Knotweed Treatment
In the Cedar River Municipal Watershed
2017

Annual Report
Seattle Public Utilities Committee
Seattle City Council

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EXECUTIVE SUMMARY

Seattle Public Utilities has been treating Bohemian knotweed in the Cedar River Municipal Watershed with the herbicide imazapyr annually since 2010. Three city ordinances have authorized this treatment (2010-2012, 2013-2015, and 2016-2018). In total, 18 acres have been treated in the past eight years, most acres seven or eight times, but 2.1 acres have received only five treatments. It often takes eight or more consecutive annual treatments to eradicate large knotweed patches, because of the large root mass and the plant's ability to compartmentalize, shutting off portions of the root system to the herbicide. In 2017, for the first time, we treated less acreage (14.8 acres) because the footprint of the knotweed was reduced, indicating the success of the program. There have been no spills during the treatments, and no herbicide has entered the municipal water supply.

Herbicide use closely tracks the total knotweed leaf biomass, because the herbicide is applied to all leaves on each plant. The maximum legally allowed application rate for imazapyr is 96 ounces per acre. The maximum amount used in the watershed was 43.5 ounces per acre (a total of 678 ounces) in 2011. Both the total amount of imazapyr used and the number of acres infested with knotweed decreased in 2017. There were only small individual plants found in 2017, scattered over 14.8 acres. Total amount of imazapyr used was 32 ounces, or 2.2 ounces per acre treated. This reflects an approximate 21-fold decrease in the above-ground biomass of knotweed, or >95% reduction from pre-treatment levels. Annual cost of the herbicide treatment has decreased from a high of $32,000 in 2011 to $5,700 in 2017.

From 2010 through 2016, SPU staff surveyed over 1,100 acres of off-road habitat for knotweed. No additional off-road habitat was surveyed in 2017 due to staff shortages. In 2013, an additional 2.15 acres of knotweed, mostly at the Taylor townsite, were found and treated for the first time. No other patches were found 2014-2016. In addition to the 1,100 acres, staff also surveys approximately 475 acres of off-road habitat and over 300 miles of road annually.

The two largest knotweed sites (Education Center and the Taylor townsite) have had extensive restoration efforts, starting in 2013. Numerous other non-native invasive species, including Himalayan blackberry, evergreen blackberry, Scots broom, and English ivy, started to take over the areas previously dominated by knotweed. We grub out the non-natives annually and have planted a variety of native trees and shrubs that should eventually provide shade to help suppress invasive plants in the future. At the Education Center, we have planted a total of 204 native overstory trees (7 species) and 3,883 shrubs (36 species). At the Taylor townsite, we have planted a total of 2,545 native overstory trees (8 species). In addition, we planted 7,997 native small trees and shrubs (31 species), to restore native habitat for birds, mammals, amphibians, and insects. This variety of native trees and shrubs was designed not only to restore basic ecological functioning, but also to provide a diversity of flowering plants to enhance pollinator habitat throughout the growing season.

BACKGROUND

The highly invasive species Bohemian knotweed (*Polygonum* x *bohemicum)* poses an extreme ecological threat, especially to riparian areas. Many years of experience by multiple agencies in the Pacific Northwest has found that herbicide is the only way to successfully treat large patches of knotweed. Consequently, since 2010 Seattle Public Utilities has been treating the knotweed within the Cedar River Municipal Watershed (CRMW) under special ordinances that allow the limited application of the herbicide imazapyr. For a full report on the threat posed by knotweed, the background that lead to this decision, as well as treatment results 2010-2012, see the report, Knotweed Treatment 2010-2012, Annual Report to City Council, online at: http://www.seattle.gov/util/cs/groups/public/@spu/@ssw/documents/webcontent/01_026334.pdf

Reports detailing the 2013-2015 treatments and the 2016 treatment are available in the project plans and reports section on: http://www.seattle.gov/util/EnvironmentConservation/OurWatersheds/Habitat_Conservation_Plan/ManagingtheWatershed/StreamRiparianHabitatRestoration/Metrics/index.htm

The 2013-2015 document includes a detailed risk assessment and literature review of the latest available science on the environmental and human health effects of imazapyr, including any possible effects of imazapyr on European honey bees. Additionally, it includes an evaluation of the long-term financial and environmental implications for knotweed control. Current research continues to find that imazapyr specifically targets enzymes found only in plants and thus has low direct toxicity to animals, including insects.

To date a total of three ordinances have been passed by Seattle City Council allowing knotweed treatment with imazapyr, each for a three-year period. This limited authority allows sufficient oversight and feedback from City Council and interested stakeholders on the knotweed program. The most recent ordinance (Number 124852) was passed on September 8, 2015, and allows treatment through 2018. All ordinances have limited the herbicide treatment to imazapyr, with water quality testing after each treatment, ongoing monitoring, and annual reports to City Council. The treatment is working very well on small patches and in 2017 we made significant progress on the large patches. Details and recommendations for future work are provided later in this report.

For more information about the Watershed Invasive Species Program, see the Major Watersheds Invasive Species Management Plan, available online: http://www.seattle.gov/util/cs/groups/public/@spu/@ssw/documents/webcontent/01_029017.pdf

SURVEYS FOR KNOTWEED

In 2013, on recommendations from interested stakeholders, we identified over 1,500 acres of off-road habitat that potentially could contain knotweed, based on location of known knotweed patches, streams and other water bodies, and extent of deciduous forest canopy. None of these sites had previously been surveyed for knotweed. These areas were sorted into high (1,219 acres) and medium (388 acres) priority based on their proximity to existing knotweed and flowing water. These off-road surveys were initially successful in finding more knotweed patches. In 2013 we found a total of 2.15 additional acres of knotweed (most in the old Taylor townsite), all of which were treated for the first time that year. By the end of 2016, less than 100 acres classified as high priority remained to be surveyed, and no further large knotweed patches had been found (Figure 1). Unfortunately, due to staff shortages, no additional surveys were conducted in 2017.

In addition to these prioritized areas, we also annually survey approximately 475 acres of off-road habitat. This includes all known off-road knotweed patches plus areas routinely surveyed for other projects (e.g., wetlands surveyed for amphibian egg masses). These surveys were completed in 2017, and we anticipate this level of survey to continue. We will include additional priority acres as funding and staffing allow. We also conduct annual comprehensive invasive species surveys of more than 300 miles of road and 13 gravel pits (8 active) as part of the Early Detection/Rapid Response protocol used by the Major Watersheds Invasive Species Program. This level of road survey is also expected to continue. In 2017, we surveyed 304 miles of road. To date, knotweed dispersal appears to be by spread of plant fragments along travel corridors (streams, roads, wildlife paths). No new knotweed seedlings that appear to have been spread via seed have been found.

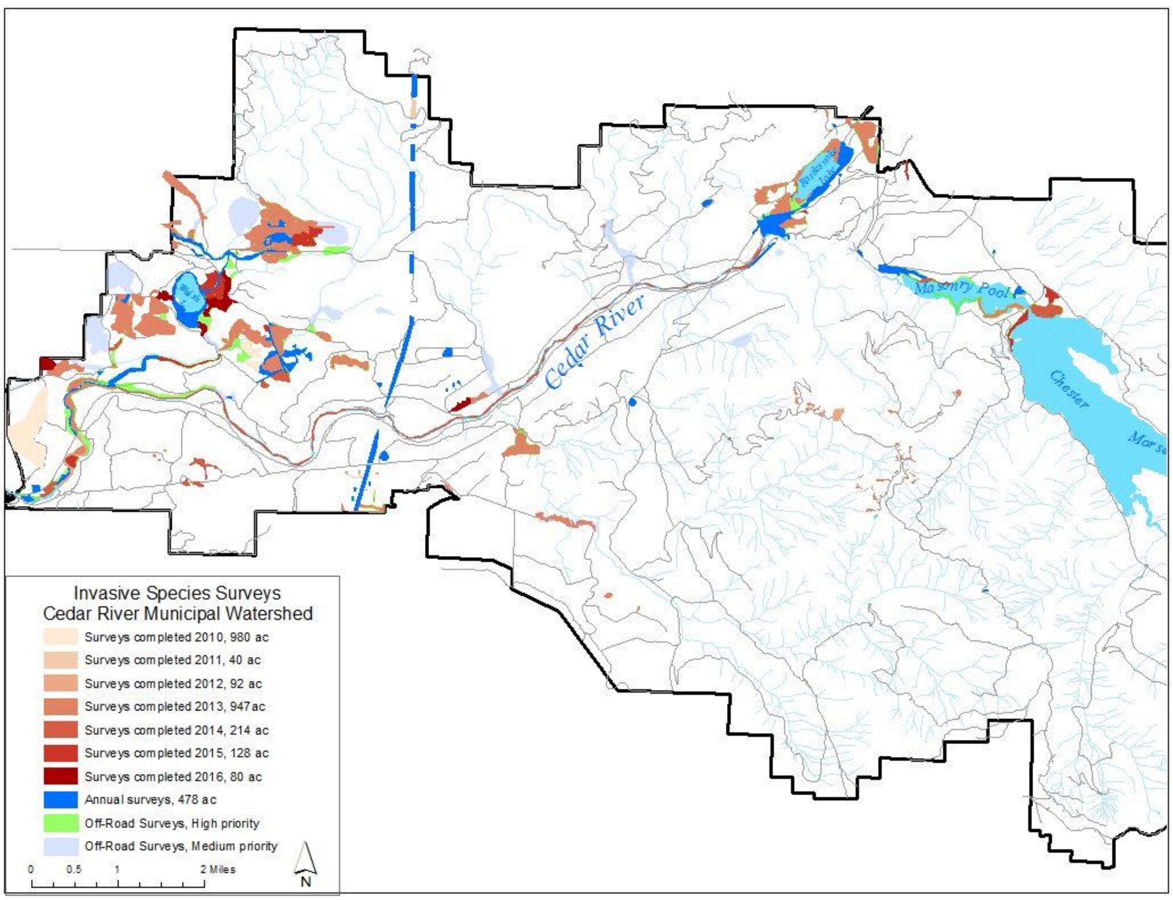

Figure 1. Off-road areas of high and medium priority to survey for knotweed, plus areas surveyed annually and areas surveyed by year, 2010–2016. No further off-road surveys were conducted in 2017.

AREA TREATED WITH HERBICIDE

In 2017, we surveyed all areas previously treated with herbicide in 2010-2016 and treated the small scattered individual plants (Figure 2). Fewer acres contained plants in 2017 than in previous years, with a total of 14.8 acres treated, down from a maximum of 18 acres 2013-2016 (Table 1). Most sites have now received seven or eight annual treatments, with only 2.4 acres receiving a total of five or six treatments

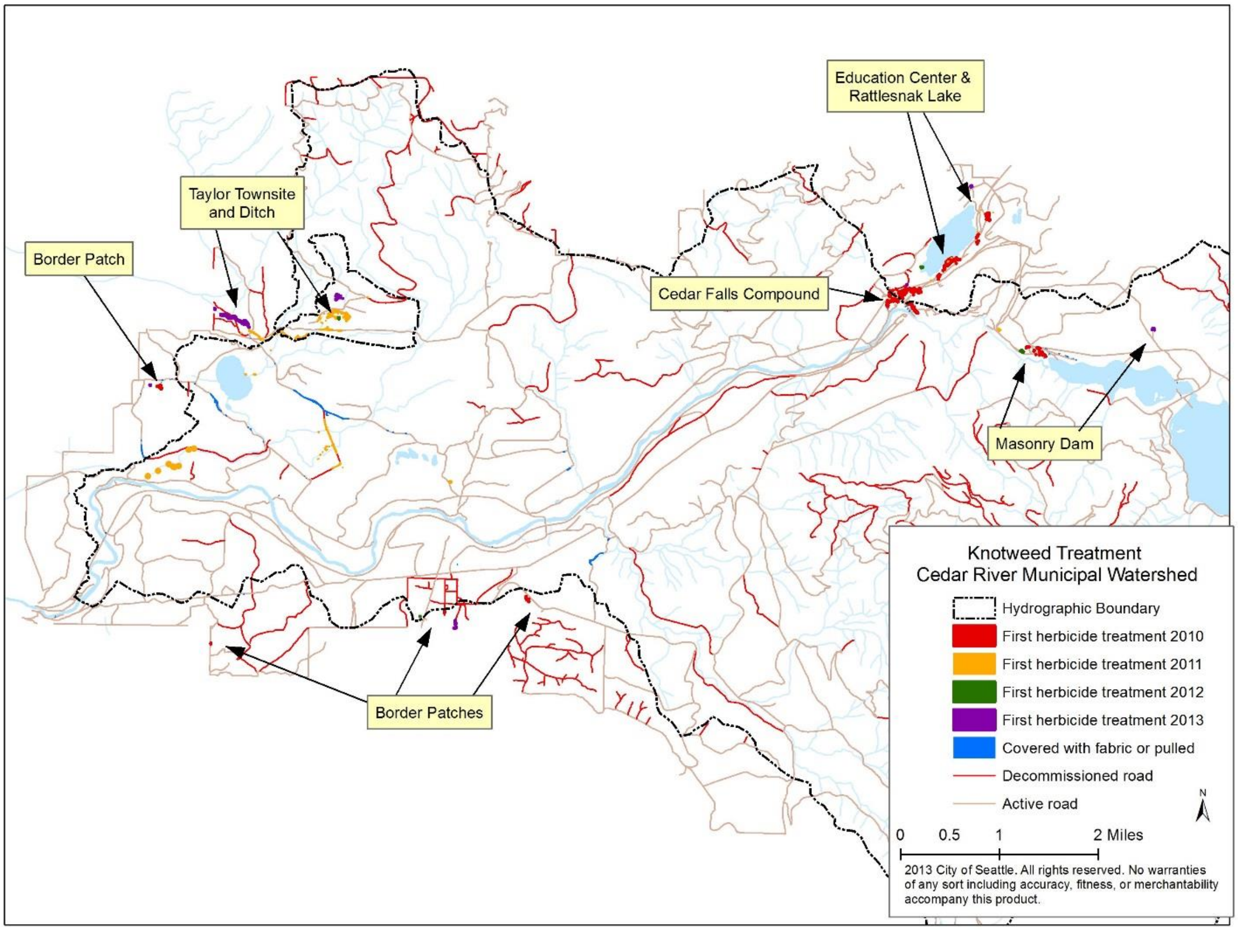

Figure 2. All known knotweed in the Cedar River Municipal Watershed symbolized by year first treated.

Table 1. Number of acres treated by site and year

Site	Hydrographic Boundary	2010	2011	2012	2013-2016	2017
Masonry Dam	In	0.31	0.39	0.58	0.68	0.30
Cedar Falls In	In	1.55	1.55	1.55	1.55	1.50
Cedar Falls Out	Out	1.71	1.75	1.75	1.75	1.50
Ed Center/Rattlesnake Lake	Out	3.04	3.10	3.18	3.29	1.70
Border	Out	1.11	1.13	1.13	1.44	1.00
Taylor	Out	0	7.60	7.67	9.30	8.80
Total In Hydro Boundary		1.86	1.94	2.13	2.23	1.80
Total Out Hydro Boundary		5.86	13.58	13.73	15.78	13.00
Grand Total		**7.72**	**15.52**	**15.86**	**18.01**	**14.80**

TREATMENT LOGISTICS

In 2017, we used the same application method and herbicide concentration as in 2010 – 2016, i.e., a targeted backpack foliar spray of 1% aquatic formulation imazapyr mixed with 0.5-1% modified vegetable oil surfactant and a small amount of non-toxic blue dye in water. It was applied strictly according to label instructions, including restrictions such as not applying during rain, wind, or when there is a temperature inversion. All the same safety procedures were followed, with certified herbicide applicators on site performing all the mixing of the tank solutions. No spills, injuries, or any adverse effects were incurred by SPU staff conducting any of the applications.

In 2017, knotweed plants were even smaller and more difficult to see amongst the thick understory of shrubs and tall grass than in 2016. In addition, plants had a large variation in timing of growth, with small newly emerged growth found as early as May and as late as October. To get as much herbicide into the root system as possible, we attempt to time the herbicide application when the plants have put on maximum leaves, but before the leaves start to senesce. Application when the plant is actively growing and during the pre-bud stage, i.e., before the plant starts to flower, has been reported to be the most effective. This timing varies depending on elevation and site-specific conditions. For untreated knotweed at elevations in the CRMW, flowering generally occurs in early September, so the target timing is mid to late August. However, because we bent the canes prior to the first application and the vast majority of plants that have been treated at least once do not flower, the pre-bud issue was not applicable. The other primary consideration on timing of application is the weather. August is generally the driest month, with September weather being less predictable. For these reasons, we target the first treatment during August whenever possible. In 2017, our first treatment occurred August 7-17. It took longer than in previous years because contractors were not used and a single staff person did all of the treatment. This approach allowed staff to slowly and methodically search all sites for small plants, hopefully resulting in more complete coverage.

To ensure that we treated all knotweed plants, we surveyed and treated each large site twice, four to six weeks apart. Plants treated with imazapyr show signs of decline within that time and are easily identifiable. During the second survey, we treated any newly emerged or previously missed plants. Other land managers in western Washington have also found this to be a useful technique. During 2017, the second survey and treatment occurred September 12- October 5. As in previous years, no flowering plants were found.

All of the herbicide was applied in terrestrial environments and did not require a permit. All treatment sites were more than 250 feet away from the Cedar River and the nearest large patch was over 10 miles from the municipal water intake at Landsburg.

AMOUNT OF IMAZAPYR APPLIED

In all treatment sites combined, the average application was 2.2 ounces imazapyr per acre (with a range of 1.4 to 5.2). This rate compares with a maximum allowable application rate of 96 ounces per acre. Total amount of imazapyr applied in 2017 was 32 ounces spread over 14.8 acres. Of this amount, a total of 5.2 ounces was applied inside the hydrographic boundary, spread over 1.8 acres. Total amount of herbicide applied has declined each year, from approximately 43 ounces per acre in 2010 and 2011, to an average of 2.2 ounces per treated acre in 2017 (Table 2). The decline in application rate is due to the decreasing above-ground biomass of the knotweed resulting from the herbicide treatments (see following section).

Table 2. Total amount of imazapyr applied and application rate by year.

Year	Amount Imazapyr (oz)	Area Treated (ac)	Application Rate (oz/ac)
2010	334	7.7	43.4
2011	678	15.6	43.5
2012	241	15.9	15.2
2013	163	18.0	9.1
2014	120	18.0	6.7
2015	61	18.0	3.4
2016	46	18.0	2.6
2017	32	14.8	2.2

IMAZAPYR TREATMENT RESULTS

In 2017, most of the smaller knotweed sites, especially those along the watershed border, had either no or very few small stems. Above ground knotweed leaf biomass has declined by over 21 times from pre-treatment levels, indicated by the decline in application rate. Because we attempt to evenly coat every leaf on each plant, application amount is a good proxy for leaf biomass and demonstrates the success we've had in decreasing knotweed in the municipal watershed. This is a greater than 95% reduction in regrowth from the maximum amount treated in 2011.

Most of the larger sites that have received five to eight previous treatments still had small to medium knotweed plants scattered throughout the site, indicating that the large root mass, although clearly damaged, was not yet dead. Experts hypothesize that the root system can compartmentalize, shutting off some sections from receiving an adequate herbicide dose.

Because the rhizomes (roots that can sprout) can be up to 65 feet long and seven feet deep, that is potentially a very large reservoir. It is important to wait until all root segments send up shoots so sufficient herbicide can be applied to each segment of the root system to kill it. Because roots can essentially hibernate for several years without sending up shoots, this process can take many years.

A visual record of Education Center knotweed response to treatment and site restoration through the years is found in Appendix I. This site has had the most re-growth and represents the worst-case scenario in the municipal watershed.

WATER QUALITY TEST RESULTS

In each year, 2010-2017, water samples were taken both before (baseline) and after (post-treatment) the herbicide application. Samples were taken from two locations on the Cedar River (one at the point closest to a knotweed patch = 250 feet away, and the other at the Landsburg water supply intake facility), one location at Rattlesnake Lake, and one location on a small creek running through the Taylor townsite. All water samples were analyzed for imazapyr at Pacific Agricultural Laboratory (PACLAB) near Portland, Oregon.

Because there were some minor contamination issues with PACLAB in the past several years, in 2017 SPU staff conducted a blind test of the lab. For the blind test, two water samples were taken simultaneously in the Cedar River at a site upstream from any imazapyr application, so there was no possible source of imazapyr in the water. The only difference between the samples were the sample vials (all provided by the lab) and the notes on the label. As part of the blind test, the label was intentionally written such that the samples appeared to have been taken from the normal sampling locations. One of the blind test samples came back negative and the other positive. The lab was then subsequently informed that we had been testing their procedures, after which they admitted that in the past they had found some contamination in their vials. They tested a small number of vials from the batch that had been used, and found no contamination in them. Of course, this finding doesn’t mean that other vials in that batch weren’t contaminated. Because of the on-going contamination issues, SPU recommends using a different laboratory for water testing in 2018.

No imazapyr was detected in any of the actual municipal water samples in 2017.

COSTS

Cumulative total cost (including staff and contractor labor and materials) to treat 18 acres of knotweed with herbicide from 2010 through 2017 was approximately $117,000. Annual cost per acre to treat the knotweed with imazapyr has declined from a high of $3,400/acre in 2010 to $387/acre in 2017. This compares with a cumulative cost of approximately $200,000 ($44,000/acre) to treat small scattered patches of knotweed by covering with geotextile fabric, a treatment we tried experimentally on a total of 4.5 acres from 2004 to 2012. Covering was only marginally successful on very small patches. The larger patches were still alive after more than eight years of continual covering. Fabric experimentally taken up along active roads was replaced and will be left down indefinitely. Isolated patches away from active roads and formerly covered were spot-treated with herbicide. Area treated and amount of herbicide used on these small patches was negligible.

Total annual cost to treat the knotweed with herbicide has decreased from a high of about $32,000 in 2011 to about $5,700 in 2017. This annual cost is expected to continue to decline as there are fewer and fewer knotweed plants to treat. It will likely stabilize at around $5,500 because staff will need to continue to survey and monitor all the sites, which takes approximately 60 person hours to thoroughly survey the entire 18 acres. The time and cost to continue to control knotweed should be easily covered by the existing watershed Invasive Species Management Program budget and staff.

SITE RESTORATION

Ensuring knotweed treatment sites are repopulated with native plants following treatment is the most effective method for preventing re-infestation of knotweed and other invasive plants. Our goal is to restore areas formerly occupied by knotweed to naturally functioning ecosystems dominated by a variety of native trees and shrubs. This restoration will both increase resistance to future invasions by non-native species and provide high quality habitat for native wildlife, including birds, mammals, amphibians, and insects. Most large sites formerly occupied by knotweed became infested with other non-native invasive species after treatment. Consequently, these sites need continued restoration work, including removal of other invasive species and planting native trees and shrubs.

In 2013, the non-profit group Friends of the Cedar River Watershed (FCRW), in conjunction with SPU, received a 5-year King Conservation District (KCD) grant (total of $46,000) to restore the formerly knotweed-infested area near the Education Center to native trees and shrubs. The grant funded several volunteer events and six weeks of Washington Conservation Crew (WCC) time spread over the five years (through 2017). It also funded the purchase of approximately 2,800 native plants. In 2015, FCRW dissolved and Forterra assumed management of the grant.

In 2013-2017, SPU and FCRW staff, volunteers, and WCC crews cleared the Education Center site of invasive blackberry (*Rubus armeniacus* and *Rubus laciniatus*), English ivy (*Hedera helix*), black locust (*Robinia pseudoacacia*), foxglove (*Digitalis purpurea*), mullein (*Verbascum thapsus*), Scots broom (*Cytisus scoparius*), and birdsfoot trefoil (*Lotus corniculaus*) that had invaded the area formerly dominated by knotweed. SPU staff partitioned the site into seven planting zones, each with different long-term goals and specific planting plans (Figure 3). A total of 204 native overstory trees (nine species) and 3,883 small trees and shrubs (34 species) were planted from late 2013 through 2017 (Table 3). In addition, volunteers and contractors moved several hundred yards of mulch, surrounding each native planting with mulch to help suppress non-native weeds and provide more growing space for the plantings. We will continue to densify native plantings as needed, both from purchased stock and from transplanting appropriate species from nearby sites in the municipal watershed. The final plantings under the KCD grant (approximately 400 small trees and shrubs) will be conducted in early 2018, as soon as the bare-root stock becomes available.

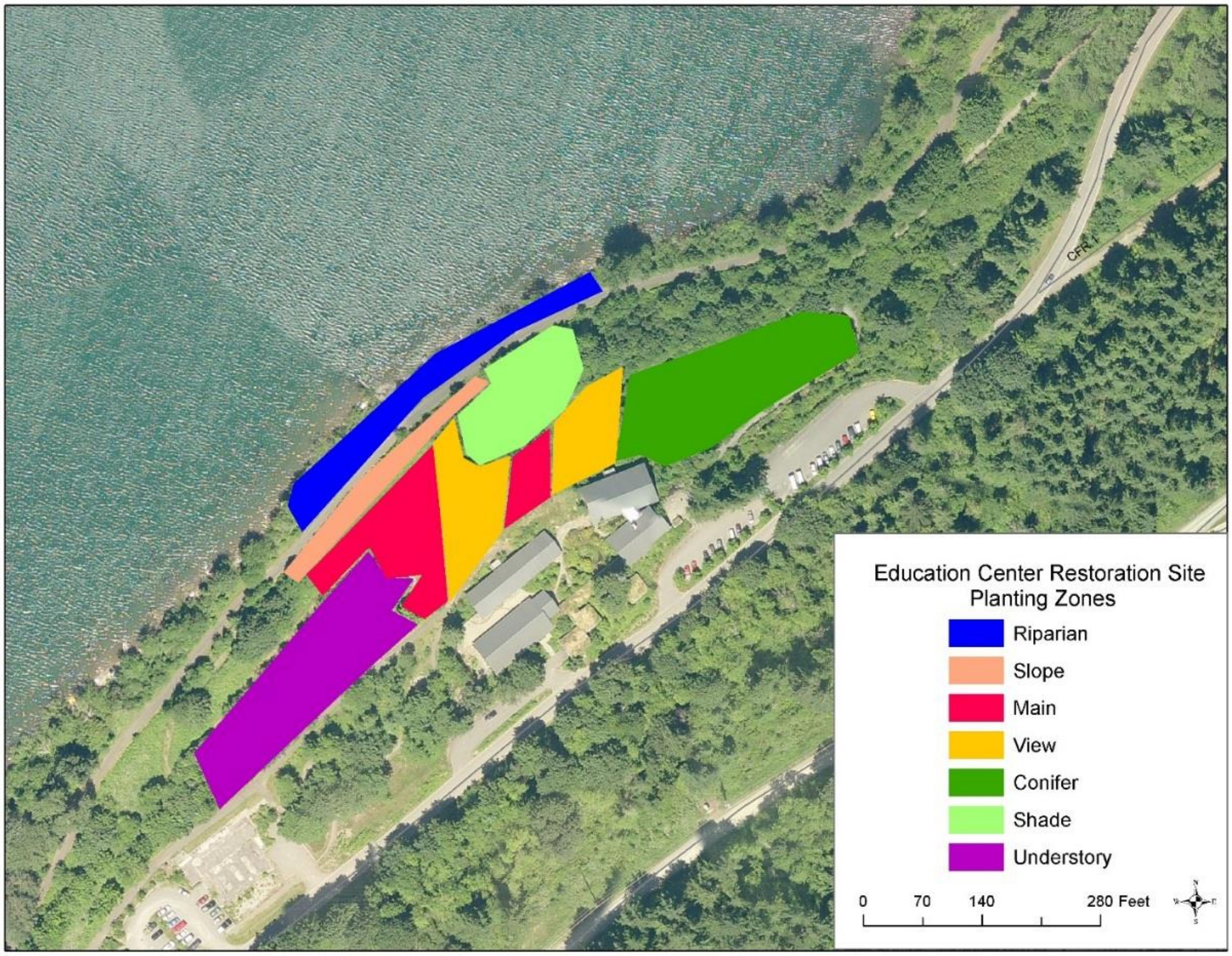

Figure 3. Location of the seven planting zones near the Education Center

Table 3. Species and number of native trees and shrubs planted near the Education Center, 2013-2017

Overstory Trees			
Big-leaf maple	15	Western hemlock	29
Cottonwood, black	15	Western redcedar	50
Douglas-fir	30	White white pine	25
Sitka Spruce	40		
Total trees planted			**204**

Small Trees and Shrubs			
Cascara	125	Ocean spray	186
Ceanothus, redstem	50	Oregon grape, tall	180
Cherry, bitter	50	Red elderberry	57
Crabapple, Pacific	25	Rhododendron, Pacific	50
Currant, red-flowering	135	Rose, baldhip	155
Dogbane, spreading	6	Rose, peafruit	120
Redtwig dogwood	200	Rose, Nootka	145
Fern, Deer	75	Salal	5
Fern, Oak	75	Salmonberry	60
Fern, Sword	165	Serviceberry	75
Gale, Sweet	20	Snowberry	135
Goatsbeard	165	Spirea	65
Hawthorn, black	50	Thimbleberry	120
Hazelnut, beaked	70	Twinberry	150
Indian plum	80	Vine maple	235
Kinnickinnick	54	Willow, Hookers	100
Mock orange	25	Willow, Pacific	230
Ninebark, Pacific	125	Willow, Sitka	320
Total small trees and shrubs planted			**3,883**

In 2014-2017 at the Taylor townsite and overflow ditch, contract crews cleared the 9.3 knotweed-infested acres plus adjacent wetlands and nearby areas of invasive species, including invasive blackberry, foxglove, mullein, and non-native thistles (total area of 12.4 acres). We planted a total of 2,545 native overstory trees that will eventually provide long-term shade to suppress future invasive plants. In addition, we planted 7,997 native small trees and shrubs, to restore native habitat and ecological functioning (see Table 4 for number planted by species). We split the area into 21 different planting sites, and developed specific prescriptions and species mixes for each site, depending on the amount of soil moisture and sun exposure (Figure 4).

Table 4. Number and species of native trees and shrubs planted at the Taylor townsite

Overstory Trees			
Cottonwood, black	325	Sitka Spruce	604
Maple, big-leaf	380	Western hemlock	220
Noble fir	135	Western redcedar	494
Shore Pine	82	Western white pine	305
Total trees planted			**2,545**

Small Trees and Shrubs			
Birch, paper	80	Sedge, Dewey's	400
Cascara	475	Sedge, slough	200
Ceanothus, red-stem	300	Sedge, thick-headed	200
Cherry, bitter	345	Serviceberry	300
Choke cherry	25	Snowberry, western	300
Crabapple, Pacific	320	Snowbrush	300
Current, red-flowering	350	Spirea	50
Dogwood, Pacific	20	Sweet gale	200
Dogwood, red osier	325	Thimbleberry	200
Hazelnut, beaked	7	Twinberry	300
Indian plum	310	Vine maple	200
Mock-orange	320	Willow, hooker	350
Ninebark, Pacific	350	Willow, Pacific	550
Oceanspray	120	Willow, Scoulers	300
Rose, Nootka	350	Willow, Sitka	300
Rose, peafruit	150		
Total small trees and shrubs planted			**7,997**

In both the Education Center and the Taylor townsite restoration projects, the variety of native trees and shrubs was designed not only to restore ecological functioning, but also to provide a diversity of flowering plants to enhance pollinator habitat. Pollinators in the watershed include bees, butterflies, moths, flies, beetles, birds, and bats. The trees and shrubs we plant have a variety of different flower colors and shapes, with flowering periods that vary throughout the growing season, providing nectar and pollen to many pollinator species. Numerous bee species, especially the native western bumblebee (*Bombus occidentalis*), have suffered population declines in recent years and are of particular concern. Bumblebees are often the first bees active in spring and the last bees active in fall, so flowers at these times of year are especially important. Plants such as Indian plum, red-flowering current, vine maple, and Oregon grape provide early spring flowers, Pacific ninebark, red-twig dogwood, and oceanspray provide late spring and early summer flowers, and goatsbeard and the native roses flower during summer. Late flowering plants are primarily forbs, including goldenrod, pearly everlasting, yarrow, and asters, but also include western flowering dogwood. We plan to add forbs where appropriate in open sunny areas. This diversity of native species provides better pollinator habitat than non-native invasive plants, which flower for single short periods, often during the middle of the growing season.

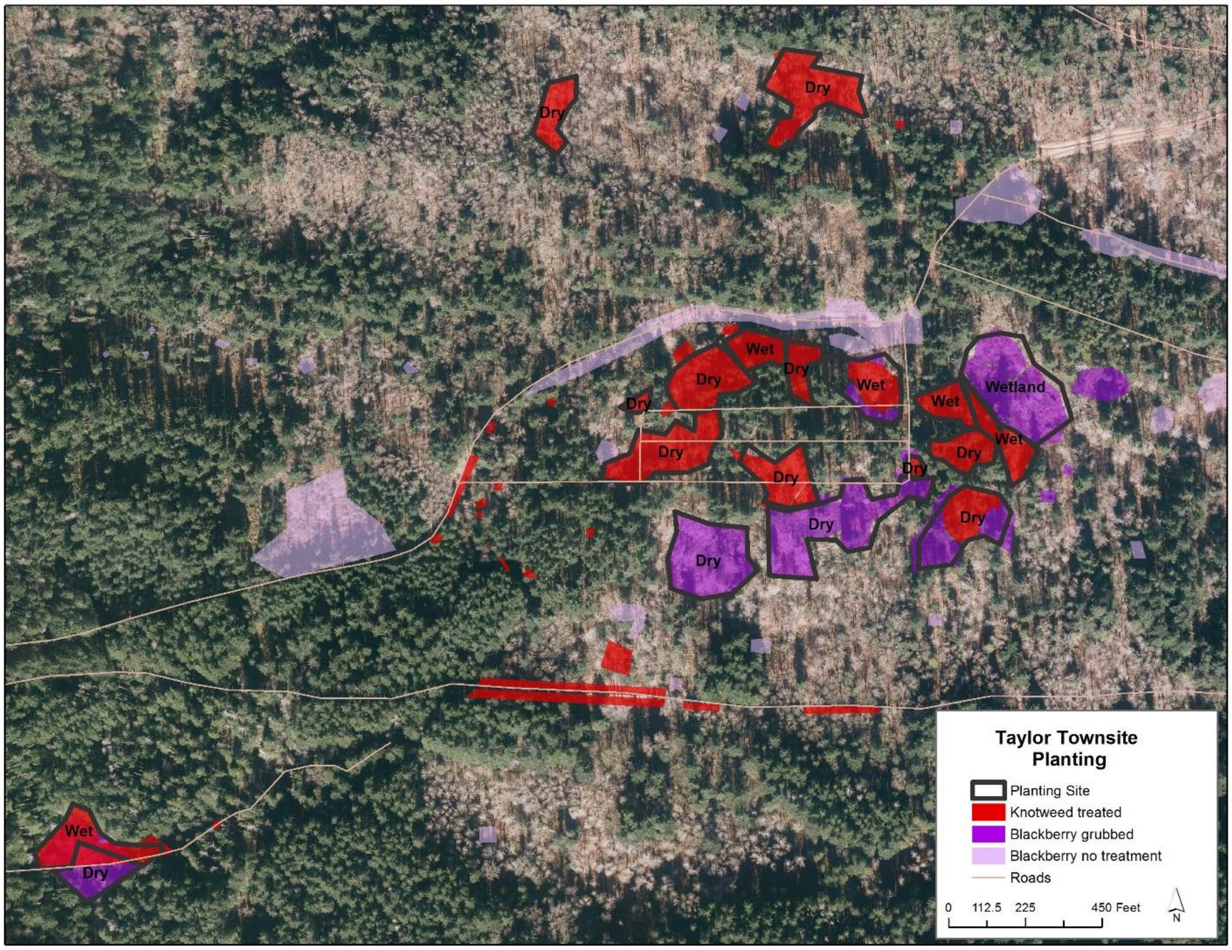

Figure 4. Planting sites at the Taylor townsite, categorized as wet or dry

2018 PLANS AND MONITORING

We plan to monitor all known knotweed patches and re-treat with imazapyr as needed in 2018. We anticipate the sites will continue to require less herbicide than previous years and the amount of infested acreage will decline. We will continue to monitor for knotweed patches during our annual road and gravel pit surveys and will conduct off-road surveys in high priority areas as funding and staffing allows. If we find any additional knotweed patches, we will treat them in 2018 under the current ordinance. As in previous years, we will re-check the large knotweed patches four to six weeks after treatment, and, weather-permitting, will treat any newly emerged or untreated plants at that time.

LONG-TERM IMPLICATIONS FOR KNOTWEED CONTROL

We are hopeful that by the end of 2018, the 15.6 acres that will have received eight or nine imazapyr treatments will have either been completely eradicated, or at such a low level that we can control any small growth by non-herbicide means (pulling or long-term covering). The 2.4 acres that will have received only six or seven treatments may or may not be reduced to this state by 2018, depending on site-specific conditions. By 2018, all large sites where natural regeneration of native trees and shrubs was insufficient will have been planted to native species.

If left untreated, there is evidence that a small amount of live knotweed present at treatment sites can return to the original infestation level in as little as three seasons, eventually surpassing the infestation level that was present before any investments in knotweed control. This would result in the loss of progress toward long-term knotweed control, increased future control costs, degradation of environmental quality, and the alteration of the sustainable ecological services of invaded sites. In addition, it could jeopardize the extensive ongoing restoration projects along the Cedar River downstream of Landsburg. As mentioned above, long-term maintenance and control costs of knotweed in the CRMW should be minimal. However, an ongoing monitoring program is essential to ensure that all known knotweed is eradicated and any newly discovered patches are treated before they have a chance to spread.

After the 2018 field season, we will evaluate future monitoring and treatment options, consistent with our policy to manage adaptively. One option might be proposing an ordinance to continue annual imazapyr treatment until all plants have been eradicated. Another might be to just monitor the sites in 2019, with no treatment, and document location and amount of knotweed re-growth. If we allow the remaining plants to increase leaf area, they would be easier to find, and would have greater leaf surface area to treat in 2020. Depending on results, this could mean attempting to control remaining knotweed by covering or potentially requesting an ordinance to use imazapyr in 2020.

APPENDIX I

Photographic record of results of knotweed treatment with imazapyr and site restoration at the Education Center, 2010 – 2017. This site has had the most knotweed re-growth of any of the large treatment sites, so represents the worst case scenario during this time period.

Knotweed before initial 2010 treatment. 12-foot tall knotweed covered the entire site.

May 2011. Spring after the first treatment, showing the dead canes from the first treatment. Canes had been bent prior to treatment to facilitate access for the applicators.

August 2011. One year after first treatment, showing dead canes, knotweed regrowth, and initial invasion by Himalayan blackberry.

August 2011. Large patch of Himalayan blackberry encroaching one year after first treatment.

September 2012. One year after 2nd treatment, showing scattered medium sized knotweed plants. Dead canes had been hand-cleared from the site to make finding re-growth easier.

September 2012. Invasive black locust take over a portion of the site one year after 2nd treatment. Mullein, foxglove, and other non-native plants are also starting to invade.

September 2013. One year after 3rd treatment and initial KCD grant restoration work (blackberry, locust, other invasive species removal, planting native trees and shrubs).

October 2014. One year after 4th treatment, with continued KCD grant restoration work (spreading mulch, planting).

August 2015. One year after 5th treatment, showing small scattered knotweed plants amongst the planted native trees and shrubs.

September 2016. One year after 6th treatment, with small scattered knotweed plants still growing amongst the planted native trees and shrubs.

September 2016. Trees and shrubs planted on the site have had high survival and are growing vigorously

September 2016, (cont)

July 2017. One year after 7th treatment. There was a dramatic drop in number and size of knotweed plants in 2017. Planted native trees and shrubs continue to grow vigorously and are beginning to shade major portions of the site, which should help suppress future knotweed and other non-native invasive plants.

July 2017 (cont)