55 Road 2013/14 Ecological Thinning Project Plan and As-Built Report

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Plan Purpose

The purpose of this project plan is to describe and justify the ecological restoration of forests with low resistance and resilience to combined disturbance through wind, insects, pathogens, and ungulate browse and future extended summer drought brought on by climate change. Forest management in this area is guided by the Cedar River Habitat Conservation Plan (CRW-HCP) to restore and protect habitat for species of concern including the northern spotted owl. The current disturbance regime has a high likelihood to lead to large scale disturbance in the homogeneous second-growth forests in this area. The proximity to rural development increases the risk of wildfire which would likely to propagate into the watershed under the current forest conditions. The plan defines project objectives, describes current and desired future conditions (DFCs) of the proposed project site, lays out a treatment plan to achieve those DFCs, and prescribes monitoring needs to measure project success. Our management goal in the project area is to provide stable and improved ecosystem functions such as water and nutrient cycle regulation, forest productivity, and wildlife habitat. The stability of the forest ecosystem providing these functions depends on its ability to resist biotic and abiotic disturbances and its resilience to recover ecological functions after large scale disturbance.

Stability =
Resistance + Resilience

Project Objectives

The upland forest restoration program under the CRW-HCP aims to restore late-seral forests in the watershed to provide habitat for species that depend on attributes of western Cascades old-growth (primary) forests such as large trees, vertically structured canopies, and decadence. The lack of existing primary forest in this part of the watershed makes development of nesting habitat for the northern spotted owl and potentially marbled murrelet a long-term goal, while foraging and dispersal habitat for the owl may develop sooner. The slow development of structural attributes in forests of low site productivity appears to be a risk in the lower watershed, but improvement in forest resistance to disturbance agents and functional resilience will improve the likelihood of achieving HCP goals. This project focuses on improving the stability of the forest stand, attempting to mitigate the real threats to the long-term development of late-seral forest habitat on this site. By improving the stability of the stand through improved tree vigor and biodiversity, we contend that we are increasing the probability that the stand will provide foraging and dispersal habitat for at-risk species into the future.

Historic forest conditions in this area could be described as structurally complex due to low site productivity and persistent disturbance. The two images of primary forest, south of the transmission line (50 Road), show forests that are similar in height to the today's conditions, broken crowns, a high number of snags, long crowns, multiple canopy layers, and a variety of tree species (Figure 1) .

Figure 1: Historical photos of the project area taken in 1909, from Seattle Municipal Archive.

Forests of the lower elevation Cedar River Municipal Watershed (CRMW), particularly south of the Cedar River, grow on droughty outwash gravel soils that increase susceptibility to large-scale disturbance. In most places, the forest is dominated by a relatively slow-growing Douglas fir tree canopy and a dense salal understory. The landscape, topographic, and edaphic characteristics of this forest make it particularly prone to wind damage, both branch breakage limiting crown development and windthrow. The uniformity of the forest in this area increases the likelihood that other disturbances such as root rot, bark beetle infestations, and fire will propagate in this landscape, leading to large scale disturbance of the forest. Further, as climate conditions are expected to change towards milder winters and drier, warmer summers, the susceptibility of the forest to large scale disturbance is expected to increase over time. This project will address these stability concerns in selected areas with the goal of improving the forest's resistance to disturbance and resilience to recover ecosystem functions following a large disturbance.

The objectives of this project are:

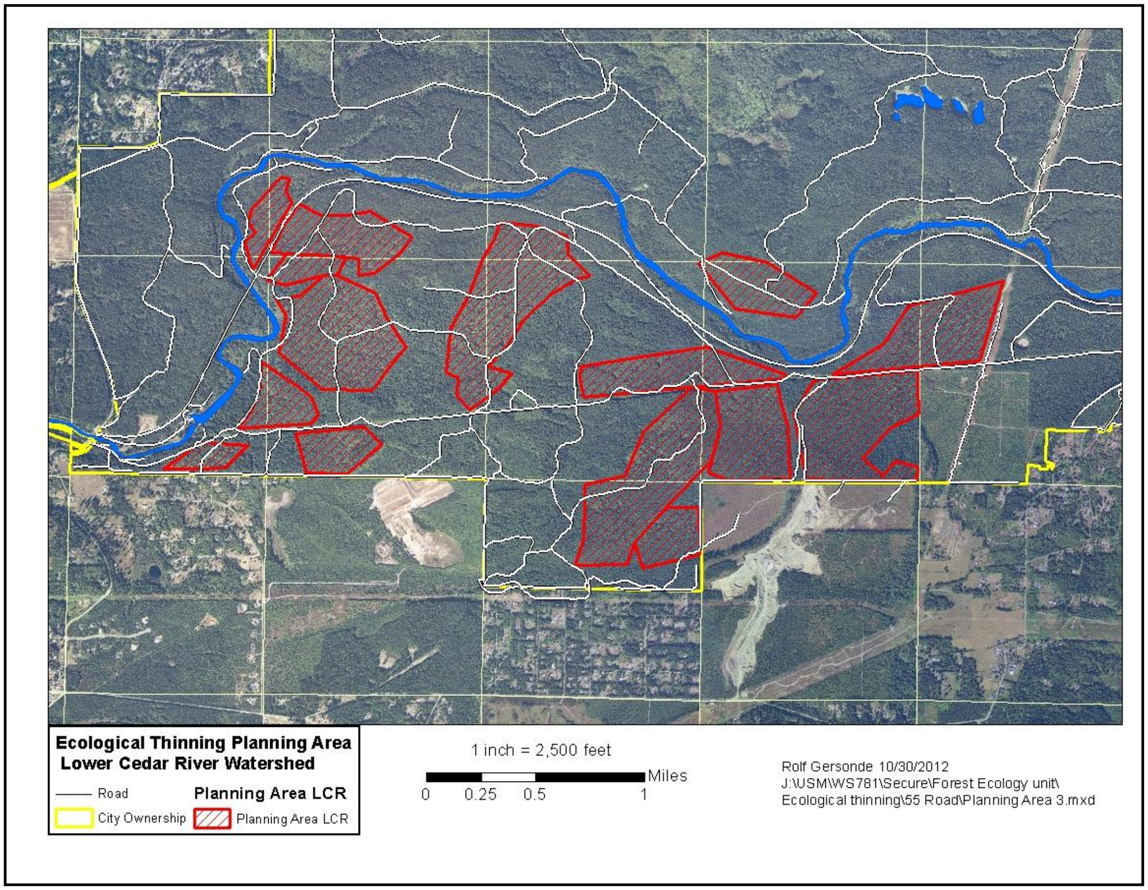
- *Increase species diversity*: A wider diversity of both overstory and understory plant species will provide resistance to disease and insect disturbance, which often are species-specific in their impacts. Species diversity may also provide resistance to exotic species invasion, by occupying a wider array of habitat niches. Higher plant species diversity is also linked with greater structural complexity. Species diversity will provide resilience following disturbance by creating more pathways to recovery.
- *Improve structural diversity*: A forest with structural diversity, such as the vertical layering of the forest canopy or variable densities of trees, will provide stability (i.e., resistance and resilience) in providing ecological functions, such as habitat, productivity, soil development, and water cycle regulation. Increased structural complexity and species diversity will improve the maintenance of these functions through regeneration and replacement of overstory trees in the face of disturbance. They also provide stability to wildlife by supporting a variety of habitat niches. A structurally diverse forest is also likely to have relatively high species diversity, and vice-versa. Spatial heterogeneity of canopy structure and forest composition is more likely to limit the propagation of disturbance (insects, pathogens, fire, and wind) than a homogeneous forest canopy of limited structural and species composition.
- *Increase individual tree resistance to disturbance*: Key habitat elements such as large trees are susceptible to insects and pathogens under the current conditions of resource competition. Reduced stem density (number of trees per acre) will improve vigor of residual trees and increase their resistance to disturbance agents.
- *Improve landscape habitat connectivity*: A more resistant and resilient forest will be more stable in providing wildlife habitat over time and space. Though the environmental conditions of the site may limit its ability to develop attributes of low-elevation old-growth forests, it will continue to provide habitat (nesting) to a host of wildlife species

and provide habitat connectivity (foraging and dispersal) through the lower CRMW, to riparian forests along the Cedar River, and regional lower-elevation forests. The site also provides a buffer and habitat connection between the private lands to the south of the CRMW, where some disturbances are more likely to originate, and both the Cedar River and interior core forests of the CRMW.

Location

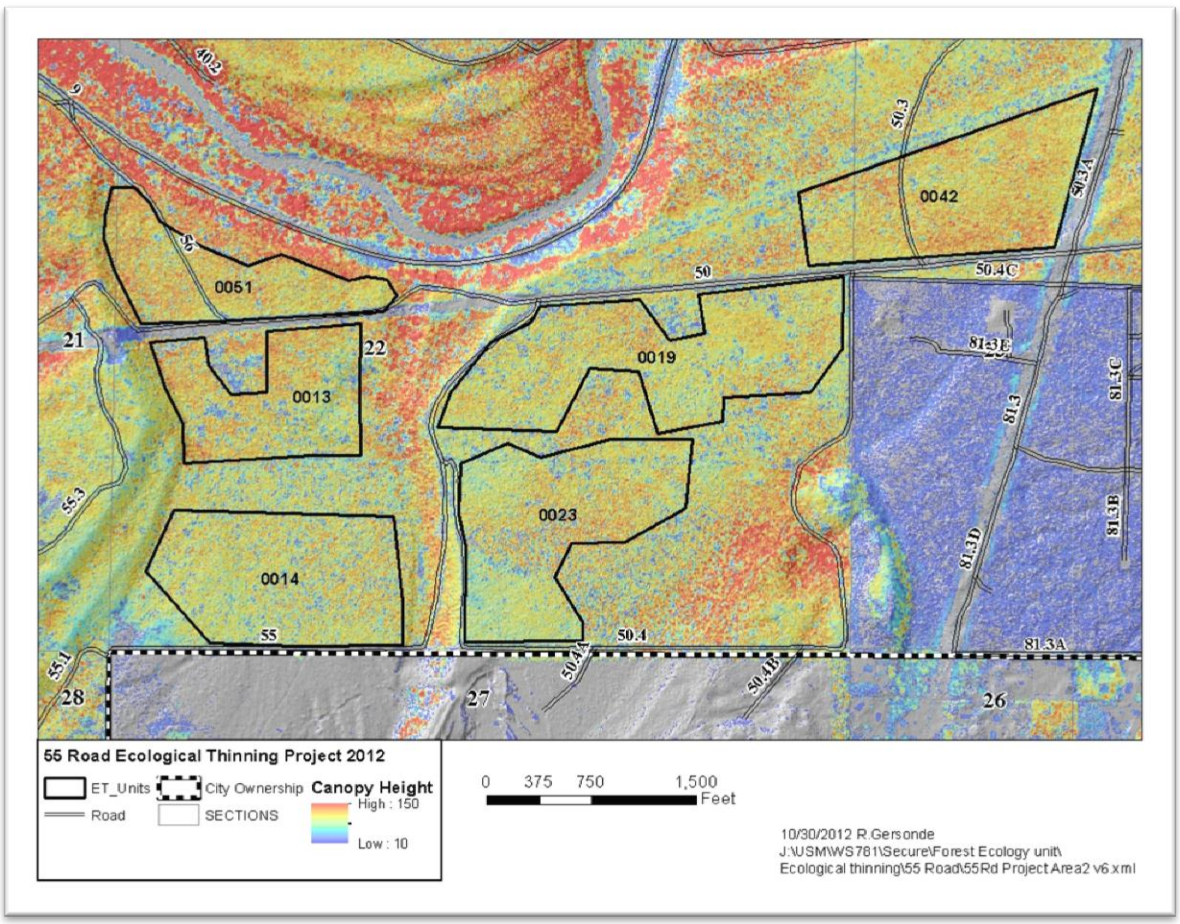
The Planning Areas for the above restoration objectives are the forests growing on low productivity outwash gravel terraces along the Cedar River in the lower CRMW. This area includes about 3,400 acres of upland forest of which approximately 1,200 acres are homogeneous Douglas-fir forest that are between 60 and 80 years old (Figure 2). The area will be split up into Project areas for project management purposes over 5-10 years. Some areas have become inaccessible to forest operations due to road decommissioning and abandoning of additional roads may restrict access in the future.

Figure 2: Forest Resistance and Resilience Planning Area in the lower CRMW.



The project area for 2013/2014 is in Sections 21, 22, and 23, Township 22 North, Range 7 East (Figures 2 and 3). The project encompasses approximately 200 acres that are bounded by the 9 road to the north, the 50.4 and 55 roads along the watershed boundary to the south, a decommissioned section of the 50.4 road and the power line ROW to the east, and the decommissioned 55.3 road to the west (Figure 3). Access is provided by the 50, 55, 50.4, and 50.3 roads. The site is relatively flat with a topographic break to the west of the bisecting 55 road. The flat area to the west of the road (called “Poverty Flats”) is 750 feet above sea-level (asl), while the flat area to east of the road is 850 feet asl. The site has continuous forest cover with a few wind throw gaps. The southern boundary runs along the CRMW boundary which is bordered by ruderal shrubland of a gravel pit and a revegetated clearcut with sparse tree cover. To the east, the project area borders the Douglas-fir plantation of the Foothills Property along the decommissioned 50.4 road. The northern boundary is close to the steep slope where the Cedar River has carved its bed into the outwash gravel and moraine material. An old abandoned trail or fence line appears to bisect the project area from east to west.

Figure 3: The 2013/14 Project Area between the Cedar River and CRMW boundary.



Analysis

The project area is located at the foothills of the western Cascade Range where glacial outwash and moraine material were deposited when glaciers retreated during the last ice age. The topography is flat and terraced. Soils in the project area are of the Barneston soil series and are composed of glacial outwash and volcanic ash deposits. The sandy loam soils have high coarse gravel content and are excessively drained with low water holding capacity. This site is characteristic of the transition from Puget Sound Lowlands to the Western Cascades.

The area has a temperate climate with average monthly temperatures ranging from 31.4 °F in January to 75.7 °F in July. Of the 57 inches of total annual precipitation, most falls during November to March, while only three inches fall during July and August. Precipitation is rain dominated with a total of 9.5 inches falling as snow, but snow accumulation only occurs in January. This climate creates favorable growing conditions during 6 months of the year, with a water deficit during the summer.

Climate predictions (derived from models in Climate FVS, USDA-FS, Crookston et al. 2010[1]) for the next 50 years show an increase of mean annual temperature of 5.4° F, an increase in annual precipitation of ~7.9 inches (changing from 65.1 to 72.4 inches), but no change in precipitation during the growing period. Mean minimum temperature is projected to increase by 7.5 °F (4.2 °F) and the frost free period is projected to increase from 182 days (in 1990) to 313 days (in 2060). Forests in the project area are projected to experience milder winters, earlier spring, and longer water deficits during the summer. The increase in winter precipitation is unlikely to lower water deficit during the summer due to the low water holding capacity of the soils in the project area.

The project area lies in the western hemlock forest zone and due to the soils in this area belongs to the dryer association of the series, the western hemlock/ocean spray – salal association (a list of plant names is included in Appendix I). Given the dryer site conditions it appears that Douglas-fir will retain dominance in late seral conditions along with western hemlock. This forest type is closely associated with the dryer, more open Garry oak woodlands of the Puget Sound Lowlands, which transition at richer sites into dry Douglas-fir forests. Tree species associated with Garry oak – Douglas-fir forests are western white pine, Shore pine, Pacific madrone, bigleaf maple, western redcedar, and bitter cherry. Deciduous shrub species in these forests include ocean spray, wood rose, poison oak, service berry, beaked hazel, trailing blackberry, Indian plum, snowberry, snowbrush, mooseberry, salal, Oregon grape, Pacific rhododendron, and twinberry.

The forest at the 2013/14 project site has an abrupt edge to the south where a neighboring landowner has cleared the forest. This edge appears to be permanent and is a gateway for several

[1] Crookston, Nicholas L.; Rehfeldt, Gerald E.; Dixon, Gary E.; Weiskittel, Aaron R. 2010. Addressing climate change in the forest vegetation simulator to assess impacts on landscape forest dynamics. Forest Ecology and Management. 260: 1198-1211.

invasive plant species. There are scattered English holly growing in the forest and Scot's broom grows in the young forest bordering to the east. However, the abrupt edge also connects the open shrub habitat to the south with the interior forest habitat in the watershed and provides transitional habitat for many wildlife species.

Due to the flat and plateau topography, there are no streams with perennial flow in the area. The area is, however, included in the hydrographic boundary of the Cedar River and two depressions seem to provide greater soil moisture availability, as indicated by taller tree growth in Figure 3.

Current conditions

The current forest structure consists of even-aged Douglas-fir forests. The stands originated after the primary forest was logged between 1918 and 1922 and subsequently experienced repeated fires caused by railroad traffic. Forest stand ages are between 50 and 80 years (based on the 2003 Inventory). Most stands are dominated by Douglas-fir with few western hemlock and redcedar and some patches of red alder. Younger stands are in the stem exclusion phase of structural development while older stands have differentiated larger trees. The canopy is mostly single-layered with scattered mid-story trees and a few patches of multi-layered structure. The understory is dominated by salal with some areas of higher soil moisture having greater cover of sword fern.

In most of the younger stands, competitive mortality dominates stand development resulting in many smaller diameter snags that are either standing or have recently fallen or broken from snow load or wind. The dominant disturbance agent in this area is wind from southeast direction, which causes uprooting of individual larger trees, patchy wind throw, and breakage of limbs.

This area of the lower watershed was inventoried by consulting foresters in 2003, and that data was recently updated to 2013 conditions using the Forest Vegetation Simulator (Table 1). Model results were field verified in 2013 and the deviations between check cruise and model by stand are given in Table 2. Differences in trees per acre in Stands 51 and 23 are likely due to the very small number of trees in the lower diameter classes that were sampled in 2012. The larger difference in basal area in stands 19 and 23 are likely due to windthrow. The remaining differences in sampled stand density may indicate variability in stand structure but need to be taken into account when designing thinning prescriptions because sampling intensity was higher in 2012. Because the bias in model results was not consistent among units, the projected model results in Table 1 were used in further analysis and timber volume calculations.

Table 1: Stand structure statistics of six identified sub-units in the project area. See figure 2 for Stand ID. All stand statistics are derived from 2004 timber cruise data and projected forward to 2012 using FVS.

Stand ID	TPA	BA	SDI	QMD	CuFt	BdFt	CuFt Growth	Top Height	Avg Ht
51	297	213	369	11.5	6292	32084	35	113	67
13	261	183	319	11.3	5410	27389	33	112	69
14	149	158	254	13.9	4827	25138	35	111	88
42	239	219	362	12.9	6563	33678	50	109	76
19	230	216	356	13.1	6639	33549	57	113	83
23	427	243	441	10.2	6640	32688	54	110	65

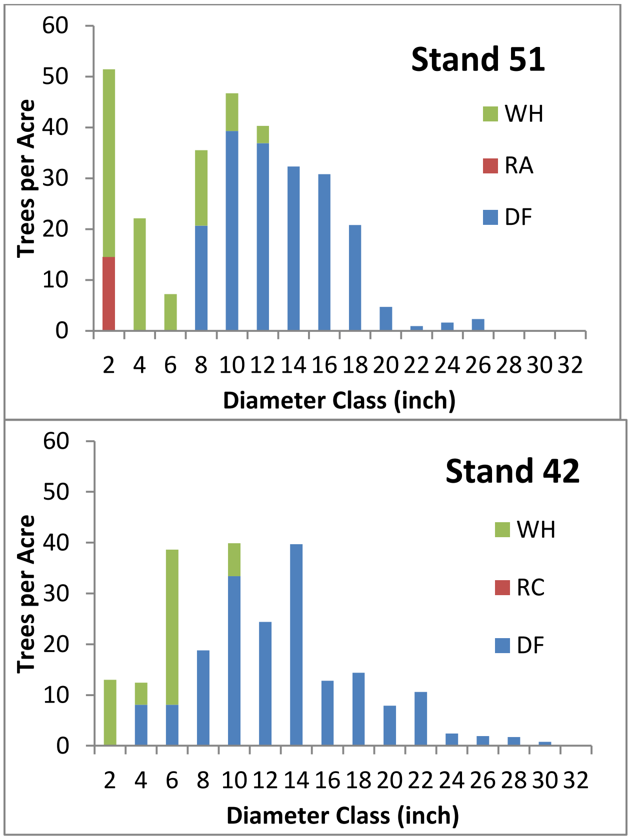
Table 2: Sub units were resampled in 2012 to determine the effect of windthrow and ingrowth and subsequent deviations from model projections.

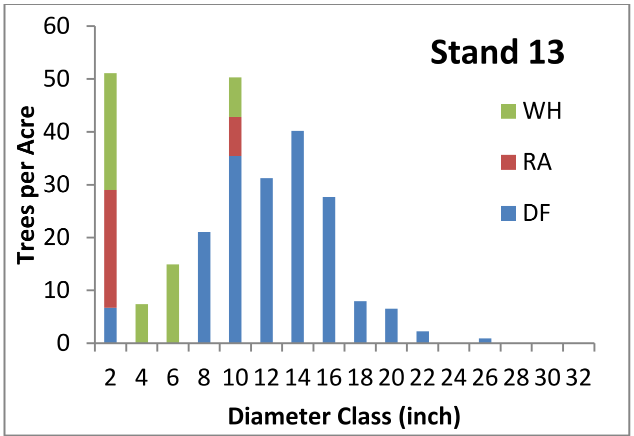
Stand ID	TPA-FVS	TPA-2012	Diff	BA-FVS	BA-2012	Diff
51	297	216	-81	213	200	-12
13	261	335	74	183	263	80
14	149	257	108	158	198	40
42	239	309	70	219	210	-9
19	230	209	-21	216	162	-54
23	427	263	-164	243	218	-25

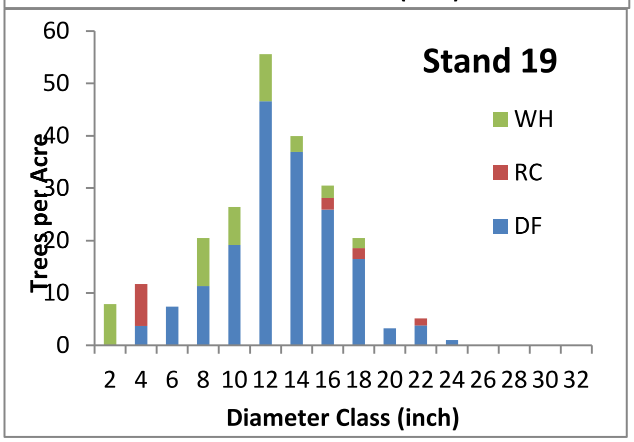
The following figures provide a graphic description of the forest conditions in the project area. Stand data were taken from the 2003 forest inventory and projected through 2012 using the Forest Vegetation Simulator.

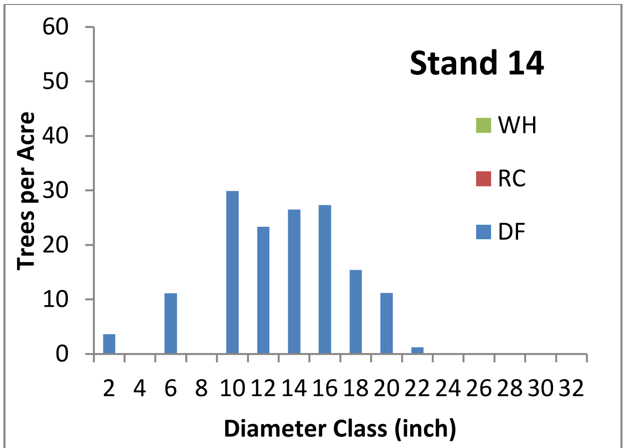
Figure 4 shows the frequency distribution of trees per acre by diameter class in the six forest stands. Forest stands 42 and 23 show a diameter frequency distribution that is right skewed, which indicates crown class differentiation and bimodality of the first cohort. Hemlock, redcedar, and alder occur in the smaller diameter classes and have established after the Douglas-fir. In forest stands 51, 42, and 13, establishment of a new cohort, in particular of western hemlock, is apparent in the smallest diameter classes. The total number of trees per acre varies between 149 and 427.

Figure 4: Frequency distribution of tree diameter classes by species in each unit of the project area; RC=western redcedar, RA= red alder, WH= western hemlock, DF= Douglas-fir.




Stand 13
WH
RA
DF
Trees per Acre
0
10
20
30
40
50
60
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32
Diameter Class (inch)


Stand 19
WH
RC
DF
Trees per Acre
0
10
20
30
40
50
60
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32
Diameter Class (inch)



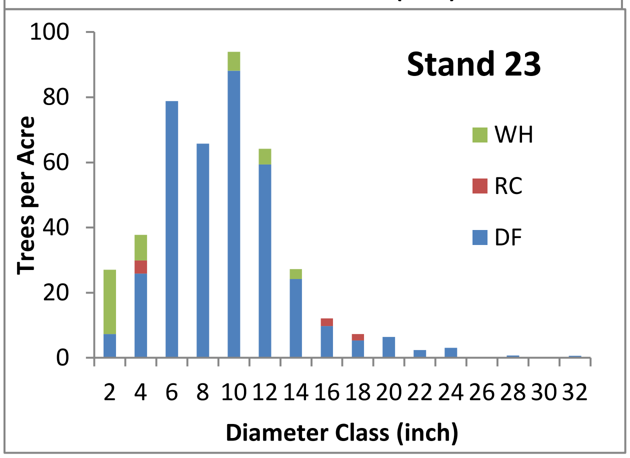
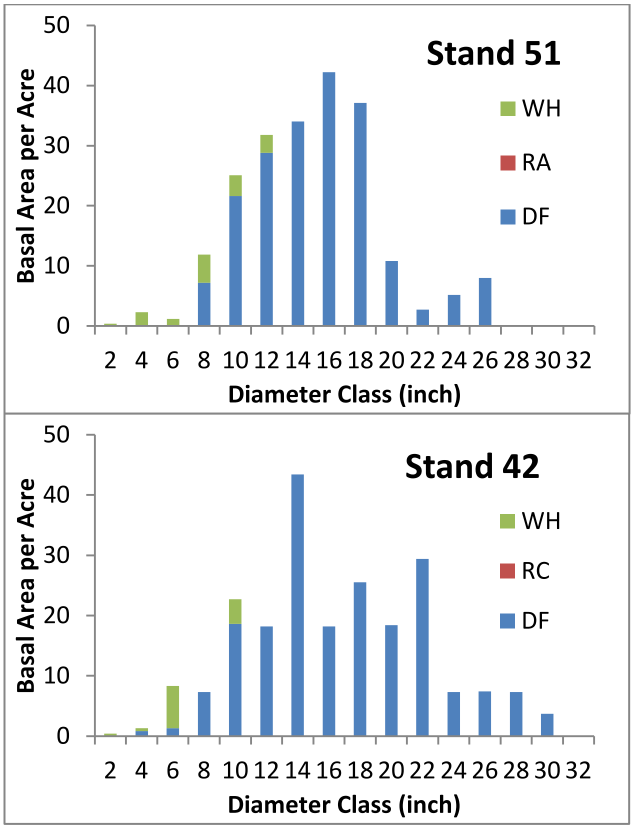
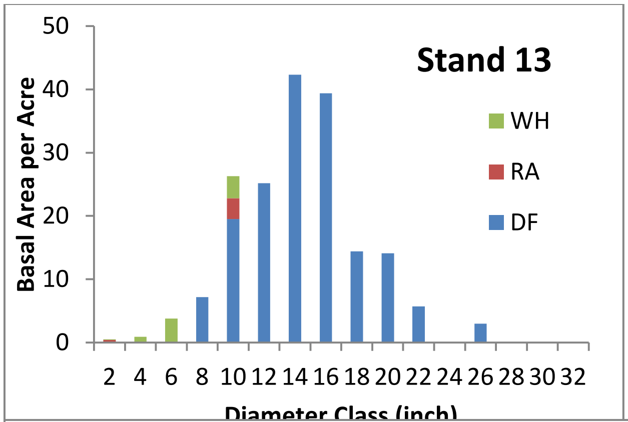
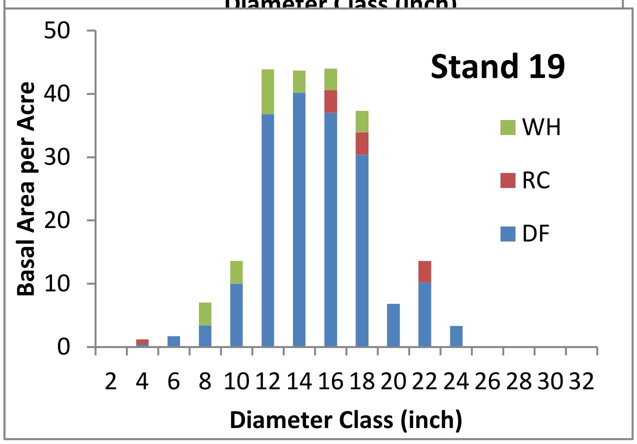


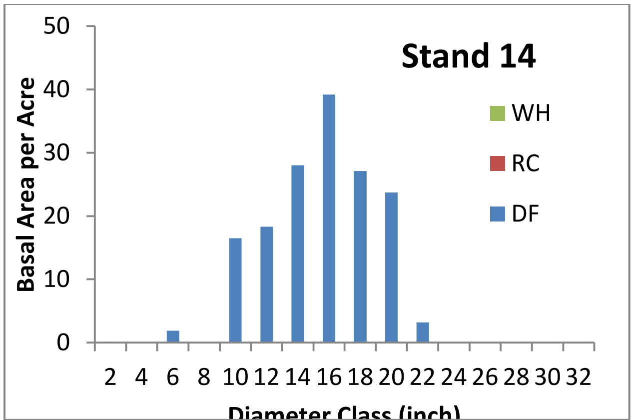
Figure 5 shows the basal area by diameter class of the six forest stands, which are dominated by Douglas-fir with most of the basal area in diameter classes between 10 and 22 inches DBH. Total basal area in 2012 is between 158 and 243 square feet per acre (Table 1). Western hemlock and red alder are scattered throughout the stands and occupy small proportions of the basal area. Stand density index ranges from 254 – 441 (Table 1) or 43 - 74% of maximum SDI for Douglas-fir (SDI 595). The SDI of 254 is relatively low for an unthinned stand at the age of 65 and is likely due to wind breakage of branches and reduced crown size, resulting in slower growth and reduced relative stand density. Four of the six stands have SDI >360 at which point competitive mortality occurs. Model output also estimates that average canopy cover is as low as 60%, which is 30% lower than comparable stands on better sites and less wind disturbance. The quadratic mean diameter (diameter of the tree with average basal area) varies between 10.2 in the densest stand and 13.9 in the stand with the lowest density.

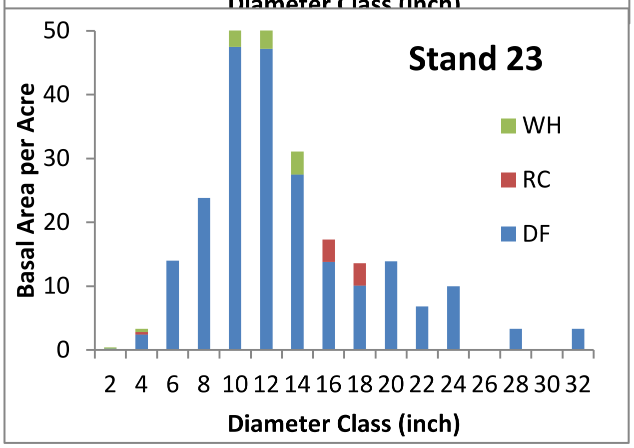
Figure 5: Distribution of basal area among tree diameter classes by species in each unit of the project area; RC – Redcedar, RA- red alder, WH- western hemlock, DF- Douglas-fir.




Stand 13
WH
RA
DF
Basal Area per Acre
50
40
30
20
10
0
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32
Diameter Class (inch)

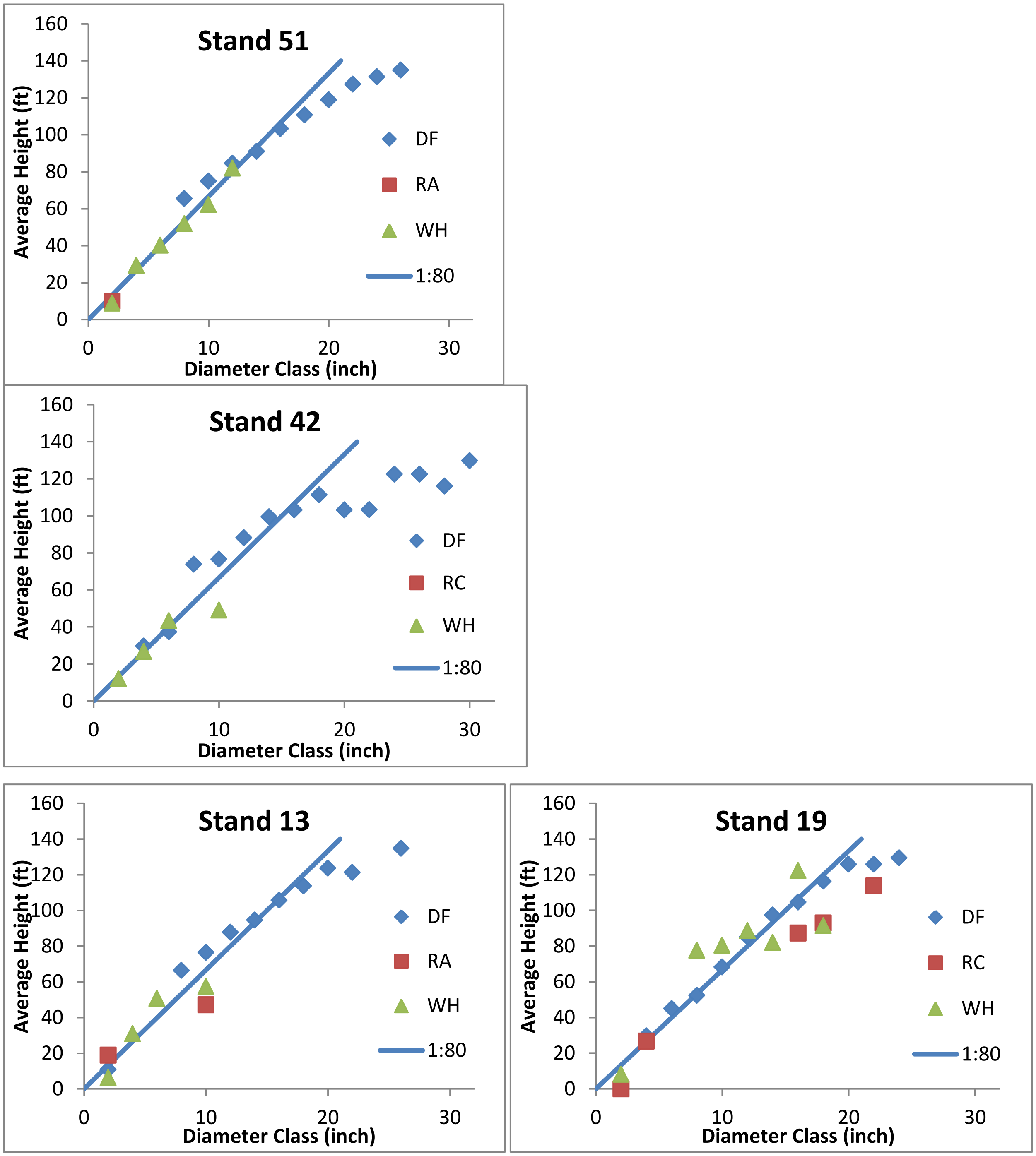

Stand 19
WH
RC
DF
Basal Area per Acre
50
40
30
20
10
0
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32
Diameter Class (inch)

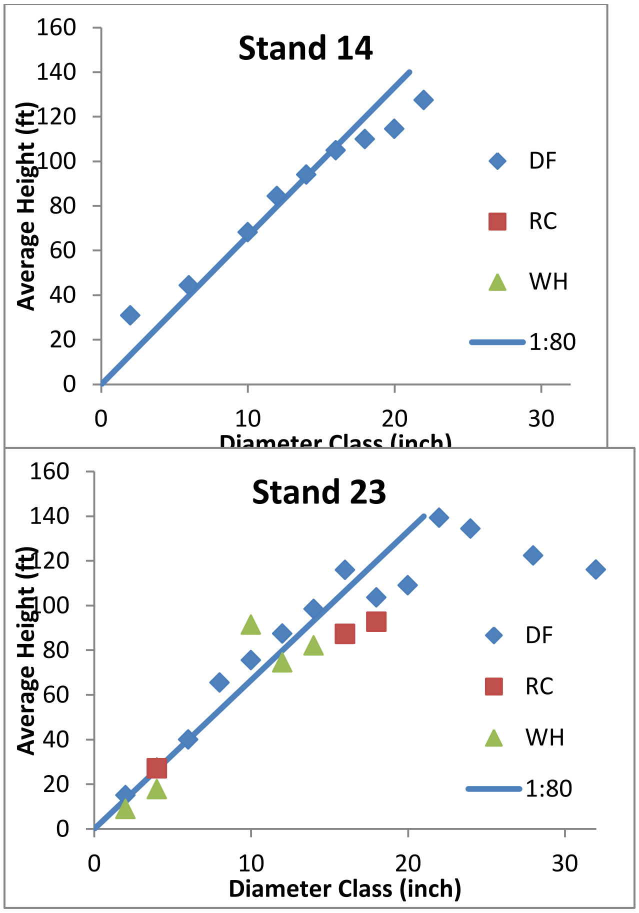




The distribution of tree heights by diameter class shows that most of the larger trees are relatively wind firm (Height/Diameter<80, Figure 6). Trees <14 inch DBH are more susceptible to wind throw in this area, but they are less exposed to wind through their lower height; these trees would become more susceptible if released through thinning. Stand 23 shows increasing top breakage from wind in large exposed crowns.

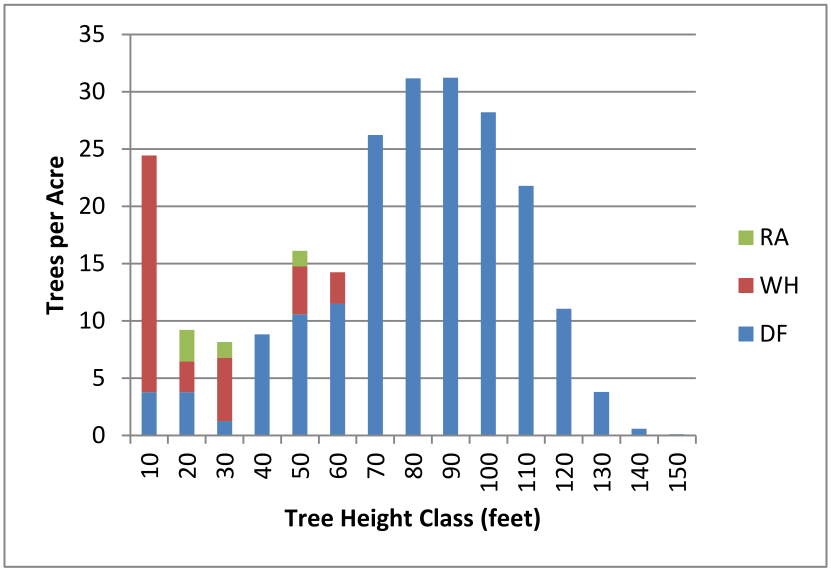
Figure 6: Average tree height by diameter class in the project area; RC – Redcedar, RA- red alder, WH- western hemlock, DF- Douglas-fir; trees below the 1:80 line are relatively stable to windthrow.





The tree height distribution is left skewed (Figure 7), which is typical for single cohort stands with sporadic regeneration, with most of the regeneration being shade tolerant species (hemlock) and red alder establishing only in canopy gaps. The relatively wide height distribution of western hemlock indicates that these understory trees did not establish following a single disturbance event, but are establishing at a low annual rate.

Figure 7: Frequency distribution by tree height class for Stand 14.



The stand volume was estimated to be 5,649 cubic feet or 22,337 board feet per acre in 2003. Projecting the stand volume development forward, stand volume in 2012 is estimated to be 6,008 cubic feet or 23,785 board feet per acre. The inventory check-cruise in 2012 showed deviation from the model results for individual stands. Average stand density and volume across the project area was confirmed. Stand volume increment is estimated to be 160 board feet per year per acre, which is low compared to average Douglas-fir stands in this region.

Desired future conditions

The desired future conditions (DFCs) of the forests in the project area would ensure provision of current ecosystem services as well as greater resistance and resilience to large-scale disturbance events. Forest conditions that provide these functions maintain a continuous forest cover, include multiple canopy layers, comprise diverse species composition of site adapted species, maintain vigorous tree growth and regeneration, and maintain standing and down dead trees. We have identified DFCs as follows:

- A variety of species is established and can function as seed source to assist with forest recovery after disturbance. Their distribution can provide seeds to 50% of the area. Tree numbers are high enough to allow for disturbance mortality while still maintaining sufficient propagule sources for recovery.
- Forest edge habitat has a diverse plant community. Permanent forest edge is not dominated by conifers but a variety of deciduous species that connect forest and shrub habitat types.

- Small canopy gaps, similar to those created by small-scale windthrow, are frequent allowing for establishment of additional tree and shrub species across project site, thus increasing species diversity.
- The currently homogeneous single-layered canopy is diversified by introducing processes of vertical and horizontal diversification in a patchy mosaic. Forest canopy structure is balanced between (1) existing tall closed canopy, (2) initiated two cohort canopy, (3) created diverse canopy gap, and (4) thinned high open canopy. Individual structure types are interspersed.
- Large trees with long crowns are released from intra-cohort competition through thinning.
- Areas of homogeneous canopy are intersected by contrasting canopy types and diverse outside edge structure.
- Planted trees and shrubs are growing vigorously through released from competition (primarily by salal) and are large enough to be unaffected by browse.
- Areas of continuous canopy structure are large enough to provide interior forest habitat in the future despite ongoing disturbance. The forest has age class diversity resulting from disturbance and regeneration with 2/3 of the area in mature forest structure. Standing and down dead wood is provided through competition mortality in unthinned skips and disturbance mortality of individual large trees.

Management constraints

Canopies are dominated by Douglas-fir and understory by salal. Species diversity can only be improved through planting of alternative species and release of minor species from competition. The existing salal understory will exert strong belowground competition for water on any planted seedling and may increase seedling mortality and establishment time. The size of canopy gaps, which reduce competition of overstory trees on planted seedlings, is limited to the extent of small size windthrow gaps in this area, consistent with the overall goal of developing late-seral forest stand structure. Introduction of additional, less shade tolerant species is limited to these gaps.

Portions of the forest experience strong resource competition and competitive exclusion among trees. Trees in these areas will be susceptible to wind disturbance if thinned. Stands that do not show advanced crown differentiation (stand 23) have more trees with instable height to diameter ratios and require more canopy closure to resist windthrow. Prescribed residual tree density will be higher in these stands.

Risks and Mitigation Strategies

This area is winter range for elk and deer. Past experience with planting unprotected tree seedlings have shown heavy browse and mortality. Success of planting additional species, especially western redcedar and bigleaf maple, in this area depends on protection from browse. Higher planting density as well as planting larger seedlings may increase overall success of establishing these species.

The Douglas-fir dominated forests in the lower watershed have experienced recent elevated numbers of Douglas-fir beetle and Armillaria root disease, which have led to individual tree mortality. Droughty site conditions make individual trees susceptible to bark beetle attack and root disease. While the lowering of resource competition through thinning and release will increase tree vigor and lower tree susceptibility, mortality from a variety of causes is still likely to continue. In order to maintain Douglas-fir canopy cover, enough trees should be maintained to allow for beetle mortality as well as windthrow and wind breakage.

Invasive species may establish in canopy gaps and forest edges where growing space is created for planting; make planting areas discontinuous to limit spread of invasive species.

Prescription

Prescriptions for activities to achieve management objectives and desired future conditions are outlined in the following table. Activities are listed in order of effectiveness to achieve our objectives, and will be most effective if implemented in concert, whether on the same site or in distinct areas.

The restoration activities in Table 3 are translated into structural and spatial prescriptions in Table 4. Structural prescriptions apply at the patch scale and are designed to promote stand development processes and increase diversity. Spatial prescriptions address size and location of structure types to improve spatial heterogeneity and connectivity, but also address operational constraints.

Table 3: Management activities that address individual objectives in order of their effectiveness.

Management Objectives	Activities to Address Objectives			
Increase species diversity	Plant diverse species in canopy gaps	Vary tree density at stand edges, diversify ecotones	Underplant less abundant species	Release less abundant species
Improve seed sources	Release dominant trees from competition	Release less abundant species	Limit browse disturbance on less abundant species	Plant to augment seed sources
Improve structural diversity	Patches of lower canopy cover, retain larger trees	Underplant with trees and shrubs	Facilitate canopy stratification	Release dominant trees from competition
Diversify age classes	Plant canopy gaps	Underplant with trees and shrubs	Limit browse disturbance on less abundant species	
Facilitate or maintain decadence	Retain CWD	Maintain large tree component	Retain areas with high density	Create snags
Increase resistance to disturbance	Release dominant trees from competition	Lower stem density, retain largest trees	Create discontinuous canopy	
Improve landscape connectivity	Improve connectivity on patch scale	Improve connectivity on landscape scale	Contrast adjacent treatments	Diversify ecotones

Table 4: Prescriptions for implementation of management activities in Table 3.

Activity	Structural Prescription	Spatial Prescription
Improve connectivity		Create elongated areas of structure types, emphasize South-North connectivity
Create discontinuous canopy	Create ½ acre of canopy gaps every 10 acres, of ¼ - ½ acre gap size	Gaps marked on map and located by operator, make use of existing gaps
Contrast adjacent treatments		Intersperse skips and gaps
Release dominant trees from competition	Identify 5-6 large vigorous trees per acre and cut competitors in 30 feet radius	Leave trees and cut trees marked within other structure types
Lower canopy cover	Where avg H/D >80, thin from below to 40% overstory canopy cover	
	Where large tree H/D <80 thin to 30% overstory canopy cover	
Vary tree density at stand edges	Create 20-40 ft spacing of overstory trees, wider spacing at road edge	Indicate on map along south border and along 50 road
Release less abundant species	Release hardwood and minor species in overstory, cut competitors in 30 ft radius	Leave trees and cut trees selected by operator
Retain areas with high density	Leave some untreated areas	Areas outside marked boundary of other types, and small interspersed patches
Underplant less abundant species	Plant 300-350 trees per acre: THPL, ABGR, PREM, ACMA	Underplant 30% of thinned area in clustered planting at 10ft spacing in one acre patches where canopy cover is lowest
Plant diverse species in canopy gaps	Plant 300-350 trees per acre (ACMA, PIMO, PICO, POTR, PREM) + shrubs (refer to Table 6)	Clustered planting in gaps, trees at 10ft spacing, shrubs at 5ft spacing
Plant diverse species in stand edge	50 each per acre (ACMA, PREM, MAFU, QUGA) + shrubs	Dispersed planting along edge, trees at 10ft spacing, shrubs at 5ft spacing
Limit browse disturbance on less abundant species	Single tree protection of seedlings (THPL, ACMA) in canopy gaps, underplanting patches, and edge treatments	

The larger trees (>18 inch DBH) in this forest will not be cut, except in small canopy gaps. Stands will be thinned from the small end of the diameter distribution (thinning from below). Implementation of the project with ground-based logging equipment increases the flexibility of avoiding larger trees in yarding corridors.

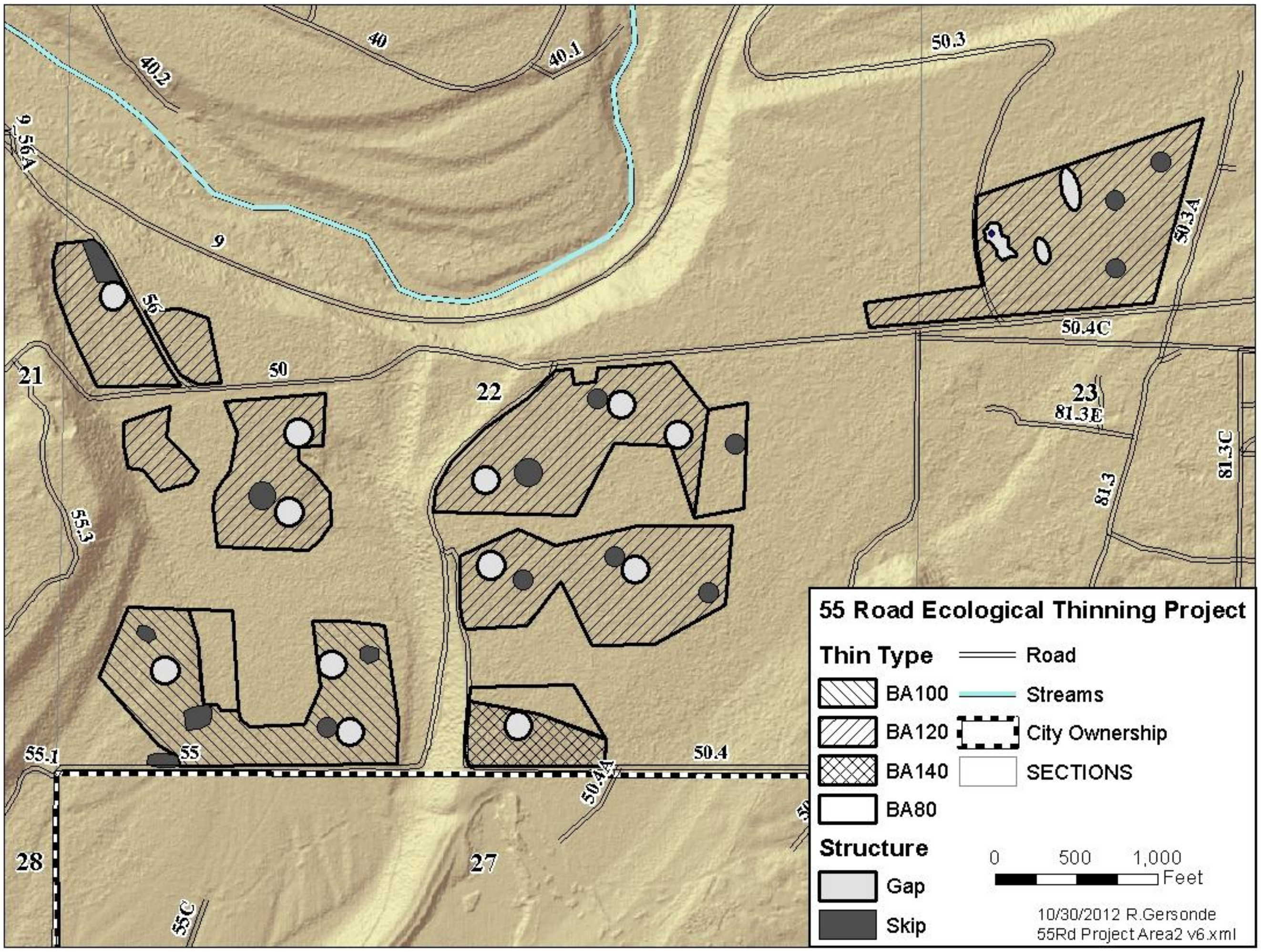
The retention targets for the treatment options in this project are within the natural variability of forests of this type. The objective of the retention levels is to increase the variability of canopy coverage across the landscape while providing growing space for the various planted species that augment the area's biodiversity.

While the management of deer and elk habitat is not part of this project objectives or the HCP, this project may provide short-term foraging habitat for these species. The long-term goals for this project focus on forest stability and resilience to support the objective of developing late-seral forest habitat.

Spatial Scale of Variability

Current variability of structure and composition in the project area is provided by change in edaphic conditions at 50-200 acre scale, but is masked by structural homogeneity due to forest management history. Small scale heterogeneity is being created through wind-throw gaps at the sub-acre scale. Spatial variability at intermediate scales can be increased by creating thinning units of variable size and irregular shape. Unit size varies between 12 and 28 acres with lower density areas of 3 acres (Figure 8). Thinning is prescribed in areas of relatively homogeneous canopies. Areas of irregular canopy and existing gaps are excluded from thinning. Additional heterogeneity is created through placement of canopy gaps (0.25-0.5 acre) and unthinned areas (skips, 0.25-0.5 acre) at the sub-acre scale. Skips are located to retain areas of two-layered canopy, protect large individual trees or snag clusters, or are associated with canopy gaps to increase structural contrast. A network of unthinned area is maintained to provide connected areas of higher CWD and canopy cover. Within-unit heterogeneity is achieved by thinning to basal area targets, rather than a more uniform spacing prescription. Variability at the inter-tree distance is created by retaining neighbor tree groups (see thinning prescription) and operator located 10^{th} acre gaps. Variability in vertical structure is created by under-planting in clusters of 1-2 acres in size in areas of lower canopy cover.

Figure 8: Layout of thinning units with varying density, canopy gaps, and unthinned skips in the 55 Road Project.



Thinning and Canopy Gaps

Thinning density is prescribed by management unit (see Table 5). In all units, trees are thinned starting from the smaller diameter classes (>7.5" DBH, thinning from below) to a maximum diameter of 18" DBH. Residual stand density ranges from 80 square feet of basal area (BA) to 140 BA. Variability in tree density within the management unit scale is achieved by following basal area prescriptions throughout the variable size class distribution, resulting in variability in numbers of trees per acre depending on average tree size. Additional variability is achieved by retaining small unthinned areas (skips) and creating canopy gaps up to half-acre in size. Due to variability in stand density and structure within the management units, harvested and retained stand volume will vary between units. Increase in tree species diversity is achieved by cutting only Douglas-fir and retaining all minor species, including western hemlock, western redcedar, big leaf maple, red alder.

Feathering of the southern canopy edge through creating lower density areas is prescribed along core roads. This low density canopy edge will be under-planted with diverse deciduous and evergreen shrubs and trees to create deep transitional edge habitat. Additional Cut&Leave treatment to augment CWD outside the thinning areas is not prescribed because of existing CWD and expected input through various causes of mortality.

Prescriptions:

BA80 – Thin trees to a residual basal area of 80 square feet per acre by thinning from below (cutting smaller diameter trees first). Do not cut live trees smaller than 7.5 inches DBH or trees larger than 18 inches DBH. Retain 5 (five) groups of close neighbor-trees per acre (2-3 trees).

BA100 – Thin trees to a residual basal area of 100 square feet per acre by thinning from below. Do not cut live trees smaller than 7.5 inches DBH or trees larger than 18 inches DBH. Retain 10 (ten) groups of close neighbor-trees per acre (2-3 trees). Create 5 (five) 1/10 acre gaps per acre.

BA120 – Thin trees to a residual basal area of 120 square feet per acre by thinning from below. Do not cut live trees smaller than 7.5 inches DBH or trees larger than 18 inches DBH. Retain 10 (ten) groups of close neighbor-trees per acre (2-3 trees). Create 5 (five) 1/10 acre gaps per acre.

BA140 – Thin trees to a residual basal area of 140 square feet per acre by thinning from below. Do not cut live trees smaller than 7.5 inches DBH or trees larger than 18 inches DBH. Retain 15 (fifteen) groups of close neighbor-trees per acre (2-3 trees). Create 5 (five) 1/10 acre gaps per acre.

Canopy Gap – Locate gaps in areas that have no minor species. Cut all trees within the circular perimeter of a ½ acre gap with a diameter of 166 feet. Remove or pile slash to provide planting spots.

Table 5: Post-thinning stand structure and harvested component for each stand and prescription.

Unit #	Prescription	Acres	Post-Thin TPA	Post-Thin BA	Harvested TPA	Harvested %BA	Harvested CUFT/ac	Harvested BDFT/ac
19	80BA	3.85	86	87	143	60	3543	19715
	120BA	21.55	115	127	114	42	2295	12948
	Gap	1.5	0	0	230	100	6187	33549
	Skip	1	230	216	0	0	0	0
23	80BA	2.9	217	106	208	57	3266	18865
	120BA	21	254	146	171	40	2154	12719
	140BA	5.5	278	165	147	32	1645	9856
	Gap	1.5	0	0	427	100	5855	32689
	Skip	0.75	427	243	0	0	0	0
42	120BA	27.75	123	130	115	41	2250	12803
	Gap	1.28	0	0	239	100	6097	33679
	Skip	0.78	239	219	0	0	0	0
13	120BA	15.4	169	127	91	30	1203	6908
	Gap	1	0	0	261	100	4941	27390
	Skip	0.5	261	183	0	0	0	0
14	80BA	3.2	63	82	86	48	1962	11035
	100BA	23	77	102	71	35	1349	7674
	Gap	1.5	0	0	149	100	4552	25138
	Skip	1.05	149	158	0	0	0	0
51	120BA	11.25	173	128	123	40	1910	10968
	Gap	0.5	0	0	297	100	5781	32084
	Skip	0.75	297	213	0	0	0	0

Total Area 135.4 acres

Planting

Areas thinned to 80-120 square feet of basal area will be underplanted in one-acre patches covering one third of the area. Shade tolerant grand fir and western redcedar will be planted in clusters with small groups of big leaf maple and bitter cherry interspersed in small canopy gaps. Areas with lower canopy cover will be prioritized for planting. Larger canopy gaps (0.5 acre, total area of 7.28 acres) will be planted with groups of white pine, big leaf maple, black cottonwood, shore pine, and shrub species including beaked hazel, cascara, and red elderberry. Planting density will allow for mortality from browse, shrub competition, and summer drought. Grouped planting patterns will reduce inter-species competition and retain less competitive species in the future stand. A section of the south-facing forest edge along the 55 and 50 roads will be thinned to lower density and interplanted with diverse species to create a deep transitional edge habitat between forest and open-shrub habitat. Plant species include trees and shrubs that are common in lowland Puget Sound plant associations as well as Garry oak/Douglas-fir associations. Browse protection for individual trees and shrubs will be applied to a portion of the planted stock in each of the areas.

Table 6: Planting specifications for structure types.

Structure Type	Acres	Species (per acre)	Count	Pattern
30% Canopy Cover BA80	5.0	Western redcedar (150)	750	1 acre patches 10x
		Grand fir (100)	500	10x10 group of 16
		Bitter cherry (50)	250	10x10 group of 9
		Big leaf maple (50)	250	10x10 group of 9
40% Canopy Cover BA100-120	30.0	Western redcedar (100)	3000	1 acre patches 10x
		Grand fir (100)	3000	10x10 group of 16
		Bitter cherry (50)	1500	10x10 group of 9
		Big leaf maple (50)	1500	10x10 group of 9
Canopy Gap	7.0	Big leaf maple (50)	350	10x10 group of 16
		Western white pine (100)	700	10x10 group of 16
		Black cottonwood (50)	350	10x10 group of 9
		Shore pine (50)	350	10x10 group of 9
		Beaked hazel (50)	350	5x5 group of 9
		Cascara (50)	350	5x5 group of 9
		Red elderberry (50)	350	5x5 group of 9
Edge	2.0	Bigleaf maple (50)	100	10x10 group of 3
		Black cottonwood (50)	100	10x10 group of 3
		Bitter cherry (50)	100	10x10 group of 3
		White oak (50)	100	10x10 group of 3
		Crabapple (50)	100	10x10 group of 3
		Beaked hazel (50)	100	5x5 group of 3
		Indian plum (50)	100	5x5 group of 3
		Chinquapin (50)	100	5x5 group of 3
		Service berry (50)	100	5x5 group of 3
		Red elderberry (50)	100	5x5 group of 3
		Snow brush (50)	100	5x5 group of 3
TOTAL	44.0			

Layout

Thinning and Canopy Gaps

Locations for specific activities are guided by local stand conditions and desired pattern of structural diversity at the patch and landscape scale. Multiple management objectives (tree stability, vertical diversification) can be achieved in the same location while others (species diversification, edge habitat) can only be achieved in discrete areas.

Unit boundaries are marked in the field. Interior boundaries such as gaps and changes in thinning density are only provided on the map and need to be located by the contractor using a GPS. Some skips that are located to explicitly protect areas of larger trees and multiple canopy layers will also be marked in the field.

Thinning units are located along roads to allow access by yarding equipment. Unthinned areas are located where access is restricted and where sensitive features or complex canopy structures exist. Areas of lower density thinning (80 BA) are located where large diameter, wind-firm trees exist that already grow at wider spacing.

Planting

Planting in canopy gaps and under-planting in low density thinning areas will use a clumped planting pattern. Trees will be planted at 10 feet spacing in groups of 16 trees per species in canopy gaps. Shrub species will be planted at 5 feet spacing in groups of 9 plants. Under-planting will be patchy (approximately 1 acre patches) with trees planted in groups of 9 or 16 trees per species.

Safety and Access

Site access is through the 50, 55, and 50.4 roads. Access for log haul is through the Selleck Gate, 81 and 80 Roads. Traffic control will easily be addressed via road closed signs on the 55 Road at either end during the tree felling and yarding operation. The 55 and 50.4 roads will be open to traffic after work hours and on weekends. SPU staff will also be notified in advance of this work to minimize disturbance to other required road access needs. Access permits for crews needing entry to the project site will be facilitated through the Project Manager as needed, in cooperation with SPU Security. The contractor is responsible for providing and servicing a sanican at the worksite, and to abide by SPU watershed access regulations.

SPU will develop a safety and communication plan for this project that addresses protocols for emergency and fire management, spill response, and communication with SPU personnel.

Two small sections of road on the east and west end of the project area will be rocked prior to the thinning operations. Occasional grading on the 80 road will remove washboard surface due to haul traffic. Speed limit signs of 25mph will be posted on the 50 Road during thinning and haul operations.

Monitoring and Adaptive Management

The objectives for monitoring are:

- assure that the prescriptions are followed during the implementation,
- the desired stand density, variability, species composition are achieved,
- track growth and mortality of planted seedlings,
- establish baseline to track tree growth and mortality of overstory trees.

Compliance monitoring will be conducted by SPU staff throughout the thinning and planting activities to assure that the project is implemented according to the project plan and implementation contracts. Compliance monitoring will also provide information on post-treatment stand structure and composition that will be used to update the forest inventory database. The evaluation of project implementation will be based on compliance monitoring data and will be used in future project design. A subsample of planted trees and shrubs in gaps and under the canopy will be marked in the field and surveyed for survival and growth over the first three years. This information will be used for future plant selection, gap opening size, and plant protection.

Monitoring plots for tracking tree growth and mortality will be established by student volunteers or interns. These plots will provide baseline data for possible long-term tracking of forest development in different stand structure types. Students will have the opportunity to use sampling methods and monitoring data in academic projects.

Appendix I. Plant species names and abbreviations:

Common Name	***Scientific Name***	**Abbreviation**
Beaked hazel	*Corylus cornuta*	COCO
Bigleaf maple	*Acer macrophyllum*	ACMA
Bitter cherry	*Prunus emarginata*	PREM
Black cottonwood	*Pupulus trichocarpa*	POTR
Crabapple	*Malus fuscum*	MAFU
Cascara	*Rhamnus pursiana*	RHPU
Chinquapin	*Castanopsis crysophyllum*	CACR
Douglas-fir	*Pseudotsuga menziesii*	PSME
Elderberry	*Sambucus racemosa*	SARA
English holly	*Ilex aquifolium*	ILAQ
Garry oak	*Quercus garryana*	QUGA
Grand fir	*Abies grandis*	ABGR
Indian plum	*Oemleria cerasiformis*	OECE
Madrone	*Aburtus menziesii*	ABME
Mooseberry	*Viburnum edule*	VIED
Ocean spray	*Holodiscus discolor*	HODI
Oregon grape	*Mahonia nervosa*	MANE
Pacific rhododendron	*Rhododendron macrophyllum*	RHMA
Poison oak	*Toxicodendron diversiloba*	TODI
Salal	*Gaultheria shallon*	GASH
Scot's broom	*Cytisus scoparius*	CYSC
Service berry	*Amelanchier alnifolia*	AMAL
Shore pine	*Pinus contorta var. contorta*	PICO
Snow berry	*Symphoricarpos albus*	SYAL
Snowbrush	*Ceanothus velutinus*	CEVE
Trailing blackberry	*Rubus ursinus*	RUUR
Twin berry	*Lonicera hispidula*	LOHI
Western hemlock	*Tsuga heterophylla*	TSHE
Western redcedar	*Thuja plicata*	THPL
Western white pine	*Pinus monticola*	PIMO
Wood rose	*Rosa gymnocarpa*	ROGY

As-Built Documentation of the 55 Road Ecological Thinning Project

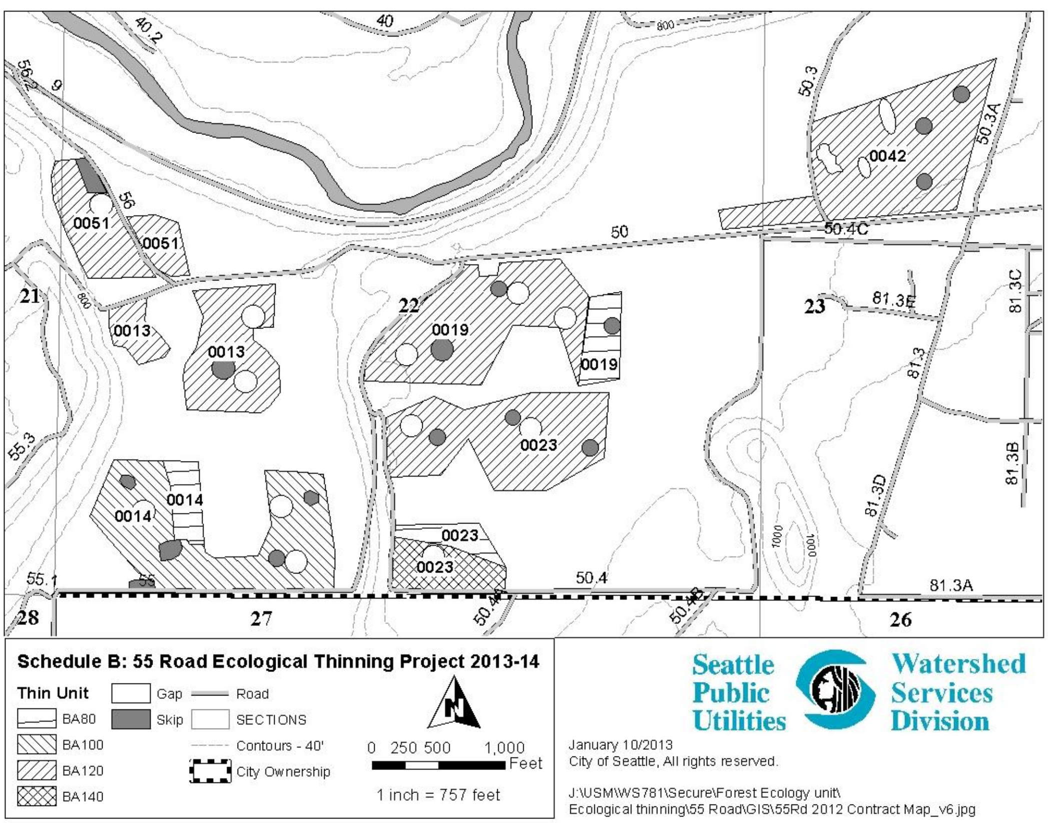
Project Layout and Permits

This ecological thinning project was approved by Ordinance for Ecological Thinning Council Bill Number 117567. The ordinance allows SPU to conduct ecological thinning in select locations on approximately 2800 acres of second-growth forest over a period of 5 years.

We submitted a SEPA exemption letter for the project that was approved and signed on 9/20/2012.

A forest practices application was submitted to the WA DNR for a previous version of the project plan in 2012, which was approved on 5/18/2012. Because of significant changes in the project re-design in 2013, we requested to withdraw the 2012 FPAN and resubmitted a new FPA in 2013, which was approved on 3/6/2013.

The project boundaries were laid out during the winter of 2012/13 according to the project map. Location of skips and gaps was modified to accommodate the logging operation.



Project bids, costs, and revenue

A request for proposal was sent to the vendor pool developed in 2013. SPU awarded the 55 Road Ecological Thinning Project to Pulley Corporation under the blanket contract 3062-1. The contact was awarded for one year with a bid price of $35.33 per ton of saw timber sold to the contractor. Pulpwood was sold for $1 per ton to the contractor. A second bid, received from Westek Forest Ldt., was not awarded.

Thinning operations started after March 15, 2013 with cutting in Unit 0014 and finished on August 8, 2013. A total of 11,089 tons of timber (1431 MBF) were shipped during that period. Total stumpage payments were $343,332. The contractor was credited a total of $12,855 for slash management. The contractor paid a total of $3037 to SPU for road construction and maintenance (see below). The total revenue from the sale of surplus timber, deposited into the SPU Water Fund was $333,514.

Total project costs were approximately $69,430, including planning ($12,660), design ($13,900), contracting ($12,270) and implementation ($30,600)

Roads

Two short (50 feet) rock spurs were constructed under the SCL ROW along the 50 road to facilitate access to units 0013 and 0019. The rock spurs were constructed by SPU and the contractor reimbursed SPU for the work. Road maintenance during the operation consisted of rocking two short section of the 55 Road along the fence line and grading of the access roads during operations. The contractor reimbursed SPU for the road maintenance costs.

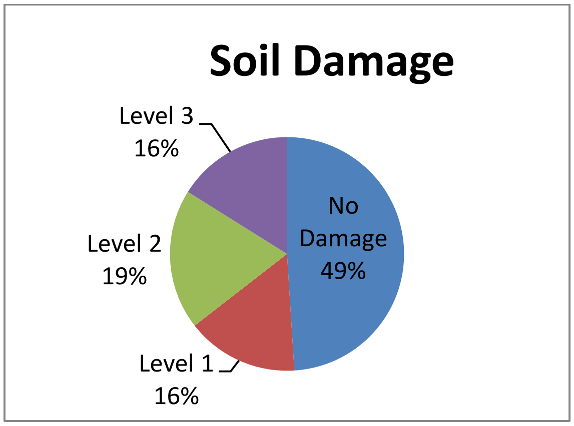
Thinning Units

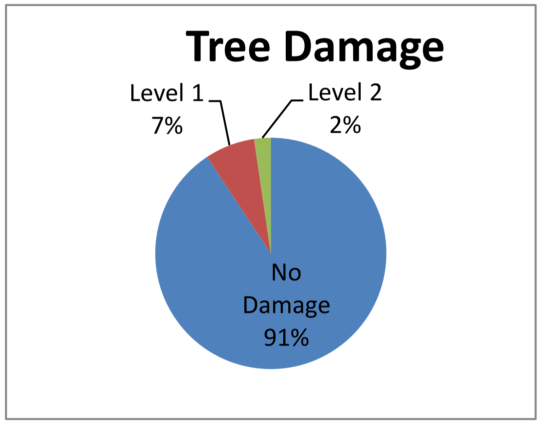
The project area was divided into distinct thinning units as outlined in the Project Plan. The units were thinned according to the prescriptions in the plan and post-thinning statistics can be found in the following table.

Unit ID	*Plots*	*Trees*	*Trees/Acre*	*Avg_DBH*	*Avg_Hight*	*Rel_Density*	*Basal_Area*
0013	12	80	106	15.2	94	34.2	134
0019	22	130	106	14.3	101	31.1	117
0023	17	122	101	16.1	108	35.6	143
0042	21	130	89	16	114	31	124
0051	9	62	128	13.9	118	36.4	136
0231	7	41	146	21.1	91	33.7	117
0014	27	238	88	15.8	NA	30.2	120

Soil and Tree Damage

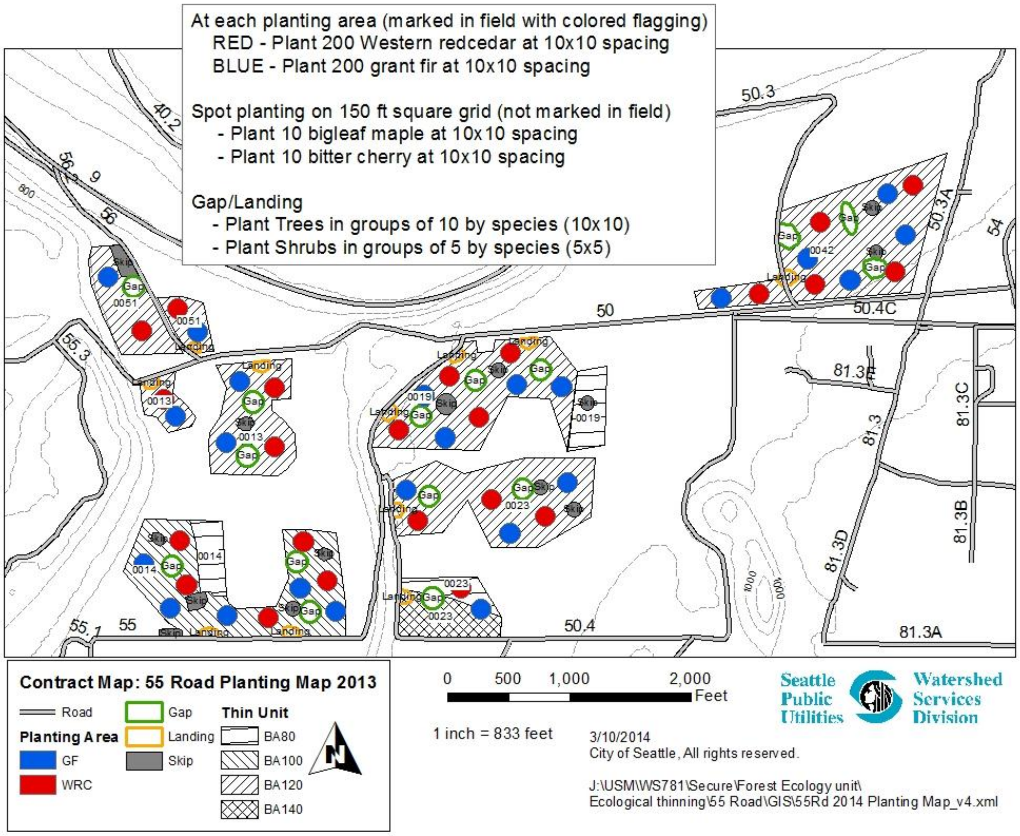
We conducted compliance monitoring on stand density, tree and soil damage. Tree and soil damage were assessed on randomly located transects of 100 feet length. Soil damage was assessed along the transect in 1 foot increments and recorded as four levels of disturbance with increasing severity (see Protocol for Soil Disturbance Transects, below). The following graph shows Soil and Tree damage for unit 19 (23 sample plots). Soil and tree damage was estimated to be similar between all units and no further sampling was conducted in the remaining units.





Planting

The thinning units were planted in the winter of 2014 with a variety of shrub and tree species. See 2014 Restoration Planting Plan and As-Built for detail of the planting project (available on: http://www.seattle.gov/util/EnvironmentConservation/OurWatersheds/Habitat_Conservation_Plan/ManagingtheWatershed/UplandForestHabitatRestoration/Metrics/index.htm). Planting followed the spatial pattern and prescription in the following graphic. The planting specifications of the project plan were followed in canopy gaps, including landings, and edge plantings. Thinned areas were planted with the prescribed number of trees and species according to the plan, however, the total area planted was larger. Tree planters concentrated planting more along the skid trails due to the dense brush cover outside the trail. The total area affected by planting is therefore estimated to be 87 acres within the 135 acres of project area.


At each planting area (marked in field with colored flagging)
RED - Plant 200 Western redcedar at 10x10 spacing
BLUE - Plant 200 grant fir at 10x10 spacing
Spot planting on 150 ft square grid (not marked in field)
- Plant 10 bigleaf maple at 10x10 spacing
- Plant 10 bitter cherry at 10x10 spacing
Gap/Landing
- Plant Trees in groups of 10 by species (10x10)
- Plant Shrubs in groups of 5 by species (5x5)
50
50.3
50.3A
50.4C
50.4
55
55.1
55.3
56
40.2
54
81.3
81.3A
81.3B
81.3C
81.3D
81.3E
Contract Map: 55 Road Planting Map 2013
Road
Planting Area
GF
WRC
Gap
Landing
Skip
Thin Unit
BA80
BA100
BA120
BA140
0 500 1,000 2,000 Feet
1 inch = 833 feet
3/10/2014
City of Seattle, All rights reserved.
J:\USM\WS781\Secure\Forest Ecology unit\
Ecological thinning\55 Road\GIS\55Rd 2014 Planting Map_v4.xml
Seattle Public Utilities
Watershed Services Division

Protocol for Soil Disturbance Transects

Plots were spaced on a 1 acre grid with 100' transects in random directions.

Both soil disturbance and tree damage measurements were taken. The soil disturbance measurement is a linear measurement with disturbance recorded in 1 foot increments. The tree damage was recorded on all trees within 5 feet of the soil transect.

Soil disturbance – the first unit was sampled on a scale from 0-2 with 0= no disturbance, 1= light disturbance and 2=heavy disturbance. In the second unit a scale of 0-3 was used. It was decided after the first unit was complete that a level 2 disturbance included a lot of variability and that adding an additional, more severe level of disturbance (3) would be useful. In the second unit 2= moderate disturbance and 3= heavy disturbance. Note: in the first unit sampled classes 2 and 3 are represented in one class (2).

Soil Disturbance Classes

0- No damage
- No evidence of equipment
- No depressions from tires or equipment track marks
- Duff layer is present and intact
- No soil displacement
- No compaction

1- Low damage
- Wheel tracks or depressions can be present but are faint and shallow
- Duff layer has been disturbed or removed
- Surface soil has not been displaced
- Soil compaction is shallow

2- Moderate damage
- Wheel tracks are present and moderate
- A horizon is removed
- Some surface soil is present and may be mixed with subsoil
- Soil compaction is moderately deep

3- Heavy damage
- Wheel tracks are present and deep
- Surface soil is removed through gouging or piling
- Surface soil is displaced
- Soil compaction is severe and deep

Tree damage was measured on all trees 5 feet out on both sides of every soil damage transect.

Tree Damage Classes

- **0-** No visible damage to the tree
- **1-** Less than 30 square inches of visible damage
- **2-** More than 30 square inches of visible damage