

Invasive Species Strategic Management Plan For Seattle's Major Watersheds: Cedar, Tolt, and Lake Youngs

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Executive Summary

Invasive species are non-native species that pose significant risks to native biodiversity, fish and wildlife habitat, and in many cases, basic ecological functioning. The Invasive Species Program for Seattle's three major watersheds fulfills several legal and policy requirements to eradicate (all plants must be eliminated) or control (no reproduction or spread of plants allowed) invasive species.

The Program, initiated in 2007, has three main components:

1. Terrestrial plants and animals
2. Aquatic plants and animals
3. Insects and pathogens

Program goals include maintaining municipal water quality and maintaining or restoring native biodiversity, habitat, and natural ecological functions.

Specific Program objectives are to

- Prevent introduction of invasive species whenever possible.
- Minimize human-caused dispersal and spread of invasive species.
- Minimize human-caused ground disturbance that facilitates invasive species introduction and spread.
- Find and treat new infestations while they are small enough to eradicate in a cost-effective manner before they cause significant ecological damage (an approach termed Early Detection/Rapid Response that has been proven worldwide to be the most cost-effective way to deal with invasive species).
- Use the most cost-effective, efficacious treatments with the least adverse environmental and social impact (using Integrated Vegetation Management principals).
- Eradicate certain target species that are legally required, have extremely limited distribution, or pose a highly significant ecological threat (eradication is more cost-effective over the long term than on-going control).
- Significantly reduce the existing number and size of infestations of targeted invasive species, especially in sensitive and limited habitats such as wetlands and riparian areas, such that they can be easily and cost-effectively controlled.
- Restore native biodiversity and ecosystem functioning in key habitats to increase resistance to future invasions.
- Work collaboratively with local and state agencies and other land managers.
- Help educate people working in or using the watersheds about the adverse impacts of invasive species and enlist their help, as possible, in preventing introduction or spread of invasive species, (implement as funding and staffing permit).

To date the primary focus has been on invasive plants. Extensive surveys are complete, with 47 terrestrial and 2 aquatic invasive plant species documented. An ecological risk analysis was completed for all 49 species, and varying levels of control have been initiated on 39 of them (maps and details of treatments are provided in Appendix I). Seattle Public Utilities Water

Quality Laboratory developed a document addressing prevention of aquatic nuisance species in Seattle water supply watersheds, with initial implementation in 2010. For forest insects and pathogens, Forest Ecology staff monitors annual data from Washington Department of Natural Resources flights to document cause and extent of tree death, and investigates unusual occurrences for a possible outbreak.

The Invasive Species Program manager used information from local, state, and national experts, site-specific data, and consultation with SPU staff to develop a series of ecological management recommendations to prevent, reduce, control, or eradicate invasive species from the watersheds. Most are already implemented (marked with asterisk), and should reduce Program costs over time. SPU managers will balance risks, benefits, and costs, and decide whether and how to implement the remainder of the recommendations.

- Prevent introduction and spread of invasive species by:
 - Maintaining the policy of no unsupervised public access to the watersheds*
 - Requiring decontamination and inspection of vehicles, equipment, and materials (e.g., pipe) used in the municipal water supply*
 - Limiting the use of vehicles driven outside the watersheds and washing vehicles (e.g., automatic tire and undercarriage washer) when entering the watersheds
 - Frequent washing of vehicles and equipment stationed within the watersheds*
 - Decreasing human-caused ground disturbance, including elevating brushing blades to a minimum of four to six inches of ground clearance, decreasing brushing frequency, and brushing only those areas where it is required for safety or project implementation*
 - Rapidly re-vegetating areas of human-caused ground disturbance*
 - Using only uncontaminated gravel and instituting a gravel tracking system
 - Limiting use of straw and using only certified weed-free straw*
 - Enhancing native biodiversity and forest health through various silvicultural techniques including creating canopy small gaps, snags, and logs, thinning, and planting*
- Qualified biologists conduct routine surveys to find and treat new infestations while they are small enough to eradicate in a cost-effective manner before they cause significant ecological damage (Early Detection/Rapid Response).*
- Program manager prioritize eradication and control of existing infestations among species by using legal requirements and ecological risk assessment. Prioritize within species using number, size, and location of patches.*
- Use Integrated Vegetation Management principles to determine the most cost-effective, efficacious treatments with the least adverse environmental and social impact.*
- Monitor treatments for effectiveness and change approaches when appropriate.*

To continue current levels of service, the Invasive Species Program recommend the following components:

1. Program manager with scientific biological and botanical expertise to oversee and coordinate all projects, contracts, and budget, as well as conduct botanical surveys, collect and analyze data, and implement treatments
2. Staff or seasonal field technician to implement treatments and collect data
3. Contract field crews to implement restoration projects and treatments requiring several people within a short time frame during the growing season
4. Consultants providing specific expertise such as certified underwater divers with expertise in aquatic plant identification and removal

To continue to deal with the current levels of infestation and the on-going threat of new invasive species introductions into the watersheds, especially in light of climate change, this needs to be an on-going program.

1.0 Background/Overview

The City of Seattle owns two major municipal watersheds on the western slopes of the Cascade Mountains, the Cedar River Municipal Watershed (Cedar) and the South Fork Tolt Municipal Watershed (Tolt). In addition, Seattle owns a reservoir and water treatment facility near Maple Valley, the Lake Youngs Reserve (Lake Youngs). These watersheds are managed by Seattle Public Utilities (SPU) to supply drinking water to over 1.3 million people. They encompass over 100,000 acres of mainly forested land, much of which was historically used for resource extraction, primarily timber harvest. Over 85% of the forest was logged and there were several logging and mining towns and camps in the Cedar, as well as farms at Lake Youngs. Since the City acquired much of the land in the 1900s, all areas have been closed to unsupervised public access. The watersheds are currently managed to provide a high quality drinking water supply, as well as restoration of fish and wildlife habitat, native biodiversity, forest health and resiliency, and natural ecosystem functions.

Invasive species are non-native species that pose significant risks to native biodiversity, fish and wildlife habitat, and even basic ecological functioning, with some invasive plants and animals threatening water quality and supply. Globally, invasive species are considered the second greatest threat to endangered wildlife populations next to habitat loss. Global climate change is expected to further increase the risks posed by invasive plants and some animals, because changed disturbance regimes and higher carbon dioxide content in the atmosphere have been shown to favor many invasive over native species. In addition, changed environmental circumstances may create conditions where some native species of insects or pathogens have outbreaks that can kill massive areas of forest. Control and eradication of invasive species in the three major municipal watersheds is necessary not only to carry out the core utility function of protecting water quality and supply, but also to meet several legal and policy requirements.

The purpose of this document is to describe SPU's invasive species management program in its major watersheds by documenting the history and current status of invasive species management efforts, providing a summary of accomplishments, and establishing program goals and objectives, management strategies, and recommendations for the future.

1.1 Legal and Policy Requirements

- 1) **State and County Law.** In 2016 in King County, Washington State and King County law required 37 noxious weed species to be eradicated (Class A – all plants must be completely eradicated) and 50 species or species groups to be controlled (Class B and some Class C - no reproduction or spread of the plants allowed). An additional 56 species or species groups are recommended for control because of the ecological damage they can cause, but are currently so widespread that control is not legally required (termed “non-regulated noxious weeds” and “weeds of concern”). Of these listed species, 9 King County Class B, and 33 recommended control species are known to occur within one or more of the three watersheds. If a landowner does not comply with the laws to eradicate or control invasive species, King County has the legal authority to impose fines or file a Failure to Control Notice. The County can then come onto the landowner's property and control the species using whatever method they choose (including herbicide). They will then bill the landowner for their costs, which is usually

much more expensive than if the landowner had initially controlled the invasive themselves.

- 2) **SPU Policy.** SPU's corporate environmental objectives state that SPU will "implement strategies and actions to achieve and exceed goals and expected outcomes of environmental laws" and will "lead on regional environmental issues, working cooperatively with other organizations to promote common environmental goals and objectives" (SPU Environmental Policy 2004). As such, SPU's control or eradication of certain invasive species found within Seattle's ownership, as required and recommended by Washington State and King County, is consistent with SPU's Environmental Policy.
- 3) **Cedar River Watershed Habitat Conservation Plan (HCP).** The HCP does not directly address invasive species, but it does commit SPU to protect and restore habitat for federally listed species and enhance native biodiversity within the Cedar. Invasive species are one of the greatest current threats to biodiversity, and critical habitat for some fish and wildlife species listed in the HCP may be threatened by invasive species. To the extent that invasive species threaten native biodiversity or habitat for listed fish and wildlife species, invasive species control should be performed to support HCP goals.

1.2 Invasive Species Program Background

In January 2007, an Invasive Species Program Development Plan (PDP) for Seattle's three major municipal watersheds was approved and funded as a Capital Improvement Project. In February 2009 the Program was moved to Operations and Maintenance funding as a result of recommendations by an auditor.

As part of this initial PDP, several key objectives were fulfilled:

- The extent of the problem was determined by having qualified botanists conduct intensive surveys for non-native invasive plants.
- Literature was reviewed on effectiveness, risks, and costs of potential methods of eradication, control, and containment for key invasive species.
- Several experimental control methods for key invasive species were initiated.
- Reproduction and spread were controlled for all species legally required to control.
- An ecological risk analysis was completed for each invasive species found to be present in the watersheds.
- Recommendations were developed to minimize invasive species spread from operational practices such as road maintenance and improvement, and rights-of-way (ROW) management.
- A prioritization scheme was developed for deciding which species and locations should be controlled first.

A detailed summary of the plant surveys conducted and all the invasive plants eradication and control work accomplished to date is provided in Appendix 1.

1.3 Invasive Species Program Goals and Objectives

The primary goals of the Invasive Species Program are to:

1. Maintain municipal water quality.
2. Maintain or increase native biodiversity, restore habitat for native HCP-listed fish and wildlife species, and maintain and restore natural ecological functions.

Specific objectives are to:

- Prevent introduction of invasive species whenever possible.
- Minimize human-caused dispersal and spread of invasive species.
- Minimize human-caused ground disturbance that facilitates invasive species introduction and spread.
- Find and treat new infestations while they are small enough to eradicate in a cost-effective manner before they cause significant ecological damage (an approach termed Early Detection/Rapid Response).
- Use the most cost-effective, efficacious treatments with the least adverse environmental and social impact (using Integrated Vegetation Management principals).
- Eradicate certain target species that are legally required, have extremely limited distribution, or pose a highly significant ecological threat (more cost-effective than on-going control).
- Significantly reduce the existing number and size of infestations of targeted invasive species, especially in sensitive and limited habitats such as wetlands and riparian areas, to a point where they can be easily and cost-effectively controlled.
- Restore native biodiversity and ecosystem functioning in key habitats to increase resistance to future invasions.
- Work collaboratively and share data with local and state agencies, as well as other land managers.
- Help educate people working in or using the watersheds about the adverse impacts of invasive species and enlist their help, as possible, in preventing introduction or spread of invasive species, (implement as funding and staffing permit).

2.0 Watershed Inventories for Invasive Species

It is essential to determine the extent of an invasive species problem before effective treatment strategies can be developed. Consequently, in 2007 and 2008 we had expert botanists conduct surveys in selected areas of the three municipal watersheds for 44 invasive terrestrial plant species legally required to control (Class A, B, and some C) and 11 plant species recommended

for control. Surveys were concentrated in areas most likely to contain invasive plants, including areas of frequent disturbance such as roads, gravel pits, and riparian areas, as well as sensitive habitats such as wetlands and meadows. Survey protocol included slowly riding a bicycle along roads, and walking through other habitats. The botanists documented locations of all invasive plants on the target list with GPS and estimated the size of each located population. The botanists spent approximately 730 hours surveying the Cedar, 100 hours surveying the Tolt, and 70 hours surveying Lake Youngs.

SPU biology staff supplemented surveys for these target species, plus conducted surveys for numerous other invasive terrestrial plant species that pose significant risks but are not legally required for control. These surveys are ongoing as part of the Early Detection/Rapid Response protocol (Section 4.2). Presence of non-target invasive terrestrial plant species were noted, but many are not yet mapped. A total of 47 invasive terrestrial plant species were documented from all surveys (Table 1). Of these, 37 species have had at least some level of control. Areas surveyed and maps of the locations of each species in each watershed, along with all treatment conducted, are found in Appendix 1.

Surveys for invasive aquatic plants have been conducted in Walsh Lake, Rock Creek Wetland, and the 14 Lakes complex of small pond in the Cedar. Two aquatic invasive plant species (Eurasian milfoil and white water lily) were found in Walsh Lake and none elsewhere. Both species are being controlled in Walsh Lake. The Lake Youngs reservoir is periodically surveyed for Eurasian milfoil, which was eradicated there in the 1990s, but it is not surveyed for other invasive aquatic plants. Chester Morse Lake (Cedar) had limited plant surveys conducted on both submerged and emergent sections of the Cedar River delta, Youngs Cove, and selected portions of the Masonry Pool in 1989, 1996, and 2007. Although these surveys targeted native plants, no invasive species were noted. The Tolt Reservoir has not been surveyed for invasive aquatic plants, but poses low risk because of the high elevation and generally steep rocky sides.

Specific surveys have not yet been conducted for invasive aquatic or terrestrial animals, insects, or pathogens. However, Washington Department of Natural Resources conducts annual flights to document cause and extent of tree death, which include both non-native and native causes. Natural Resources forest ecology staff monitors these annual data, and any unusual occurrences of non-native species are investigated. If large outbreaks of native insects or pathogens should occur, these will also be investigated and any management actions developed at that time.

Table 1. Non-native Invasive Plant Species in Seattle's Major Municipal Watersheds
(species listed alphabetically by scientific name within each management priority section)

SCIENTIFIC NAME	COMMON NAME	ECOLOGICAL RISK	KING COUNTY LISTING STATUS (2013)	WA STATE LISTING STATUS (2013)	WHERE LOCATED	DISTRIBUTION	GOAL
High Management Priority (Legally Required)							
<i>Centaurea biebersteinii</i> (maculosa)	Spotted knapweed	High	Class B	Class B	Cedar, Lake Youngs	Few locations	Eradicate
<i>Hieracium aurantiacum</i>	Orange hawkweed	High	Class B	Class B	Cedar, Lake Youngs	Scattered, mainly in lower elevations	Control spread, reduce size & number of patches
<i>Hieracium caespitosum</i>	Yellow (meadow) hawkweed	High	Class B	Class B	Cedar, Tolt	Widespread, mainly in upper elevations	Control spread, reduce size & number of patches
<i>Hieracium piloselloides</i>	Tall hawkweed	High	Class B	Class B	Cedar	3 known locations	Eradicate
<i>Hieracium sabautum</i>	European hawkweed	High	Class B	Class B	Cedar	4 known locations	Eradicate
<i>Impatiens glandulifera</i>	Policeman's helmet	High	Class B	Class B	Cedar	1 known location	Eradicate
<i>Linaria dalmatica</i>	Dalmatian toadflax	High	Class B	Class B	Cedar	2 known locations	Eradicate
<i>Lythrum salicaria</i>	Purple Loosestrife	High	Class B	Class B	Lake Youngs	1 known location	Eradicate
<i>Potentilla recta</i>	Sulfur cinquefoil	High	Class B	Class B	Cedar	2 known locations	Eradicate
<i>Senecio jacobaea</i>	Tansy ragwort	High	Class B	Class B	Cedar, Tolt, Lake Youngs	Widespread, mainly in lower elevations	Control spread, reduce size & number of patches
High Management Priority (Very High Ecological Threat, Control Recommended)							
<i>Myriophyllum spicatum</i>	Eurasian water-milfoil	Very High	Non-regulated noxious weed	Class B	Cedar	1 known location (Walsh Lake)	Eradicate
<i>Polygonum bohemicum</i>	Bohemian knotweed	Very High	Class B within 200 feet of Cedar River	Class B	Cedar, Lake Youngs	About 22 acres total, mainly in lower Cedar. 1 plant in Lake Youngs	Eradicate

High Management Priority (High Ecological Threat with Limited Distribution, Control Recommended)							
Buddleia davidii	Butterfly-bush	High	Non-regulated noxious weed	Class B	Cedar, Tolt, Lake Youngs	Few locations	Eradicate
Clematis vitalba	Old man's beard	High	Non-regulated noxious weed	Class C	Cedar	1 known location	Eradicate
Hedera helix	English ivy	High	Non-regulated noxious weed	Class C	Cedar, Lake Youngs	Several locations	Eradicate in Lake Youngs; Eradicate small patches in Cedar
Iris pseudacorus	Yellow flag iris	High	Non-regulated noxious weed	Class C	Cedar	1 known location	Eradicate
Lamium galeobdolon	Yellow archangel	High	Non-regulated noxious weed	Class B	Cedar	2 known locations	Eradicate within forest. Prevent spread from neighboring property
Nymphaea odorata	White water lily	High	Non-regulated noxious weed	Class C	Cedar	1 known location (Walsh Lake)	Eradicate
Prunus laurocerasus	English laurel	High	Weed of concern		Lake Youngs	3 known locations	Eradicate
Medium Management Priority (High Ecological Threat, Generally Already Widespread, Control Recommended)							
Cirsium arvense	Canada thistle	High	Non-regulated noxious weed	Class C	Cedar, Tolt, Lake Youngs	Widespread	Eradicate or Control key patches
Cirsium vulgare	Bull thistle	High	Non-regulated noxious weed	Class C	Cedar, Tolt, Lake Youngs	Widespread	Eradicate or Control key patches
Convolvulus arvensis	Field Bindweed	High	Non-regulated Noxious weed	Class C	Cedar, Tolt	20 locations in Cedar, 1 in Tolt	Eradicate key patches. Control small and new infestations
Cytisus scoparius	Scots broom	High	Non-regulated noxious weed	Class B	Cedar, Tolt, Lake Youngs	Widespread	Eradicate or Control key patches
Dipsacus fullonum	Fuller's (common) teasel	High	Non-regulated noxious weed	Class C	Cedar	1 known location	Eradicate

Hieracium lachenalii	Common hawkweed	High	Non-regulated noxious weed	Class B	Cedar, Tolt	Widespread, mainly in upper elevations	Control key patches
Ilex aquifolium	English holly	High	Weed of concern		Cedar, Lake Youngs	Widespread	Eradicate or Control key patches
Rubus armeniacus	Himalayan blackberry	High	Non-regulated noxious weed	Class C	Cedar, Tolt, Lake Youngs	Widespread, especially in wetlands, riparian areas	Eradicate key patches
Rubus laciniatus	Evergreen (cutleaf) Blackberry	High	Non-regulated noxious weed	Class C	Cedar, Tolt, Lake Youngs	Widespread, especially in wetlands, riparian areas	Eradicate key patches
Solanum dulcamara	Bittersweet nightshade	High	Weed of concern		Cedar	Large matting patches in wetlands	Eradicate or Control key patches
Tanacetum vulgare	Common tansy	High	Non-regulated noxious weed	Class C	Cedar, Lake Youngs	Widespread in lower elevations	Eradicate or Control key patches
Verbascum thapsus	Common mullein	High			Cedar, Tolt	Widespread	Eradicate or Control key patches
Low Management Priority (Lower Current Ecological Threat, Distribution Variable)							
Acer pseudoplatanus	Sycamore maple	Moderate or Low			Cedar	Uncommon but spreading from Cedar Falls Compound	Eradicate or Control key patches
Aralia spinosa	Devils Walkingstick	Moderate or Low			Cedar	1 known location	Eradicate as part of restoration project
Arctium lappa	Greater Burdock	Moderate or Low			Cedar	Increasing numbers, especially in lower elevations	Eradicate or Control key patches
Cotoneaster horizontalis	Cotoneaster	Moderate or Low			Cedar	Several locations	Control key patches
Crataegus monogyna	Common hawthorn	Moderate or Low	Weed of concern		Lake Youngs	Scattered, mainly in large wetland	
Digitalis purpurea	Foxglove	Moderate or Low			Cedar, Tolt, Lake Youngs	Widespread & spreading rapidly	Control key patches
Geranium robertianum	Herb-robert	Moderate or Low	Non-regulated noxious weed	Class B	Cedar	Widespread	
Hypericum perforatum	Common Saint Johnswort	Moderate or Low	Non-regulated noxious weed	Class C	Cedar, Tolt	Widespread	Monitor results of biocontrol experiment

<i>Hypochaeris radicata</i>	Common catsear	Moderate or Low	Non-regulated noxious weed	Class C	Cedar, Tolt, Lake Youngs	Widespread	
<i>Impatiens capensis</i>	Spotted jewelweed	Moderate or Low	Weed of concern	Proposed Class C addition	Cedar	Widespread in wetlands, riparian areas	Monitor key patches
<i>Leucanthemum vulgare</i>	Oxeye Daisy	Moderate or Low	Non-regulated noxious weed	Class B	Cedar, Tolt	Widespread in high elevations	
<i>Linaria vulgare</i>	Yellow toadflax (butter and eggs)	Moderate or Low	Non-regulated noxious weed	Class C	Cedar	Widespread in low elevations	
<i>Phalaris arundinacea</i>	Reed canarygrass	Moderate	Non-regulated noxious weed	Class C	Cedar, Tolt, Lake Youngs	Common in some wetlands	Experimental control key patches
<i>Ranunculus repens</i>	Creeping buttercup	Moderate or Low	Weed of concern		Cedar	Widespread, especially in wetlands	
<i>Robinia pseudoacacia</i>	Black locust	High			Cedar	1 known location	Eradicate as part of restoration project
<i>Senecio vulgaris</i>	Common groundsel	Moderate or Low	Non-regulated noxious weed	Class C	Cedar, Tolt	Widespread	
<i>Sorbus aucuparia</i>	European mountain-ash	Moderate or Low	Weed of concern		Cedar	Near Cedar Falls Compound	Monitor
<i>Taraxacum officinale</i>	Dandelion	Moderate or Low			Cedar, Tolt, Lake Youngs	Widespread	

3.0 Invasive Species Program Components and Responsibilities

The Invasive Species Program consists of three main components: terrestrial plants and animals, aquatic plants and animals, and insects and pathogens.

3.1 Terrestrial Plants and Animals.

Survey and control of invasive terrestrial plants and animals is the responsibility of the Invasive Species Program manager. To date the Program has focused primarily on survey and control of invasive terrestrial plants because of the large number and generally wide distribution already present in the watersheds. Surveys for non-native invasive terrestrial animals will occur as it becomes necessary.

3.2 Aquatic Plants and Animals.

Because of the significant threat posed by invasive aquatic plants and animals to water quality and supply, the SPU Water Quality Laboratory (WQL) is responsible for survey and control of aquatic plants and animals in Chester Morse Lake and the Masonry Pool (Cedar), the Tolt Reservoir, the Tolt Regulating Basin, and the Lake Youngs reservoir. Key WQL and SPU Protection staff have been formally trained in detection of Aquatic Nuisance Species (ANS). Because of the extremely high risk to the municipal water supply from species such as quagga and zebra mussels, a detailed plan for prevention of ANS in Seattle's water supply watersheds has been developed by the WQL. This plan details specific decontamination procedures required by anyone working in the water supply, with initial implementation in 2010. The Invasive Species Program is responsible for survey and control of aquatic plants and animals found in all other small lakes, streams, and wetlands, as well as communication and coordination of these activities with the WQL. A list of aquatic plants and animals that could potentially infest the watersheds is found in Appendix 2.

3.3 Insects and Pathogens.

Natural Resources forest ecology staff are responsible for survey and response to invasive insects and tree pathogens in the watersheds. The primary threat currently is from non-native species. Native insects and pathogens have evolved with the forest and generally provide small to intermediate levels of disturbance that increase forest structural diversity and facilitate greater native biodiversity. However, some native insects and pathogens could potentially have major outbreaks as a result of changes in the forest, as might be seen with climate change or after a major fire. In-house monitoring has been conducted for the native Douglas-fir beetle in target areas, but more species may need to be monitored in the future. A list of both non-native and native forest insects and pathogens that could potentially adversely impact the watershed forests is found in Appendix 3 and maps of tree death in the Cedar by causal agent (species of insect or pathogen) in Appendix 4. The Invasive Species Program manager is responsible for communication and coordination with forest ecology staff, as well as supplying support when requested.

4.0 Management Strategies and Recommendations

The Invasive Species Program is incorporating several key strategies and recommendations widely used at the local, state, national, and international levels. The following recommendations were developed using ten years of site-specific data and in consultation with

Watershed Natural Resources and Operations Section personnel. These are ecological recommendations only, and do not consider ease or cost of implementation, or other factors. Most of the recommendations are already implemented in the Cedar as part of normal operating procedures. SPU managers will assess the trade-offs of risk of invasion with difficulty and cost of implementing the remaining recommendations. They will then decide whether and how to apply these recommendations, and may develop policies and procedures as they see fit.

4.1 Prevent Introduction of New, and Spread of Existing Infestations.

The easiest and most cost-effective strategy concerning invasive species is to prevent their occurrence in the first place. Preventing spread of existing infestations is legally required for several species and is the most cost-effective way to deal with all existing infestations. Methods we recommend to prevent introductions and spread of invasive species in the watersheds include:

- **Maintain the existing policy of no unsupervised public access in the watersheds.** This is the most essential strategy, as it has been demonstrated innumerable times that the public is the most common vector for invasive species introduction and spread, especially for terrestrial plants and aquatic plants and animals. Vectors include their vehicles, clothing, shoes, equipment, pets, etc.
- **Require decontamination and inspection of vehicles and equipment used in the water bodies.** Preventing ANS from entering the water supply system is critically important because of the risk to both water quality and supply, and the extreme cost of control if certain ANS are introduced. Detailed decontamination requirements for ANS are presented in the Prevention of Aquatic Nuisance Species in Seattle Water Supply Watersheds document. Initial implementation began in 2010.
- **Limit the use of vehicles that have been driven outside the watersheds from using roads within the watershed and decontaminate vehicles when entering the watersheds.** The most common vector for dispersal of invasive plants is seeds or other plant propagules caught in tires, wheels, or undercarriages of vehicles and trailers.
 - SPU Watersheds Staff. Watersheds staff use City vehicles and heavy equipment that are rarely driven outside the watershed, which minimizes the risk of new introductions. However, when City vehicles are driven outside the watershed, especially through areas of known infestation, we recommend that the vehicle is washed thoroughly upon re-entering the watershed, paying particular attention to the tires and undercarriage. This can easily be accomplished for the Cedar at the drive-through tire and undercarriage washer or the wash station both located near the main entrance at Cedar Falls.
 - State and federal agency staff, contractors, researchers, tribal members, and others. Most non-SPU staff currently use their own vehicles and usually do not wash their vehicle upon entering the watersheds. This happens most often in the Cedar, where the most non-staff use of a watershed occurs. Many of these vehicles are driven through infestations on forest roads in other ownerships. To reduce this risk, we recommend that vehicles entering the watershed at Cedar Falls use the drive-through wheel washer prior to driving further into the watershed. This requirement could be made a part of future contracts and access agreements.

- **Frequent washing of vehicles and equipment stationed within the watersheds.** The best way to prevent infestation spread via vehicles and equipment is frequent washing. It is especially important to wash equipment when it moves out of an area known to be contaminated. It is also important to wash vehicles after they have been used in one area of the watershed before moving into another (e.g., lower to upper watershed). This is particularly important if vehicles are driven on roads that have not been brushed recently (increasing the risk of seeds or other plant parts catching in the undercarriage), as is frequently necessary for staff surveying for invasive species and Protection staff. This is easily facilitated with the tire and undercarriage washing station at Cedar Falls.
- **Decrease human-caused disturbance.** Most invasive plant species flourish in areas of ground disturbance. Minimizing human-caused disturbance will decrease the likelihood that a new species will invade or existing species will spread. Methods to do this are already being implemented along roads in the Cedar by Operation staff. They include:
 - Elevating brushing blades along roads and in ROWs such that at least four to six inches of vegetation remain (more if the native vegetation is low-growing). This will limit ground disturbance and allow existing native vegetation to better outcompete invasive species.
 - Decreasing brushing frequency along roads and in ROWs so native vegetation has adequate time to recover and out-compete potential invasive species.
 - Brushing only those areas required, for example, brush only where native vegetation has grown to a height where it causes a safety issue or interferes with work. Not brushing areas of sword fern and low-growing salal can both save money in time and labor and discourage or prevent invasive species.
- **Rapidly re-vegetate areas of human-caused ground disturbance.** The most common instance when this will occur is during road decommissioning and other required road and bridge work. In accessible areas re-vegetation can be easily completed (and is already being implemented) with the hydro-seeder currently stationed at Cedar Falls. In addition, areas of known plant infestations on roads scheduled for decommissioning should be targeted for planting with native trees and shrubs that will eventually shade out most invasive species (also being implemented in the Cedar as funding allows). The Invasive Species Program coordinates with the Operations Section and the HCP Planting Program on these projects.
- **Use only uncontaminated gravel and institute a gravel tracking system.** Contaminated gravel is a very common way that invasive plants are introduced and spread. The best way to minimize this risk is to ensure that invasive plants are controlled in on-site gravel pits and that any gravel purchased from off site is weed free. Instituting a gravel tracking system that includes the source of the gravel and where it is used would aid in identifying contaminated gravel sources. The Invasive Species Program has coordinated with the Operations Section in the Cedar to initiate this system by adding a quick and simple note in the Maximo program already used to track all road-related projects.
- **Limit use of straw; Use only certified weed-free straw.** Contaminated straw is another common source for invasive plants. Limiting the use of straw to allow more rapid growth

of native plants and only using certified weed-free straw will help minimize the risk of bringing in new invasive species (often from eastern Washington). Cedar Operations has already greatly reduced their use of straw on decommissioned roads, using it only in specific areas as needed for erosion control, and already uses only certified weed-free straw.

- **Enhance native biodiversity in habitats that are at risk of invasion.** A healthy diverse habitat is often more resistant to invasion by non-native species than an area dominated by only one or two plant species. Projects enhancing native biodiversity are being implemented in the Cedar as part of the HCP and in the Tolt under the Tolt Management Plan. They include thinning, creating small canopy gaps, and planting native species. Projects at Lake Youngs are conducted as funding and staff are available. The Invasive Species Program contributes to this effort by removing invasive species in restoration sites and coordinating with HCP and Tolt restoration programs.
- **Enhance forest health and resilience.** A healthy forest will be much more resistant to infestation by insects and pathogens than one that consists of trees stressed by low levels of water, nutrients, or light. Projects that will increase forest health are being implemented in the Cedar as part of the HCP and in the Tolt under the Tolt Management Plan and include thinning, creating small canopy gaps, and planting a variety of native trees and shrubs. Projects at Lake Youngs are conducted as funding and staff are available.

4.2 Early Detection/Rapid Response.

Early Detection/Rapid Response (EDRR) is a strategy that involves routine monitoring for numerous invasive species. 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 significant ecological damage. This strategy has been proven world-wide to be the most cost-effective way to deal with invasive species.

EDRR in the three watersheds focuses primarily on terrestrial plants and consists of botanical surveys conducted by qualified biologists. Surveys target both new invasive species that potentially could invade but have not yet been documented and species known to be present in the watershed. Particular attention is paid to species that have been found in areas adjacent to the watershed (maps available from the King County Noxious Weeds Program). EDRR is implemented annually in the watershed to varying degrees, depending on staffing and funding

Not every area of each watershed needs to be surveyed for invasive species. For insects and pathogens, only some of the areas of tree death identified during flights (e.g., those identified as caused by non-native species) need to be targeted. For Aquatic Nuisance Species only those aquatic areas that can support the high-risk species that pose significant threats to the water quality and supply need to be surveyed frequently. High priority areas for invasive plants, including those at high risk due to frequent disturbance and sensitive habitats such as wetlands, have already been identified (see Appendix 1, maps of areas surveyed for invasive plants in each watershed). For plants, we use a survey strategy based on risk of invasion.

- Very high risk areas because of frequent disturbance (e.g., heavily used roads and gravel pits) are surveyed annually or semi-annually.
- Areas that are disturbed less frequently (e.g., roads that are graded and brushed every two or three years, areas of episodic natural disturbance from flood or windthrow, recently decommissioned roads, restoration sites) are surveyed approximately one year after the disturbance, then periodically on a site-specific basis, depending on initial survey results and amount of disturbance.
- Sensitive habitats with low disturbance rates (e.g., certain wetlands, meadows) are surveyed using a rotating panel method, in which a limited number of habitats are surveyed each year, rotating through all the sites such that each is surveyed once every four or five years.

4.3 Eradication and Control of Existing Infestations.

Because large number of invasive plant species is already present in the watersheds, it is critical to have eradication and control strategies to deal with them. Work on each species and patch location needs to be prioritized such that the species and patches posing the greatest ecological risk are treated first (see prioritization guidelines in Section 5). Once species and locations are prioritized, then the most efficacious and cost-effective treatment method needs to be determined. The guidelines to determine methods are detailed in Section 6. Generally the most cost-effective method is to eradicate small patches and control larger ones. For occurrences of non-native insects, such as the Balsam woolly adelgid, areas of infestation need to be located and populations monitored. Then thresholds for treatment and types of treatment need to be determined.

4.4 Habitat Restoration.

Areas where invasive plant species have been eradicated or controlled are being restored to a diverse native vegetation community. An evaluation of the reasons for the initial successful invasion is conducted and site-specific conditions are altered, if possible, to decrease the likelihood of future re-invasion or invasions by other species. This usually consists of restoring the site with an appropriate array of healthy native species, as biodiverse areas are generally more resistant to invasion than areas with few species or unhealthy plants.

If there is high potential that an appropriate diversity of native plants will colonize the restoration site naturally, then the site is simply monitored. If the site is not recolonized within a reasonable time (e.g., two growing seasons), or if it appears that there are insufficient native seed sources nearby, then a planting project is instigated. This is usually accomplished by coordinating with the HCP Planting Program in the Cedar and SPU staff with expertise in native plants and plant ecology.

5.0 Prioritization Guidelines

The following prioritization guidelines are used to determine 1) which plant species are the highest priority to treat and 2) within each plant species, which patches are the highest priority for treatment. Although these prioritization guidelines were developed for plant species already present in the watersheds, they could also be applied to forest insects and pathogens, and Aquatic Nuisance Species, as necessary.

Prioritization among species:

- Is the species legally required for eradication or control?
 - All species required to be eradicated or controlled are high management priority because Washington State and King County has already determined that these species pose a high ecological risk and are still present in small enough numbers regionally that they can effectively be controlled.
- If the species is not legally required for eradication or control, what is the level of ecological risk posed by the species?
 - Evaluate the degree of invasiveness; ability to outcompete natives; rate of potential spread; type of habitats the species occupies; and ecological impact of the species on native species, ecological processes, and ecological functions.
 - If the ecological risk of the species is determined to be very high, then that species is a high management priority for treatment.
 - If the ecological risk is high and there are limited locations within the watershed, then that species is a high management priority for treatment.
 - If the ecological risk is high, but the species is already widespread, it is moderate priority for treatment.
 - If the ecological risk is currently considered to be low, then the species will get a low priority for treatment. See Table 1 for list of invasive plant species present in the watersheds sorted by management priority.

Prioritization of locations to treat for species with high or moderate management priority:

- How many patches are there?
 - One or very few patches - attempt eradication unless there is no allowed treatment that is efficacious or it is very cost-prohibitive.
 - If there are many patches, prioritize treatment among patches based on a combination of patch location and size (see below).
- Where are the patches located? High priority locations are:
 - In or near sensitive or rare habitats, including wetlands, riparian areas (especially immediately adjacent to streams or ponds), meadows, and old-growth forest.
 - Along well traveled roads that pose a significant risk of spread.
 - In or near frequently disturbed and used areas (e.g., gravel pits) that pose a significant risk of spread.
 - Restoration sites where ground disturbance poses a significant risk of spread.
- How big are the patches?
 - Small patches are higher priority for early treatment because there is a greater chance of eradication, it takes less time and resources to treat, and it eliminates scattered patches as sources for new infestations.

6.0 Treatment Options for Invasive Plants

Integrated Vegetation Management (IVM) is an integrated, ecological approach to invasive plant species treatment. It relies on comprehensive information about the invasive species life cycle and its interaction with the environment, in combination with all potential control methods, to design the most effective combination of treatments to eradicate or control each species. We use this integrated approach for each species and site when determining the most efficacious and cost-effective treatment methods.

Each site is examined and an evaluation made as to what ecological condition made it favorable for the initial invasive species establishment and spread. If that condition can be changed (e.g., decreasing human-caused disturbance, planting native species), it is incorporated in the treatment plan. However, in most situations simply changing the ecological conditions is insufficient to control or eradicate the existing infestation. Consequently, a determination must then be made as to which treatment(s) will be effective on that particular site. Species, location, and size of patch are all significant variables considered.

Eradication and control treatment options we consider include:

- Mechanical removal, including hand pulling, cutting, or grubbing out roots, and excavating the roots by machine.
- Starving the roots by shading, generally using geotextile fabric.
- Biocontrols, if available and approved by the USDA Animal and Plant Health Inspection Service (APHIS). These are generally insects that target only the invasive plant species and no native species. It can take several years to build their populations to a point where they significantly influence the infestation, and they generally require a large concentrated population of the invasive plant.
- Herbicides are prohibited in the Cedar by Seattle City Council ordinance, with the current exception of a three-year window (2016-2018) in which knotweed may be treated with Imazapyr (see knotweed section in Appendix 1). They are allowed within the Tolt and Lake Youngs, however, and are considered on a case by case basis.

The treatment(s) with the least environmental impact are chosen unless they are not effective or are logistically impossible. Then the combination of treatments that are both effective and have the least adverse environmental impact are chosen. If treatments are equally effective with the same adverse environmental impact, then the least expensive option is chosen.

Most patches will take several consecutive years of treatment before they are reduced significantly, because of the extreme difficulty in removing all root and stem fragments, or a large seed bank in the soil. Repeated treatments will often create ground disturbance, which increases the likelihood that the site will be invaded or re-infested. It is important to re-vegetate the soil as soon as possible. However, it may not be appropriate to immediately plant the native species that will ultimately occupy the site (often trees and shrubs). If these species are planted throughout the site too soon, they can interfere with future control treatments, making it much more difficult and expensive to extract the invasive species. In addition, planting too early often

results in higher mortality of the native plants because of the disturbance to their roots from future grubbing of the invasive species. A good option is to seed the disturbed area to grasses and forbs during the first few years of treatment, perhaps planting native trees and shrubs around the edges of the patch. Then, as the infestation is greatly reduced, native trees and shrubs can be safely planted throughout the site.

If the site is an area that is chronically disturbed and cannot be re-vegetated (e.g., active gravel pit), then an on-going control plan for the invasive species needs to be implemented.

7.0 Monitoring and Adaptive Management

Because treating invasive species (plants, animals, insects, pathogens, and aquatic nuisance species) is virtually always a multi-year effort, it is critically important to monitor active treatment sites. Assuming a treatment was successful without verification often results in the few remaining individuals quickly re-colonizing the site, thus wasting all previous efforts at control. The frequency of monitoring will be both species and site-specific.

It is also important to keep detailed and accurate records of the results of every treatment and site visit. Because of the extreme variability between sites, research results in the literature may not always apply to each location. These site-specific datasets allow managers to determine the effectiveness of each treatment at each site, and whether future changes should be implemented. Only by having these long-term datasets can the most effective treatment with the least adverse environmental impact be determined and appropriate management changes made.

Invasive Species Program staff have found it is most cost-effective to combine invasive plant site monitoring with treatment because of the often long travel distances involved in reaching sites. That is, active treatment sites are visited, and if any invasive plant growth is observed, it is treated immediately before it has a chance to grow or reproduce. Of course, this applies only to those sites that can easily and efficiently be treated by a single person. We record detailed notes each time a treatment site is visited. Records include the date and staff person who conducted the monitoring and treatment, whether there were any invasive plants present, number and growth stage of plants, area covered by the plants, and type and amount of any treatment applied. These extensive records are maintained for each separate patch of each species and are used by the Program manager to determine future treatments and estimate work load and resource needs.

8.0 Invasive Species Program On-going Needs

The following recommendations are based on nine years of program development, extensive field experience in surveying and implementing a wide variety of treatments, and collecting and analyzing many years of data. This level of support will fulfill legal obligations and SPU policy requirements for the municipal watersheds and maintain the level of service provided annually since 2007.

- **Program Manager.** Must have extensive scientific background, strong botanical skills, experience in restoration ecology, and excellent writing and communication skills. Oversee and coordinate all projects; manage the budget; develop, oversee, and implement

contracts; supervise field staff and contractors; collect and analyze data; design new treatments and make treatment decisions; make management recommendations; manage the databases; create GIS maps; conduct surveys and monitoring, and implement treatments.

- **SPU regular or temporary field staff.** Conduct field work, including surveys, treatments, and data collection.
- **Contract field crews.** Implement habitat restoration projects or invasive species treatments.
- **Consultants.** Provide expertise not otherwise available in SPU, such as certified underwater divers with expertise in identifying all native and non-native aquatic plants and animals, certified herbicide applicators, and laboratories conducting specific water quality tests, used on an as-needed basis.
- **Basic supplies, equipment, miscellaneous.** Includes tools, radios, waders, sprayers, herbicides, geotextile fabric, etc.

9.0 Invasive Species Program Future Projections

After several years of intensive effort, we have good documentation on the extent of the terrestrial invasive plant situation within Seattle's major watersheds and have made significant progress in controlling many species. We anticipate the current level of effort will need to be continued until all high-risk areas are surveyed and current infestations are either eradicated (small patches) or brought down to levels where they can be more cost-effectively controlled (large patches).

As the management recommendations for preventing new infestations are implemented, risk of future invasion will be reduced. Increasing development around watershed boundaries and the uncertainty of the effects of climate change, however, mean we need to continue to do routine annual surveys as part of the Early Detection/Rapid Response protocol.

The Invasive Species Program long-term goals are to eradicate all small patches of invasive species that pose a high ecological risk, reduce current size of large infestations to small, manageable levels, restore key sensitive habitats such as wetlands and meadows to fully functioning native plant communities, prevent new infestations to the extent possible, and continue to implement Early Detection/Rapid Response protocols. Although this needs to be an on-going program to continue to deal with current and emerging threats, we anticipate that future Program costs will decrease as current infestations are reduced. Uncertainties concerning survey results and future invasions, however, make it impossible to accurately estimate costs that far into the future.

Appendix 1. Invasive Plant Species Survey and Treatment

INVASIVE PLANT SPECIES SURVEYS

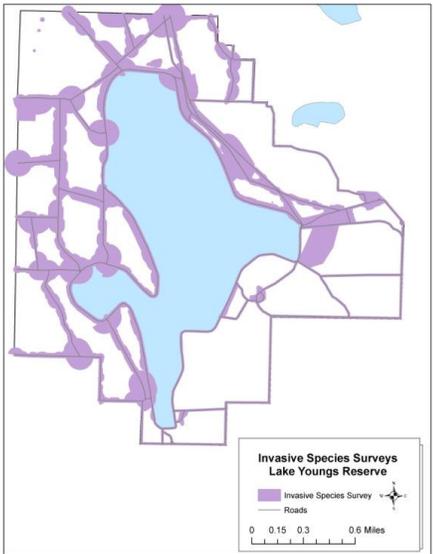
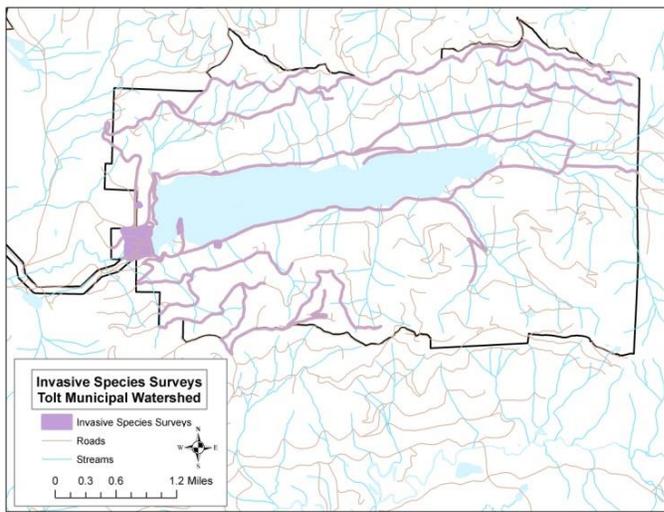
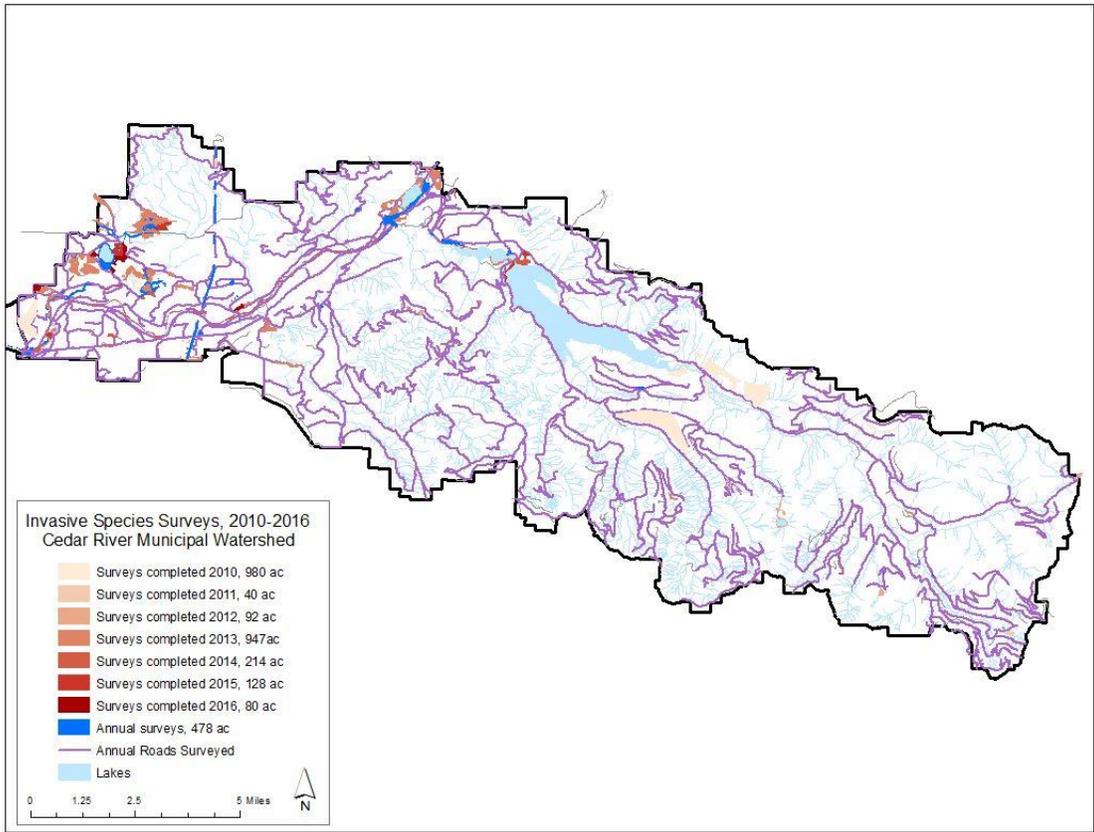
Extensive surveys for all invasive terrestrial plant species legally required for eradication or control, plus numerous species that pose significant ecological risk but are not currently legally required to control, have occurred in all three watersheds (shown in purple and shades of brown in the maps of surveys conducted in the Cedar, Tolt, and Lake Youngs on the following page).

In 2007 and 2008 expert botanists surveyed selected areas of the three municipal watersheds for 44 legally required invasive terrestrial plant species (Class A – eradication required, Class B and some C – control of reproduction and spread required), plus 11 recommended control species.

Starting in 2007, SPU biology staff conducted surveys for numerous invasive terrestrial plant species, both those legally required for control and those that pose significant risks but are not currently legally required for control, as part of the Early Detection/Rapid Response (EDRR) protocol. This includes along active roads, decommissioned roads, and in off-road high-risk habitats such as wetlands, meadows, and riparian zones.

In 2011 a rotating panel of surveys was developed for wetlands, meadows, riparian areas, decommissioned roads, and gravel pits. The survey schedule is based on degree of risk and frequency of disturbance, with survey intervals varying from one to five years. Implementation of the EDRR rotating panel schedule was initiated in 2013 and varies annually depending on staffing and funding.

From 2010 through 2016 staff conducted surveys in approximately 2,500 acres of off-road habitat, focusing primarily on areas of high risk for knotweed. In addition, about 475 acres of off-road habitat in the Cedar are surveyed annually, including all off-road knotweed patches, plus areas routinely surveyed for other projects (e.g., wetlands surveyed for amphibian egg masses). We conduct annual surveys of over 300 miles of active roads, with all drivable roads surveyed at minimum every 2 years. We also annually survey 13 gravel pits, eight of which are active.

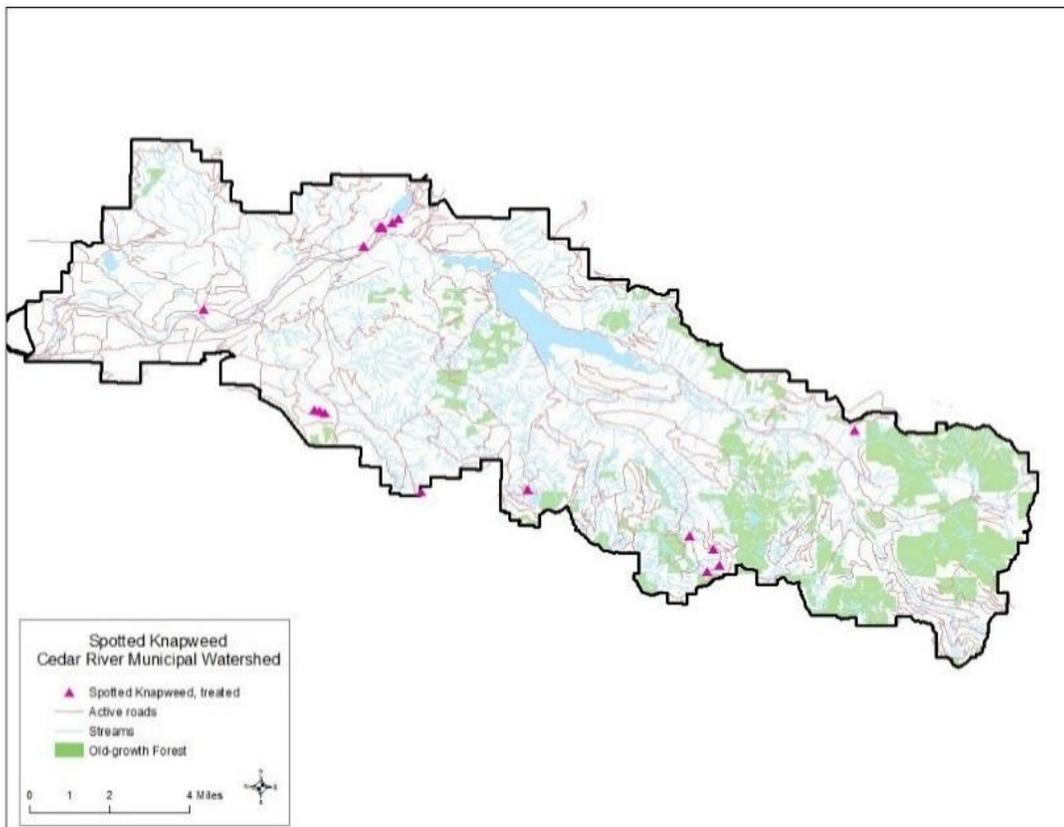


**INVASIVE SPECIES TREATMENT - HIGH MANAGEMENT PRIORITY, CONTROL
LEGALLY REQUIRED** (species listed alphabetically by scientific name)

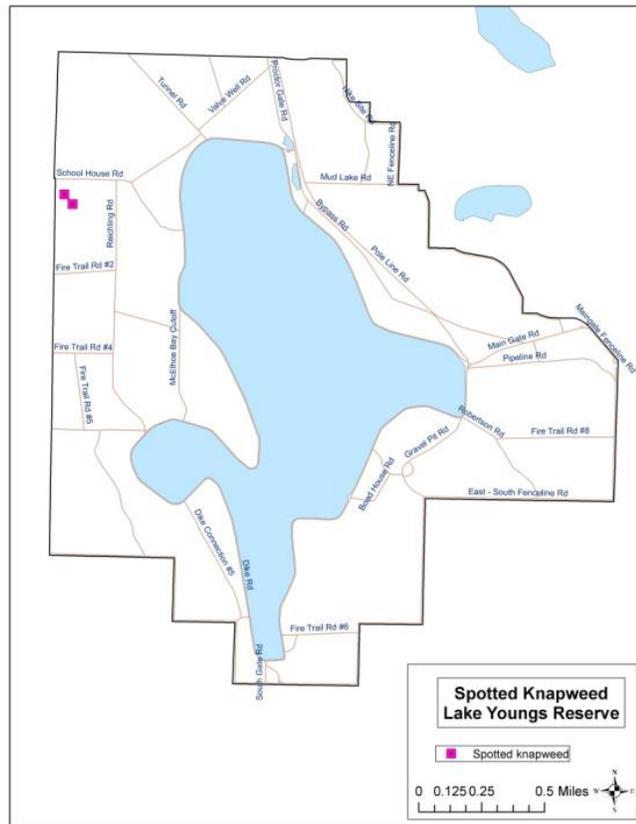
Spotted Knapweed (*Centaurea biebersteinii*)

Spotted knapweed is a very aggressive invasive species, outcompeting most native species in open sunny areas. Initial infestation is usually in disturbed areas, but it may invade adjacent undisturbed natural areas such as meadows. Up to 146,000 seeds per square meter have been reported in dense infestations, with seeds generally falling adjacent to the parent plant. Seeds can remain viable for over 8 years. It forms dense patches, and causes decreased water storage capacity and increased soil erosion. Control is legally required, and it is a top priority of the Washington Invasive Species Council.

- Extensive surveys have been conducted in all three watersheds. Seventeen locations in the Cedar and one at Lake Youngs have been found. None has been found in the Tolt.
- In the Cedar, control on the first patches started in 2005. Six of the patches were covered with a total of 318 ft² of geotextile fabric. The remaining patches have been dug and all patches have been monitored annually from the date of first discovery (ranging from 2005 to 2016). Seven of the patches were small populations or single plants that have had no growth since 2010.
- All patches in the Cedar will be monitored and controlled annually until they are eradicated. All sites will be monitored annually for at least 8 years after the last plant is documented, to ensure the entire seedbank is depleted.

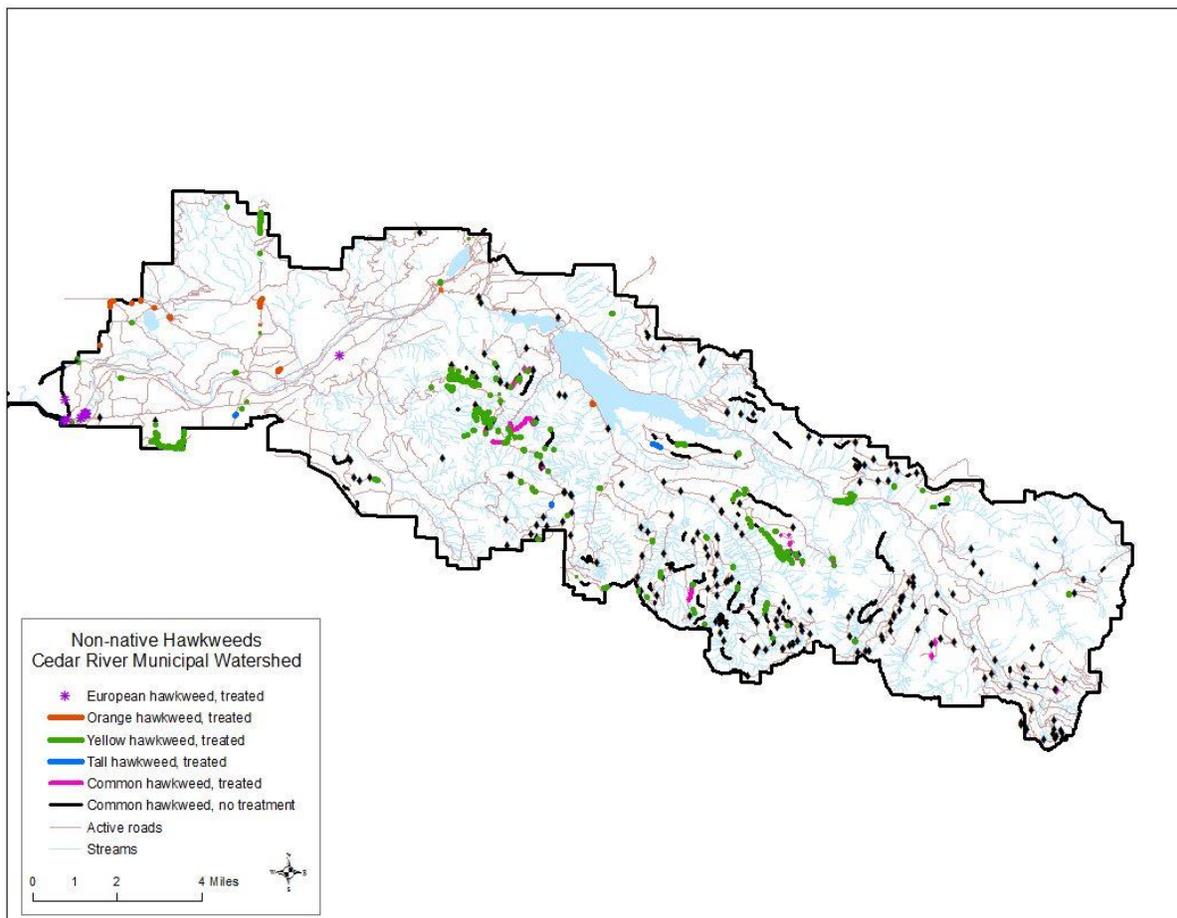


- A single patch on a heavily used hard-packed gravel site near the fenceline was found at Lake Youngs. It consisted of about 2,700 plants scattered over 8,900 ft². Because of the difficulty of treating this site, we used a targeted hand-spray of the herbicide aminopyralid, a chemical with an extremely low toxicity to animals and birds. Treatment started in 2011. In 2012 only 27 rosettes and no bolting plants were found and treated. In 2016 a total of 4 plants were found and treated. Treatment will continue annually until the patch is eradicated, and the site will be monitored annually for any recurrence.



Non-native Hawkweeds (*Hieracium sp.*)

Invasive hawkweeds are found primarily in sunny areas, mainly along roads and in disturbed areas. They spread very rapidly by seeds and quickly out-compete native plants, forming dense homogeneous mats that can have as many as 3,200 plants per square yard. Seeds remain viable for 2 to 3 years. They pose an ecological threat of invading and degrading meadows and other open habitats, and are a top priority of the Washington Invasive Species Council. Extensive surveys have been completed. We conduct ongoing annual surveys of all known sites and areas at high risk for new infestations. Surveys generally occur during flowering, with timing variable depending on elevation. Five invasive hawkweed species were found in the Cedar (see map), two in the Tolt, and one at Lake Youngs. These include European, orange, yellow, tall, and common hawkweed. See the following pages for control information by species.

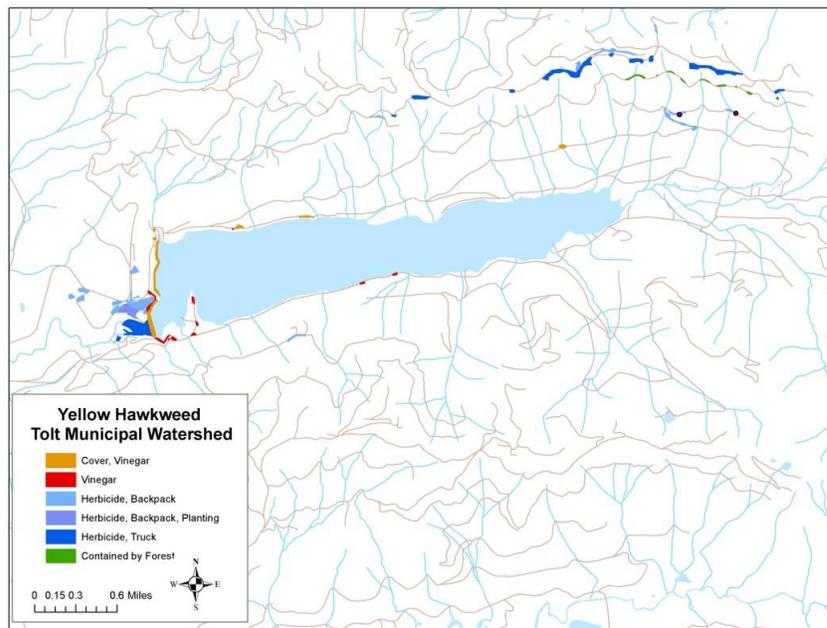


European hawkweed (*Hieracium sabautum*) – Control is legally required.

- A total of seven patches have been found in the Cedar, none in the Tolt or Lake Youngs. All Cedar patches are either within the Landsburg complex or near the far western border of the watershed. The largest patch was found in September 2009, where a total of 520 plants scattered over a 3,400 ft² area were dug in 2009 and 2010. All European hawkweed patches have been covered with geotextile fabric, as digging proved ineffective. All patches are monitored and maintained multiple times per year.

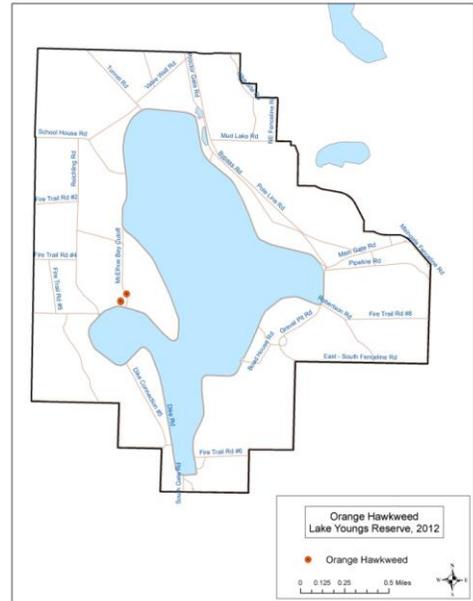
Yellow (meadow) hawkweed (*Hieracium caespitosum*) – Control is legally required.

- Extensive locations throughout Cedar and Tolt, mainly in upper elevations. None found at Lake Youngs.
- Control of yellow hawkweed in the Cedar started in 2005. Currently approximately 15 infested acres are monitored multiple times per year and treated as needed.
 - Over 3 acres of fabric has been installed on dense patches and is maintained multiple times per year.
 - Scattered, isolated individuals are treated with ordinary 5% table vinegar several times a year. This treatment appears efficacious and cost-effective if conducted during warm dry weather and is now the predominant treatment used on scattered individuals.
 - Several decommissioned roads have been planted densely with conifer trees to provide long-term shade me to suppress or eliminate the hawkweed. Much of the infested area on these decommissioned roads was seeded to a grass mixture that provides competition while the trees and shrubs are growing. Five years post-planting, the hawkweed on these decommissioned roads was much reduced.
- Control in the Tolt was initiated in 1999 and was incorporated into the Invasive Species Program in 2010.
 - Digging was attempted from 1999 to 2009 and proved ineffective.
 - Infestations outside hydrographic boundary or greater than 250 feet from the reservoir are spread over approximately 65 acres. They are treated annually with the herbicide aminopyralid, and after 6 years of consecutive treatment have been reduced to small scattered patches and individuals.
 - Fabric was installed on approximately 6 acres of dense patches near the reservoir. It was monitored and maintained multiple times per year for 5 years, then most of the fabric was removed. This treatment eliminated all dense patches and remaining scattered isolated individuals are currently treated with 5% vinegar several times a year.
 - About 2.8 acres of infested area on decommissioned roads is being contained and suppressed by native trees and shrubs now growing on the old roadbeds.



Orange hawkweed (*Hieracium aurantiacum*) – Control legally required.

- 19 locations in Cedar, primarily in lower elevations, 2 adjacent locations at Lake Youngs, none in the Tolt.
- Control in Cedar started in 2005. Eight of the patches appear eradicated and all others are reduced to scattered individuals.
 - Over 10,000 ft² of fabric was installed on dense patches and is maintained multiple times per year.
 - About 10,000 ft² of isolated individuals are treated with ordinary 5% vinegar several times a year.
 - A total of 27,500 ft² is controlled by routine mowing of lawns at the Cedar Falls and Landsburg complexes to prevent seeding.
- The Lake Youngs patch spread over approximately 5,000 ft². Control started in 2011 and included a combination of covering dense patches (768 ft²) and vinegar on isolated individuals. The fabric was subsequently removed and only a few scattered individuals remain. The site is monitored multiple times per year and treated with vinegar as needed.



Tall hawkweed (*Hieracium piloselloides*) - Control legally required.

- Three sites in the Cedar, none in the Tolt or Lake Youngs
- Control of two Cedar patches began in 2009, with the third found and initially treated in 2013.
 - Two patches are covered with fabric that is monitored and maintained multiple times per year
 - The third site plus scattered individuals at the first two sites are treated multiple times per year with table vinegar.

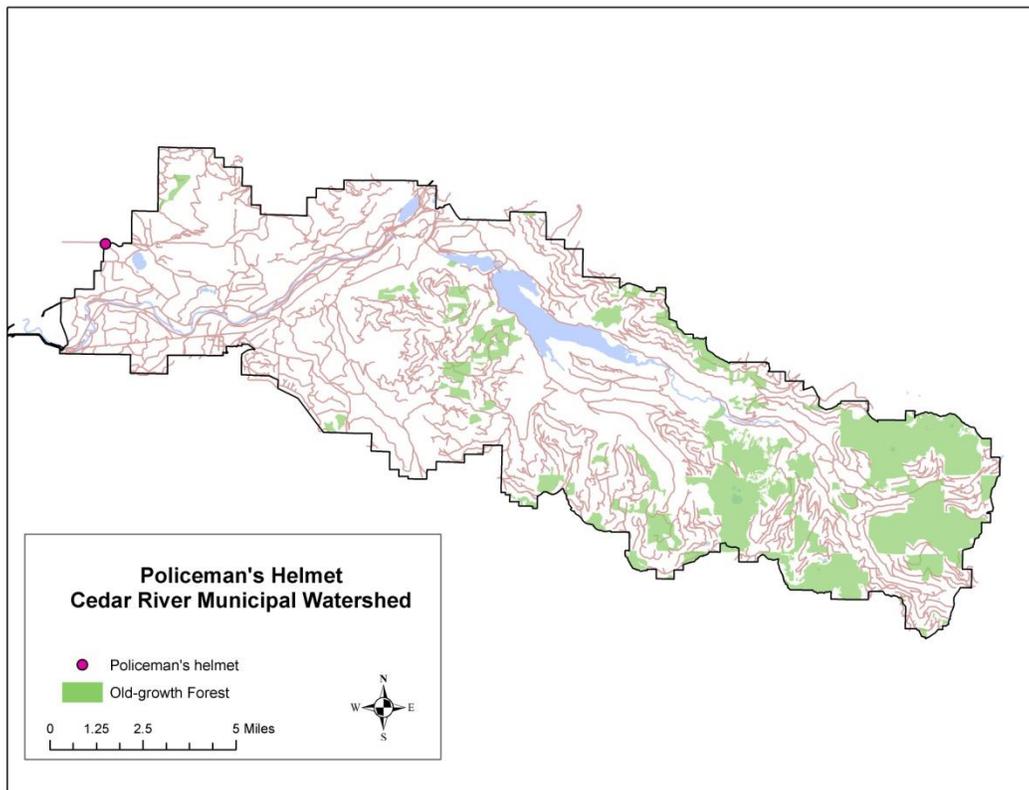
Common hawkweed (*Hieracium lachenalii*) – Control legally required where feasible and a local threat is posed

- Abundant throughout higher elevations in Cedar; occasionally seen in Tolt, none found at Lake Youngs.
 - Over 18,000 ft² fabric was installed and maintained multiple times per year for 3 to 4 years on several dense high-risk patches in the Cedar. High risk was defined as patches near sensitive habitats such as meadows or exposed landings where wind would widely disperse the seeds. Most fabric was then removed and sites either planted to native trees, seeded with grasses, or both.
- In the Tolt common hawkweed is treated if it occurs in conjunction with yellow hawkweed or if small isolated patches are seen (using the same treatment method as for the adjacent yellow hawkweed).

Policeman's helmet (*Impatiens glandulifera*)

Policeman's helmet is highly invasive in riparian areas and other moist natural areas. It can grow to ten feet tall and is partially shade tolerant. Consequently, it poses a large threat to the understory in our native moist forest. Each plant can produce up to 800 seeds and eject the seeds over 20 feet, with seeds remaining viable for over 18 months. Control is legally required.

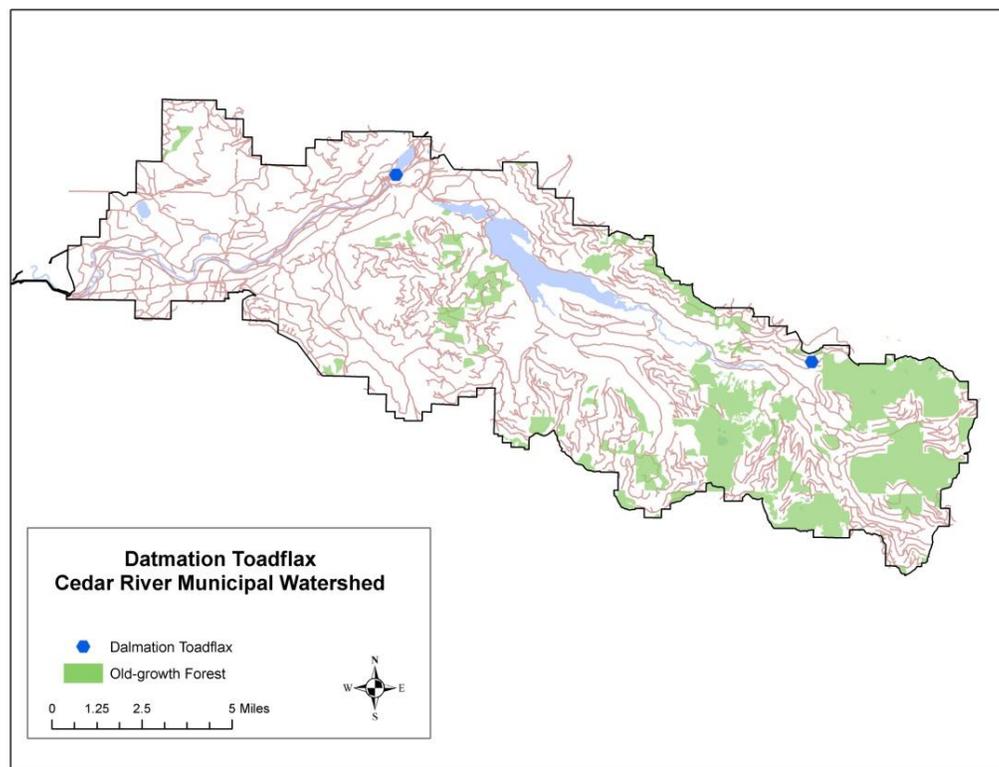
- Extensive surveys have been completed in all three watersheds and only one location in the Cedar was found, with none in the Tolt or Lake Youngs.
- Five plants were dug in 2009 and 1 plant in 2010. No plants have been seen since 2010.
- The area will continue to be monitored annually and all plants found will be dug prior to seeding.



Dalmatian Toadflax (*Linaria dalmatica*)

Dalmatian toadflax is a strong competitor with native plants in dry, open natural areas. It spreads by deep creeping root systems, forming dense mats, as well as producing up to 500,000 seeds per plant. Seeds may live up to ten years in the soil. Control is legally required, and it is a top priority of the Washington Invasive Species Council.

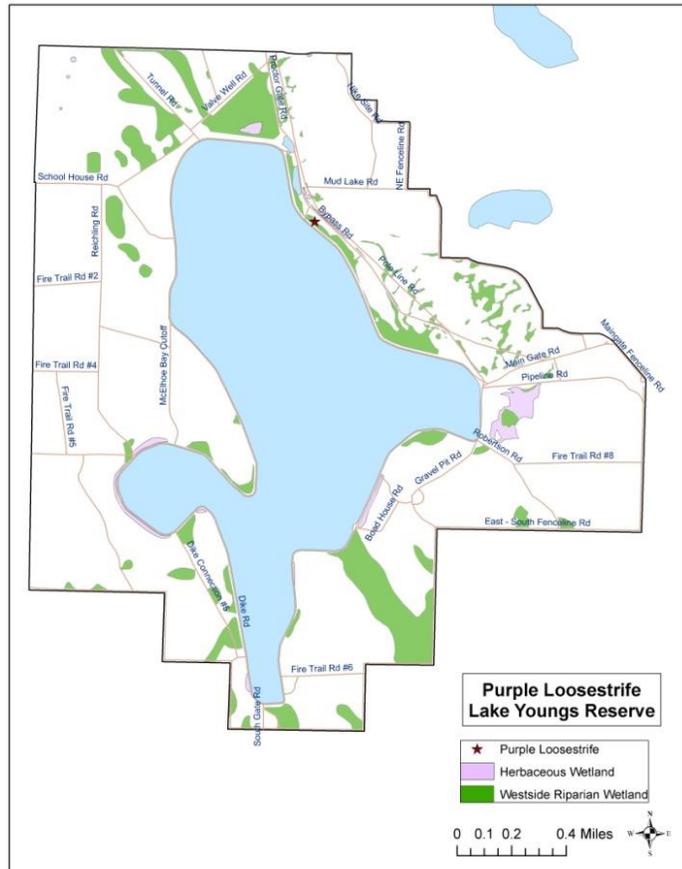
- Extensive surveys have been completed in all three watersheds and only two locations in the Cedar were found, none in the Tolt or at Lake Youngs. One site was in the Cedar Falls Compound and the other near the end of a road decommissioned in 1994 and likely introduced via contaminated straw.
- The two patches were covered with a total of 326 ft² of geotextile fabric in 2008. The fabric was maintained annually in 2009 and 2010, with little to no growth near the edges.
- The patch at Cedar Falls was uncovered in 2010 and no further growth was seen. The patch on the decommissioned road has not been checked since 2010 due to staff shortages, but remains covered.



Purple Loosestrife (*Lythrum salicaria*)

Purple loosestrife poses a major threat to wetland and riparian areas and can even invade drier sites. Each plant can produce 2.7 million seeds which spread easily by wind or water and over 400,000 seed per square meter of wetland have been documented. The seed life is currently unknown, but is likely at least five years. In addition, it has a taproot and fibrous rhizomes that form dense mats. Dense stands of purple loosestrife can easily choke out native plants, dominating entire wetlands and disrupting normal ecosystem function. Control is legally required, and it is a top priority of the Washington Invasive Species Council.

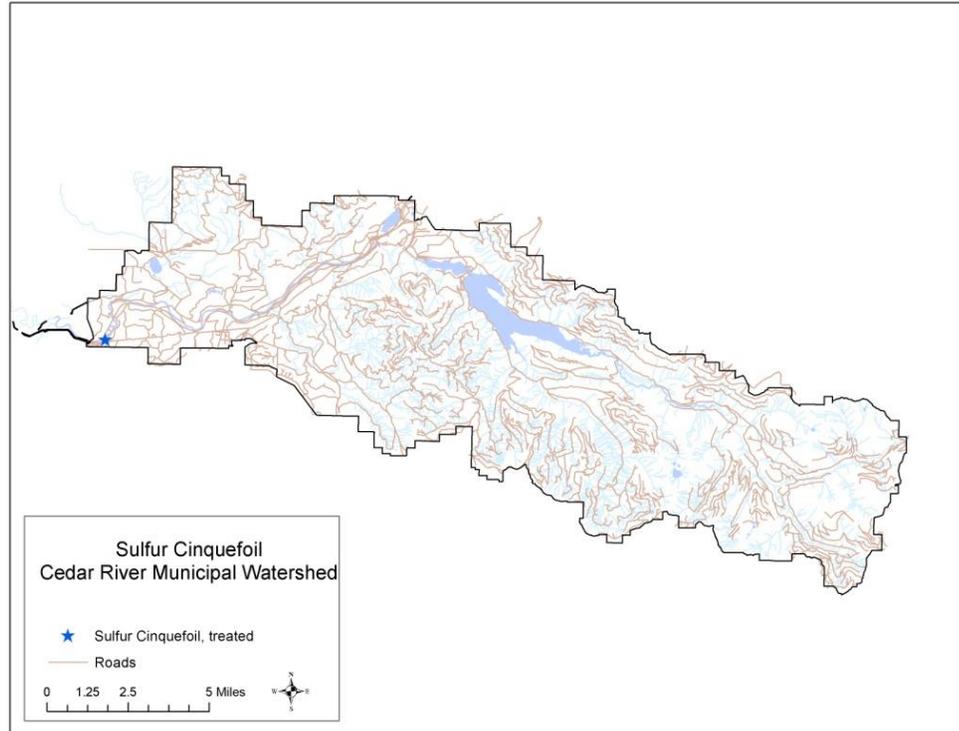
- Extensive surveys have been completed in all three watersheds. A single infestation was found, in a small wetland at Lake Youngs, spread over an area of about 4,000 ft².
- Control started in 2010. All plants were dug and removed from the site prior to their dispersing seed, including 417 large plants plus many more small seedlings. Over 22 large garbage bags of plant material were initially removed from the site in 2010. By 2016 less than half a garbage bag of plant material was removed.
- All plants will continue to be dug and removed annually prior to setting seed until the patch is eradicated, after which the site will be monitored annually.



Sulfur Cinquefoil (*Potentilla recta*)

Sulfur cinquefoil is highly invasive perennial plant, forming dense mats of vegetation. It has a deep taproot surrounded by shallow spreading side roots. Seeds remain viable in the soil for at least four years, and the plant can also sprout from root fragments.

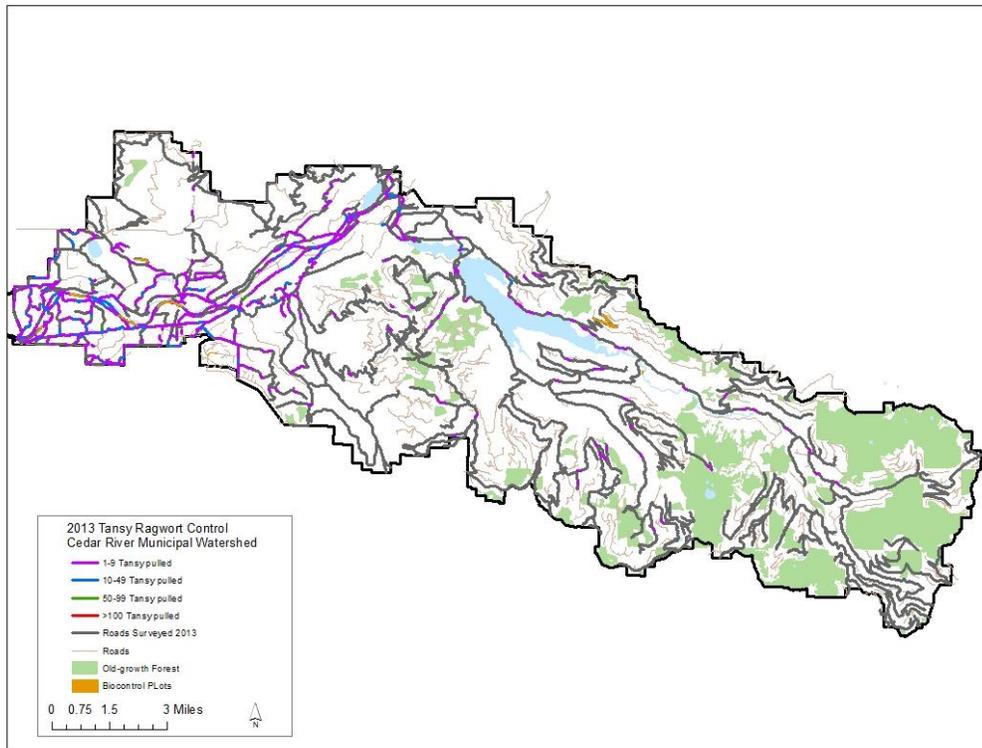
- Extensive surveys have been completed in all three watersheds. Only a single infestation was initially found in the Cedar; none in the Tolt or Lake Youngs.
- The first patch, adjacent to Landsburg Dam, was treated in 2012 by covering with about 400 ft² of fabric. It is monitored and maintained annually. In 2016 there were still occasional plants near the fabric edges.
- In 2013 another patch was found just across the Cedar River from the first. It was covered with about 100 ft² of fabric and is monitored and maintained annually.



Tansy Ragwort (*Senecio jacobaea*)

Tansy ragwort is commonly found in sunny, frequently disturbed areas. It is most often a biennial, producing a basal rosette in the first year and a flowering stalk (generally 2 to 4 feet tall) in the second year. Many plants (20 to 40% of a population) have been documented to be perennial. Each plant can produce up to 150,000 seeds which can remain viable for up to 15 years. It spreads rapidly by seed and root fragments, and can easily become large monocultures, outcompeting native plants. It is toxic to ungulates if eaten in sufficient quantities. Control is legally required, and it is a top priority of the Washington Invasive Species Council.

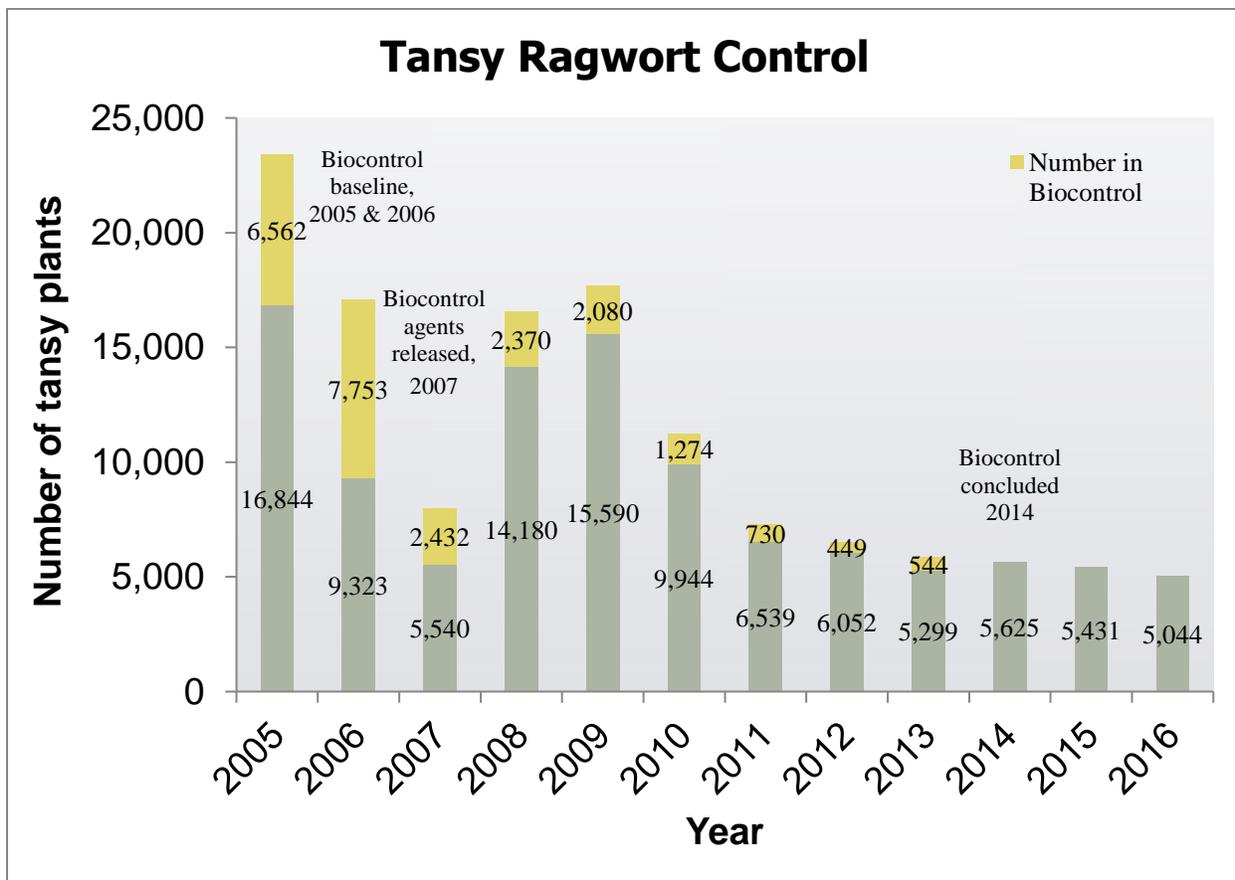
- Starting in 2002, we annually attempt to control all tansy ragwort plants in the Cedar by pulling the entire plant before or during flowering, prior to seed set. Flowers are clipped, bagged and disposed of; remaining plant parts are left to desiccate on site. Number pulled and location of plants are recorded for all plants in the Cedar.
- Distribution of the infestation has remained relatively constant since 2002, predominantly along well-traveled roads in the lower watershed. See map below from 2013 that illustrates the distribution of plants by number pulled, as well as the roads surveyed that year.



- Biocontrol experiments with tansy flea beetle were established at eight sites in the Cedar, four where bolting plants were counted and clipped and four isolated locations where plants were counted but allowed to flower and seed (to encourage more rapid population growth of the beetles). As seen in the following graph, total number of plants in biocontrol areas dropped dramatically from 2005 to 2014, when the experiment was

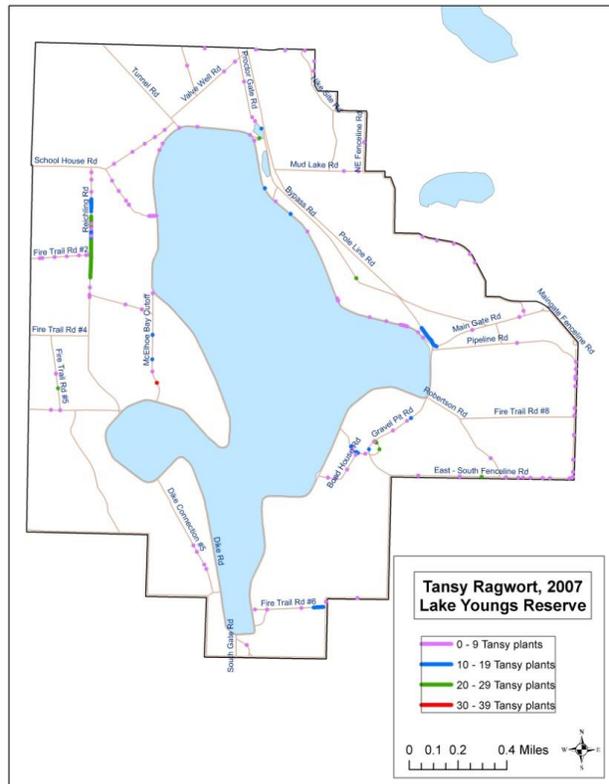
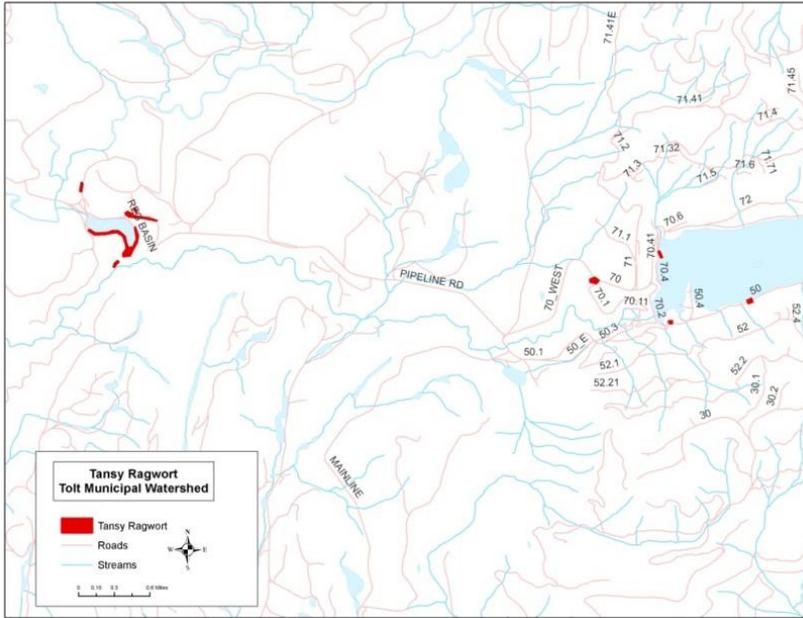
concluded because there were too few tansy ragwort plants left to sustain the beetle population.

- Total number of plants was highly variable from 2005 to 2009, likely due to amount of soil disturbance (see following graphs). Seeds are stimulated to sprout by ground disturbance. Since 2010 we have worked with SPU Operations crews to minimize the amount of ground disturbance during routine road maintenance projects.
- Tansy ragwort numbers dropped consistently from 2009 to 2013, indicating the control effort was successful in reducing the overall population and soil seed bank.
- Numbers were essentially unchanged from 2014 to 2016. The reason for this is unknown, as the control effort was comparable to previous years. It is possible that with staff turnover and training, some plants were missed and went to seed, refreshing the seed bank.



- There was a dense infestation adjacent to the Tolt regulating basin (see map on following page). These plants (initially >9,000 plants) are pulled annually by SPU Transmission staff or contractors. Starting in 2011 the Invasive Species Program assisted by annually controlling a large infestation of tansy ragwort in the main gravel pit and on SPU land in the upper watershed. These sites dropped to negligible numbers of plants by 2016.
- In 2007 a complete survey was conducted at Lake Youngs. Plants were scattered throughout the reserve, along most roads. Prior to 2011 plants were sporadically

controlled along main roads by Lake Youngs staff. In 2011 and 2012 the Invasive Species Program assisted in control of tansy at Lake Youngs in off-road areas (gravel pit, fields, mitigation restoration site). In 2013 Lake Youngs staff implemented a more comprehensive control effort along all roads, which has continued annually, resulting in a large reduction in plants. Data on number of plants controlled each year is not documented in either the Tolt or Lake Youngs.

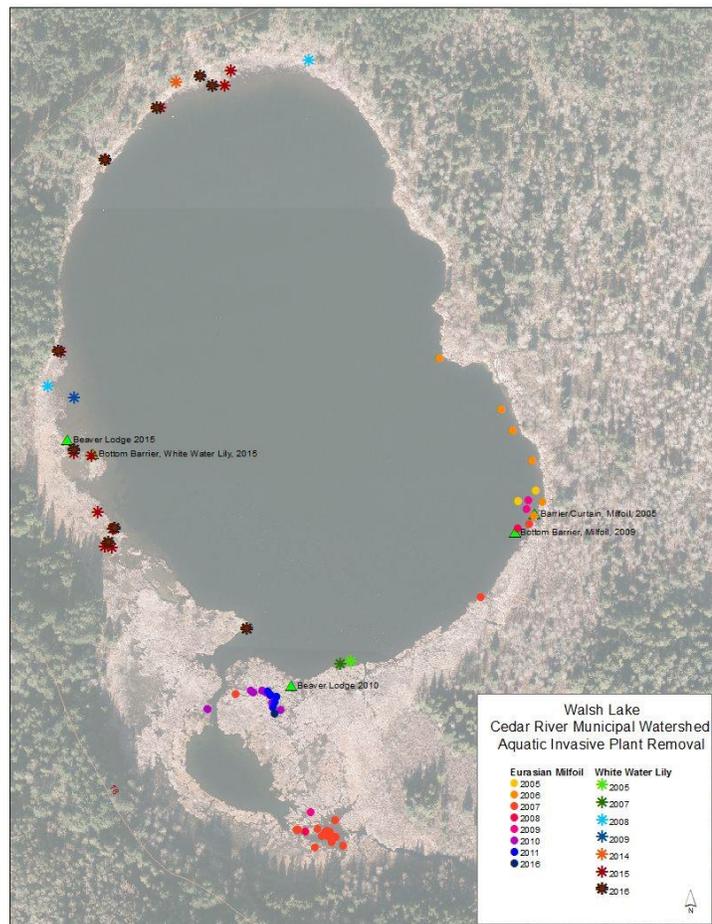


INVASIVE SPECIES TREATMENT - HIGH MANAGEMENT PRIORITY – VERY HIGH ECOLOGICAL THREAT, CONTROL RECOMMENDED (species listed alphabetically)

Eurasian Water-milfoil (*Myriophyllum spicatum*) and **White Water Lily** (*Nymphaea odorata*)

Eurasian milfoil is an extremely invasive aquatic plant that can completely clog native water bodies, forming huge stagnant masses that rob oxygen from the water and increase sedimentation rates. It reproduces very rapidly, primarily through plant fragments. Control is not legally required because it is widespread, but is highly recommended. It is a top priority of the Washington Invasive Species Council. White water lily can also form huge mats, shading out native aquatic plants. Because there are few white water lily plants in the Cedar, they are controlled along with the milfoil.

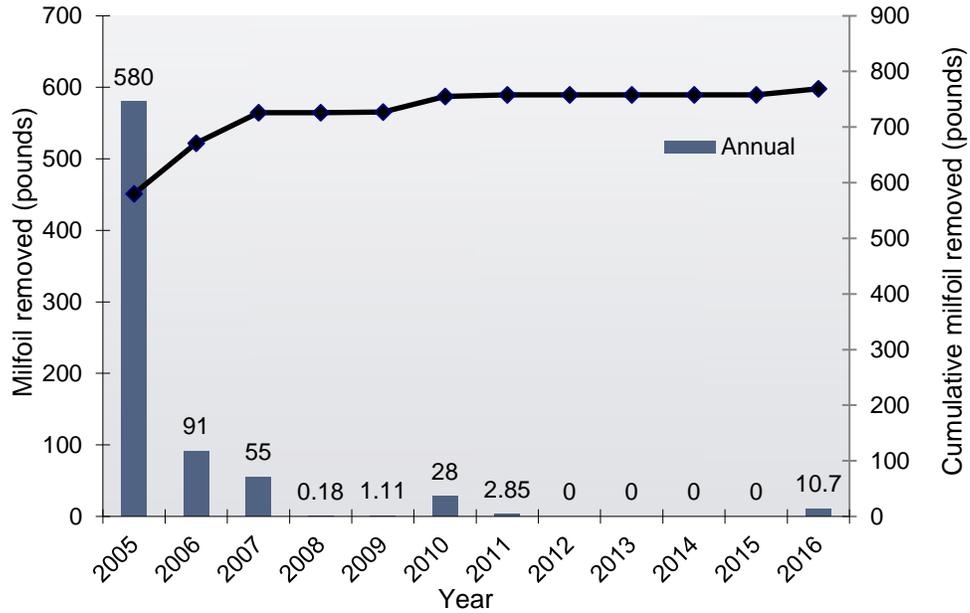
- Milfoil was first detected in Lake Youngs in 1992. An intensive and expensive eradication effort occurred from 1993-1996. No milfoil has been detected in surveys there from 1997 to the present.
- Milfoil was first detected in Walsh Lake, a small natural lake in the western portion of the Cedar, in 2001.
- Because the risk of re-infesting Lake Youngs was high, control (diver hand pulling) of both milfoil and white water lily began in 2005. At that time a containment curtain was installed around the initial milfoil infestation.
- Diver surveys and hand pulling has continued annually, multiple times per year.
- In 2008 the containment curtain was removed and in 2009 a bottom barrier over the initial infestation was installed.
- Total pounds of milfoil removed have greatly decreased over the years, but eradication is complicated by extensive beaver activity (see following graph).
- No milfoil was found in 2012 through 2015, but a patch was found and dug in 2016. To be declared eradicated, five



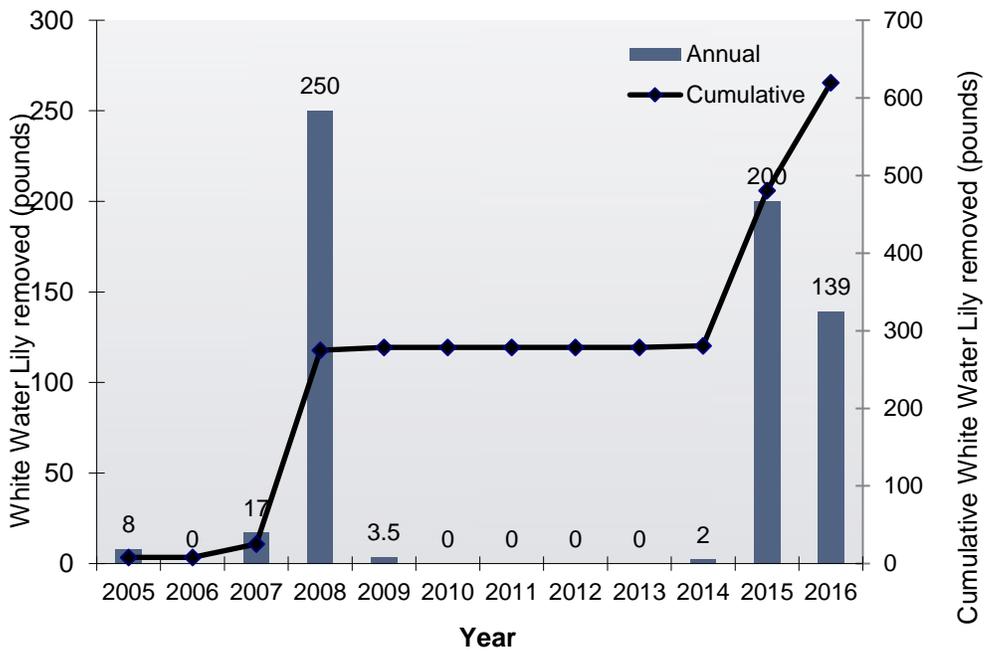
consecutive years with no detections must be completed.

- Total pounds of white water lily removed from Walsh Lake has been extremely variable, ranging from no detections 2010-2013 to 250 pounds in 2008, and 200 pounds in 2015 (see graph on following page).

Milfoil Removed from Walsh Lake



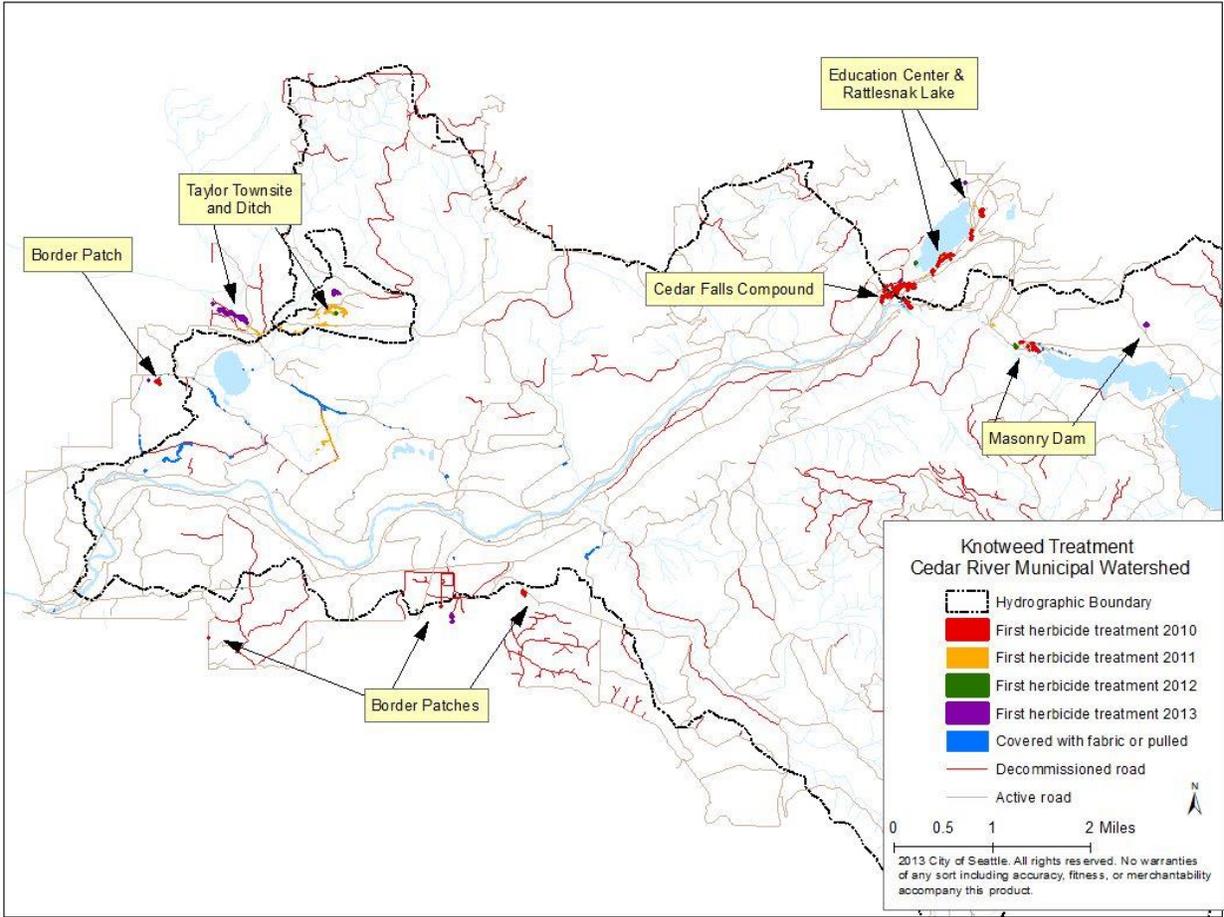
White Water Lily Removed from Walsh Lake



Bohemian Knotweed (*Polygonum x bohemicum*)

Because it is so widespread, knotweed control is not yet legally required throughout King County, but control along the Cedar River has been legally required since 2013. Knotweed poses one of the greatest ecological threats of any non-native invasive species in the watersheds, and is a top priority of the Washington Invasive Species Council. Knotweed forms huge dense monocultures, threatening riparian and wetland habitat, and potentially aquatic habitat. It spreads easily by water, primarily by dispersal of tiny root or stem fragments that form new colonies. The species present in the Cedar is Bohemian knotweed (*Polygonum x bohemicum*), a hybrid between Japanese and giant knotweed. This hybrid is more difficult to control than either of the parent species and may produce a higher percentage of viable seeds, although no evidence of reproduction through seeding has been found in the Cedar.

- Extensive surveys throughout the three watersheds are complete, with large numbers of patches mapped in the Cedar and a single plant found in a gravel pit in Lake Youngs. None has been found in the Tolt.
- Total area in the Cedar is estimated to be about 22.5 acres. See map on following page for locations.
- From 2004 through 2013 a total of 4.5 acres of the smaller patches was treated by covering with fabric. The fabric was maintained every two to six weeks during the growing season (less frequent maintenance is required the longer it is covered). When fabric was removed after eight years, very small patches appeared dead. However, larger patches quickly re-grew, indicating this treatment may be insufficient to kill large root masses. Fabric along active roads will be left down indefinitely. Fabric distant from the roads was removed and these patches added to the imazapyr treatment described below.
- Three consecutive city ordinances have authorized treating knotweed with the herbicide imazapyr (2010-2012, 2013-2015, and 2016-2018). A total of 18 acres has been treated with imazapyr, with leaf biomass in these sites reduced over 16 times from pre-treatment levels in 2010 to 2016.
- In 2012 the single patch at the Lake Youngs gravel pit was treated with glyphosate. No new growth has been seen.

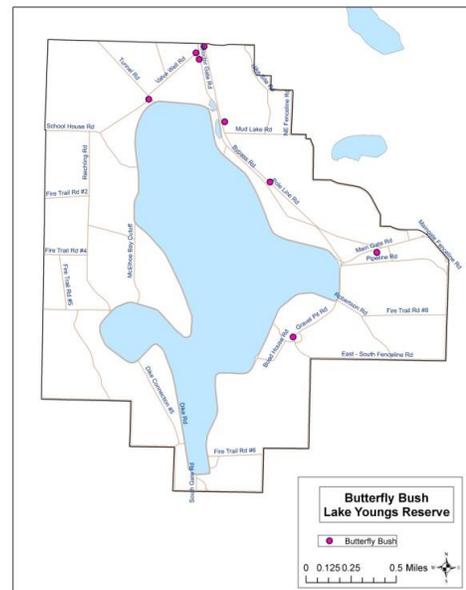
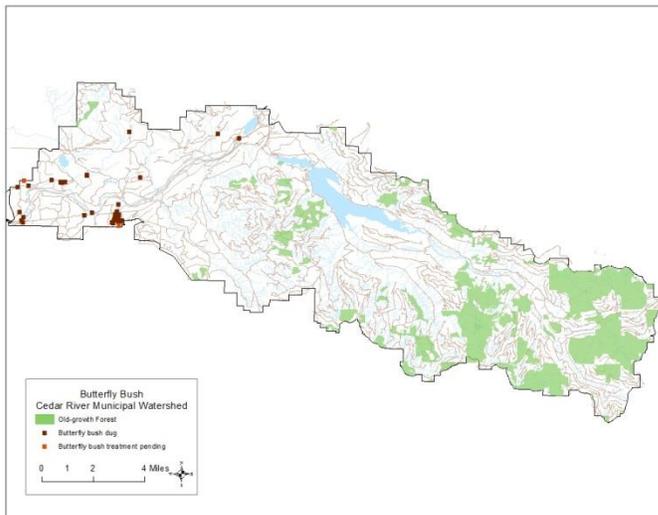


INVASIVE SPECIES TREATMENT - HIGH MANAGEMENT PRIORITY - HIGH ECOLOGICAL THREAT, LIMITED DISTRIBUTION, CONTROL RECOMMENDED
(species listed alphabetically)

Butterfly Bush (*Buddleia davidii*)

Butterfly Bush is increasingly being recognized as major invasive species in Washington, particularly in riparian areas. It has a wide tolerance for environmental conditions and can produce up to 3 million seeds per plant, with seeds remaining viable for up to five years. In recent years it has been documented reproducing in a wide variety of natural habitats, including gravel bars in rivers, riparian forests, and upland habitats. It can re-sprout from rootstock and cut stems may grow into new plants. Control is not legally required because it is widespread, but is highly recommended. It is a top priority of the Washington Invasive Species Council.

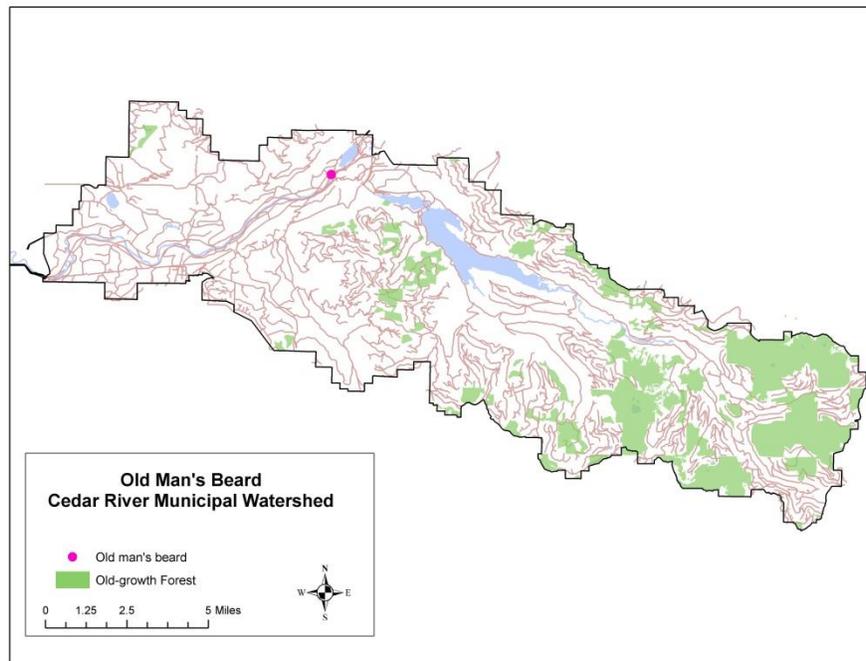
- Extensive surveys have been completed in all three watersheds. 35 locations in the Cedar, 11 at Lake Youngs, and a large infestation in a gravel pit near the Tolt regulating basin were found.
- All sites in the Cedar had relatively few plants. Control (grubbing out the entire plant, including roots) started in the Cedar in 2008 and continued annually, with some sites treated multiple times.
- No live plants have been found at any of the sites since 2014. All sites in the Cedar are now checked at least every 3 years.
- In 2009 over 400 plants were pulled out of the very large infestation in the Tolt gravel pit. Many more plants were grubbed out in subsequent years, and control continues annually.
- The Lake Youngs patches consisted of about 40 plants. Control started in 2012 and continues annually.



Old Man's Beard (*Clematis vitalba*)

Old man's beard is a woody vine that can reach 100 feet long. It will both cover the ground and completely blanket trees and shrubs, eventually killing them. Each plant can produce more than 100,000 seeds annually, plus vine fragments can root and form new plants. Control is not legally required because it is widespread, but is highly recommended.

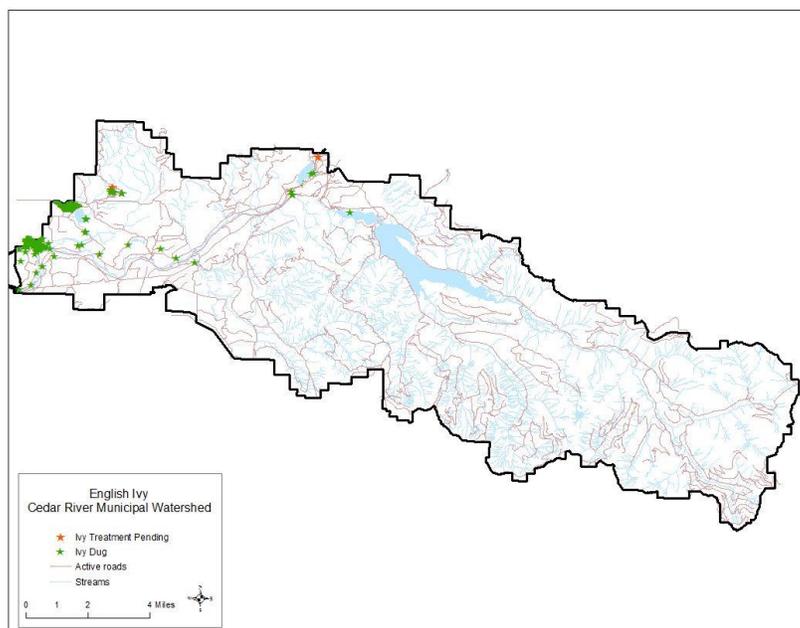
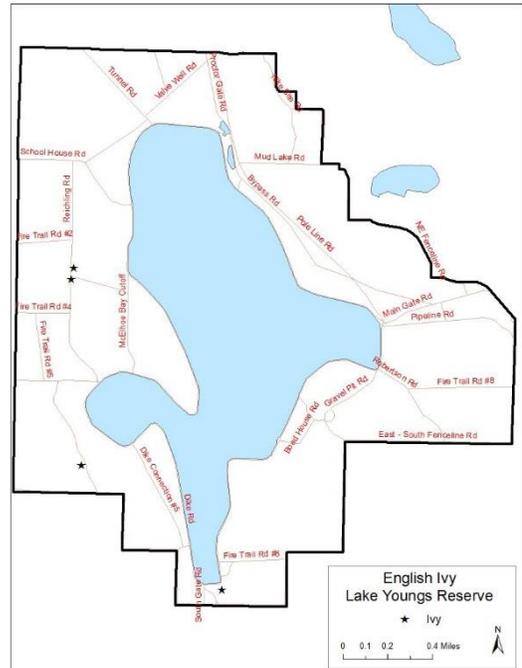
- Extensive surveys have been completed in all three watersheds. Only one plant near the Cedar Falls compound in the Cedar was found.
- Because of the limited amount present and the high risk posed by this species, in 2011 this plant was completely grubbed out.
- No growth has been seen since 2011. The area is monitored annually, and if any plants appear they will be treated as needed.



English Ivy (*Hedera helix*)

English Ivy is an extremely aggressive invasive species that is shade tolerant and thus poses a great risk to native forest ecosystems. It easily out-competes native forest understory, and when it climbs on trees will eventually girdle and kill the tree. Control is not legally required because it is widespread, but is highly recommended. Control requires grubbing out all portions of the plant, including all trailing roots. Eradication of an ivy patch usually requires several years of grubbing because it is very difficult to extract all the root material.

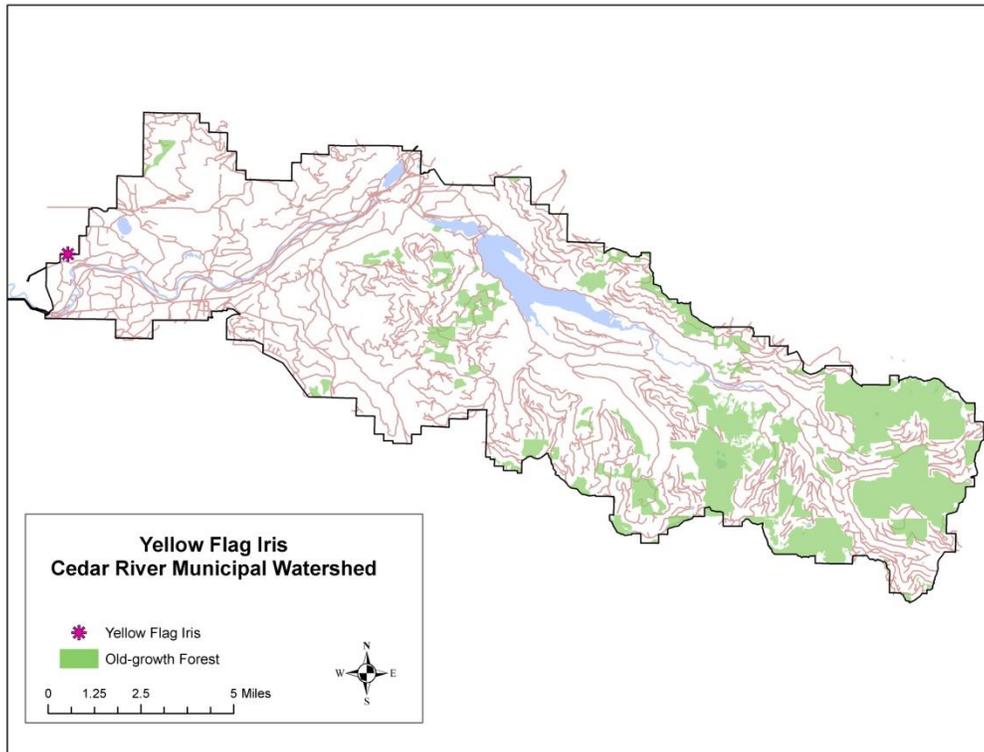
- Extensive surveys have been completed in all three watersheds. 76 sites in the Cedar encompassing over 110 acres and 4 small patches at Lake Youngs were documented.
- All sites at Lake Youngs have been grubbed. By 2016 only 1 site had any live plants. The other 3 sites had no growth since 2011.
- Of the 110 acres in the Cedar, two forest patches with sparse ivy scattered throughout them covered 107 acres. The remaining patches are small and isolated, totaling about 3 acres.
- Treatment of the first sites in the Cedar started in 2008. By 2016, all but 3 of the sites had been grubbed, most multiple times over multiple years. 12 sites had no re-growth since 2014.
- All treated sites are monitored and re-treated as needed and as funding allows.
- The 3 remaining untreated sites in the Cedar will be treated when funding and staffing allow.



Yellow Flag Iris (*Iris pseudacorus*)

Yellow flag iris is an aggressive invader in riparian areas and shallow open water. It spreads quickly by rhizomes, plant fragments, and seeds and forms dense stands of hundreds of connected plants. It traps large amounts of sediment, raising elevation, creating new streambanks, and can reduce stream width by up to ten inches per year. Once established, it is very difficult to control. Control is not legally required because it is widespread, but control is highly recommended.

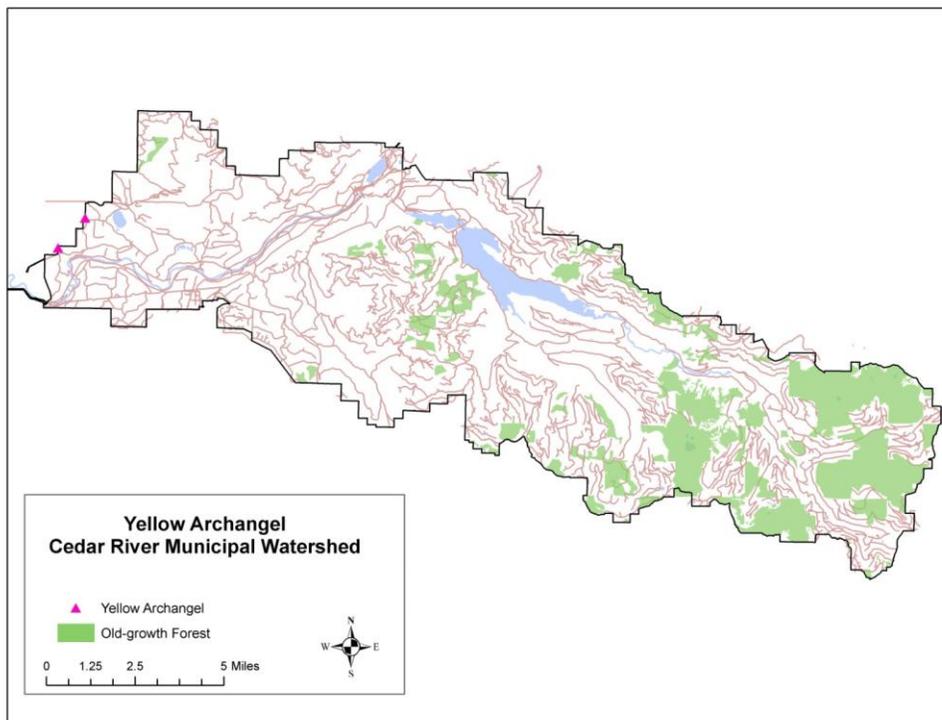
- Extensive surveys have been completed in all three watersheds. Only a single plant on the western fenceline in the Cedar was found in 2007 and was dug.
- The area is monitored periodically and no further plants have been found.



Yellow Archangel (*Lamium galeobdolon*)

Yellow archangel is a creeping groundcover that can grow in full sun or full shade. It forms large dense mats, crowding out native plants. Because it is shade tolerant, it poses a significant threat to native forest understory. Control is not legally required because it is widespread, but is highly recommended.

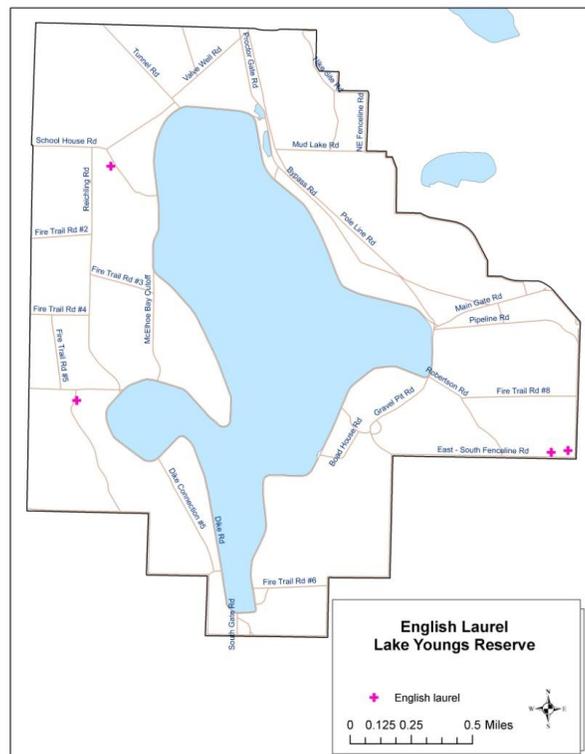
- Extensive surveys have been completed in all three watersheds. Only two infestations along the western border of the Cedar were found. Because of the limited amount present and the high risk posed by this species, both patches were treated.
- The first patch was found within the forest near the western border. It was covered in 2009 with a total of 630 ft² of geotextile fabric. Little to no growth was seen in through 2016. This small forest patch is monitored and treated annually until it is eradicated.
- The second patch was discovered in 2010 and was covered with a total of 3,350 ft² of geotextile fabric in 2010 and 2011. This patch is along the fenceline, and the understory of the forest on the neighboring property was completely blanketed with the plant. The goal for this site is to stop the plant from reaching the forest on the opposite side of the road because it will be impossible to control along the fenceline as long as the infestation is present on the neighboring property. The fabric along the fence is maintained as funding and staffing allow. The nearby forest is monitored annually and any small infestations are treated immediately by covering or digging.
- In 2013 a patch was found in the gravel pit at Lake Youngs and was initially treated with aminopyralid. It is monitored and treated annually, as needed.



English Laurel (*Prunus laurocerasus*)

English laurel is a large evergreen shrub/small tree that can form dense thickets. It grows well in both sun and shade, and thus is a threat to native forest understory. It is now found in natural areas and is the second most common invasive tree species in Washington. It is fast-growing and can out-compete most native understory trees and shrubs. Control is not legally required because it is widespread, but control is highly recommended in natural areas.

- Extensive surveys have been completed in all three watersheds. Four trees were found in the understory of a conifer forest at Lake Youngs, with none in the Cedar or Tolt.
- All trees were treated with the cut-stump method using glyphosate painted on the stump. By 2015, only 1 tree was still alive and needed re-treatment. Sites are monitored periodically as staffing and funding allow.

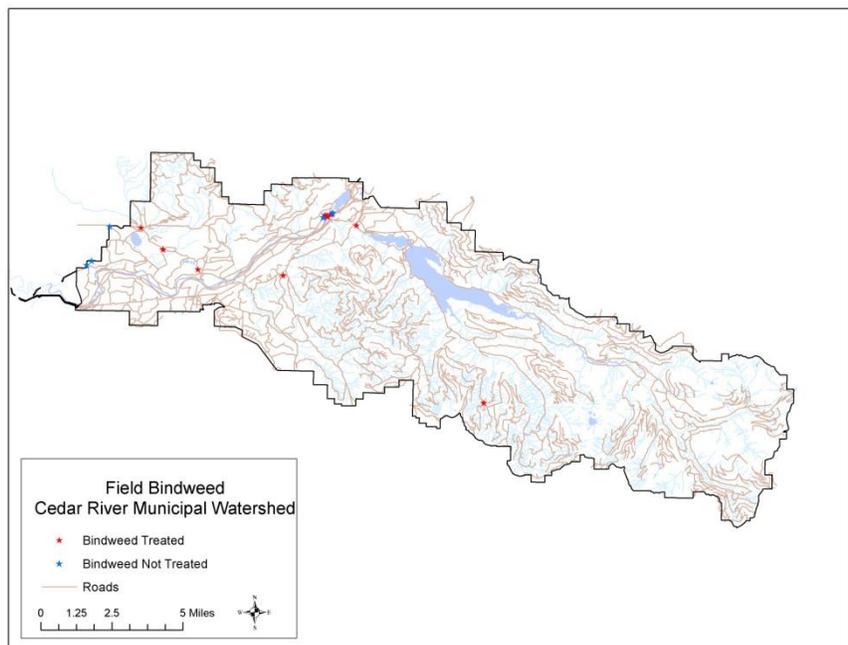


INVASIVES SPECIES TREATMENT - MEDIUM MANAGEMENT PRIORITY – HIGH ECOLOGICAL THREAT, WIDESPREAD, CONTROL RECOMMENDED (species listed alphabetically)

Field Bindweed (*Convolvulus arvensis*)

Field bindweed is a deep rooted perennial vine that both grows along the ground and climbs aggressively. It flourishes in a wide variety of conditions, from full sun to full shade. It reproduces from roots, rhizomes, stem fragments, and seeds that remain viable for over 20 years. Roots spread widely both vertically and horizontally, forming dense mats. Once established, it is nearly impossible to eradicate. It is very widespread, so is not legally required to control, although control, especially of new infestations, is highly recommended.

- Surveys were completed in 2007 and 2008 as part of the overall invasive species surveys conducted by expert botanists. Some large and a few limited infestations were found in the Cedar, one infestation in the gravel pit near the Tolt regulating basin, and one at the gravel pit at Lake Youngs.

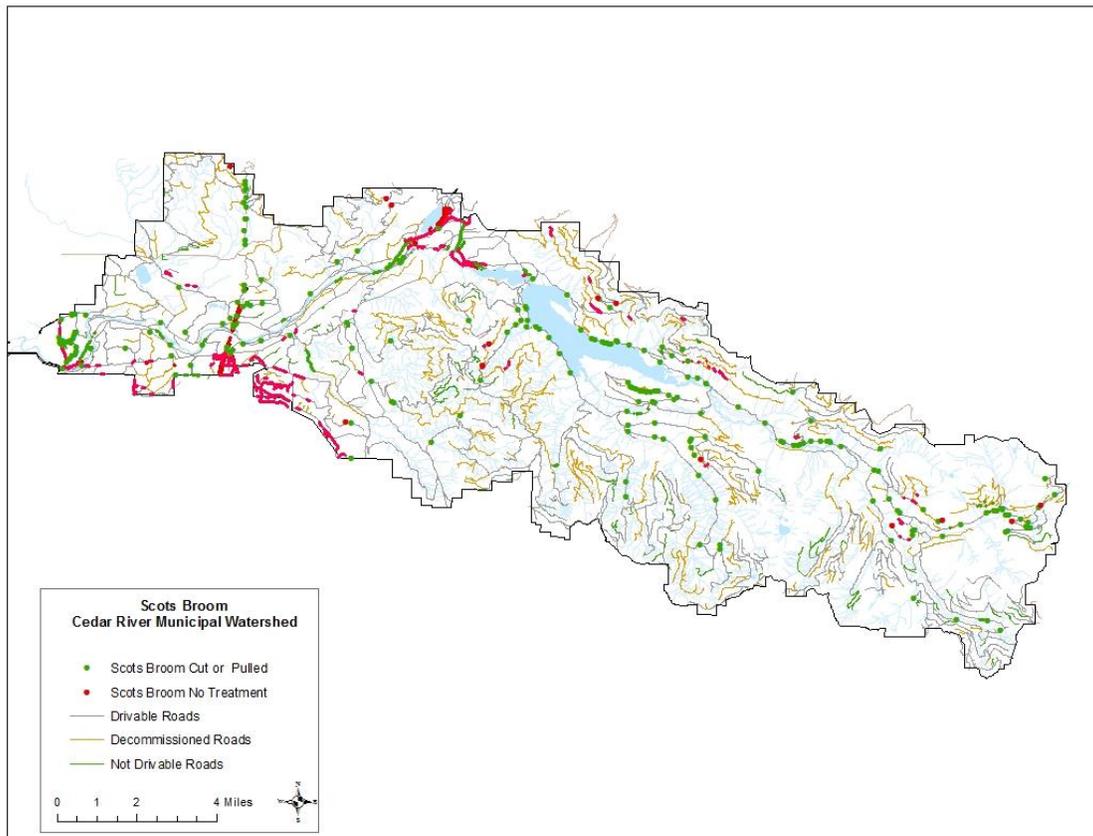


- The ten small patches in the Cedar have been dug or covered with geotextile fabric.
- The large patch in the Tolt regulating basin gravel pit was treated with aminopyralid, along with numerous other invasive species in the pit, to limit dispersal in the gravel when it is used on roads throughout the watershed.
- The patch in the gravel pit at Lake Youngs was successfully treated with aminopyralid.

Scot's Broom (*Cytisus scoparius*)

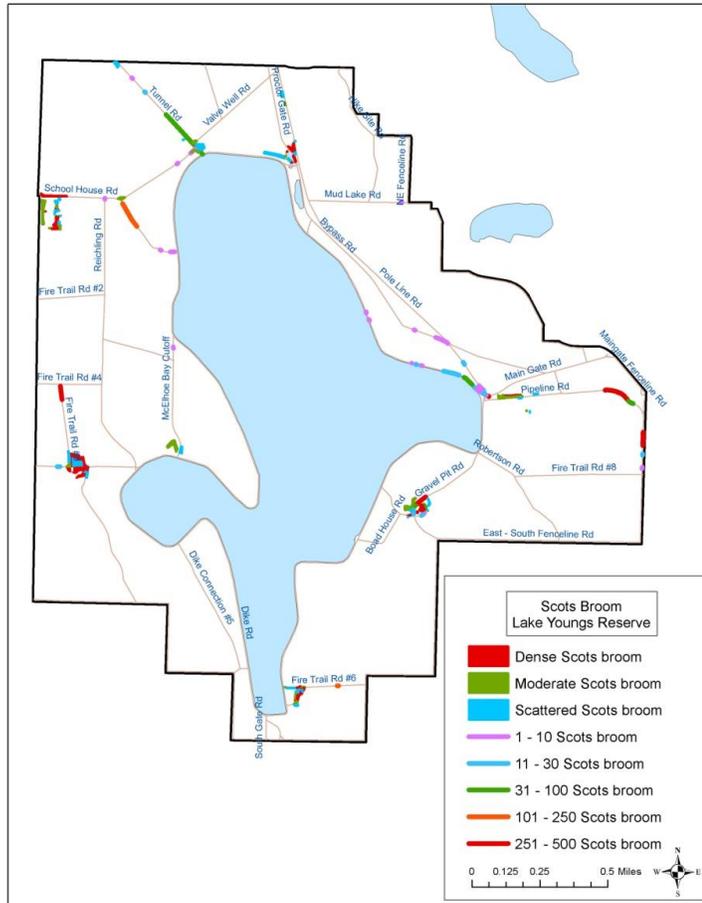
Scot's broom is an extremely common invasive species that can form large, impenetrable thickets in dry sunny areas. Each plant can produce over 10,000 seeds which remain viable for more than 60 years. Dense thickets of Scots broom displace native plants, prevent native tree regeneration, and are a potential fire hazard because of their flammability. In addition, the seeds are toxic if eaten. Scot's broom is legally required for control along I-90 east of North Bend, and recommended for control wherever feasible. It is a top priority of the Washington Invasive Species Council.

- We started surveys along roads in the Cedar in 2004 and update annually as new plants are found during general surveys.
- Limited surveys have been conducted in restoration sites and other off-road areas. The largest infestations are along the southern border, in rights of ways, and in developed areas around Cedar Falls and the Masonry Dam.



- Thousands of plants have been cut or pulled in the Cedar starting in 2005. Target areas include:
 - Small isolated plants to ensure new thickets are not established (most of the control seen in the upper elevations are this type, usually from seeds in contaminated gravel)

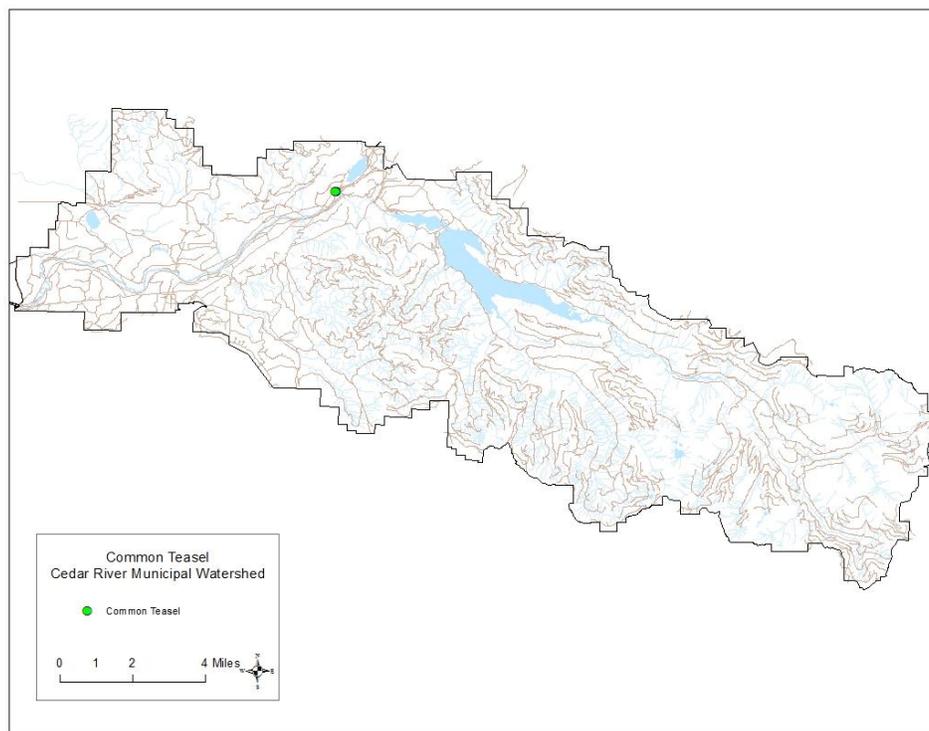
- Areas in and near major gravel pits and gravel storage areas, to help reduce spread of the seed through road and culvert projects
- Areas of infestation adjacent to or near off-road areas of recent disturbance, such as windthrow, to ensure these natural areas are not infested.
- Infested areas along roads slated for decommissioning are targeted for dense planting with native conifer trees, to help shade out the Scot's broom over time.
- Scot's broom is also removed as part of habitat restoration projects, including controlling invasion after the 45 Road Ecological Thinning Project and the expansion of the BPA ROW in 2003, as well as several experimental planting projects in the BPA ROW.
- In 2007 a survey along all the roads at Lake Youngs was completed and Scot's broom was mapped by density categories (see map).
- Starting in 2011, Scots broom in three fields and the gravel pit at Lake Youngs was controlled by digging. Infested areas were seeded heavily to grass to provide competition
- Surveys for Scots broom have not been completed at the Tolt, although there were dense infestations in the Regulating Basin gravel pit and near the Vista House.
- Starting in 2011, large Scots broom plants in the gravel pit and near the Vista House and on the slopes west of the Vista House were pulled. Control continues as staffing and funding allow.



Common Teasel (*Dipsacus fullonum*)

Common teasel thrives in open sunny habitats with moderately moist soil. It can create large dense monocultures, and is highly competitive in open grassy habitats. It has a deep taproot up to two feet long, and a single plant can produce up to 30,000 seeds. The plants generally die after they set seed, and reproduction is entirely by seed.

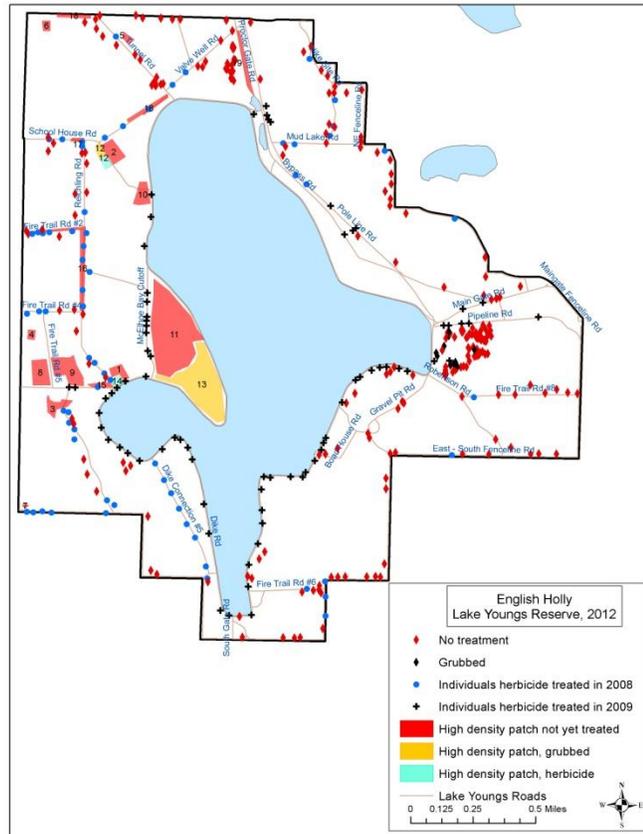
- Extensive surveys have been completed in all three watersheds. Only a single small patch was found in the Cedar. Control (pulling) started in 2011, when 33 plants were pulled. By 2015 only 2 plants were pulled, and none were seen in 2016.



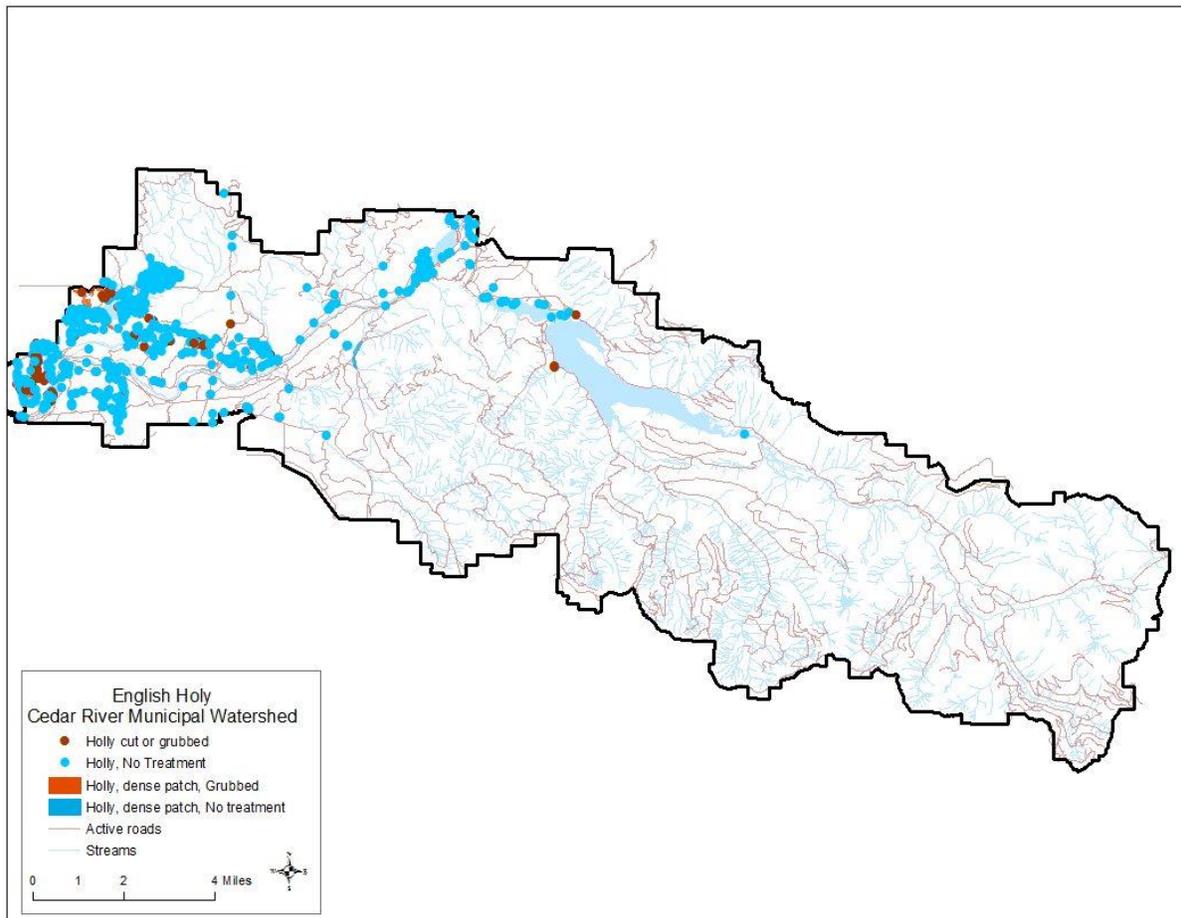
English Holly (*Ilex aquifolium*)

English holly is a shade tolerant small tree that is invading native forests at an alarming rate throughout western Washington. It is the most common invasive tree species in Washington and can form solid thickets, shading out all native understory shrubs and native tree regeneration. Control is not legally required because it is widespread, but is highly recommended in natural areas.

- By 2012 we completed surveys of all areas visible from roads at Lake Youngs. Many scattered individual holly trees were mapped, as well as 14 patches totaling 76 acres of extremely dense holly. In these dense patches holly basically formed a continuous cover in the forest understory (see map), shading out all native understory shrubs and preventing tree regeneration.
- In 2008 and 2009 we began experimental treatment of holly at Lake Youngs as part of a forest habitat restoration project. This consisted of a combination of grubbing out the entire plant, girdling larger trees, and cutting larger trees (a total of 21.1 acres shown in yellow on the map). In addition, because the forest is outside the hydrographic boundary, we also implemented an herbicide treatment (glyphosate) in which we frilled the bark and sprayed a 50% solution of the herbicide directly onto the frill. No herbicide reached the ground during this procedure. Many individuals near the roads (142 individual trees shown in blue or black) and two small dense patches (2.3 acres, shown in green) were treated in this manner.
- In 2011 we monitored the results of the Lake Youngs treatments, documenting amount of mortality. A subsample of 82 trees that had been treated with herbicide in 2008 or 2009 was monitored. Of these, 19 were dead (23%), 11 appeared dead but had some root sprouting (13%), 31 showed damage, but were not dead (38%), 4 showed no damage (5%), and the remaining 17 were not found (21%). Holly is treated with the cut-stump method (cutting the tree and painting the herbicide on the xylem and phloem) using 100% glyphosate with a surfactant as staffing and funding allows. This technique is proving to be much more successful.



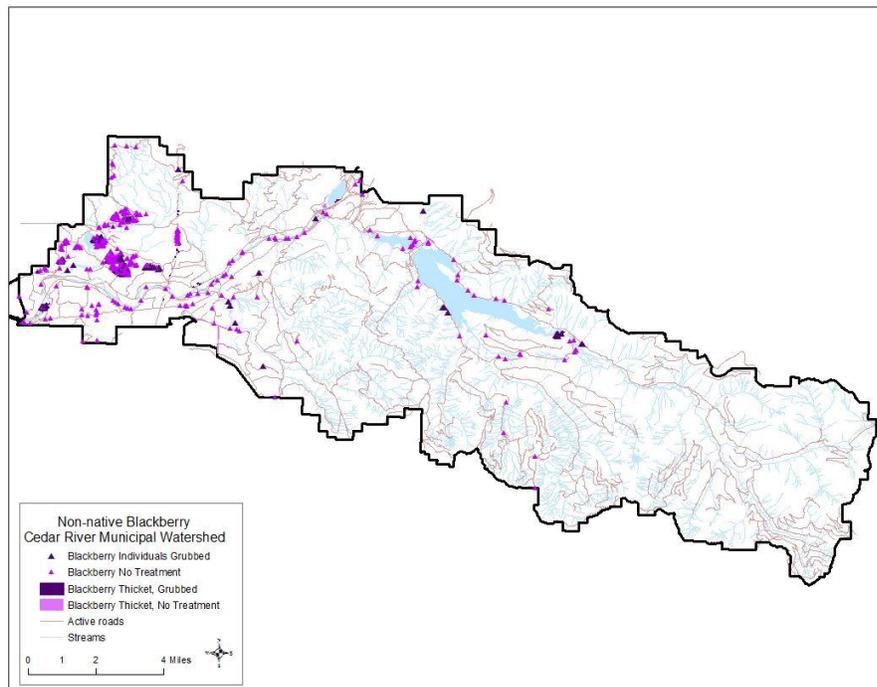
- In the Cedar we surveyed along all drivable roads, plus a small portion of the forest and wetlands in the western portion of the watershed. We found many areas with extensive holly, although not as dense as that found at Lake Youngs. The patches are concentrated in the west end and along major roads. Very few holly have been found in higher elevations (see map).
- Starting in 2006, we controlled selected holly patches and isolated trees in the Cedar by grubbing out the entire plant or, if it was a large tree, cutting the tree to prevent fruiting. We focused work in the Cedar in wetlands, high quality forest patches, and forest patches where other restoration projects had either been completed or were ongoing. Work continues as staffing and funding allows.
- We tried an experimental technique, phloem girdling, in which the phloem, but not the xylem, was girdled on a few selected larger holly trees near Cedar Falls. After several years there had been no effect on the trees, so this technique was abandoned.
- Although no formal surveys for holly have been conducted at the Tolt, only scattered individuals have been noted. These trees will be controlled and further surveys will be conducted as funding and staffing permit.



Himalayan and Evergreen (Cutleaf) Blackberry (*Rubus armeniacu*, *Rubus laciniatus*)

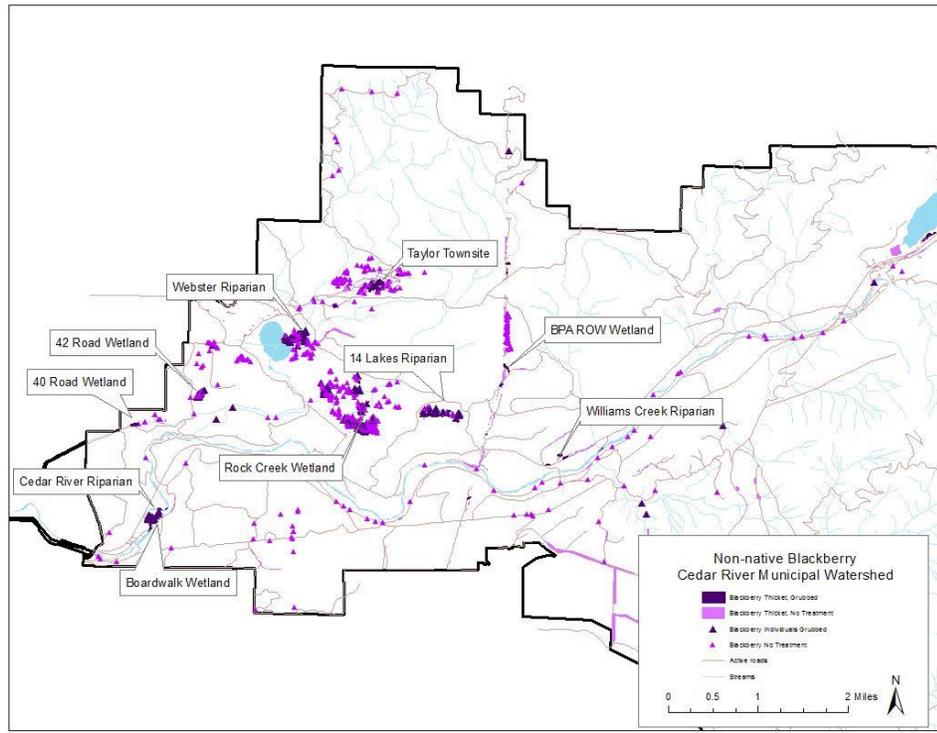
Himalayan and evergreen blackberries are some of the most common invasive species in western Washington. They thrive in a variety of habitats, and often completely take over riparian areas, forest openings, and non-inundated portions of wetlands. They can form impenetrable thickets, with up to 525 canes per square meter, completely disrupting normal ecosystem function. These thickets can produce 7,000 – 13,000 seeds per square meter, with many birds and mammals widely dispersing the seeds. Because these non-native blackberries are so widespread, control is not legally required but is strongly recommended. They are a top priority of the Washington Invasive Species Council.

- Surveys for invasive blackberry in the Cedar have been completed in selected high quality habitats (see map).
- Extensive large thickets of both species were documented in several wetlands and riparian areas around streams, ponds, and lakes in the Cedar.

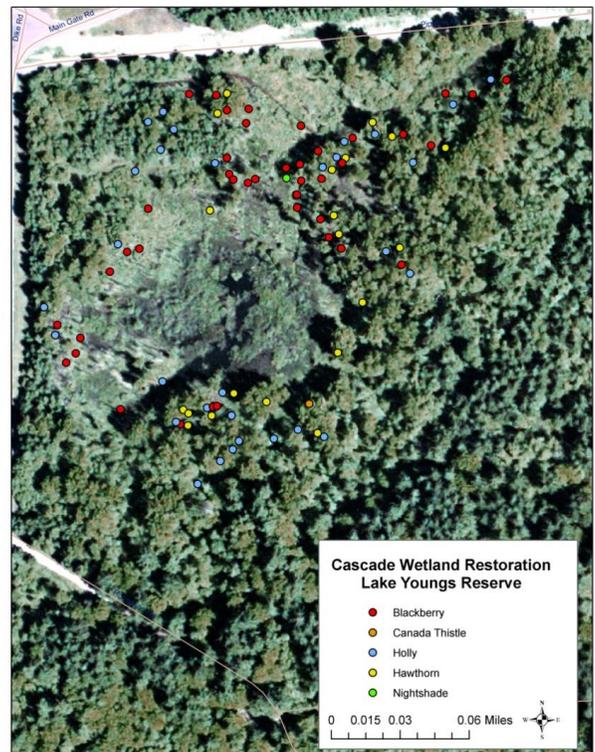


- Starting in 2005 blackberry, along with other invasive species, was hand-grubbed out of seven wetland and riparian areas in the Cedar as part of habitat restoration projects (total of 17.7 acres grubbed, see map on following page). To reduce or eradicate blackberry thickets, all portions of the plant, including roots, must be removed. This generally takes several consecutive years of grubbing because of the difficulty in removing all the roots. Large amounts of seed are present in the soil, so small seedlings must be pulled for several years as well.
- As part of these restoration projects, native shrubs and trees were planted where appropriate, to restore native functioning and compete with the invasive blackberry and

other species. Planting was site-specific; where sufficient numbers and variety of native plants were recolonizing naturally, no planting was done.



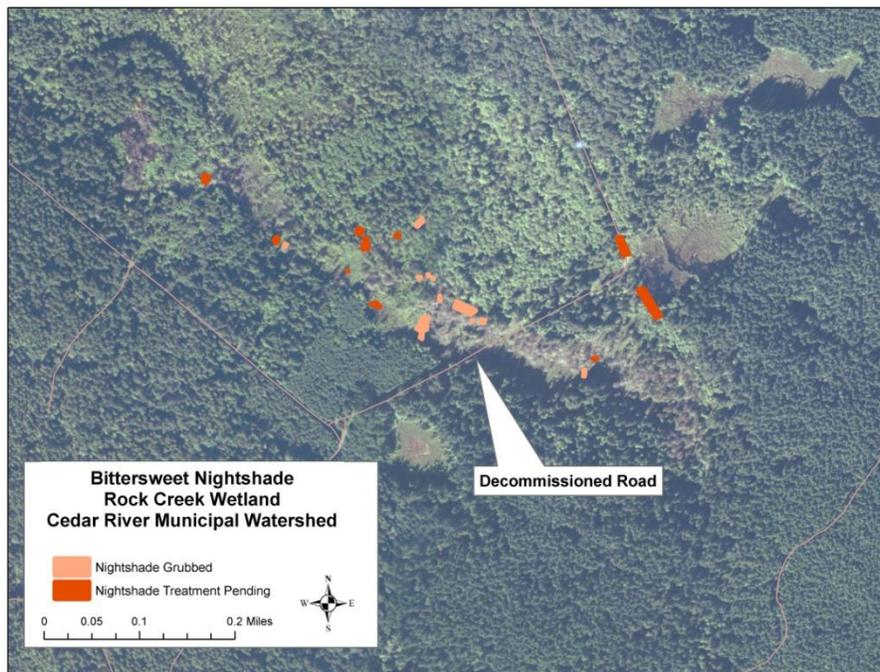
- In 2007 invasive blackberry was mapped in the largest wetland, Cascade Wetland, at Lake Youngs.
- In 2008 and 2009 invasive blackberries, along with several other invasive species, were grubbed out of this wetland (384,621 ft² treated, see figure).
- The Cascade wetland will be re-surveyed and evaluated for further restoration work, potentially including more invasive species removal and planting of native species, as funding and staffing allows.
- No surveys for invasive blackberries have been conducted in the Tolt. Surveys will be done in key riparian areas as staffing and funding allow.



Bittersweet Nightshade (*Solanum dulcamara*)

Bittersweet nightshade is a woody vine that can climb 30 or more feet and blanket trees and shrubs. It flourishes in wetlands and riparian areas where it can completely smother native plants, forming immense solid mats of vegetation. It spreads both by the berries and root fragments. Both berries and leaves are poisonous if eaten. Control is not legally required because it is widespread, but control is highly recommended.

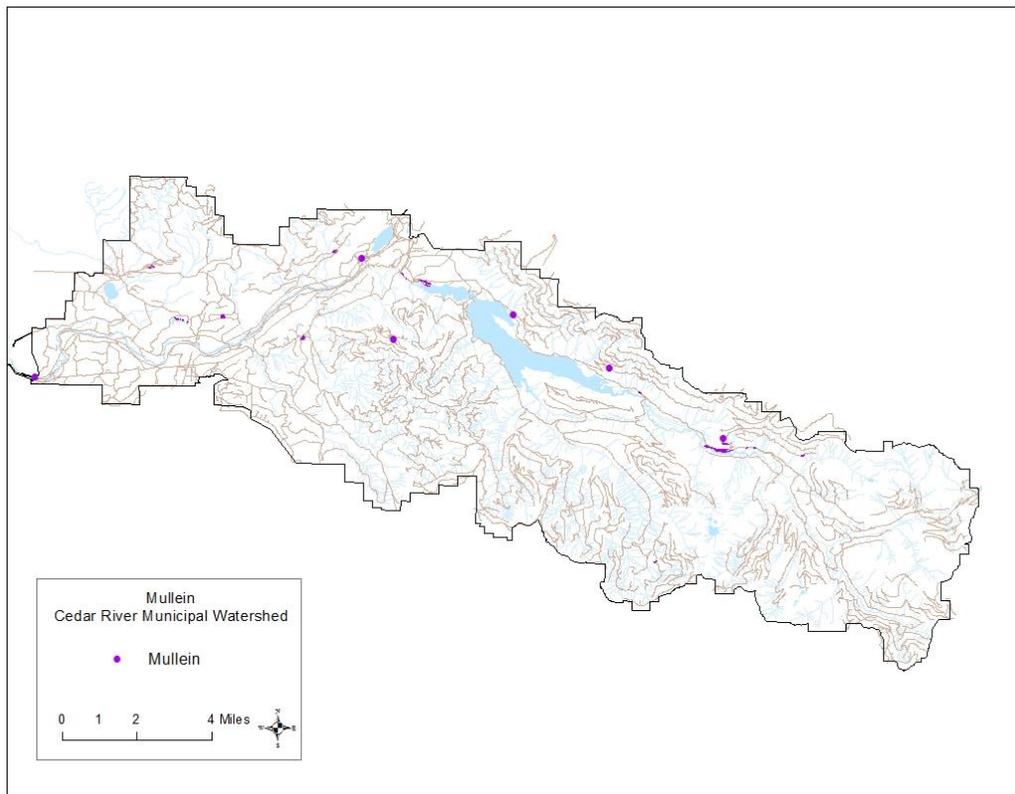
- Limited surveys in selected high quality wetland and riparian areas in the Cedar are complete.
- Several large patches were documented in Rock Creek Wetland, the largest and highest habitat quality wetland in the Cedar.
- In 2009 we experimentally hand-grubbed an extremely dense patch of nightshade blanketing a beaver dam in Rock Creek Wetland.
- In 2010 we found that the hand grubbing experiment appeared successful, so we grubbed out several more patches of nightshade (totaling 17,700 ft²) as part of a Rock Creek Wetland habitat restoration project.
- In 2012 the original patches were starting to re-grow, plus several large patches of nightshade (>4,000 ft²) remain in Rock Creek wetland. In 2013 small amounts were re-grubbed. The area will continue to be treated as funding allows.
- Small patches of nightshade in riparian areas along Webster and Rock Creek are controlled when these creeks are surveyed for other reasons.



Common Mullein (*Verbascum thapsus*)

Common mullein grows in open, sunny, disturbed sites. It is a biennial, and dies after the flowering stalk produces seed in the second year. A single plant can produce over 100,000 seeds in a year. The seeds can survive almost any conditions, and can remain viable up to 100 years.

- Extensive surveys have been completed in all three watersheds.
- Informal monitoring revealed that it was spreading rapidly in both upper and lower elevations in the Cedar. Consequently, in 2013, treatment (digging) was begun on isolated patches, in gravel pits, in restoration project sites, and along some major travel corridors so they could not serve as sources for further invasion. Treatment continues as staffing and funding allows, and is largely conducted incidental to other work. Data are not recorded for this species.



INVASIVE SPECIES TREATMENT - REMAINING MEDIUM AND LOW MANAGEMENT PRIORITY SPECIES

The other non-native invasive plant species listed in Table 1 have been documented in Seattle's major watersheds, but are not legally required for control and are not completely mapped. Some species (e.g., sycamore maple, black locust, bindweed, common tansy, reed canary grass) are being controlled in certain sites as part of habitat restoration projects, in gravel pits, and along well-travelled roads to help minimize spread of invasive plants to other areas. Data are generally not collected for these species. Other species (e.g., Saint Johns-wort) are part of biocontrol experiments.

Appendix 2. Aquatic Nuisance Species that could potentially invade the watersheds

Scientific Name	Common Name	Species Type	Habitat Type
Plants			
<i>Cabomba caroliniana</i>	Carolina fanwort	Aquatic submerged & emergent rooted plant	Lakes, ditches, canals
<i>Callitriche stagnalis</i>	Pond water-starwort	Aquatic rooted plant	Shallow water, lake edges
<i>Egeria densa</i>	Brazilian waterweed	Aquatic submersed rooted plant	Lakes
<i>Eichhornia crassipes</i>	Water hyacinth	Aquatic floating plant	Lakes
<i>Hydrilla verticillata</i>	Hydrilla	Aquatic, submersed rooted plant	Lakes
<i>Myriophyllum aquaticum</i>	Parrot feather	Aquatic rooted plant	Slow moving nutrient rich water
<i>Myriophyllum spicatum</i>	Eurasian milfoil	Aquatic submersed rooted	Lakes
<i>Nymphaea odorata</i>	White water lily	Aquatic rooted plant	Shallow lakes
<i>Nymphoides peltata</i>	Yellow floating heart	Aquatic rooted plant	Shallow lakes
<i>Potamogeton crispus</i>	Curly pondweed	Aquatic rooted plant	Shallow lakes
<i>Sagittaria graminea</i>	Grassy arrowhead	Aquatic rooted plant	Shallow lakes
<i>Utricularia inflata</i>	Swollen bladderwort	Aquatic submersed, free-floating plant	Shallow waters
Animals			
<i>Argulus japonicus</i>	Parasitic copepod	Invertebrate	Transported by fish
<i>Carassius auratus</i>	Goldfish	Fish	Freshwater ponds, lakes
<i>Corbicula fluminea</i>	Asian clam	Invertebrate	Wide range of lakes and streams
<i>Cordylophora caspia</i>	Freshwater hydroid	Invertebrate	Lake bottoms

<i>Craspedacusta sowerbyi</i>	Freshwater jellyfish	Invertebrate	Range of freshwater habitats. Blooms in warm water
<i>Cyprinus carpio</i>	Carp	Fish	Freshwater lakes, wetlands.
<i>Dreissena polymorpha</i>	Zebra mussel	Invertebrate	Wide range of lakes and rivers
<i>Dreissena rostriformis bugensis</i>	Quagga mussel	Invertebrate	Wide range of lakes and rivers
<i>Eriocheir sinensis</i>	Chinese mitten crab	Invertebrate	Lives in fresh water, but breeds in brackish water
<i>Misgurnus anguillicaudatus</i>	Oriental weatherfish	Fish	Freshwater lakes, wetlands; survives in cool water.
<i>Myocastor coypus</i>	Nutria	Mammal	Wetlands, riparian
<i>Pectinatella magnifica</i>	Magnificent bryozoan	Invertebrate	Warm freshwater lakes and rivers
<i>Potamopyrgus antipodarum</i>	New Zealand mud snail	Invertebrate	Wide range of lakes and streams
Diatoms and Algae			
<i>Didymosphenia geminata</i> ¹	Didymo	Diatom	Lakes, Streams
Parasites			
<i>Myxobolus cerebralis</i> ²	Whirling disease	Myxosporean parasite	Parasite on salmonids

¹Native species already present in Cedar. Fairly ubiquitous in Cedar River downstream of Masonry Dam. Can cause nuisance blooms, especially in regulated flow situations.

²Causes whirling disease in salmonids. Requires a segmented aquatic worm to complete its life cycle.

Appendix 3. Insects and pathogens that could invade or have outbreaks in watershed forests

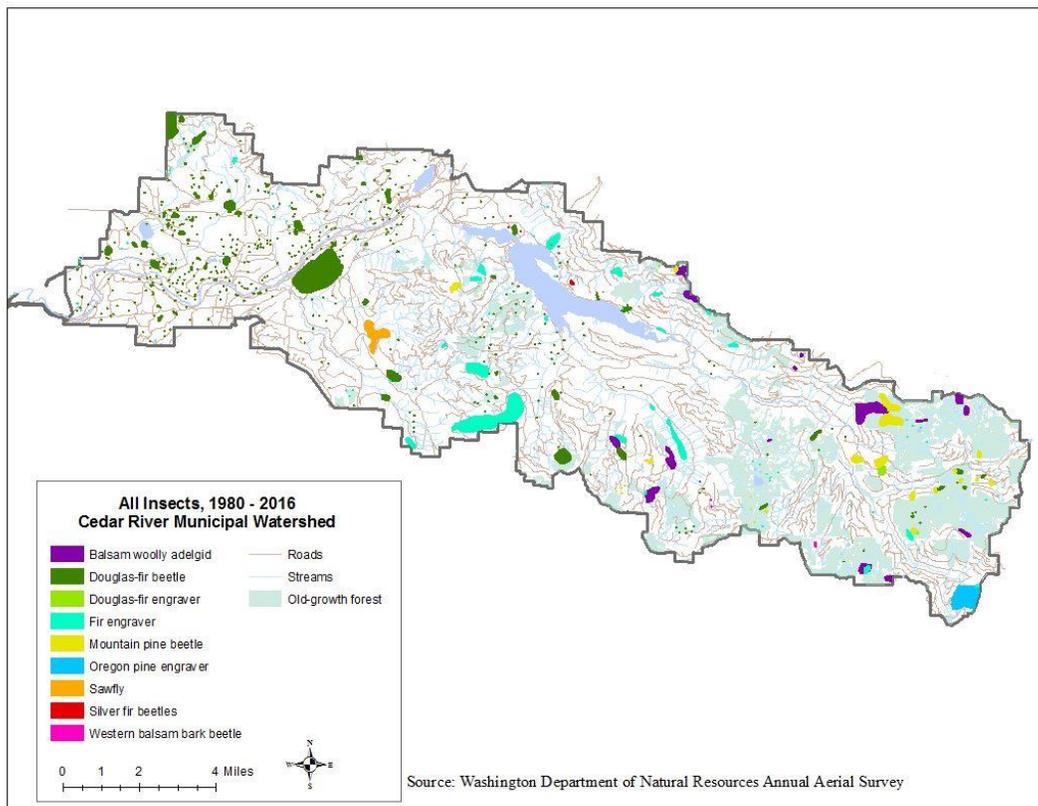
Scientific Name	Common Name	Tree species most susceptible	Action	Notes
Non-native species posing significant risk				
<i>Adelges piceae</i>	Balsam woolly adelgid	True firs (<i>Abies spp</i>) especially Pacific silver fir, subalpine fir, and possibly grand fir	Sucking insect	Can stunt terminal growth or infest entire bole, killing tree. Currently present in Cedar.
<i>Anoplophora glabripennis</i>	Asian longhorn beetle	Broadleaf trees (bigleaf maple, black cottonwood, willow)	Bark tunneling	
<i>Cronartium ribicola</i>	White pine blister rust	Western white pine	Kills young and pole size trees, forming cankers on main stem.	Has almost eliminated western white pine from forests
<i>Elatobium abietinum</i>	Green spruce aphid	Sitka spruce	Sucking insect	Can defoliate trees
<i>Lymantria dispar</i>	European or Asian Gypsy moth	Asian: Conifer and deciduous trees; European: Deciduous trees.	Defoliator	
<i>Monsoma pulveratum</i>	Green alder sawfly	Red alder	Defoliator	Can defoliate trees in riparian areas
<i>Phytophthora ramorum</i>	Sudden oak death	Conifer and deciduous trees, many shrubs	Attacks leaves	Rarely found outside nurseries, but can escape into natural areas
Native species that that could potentially have severe outbreaks under changed circumstances				
<i>Acleris gloverana</i>	Western blackheaded budworm	Western hemlock, Pacific silver fir	Terminal bud damage or death	Currently present in Cedar
<i>Armillaria spp</i>	Armillaria root disease	Conifer and deciduous tress	Root and butt decay	Generally only kills trees already under stress
<i>Choristoneura occidentalis</i>	Western spruce budworm	Douglas-fir	Defoliator	One outbreak recorded in western WA but primarily on the east side.

<i>Dendroctonus ponderosae</i>	Pine bark beetle or mountain pine beetle	Western white pine	Attack under the bark	Infestation usually always results in tree death.
<i>Dendroctonus pseudotsugae</i>	Douglas-fir beetle	Douglas-fir	Attack under the bark	Current monitoring program in localized portion of the Cedar
<i>Heterobasidion annosum</i>	Annosum root disease	Most conifer trees in Washington	Root and butt decay	Normally kills only small pockets of trees, but widespread in portions of the Cedar
<i>Ips pini</i>	Oregon pine engraver beetle	All pine species	Attack under the bark	
<i>Lambdina fiscellaria lugubrosa</i>	Western hemlock looper	Western hemlock	Defoliator	Outbreaks linked with drought cycles
<i>Phaeocryptopus gaeumannii</i>	Swiss needle cast	Douglas-fir	Needle death	Currently causes little death, but can stress the tree.
<i>Phellinus spp</i>	Laminated root rot	Douglas-fir	Root rot	Normally kills only small pockets of trees, but widespread in portions of the Cedar
<i>Pissodes strobi</i>	Sitka spruce weevil	Sitka spruce	Kills leader	Attacks seedlings and saplings, especially planted stock
<i>Scolytus ventralis</i>	Fir engraver beetle	True firs, Douglas-fir	Attack under the bark	Can have major outbreaks under prolonged drought

Appendix 4. Locations of tree death in the Cedar by causal agent.

Each year, all forested federal, state, and private land in Oregon and Washington are aerially surveyed for insect and disease damage. This survey is flown cooperatively by the Forest Insects and Diseases group of Region 6 US Forest Service; the Insect and Disease Section of the Oregon Department of Forestry; and the Washington Department of Natural Resources. These data are collected to determine regional insect and disease trends and to serve as an indicator to land owners/managers on insect and disease activity in their area. The causal agents of the tree mortality are predicted based on the type and pattern of defoliation seen. However, these predictions are only an indicator of insect or disease activity and should be ground verified. All data are collated in GIS, posted on the internet, and available for public use.

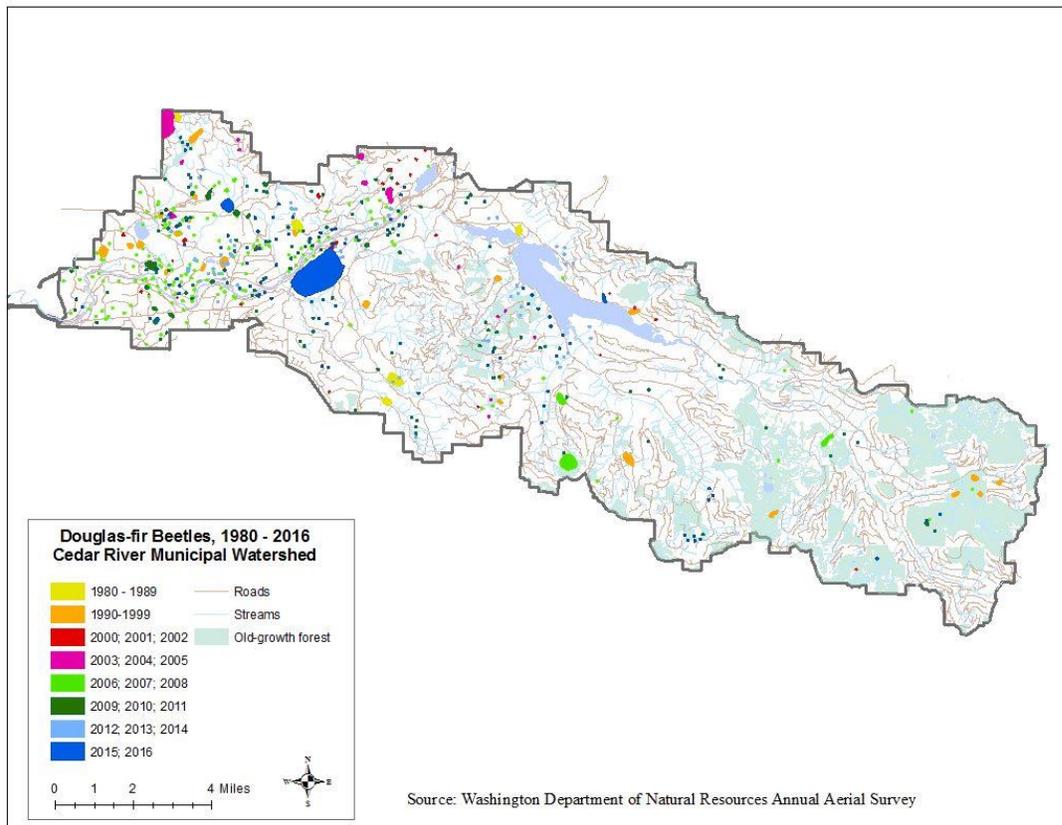
The GIS polygons indicate areas of tree mortality or defoliation; intensity of damage is variable and not all trees within the polygons are affected. The primary agent of mortality in the Cedar since 1980 is Douglas-fir beetle (see data for all years combined in the map below). The large polygons represent scattered sites throughout. The fir engraver beetle, balsam woolly adelgid, mountain pine beetle, silver fir beetle, and western balsam bark beetle have sporadically caused small pockets of mortality. The relatively large blue polygon in the southeastern corner of the watershed with mortality attributed to the Oregon pine engraver beetle occurred in 2003, with no further occurrences recorded. This site was not field verified, and there is very little pine in the watershed, so this data point may have been misclassified.



Douglas-fir Beetle

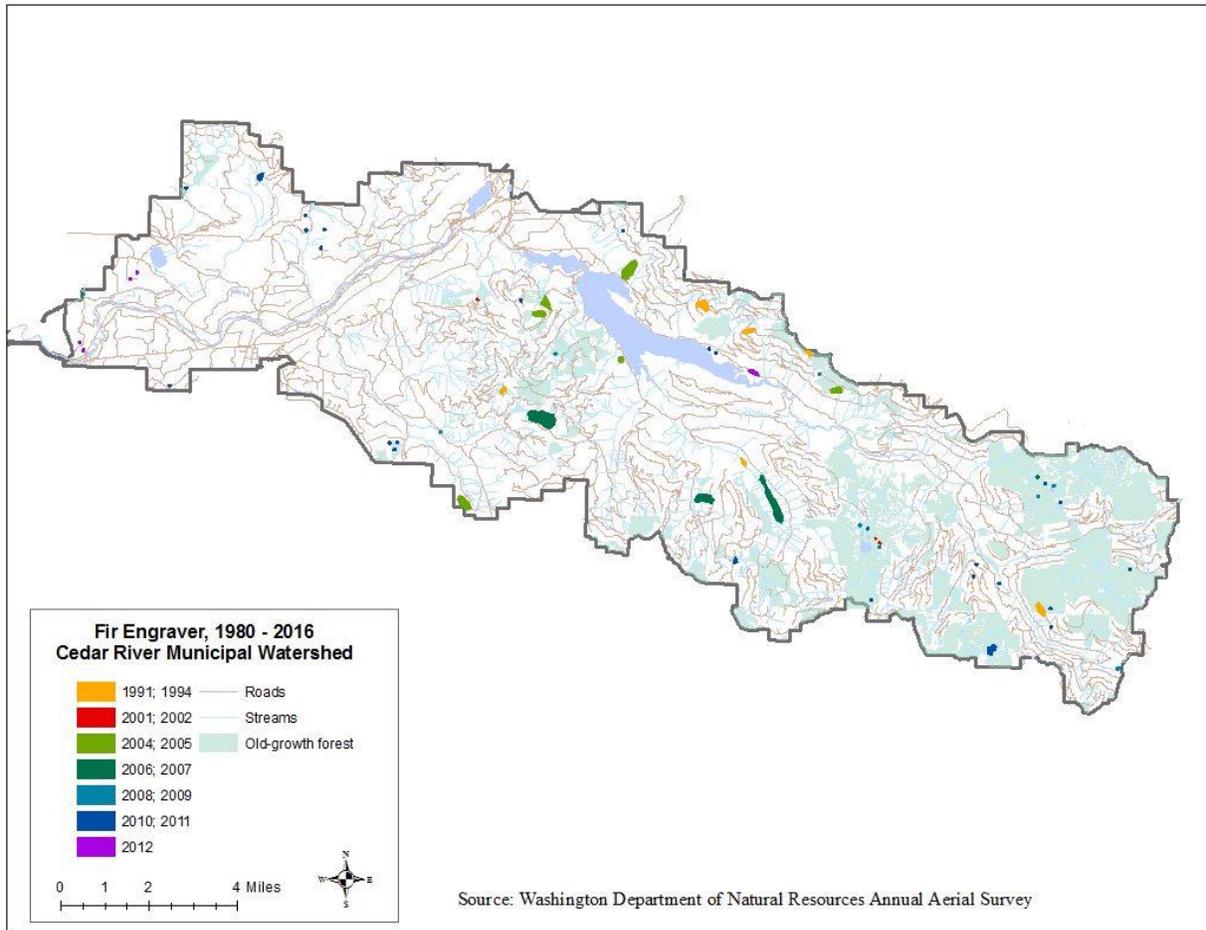
The Douglas-fir beetle is a native insect that generally causes small pockets of Douglas-fir tree mortality. In late 2003 there was a large wind storm that caused several areas of windthrow in the Cedar, and another windstorm in 2007 that caused large amounts of windthrow throughout King County. The windthrown trees provided good substrate for the beetles, whose populations then increased for the next several years leading to the highest levels of Douglas-fir beetle-caused mortality in western Washington in 30 years. The map shows that the majority of tree death in the Cedar from the beetles occurred from 2004-2011, with far less in 2012-2014. There was more tree death in 2015-16, although the large polygon represents a different mapping method rather than increased mortality.

Mortality has been concentrated in the lower elevation western portion of the watershed, which is dominated by relatively dense stands of Douglas-fir, often with root rot present. The mortality has created small snag patches that benefit numerous snag dependent species, as well as creating structural diversity and opportunity for plant species diversification in the forest. These data will continue to be annually monitored to see if these patterns change through time.



Fir Engraver Beetle

The fir engraver beetle is another native species that generally feeds on true firs (*Abies sp*), but can also attack Douglas-fir. Areas of mortality have been scattered in the higher elevation forest in the eastern portion of the watershed, with some mortality (2010-11) seen in or near old-growth forests. To date, patches of mortality have been generally small, with the largest patches recorded in 2006-07. None have been seen since 2012. Sites will be ground verified if future data show cause for concern.



Balsam Woolly Adelgid

The balsam woolly adelgid is a species of concern because it is non-native and has not evolved in these forests, thus poses a significant threat. There were several patches of tree mortality attributed to this species in the 1990s, but only a few scattered patches in the 2000s, with the most recent two small patches documented in 2009. There was an attempt to field verify these patches in 2010 and 2011, but no tree mortality or evidence of balsam woolly adelgid was found at either location.

