a lower-growing riparian buffer. The approach to meeting those objectives follows a typical restoration pattern, as opposed to the current cycle of cutting and mowing on the site every 2 years, as there is agreement among ELLBU and the SSIT representatives that while cutting and mowing has produced reliably safe conditions, it has contributed to the proliferation of both blackberry species present.

Spearhead Lake / Mile 56

The main objectives of collaboration between SCL and the SSIT at Spearhead Lake/Mile 56 are to control Scots broom, to cultivate native and culturally significant plant species, and to create better habitat for elk. Because of the abundance of both Scot's broom and of native species, this area has been identified by SCL as ideal for implementing another experiment on control of Scots broom. Accordingly, three treatment zones with similar plant communities and topographic patterns have been delineated, and transects – each encompassing three 10 foot by 10 foot study plots – have been mapped to this point using GPS points and pin flags. Appendix C contains figures showing where zones and plots are located, and shows the three Scots broom treatments that have been implemented: cut, cut and cover (covering with wood chip mulch), and cut and treat (spot herbicide treatment of cut stems with Milestone™). WCC crews completed the treatments as prescribed, and recorded the first two tallest plant heights as well as the percent cover by species for all study plots. Appendix B also contains the preliminary results of the inventories taken by WCC crews.

Figure 18. Management, functionality, & monitoring for Scots broom control and elk habitat cultivation on Spearhead Lake ROW



Discussion

CC presents an entirely different context coupled with vastly different social dynamics than CA and CB. The issues with ORV usage are acute, and ideally Skagit County will recognize not only the need for closure of Concrete Sauk Valley and Christian Camp Roads to prevent further damage, but also the need for allocating a more appropriate space for ORV recreation elsewhere.

With that said, projects at Lyle Creek and Spearhead Lake have lessons that relate directly to the discussions with the Stillaguamish Tribe. Both Lyle Creek and Spearhead Lake underwent a height zonation analysis to better inform how a modified wire-border zone approach - which is prescribed for this part of the transmission ROW by the Skagit Project's License Agreement - would play out. The zonation analysis assumes that a minimum 25 foot clearance distance is required around every individual transmission line to provide adequate sight-lines and safety. Appendix B contains the maps that were created from that analysis, which will be used to inform the placement of individual plants and seed mixes within 50-100 feet of Lyle Creek, and the targets for management of the wire and border zones at the Spearhead Lake treatment zones. The distribution of wire and border zones at Spearhead Lake is roughly what could be expected by anyone with prior knowledge of the approach, but the same could not be said of Lyle Creek. A multitude of critical wire zones as well as opportunity zones exist throughout Lyle Creek's 50 and 100 foot buffers, highlighting the usefulness of height zonation for managing riparian areas. Meanwhile height zonation appears to be excessively detailed for managing flatter areas depending on the specific objectives, as the plant communities desired for elk forage or pollinator habitat can be low-and-slow growing accross the ROW's width. When shading a creek is not a concern, maximizing height may not be necessary to cultivate the desired multi-functionality.

CC also reiterates the potential benefits of partnering with local tribes. Like the Stillaguamish Tribe, the Sauk-Suiattle Tribe has resided in this region for far longer than City Light's transmission lines, and their knowledge of the landscape, its ecologies, and its uses extends beyond the combined knowledge of ELLBU and VMD. As such, they not only are vested in the stewardship of the environment and cultural resources throughout the area, but also are likely to have an interest in collaborations that last not weeks or months, but years, given consensus on project objectives. Their knowledge and support should be continuously sought-out and incorporated into the adaptive management of Lyle Creek, Spearhead Lake, and the rest of CC.

Reflection

Looking west from the Oregon Trail beneath transmission lines in Boise, Idaho

Photo Credit: Dylan Marcus

In the same way that case studies were investigated using the lenses of context, stakeholder, and site, the lessons learned through evaluating those case study will be discussed using the same three perspectives. Key points are summarized in Table 9, the most salient of which are discussed in more depth in the remainder of this section.

Context

Context can predict opportunities, challenges, and functional needs ahead of stakeholder engagement.

Context is an important predictor of opportunities and challenges at every site investigated. By looking solely at the urban neighborhoods surrounding the Chief Sealth Trail, it can be inferred that opportunities for multi-modal transportation and recreation on the ROW is likely in high demand, and certain predictions of appropriate plant communities can be inferred as well. Conservation mowing may still cultivate grassy plant communities, but the modified mowing schedule accommodates wildlife habitat while keeping vegetation low enough to maintain high visibility throughout the trail's length - all the more important in a populated area, as pointed out by proponents of Crime Prevention Through Environmental Design (CPTED - Police | Seattle.Gov, n.d.). Similarly, the industrial land uses and highways that surround and fragment the Creston Duwamish Green Line make clear the need for creating connections between otherwise patchy pollinator and wildlife habitat for the benefit of both humans and the built-up local ecology.

In the same way, the presence of ecologically- or culturally-sensitive areas close to the ROW - such as any of the rivers or creeks in the Stillaguamish Valley or Spearhead Lake - indicates a range of potential functional needs. In the case of French Creek the modification of line height using newly-installed mono-towers provides adequate defensable space between the eroding bank and transmission towers on either side of the creek. At the same time taller vegetation is allowed to grow than might otherwise be possible beneath the transmission line. Although other creeks may not be spanned by mono-towers in the near future (namely Lyle Creek), the challenge posed by channel migration and the benefits offered by vegetated riparian buffers make creeks important contextual features to identify and plan around. Along the same vein, parcel maps show the ownership of Spearhead Lake by the SSIT, indicating a need to engage with the Tribe from the start, and - as described in the case study itself - a further need to implement a context-based solution like limiting ROW access via locked gates.

History provides essential context for project prioritization based on race, social, and environmental justice concerns.

In many cases, historic analysis provided a basis for prioritizing a ROW project, and for implementing the City of Seattle's RSJI and EJI in the process. The Stewardship Strategy for the Creston Duwamish Green Line was developed with full knowledge of the historical environmental, race, and social justice considerations that the ROW's demographic context brings to the table. The built-up condition, lack of tree canopy, and disproportionately adverse health outcomes for an area populated largely be people of color made the ROW in this area a high priority for a management strategy that both engaged and directly benefited the human community surrounding it. In a similar sense, the damages done to the ROW and its context over the past few decades around Spearhead Lake have resulted in a relatively fast implementation of pilot projects following only one on-site meeting and a series of email exchanges with the SSIT. Once City Light was able to hear and see SSIT's concerns and to recognize the cultural resources that the area around the ROW have historically provided, the priorities for pilot projects and ROW management throughout the corridor became abundantly clear. The fact that landscapes traversed by the ROW have historical and current cultural significance to the Sauk-Suiattle and Stillaguamish Tribes make it all the more important for formal collaborations with those Tribes to be prioritized and solidified under the City of Seattle's RSJI and EJI.

Stakeholder

An equity lens reveals that the greatest benefit is accrued when it goes to the community with the greatest need.

Related to the City of Seattle's RSJI and EJI is the idea of equitably allocating benefits. As exemplified in the case of the Creston Duwamish Green Line, the benefit accrued by residents of the Duwamish Valley through increased access to open space, ownership/stewardship of the ROW, P-Patch gardens, and the cultivation of functional habitat is greater than what might be accrued by a population of the same size in other parts of Seattle or Washington State, who may have easier access to all of those benefits. If historical analysis is able to provide insight into which communities have been marginalized through institutional and structural racism, directing engagement efforts towards those communities that have suffered the most is one way for City Light to mitigate those fraught histories.

Table 9. Matrix of Key Points

	CA		CB
	Creston-Duwamish Green Line	*Chief Sealth Trail*	*French Creek*
Context	Addressing habitat fragmentation may require fragment identification. History provides essential context for project prioritization. Context can predict opportunities and challenges ahead of stakeholder engagement.	Urban ROW contexts mean more users, more uses, and more diverse needs. Context can predict opportunities and challenges ahead of stakeholder engagement.	History provides essential context for project prioritization. Context can predict opportunities and challenges ahead of stakeholder engagement.
Stakeholder	The greatest benefit is accrued when it goes to those with the greatest need. Community/organization-driven stewardship is a management strategy and a benefit unto itself. Listening goes a long way.	The greatest benefit is accrued when it goes to those with the greatest need. Community/organization-driven stewardship is a management strategy and a benefit unto itself.	Implement positive changes through large cross-departmental projects, and follow up. Not all pilot projects need an external stakeholder.
Site	[Bio]diversity is an essential tool to holistic vegetation control. Use replicable, accessible, and scalable monitoring tools. Parcel ownership and size are leverage points.	[Bio]diversity is an essential tool to holistic vegetation control. Use replicable, accessible, and scalable monitoring tools. Parcel ownership and size are leverage points. Pick low-hanging fruit first: opt to modify management instead of overhauling when possible	Waterbodies bring both challenges and opportunities for plant and use compatibility. Use replicable, accessible, and scalable monitoring tools. Parcel ownership and size are leverage points.

Table 9. Matrix of Key Points (continued)

CB	CC		
Stillaguamish Valley	*Lyle Creek*	*Spearhead Lake*	
History provides essential context for project prioritization. Context can predict opportunities and challenges ahead of stakeholder engagement.	History provides essential context for project prioritization. Engage the neighbors.	History provides essential context for project prioritization. Context can predict opportunities and challenges ahead of stakeholder engagement.	***Context***
Pick low-hanging fruit first: pursue all leads to genuinely interested stakeholders. Community/organization-driven stewardship is a management strategy and a benefit unto itself. Listening goes a long way.	Pick low-hanging fruit first: pursue all leads to genuinely interested stakeholders. Community/organization-driven stewardship is a management strategy and a benefit unto itself. Listening goes a long way.	Pick low-hanging fruit first: pursue all leads to genuinely interested stakeholders. Community/organization-driven stewardship is a management strategy and a benefit unto itself. Listening goes a long way.	***Stakeholder***
Use replicable, accessible, and scalable monitoring tools. Parcel ownership and size are leverage points.	Waterbodies bring both challenges and opportunities for plant and use compatibility. Use replicable, accessible, and scalable monitoring tools. Parcel ownership and size are major leverage points.	Use replicable, accessible, and scalable monitoring tools. Parcel ownership and size are leverage points.	***Site***

Management through stakeholder-driven stewardship is a management strategy and a benefit unto itself, and must occur within the context of the primary objective of SCL's ROWs: transmission.

Nearly every case study investigated involves some degree of community- or organization-driven stewardship, with each stewardship effort being arranged in a different fashion. Regardless of those differences, the relationships SCL has fostered between itself and stakeholders can be viable approaches to vegetation management, and can yield benefits simply by producing new relationships between SCL and non-SCL stakeholders. Community gardening and urban restoration on the ROW are easy examples, as they manage vegetation to reasonable heights, produce food and pollinator habitat, and provide opportunities for education and building the social capital of communities. In the efforts to collaborate with the Stillaguamish Tribe, there is desire to increase biodiversity and resilience of ROW habitats and wildlife populations through vegetation management, and there is also a clear acknowledgement of the Tribe's desire to create educational opportunities for native youth.

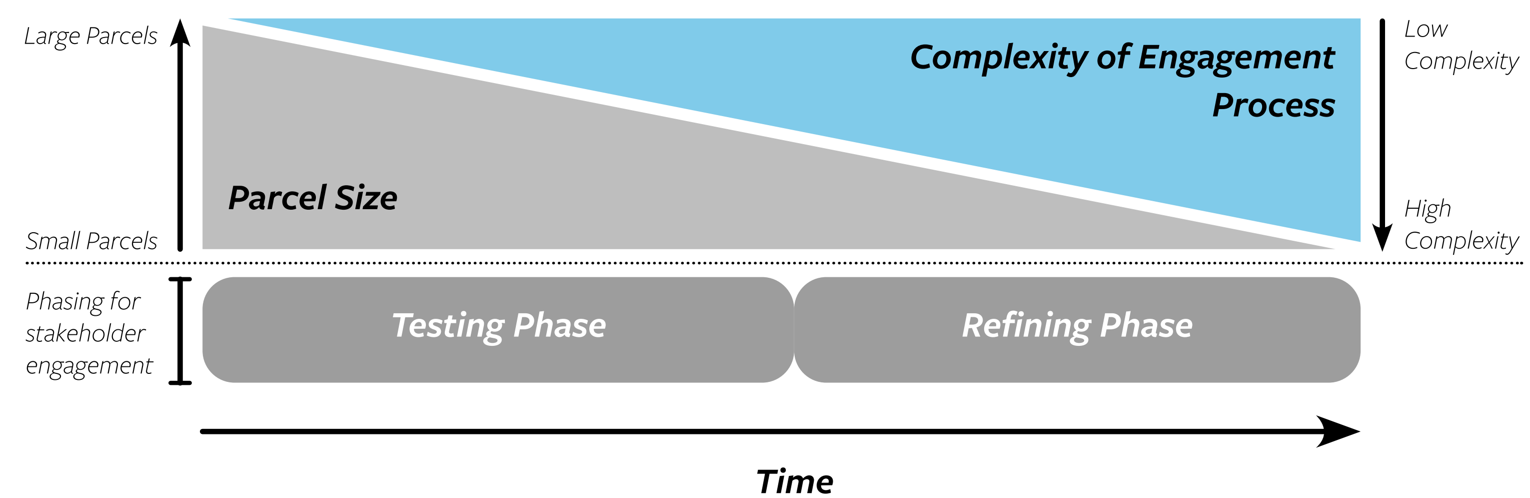
Although the same educational opportunities are not present in the collaboration with the SSIT, the fact that City Light can use effective vegetation management to build better relationships with tribes is beneficial to the process of re-licensing the Skagit Hydroelectric Project. Re-licensing is a regimented multi-year process that involves numerous ecological studies and communication between City Light and external stakeholders, so having positive relationships with tribes - who clearly have a stake in the Project - should help to make re-licensing go more smoothly than it might otherwise.

It is worth noting that facilitating community-driven stewardship allows SCL to engage with the RSJI in yet another way, in that these efforts could act as some level of workforce development in communities that might not have access to such learning or networking opportunities with SCL staff. Workforce development would only work in this way, though, if City Light employees are up front and enthusiastic about discussing employment possibilities with youth participating in stewardship programs.

Pick low-hanging fruit first: pursue all leads to genuinely interested stakeholders.

One of the most substantial hurdles in stakeholder engagement is often the first: making meaningful contact with stakeholders. Meaningful engagement does pay dividends over long periods of time, but reaching consensus and a point at which action can be taken by all stakeholders is no small feat. The transmission line P-Patches discussed in CA are excellent examples of creating multi-functionality out of minimally-functional space, but it took years to establish and gain acceptance of those gardens, despite the grassroots efforts that led to their construction. The fact that members of both the Stillaguamish and Sauk-Suiattle Tribes took the step of reaching out directly to City Light to collaborate on ROW vegetation management commands the respect and attention of SCL employees, and this type of engagement represents that "low-hanging fruit" mentioned in this paragraph's opening. If stakeholder stewardship and collaboration are valuable to City Light, instances in which stakeholders engage SCL (and not the reverse) are more valuable yet, as they can significantly speed up the timeline for action and project implementation. Figure 19 provides a conceptual interpretation of how City Light might proceed with potential changes to vegetation management approaches across its entire transmission ROW. ROW sites that involve less complex engagement processes - due either to fewer stakeholders or to high levels of stakeholder interest - can and should be prioritized. Since large, continuous ROW parcels - regardless of ownership - are inherent leverage points by having the potential to impact larger areas with fewer stakeholders contacted, they can be prioritized as well. After these preliminary pilot studies with interested stakeholders on larger parcels have produced results through rigerous monitoring, the original approaches can be refined and applied to smaller, more complex ROW areas.

Figure 19. Parcel size, engagement complexity, and time as it relates to ROW project phasing



Listening goes a long way.

Listening pairs well with pursuing interested stakeholders first, and is best exemplified through City Light's recent engagement with the Stillaguamish and Sauk-Suiattle Tribes. While communications with the Stillaguamish have led to further planning in the short term, it seems likely that one or more pilot projects will come to fruition by next summer - all as a result of two remote and one in-person listening sessions over the last three months. With regards to the Spearhead Lake ROW, a single listening session with the Sauk-Suiattle has already led to pilot project implementation. Riparian buffer establishment is still in the planning stages for Lyle Creek, but it is likely that pilot project implementation will occur there as well in the near future.

Listening to non-SCL stakeholders is essential to building social capital and fostering multi-functional ROW landscapes, but the positive impacts of those projects can only be realized if SCL stakeholders are acting as teammates. Listening sessions - both online and on-site - were also held with SCL vegetation management crew members to hear their concerns about the state of the ROW in general, and their thoughts on the potential of modified vegetation management strategies. This researcher also listened to multiple meetings between the VMD and their software contractor to discern the overall structure of the mapping system crews will be using in the near future. Buy-in from and continuous dialogue with vegetation management crews for both the new mapping system and individual pilot projects is essential to ensuring the success of those projects. Crew members are the boots-on-the-ground ensuring safety, line clearance, and good relationships with easement landowners, making them SCL's most important internal stakeholders for any vegetation management project. Their thoughts should never be discounted, and their assistance and opinions should be solicited as much as possible. Most notably, the concern of vegetation management crews over excessive work load - particularly for the ROW between the Bothell Substation and just north of Darrington - should be taken seriously, and all pilot projects should seek to reduce their workload long term.

Implement cost-saving, benefit-producing changes through cross-department projects, and monitor to confirm goals are met.

Projects that arise due to major construction on the ROW, like the installation of mono-towers near French Creek, provide opportunities for implementing IVM practices that can save on long-term costs while providing multiple functions. The design and construction of mono-towers instead of the lattice towers that inhabit most of the Skagit Line lifts height restrictions substantially, thanks in large part to the Engineering Division. In addition, members of ELLBU and VMD apply native/pollinator seed mixes, plant low-to-medium height woody species where appropriate, and manage the vegetation using targeted chemical and manual controls according to IVM best management practices. While it may be favorable for non-SCL stakeholders to participate in vegetation management on some parts of the transmission ROW, Engineering, ELLBU, and VMD (particularly the latter two) are the primary departments at City Light that must be on the same page for long-term vegetation management solutions to be explored.

If accurate inventories of non-compatible target plants (Scots broom, Himilayan blackberry, Cottonwood, etc.) are taken to establish a baseline at the time a project is initiated, monitoring change over time will better refine vegetation management techniques that can be applied system-wide. Span-by-span management is not currently possible throughout the Skagit Line, but taking full advantage of large, cross-department projects combined with well-documented follow-up allows for some number of spans to be used for experimentation. Proper mapping through VM's new GIS will facilitate better map integration and passive communication between VMD and ELLBU employees, and will track cost-per-acre more accurately than can be done under the current system. The biodiversity, height structure, and control methods used will then be evaluated to provide insight into which methods prove more or less cost-effective year-to-year. Using updated GIS, City Light can use select spans as laboratories for effective vegetation management.

Site

[Bio]diversity is an essential aspect and product of holistic, site-specific vegetation control.

Similar to how stakeholder-driven stewardship can be both a component and benefit of holistic ROW vegetation management, biodiversity should be viewed as both a tool and a yield in this arena. Biodiversity in ROW plant communities is at the core of ROW multi-functionality: strategically cultivating plant diversity can help to suppress undesirable or incompatible species (again - Scots broom, Cottonwood, and others) while providing connections between habitat patches, food sources for pollinators and wildlife throughout the seasons, and more resilient ROW ecosystems.

To the point of resilience: the saying goes "don't put all your eggs in one basket." This rings true with further changes in the world's climate on the horizon. Year-round food and habitat connections are crucial for wildlife and dwindling pollinator populations generally, and the situation will become more dire as ecologies shift north with a changing climate (Roberts et al., 2019). Cultivating biodiverse transmission ROWs provides a trove of plants, some of which will adapt to the changes in Washington's climate, and some of which will not. If ROW ecologies allow invasive plants like Scots broom and Himalayan blackberry to spread throughout their length, the impact will be felt not only through reduced biodiversity of ROWs, but also through the invasion of disconnected habitat islands vegetation managers might seek to connect.

The foregoing fails to explain the brackets around "Bio" in this section's heading. The conclusion that biodiversity is essential to ecosystem function and resilience is followed closely by the conclusion that diversity more generally is essential to the function of human communities. As this thesis makes clear, growing multiple functions through ROW vegetation management requires the consideration of multiple perspectives. At Lyle Creek, consideration of only the need for a vegetated riparian buffer might lead to unsafe or unsustainable plant growth that interferes with the transmission lines. At the same time, consideration only for visibility and powerline clearance ignores the opportunities for habitat creation along Lyle Creek, made possible only through careful analysis of line heights and topography. A sustainable, multi-functional approach to ROW vegetation management must consider and unify a diverse array of voices at the site scale.

Waterbodies bring both threats and opportunities for plant and use compatibility.

The detailed analysis conducted at the Lyle Creek and Spearhead Lake ROW sites highlights the unique challenges presented by waterbodies. On one hand, the more moderate topography and lack of any standing water found on the ROW near Spearhead Lake is reflected in the simplicity and predictability of the height zonation for the span investigated for this thesis. On the other hand, the height zonation for the ROW at Lyle Creek is quite complex, with both low and high clearance areas at often unexpected locations. Allowances for slight increases in vegetation height should be made within the 50-100 foot buffers of Lyle Creek, but those allowances must be made strategically, and the entire project will require consensus and monitoring by all stakeholders to reach a satisfactory result.

This contrast between Spearhead Lake and Lyle Creek demonstrates an important lesson: a measured MWBZ approach does provide useful information for any span of City Light's transmission lines, but the usefulness of this detailed analysis appears to be greater for ROWs containing water bodies. Riparian buffers and waterbodies can benefit greatly from the provision of shade and complex root structures. Shade helps to keep water temperatures low, fostering better salmon habitat while complex root structures provide erosion control. Allowing channel migration might be desirable in some parts of a floodplain, but - as illustrated in the case of French Creek - defending against channel migration of waterbodies within the transmission ROW is necesssary. Additionally, waterbodies can act as vectors for invasive plant species, so controlling those species in ROWs containing waterbodies is even more important. Fast-growing plants - namely cottonwood - that are incompatible in transmission ROWs also can be found adjacent to waterbodies, so implementing biological controls through a detailed height zonation scheme should, over time, assist in quelling the presence of numerous undesirable species.

Use replicable, accessible, and scalable monitoring tools.

As noted in the previous section, height zonation is the most detailed level of analysis undertaken in this thesis, and the management and monitoring style it encourages has a similar level of detail. Not all ROW areas will see the same functional benefits from this level of detailed analysis, as minimal topographic variation makes for simpler height zonation. So, while height zonation may provide useful guidance in some cases, the amount of time it takes and the level of detail it includes is not currently replicable, accessible, or scalable for the entirety of SCL's transmisson ROWs.

However, other tools for monitoring applied in these cases do check those three boxes, and City Light's new GIS should allow for better application of a range of tools throughout the utility's transmission system. 10 foot by 10 foot study plots are used widely for sampling in ecology and its allied fields, and they are already being employed at Spearhead Lake, French Creek, and other pilot sites. By replicating and varying the arrangement of such plots throughout transmission ROW pilot sites City Light can use its new GIS to monitor, predict, and compare the monetary and non-monetary costs and benefits of any management strategy it is utilizing.

A 10 foot by 10 foot plot can be an educational tool as well: in looking only at percent cover by species and plant height, WCC crew members were able to play a part in SCL's monitoring efforts, solidifying their knowledge of native and non-native plant species. The same format could easily be applied to a volunteer setting, providing a low-impact and high-benefit activity for interested citizen scientists, or with the Native Youth Corps that may undertake vegetation management efforts in the Stillaguamish Valley.

If SCL were to develop a component of their GIS that allowed for integration of plant and wildlife data collected by citizen scientists, it could grow the utility's capacity to closely monitor its ROWs even further. While 10' x 10' plots could be one arm of that integration, photo points are another monitoring tool worth utilizing in this setting. Photo points already provide for quick and easy visual monitoring of ROW sites year-to-year, giving an overview of the plant height and species composition by using tools many people already own: their phones. Increasing the temporal resolution of photo points - in other words, collecting photos more frequently - could allow City Light to gain more insight into the behavior of plants, humans, and wildlife on the ROW at specific locations. Encouraging volunteers to collect photopoints could be one way to increase that temporal resolution, and modern photo-recognition algorithms might be used to identify notable changes in vegetation height, composition, or functionality.

On the topic of modern technologies for ROW monitoring, mapping professionals would inevitably ask: what about LiDAR, remote sensing, and drones? Couldn't using those technologies allow for easier ROW monitoring? Two main answers arise from this research. First, even though LiDAR and remote sensing technologies provide essential topographic data, they remain expensive when acquired with enough frequency to monitor changes in the landscape. Drones equipped with

LiDAR or remote sensing units should help to lower the cost and increase the spatial and temporal resolution of LiDAR data compared to helicopter- or airplane-mounted units. However, sensors may be too heavy for drone mounting (Li et al., 2010), and use of drones with any frequency would create a need for more community outreach: drones have been the subject of nuisance, safety, and privacy concerns, and City Light may need to do extensive planning and outreach with ROW easement landowners and ROW-adjacent property owners to disabuse them of any negative sentiments towards drones. Considering the success of the more functionality-oriented outreach that is utilized in the case studies, it is difficult to argue for prioritizing engagement efforts around drone usage unless the benefits are definitively shown to be greater than for functional ROW improvements.

Second, City Light employees in ELLBU and VMD must be able to look at and understand the same datasets if a variety of approaches to vegetation management are instituted. Not all employees have training in any mapping software platforms, and providing that training takes time and money. Keeping monitoring tools simple and streamlined will allow them to be more easily implemented, understood, and translated between users and sites. On the same note, City Light should continue to be patient and gradual when purchasing or bringing online new and expensive high-tech tools. The benefits of VMD's new GIS are made clear here, as it will help establish a baseline of costs and benefits for each span. New, high-tech tools like LiDAR/remote-sensing-enabled drones should enhance those systems once they are understood, and should not be utilized until that point is reached.

Once again, pick low-hanging fruit first: opt to modify management instead of overhauling when possible.

While "low-hanging fruit" has already been used to describe instances in which stakeholders actively engage with City Light, the term could just as easily be applied to the case of conservation mowing along the Chief Sealth Trail. A simple adjustment in the mowing schedule has facilitated lower costs, increased biodiversity, higher habitat value, and - arguably - greater aesthetic appeal, all without actually changing the vegetation control applied to that segment of the ROW. While non-SCL stakeholders may be helpful in initiating transitions to a new vegetation management regime, slight tweaks to the existing system may be easier to initiate.

Parcel ownership and size are leverage points.

Even though parcel ownership and size were used as selection criteria for the case studies included in this paper, their importance bears reiterating. The diverse uses observed in CA would likely not occur if those parcels were a mix of private and public ownership, and routing, construction, and maintenance of the Chief Sealth Trail would have been quite difficult. City Light's ownership of this long chain of ROW properties allows them to be public space for more than just public power. In comparison, CB or CC include a mix of City Light and both public- and privately-owned parcels. The vegetation controls that can be easily employed on DNR land may not be allowed in the same manner on privately-owned easement properties. In areas like CC where certain uses (such as recreational ORV usage) are causing serious damages to easement or ROW-adjacent properties, the ownership and size of parcels present both a challenge and an opportunity. The challenge is balancing easy access for effectively managing ROW vegetation against limiting access via a sprawling trail network. The opportunity comes through effectively limiting access: ideally, a handful of well-placed gates should deter most people from accessing the ROW area, allowing an entire corridor of ROW vegetation to recover. The conclusion is clear: large and ideally publicly-owned parcels - especially when they are adjacent to one another - offer substantial leverage points for enhancing ROW functionality.

Conclusion

Looking southeast from the edge of the ROW near Spearhead Lake
Photo Credit: Dylan Marcus

Limitations of this thesis

The transmission ROW itself is an apt metaphor for this thesis: the two central questions equate to the pair of transmission lines running between Bothell and the Skagit Project, ever-present and nearly unchanging throughout the research process. But in the same way that topography and one's exact location in relation to the transmission lines collectively dictate the safe ceiling for compatible plants, an ever-changing host of obstacles placed a ceiling on the capacity of this thesis to explore certain areas in depth.

Researcher as participant

The practice of action research enables the researcher to be an active participant and collaborator in what they are researching: personal experiences, conversations, and reflections that occur throughout the course of the research are all given credence in guiding the direction, analysis, and results; and ideally others involved in a project become collaborators or co-researchers (Stringer, 2007; Westin et al., 2012). My position as a Natural Resources and Permitting Intern at City Light provided a vector for personal and professional experiences and interpersonal relationships, as well as the basis for the research itself.

However, the limitations associated with being a graduate student intern as opposed to a full-time, year-round employee of City Light were notable. Even though I worked on professional projects related to this thesis throughout their 1.5 year tenure as a SCL intern, time was a scarce resource throughout most of that period. Unrelated or semi-related work projects and coursework at times had to be prioritized over thesis work, and an already-heavy course load was made heavier by my push to begin a thesis almost a year ahead of schedule academically speaking. The ability to play a direct role in a real, meaningful project that provided the basis for a thesis was clearly a valid reason for choosing this path, but that did not change the nature of graduating early: classes took precedence over field work, and non-thesis deadlines had to be met.

It should be noted that while interns play a significant role at City Light – especially within ELLBU, the unit in which I am an intern – that does not necessarily correlate to an ability to get the desired level of attention from both internal and external stakeholders, and with good reason. While interns provide valuable services to the utility, they are - at the end of the day - students, not permanent, full-time employees. They are there to learn new skills through assisting on projects, and in this case it became clear that one of those new skills for this researcher was long-term project planning and project management. Discovering the right documents to produce; the right people to contact; and the right questions to ask throughout a multi-pronged, cross-departmental project at an electric utility was both a learning process and formed the basis for this thesis. Fortunately, members of ELLBU, VMD, and Engineering were all extremely patient and willing teachers, and helped to make the connections and to provide the work on which this thesis is based.

COVID-19

The COVID-19 pandemic came to the U.S. by way of Seattle in January, just two months after the researcher embarked on this project. The combined effects of the pandemic on the City of Seattle, the State, the nation, and my own well-being cannot be understated: at the time of writing, the American death toll had risen above 330,000, an unfathomable and unprecedented tragedy. The human population of the world has experienced immense trauma as a result, which has been well-documented from soon after the pandemic's start. Although work was able to continue remotely throughout the duration of this project, the collective trauma and stress experienced by all parties involved resulting from the pandemic itself and the upending of what is considered "normal" cannot be ignored.

Additionally, there were significant logistical hurdles to overcome associated with the pandemic. The City of Seattle mandated employees to work remotely in early March, and at the time of writing remote work is still mandatory whenever possible. As a result, the frequency with which I could learn directly from mentors in an office or field setting was greatly reduced. Making meaningful contact with coworkers was also made more difficult. Meetings with non-SCL stakeholders, let alone with SCL stakeholders, were fewer in number than they would have been otherwise: ideally I would have been able to shadow vegetation management crews for some number of days, but the unsafe conditions of any extra bodies for multiple days was too high to consider it. Finally, remote work also presented technological hurdles, as has been the case for most: access to the City's network, the Information Technology Department, and much-needed software were all significantly slowed.

Objectives

The nature of this research meant that its methodology was developed solely with SCL in mind. Components of the methodology and findings can be generalizable for other utilities, and the research or projects initiated through the case studies discussed should provide useful findings in coming years. IVM and the treatment of invasive plants are areas that benefit most from localized research, and SCL's transmission ROW pilot projects can provide just that.

The degree to which this thesis was developed based on objectives expressed by SCL employees or departments make both the methodology and findings most relevant to SCL. As noted in Chapter 2, City Light's mandate to provide public power and its durability as a publicly-owned utility in the face of large private interests makes it somewhat unique, especially considering the ways in which SCL must interact and collaborate directly with other City departments – such as the Department of Transportation (SDOT) or Seattle Public Utilities (SPU). The City's draft Urban Forestry Management Plan is an excellent and relevant example: nine City departments including SCL participated in the plan's development, and the GIS platform that City Light is currently developing is meant to provide for better integration of the utility's geographic vegetation management data with that of other City departments. This situation is relatively unique, and is indicative of the added complexity of vegetation management for SCL as opposed to other utilities – hence the need for a project catering directly to the needs of City Light, and not to those of private utilities that are not beholden to the will of the public in the same way.

Conclusion

> "It doesn't happen short term – **this is going to take some time**. It's not going to be an overnight fix." (Lewis Payne, ROW Environmental Manager at New York Power Authority)
>
> "When you look at IVM, and seriously understand what Integrated Vegetation Management is and what it's all about, it's really both an art and a science. There's no cookie-cutter method going down the floor. When I look at it, I'm managing that vegetation with vegetation, so I'm letting this compatible vegetation do a lot of work for me out there. It's a biological control for us. **Think about that for a minute: that biological control – it's free**." (Lewis Payne, ROW Environmental Manager at New York Power Authority)
>
> **"When everyone is included, everyone wins."** (Jesse Jackson, American Civil Rights Activist)
>
> *Citation: (NYPA Vegetation Management, 2020; The Power of Inclusion in the Workplace, 2020)*

In the five years leading up to graduate school I held a number of jobs, all of which could be boiled down to vegetation control. Using tractors, mowers, chainsaws, string trimmers, and just my hands, I cut and pruned and removed plants, always with a goal in mind: clean up the edge of that lawn, and make sure the grass is cut to three inches. Cut that tree back from the house, or remove it entirely. Or – most frequently – get those weeds out of that garden bed. Each job required a different tool or technique depending on the goal, and the goal always depended on the will of the customer.

Managing vegetation in a transmission right of way is far more complicated than farming or residential landscaping or tree care. Beyond the hundreds of thousands of utility customers City Light supplies with electricity - all of whom have a serious stake in making sure the power keeps running - there is a diverse array of stakeholders interested in how the transmission right of way is managed. There are any number of combinations of vegetation controls that can be applied to a given site, and some that might be favorable to one stakeholder may not be to another. This potential for divergent outcomes makes City Light's efforts to pursue more holistic approaches to vegetation management both incredibly complex and incredibly important. The utility must continue to actively engage ROW stakeholders; collaborate when possible; experiment with new methods; and rigorously track controls used, money spent, and functions produced (and for whom) throughout the ROW. The methods used and case studies presented in this thesis should provide insights, guidance, and a menu of potential options for ROW vegetation managers as City Light continues to push the boundaries of social and ecological sustainability on transmission line right of ways.

Works Cited

50 years of biodiversity research. (Tools & Equipment). (2003, June). Arbor Age, 23(6), 8-. Gale General OneFile.

American Cancer Society. (2017, April 18). Power Lines, Electrical Devices, and Extremely Low Frequency Radiation. American Cancer Society. https://www.cancer.org/cancer/cancer-causes/radiation-exposure/extremely-low-frequency-radiation.html

Araneo, R., Celozzi, S., & Vergine, C. (2015). Eco-sustainable routing of power lines for the connection of renewable energy plants to the Italian high-voltage grid. International Journal of Energy and Environmental Engineering, 6(1), 9–19. https://doi.org/10.1007/s40095-014-0143-z

Baggett, K., Cunningham, C., & Maxwell, R. (2019). The Power of Pollinators Reclaiming ROW Habitat. Utility Arborist Newsline, 10(6), 48.

Bramble, W. C., & Byrnes, W. R. (1979). Evaluation of the Wildlife Habitat Values of Rights-of-Way. The Journal of Wildlife Management, 43(3), 642–649. JSTOR. https://doi.org/10.2307/3808742

Bramble, W., Yahner, R., & Byrnes, W. (1999). Effect of herbicide maintenance of an electric transmission line right-of-way on butterfly populations. 25.

Brown, C., Reyers, B., Ingwall-King, L., Mapendembe, A., Nel, J., O'Farrell, P., & Dixon, M. (2014). Measuring Ecosystem Services: Guidance on Developing Ecosystem Service Indicators. United Nations Environment Programme.

Cain, N. L., & Nelson, H. T. (2013). What drives opposition to high-voltage transmission lines? Land Use Policy, 33, 204–213. https://doi.org/10.1016/j.landusepol.2013.01.003

Canfield, J., Yang, B., & Whitlow, H. (2018). Evaluating Landscape Performance: A guidebook for Metrics and Methods Selection. Landscape Architecture Foundation.

CDC's Social Vulnerability Index. (2018, September 5). https://svi.cdc.gov/

City of Seattle, O. of E. M. (2014). The Seattle Hazard Identification & Vulnerability Analysis. https://www.seattle.gov/Documents/Departments/Emergency/PlansOEM/SHIVA/SHIVAv6.3Final.pdf

Cotton, M., & Devine-Wright, P. (2013). Putting pylons into place: A UK case study of public perspectives on the impacts of high voltage overhead transmission lines. Journal of Environmental Planning & Management, 56(8), 1225–1245. https://doi.org/10.1080/09640568.2012.716756

CPTED - Police | seattle.gov. (n.d.). Retrieved December 30, 2020, from http://www.seattle.gov/police/crime-prevention/cpted

Crossman, N. D., Burkhard, B., & Nedkov, S. (2012). Quantifying and mapping ecosystem services. International Journal of Biodiversity Science, Ecosystem Services & Management: Quantifying and Mapping Ecosystem Services, 8(1–2), 1–4. https://doi.org/10.1080/21513732.2012.695229

Definition of RIGHT-OF-WAY. (n.d.). Retrieved November 28, 2020, from https://www.merriam-webster.com/dictionary/right-of-way

Elder, A. (n.d.). Library Guides: Research Methodologies Guide: Action Research. Retrieved November 12, 2020, from https://instr.iastate.libguides.com/c.php?g=49332&p=318066

Electrical Grid | Student Energy. (2020). https://www.studentenergy.org/topics/electrical-grid

Equity & Environment Initiative—Environment | seattle.gov. (n.d.). Retrieved November 29, 2020, from https://www.seattle.gov/environment/equity-and-environment/equity-and-environment-initiative

Feld, C. K., Silva, P. M. da, Sousa, J. P., de Bello, F., Bugter, R., Grandin, U., Hering, D., Lavorel, S., Mountford, O., Pardo, I., Pärtel, M., Römbke, J., Sandin, L., Jones, K. B., & Harrison, P. (2009). Indicators of Biodiversity and Ecosystem Services: A Synthesis across Ecosystems and Spatial Scales. Oikos, 118(12), 1862–1871.

Gilstrap, M., Amin, S., & DeCorla-Souza, K. (2015). United States Electricity Industry Primer. U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2015/12/f28/united-states-electricity-industry-primer.pdf

Gould, L., & Cummings, B. J. (2013). Duwamish Valley Cumulative Health Impacts Analysis: Seattle, Washington (p. 48). Just Health Action, Duwamish River Cleanup Coalition. http://www.seattle.gov/Documents/Departments/Environment/EnvironmentalEquity/CHIA_low_res.pdf

Hakenholz, G. J. (1980). Use of video tape aerial photography to develop vegetation management plans on transmission power line right-of-way. Remote Sensing Quarterly, 2(1), 45–54.

Harrison, P. A., Berry, P. M., Simpson, G., Haslett, J. R., Blicharska, M., Bucur, M., Dunford, R., Egoh, B., Garcia-Llorente, M., Geamănă, N., Geertsema, W., Lommelen, E., Meiresonne, L., & Turkelboom, F. (2014). Linkages between biodiversity attributes and ecosystem services: A systematic review. Ecosystem Services, 9, 191–203. https://doi.org/10.1016/j.ecoser.2014.05.006

Hooper, B., & Baily, T. (2004). Aerial Surveys Calculate Vegetation Growth. Transmission & Distribution World.

Initiatives, Referenda, & Charter Amendments Guides—CityClerk | seattle.gov. (n.d.). Retrieved December 30, 2020, from https://www.seattle.gov/cityclerk/city-clerk-services/initiative-referendum-and-charter-amendment-guides

Jackson, T. O., & Pitts, J. (2010). The Effects of Electric Transmission Lines on Property Values: A Literature Review. Journal of Real Estate Literature, 18(2), 239–260. JSTOR.

Jardini, M. G. M., Jacobsen, R. M., Jardini, J. A., Magrini, L. C., Masuda, M., Silva, P. R. L., Quintanilha, J. A., & Beltrame, A. M. K. (2007). Information System for the Vegetation Control of Transmission Lines Right-of-way. 28–33. https://doi.org/10.1109/PCT.2007.4538287

Jardini, M. G. M., Jardini, J. A., Magrini, L. C., Masuda, M., Le Silva, P. R., Quintanilha, J. A., Beltrame, A. M. K., & Jacobsen, R. M. (2007). Vegetation Control of Transmission Lines Right-of-way. 660–665. https://doi.org/10.1109/RAST.2007.4284075

Jauchem, J. R. (1997). Exposure to extremely-low-frequency electromagnetic fields and radiofrequency radiation: Cardiovascular effects in humans. International Archives of Occupational and Environmental Health, 70(1), 9–21. https://doi.org/10.1007/s004200050181

King County. (n.d.). Standards and indicators for emergency preparedness and response. Retrieved May 4, 2020, from https://www.kingcounty.gov/depts/health/emergency-preparedness/Community-Resilience-Equity/standards.aspx

Li, Z., Walker, R., Hayward, R., & Mejias, L. (2010). Advances in vegetation management for power line corridor monitoring using aerial remote sensing techniques. 1–6. https://doi.org/10.1109/CARPI.2010.5624431

Matikainen, L., Lehtomäki, M., Ahokas, E., Hyyppä, J., Karjalainen, M., Jaakkola, A., Kukko, A., & Heinonen, T. (2016). Remote sensing methods for power line corridor surveys. ISPRS Journal of Photogrammetry and Remote Sensing, 119, 10–31. https://doi.org/10.1016/j.isprsjprs.2016.04.011

Moreno Marimbaldo, F. J., Manso-Callejo, M.-Á., & Alcarria, R. (2018). A Methodological Approach to Using Geodesign in Transmission Line Projects. Sustainability, 10(8), 2757. https://doi.org/10.3390/su10082757

Mueller, C. E., Keil, S. I., & Bauer, C. (2017). Effects of spatial proximity to proposed high-voltage transmission lines: Evidence from a natural experiment in Lower Saxony. Energy Policy, 111, 137–147. https://doi.org/10.1016/j.enpol.2017.09.023

Mutchler, D., & Barnard, S. (2020, August 6). Personal Communication with members of City Light Vegetation Management Division [Personal communication].

Mutchler, D., Weiser, A., Denovan, R., Bayard, D., & Anonymous. (2020, October 9). Listening session with SCL Vegetation Management and representatives of the Stillaguamish Tribe [Personal communication].

National Grid. (2010). Transmission Right-of-Way Management Program. https://www.fws.gov/northeast/nyfo/es/NG%20HCP%20Appendices/HCP%20App%20D.Part%2084%20Full%20Document%20Final.pdf

Navrud, S., Ready, R. C., Magnussen, K., & Bergland, O. (2008). Valuing the social benefits of avoiding landscape degradation from overhead power transmission lines: Do underground cables pass the benefit–cost test? Landscape Research, 33(3), 281–296. https://doi.org/10.1080/01426390802045921

Nelson, H. T., Swanson, B., & Cain, N. L. (2018). Close and Connected: The Effects of Proximity and Social Ties on Citizen Opposition to Electricity Transmission Lines. Environment and Behavior, 50(5), 567–596. https://doi.org/10.1177/0013916517708598

NERC Vegetation Management Standard Drafting Team. (2009). Transmission Vegetation Management NERC Standard FAC-003-2 Technical Reference. North American Electric Reliability Corporation. https://www.nerc.com/pa/Stand/Project%20200707%20Transmission%20Vegetation%20Management/FAC-003-2_White_Paper_2009Sept9.pdf

Nowak, C. A. (2020). What is this Integrated Vegetation Management, this IVM – Now, Today, and into the Future? 13.

Nowak, C. A., Abrahamson, L. P., & Neuhauser, E. F. (1992). Cost Effective Vegetation Management on a Recently Cleared Electric Transmission Line Right-of-Way. Weed Technology, 6(4), 828–837. https://doi.org/10.1017/S0890037X00036344

NYPA Vegetation Management. (2020). New York Power Authority. https://www.nypa.gov/power/transmission/vegetation-management

Overview of Action Research Methodology. (n.d.). Retrieved November 12, 2020, from https://www.web.ca/~robrien/papers/arfinal.html#_Toc26184651

Paulin, M. J., Remme, R. P., van der Hoek, D. C. J., de Knegt, B., Koopman, K. R., Breure, A. M., Rutgers, M., & de Nijs, T. (2020). Towards nationally harmonized mapping and quantification of ecosystem services. Science of The Total Environment, 703, 134973. https://doi.org/10.1016/j.scitotenv.2019.134973

Payne, L. (2020, March 18). NY Power Authority IVM Discussion [Personal communication].

Penn State. (n.d.). History | Utility Rights of Way Wildlife Research. Penn State. Retrieved April 28, 2020, from https://sites.psu.edu/transmissionlineecology/history/

Pojar, J., & MacKinnon, A. (Eds.). (2004). Plants of the Pacific Northwest Coast: Washington, Oregon, British Columbia & Alaska. B.C. Ministry of Forests and Lone Pine Publishing.

Prediction of cover type on rights-of-way after maintenance treatments: W. C. Bramble, W. R. Byrnes, R. J. Hutnik & S. A. Liscinsky, Journal of Arboriculture, 17(2), 1991, pp 38–43. (1992). Biological Conservation, 61(1), 73–73. https://doi.org/10.1016/0006-3207(92)91214-D

Race and Social Justice Initiative—RSJI | seattle.gov. (n.d.). Retrieved November 29, 2020, from https://www.seattle.gov/rsji

RainWise | 700 Million Gallons | Rebates For Rain Gardens & Cisterns. (n.d.). 700 Million Gallons. Retrieved November 29, 2020, from https://www.700milliongallons.org/rainwise/

Right of Way Permits. (n.d.). Retrieved November 28, 2020, from https://www.kitsapgov.com:443/how-do-i/apply-for/right-of-way-permits

Roberts, C. P., Allen, C. R., Angeler, D. G., & Twidwell, D. (2019). Shifting avian spatial regimes in a changing climate. Nature Climate Change, 9(7), 562–566. https://doi.org/10.1038/s41558-019-0517-6

Ross, James Delmage (J. D.) (1872-1939). (n.d.). Retrieved November 30, 2020, from https://www.historylink.org/File/2557

Sauk-Suiattle—Index. (n.d.). Retrieved November 5, 2020, from http://www.sauk-suiattle.com/

Seattle City Light History. (n.d.). Retrieved November 17, 2020, from https://www.seattle.gov/light/history/default.asp

Seattle voters approve City Light purchase of Puget Power assets within city limits on November 7, 1950. (n.d.). Retrieved November 30, 2020, from https://www.historylink.org/File/2768

Sierra Pacific Industries—Our Business. (n.d.). Retrieved November 5, 2020, from https://www.spi-ind.com/Home/OurBusiness

Skagit Hydro Project Relicensing | North Cascades Conservation Council. (n.d.). Retrieved November 30, 2020, from http://www.northcascades.org/wordpress/programs/skagit-hydro-project-relicensing

Slusser, A. M. (2012). Transmission Lines in Wildland Landscapes: Gauging Visual Impact Among Casual Observers [Thesis]. https://digital.lib.washington.edu:443/researchworks/handle/1773/20509

Steelman, J. (2020, April 1). Grow With Trees IVM Discussion [Personal communication].

Stringer, E. T. (2007). Action Research (3rd ed.). Sage Publications. https://us.sagepub.com/en-us/nam/action-research/book236795

Stromberg, M. (2017, May 7). Planning for Resilience. American Planning Association. https://www.planning.org/blog/blogpost/9124762/

The cost-effectiveness of integrated vegetation management – TREE Fund. (n.d.). Retrieved April 25, 2020, from https://treefund.org/archives/15905

The Free Online Encyclopedia of Washington State History—HistoryLink.org. (n.d.). Retrieved November 30, 2020, from https://www.historylink.org/

"The life-giving Skagit has been purposely dewatered by the city of Seattle, and why?" (n.d.). Retrieved December 1, 2020, from https://www.realchangenews.org/2020/03/25/life-giving-skagit-has-been-purposely-dewatered-city-seattle-and-why

The Meadoway—Community Powered Green Spaces. (n.d.). The Meadoway. Retrieved June 12, 2020, from https://themeadoway.ca/

The power of inclusion in the workplace. (2020, September 16). Tecknuovo. https://tecknuovo.com/power-of-inclusion-workplace/

Townsend, F. E., Ray, M., Reeves, B., & Murray, B. H. (1975). Transmission Line Visual Impact Evaluation Study.

Treaty of Point Elliott, 1855. (1855, January 22). https://www.historylink.org/File/2629

Trees for Seattle—Trees | seattle.gov. (n.d.). Retrieved November 29, 2020, from https://www.seattle.gov/trees

Upper Skagit River Hydroelectric Project. (n.d.). Retrieved November 30, 2020, from https://www.historylink.org/File/5347

US EPA, OA. (2014, November 3). Environmental Justice [Collections and Lists]. US EPA. https://www.epa.gov/environmentaljustice

US EPA, OAR. (2018, November 27). Electric and Magnetic Fields from Power Lines [Overviews and Factsheets]. US EPA. https://www.epa.gov/radtown/electric-and-magnetic-fields-power-lines

US EPA, OCSPP. (2016, March 9). Integrated Vegetation Management Fact Sheet [Overviews and Factsheets]. US EPA. https://www.epa.gov/pesp/integrated-vegetation-management-fact-sheet

Vera-Art, S. (2020, March 18). Grow With Trees IVM Discussion [Personal communication].

Vilà, M., & Hulme, P. (Eds.). (2017). Impact of Biological Invasions on Ecosystem Services. Springer International Publishing. https://doi.org/10.1007/978-3-319-45121-3

Wagner, D. L., Ascher, J. S., & Bricker, N. K. (2014). A Transmission Right-of-Way as Habitat for Wild Bees (Hymenoptera: Apoidea: Anthophila) in Connecticut. Annals of the Entomological Society of America, 107(6), 1110–1120. https://doi.org/10.1603/AN14001

Wagner, D. L., Metzler, K. J., & Frye, H. (2019). Importance of transmission line corridors for conservation of native bees and other wildlife. Biological Conservation, 235, 147–156. https://doi.org/10.1016/j.biocon.2019.03.042

Walter, M. (2009). Participatory Action Research. Social Research Methods, 8.

Washington State Noxious Weed Control Board. (n.d.). Retrieved December 30, 2020, from https://www.nwcb.wa.gov/

Waterlines: The Waterlines Project Map. (2014). https://www.burkemuseum.org/static/waterlines/project_map.html

Westin, M., Hellquist, A., Kronlid, D. O., & Colvin, J. (2012). Towards Urban Sustainability. 29, 19.

WHO | Electromagnetic fields and public health. (n.d.). WHO; World Health Organization. Retrieved April 29, 2020, from http://www.who.int/peh-emf/publications/facts/fs322/en/

William C. Bramble, & Byrnes, W. R. (1996). Integrated Vegetation Management of an Electirc Utility Right-Of-Way Ecosystem. Down To Earth, 51(2).

Woolley, A. (2008). Enemies of the State—The Alberta Energy and Utilities Board, Landowners, Spies, a 500kV Transmission Line and Why Procedure Matters. Journal of Energy & Natural Resources Law, 26(2), 234–266.

World Resources Institute. (2005). Millennium Ecosystem Assessment. Island Press, Washington DC. http://www.millenniumassessment.org/documents/document.356.aspx.pdf

Yahner, R. H., Bramble, W. C., & Byrnes, W. R. (2001). Response of Amphibian and Reptile Populations to Vegetation Main—Tenance of an Electric Transmission Line Right-of-Way. /paper/RESPONSE-OF-AMPHIBIAN-AND-REPTILE-POPULATIONS-TO-OF-Yahner-Bramble/07cd814459793fe8b3260a5cde1c91fa124bc874

Appendices

Appendix A: Historical presence of Scot's broom around French Creek study plots

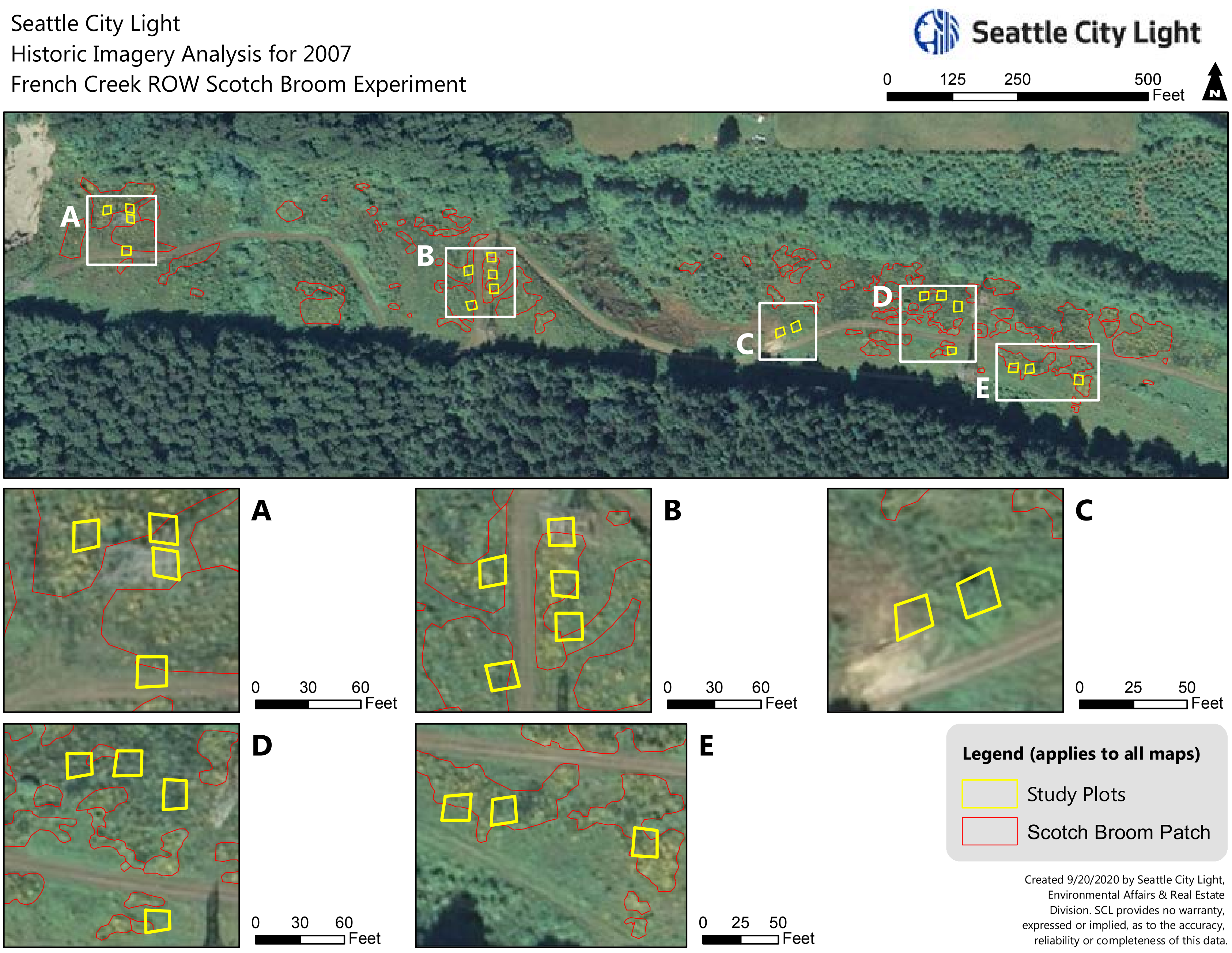
The following maps were produced using publicly-available imagery from Google Earth and Snohomish County. A generalized version of the workflow used to estimate the locations and areas of Scots broom patches within the French Creek ROW are as follows:

- Select imagery for as many years as possible, making sure that the resolution is high enough to allow for identification of Scots broom. If not yet georeferenced, do so in ArcMap to a set of base imagery that has been projected. Only color imagery can be used.
- Create a new polygon layer in ArcMap with attributes for "Confidence Level" and "Density Level " (both with scales of 1-5, with one being low confidence or low density, and 5 being high confidence or high density).
- Use the editor function to draw polygons around identifiable patches of Scots broom along the area of interest. Zoom in and out to view each dataset at multiple scales - doing so helps to identify continuous patches.
- As each polygon is drawn, the user should record their estimation for the density of the patch in the "Density Level" field, as well as their confidence in the patch having Scots broom at the estimated density in the "Confidence Level" field.
- Overlay the polygon layer representing study plots, and compare the change in estimated abundance of Scots broom from year to year.

A major disadvantage to this method of analysis is the lack of ability to clarify the accuracy and precision of the findings, as on-site surveys were not performed in the years corresponding to each set of historical imagery. However, that disadvantage can be disregarded, as the primary purpose of this analysis was to gain a rough idea of the abundance and location of Scots broom on this portion of the ROW. The conclusions drawn from the historical imagery analysis are listed below. Those conclusions indicate that because Scots broom has been present in the area of interest for many years, the site may provide a valuable testing ground for application of IPM on Scots broom (which is still in a developmental stage), in addition to the Scots broom control pilot studies already underway there.

- The prevalence of Scots broom along the entire ROW corridor that was viewed decreased substantially after 2007. Imagery from 2013 and 2016 showed the least estimated area containing patches of Scots broom, and there appears to have been a slight increase in the presence of the species since then based on the imagery from 2019.
- The analysis indicates that there has been little or no presence of Scots broom within any of the Study Plots since 2012. Scotch broom was present within the bounds of every study plot in one or more years between 2007 and 2012.
- It is possible that the construction of mono-towers around 2016 on this stretch of ROW may have resulted in the spreading of Scots broom, given the sudden increase in its presence in 2019.

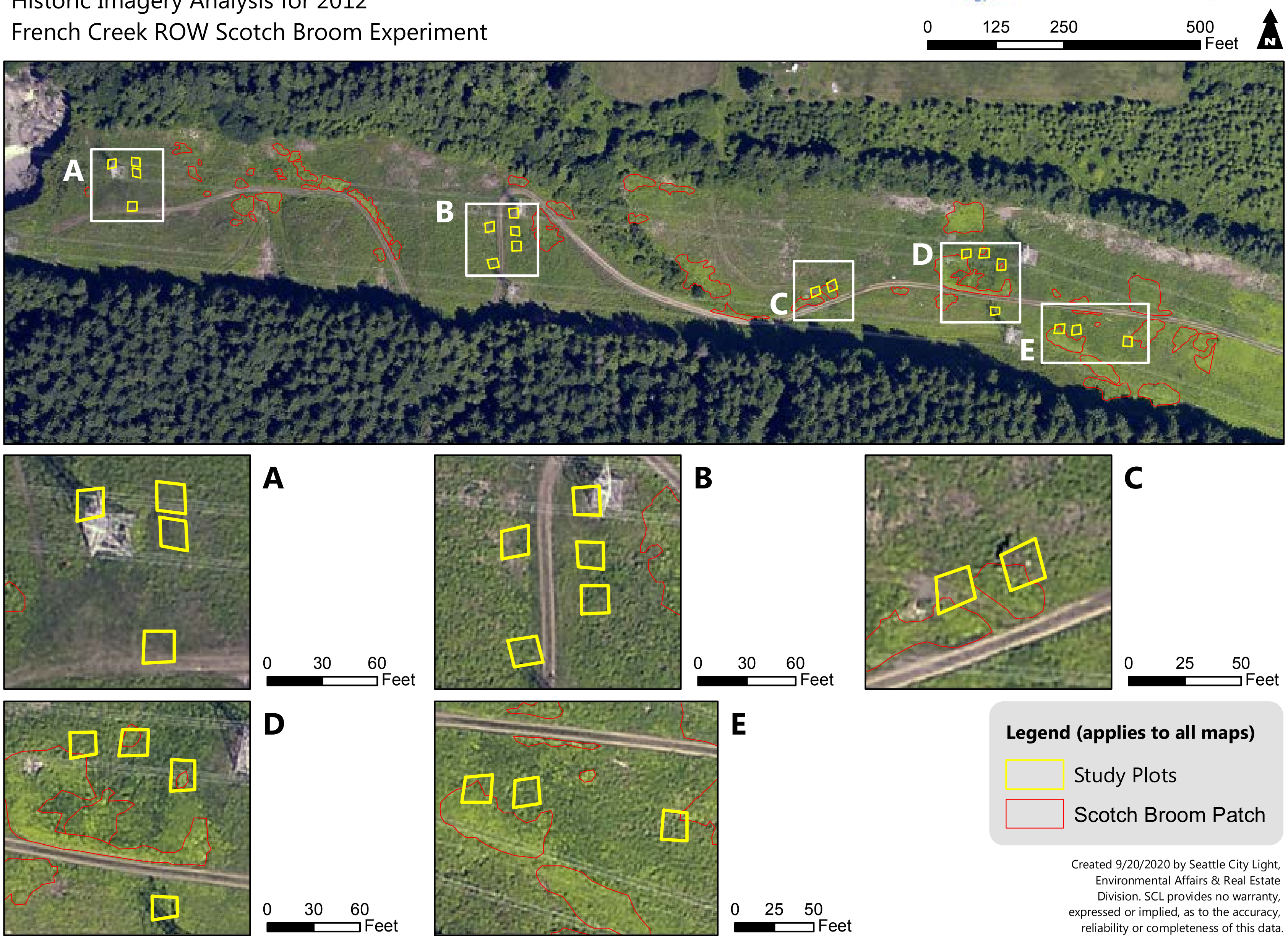
Seattle City Light
Historic Imagery Analysis for 2007
French Creek ROW Scotch Broom Experiment



Seattle City Light
Historic Imagery Analysis for 2011
French Creek ROW Scotch Broom Experiment

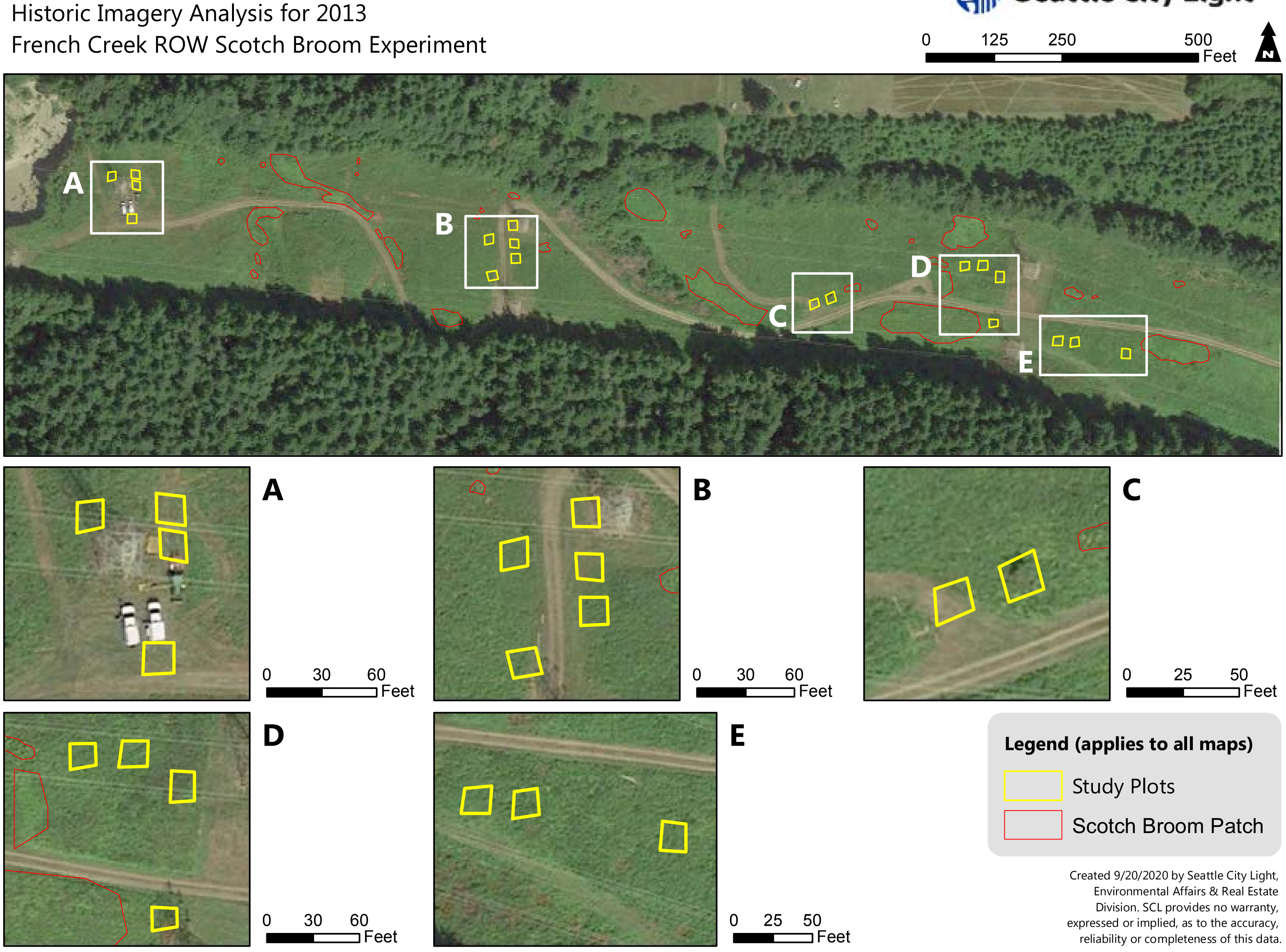
Seattle City Light
Historic Imagery Analysis for 2012
French Creek ROW Scotch Broom Experiment

Seattle City Light

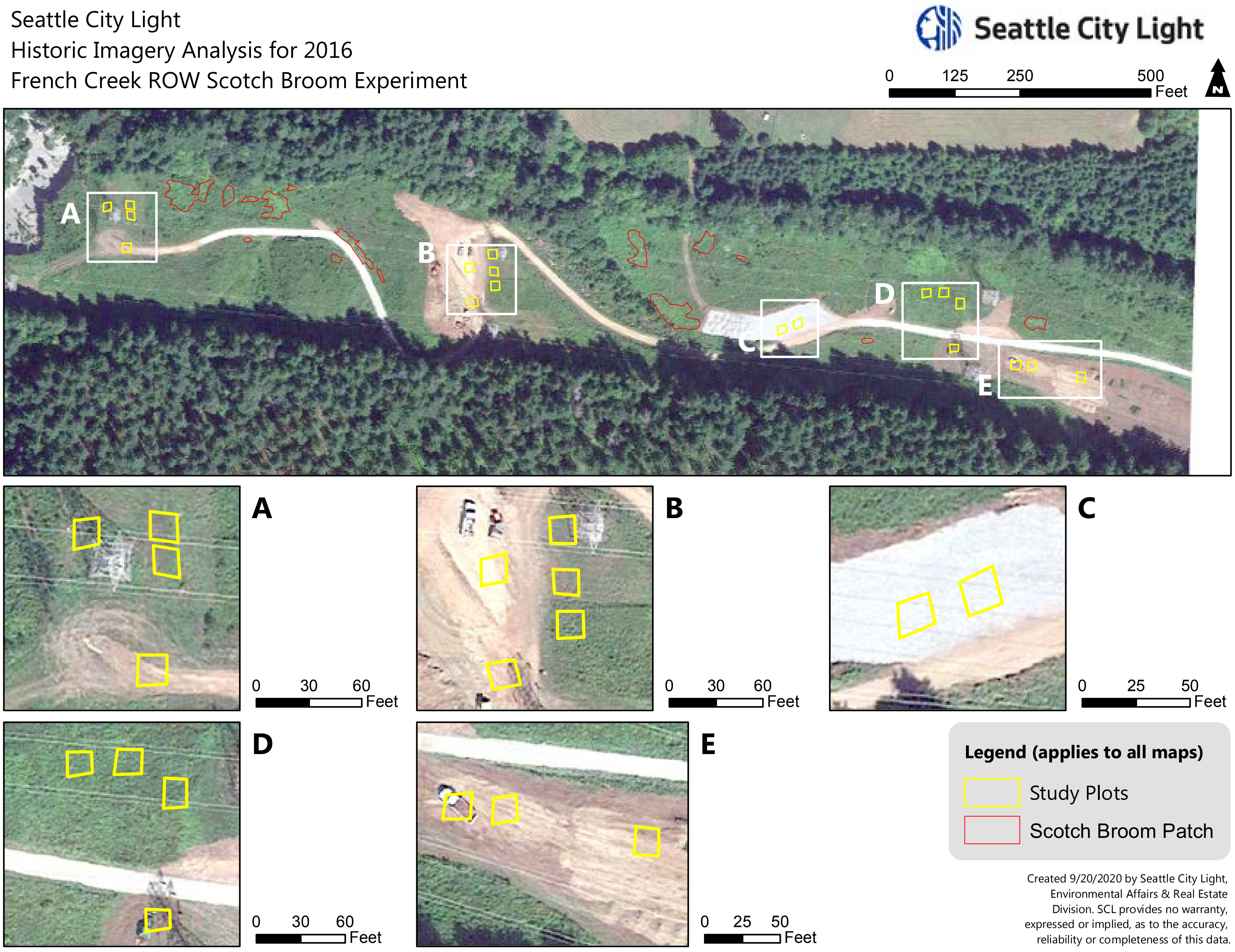


Seattle City Light
Historic Imagery Analysis for 2013
French Creek ROW Scotch Broom Experiment

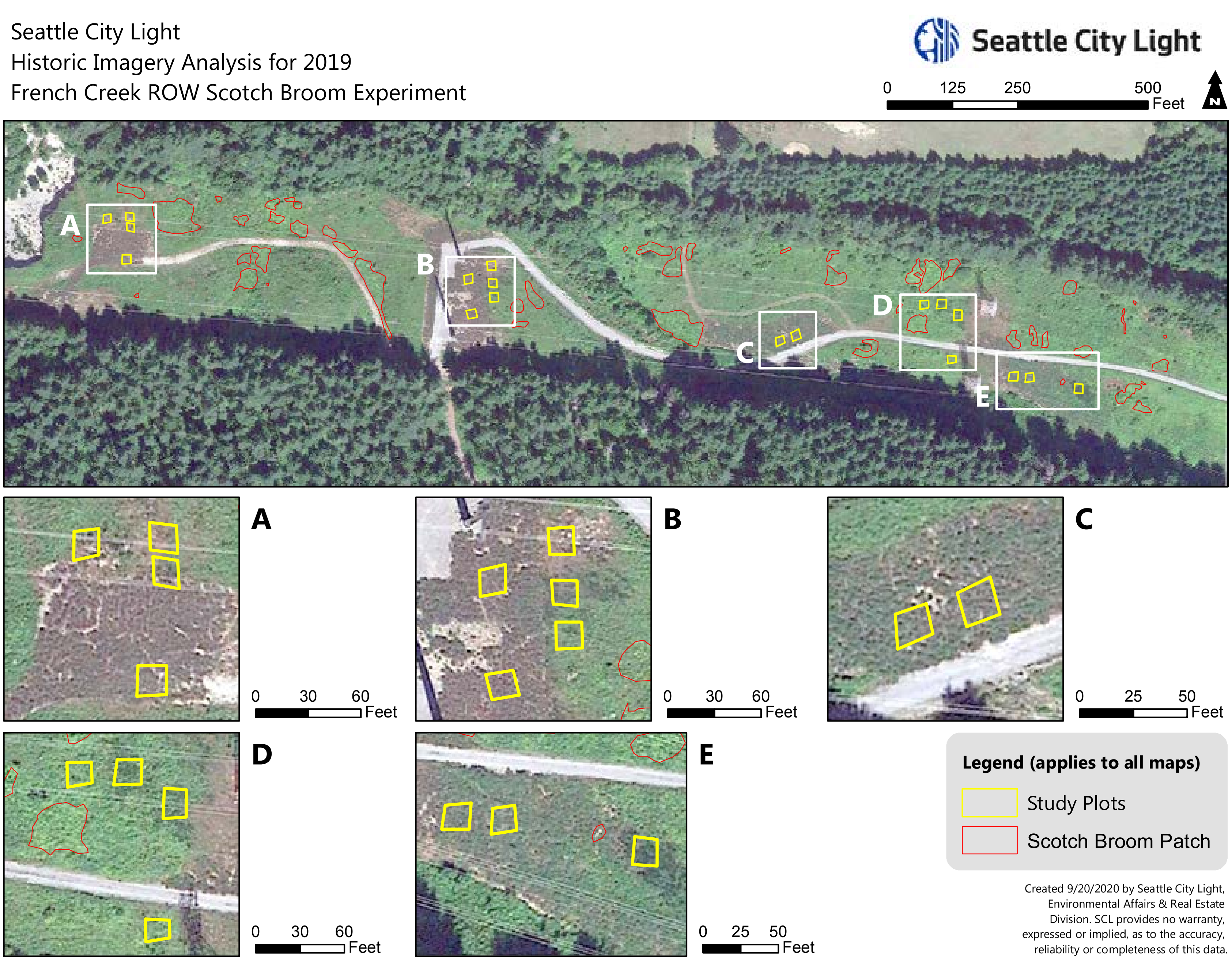
Seattle City Light



Seattle City Light
Historic Imagery Analysis for 2016
French Creek ROW Scotch Broom Experiment



Seattle City Light
Historic Imagery Analysis for 2019
French Creek ROW Scotch Broom Experiment



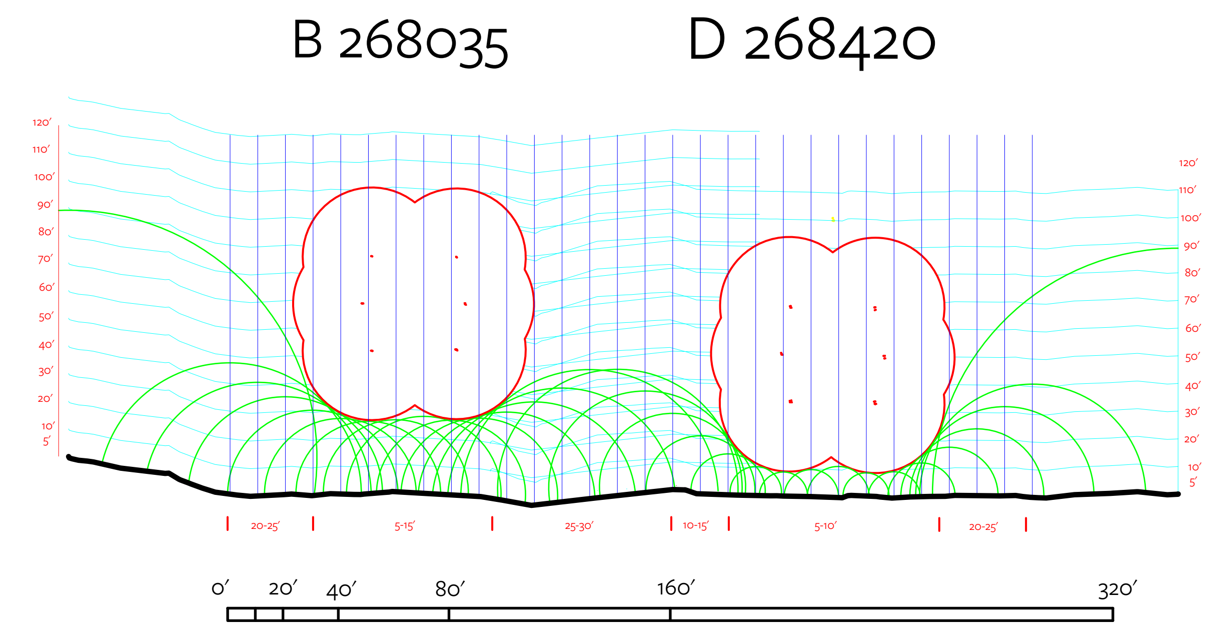
Appendix B: Sectional analysis workflow and zonation maps for Lyle Creek and Spearhead Lake

Zonation of segments of the ROW by maximum allowable plant height requires a detailed analysis, and collaboration with SCL Engineers to acquire line heights for any given location. The level of detail is high enough that managing vegetation based on height zones would not be practical for the entire ROW. However, in instances where certain functions are needed, these maps can provide a level of precision that could allow for a more diverse array of plant species and heights to be cultivated in the ROW.

Software used for the zonation analysis included AutoCAD and ESRI ArcMap. The generalized workflow for producing the zonation maps in this section is as follows:

- Select ROW area of interest, and communicate that area to engineers through traced satellite imagery. Articulate the number of cross sections desired, and their location (if specific sections are needed) OR the distance between sections
- Engineers will extract sections for a single line using PLS-CADD, which will show the locations of individual transmission lines. When those sections are returned as DWG files, make note of the number codes for each section - this indicates the location of each section in relation to the nearest transmission tower, and will be used in translating from section to plan view
- If zonation for the ROW beneath both lines is being performed, match the single-transmission-line sections based on the codes described above in AutoCAD. If not, skip this step. Positioning the sections in relation to each other may require taking distance measurements in ArcMap or Google Earth of the ROW width and/or position of roads or other notable features.
- In AutoCAD, delineate the borders of the ROW on each section, and buffer the markers from each transmission lines with a 25 foot radius circle. Draw circles along the ground plane (approximately every 10 feet) that nearly intersect with the buffer lines to illustrate the maximum allowable fall lines for trees, and/or the maximum allowable heights for vegetation.
- Use the intersections between fall lines to delineate height zones for each section. Once sections have had zones delineated, transfer those zones to a scaled satellite image in AutoCAD, inserting them at the proper location. Export a high resolution image of the map with sections overlaid.

Below: *Sample of sectional analysis results in AutoCAD, prior to transfer to plan view*



- In ArcMap, georeference the image that was exported from AutoCAD containing the sections. Using the heights listed in each section in combination with a hillshade, contour layer, or similar, draw polygons for each height zone. Be sure to edit attributes so that the maximum height for each polygon is listed in an attribute field.
- Symbolize the height zones, and/or import the layer to a mobile device for use in the field. Layers can also be used as a basis for planting plans if planting activity is to take place at the site.

Seattle City Light
Allowable Height Zones / Lyle Creek Buffer
Lyle Creek / Mile 50

Seattle City Light

0 100 200 400 Feet

Transmission Towers
Lyle Creek Buffer (50ft)
Lyle Creek Buffer (100ft)

Maximum Height
(+25 foot line buffer)

- 5 feet
- 10 feet
- 15 feet
- 20 feet
- 25 feet
- 30 feet
- 35 feet
- 40 feet

Created 12/15/2020 by Seattle City Light, Environmental Affairs & Real Estate Division. SCL provides no warranty, expressed or implied, as to the accuracy, reliability or completeness of this data.

Seattle City Light
Allowable Height Zones
Spearhead Lake / Mile 56

Seattle City Light

0 100 200 400 Feet

Transmission Towers

Maximum Height
(+25 foot line buffer)

- 5 feet
- 10 feet
- 15 feet
- 20 feet
- 25 feet
- 30 feet
- 35 feet
- 40 feet

Created 12/15/2020 by Seattle City Light, Environmental Affairs & Real Estate Division. SCL provides no warranty, expressed or implied, as to the accuracy, reliability or completeness of this data.

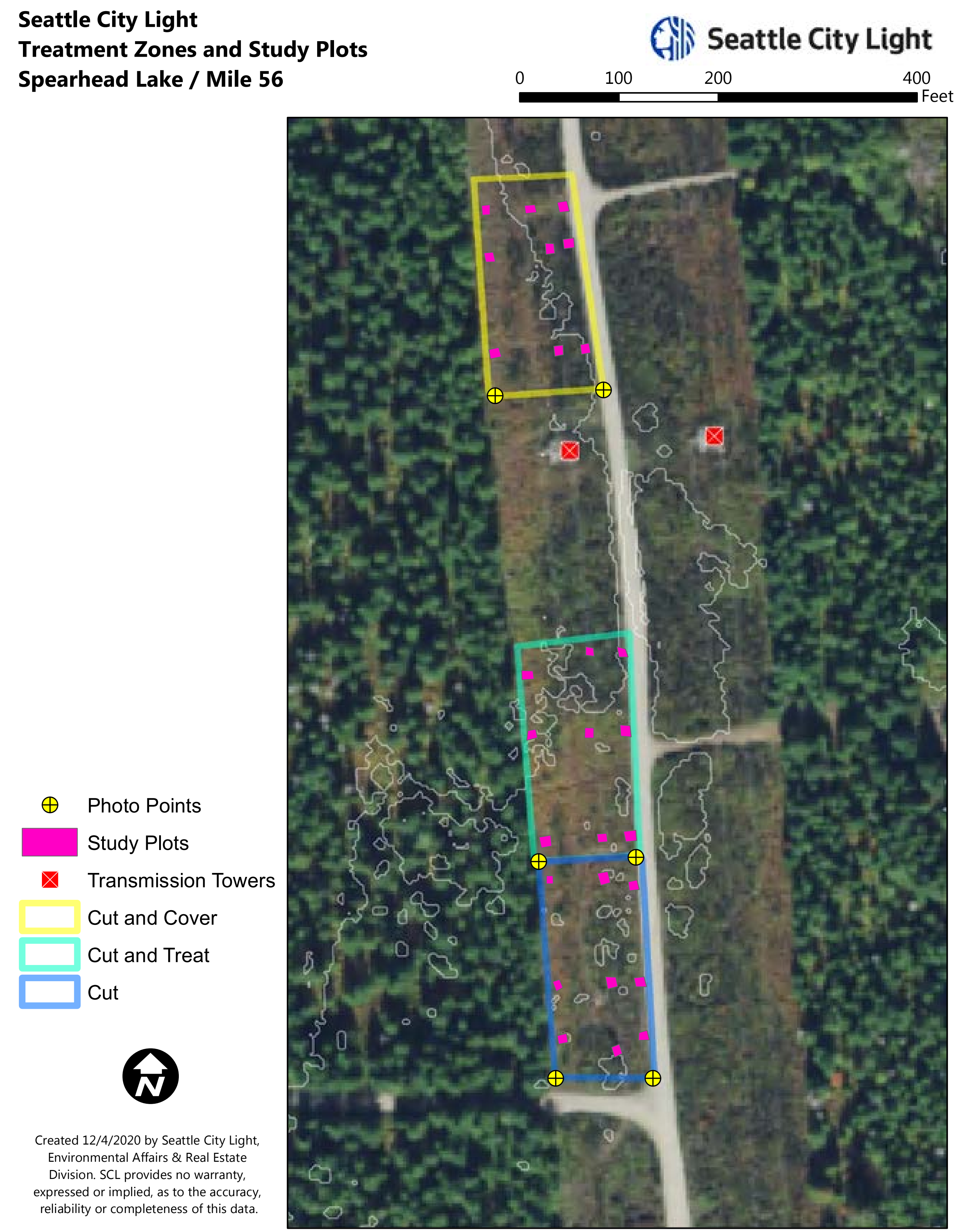
Appendix C: Treatment zones and study plots set up at Spearhead Lake

Following on-site listening sessions with the SSTI, City Light had WCC crews set up an experiment on Scots broom control within the transmission ROW near Spearhead Lake. The objectives of thisi experiment/pilot study are **a)** to compare the success of three control methods on cultivating more diverse plant species and height strata within the ROW; **b)** to monitor the plant species and heights that grow in the roadside, wire, and border zones of the ROW during continued Scots broom control; and **c)** to make the habitat provided by the ROW more attractive to elk. The treatments applied were:

- Cut and Cover
- Cut and Treat
- Cut (only)

Treatment zones were delineated in areas with similar topography and overall plant species composition following a visual survey. Study plots are each 10 feet by 10 feet in size, and were set up in sets of three along a transect running perpendicular to the ROW. The starting point of each transect was chosen along the access road at random, and study plots were spaced such that the first is five feet west of the access road; the second is 25 feet west of the first plot; and the third plot is five feet east of the ROW edge. Photo points were also set at the southwest and southeast corners of each treatment zone. All photopoints, study plot corners, and treatment zone corners were recorded on a Trimble GPS unit with approximately 10-24 inch accuracy.

After treatment zones, study plots, and photo points were set, WCC crews used ocular surveys to collect data on the heights of the tallest two plant species in each study plot, and on the percent cover by species within each study plot. By recording those measurements and treatments for 3-5 years (and, ideally, replicating the experiment in other infested portions of the ROW), it should be possible to discern which treatment most successfully accomplishes the objectives of the pilot study.



Appendix D: Plant lists from field visits at French Creek, Lyle Creek, and Spearhead Lake

Plants were surveyed during field visits to the sites French Creek, Lyle Creek, and Spearhead Lake. Surveys were not completed for the sites in CA due to the fact that the researcher was not directly involved with the projects taking place there; nor were they completed for the potential sites in the Stillaguamish Valley due to the fact that those sites were selected just prior to the completion of this thesis.

The plant surveys that were completed were not meant to be exhaustive, but instead were meant to discern which plants were relatively abundant on each of the three ROWs visited. While knowledge of where rare plant species are located is valuable, data on plant communities as a whole was deemed to be more valuable. Since an IVM approach seeks to find the path of least resistance in encouraging compatible species to grow, it makes sense to look at which species are already abundant so that vegetation managers can anticipate which compatible and incompatible species are likely to be focal points for a given pilot project. Additionally, many species that are already present in the ROW provide valuable habitat or cultural functions. To manage for those species, one first needs to know where they are already present as a starting point. Plant lists are as follows, including only common names (red indicates incompatile invasive plants):

French Creek

- Alder (Sitka)
- Blackberry (Himalayan)
- Blackberry (Trailing)
- Burdock
- Cascara
- Cedar (Red)
- Currant
- Fern (Bracken)
- Fern (Lady)
- Fern (Sword)
- Fir (Douglas)
- Elderberry (Black)
- Hemlock (Western)
- Huckleberry (Red)
- Kinnickinik
- Lupine
- Maple (Vine)
- Oceanspray
- Oregon Grape
- Rose (Nootka)
- Thimbleberry
- Salal
- Salmonberry
- Scots broom
- Snowberry
- Spirea
- Strawberry
- Yarrow

Lyle Creek

- Blackberry (Cutleaf)
- Blackberry (Himalayan)
- Crabapple
- Fern (Bracken)
- Grasses (Misc.)
- Indian Plum

- Mullen
- Nettle (Stinging)
- Rose (Nootka)
- Snowberry
- St. John's Wort
- Tansy (Common)
- Thimbleberry
- Thistle
- Willow
- Yarrow

Spearhead Lake

- Blackberry (Trailing)
- Cascara
- Fern (Bracken)
- Fireweed
- Goldenrod
- Grasses (Misc.)
- Maple (Vine)
- Oregon Grape
- Salal
- Scots broom
- Self-heal
- Spirea
- Strawberry
- Tansy (Common
- Twinberry
- Yarrow