Knotweed Treatment through 2011
Cedar River Municipal Watershed

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BACKGROUND

On August 2, 2010, Seattle City Council, recognizing the extreme ecological threat posed by the highly invasive species Bohemian knotweed (*Polygonum* x *bohemica)*, a hybrid between Japanese (*P. cuspidate*) and giant knotweed (*P. sachalinense*), passed Council Bill Number 116902. This ordinance amended the Cedar River Municipal Watershed Secondary Use Policy Number 6-13, to allow limited application of the herbicide Imazapyr to treat knotweed within the municipal watershed. The ordinance is effective through December 31, 2012 after which the Secondary Use Policy prohibiting all herbicide use within the Cedar River Municipal Watershed will again apply.

In 2008 the total area covered by knotweed within the municipal watershed was measured at 15 acres. Of this, small scattered patches totaling 4.5 acres were experimentally treated by covering with geotextile fabric. This is a difficult and expensive process by which we attempt to starve the roots by not allowing any light to reach the plant. The fabric must be actively checked and maintained multiple times per year or wild animals will tear it up, wind will dislodge it, plants will grow through it, etc. Seattle Public Utilities (SPU) staff started covering small knotweed patches in 2004 and continued covering various small patches through 2009, when fabric installation was completed. In 2010 and 2011 we experimentally removed some of the fabric after five or six years of continual covering. The plants appear to have died within the smallest patches. On some patches, however, there was extensive re-growth even after six years of continual covering. It is unknown whether this covering treatment will eventually be successful in eradicating these knotweed patches.

The remaining 10.5 acres of knotweed (as measured in 2008) were in patches too large to logistically cover with fabric and maintain. We started treating these patches with Imazapyr in 2010 after passage of the ordinance. Approximately half of the large patches were treated for the first time in 2010. The remaining patches were treated for the first time in 2011.

This knotweed project is part of the Major Watersheds Invasive Species Program, with operations and maintenance funding provided through SPU. This Program, funded since 2007, encompasses the Cedar River Municipal Watershed, the Tolt Municipal Watershed, and the Lake Youngs Reserve (total of more than 100,000 acres). There are 39 terrestrial and two aquatic invasive plant species present in the watersheds, eight of which are legally required to eradicate or control. The Invasive Species Program controls all eight legally required species, plus nine other species that either pose a very high ecological risk or pose a significant ecological risk but are not yet widespread. Ten additional species that pose significant ecological risk but are already widespread are controlled where they occur in sensitive habitats. Knotweed is not currently legally required to control in the watersheds, but poses one of the greatest ecological risks of any of the invasive species. One Invasive Species Program goal is to eradicate all knotweed from the Cedar River Municipal Watershed.

Current Invasive Species Program funding is sufficient to cover all planned knotweed treatment, monitoring, and site restoration activities. This is an ongoing watersheds program, so we expect that funding for the knotweed project will continue for as long as necessary.

HERBICIDE APPLICATION METHOD

In both 2010 and 2011 we used a targeted backpack foliar spray of 1% Imazapyr mixed with 1% surfactant in water. We used an aquatic formulation of Imazapyr so that we could use the least toxic surfactant available (modified vegetable oil). Because Imazapyr is a clear liquid, a small amount of non-toxic blue dye was added to this solution to allow us to see what portions of the plant had been sprayed. All applications were done during calm dry weather when no atmospheric inversion was present. The backpack foliar spray method proved very effective at focusing the spray on the knotweed foliage and produced little or no overspray or drift onto adjacent plants. Neither native nor non-native plants immediately adjacent to knotweed plants were damaged by the backpack spray application. As expected, the knotweed plants showed no immediate effects from the spray, because Imazapyr works slowly over time within the plant, inhibiting an enzyme found only in plants.

We did not choose the stem injection method because compared to the foliar method it 1) uses an order of magnitude more herbicide, 2) does not produce any higher knotweed mortality, and 3) is not significantly better at minimizing damage to adjacent plants. We chose to use Imazapyr because it is the least toxic herbicide available, less toxic than Glyphosate (the herbicide found in Roundup, available for purchase by the general public). Glyphosate is currently the only herbicide legally allowed to be used with the stem injection method.

SAFETY

At least one Washington State certified herbicide applicator was on site during all knotweed spraying activity. Certified applicators mixed all herbicide tank solutions and supervised all aspects of the application process. Both an Operational Plan and Safety Plan were developed and successfully implemented during the treatments. There were no spills, and no injuries or adverse effects were incurred by SPU staff or the contract crew members conducting the herbicide application. Trails adjacent to the knotweed patches were closed to the public during the application. Permanent interpretive signs were placed at strategic locations near the Education Center knotweed patches to inform the public about the project and temporary signs were placed adjacent to all sprayed patches accessible by the public.

AREA TREATED

A total of 7.72 acres of knotweed received the first herbicide treatment in 2010. These patches were located at the Cedar Falls Compound, the Education Center, Rattlesnake Lake, Masonry Dam, and isolated boarder patches near the southern and western watershed boundaries. This same 7.72 acres was treated for the second time in 2011(see areas in red in Figure 1). In addition, 7.70 acres were treated for the first time in 2011 (primarily Taylor Townsite - see areas in orange in Figure 1), for a total of 15.42 acres treated in 2011. This total area treated exceeds by 4.92 acres the 10.5 acres originally estimated to be infested with large patches of knotweed in 2008. Newly discovered patches account for 0.11 acres of this increase. The remaining 4.81 acres resulted from rapid patch expansion, one illustration of the extreme ecological threat posed by knotweed.

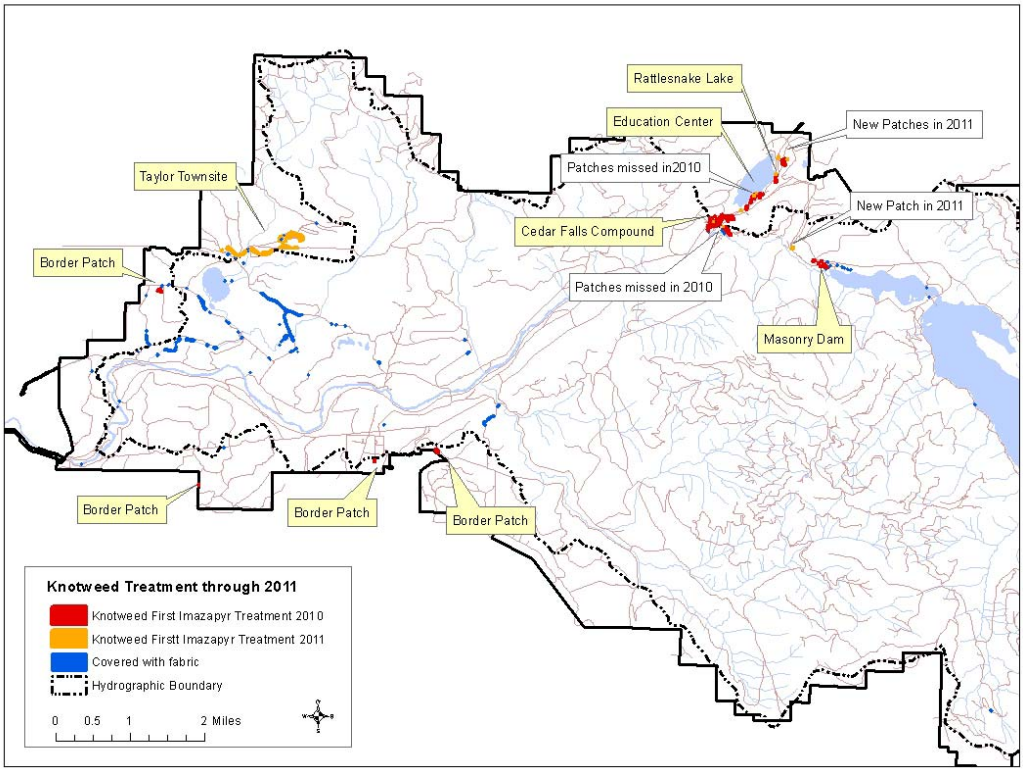

Figure 1. Location of knotweed patches treated in 2010 and 2011. Areas in red were treated for the first time in 2010 and the second time in 2011. Areas in orange were treated for the first time in 2011. The Cedar River hydrographic boundary is shown as a dashed black line.

Of the 15.42 acres of knotweed treated with Imazapyr in 2011, only 1.94 acres are located within the hydrographic boundary of the Cedar River, i.e., occupying land that drains into the Cedar River. The remaining 13.48 acres are on land draining to other streams, primarily the Snoqualmie River and Issaquah Creek (see Table 1). The knotweed patch nearest to the Cedar River or any of its tributaries is more than 250 feet distant from the river, with forested land between the patch and the river. Of the knotweed patches within the hydrographic boundary, the one nearest to the Landsburg municipal water intake is greater than 12 river miles away.

Because of the logistical difficulty of spraying every plant within a huge continual mass of dense knotweed canes, large patches treated for the first time inevitably have areas that are missed during spraying and not treated. In addition, we discovered two new patches in 2011, one near the Masonry Dam (inside the hydrographic boundary, 0.08 acres) and the other near Rattlesnake Lake (outside the hydrographic boundary, 0.03 acres). Total acreage of missed and newly discovered patches that were treated for the first time in 2011 was 0.2 acres. In addition, 0.1 acres of knotweed was missed during the first treatment of the large Taylor Townsite patches in 2011. This will be treated for the first time in 2012, bringing the total acreage treated 2010 through 2012 to 15.52 acres (assuming no additional new patches are discovered).

Table 1. Number of knotweed-infested acres treated by site and year.

Cedar River Hydrographic Boundary	Site	Number acres	Treated in 2010	Treated in 2011	Treated in 2012**	Anticipated Total Number Treatments**
Inside	Masonry Dam	0.31	X	X	X	3
		0.08*		X	X	2
	Cedar Falls	1.55	X	X	X	3
	Total Inside	**1.94**				
Outside	Cedar Falls	1.71	X	X	X	3
		0.04*		X	X	2
	Education Center/ Rattlesnake Lake	3.04	X	X	X	3
		0.06*		X	X	2
	Border	1.11	X	X	X	3
		0.02*		X	X	2
	Taylor	7.50		X	X	2
		0.10*			X	1
	Total Outside	**13.58**				

*Patches missed during the first application or newly found in 2011

**Planned 2012 work illustrated in red

PRE-TREATMENT

The majority of the knotweed patches scheduled for a first herbicide application was pre-treated by bending canes four to six weeks prior to the herbicide application. This pre-treatment worked very well, allowing access through the dense mass of canes and ensuring the applicators could safely spray all portions of the plants. In 2010 canes were bent in late July, with spraying commencing in late August and extending through mid September. There was a variable and generally moderate amount of knotweed re-growth during this time, depending on the site. September of 2010 was extremely wet, making the logistics of obtaining contract crew time to spray only on dry days difficult. Consequently, in 2011 canes at Taylor Townsite were bent in early to mid-June so we could spray in early August, generally the driest month of the year. Spraying started the first of August and was basically completed by the end of August. There was an extremely large amount of re-growth of the pre-treated patches in 2011, likely due to the very wet June and July and the longer time between bending canes and the herbicide treatment. No pre-treatment is required for a second application because the first herbicide treatment results in a very low density of smaller canes during the subsequent year.

AMOUNT OF IMAZAPYR APPLIED

The Imazapyr label recommends using an amount of 48 to 64 ounces of Imazapyr per acre of knotweed. The maximum legal allowable dose is 96 ounces per acre. In 2010 we averaged 43 ounces of Imazapyr per acre for the first treatment of the patches at the Cedar Falls Compound, Education Center, Rattlesnake Lake, and Masonry Dam, and the border patches. This was below the recommended rate because we had less re-growth than anticipated after the cane-bending

pre-treatment, likely because of the short time interval between pre-treatment and herbicide application and the dry August in 2010.

In 2011 we averaged 65 ounces of Imazapyr per acre of knotweed on those sites treated for the first time at Taylor Townsite. This is essentially at the top of the recommended range, while remaining well below the maximum allowable rate. The reason for the application rate difference between 2010 and 2011 is that there was much greater re-growth after the cane-bending pre-treatment at Taylor Townsite in 2011, and consequently much greater leaf area to treat.

For those patches receiving the second treatment in 2011, we averaged 24 ounces of Imazapyr per acre of knotweed. This lower rate was expected because the first treatment resulted in fewer and smaller canes with less leaf area than plants that had not received any herbicide treatment.

IMAZAPYR TREATMENT RESULTS

In the spring of 2011, there was an approximate 90% biomass reduction in the knotweed patches treated for the first time in 2010 (Figure 2). As expected, small isolated canes grew during the summer of 2011, scattered throughout the treated patches (Figure 3). What was unexpected was that if we removed the remnants of dead canes and carefully examined the base of the plant, we found small growth nodules on over 50% of the plants treated for the first time in 2010 (Figure 4). So although we achieved a high biomass reduction, our individual plant mortality rate after one treatment was relatively low, around 50%. This may be due to the relatively low application rate of 43 ounces per acre in 2010, or may be typical, but not normally observed because most land managers do not have to eradicate knotweed in such a short time frame.

In 2011, we had the herbicide applicators examine the base of every plant that had been treated in 2010 and spray these small growth nodules, if present. We will not know until the summer of 2012 whether spraying the small growth nodules will be sufficient to kill the plants. There is also considerable uncertainty whether large patches of knotweed can be eradicated with only one or two herbicide applications (as will be applied to the Taylor patches through 2012, see Table 1). Experts from King County Noxious Weeds and Washington State University have stated they believe it is impossible to eradicate knotweed with one herbicide application, and have expressed doubt that it is possible with only two applications. We expect that after three applications, any re-growth that may occur will be small. We plan to control and eventually eradicate these small patches by covering with geotextile fabric.

After each treatment, we surveyed the patches for any animal mortality resulting from the herbicide application. No animal mortality was seen in any of the knotweed patches during these surveys.

Figure 2. Large knotweed biomass reduction one year after first Imazapyr treatment

Figure 3. Small scattered knotweed re-growth one year after first Imazapyr treatment

Figure 4. Small growth nodules at the base of knotweed plants one year after first Imazapyr treatment

WATER QUALITY TEST RESULTS

Water samples were taken both before (baseline) and after (post-treatment) the 2010 and 2011 herbicide applications, in accord with the sampling plan outlined in Attachment A to the ordinance. All water samples were analyzed for Imazapyr at Pacific Agricultural Laboratory (PACLAB) in Portland, Oregon. This laboratory is accredited with the Washington Department of Ecology and was recommended by the SPU Water Quality Laboratory. PACLAB specializes in analysis of all types of pesticides and has an extremely low detection limit for Imazapyr of 0.02 ug/L (= 0.02 parts per billion).

For knotweed patches within the hydrographic boundary, baseline samples were taken the morning prior to herbicide treatment in both the Cedar River (at the point closest to a knotweed patch = 250 feet away from a patch) and at the Landsburg water supply intake facility (over 12 miles downstream from the closest knotweed patch). Post-treatment samples were taken at these same sample locations early the morning following treatment (approximately 16 -20 hours post-treatment). Water samples were taken from Rattlesnake Lake (outside the hydrographic boundary) prior to treatment of patches at the Education Center and Rattlesnake Lake, and on the morning following treatment of these patches. No Imazapyr was detected in any of these samples in either 2010 or 2011.

At Taylor Townsite there is a small creek (bankfull width less than three feet) that runs along the edge of and through a small portion of the large knotweed patch. It flows into the Taylor Overflow Ditch which eventually reaches Issaquah Creek. The Taylor Overflow Ditch is surface dry for much of the year and the creek itself is often dry during summer. The summer of 2011 was unusually wet, so there was a small amount of water in the creek during the treatment period. We took water samples both the day before (baseline) and the morning after the 2011 treatment, sampling at a site where knotweed was growing on both sides of the creek and within the creek bed itself. The water level was low with very little flow during sampling. Most water

had collected in a small pool at the sample site, although there was a small amount of surface flow continuing in the creek. The creek, however, did go surface dry prior to reaching the Taylor Overflow Ditch, which was also surface dry, so there was no surface flow connectivity to Issaquah Creek.

PACLAB unexpectedly found 0.07 ug/L Imazapyr in the Taylor Townsite baseline sample. The laboratory did extensive testing for cross-contamination and re-ran the sample, finding the same result. The only plausible explanation was that when SPU staff collected the water sample, they stepped into the creek with boots that had been worn when walking through a different, recently treated site. It is likely that a small amount of Imazapyr adhered to the boots, was transferred to the stream during sampling, and was subsequently detected in the test, a definite indication that the test is extremely sensitive to even very small amounts of Imazapyr.

When the water sample was taken the day after treatment, several large knotweed canes that were treated the previous day had fallen into the creek and were floating in the small pool of water. We realized this would result in a positive reading of Imazapyr, and indeed the laboratory detected an Imazapyr concentration of 0.12 ug/L (=0.00012 mg/L) in the sample. This is an extremely low concentration, many orders of magnitude below levels that have been proven to have no adverse effect to humans or other animals. For example, the No Observable Adverse Effect Level (NOAEL) of Imazapyr for a 10 kg human child is 250 mg/kg/day. To be extremely conservative, the Environmental Protection Agency uses a reference dose 100 times lower than the NOAEL, or 2.5 mg/kg/day. A child is assumed to consume 1.5 liters of water per day. If a child consumed 1.5 liters of the water from this creek, that would be a total of 0.00018 mg of Imazapyr, or a dose of 0.000018 mg/kg/day. This is approximately 140,000 times lower than an Imazapyr dose that is 100 times lower than a dose that has no adverse effects.

This result demonstrated that even this worst-case scenario of recently treated canes falling directly into a very small amount of slowly flowing water resulted in only minute concentrations of Imazapyr in the water. We took additional samples from this same location on the creek 15 and 27 days after treatment. The concentration in the sample taken at 15 days post-treatment had decreased to 0.02ug/L, with the Imazapyr degrading in sunlight in water at the expected rate, decreasing by over three half lives (half-life of five days). As expected, there was no detectable Imazapyr in the final sample.

2012 PLANNED WORK

For the 2012 Imazapyr treatment, we will implement the same protocols as used in 2010 and 2011, that is, targeted backpack foliar spray with a 1% Imazapyr solution, 1% surfactant, and non-toxic blue dye. We will spray during August, 2012, to increase the chance of dry weather.

Water quality sampling identical to that completed in 2011 (see above) will be conducted in 2012. Baseline and post-treatment water samples will be collected at all the same locations as in 2010 and 2011 (i.e., Cedar River, Landsburg water intake, Rattlesnake Lake, and the small creek at Taylor Townsite). All water samples will be analyzed for Imazapyr by PACLAB.

All knotweed patches will be surveyed for visible growth prior to Imazapyr treatment. Because of the discovery in 2011 of small growth nodules at the base of many of the knotweed plants first

treated in 2010, we will clear the dead canes off patches prior to the 2012 spraying. This will increase the efficiency and accuracy of examining the knotweed plants and spot spraying any live growth.

We will apply the third Imazapyr treatment, as needed, as a spot treatment on any live knotweed growth (canes, leaves, nodules) within the 7.72 acres at Cedar Falls, Education Center, Rattlesnake Lake, Masonry Dam, and the border patches (Figure 1). We expect to have far less growth than in 2011 in these patches and expect to average less than12 ounces of Imazapyr per acre in these areas. We do not know how effective spraying the growth nodules in 2011 will be in killing the plants, and do not know how widespread growth will be after two treatments, so this prediction has a significant amount of uncertainty.

We will apply the second Imazapyr treatment to the 7.5 acres at Taylor Townsite and the 0.2 acres in the other sites that were treated for the first time in 2011 (Figure 1). We expect widely scattered re-growth and predict that approximately 25 ounces of Imazapyr per acre will be required on these knotweed patches (based on the amount used for the second treatment in 2011).

We will apply the first Imazapyr treatment to the 0.1 acres at Taylor Townsite that was missed in 2011. This patch will be the only one requiring pre-treatment with bending canes. Pre-treatment will occur in early to mid-June. This patch will likely require about 64 ounces of Imazapyr per acre if there is significant re-growth after the pre-treatment.

MONITORING

A key tenant of the Major Watersheds Invasive Species Program is the Early Detection/Rapid Response (EDRR) protocol. This strategy, implemented since 2007, involves routine surveys for invasive species, including surveying for species already present in the watershed, as well as species that potentially could invade but have not yet been documented. If a new infestation is found, it is rapidly treated while it is still small enough to eradicate in a cost-effective manner and before it has a chance to spread and cause ecological damage. This strategy has been proven world-wide to be the most cost-effective way to deal with invasive species.

As part of the EDRR protocol, we conduct annual surveys of all high risk areas to find any new knotweed patches that might occur. Surveys of areas at lower risk for invasion are conducted on a routine, but less frequent basis. High risk areas include riparian areas downstream of known patches. If new patches are small, they will be treated immediately by covering with geotextile fabric. If we happen to find any large previously undiscovered patches in 2012, under the ordinance we will treat them using the same protocol as described above (targeted backpack spray with 1% imazapyr solution).

Once herbicide treatment is complete, all knotweed patches in the municipal watershed will be monitored at least twice per year during the growing season to document response to treatment. If any small patches of knotweed re-growth are found, they will be immediately covered with geotextile fabric. Once the fabric is placed, it will be monitored multiple times per year the first year it is placed. Monitoring frequency of fabric patches can slowly decrease over time, eventually down to twice per year. We will experimentally remove the fabric after several years

(likely at least five years), and then monitor the patches frequently. If re-growth occurs, the fabric will be again placed on the patch and left down for several more years.

If no knotweed growth is found, routine monitoring will continue twice a year for a minimum of five years after complete mortality is achieved. After that, monitoring will be on-going but on a less frequent basis.

SITE RESTORATION

All former knotweed patches will be restored to native plant communities. During the routine monitoring described above, notes about natural regeneration of native plant species, as well as invasion by non-native invasive species will be recorded. Non-native invasive species will be removed using hand methods (pulling, grubbing out roots). All large knotweed patches will be planted with native trees and shrubs within two years after herbicide treatment is complete. Planting costs will covered by the existing budget of the Invasive Species Program. Future planting to densify native plant species will be conducted as needed until the sites are returned to a more naturally functioning native ecosystem.