Grant County
PUBLIC UTILITY DISTRICT

Connecting Generations
Since 1938

VIA ELECTRONIC FILING

December 11, 2018

Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
Mail Code: DHAC, PJ-12
888 First Street NE
Washington, DC 20426

RE: Priest Rapids Hydroelectric Project No. 2114
License Article 412 Compliance Filing – Northern Wormwood Conservation Plan Report

Dear Secretary Bose,

Pursuant to Article 412 of the Order Issuing New License dated April 17, 2008 for the Priest Rapids Hydroelectric Project[1], Public Utility District No. 2 of Grant County, Washington (Grant PUD) submits the Northern Wormwood Conservation Plan Report (Report). The Report is being submitted consistent with Grant PUD's Northern Wormwood Conservation Plan (Plan) and associated implementation schedule that was filed on August 5, 2008, and approved on November 10, 2010[2].

The 2008 Plan included the following measures: (1) conducting annual demographic monitoring consistent with the efforts reported in the 2003 license application for a period of 10 years to empirically describe the population status of Northern Wormwood at the Project; (2) maintaining 5,000 linear feet of fencing to control vehicle access at the Beverly population site; and (3) controlling noxious weeds at the Beverly population site. In addition, modeling of the northern wormwood population would be conducted every third year, and Grant PUD, in consultation with the agencies, would file a comprehensive report including the results of the modeling and annual monitoring and any recommendation for further protection, access control, and/or data management by December 31, 2018. The report would also include an implementation schedule of any recommendations.

On October 18, 2018, Grant PUD distributed the draft comprehensive Report for review and comment to U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, Washington Department of Natural Resources, and the Washington Natural Heritage Program. Comments were received by U.S. Fish and Wildlife Service (USFWS), U.S. Bureau of Reclamation (USBR), and Washington State Department of Natural Resources (WDNR) Heritage Program. Copies of those comments, along with a summary table of Grant PUD's responses have been incorporated in Appendix B of the Report.

---

[1] 123 FERC ¶ 61,049 (2008)
[2] 133 FERC ¶ 62,138 (2010)

FERC staff with any questions should contact Tom Dresser at 509-754-5088 Ext. 2312 or Mike Clement at 509-754-5088 Ext. 2633.

Respectfully,

Ross Hendrick
License & Environmental Compliance Manager

Enclosures: Northern Wormwood Conservation Plan Comprehensive Report

Cc:	Tara Callaway	USFWS
	Gina Hoff	USBR
	Walter Fertig	WDNR Heritage Program

Northern Wormwood (*Artemisia borealis var. wormskioldii*) Population Viability Analysis Results and Conservation Plan for the Priest Rapids Project 2019 – 2029

Public Utility District No. 2 of Grant County, Washington
30 C Street SW
Ephrata, WA

December 2018

Table of Contents

List of Figures

List of Tables

List of Appendices

1.0 Introduction

Artemisia borealis var. *wormskioldii* (Shultz 2006[1]) (Asteraceae: Anthemideae) (Northern Wormwood) is an Endangered taxon in Washington state. One of two known natural populations of Northern Wormwood occurs on gravel bars in the Columbia River near the town of Beverly, WA (River Mile [RM] 412.75), within the boundaries of the Priest Rapids Hydroelectric Project, FERC No. 2114. The Priest Rapids Project (Project) is owned and operated by Public Utility District No. 2 of Grant County (Grant PUD) in Washington State.

Casual observations of the Beverly population of Northern Wormwood during the 1980s and 1990s suggested dramatic declines, prompting its state and federal listing status. Herbicide applications, recreational pressures, exotic weeds, hydrology, and hydroelectric operations were all cited as potential threats or impacts to the taxon (Carlson 1997, Gamon 1989). This document provides information on Grant PUD's Northern Wormwood Conservation Plan within the Project. Updated biological information is presented as well, but readers are referred to Howard (1998), Carlson (1997), and Gamon (1989) for a full biological description.

The Federal Energy Regulatory Commission (FERC) issued a new license for the Priest Rapids Project on April 17, 2008[2]. The license includes Article 412, which requires that Grant PUD file an implementation schedule for the Northern Wormwood Conservation Plan[3]. This Plan includes the following measures: (1) conducting annual demographic monitoring consistent with the efforts reported in the 2003 license application for a period of 10 years to empirically describe the population status of Northern Wormwood at the Project; (2) maintaining 5,000 linear feet of fencing to control vehicle access at the Beverly population site; and (3) controlling noxious weeds at the Beverly population site.

2.0 Biology

A. borealis has four varieties and two subspecies recognized by the Integrated Taxonomic Information System (ITIS). Morphologically Northern Wormwood is most closely related to field sagewort (*A. campestris* var. *scouleriana*).

2.1 Description and Taxonomy

Carlson (1997) provides the following non-technical description of Northern Wormwood:

> *A low (6-12 inches) taprooted biennial or perennial. The basal leaves are 1-4 inches long, two or three times divided into mostly linear divisions, and are crowded in rosettes. The herbage, especially the leaves, are conspicuously covered with silky hairs. The inflorescence is narrow, with relatively large heads, the involucres about 1/8 inch. The outer flowers of the heads are pistillate (female) and fertile, but the disk flowers are sterile and the ovaries abort. The achenes and receptacle are glabrous.*

The taxonomy of the *A. borealis* complex is difficult and poorly understood, with four varieties and two subspecies currently recognized (ITIS 2008, Howard 1998). In addition to its current varietal designation, Northern Wormwood has been variously treated as a form (*A. borealis* f.

---

[1] Recent information from Shultz (2006) elevates *A. campestris* ssp. *borealis* to a species. From this point forward in this document it will be known as *Artemisia borealis* var. *wormskioldii*.

[2] 123 FERC ¶ 61,049 (2008)

[3] 133 FERC ¶ 62,138 (2010)

wormskioldii Rousseau), subspecies (*A. borealis* ssp. *wormskioldii* Piper), and species (*A. ripicola* Rydb.) (Carlson 1997, Gamon 1989). Specimens of Northern Wormwood were apparently included within both ssp. *borealis* and ssp. *spithamaea* by Hall and Clement (1923), who also noted some specimens' strong resemblance to the European taxon *A. campestris* var. *maritima*. Northern Wormwood is most recently referred to as *A. borealis* var. *wormskioldii* in recent documents (Shultz 2006).

Morphologically, Northern Wormwood is most similar to field sagewort (*A. campestris* var. *borealis*). The two taxa share the large capitula and short, spicate inflorescences that reliably differentiate Northern Wormwood from field sagewort, with which it often grows adjacent to (Carlson 1997, Gamon 1989). Carlson (1997) hypothesized that Northern wormwood and field sagewort diverged from a common ancestor following the most recent glacial retreats. Cronquist (1950) differentiated the two taxa based on the density of leaf and involucre pubescence.

2.2 Range, Distribution, and Habitat

Members of *A. borealis* are circumboreal, inhabiting dunes, shorelines, and rangelands throughout much of the northern hemisphere (Howard 1998). Northern Wormwood grows in sand, cobble, and basaltic habitats within the Columbia Basin physiographic province (Carlson 1997, Gamon 1989) (Figure 1).

Figure 1 Northern Wormwood habitat near Beverly, Washington, November 2001. Note low plant cover and cobble-based soil.

Northern Wormwood is presently known from only two natural populations; one on Miller Island in the lower Columbia River, and a second on Priest Rapids Reservoir, north of the Town of Beverly, WA. The Beverly population was once the larger of the two extant occurrences, with more than 1,500 individuals, most of which occur on stabilized cobble-sand islands and peninsulas within the main channel of the Columbia River (Beverly Island Complex) (Figure 2). This population was first documented in 1983, but its size at the time is not known. In addition to these two extant populations, another eight documented populations are believed to have been extirpated by hydroelectric development on the Columbia River (Carlson 1997, Gamon 1989).

The Beverly population of Northern Wormwood has been loosely grouped into five subpopulations. The largest subpopulation (monitoring subpopulation) is at the extreme southwestern tip of the peninsulas supporting the taxon. The smaller populations (Figure 2) have been slowly declining over time. Grant PUD demographic monitoring plots referred to in this document are established within the boundaries of the monitoring subpopulation.

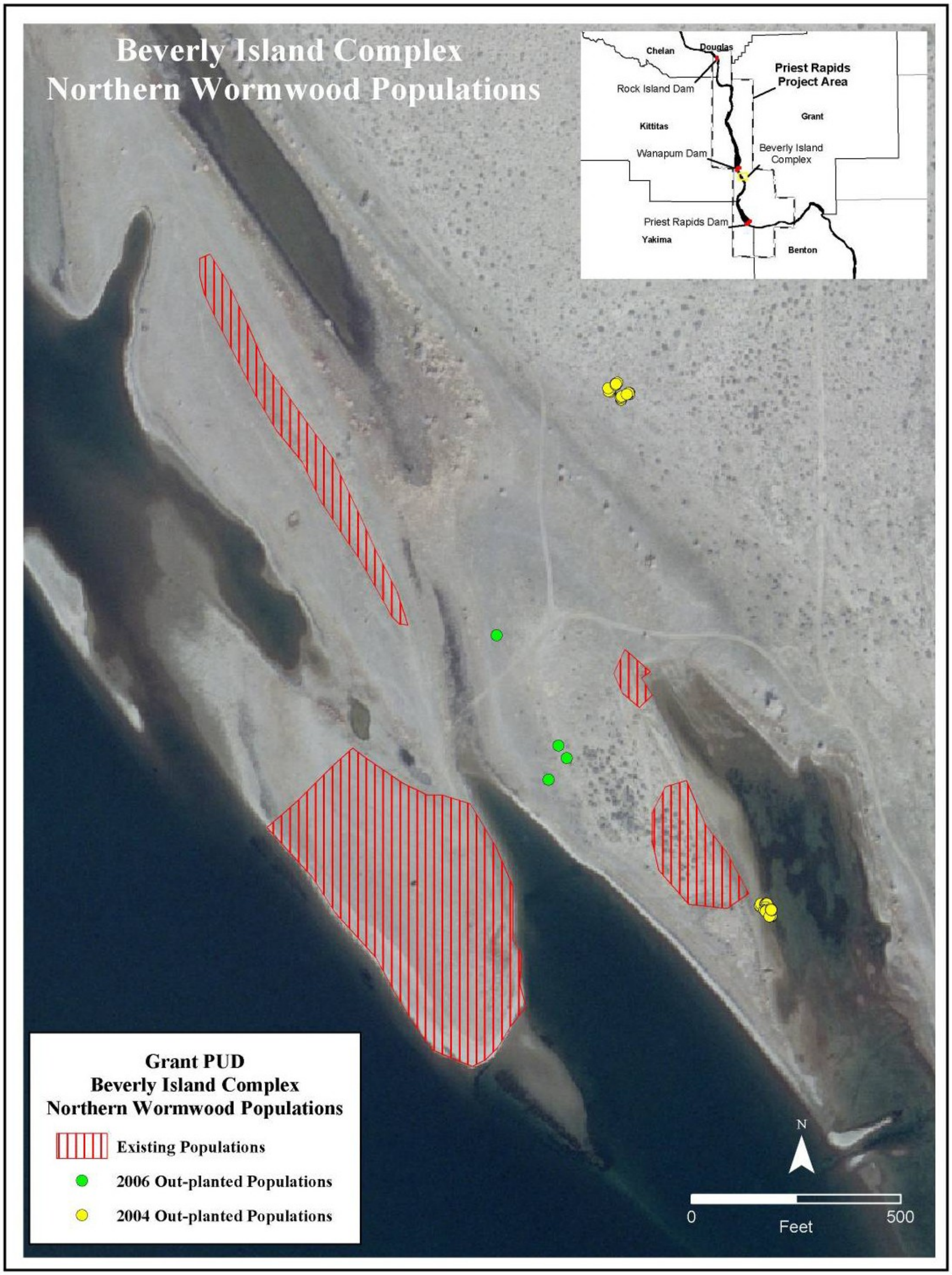

Figure 2 **Northern Wormwood (*Artemisia borealis var. wormskioldii*) main population and out-planted locations in 2004, 2006, Beverly Island Complex, mid-Columbia River, WA.**

2.3 Reproductive and Population Biology

Northern Wormwood reproduction is believed to be entirely sexual (Carlson 1997, Gamon 1989). The taxon flowers in April, producing single to multiple spicate inflorescences of inconspicuous flowers arranged in capitula. Like most of its congeners, Northern Wormwood appears to be wind-pollinated (see Carlson [1997] and Gamon [1989]). Northern Wormwood seeds are presumably dispersed by wind, gravity, and perhaps water, because they lack the specialized dispersal mechanisms otherwise common in Asteraceae (Carlson 1997, Gamon 1989).

Most flowering Northern Wormwood individuals generate few seeds (typically fewer than ten achenes per capitulum) (Reynolds 2002). However, it is unclear to what degree this seed production reflects actual pollination efficiency, as only the ray flowers of Northern Wormwood are normally fertile. Plants with zero to over 1,000 capitula have been observed at both the Beverly and Miller Island populations, with an average of nearly 54 per plant at the Beverly population in 2001 (Grant PUD 2003). Although seed germination percentage and seedling establishment has not been quantified in the field, seeds approached 100% germination under testing conditions, and a total of 495 seedlings were observed in 31 monitoring plots in 2006. Only 23 had been observed in 2001. Seedling emergence has not been observed in the field, but Yun and Maun (1997) reported that *A. campestris* ssp. *caudata* seedlings germinate "throughout the summer from May to October."

The longevity of Northern Wormwood individuals is unknown. Most members of *A. borealis* are considered short-lived perennials (Yun and Maun 1997), and multiple years of flowering by Northern Wormwood has been observed. Population dynamics appear to fluctuate strongly at both the Beverly and Miller Island populations (pers. comm. Florence Caplow, WNHP botanist, October 2002). For example, Kaye (1995) observed 335 Northern wormwood individuals on Miller Island, a substantial increase from the 75 plants reported by Gamon (1989). However more recent counts of 41 (2006), 36 (2007), and 33 (2008) indicate a decreasing trend (Arnett 2008).

2.3.1 Competition and Hybridization

Northern Wormwood grows in open habitat with relatively low plant cover, suggesting the overall potential for interspecific competition is small. However, parts of the monitoring subpopulation that support few Northern Wormwood individuals support moderate concentrations of diffuse knapweed (*Centaurea diffusa)*, an exotic weed that may compete with Northern Wormwood. Diffuse knapweed is highly competitive, and is also known to produce allelopathic (inhibiting growth in other organisms) compounds (Carpenter and Murray 1998). Northern Wormwood may also produce allelopathic compounds, as do many of its congeners and at least one of its conspecifics (Yun and Maun 1997).

Intraspecific competition in Northern Wormwood has not been examined. Although most adults are spatially separated by six inches or more at the Beverly population, patches of individuals are not uncommon. Kaye (1995) noted that seedling recruitment in bedrock at the Miller Island population was limited relative to sandy habitat, possibly suggesting intraspecific competition for safe sites (Carlson 1997). Alternately, bedrock could represent poor habitat in general.

Because it flowers in April, Northern Wormwood is for the most part phenologically isolated from the sympatric *A. borealis* var. *scouleriana*, which flowers in August and September.

However, 35 Northern Wormwood individuals were observed flowering in November of 2001 (Grant PUD 2003), and Gamon (1989) reported observing at least one individual flowering in September. One *A. borealis* individual of apparently intermediate morphology was observed in 2003. As a result, some potential for hybridization appears to exist.

3.0 2008 – 2018 Northern Wormwood Conservation Plan Measures and Schedule

Article 412 of the April 17, 2008 FERC license issued for the Project required that Grant PUD file an implementation schedule for Northern Wormwood and implement a Northern Wormwood Conservation Plan that included the following measures: (1) conducting annual demographic monitoring consistent with the efforts reported in the 2003 license application for a period of 10 years to empirically describe the population status of Northern Wormwood at the Project; (2) maintaining 5,000 linear feet of fencing to control vehicle access at the Beverly population site; and (3) controlling noxious weeds at the Beverly population site. The Plan was filed on August 5, 2008 and was approved by FERC on November 10, 2010[4]. The 2008 – 2018 conservation measures is presented below.

Table 1 2008 – 2018 Northern Wormwood Conservation Measures Schedule

Task	Purpose	Duration	Start	Finish
FERC review/approval for Northern Wormwood Conservation Plan Implementation Schedule	Per Priest Rapids Project License Order Article 412	90 days (estimated)	7/17/08	10/17/08
Annual Northern Wormwood Demographic Monitoring	To empirically describe the population status of northern wormwood at the Project.	Annually for 10 years	10/17/08	10/17/18
Maintain 5,000 linear feet of fencing at the Beverly population site	To control vehicle access	Annually for 10 years	10/17/08	10/17/18
Control noxious weeds at Beverly population site		Annually for 10 years	10/17/08	10/17/18
Provide annual Northern Wormwood Demographic Monitoring Results Report w/consulting parties.		Annually for 10 years	10/17/08	10/17/18

---

[4] 133 FERC ¶ 62,138 (2010)

File Annual Northern Wormwood Demographic Monitoring Results Report with FERC	Include recommendations for further monitoring and protection measures, including additional access control measures, data management or other research, and implementation schedule			12/31/2018

As shown above, Grant PUD’s 2008 – 2018 Northern Wormwood Conservation Plan Schedule (Table 1) included measures to continue annual demographic monitoring, filing of annual reports with the consulting parties, maintenance of exclusion fencing to control vehicle access, controlling noxious weeds at the Beverly monitoring subpopulation, and filing a report to the Commission by December 31, 2018, in consultation with the United States Bureau of Reclamation (USBR), United States Fish and Wildlife Service (USFWS), and Washington Natural Heritage Program (WNHP).

4.0 Methods

This section describes the previous methods associated with demographic monitoring of Northern Wormwood populations at the Beverly Island Complex in the Project. Demographic monitoring of this taxon was initiated in 2001 and continued through 2018. Procedures described below were performed annually.

4.1 Demographic Monitoring

A total of 31 plots were established at random locations within the main Beverly subpopulation in 2001. In that year and through 2018 these plots were sampled annually during peak flowering (April-May). Plots were 1 x 10 m and marked with rebar posts. A 1 m^2 frame was used to map the position of each individual plant in each 1-m section of plot. Plants were given a number on the maps, and information on plant size was recorded, including rosette diameter, number of flowering stems, and number of flower heads. In each year of observation, plants retained the same number as in previous years so that individual plants could be followed through time. Newly encountered plants were given the next higher unique number. Full monitoring protocols are described in Appendix A of the Draft Research Summary and Threats Assessment for *Artemisia campestris* var. *wormskioldii* (Malkin 2003).

A second taxon, Scouler’s wormwood (*Artemisia campestris* var. *scouleriana*), occurs sympatrically with Northern wormwood at Beverly. These varieties are difficult to distinguish from one another when they are in the seedling and other vegetative stages, so it is necessary to map and measure all plants of both varieties (flowering and vegetative) in the sampling plots in order to prorate the vegetative plants and seedlings in any given year among the taxa (a step necessary for demographic modeling). Flowering plants were noted on the maps and data sheets as to their variety, and vegetative plants were considered “ambiguous.” This was done in 2001-02, and again in 2005-18, while during 2003-04 ambiguous plants were well recorded but flowering status and stem counts for reproductive plants of Scouler’s wormwood were omitted.

Figure 3 Drawing square used for mapping *Artemisia borealis* individuals in subplots.

During monitoring, each subplot is examined and *A. borealis* individuals within it are mapped using a drawing square measuring one meter by one meter on its outside edge (Figure 3). The drawing square is segmented into 20-centimeter squares by a grid of elastic cords; individual plants are mapped relative to the gridlines.

4.2 Estimating Population Size of Reproductive Plants

The total number of flowering Northern wormwood plants in the Beverly population was estimated through direct census in 2000, 2005, and 2007-18. Censuses were conducted by one observer in 2000 (Malkin 2003) and two different observers since 2005. Note that at high flow, not all plants could be counted. For example, during 2012 census, several flowering adults were observed inundated by flows, and it was impossible to determine how many individuals were not counted.

Information from the demographic plots was used to estimate the size of the entire population of reproductive Northern wormwood plants in each year (2001-2018) by multiplying the average number of plants per 10 x 1-m plot by the total population area (i.e., the number of possible plot locations). The habitat area of the main subpopulation sampled by the demographic plots was 88,339 ft^2, which is 8206 m^2 and therefore contains approximately 821 possible plot locations (this is N, below):

$$\text{population size estimate} = 10^{\bar{x}} * N$$

where $\bar{x}$ is the average $\log_{10}$-transformed number of plants per sample plot and N is the total number of possible sample plot locations in the reference area. In addition, a 95% confidence interval for this estimate was calculated as follows:

$$95\%\ \text{confidence interval for pop. size est.} = 10^{(\bar{x} \pm 1.096 * SE)} * N * \sqrt{\frac{N-n}{N}}$$

where SE is the standard error of the mean plot density (x), n is the total number of sample plots (n = 31), and (N-n)/N is the finite population correction factor, which is applied because the population area (N) is of limited size (not infinite or extremely large) (Elzinga et al. 1998).

4.3 Survival Rates and Fertility in a Mid-Taxon Population

Five life history stages of Northern wormwood were identified for the purposes of this study: seedlings, small vegetative plants (rosette < 8 cm diameter), large vegetative plants (rosette ≥ 8 cm), small reproductive plants (1 or 2 flower stalks), and large reproductive plants (≥ 3 flower stalks) (Figure 2). All first year vegetative plants ≤ 2 mm in diameter were considered seedlings, and they often retained their cotyledon leaves; larger plants that appeared without observation in a previous year were not considered seedlings. In addition, plants in vegetative and reproductive stages that first appeared in a year without being present as a seedling in the previous year were assumed to have been seedlings in the previous year.

Northern wormwood has a complex life-history. With five stages recognized, a large number of possible transitions among the stages are possible (Figure 2). Both flowering stages can contribute to seedling recruitment in any given year. Seedlings were defined as first year plants only, so they cannot stay seedlings from one year to the next, but must instead grow to a larger stage. All other stages can (and often do) remain in the same stage for multiple years, grow to a larger stage, or decline to a smaller or less reproductive stage. For this report, the statistical package R version 3.5.1 (R Core Team 2018) was used to calculate the proportion of each stage that survived to enter another stage, or remained the same, between consecutive years and the number and proportion of individuals in each stage in each year.

Quantification of seedling dynamics in the field differed from year to year. In 2001 and 2004-18, all observed seedlings were mapped (except in 2018), measured, and recorded on data sheets. Seedlings were totaled per plot, but not mapped during 2018 because it was the final year of sampling and therefore seedling locations were not needed to calculate transition rates to 2019. In 2002 and 2003, seedlings were mapped and measured as above in some cases, but the majority of seedlings were simply counted in each 1-m segment of sample plot and not mapped. This was apparently done to save time because large numbers of seedlings (> 1000) were encountered in those years, but forced some assumptions in the analysis reported here. For example, all new non-seedling plants encountered were assumed to be seedlings the prior year, and the difference between the number of new plants and the number of seedlings the previous year was assumed to be due to seedling mortality. This made tracking seedlings for this analysis more difficult because some seedlings were mapped, some were simply counted, some were assumed to have occurred in plots where no seedlings were counted, and some seedlings may have died without ever having been mapped. When all seedlings are mapped and numbered, tracking them is simplified.

Positively identifying individuals of either variety was straightforward once flowering. If a plant flowered at any time since monitoring began, its identity was known and could be ascribed to years when it was vegetative. In this way, the identity of some vegetative plants was known. However, the majority of vegetative plants were ambiguous. Vegetative scouleriana and wormskioldii plants were assumed to have the same probability of survival from one vegetative stage to another, and could therefore be grouped together and treated as wormskioldii plants for the purposes of determining vegetative transitions for that variety. This assumption was supported by the fact that vegetative plants became reproductive (and therefore identifiable) at similar rates for both scouleriana and wormskioldii from 2001 to 2002. However, based on log-linear analysis (following methods in Anderson and Goodman 1957 and Caswell 2001) of seedling and vegetative stage transitions of identified plants across all study years (df = 9), transitions from vegetative stages are significantly different ($p < 0.001$) between Northern wormwood and Scouler's wormwood (Kaye and Pfingsten 2012). Still, elasticities of vegetative plant transitions are low on average (Table 3), which suggests these plant stages may not be as important to population growth as reproductive plants. Therefore, the assumption of equal transitions for vegetative plants in both varieties, though somewhat incorrect, is unlikely to have a large effect on our modeling results, and it would be difficult to correct for this given the small amount of data that is available upon which to base improved estimates.

To estimate the number of seedlings produced by an individual in each reproductive stage (i.e., the fecundity of each stage), it was assumed that the seedling recruitment per seed produced was identical for both Northern wormwood and Scouler's wormwood. Following that, observed seedlings were prorated among the two taxa based on the relative contribution to the entire seed pool of each taxon in each year. This was accomplished with two separate approaches. Results are only reported for the second approach that used seedlings prorated by the number of seeds produced.

Seedlings prorated by the number of stems: The proportion of seedlings that were Northern wormwood were calculated based on the relative proportion of stems in the entire population (including Northern wormwood and Scouler's wormwood) that were Northern wormwood. This was done by multiplying the number of seedlings in a given year by the proportion of stems that were Northern wormwood in the year before. This is the approach that was used in the preliminary PVA reported in 2004.

Seedlings prorated by the number of seeds: In this approach, information was used from a separate study by Grant PUD and Oregon State University (OSU) in which the number of seeds per stem was estimated for each taxon in 2006 (Keeler and Woodward 2007). These estimates were used to calculate the total number of seeds produced in the population and the proportion of those seeds that were Northern wormwood. Next, the number of seedlings observed in a given year was multiplied by the estimated proportion of seeds that were wormskioldii in the previous year. This approach was recommended after the 2004 report and supported by the seed counting accomplished by Grant PUD and OSU, and was outside the requirements for Grant PUD. This work was conducted to gain a better understanding about limiting factors to the population.

Our approach based on prorating seedlings by the number of stems in the population that were Northern wormwood produced higher population growth rates because it used much higher estimates of fecundity in the models (Kaye and Pfingsten 2008, 2012). These models appear to be highly sensitive to changes in fecundity estimates.

Survival rates and estimates of fertility for each stage were arranged into "transition matrices" for each pair of years from 2001 through 2018, except for 2006 to 2007 and 2007 to 2008 (see Important note 1, above). See Kaye and Pyke (2003), Kaye et al. (2001), Caswell and Kaye (2001), Caswell (2001) or Menges (2000) for complete discussions of transition matrix models for plant population dynamics and viability analyses. Because information on reproductive status (number of stems per plant) of Scouler's wormwood individuals was missing for 2003 and 2004, it was assumed that the total number of stems of those years was equal to the average stem number for 2001-02 and 2005-18.

4.4 Population Viability Analysis

Population growth rate and viability were evaluated with the annual transition matrices. For this analysis, the approach was to calculate both deterministic and stochastic measures of population growth, lambda (λ) and stochastic lambda (λ_s), respectively. Lambda is the equilibrium population growth rate (and the dominant eigenvalue of the transition matrix), and can be used as a single measure of population viability to compare sites or years. Stochastic lambda does not assume equilibrium population dynamics and incorporates observed environmental variability. If either type of growth rate is less than 1.0, the population is projected to decrease in size, and eventually become extinct (a non-viable population). If lambda is greater than 1.0, the population will grow (a viable population), given that current conditions remain constant. Lambda was calculated for nine consecutive pairs of years with available data (2001-02, 2002-03, etc.).

Elasticities of the matrices were also calculated. Elasticities, which sum to one across the transitions in a matrix, are the proportional sensitivity of lambda to small changes in the transition probabilities. Elasticities provide valuable information about the extent to which population growth depends on survival, growth, and reproduction at different stages in the life-cycle (Caswell 2001). R version 3.5.1 (R Core Team 2018) was used to produce and analyze the matrices.

Environmental stochasticity was modeled to evaluate population viability in two ways, stochastic growth rate (λ_s) and extinction probability. Both involved projecting future population dynamics by randomly selecting survival and fecundity measures from past years. Environmental variability was incorporated into the model through the matrix selection procedure in which each available transition matrix is selected at random with equal probability at each time step of a simulated population (Kaye 2001a, Kaye and Pyke 2003). The matrices represent each year-pair of the study, and the variation between them is considered to be environmental stochasticity. More detailed descriptions of this method can be found elsewhere (e.g., Burgman et al. 1993, Kaye and Pyke 2002).

To calculate λ_s, the numerical simulation method outlined in Caswell (2001:396) was followed. When the log of population growth is averaged over a very large number of time steps, it converges to a fixed value determined by vital rates and environmental processes (Caswell 2001, Tuljapurkar 1997). Simulations were run for 100,000 time steps (discarding the first 500 to omit transient effects) to calculate the stochastic growth rate. All stochastic modeling described in this report was implemented in R ver. 3.5.1 (R Core Team 2018) with functions in the popbio package (Stubben and Milligan 2007). The initial population structure used in these simulations was the mean relative abundance of each stage in the var *wormskioldii* population as recorded between 2001 and 2015 (stages in 2016-18 were excluded due to ambiguity in identification): seedling (9.4%), small vegetative (25.7%), large vegetative (13.9%), small reproductive (23.7%), and large reproductive (27.3%).

Estimation of extinction probability involved projecting future population dynamics by randomly selecting survival and fecundity measures from past years with the matrix selection method. These simulations ran for 10 and 50 years and consisted of 10,000 iterations, which allowed us to determine an average projected population trend and frequency with which the population declined below specific thresholds. The starting population size for each simulation was 8,124 plants distributed among the five stages according to the average population structure. This initial size corresponds to the 2000 census total of 1,260 reproductive plants, plus vegetative plants in proportions to match the observed relative abundance of plants in each stage. The simulations stopped at the quasi-extinction thresholds of 50%, 90%, and 99% decline to provide various estimates of extinction dynamics.

5.0 2001 – 2018 Northern Wormwood Demographic Monitoring Results

5.1 Observed Population Trends

The total number of flowering Northern wormwood plants was estimated through direct census in 2000 to be 1,260 at the main population at Beverly (Malkin 2003). Repeat censuses of the main population have tracked an on-the-ground decline from 1,667 in 2005 to just 12 in 2018 (Table 1).

Annual estimates of total flowering population size of Northern wormwood show substantial variation through time (Figure 4). In addition, these estimates have a relatively large amount of uncertainty. For example, the 95% confidence interval for estimated flowering plant number in 2001 was between 951 and 2,888 (Figure 4). The observed population dropped in 2004 to between 424 and 1,422 flowering plants, but the population recovered somewhat in 2005-06. After 2006, the estimated number of flowering plants continued to decline to between 0 and 303 individuals in 2011, but rose slightly in 2013 to between 177 and 819 individuals. In 2018, the estimated population was 38 while the actual census count of flowering plants was 12.

The census results, when available, are within the 95% confidence intervals of the population estimates from the sample plots (except in 2011), suggesting that the two methods yielded similar results and the sample plots produced an accurate estimate of the entire population.

Table 2 Census estimates of the flowering Northern Wormwood in the Beverly population from 2000 – 2018. Censuses were conducted by two different observers (OBS) since 2005.

Year	Observer 1 plant counts	Observer 2 plant counts	Average plant counts
2000	1260	*N/A*	1260
2001	*N/A*	*N/A*	*N/A*
2002	*N/A*	*N/A*	*N/A*
2003	*N/A*	*N/A*	*N/A*
2004	*N/A*	*N/A*	*N/A*
2005	1623	1710	1667
2006	*N/A*	*N/A*	*N/A*
2007	1585	1656	1621
2008	1084	1022	1053
2009	763	764	764
2010	401	405	403
2011	350	352	351
2012	436	429	433
2013	538	546	542
2014	326	317	322
2015	261	260	261
2016	74	73	74
2017	195	189	192
2018	12	12	12

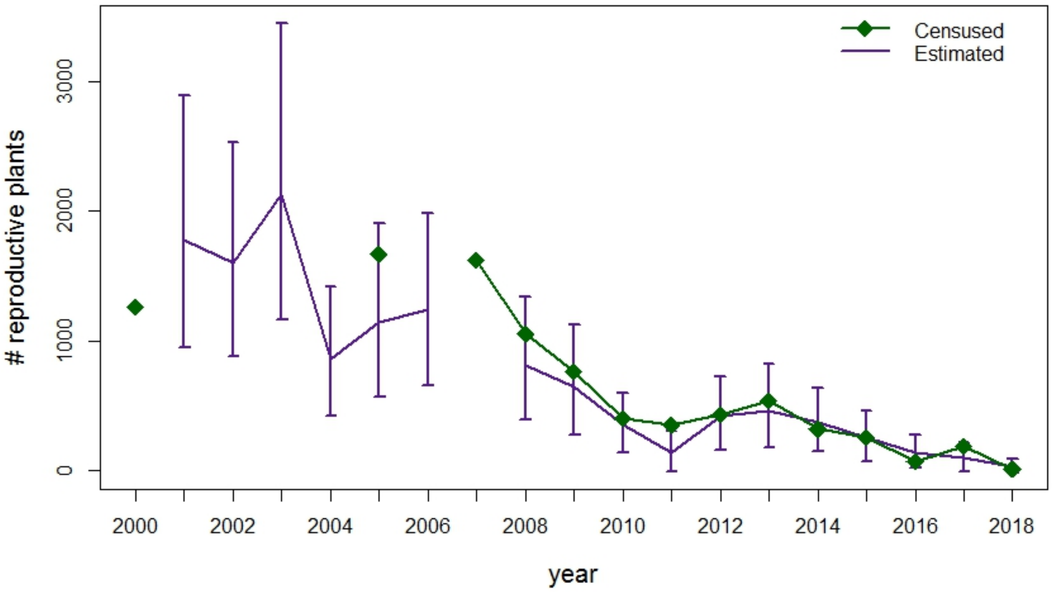

Figure 4 **Estimated and censured number of reproductive plants of Northern Wormwood at the Beverly population. Error bars on estimates represent 95% confidence intervals. The estimates are derived from the mean and variability of flowering plants in the 31 sampling plots. Census values for 2005 – 2018 represent the average of the two counts from two observers.**

5.2 Population Dynamics and Growth Rates

Transition matrices developed for each pair of years in these data indicate that the population dynamics of this species at Beverly are highly stochastic (Kaye and Pfingsten. 2018). During the period of time the population has been monitored the annual growth rate has varied widely between a low of 0.206 and high of 1.432 (Kaye and Pfingsten. 2018) reflecting both population declines (values under 1) and increases (values over 1). These values are both very low and very high, depending on the year. As in previous reports, this is cause for concern because highly stochastic populations are generally at greater risk of extinction than more stable populations. The current flowering plant size of only 12 individuals shows that this risk pointed out earlier has been borne out with time.

Stage transitions followed a general pattern that validated our life history model (Kaye and Pfingsten. 2018). If plants survived, seedlings mostly became small vegetative plants; small and large vegetative plants mostly remained in the same stage or switched vegetative stages; small and large reproductive plants mostly remained reproductive, although transitions to small vegetative plants were also common; and large reproductive plants produced over 3 times as many seedlings as small reproductive plants (Kaye and Pfingsten. 2018).

The relatively low growth rates (<0.5) in 2003, 2009, 2015, and 2017 coincided with relatively high mortality (> 0.5) of plants in almost all stages, especially in 2017 where small and large reproductive plants had 83.3% and 100% mortality, respectively (Kaye and Pfingsten. 2018). Likewise, years 2002 and 2011 when mortality was low (< 0.2) across stages, especially reproductive stages, corresponded to high growth rates (> 1.0). In general, either the seedling and vegetative stages had the highest mortality or all stages had similar mortality. In 2009, for example, seedling mortality was 97.1%, while small and large vegetative plants suffered 78.6% and 75.0% mortality, respectively (Kaye and Pfingsten. 2018). However, seedling mortality was below 5% in 2001 and 2011. There was > 30% difference between vegetative and reproductive stage mortality in 2001 and 2009, while there was < 30% difference among stage mortality in 2003, 2008, 2010, 2013, 2014, and 2018.

Estimates of seedling recruitment varied by two orders of magnitude among the available transition matrices. For example, fecundity of large reproductive plants was 29.1 seedlings per plant in 2011, 4.8 in 2002, and only 0.1 in 2004 (Kaye and Pfingsten. 2018).

5.3 Elasticities

Elasticities suggest that population growth in Northern wormwood was most sensitive to changes in stasis of large reproductive plants and of small vegetative plants, depending on the year, although there were exceptions (Kaye and Pfingsten. 2018). Population growth in 2001 and 2011 was most influenced by fecundity of large reproductive plants instead of stasis. Stasis of small reproductive and large vegetative plants was most influential to population growth in 2015 and 2016, respectively, and may be due to ambiguous identities of vegetative plants in more recent years that had yet to flower. Years when elasticity of small vegetative plant stasis was greatest may be associated with high-water years at the Beverly population, but this hypothesis needs additional research (see Kaye and Pfingsten, 2012). Other patterns of elasticity varied from year to year, suggesting that the basic behavior of the population changed over time. For example, elasticity of seedling survival overall varied from 0.001 in 2016 and 2017 to 0.254 in 2001 Finally, fecundity of large reproductive plants was at its lowest elasticity in 2017 at 0.000 and highest in 2001 at 0.171 (Kaye and Pfingsten, 2018).

5.4 Population Viability Analysis

The stochastic population growth rate for the population of Northern wormwood at Beverly is estimated to be 0.668 with a 95% confidence interval of 0.665 and 0.670. This is a large decrease from the rate of 0.895 and 0.827 in the 2012 and 2015 analyses, respectively (Kaye and Pfingsten 2012, 2015), and it is well below 1.0, which suggests that the population has very low viability in the long term unless conditions at the site change. Dramatic differences between the annual lambda values suggest that this population experiences substantial year-to-year variation and that our uncertainty about future population growth is high.

The risk of catastrophic decline (50% loss) of the population in 50 years was estimated at 100.0% (Table 3 and Figure 5). Even in a 10-year window the population has a 92.0% chance of declining by 50%, and within the study period (18 years) have already observed about a 99% population decline based on the census of flowering Northern wormwood plants (Table 1 and Figure 4). The risk of quasi-extinction of the population (99% decline) over a 50-year period was 100.0% but only 26.7% in a 10-year period. The risk of 90% decline in the same periods was intermediate (69.0%), although much higher by 50 years (100%).

Table 3 **Extinction Probabilities (EP) and Standard Errors (SE) for Northern Wormwood at the Beverly population in 10 and 50 year forecasts. Declines of 50%, 90%, 99% are different levels of quasi extinction.**

	10-year risk		50-year risk	
Decline	*EP*	*SE*	*EP*	*SE*
50%	92.0%	0.3%	100.0%	0.0%
90%	69.0%	0.5%	100.0%	0.0%
99%	26.7%	0.4%	100.0%	0.0%

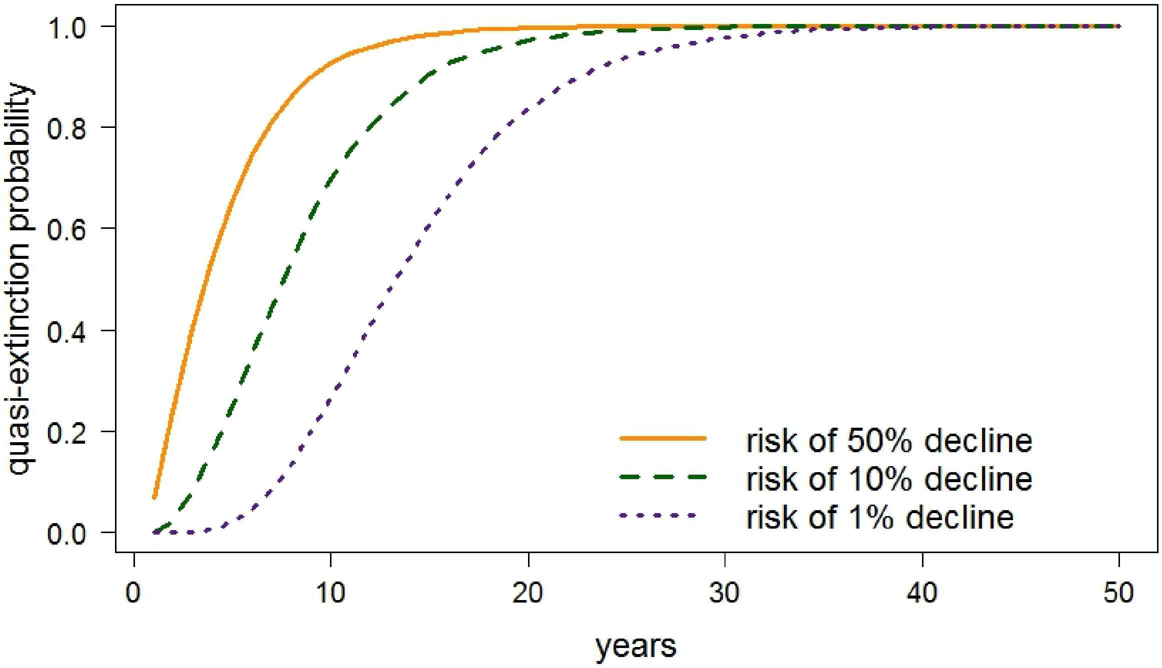

Figure 5 **Quasi extinction probabilities of *Artemisia campestris var. wormskioldii* at the Beverly population estimated from 10,000 iterations to 50 years. The lines indicate the probability that population size will decline to 50%, 10%, and 1% of the initial population size, 8,124, which was estimated from the 2000 census of flowering plants.**

The projected population size of the Beverly population is likewise uncertain and expected to decline further over time due to the low stochastic population growth rates. About 95% of the simulated populations were between 0 and 20,000 plants after ten years and between 0 and 2,000 plants after 20 years (Figure 6). After 50 years, the simulated populations were all less than 2 plants.

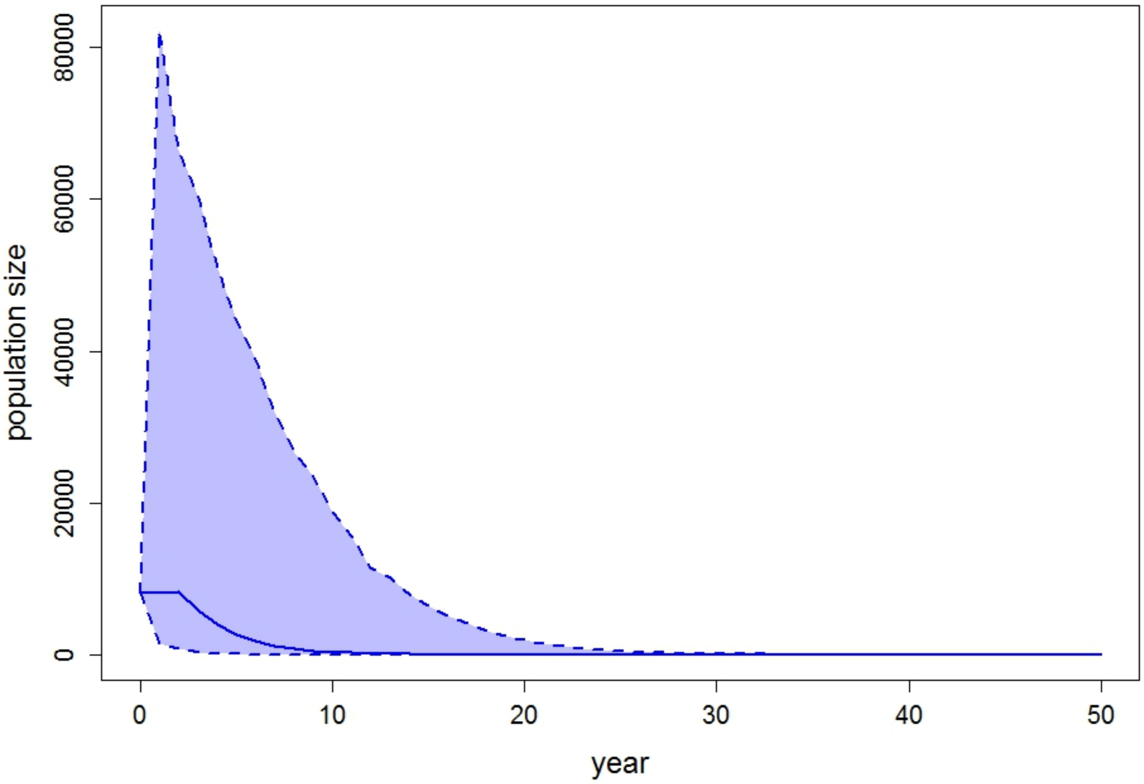

Figure 6 Projected population size of *Artemesia campestris var. wormskioldii* at the Beverly population estimated from 10,000 iterations to 50 years. The solid line represents the median, and dashed lines represent the 2.5th and 97.5th quantiles. The initial population size was 1200-2000 individuals.

6.0 Discussion

Northern wormwood appears to be near extinction throughout its range. Currently, several threats appear to affect this species' viability, but among them are its small population sizes and limited distribution. Northern wormwood is unlikely to recover without direct intervention that improves population sizes and establishes new populations within its historic range, while also addressing threats such as invasive species. The population of Northern wormwood at Beverly, Washington, has fallen to near-extinction levels. Over the 18 years of observation it has declined while experiencing substantial year-to-year variability in population growth rate, elasticities, flowering plant abundance, mortality rates, and seedling recruitment. Two years saw very high population growth (over 30% increase) while seven years had substantial declines (over 30% decrease), and this variation in performance lead to uncertainty in projected population size as well as long-term population decline from the combination of multiple low growth rates and high variability.

Extinction of the Beverly population in the very near term (ten years) is a very real possibility given the past performance, trajectory, and significant observed population declines. The risk of 99% population loss in ten years was estimated to be 26.7%, but in a fifty-year period this probability rose to 100.0%. The chance that the population will decline by half was 92.0% in ten years. Two factors drive these risks: how far from stability ($\lambda = 1$) population growth rates are in any given year, and the variability in growth rates among years. In the case of Northern wormwood, two of the fifteen observed growth rates were above 1, but the growth rates overall have been low and stochastic enough that extinction is likely in the near future.

It is important to note that the population viability analysis reported here is made tentative because Northern wormwood occurs in a mixed population with a similar plant, Scouler's wormwood, at the Beverly site. These two plants cannot be distinguished in their non-flowering state through visual inspection. This forces several assumptions on our analysis, and especially impacts estimates of fecundity (seedlings produced by each variety) used in our models. Even so, the fact that the census population sizes matched the sampled and modeled trajectories suggests that the models are robust to this ambiguity.

Estimates of population size for Northern wormwood at Beverly remain difficult to make at this time because of the number of ambiguous, vegetative individuals that could be either Scouler's wormwood or Northern wormwood. The number of flowering individuals of Northern wormwood can serve as a useful index of population size. This value has ranged from a low of 38 (95% Confidence Interval (C.I.): 0-90) in 2018 to a high of 2,128 (95% C.I.1,166-3,441) in 2003. The previous (2018) census of flowering wormskioldii plants, stands at 12 individuals, suggesting that the overall population size (including vegetative plants and seedlings) is larger, but it may have reached an extinction threshold where demographic stochasticity makes reproduction and thus population growth uncertain (see Menges 2000, Caswell 2001). Although these population estimates have some uncertainty, they are very close to the population censuses of flowering plants.

7.0 2019 – 2029 Conservation Agreement and Measures

Results from the Northern Wormwood Conservation Plan will consist of the following: (1) Continued Annual Census Monitoring and Reporting, (2) Limited Access Control, (3) Weed Control, (4) Seed and/or Plug Outplanting, (5) Seed Production Facilities, (6) Alternative Seeding and Outplanting Locations, (7) Alternative Management Actions and Life History, (8) Annual Reporting and NWWG Coordination Activities, and (9) Federal Energy Regulatory Commission Reporting 2029.

Table 4 2019 – 2029 Northern Wormwood Conservation Measures Schedule

Task	Purpose	Duration	Start	Finish
FERC review/approval for 2019-2029 Northern Wormwood Conservation Plan Implementation Schedule	Per Priest Rapids Project License Order Article 412	90 days (estimated)	12/31/18	3/30/19
Annual Northern Wormwood Census Monitoring	To describe the population status of northern wormwood at the Project.	Annually for 10 years	5/2019	5/2029
Maintain 5,000 linear feet of fencing at the Beverly population site	To control vehicle access	Annually for 10 years	Ongoing	5/2029

Task	Purpose	Duration	Start	Finish
Implement Northern Wormwood Weed Management Plan	To control noxious weeds at Beverly population site	Annually for 10 years	Ongoing	5/2029
Propagate Northern Wormwood seeds and plugs for out-planting and population augmentation and potential reintroduction efforts	To increase and recover the local population(s) of Northern Wormwood at the Beverly site and explore other potential locations for reintroduction.	Annually for 10 years	1/01/2019	12/2029
Monitor Northern Wormwood demographics direct seeding and/or out-planting efforts.	To evaluate the effectiveness of direct seeding and/or out-planting efforts in order to inform future augmentation and reintroduction efforts.	Annually for 10 years	TBD by the NWWG - Ongoing	12/2029
Explore alternative reintroduction site locations within the Priest Rapids Project.	To experimentally evaluate alternative locations, soil type, terrain, or other environmental factors and to establish surrogate populations.	TBD by the NWWG - Ongoing	TBD by the NWWG - Ongoing	12/2029
Alternative management actions and life history.	To evaluate native plant control, potentially reduce competition, determination of pollination and pollinator species, effects of flooding and water levels for failure or successes.	TBD by the NWWG - Ongoing	TBD by the NWWG - Ongoing	12/2029
NWWG Coordination and Annual Reporting	Bi-annual meetings and site visit to share seed/plug propagation, population, weed control, and other relevant data to inform future activities.	Bi-annually for 10 years	TBD by the NWWG - Ongoing	12/2029
File 2029 Northern Wormwood Conservation Agreement Results Report with FERC	Include recommendations for further monitoring and protection measures, including, population status, out-planting results, access control measures, data management or other research, and implementation schedule			12/31/2029

7.1 Annual Census Monitoring and Results

The census counts focus on flowering plants that can be confidently identified as Northern wormwood, and have provided a useful validation and accurately reflect the demographic models. The census population counts are clearly a reliable indicator of population size and trajectory, and they require less time, expertise, and cost to implement and analyze than the demographic sampling. The census does not utilize plots but instead encompasses the entire population including all sub-patches, and this method of tracking population trends will be continued. Grant PUD will share the results of the annual census with the identified parties as described in the Annual Reporting and Coordination Activities described below.

7.2 Limited Access Control

Grant PUD will continue to work cooperatively with the USBR to develop a policy to discourage motorized vehicles or overnight use of the Beverly Complex Islands. Grant PUD will inspect and maintain the approximately 5000 feet of fencing around the Beverly Island Complex that was installed in cooperation with the USBR during efforts in 2001. Grant PUD's maintenance inspections of the fencing will occur at a minimum of monthly, and more frequently during the main recreational season of April-October if needed, and will continue until 2029. Grant PUD's river patrol regularly includes the Beverly Island Complex as part of their monitoring patrols, and will enforce these use restrictions.

7.3 Weed Control

Grant PUD staff has continued to managed two main invasive plant species at the Beverly Island site, Dalmation toadflax (*Linaria dalmatica* spp. *dalmatica*) and diffuse knapweed (*Centaurea diffusa*), annually from 2008 to 2018 (M. Woodward pers. comm.). Diffuse knapweed has been hand pulled once or twice per year and the species' abundance has gradually declined over the years. Currently, there are an estimated 300 diffuse knapweed plants remaining at the Beverly site. Dalmation toadflax has been hand pulled for several years until that method was no longer recommended as it was thought to cause the plant to produce more stalks from the root system. Following hand removal efforts, herbicide treatments were used until 2016 when a biocontrol agent (Dalmation toadflax stem weevil, *Mecinus janthiniformis*) was released. In 2018, the stem weevil is still present.

Weed management at the Beverly site has become very important as this Northern wormwood population, once the largest and most robust, has crashed to only 12 flowering individuals in 2018 (Kaye and Pfingsten 2018), who also noted that the locations with the highest weed infestations contained zero Northern wormwood individuals. These weed species may outcompete Northern wormwood for limited resources such as space and moisture, thus limiting survival, recruitment, and persistence of Northern wormwood.

Manual, mechanical, biological, cultural (e.g., prescribed fire, competitive plantings), and chemical treatment methods will be utilized to achieve prioritized weed control objectives as determined by the Northern Wormwood Working Group (NWWG) which will meet twice annually. Invasive species managers will draw upon the full range of appropriate control technologies to develop treatment plans for active weed species at selected priority sites. Treatment methodologies will be based upon the best information available from weed management literature and professional experience, tailored to the characteristics of the particular species and site.

The NWWG will develop a Threat Matrix (Appendix A, Grant PUD Weed Management Plan) in 2019 that will help determine the priority areas and control methods for weed management. In subsequent years, the NWWG will assemble weed monitoring data and conduct a site visit to evaluate the effectiveness of treatment methods and record current site conditions. Following the site assessment, the NWWG will update the Threat Matrix for each area at the Beverly site and determine the highest priority area(s) for invasive plant control measures and which control measures should be implemented the following year.

The NWWG will use this information to adjust priorities and objectives using the Threat Matrix (Appendix A, Grant PUD Weed Management Plan), to modify treatment methodologies for greater effectiveness and to improve precision in budgeting and planning processes. The most recent Threat Matrix would represent the best information available regarding invasive and nonnative plant infestations that occur in occupied and potential Northern wormwood habitat. However, invasive and nonnative plants that may occur in subsequent growing seasons may vary from the species identified in the current Threat Matrix due to habitat and moisture conditions, microsites, and other factors. Annual site visits to update the Threat Matrix should occur in order to evaluate the site conditions for future control measures. Management of invasive and nonnative plants at sites will rely on information gathered from most current site visits, the Threat Matrix, and consensus from the NWWG.

In the event that new invasive and nonnative species is discovered at the Beverly Site, Grant PUD will notify the NWWG with the species name, location, approximate size of population, and occupied habitat within 30 calendar days. Grant PUD will also recommend a management strategy including, but not limited to: potential control actions, timing, identify potential source of infestation, and ideas for preventing future infestations. A full description of the Threat Matrix as well as potential control and treatment methods for Grant PUD’s Weed Management Plan for the Beverly site has been developed by the NWWG and is included as Appendix A.

7.4 Seed and/or Plug Production Activities

Given the very small population sizes of Northern wormwood at the two remaining wild populations, as well as those populations established in recent years to increase plant numbers along the Columbia River, increasing the availability of plants for conservation purposes is vital. Seed and plug production beds can substantially increase the amount seed available for direct seeding or plug out-planting into field sites for augmentation and reintroduction. Grant PUD conducted experimental plug out-planting at different elevations along the Columbia River in 2004 and 2006 (Figure 2) near the main Beverly population, however, these plants were not observed after 1 – 2 years following planting.

Due to the sharp decline of reproductive plants over the past few years, Grant PUD contracted with Benson Farms Incorporated (BFI) in 2017 to immediately establish a seed production bed to produce seed and plants of Northern wormwood for direct seeding or plug out-planting. Based on the amount of seed and/or plugs needed for future direct seeding and plug out-planting, Grant PUD and the NWWG will expand the seed beds to two sites with a goal of producing 500 – 1000 (or more) seeds and/or plugs annually. Establishing more than one seed and plug production bed creates redundancy as a prudent contingency in case of catastrophic failure at either production site. Grant PUD and the NWWG will work toward acquisition of alternative seed sources for seed and plug production. One potential source of additional accessions is located in cryogenic storage at the Rae Selling Berry Seed Bank in Portland, Oregon which currently stores seeds from both the Beverly and Miller's Island populations. The additional accessions could be used at BFI with the goal of producing more seeds and plugs, while preserving the genetic diversity of the Beverly population.

7.5 Demographic Monitoring of Direct Seeding and Outplanting Efforts

Demographic monitoring of direct seeding and outplanted efforts can help document augmentation and reintroduction success and support recovery decisions. Direct seeding into existing high-quality habitat has a wide range of success for many species, from very few plants to high numbers of established plants, although the percentage of seeds establishing plants is typically below 10%. Predicting where a species will establish is difficult, in part because the portion of a habitat that is best for plant establishment can vary subtly across a site, and even differ among years. Therefore, seeding across environmental gradients or patches of habitat in long, narrow plots, as well as in multiple years, can increase the likelihood of success in at least some portion of the site (Kaye 2008). Grant PUD and the NWWG will conduct direct seeding and/or planting plugs of Northern wormwood in plots (that are 5 m by 40 m or other) and oriented perpendicular to the river shore. This method could be an efficient strategy because plants would experience a variety of moisture and flood regimes. Alternatively, seeds or plants could be placed in a similar size and shape plot but oriented across habitat patches within the site. The number of seeds and/or plugs will be determined by annual seed and plug production and discussed within the NWWG.

Reintroduction or augmentation attempts may succeed or fail for multiple reasons. Tracking the demography of Northern wormwood under a wide range of conditions should assist to understand how environmental conditions affect all stages of its life, including germination, seedling, reproductive adult, and death. Reintroduction attempts will be more predictably successful if the NWWG can achieve an understanding of the mechanisms or population growth in different environments. Demographic monitoring transects established in seeded or plugged locations can be used to track plant establishment, survival, size and flowering, as well as seedling recruitment. Some planting sites or transects may lack populations of Suksdorf's wormwood, making data collection and analysis easier than where the species are mixed. Photopoints may also provide a source of value to not only monitor direct seeded and out-planted transects and/or plots, but to capture potential abundance of native and non-native species and the localized habitat. The demographic monitoring will occur for a minimum of three years following outplanting or direct seeding of individual transects and reviewed annually by the NWWG to help inform future augmentation and reintroduction efforts.

In areas where weeds have been controlled in patches of habitat, reseeding with native species will be necessary to restore habitat and reintroduce Northern wormwood. Reestablishing Northern wormwood into habitat patches opened up through weed control efforts has the potential to return the species to portions of the Beverly site where it has been lost and where the physical environment may remain appropriate for the species successful growth.

7.6 Alternative Seeding and Outplanting Efforts

Grant PUD and the NWWG will evaluate direct seeding and outplanting of seeds and/or plugs at alternative locations within the Priest Rapids Project when seed or plugs become available in order to establish surrogate populations as a means to offset the overall severe decline of the Beverly population and to serve as another potential source for seed collection if warranted. Several sites have been identified within the Project (Arnett, 2015) and proposed for potential reintroduction in recent years by the WNHP. Establishment of additional surrogate populations will also help evaluate different environmental factors such as moisture regime, soil, microhabitat, and potential disturbance types. Out-planting of propagated plugs was conducted in 2004 and 2006 (Figure 2), and survival was poor based on few individuals. These renewed efforts of augmentation and reintroduction will serve to inform and determine preferred reintroduction techniques and suitable habitat for Northern wormwood while also creating additional sustainable populations.

7.7 Alternative Management Actions and Life History

Grant PUD and the NWWG will evaluate alternative management actions that may aid conservation efforts such as, but not limited to, native plant control (i.e., Scouler's wormwood (A. campestris var. scouleriana)) to reduce competition, determination of pollination process and pollinator species, effects of flooding events and water levels on Northern wormwood survival and recruitment. Alternative management actions and life history evaluations may inform potential reasons for failures and successes of augmentations and reintroductions of Northern wormwood, and thereby increasing the effectiveness of management actions leading to the conservation of the species.

7.8 Annual Reporting and NWWG Coordination Activities

Grant PUD will provide an updated census report annually and report on relevant information relating to Northern wormwood conservation at the Beverly site to the NWWG at bi-annual meetings (likely February and August of each year). The NWWG consists of representatives and interested parties of the United States Fish and Wildlife Service (USFWS), Washington Natural Heritage Program (WNHP), Bureau of Reclamation (USBOR), and Grant PUD. Other parties (such as BFI, Institute for Applied Ecology, etc.) with expertise of Northern Wormwood will be encouraged to attend. Information such as, but not limited to, weed management (new occurrences, management actions, effects of management actions, and updated Threat Matrix from previous site visit), and population augmentation and reintroduction efforts (monitoring and seed and/or plug production, etc.) will all be relevant topics for the NWWG to review to inform future years activities. The NWWG will utilize an adaptive management approach as needed to implement measures identified in this Conservation Agreement. In the event that conservation measures are identified which may provide a significant benefit to Northern wormwood, however, unknown during the drafting of this Conservation Agreement, the NWWG may agree to implement those measures.

7.9 Federal Energy Regulatory Commission Report 2029

Following census monitoring, fence maintenance, noxious weed control, seed and plug augmentation, and demographic monitoring, Grant PUD, in consultation with the USBR, USFWS, and WNHP, will meet in the summer of 2028 to discuss the Conservation Plan results to date, whether or not to continue or modify the Conservation Plan (based on current information), and then, will file a report to the Federal Energy Regulatory Commission no later than December 31, 2029 describing the results of these activities and any recommendations for further protection measures, including additional access control measures, population augmentation, or other research to further support long-term conservation of the species at the Project based on the monitoring results. The report will include an implementation schedule for the recommended measures.

List of Literature

Arnett, Joseph. 2008. Letter RE: Priest Rapids Hydroelectric Project No. 2114, Article 412 License Compliance Filing – Northern Wormwood Conservation Plan. Received July 21, 2008.

Arnett, Joseph. 2015. White paper review of potential outplanting sites for *Artemisia campestris var. wormskioldii*. Prepared for the U.S. Fish and Wildlife Service, Western Washington Fish and Wildlife Office. Received March 31, 2015.

Caplow, F. 2001-2002. Personal communication. Botanist, Washington Natural Heritage Program, Olympia, WA.

Carpenter, A.T., and T.A. Murray. 1998. Element stewardship abstract for *Bromus tectorum* L. (*Anisantha tectorum* (L.) Nevski). The Nature Conservancy, Davis, CA. 27 pp.

Carlson, M. 1997. Status report for *Artemisia campestris var. wormskioldii* (Bess.) Cronq.

Unpublished report prepared for the Oregon Natural Heritage Program, Portland, Oregon. 32 pp.

Caswell, H. and T.N. Kaye. 2001. Stochastic demography and conservation of an endangered perennial plant (*Lomatium bradshawii*) in a dynamic fire regime. Advances in Ecological Research 32:1-51.

Caswell, H. 2001. Matrix population models. Second edition. Sinauer Associates Inc., Sunderland, Massachusetts.

Cronquist, A. 1950. Notes on the Compositae of the northwestern United States. Leaflets of Western Botany 6: 41-50.

Elzinga, C.L., D.W. Salzer, and J.W. Willoughby. 1998. Measuring and monitoring plant populations. In USDI-BLM Technical Reference 1730-1. USDI–BLM: Denver; 477.

Federal Energy Regulatory Commission. 2008. Order Issuing New License for the Public Utility District No. 2 of Grant County, WA (Project No. 2114). April 17, 2008.

Gamon, J. 1989. Report on the status of *Artemisia campestris* L. var. *wormskioldii* (Bess.) Cronquist. Unpublished report prepared by the Washington Natural Heritage Program, Olympia, Washington. 29 pp.

Grant PUD. 2003. Research Summary and Threats Assessment for *Artemisia campestris var. wormskioldii* (Bess. ex Hook.) Cronq. In the Priest Rapids Project Area, Final Report, February 2003, FDE&S.

Grant PUD. 2005. 2005 Northern Wormwood Census Results. Internal document, Public Utility District No. 2 of Grant County.

Hall, H.M., and Clements, F.E. 1923. The phylogenetic method in taxonomy: the North American species of *Artemisia*, *Chrysothamnus*, and *Atriplex*. Carnegie Institution of Washington, Washington, D.C. 355 pp.

Howard, J.L. 1998. *Artemisia campestris*. In: Fire effects information system. Online document available at www.fs.fed.us/database/feis. Accessed 18 September 2000.

Integrated Taxonomy Information System. 2008. *Artemisia campestris* var. *wormskioldii*. Online data available at http://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=566593. Accessed 27 May 2008.

Kaye, T. 1995. Monitoring plan for northern wormwood at Miller Island, Columbia River Gorge National Scenic Area. Unpublished report prepared by the Oregon Department of Agriculture Natural Resources Division, Salem, OR. 32 pp.

Kaye, T.N. 2001b. Review of the monitoring plan for *Artemisia campestris* ssp. *borealis* var. *wormskioldii*. Report prepared by Institute for Applied Ecology, Corvallis, Oregon for Duke Engineering & Services, Bothell, Washington.

Kaye, T.N. and D.A. Pyke. 2003. The effect of stochastic technique on estimates of population viability from transition matrix models. Ecology 84:1464-1476.

Kaye, T.N. 2004. Population viability analysis for Northern Wormwood (*Artemisia campestris* var. *wormskioldii*) at Beverly, Grant County, Washington. Institute for Applied Ecology, Corvallis, Oregon under contract to Grant County PUD.

Kaye, T.N. and I.A. Pfingsten. 2008. Population viability analysis for Northern Wormwood (*Artemisia campestris* var. *wormskioldii*) at Beverly, Grant County, Washington for 2001-2007. Institute for Applied Ecology, Corvallis, Oregon under contract to Grant County PUD.

Kaye, T.N. and I.A. Pfingsten. 2012. Population viability analysis for Northern Wormwood (*Artemisia campestris* var. *wormskioldii*) at Beverly, Grant County, Washington for 2001-2012. Institute for Applied Ecology, Corvallis, Oregon under contract to Grant County PUD.

Kaye, T.N. and I.A. Pfingsten. 2015. Population viability analysis for Northern Wormwood (*Artemisia campestris* var. *wormskioldii*) at Beverly, Grant County, Washington for 2001-2015. Institute for Applied Ecology, Corvallis, Oregon under contract to Grant County PUD.

Kaye, T.N. and I.A. Pfingsten. 2015. Population viability analysis for Northern Wormwood (*Artemisia campestris* var. *wormskioldii*) at Beverly, Grant County, Washington for 2001-2018. Institute for Applied Ecology, Corvallis, Oregon under contract to Grant County PUD.

Keeler, C. and M. Woodward. 2007. Northern Wormwood (*Artemisia campestris* var. *wormskioldii*) Status of Experimental Out-planting at the Beverly Island Complex, Columbia River, WA. Public Utility District No. 2 of Grant County, Ephrata, WA 98823.

Malkin, D. 2003. Research summary and threats assessment for *Artemisia campestris* L. ssp. *borealis* var. *wormskioldii* (Bess.) Cronq. in the Priest Rapids Project Area. Prepared for Grant County Public Utility District No. 2 by Framatome ANP DE&S, Bothell, Washington.

Menges, E.S. 2000. Population viability analyses in plants: challenges and opportunities. Trends in Ecology and Evolution 15:51-56.

R Core Team. 2018. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/

Reynolds, D. 2002. Report on 2002 germination and propagation of *Artemisia campestris* var. *wormskioldii*. Unpublished report prepared for Framatome ANP DE&S. Rainshadow Nursery, Ellensburg, WA. 1 p.

Rush, T. 1999. Conservation Strategy and Monitoring Plan for *Artemisia campestris* var. *wormskioldii* (northern wormwood). Unpublished report prepared by the Washington Natural Heritage Program, Olympia, Washington. 19 pp.

Shultz, Leila M. 2006. *Artemisia*. In: Flora of North America Editorial Committee, eds. 1993+. Flora of North America North of Mexico. 12+ vols. New York and Oxford. Vol. 19, 20, and 21, pp 6, 26, 50, 53, 398, 486, 487, 498, 503, 504.

Tuljapurkar, S. 1997. Stochastic matrix models. Structured-Population Models in Marine, Terrestrial and Freshwater Systems (Ed. by S. Tuljapurkar and H. Caswell), 59-87. Chapman & Hall, New York.

Yun, K.W., and M.A. Maun. 1997. Allelopathic potential of Artemisia campestris ssp. Caudate on Lake Huron sand dunes. Canadian Journal of Botany 75:1903-1912.

Appendix A
Grant PUD Northern Wormwood Weed Control Plan

Invasive and Nonnative Plant Species Inventory and Management Plan for the Benefit of Northern Wormwood (*Artemisia borealis* var. *wormskioldii*) at Beverly, Grant County, Washington for

2019-2029

Introduction

Artemisia borealis var. *wormskioldii* (Bess. ex Hook.) Cronq. (Asteraceae: Anthemideae) (Northern wormwood) was recently a federal Candidate for listing under the Endangered Species Act (ESA) and is an Endangered taxon in Washington State. There are currently only two known natural populations and both occur along the Columbia River in Klickitat and Grant Counties in Washington. One population is located on Miller Island in Klickitat County at milepost 206. The Miller Island population covers about 0.10 hectares (ha) (0.25 acres [ac]) of land and is managed by the Columbia River Gorge National Scenic Area of the Gifford Pinchot National Forest.

The Grant County natural population (herein referred to as the Beverly population) is the northernmost population located near the town of Beverly (RM 412.75; herein referred to as the Beverly site) and covers about 1.1 ha (2.8 ac). The Beverly site is located on land owned by the Bureau of Reclamation (BOR) and is managed by the Grant County Public Utility District No. 2 (Grant PUD). The site is within the boundaries of the Priest Rapids Hydroelectric Project, FERC No. 2114, and the project is owned and operated by Grant PUD. Based on the license articles contained in the new operating license for the Priest Rapids Hydroelectric Project (FERC No. 2114), the Northern Wormwood Conservation Plan was implemented from 2008 to 2018 with specific measures to monitor the Beverly population and control invasive and nonnative plant species to protect Northern wormwood at the Beverly site. This weed plan is a result of a check-in for the 10-year Northern Wormwood Conservation Plan in accordance with the new operating license where managers agreed modifications were necessary to address conservation concerns. Annual monitoring has indicated steep declines in this population even with conservation measures in place; subsequently, managers have agreed to pursue elevated conservation efforts on threats such as invasive and nonnative plant species.

Impacts of Invasive and Nonnative Plant Species

Invasive and nonnative plant species (also referred to collectively as weed species) pose one of the most serious threats to the native biodiversity, wildlife habitat, and scenic values for natural areas. At the Beverly site, as elsewhere in western North America, invasive and nonnative plant species compete against one another and reduce habitat available for rare plant taxa and native plant species in general. Weeds alter ecosystem structure and function, disrupt food chains and other ecosystem characteristics vital to wildlife (including rare and endangered species), and can dramatically alter key ecosystem processes such as hydrology, productivity, nutrient cycling, and fire regime (Randall 2001, Brooks and Pyke 2001, Mack et al. 2000). Weed species can be seemingly restricted to the margins of major plant communities for a time, even many years, before acquiring some poorly understood critical mass or the timely coincidence of favorable environmental conditions that allow them to explode onto the broader landscape (Brooks and Pyke 2001).

At the Beverly site, Grant PUD staff has managed two invasive plant species, Dalmation toadflax (*Linaria dalmatica* spp. *dalmatica*) and diffuse knapweed (*Centaurea diffusa*), annually from 2008 to 2018 (M. Woodward pers. comm.) Diffuse knapweed has been hand pulled once or twice per year and the species' abundance has declined over the years. Currently, there are an estimated 300 diffuse knapweed plants remaining at the Beverly site. Dalmation toadflax was hand pulled for several years until that method was no longer recommended as it was thought to cause the plant to produce more stalks from the root system. Thereafter, herbicide treatments were used until 2016 when a biocontrol agent (Dalmation toadflax stem weevil, *Mecinus janthiniformis*) was released. In 2018, the stem weevil was still present.

Weed management at the Beverly site has become very important as this Northern wormwood population, once the largest and most robust, has crashed to only 12 flowering individuals in 2018 (Kaye and Pfingsten 2018). It was noted that the locations with the highest weed infestations contained zero Northern wormwood individuals. These weed species may outcompete Northern wormwood for limited resources such as space and moisture, thus limiting survival, recruitment, and persistence of Northern wormwood. The purpose of this document is to provide an integrated and adaptive weed management approach for the duration of the Northern Wormwood Conservation Plan (2019-2029).

Management Areas

The Beverly population is divided into three areas (See Figure 2 of the NW Population Viability Analysis and Conservation Plan): Northern, Core, and Hawk's Pole. Land ownership for the entire Beverly site resides with the BOR; however, Grant PUD exercises direct management over the 1.1 ha (2.8 ac).

The Northern area. The Northern area lies within the northern portion of the Beverly site and was previously the area for most, if not all, seed collections of Northern wormwood. Currently, the area is overridden with weed species' cover; in 2018, zero Northern wormwood plants were found there.

The Core area. This area is south of the Northern area and west of the Hawk's Pole area. Historically, there was a gravel road that ran through the central part of this area. Use of the road has been discontinued. This area contains the majority of individuals within the Beverly population but has seen steep declines in Northern wormwood individuals. Weed management is evident here as weed species' ground cover is much more reduced than the Northern area.

The Hawk's Pole area. This small area is east of the Core area, southeast of the Northern area, and directly below a Hawk's pole nesting platform. Historically, this area has not contained a large number of Northern wormwood, and in 2018, zero individuals were found here.

Management Program Overview

Conservation Targets

A weed control program must be based on the overall conservation and management goals of the area for which it is designed. The following generalizations have been made regarding the Beverly site conservation goals as a basis for this weed management plan:

- Properly functioning riparian habitat and the processes that characterize and maintain them, including their full array of native plant species.
- Zero to minimal competition from weed species for nutrients, moisture, and space.

While weed management practices vary, the most successful programs adopt an adaptive, integrated management approach with emphasis on the following points (adapted from Tu and Meyers-Rice 2002, USFWS 2001, DiTomaso 2000, Zamora and Thrill 1999, Randall 1996).

Prevention

The most effective method of weed control is to prevent their establishment. Measures to minimize the introduction of potentially invasive and nonnative species near the Beverly site may include limiting access to designated entry points, fencing off restricted areas, cleaning and disinfecting personal gear and equipment before accessing site, educational programs, and other measures.

Early Detection and Rapid Response

Weed populations are dynamic, and sporadic new introductions may be expected even when preventive measures are in place. Next to prevention, the most effective method for control of weed species is to detect and treat infestations as soon after establishment as possible. Ongoing surveys to detect new occurrences of weed species is an essential component in successful weed management plans (Snyder-Conn 2001). For surveys to be successful, there needs to be adequate training of weed control staff in species identification and documentation techniques. Techniques, such as taking pictures of specimen, creating a herbarium voucher, and accurately recording the location, are required. It is critical that the photos, herbarium specimens, and/or locations be sent to a botanist for confirmation of species.

The benefits of early detection can only be realized when detection is linked to the timely initiation of a treatment program for the newly detected weed species occurrence. An aggressive program of early detection and rapid treatment response is one of the most cost-effective strategies that can be applied in weed management.

In an era where funding for natural resources management is in decline, the benefits of early detection and rapid response become critically important. Early detection of weed species occurrences makes it possible for treatment to be applied before a spot infestation can spread more extensively across the landscape. Timely intervention increases treatment effectiveness while reducing treatment duration (Belnap and Phillips 2001, Moody and Mack 1988), thus reducing expenditures for staff time and materials. Timely intervention also minimizes chemical inputs to the environment, which in turn reduces the potential for treatment impacts to non-target resources such as native plants and aquatic resources.

Inventory and Monitoring

Ongoing monitoring of weed occurrences is necessary in order to assess the status of weed populations and to evaluate the effectiveness of integrated treatment methodologies. Documented occurrences of weed species must be visited and assessed at least annually. See Comprehensive List of Invasive Plant Species Occurrences (Appendix A) for a list of basic inventory information to be collected at each occurrence.

For each area receiving treatment, a precise record of the treatment history and the effects of treatment upon the target species should be compiled. The treatment data should include precise information regarding all methods used, including herbicide and adjuvant concentrations, dates of applications, and pretreatments or integrated measures, along with quantitative measures of the target species' response to the treatment(s). Weed responses may be assessed using infestation size and abundance (percent aerial cover, or for very small infestations, stem density) of the invasive species. All areas that are undergoing active treatment should be assessed at least two times per year: in the spring, and in the fall following the end of the drought period but before the onset of dormancy. Some successful programs monitor even more often. A monitoring schedule should be flexible enough to allow the timing of monitoring visits to fit the phenology of the target species.

A biological inventory represents only a snapshot in time. Weed plant populations are dynamic and will require monitoring annually or more often to accurately apprise management of patterns of abundance and threats to biological resources. Weed species can be seemingly restricted to the margins of major plant communities for many years before acquiring some poorly understood critical mass, or the timely coincidence of favorable environmental conditions, that allows them to explode onto the broader landscape (Brooks and Pyke 2001). Conditions created by wildfire favor the spread of many noxious weed species (Grace et al. 2001, Bushey 1995). Weed species that have not yet been recorded on the Beverly site have been recorded to occur in close proximity to its boundaries as in the town of Beverly. In the future, new species of weeds will continue to arrive from near and far (McNeely 2001, Mack et al. 2000).

The ongoing monitoring of weed populations and their responses to control programs is also necessary in order to evaluate the effectiveness of integrated treatment methods applied by weed management personnel. Managers should have this information in order to adjust treatment priorities and objectives in a changing landscape, to modify treatment protocols to maximize effectiveness, and to enable greater precision in budgeting and planning processes.

Management personnel involved in the conservation of Northern wormwood (Wormwood workgroup) will require timely information regarding the distribution and abundance of weed species and the effectiveness of control efforts in order to adequately protect the Northern wormwood population at the Beverly site. Establishing and maintaining a well-staffed and trained, weed monitoring program should be a high priority for the Beverly site managers.

Prioritization of Species and Areas

Two species of invasive plants have been identified at the Beverly site (Table 1; M. Woodward pers. comm.). If other invasive or nonnative plant species appear at this site, infestations will be prioritized. A prioritization strategy for control and elimination of weed species is essential to effectively allocate limited management resources. This plan combines species-based criteria with site-based criteria to prioritize specific weed occurrence sites for treatment. Resources can then be directed to infestations with the highest priority. The following factors are among the key criteria considered in the prioritization of areas for treatment:

- Invasive potential of the weed species.
- Ecological impacts of the weed species on native species and communities (especially in relation to specific conservation targets).
- The size of the infestation.
- Proximity of the infestation to valuable biological resources.
- Susceptibility of the invasive species to treatment.
- Potential impacts of treatment upon non-target species.

Legal obligations under Washington state weed law, and neighboring land management practices, such as agriculture, will also help guide site prioritization.

Table 1 **Target list of invasive and nonnative plant species for the Beverly site. Scientific names are from Kartesz (1999). Letter codes in the right hand column indicate weed regulatory status in Washington state (Appendix B), including Monitor (M) and species not listed (NL; NWCB 2003a).**

a. Active List

Scientific name	Common name	Weed Class
Centaurea diffusa	Diffuse knapweed	B
Linaria dalmatica	Dalmation toadflax	B

b. Watch List

Scientific name	Common name	Weed Class
Amorpha fruticosa	indigobush	B
Lythrum salicaria	purple loosestrife	B
Cytisus scoparius	Scotch Broom	B
Lythrum salicaria	purple loosestrife	B
Bromus tectorum	cheatgrass, downy brome	NL
Salsola tragus	Russian thistle, tumbleweed	NL

Integrated Treatment Program and Priority Species and Sites

Manual, mechanical, biological, cultural (e.g., prescribed fire, competitive plantings), and chemical treatment methods will be utilized to achieve prioritized weed control objectives. Invasive species managers will draw upon the full range of appropriate control technologies to develop treatment plans for active weed species at selected priority sites. Treatment methodologies will be based upon the best information available from weed management literature and professional experience, tailored to the characteristics of the particular species and site.

The most appropriate treatment for an infestation typically depends on the scale of the infestation and on the morphology and ecology of the target species (Youtie 1997). Manual pulling or digging may effectively control small infestations of invasive species with minimum impact to surrounding resources. Manual methods are labor-intensive, however, and are not effective against larger infestations or against deep-rooted perennials. Mechanical methods vary in their effectiveness but can be highly disruptive to soils and microbiotic crusts. Biological controls are rarely effective by themselves, are lacking for many species, and are typically not effective for small-scale infestations. Chemical control may be the most practical and effective option for small- to moderate-scale infestations of perennial plant species but must be applied so as to minimize impacts on non-target plant species as well as other organisms and systems.

In practice, effective treatment for many weed infestations will require a long-term integrated approach utilizing all methods that are available. For example, pulling, mowing, or burning at the most favorable time of year or plant developmental stage may enhance the effectiveness of later chemical treatments, thus reducing the chemical inputs required for eradication of a species or for a target level of control (Renz 2000).

Treatment success is greatly enhanced by aggressive early intervention at newly discovered, isolated satellite weed occurrences. As mentioned above, timely intervention may reduce or, in some cases, even eliminate the need for chemical inputs, reducing potential non-target impacts to desirable native species and to the surrounding environment.

Treatment of an uninfested buffer zone around the perimeter of existing infestations is recommended when control of spread is the management goal for large infestations. If the target species' seed dispersal characteristics are well known, the area of this perimeter can be estimated by the formula

$$a = \pi d2 (2y-1)$$

where d is the maximum distance to which 95% of the infesting species' seeds disperse, and y is the years of spread (Auld and Coote 1980). While information on dispersal distances may be lacking or not readily available, this principle should be held in mind. When reduction of the infestation is the goal, the treatment area should be incrementally extended into the infestation itself.

With many invasive plant species, successful control of even small infestations requires several years of treatment, often utilizing multiple treatments per year. A long-term perspective is particularly important for established populations of deep-rooted perennials and for species that are long-lived in the soil seed bank. In some cases, total eradication is not a realistic short-term goal. Treatment success depends as much upon long-term diligence as it does upon the methods used (Mack et al. 2000, Snyder-Conn 2001). The duration of treatment required for a successful outcome is generally reduced by early detection and timely treatment.

The removal of invasive species is one step in a process of ecological restoration of a site. Reintroduction of native plant species will inhibit recolonization of treated sites by invasive species (Brooks and Pyke 2001). However, where the natural physical and biological processes of sites are not restored, sites will remain vulnerable to reinfestation by invasive plant species.

Adaptive Management

The ongoing monitoring of weed populations and the results of the weed control program is a critical component of an adaptive management approach to Integrated Pest Management. To control weeds using an adaptive and integrated approach, the Wormwood workgroup will develop and ground-truth a Threat Matrix (Appendix C) in 2019 that will help determine the priority areas and control methods for weed management. In subsequent years, the Wormwood workgroup will gather weed monitoring data and conduct a site visit to evaluate the effectiveness of treatment methods and record current site conditions. The workgroup will then update the Threat Matrix for each area at the Beverly site and determine the highest priority area(s) for invasive plant control measures and which control measures should be implemented the following year.

Managers will use this information to adjust priorities and objectives using the Threat Matrix (Appendix C of this Plan), to modify treatment methodologies for greater effectiveness and to improve precision in budgeting and planning processes. The most recent Threat Matrix document would represent the best information available regarding invasive and nonnative plant infestations that occur in occupied and potential Northern wormwood habitat. However, invasive and nonnative plants that may occur in subsequent growing seasons may vary from the species identified in the current Threat Matrix due to habitat and moisture conditions, microsites, and other factors. Annual site visits to update the Threat Matrix should occur in order to evaluate the site conditions for future control measures. Management of invasive and nonnative plants at sites will rely on information gathered from most current site visits, the Threat Matrix, and consensus from the Wormwood workgroup.

Future Invasive and Nonnative Species Occurrences

It is possible, or considerably certain, that new or unknown invasive and nonnative species will be discovered at the Beverly Site. Upon discovery, Grant PUD will notify the Wormwood workgroup with the species name, location, approximate size of population, and occupied habitat. Grant PUD will also recommend a management strategy including, but not limited to: potential control actions, timing, identify potential source of infestation, and ideas for preventing future infestations. This information will guide the workgroup at the next annual meeting to approve the management strategy and determine whether there needs to be any modifications.

Reporting

Grant PUD will provide a report annually on relevant information relating to Northern wormwood conservation. Information such as, but not limited to, any new occurrences of weed species, monitoring efforts, weed management actions, effects of weed management actions and updated Threat Matrix from previous site visit.

Conclusions

This document presents a detailed plan for the management of invasive and nonnative plant species at the Beverly site that pose critical threats to the biological resources for Northern wormwood. Grant PUD will utilize an adaptive and integrated approach to identify and treat targeted weed species on the Beverly site. Manual, mechanical, biological, cultural (e.g., prescribed fire, competitive plantings), and chemical treatment methods will be utilized to achieve prioritized weed control objectives. Managers will draw upon the full range of appropriate control technologies to develop integrated treatment plans for target species. Treatment methodologies will be based upon the best information available from weed management literature and professional experience, tailored to the characteristics of the particular species and site. Treatment success will be carefully monitored and the Threat Matrix will be modified based upon evaluation of these findings.

The provisions in this plan can and should grow and change in response to changes in invasive species populations, new information concerning either invasive species autecology or biological resources, advances in weed management technologies, and clarification of Northern wormwood conservation goals.

Weed laws, personnel, conservation goals, and even the invasive species of greatest concern may change over time, but invasive plant species will remain a relatively constant threat to native biodiversity along the Columbia River. Effective management and control of invasive plant species at the Beverly site will require a dedicated, persistent, and long-term effort. Careful planning must be coupled with sufficient resources to sustain determined and long-term inventory and control efforts in the field. At the Beverly site, invasive plants are established and control effort costs can be significant. However, the consequences of failing to meet the challenges of invasive species will be the decline of an irreplaceable species. Overall, weed management costs should decline as control objectives are gradually met.

Invasive Plant Species Profiles

Introduction

This section presents brief profiles of current target invasive plant species for the Beverly site. Each profile includes a summary of the following information for each species:

- Biology and ecological impacts.
- Legal status in Washington. Definitions of Washington state noxious weed classes are presented in Appendix B.
- Treatment methods.

Common terms and abbreviations used in the text are given below. Definitions are from Hager and Sprague (2000) and Senese (2002).

A - acres

a.i. - active ingredient. The component of a chemical herbicide that is responsible for its toxic effect upon a target species.

a.e. - acid equivalents. The herbicidally active portion of the active ingredient in an herbicide formulation; a method of comparing the actual amount of herbicidally active material between different formulations of the same herbicide. This term is not synonymous with the term 'active ingredient.' Different formulations of an herbicide may contain different amounts of active material, even when the amount of active ingredient is the same. See Appendix D or Hager and Sprague (2000) for a more complete explanation.

amine - A formulation of an herbicide with enhanced water solubility. Amine formulations may be recommended when the aim is for the herbicide to move freely through the soil solution for uptake by the target's roots.

ester - A formulation of an herbicide with enhanced lipid (fats and oils) solubility. Ester formulations enhance an herbicide's ability to penetrate the waxy leaf cuticles developed by some plant species (e.g., dalmatian toadflax).

v/v - volume-to-volume. A calculation of the volume of a solute to be added to the total volume of a solution to produce a desired concentration. See Appendix D or Senese (2002) for a more complete explanation.

Active List of Invasive Plant Species at Beverly Site

DIFFUSE KNAPWEED *CENTAUREA DIFFUSA*

Diffuse knapweed is a highly competitive annual to short-lived perennial forb of the composite family (Asteraceae). Young plants first form low rosettes with deep taproots and may remain in this stage for one to several years. At maturity plants bolt, flower, set seed, then die. Diffuse knapweed may produce as many as 146,000 seeds m^2 (Schirman 1981). Seeds are spread in tumbleweed fashion and seed-bearing stems are spread long distances attached to undercarriages of vehicles; waterborne seeds are carried along streams and irrigation ditches (Roche and Roche 1999). Seeds may remain dormant in the soil for several years.

Diffuse knapweed has infested more than one million acres of grassland, shrubland, and riparian communities in the western United States, and the area infested is increasing rapidly (Roche and Roche 1999). Disturbed or overgrazed lands are prime candidates for colonization, but diffuse knapweed will also invade undisturbed areas (Zimmerman 1997, Sheley et al. 1997). Diffuse knapweed outcompetes desirable native species and is capable of forming dense stands which reduce biodiversity, degrade wildlife forage quality, and increase surface runoff and soil erosion (Roche and Roche 1999, 1988). Diffuse knapweed leaves contain an allelopathic chemical which may contribute to the species' competitive advantage (Watson and Renney 1974).

Diffuse knapweed is classified as a Class B Non-Designate noxious weed. State law calls for containment, gradual reduction, and prevention of further spread of Class B Non-Designate noxious weeds (NWCB 2003a).

Control

Since diffuse knapweed reproduces entirely by seed, the key to controlling existing infestations is to eliminate new seed production and deplete the existing seed bank (Carpenter and Murray 1998b).

Manual, Mechanical, and Cultural Methods

Hand pulling before seed set is an effective method of control for small or widely scattered, low-density infestations, but is very labor intensive (Roche and Roche 1999). Hand pulling can be most effective where a strong, committed pool of volunteer laborers is available (Tu 2001). The labor required to maintain control should decrease over the years. Hand pulling can also be used to maintain or further reduce low knapweed densities brought about by herbicide treatments (Youtie 1997). Areas to be hand pulled should be treated three times annually: 1) during spring when moist soil allows maximum taproot extraction; 2) during late spring/early summer when remaining plants have bolted; 3) in mid-late summer before overlooked plants have dispersed seed. Plants with seeds remaining in capsules should be bagged to keep the seeds from spreading (Youtie and Soll 1994, cited in Roche and Roche 1999).

CAUTION: A single account has anecdotally linked sap from diffuse knapweed, and perhaps related knapweed species, with a form of cancer. Anyone working with diffuse knapweed or other knapweed species should wear protective gloves and avoid getting knapweed sap into open cuts or abrasions (Carpenter and Murray 1998b).

Hand pulling programs should be repeated annually for as long as diffuse knapweed is a problem in the surrounding area. Seeds in the soil may remain dormant for several years and an area can become quickly reinfested. Monitoring of a site should continue for at least five years after an infestation has apparently been eradicated. A few knapweed plants can quickly destroy years of hard work if left undetected (Carpenter and Murray 1998b).

Cutting or mowing will not eliminate diffuse knapweed but can reduce seed production, and can be used to prolong the rosette season at which herbicide treatment is most effective (Roche and Roche 1999). Mowing actually increased populations of diffuse knapweed in at least one study (Zimmerman 1997). Deep plowing may be an effective control on highly disturbed lands as diffuse knapweed seeds do not germinate below 3 cm of soil (Zimmerman 1997, Watson and Renney 1974). However, shallow plowing actually increased the amounts of diffuse knapweed in test plots (Zimmerman 1997, Watson and Renney 1974).

Biological Methods

Biocontrol agents may prove useful in integrated control programs by weakening the plants and/or reducing seed output enough to make the plants more susceptible to herbicides, prescribed fires or other techniques (Carpenter and Murray 1998b). Numerous biological control agents for diffuse knapweed have been released in Washington. Although many of these agents sharply reduce seed production or inhibit root and shoot growth, none of them has been shown to significantly reduce diffuse knapweed densities.

Urophora affinis (banded gall fly) and *Urophora quadrifasciata* (knapweed seed head fly) are seed head feeding flies native to Eurasia. These species are widely distributed throughout Washington and can reduce seed production by up to 95% (Coombs et al. 2002, Rees et al. 1996).

Larinus minutus (lesser knapweed flower weevil), a weevil native to Greece, also preys upon diffuse knapweed seeds. Anecdotal evidence from Hanford Reach National Monument suggests that this weevil can significantly reduce diffuse knapweed populations in Washington (Evans et. al. 2003). Collections of this species were released during each summer from 2000-2003 on the Saddle Mountain Unit of the Monument along the Columbia River and at wasteway ponds.

Cyphocleonus achates (knapweed root weevil) is a European root weevil. Larvae can severely damage knapweed roots (Carpenter and Murray 1998b). Excellent control has been observed in Washington, but the species is limited in its distribution (Coombs et al. 2002). Coombs et al. (2002) and Carpenter and Murray (1998b) list other biocontrols for diffuse knapweed.

Sheep and goats will graze diffuse knapweed if confined to an area where alternative forage is unavailable. Repeated grazing will weaken plant reserves and make plants more susceptible to herbicide treatments (BIRC 2000).

Chemical Methods

Roche and Roche (1999) cite the rosette stage in spring or fall as the most favorable stage for effective herbicide application. On Natural Area Preserves in Eastern Washington, however, observations by D. Wilderman suggest that mortality is highest when herbicides are applied after plants have bolted (Evans et al. 2003).

Glyphosate (Roundup, Roundup Ultra, Rodeo, Accord) is a non-selective contact herbicide that kills both broad-leaved plants and grasses. Glyphosate can be applied directly to the leaves of diffuse knapweed with a hand-held sprayer or wick applicator. William et al. (2002) recommend

3.0 lb. a.e./A (3.36 kg a.e./ha).Glyphosate will only provide control during the year of application, and will not kill seeds or inhibit germination the following season.

Clopyralid (Stinger, Transline) 0.25 - 0.5 lb. a.e./A (0.28 - 0.56 kg a.e./ha) [0.66 - 1.33 pts. product/A] is recommended for application from the rosette stage up to the bud stage (William et al. 2002). Clopyralid + 2,4-D (Curtail) at 2.0 - 5.0 qts. Product/A and clopyralid + triclopyr (Redeem R&P) at 1.5 - 2.0 pts. product/A may also be used (William et al. 2002).

2,4-D is a selective, auxin-type herbicide that can be used to control many types of broad-leaved plants. 2,4-D at 1.0 - 2.0 lb. a.e./A (1.12 - 2.24 kg a.e./ha) may kill mature diffuse knapweed but will have no effect on the seedbank (William et al. 2002). A combination of 2,4-D and dicamba may reduce infestations enough so that control of survivors can be achieved by hand pulling (Youtie 1997).

Picloram (Tordon) applied at a rate of 0.25 - 0.5 lb.a.i. /A (0.28 - 0.56 kg a.i./ha) of [0.5 - 1.0 qt. product/A] is recommended for the control of diffuse knapweed (William et al. 2002, Roche and Roche 1999). Picloram may provide residual control of diffuse knapweed for 3 to 4 years on semi- arid rangeland sites (Watson and Renney 1974). According to R. Roos, application of 1.5 pts./ A Tordon applied in late spring, before the last of the spring rains, has been very effective on diffuse knapweed near Hanford Reach National Monument (Evans et al. 2003).

Dicamba (Banvel, Clarity, Vanquish, Veteran) applied at rates of 0.5 to 1.0 lb./acre (0.5 to 1.0 qt. product/acre) provides effective control of diffuse knapweed (Beck 1997). Dicamba can also be mixed with 2,4-D for spot treatments of diffuse knapweed (Beck 1997, Youtie 1997). Dicamba should not be used in diverse natural areas, as it has a tendency to eliminate all broadleaved species (Carpenter and Murray 1998b).

Combinations. Several of these herbicides can be combined to treat diffuse knapweed (Beck 1997). Tank- mixes of picloram and dicamba (0.25 to 0.5 lb./acre + 0.125 to 0.25 lb./acre), picloram plus 2,4-D (0.188 lb./acre + 1.0 lb./acre), and dicamba plus 2,4-D (0.5 lb./acre + 1.0 lb./acre) all have been used to control diffuse knapweed (Beck 1997, Youtie 1997).

DALMATIAN TOADFLAX *LINARIA DALMATICA* SSP. *DALMATICA*

Dalmatian toadflax is a tall (0.8 to 1.5 m), short-lived, cool season perennial Eurasian forb in the figwort family (Plantaginaceae). A mature plant can produce up to 500,000 seeds, which are primarily dispersed by wind and may remain viable for up to ten years in the soil (Robocker 1970). It has been observed that seeds are also dispersed by water and automobile traffic (Evans et al. 2003). Established infestations spread aggressively via horizontal or creeping rootstocks as well as by seed.

Dalmatian toadflax is an aggressive invader of roadsides, rangelands, and agricultural areas, especially where soils are sandy or gravelly (Lajeunesse 1999). Mature plants are especially competitive and can displace native plant communities, reduce wildlife forage value, increase soil erosion, and cause economic losses to farmers (Lajeunesse 1999).

Dalmatian toadflax is classified as a Class B Non-Designate noxious weed. State law calls for containment, gradual reduction, and prevention of further spread of Class B Non- Designate noxious weeds (NWCB 2003a).

Control

Manual and Mechanical Methods

A persistent, long-term hand-pulling effort may control small infestations of Dalmatian toadflax if annual seed production is eliminated (Lajeunesse 1999, CNAP 2000). Pullers should try to follow lateral roots to their ends to remove the most root possible. Pulling may be easier in spring when soils are moist, or in sandy soils. Pulling annually for 5-6 years is often necessary to achieve control (Lajeunesse 1999).

Intensive plowing for two or more years can effectively control Dalmatian toadflax. Eight - ten plowing at 7-10 day intervals during the first year, followed by 4 - 5 cultivations in the second year is recommended (Morishita 1991). Dalmatian toadflax seedlings do not compete well against established vegetation; control efforts should include attempting to establish and manage desirable species that will compete with toadflax throughout the year (Lajeunesse 1999).

Biological Control

Calophasia lunula, a defoliating moth, is well-established in Washington and reportedly provides good control. A stem-boring weevil, *Mecinus janthinus*, has also been released but is limited in its distribution in Washington (NWCB 2003b, Coombs et al. 2002).

Chemical Methods

The waxy cuticle on leaves of mature plants makes dalmatian toadflax resistant to chemical treatments. Herbicides must be applied to plants early in spring before the cuticle matures for greatest effectiveness; applications during and after flowering have no effect (Evans et al. 2003).

Glyphosate (Roundup) was applied via a cut-stem method by TNC in Moses Coulee in 2002 with good results (R. Leonard pers. comm.). Stems were clipped to 3" above the ground and treated with a 10% solution of Roundup. Small spray bottles, or sponge-type paint brushes may be used to apply the herbicide.

Picloram (Tordon) at 1.0 lb. a.e./A applied as a spot treatment in spring before flowering, or in the fall, is effective on small infestations of toadflax and will not damage associated perennial grasses (William et al. 2002). Picloram (Tordon 22K) + 2,4-D may be applied at 0.5 lb. a.e./A picloram + 1.5 lb. a.e./A 2,4-D as a broadcast treatment (William et al. 2002).

Clopyralid + 2,4-D (Curtail) at 2.5 oz./gal. has been used with some success against dalmatian toadflax by the Washington Department of Natural Resources on their Natural Area Preserve system in Eastern Washington. A surfactant is necessary to help the herbicide penetrate the leaf's waxy cuticle (Evans et al. 2003). Curtail will damage most perennial broad-leaved plants and so should be applied carefully to minimize the damage to non-target plants.

Dicamba (Banvel, Clarity) may be applied at 4.0 to 6.0 lb.a.e./A prior to the bloom stage. Repeated applications of dicamba may be necessary to achieve complete control (William et al. 2002). Dicamba should not be used in diverse natural areas, as it has a tendency to eliminate all broadleaved species (Carpenter and Murray 1998b).

References

Auld, B.A., and B.G. Coote. 1980. A model of a spreading plant population. Oikos 34: 287-292.

Beck, G. K. 1997. Natural resources series, diffuse knapweed. Colorado State University Cooperative Extension. Internet 05/05/98. Available at: http://ozma.jefferson.co.us/dpt/openspac/weed/dfknapwd.htm

Belnap, J., and S.L. Phillips. 2001. Soil biota in an ungrazed grassland: Response to annual grass (*Bromus tectorum*) invasion. Ecological Applications 11: 1261-1275.

BIRC (Bio-Integral Resource Center). 2000. Spotted, Diffuse & Russian Knapweed. Bio-Integral Resource Center, Berkeley, CA. Available online at http://www.efn.org/-ipma/Noxknapw.html

Bossard, C.C., J.M. Randall, and M.C. Hoshovsky. 2000. Invasive Plants of California Wildlands. University of California Pres, Berkely, CA. 360 pp.

Brooks, M.L., and D.A. Pyke. 2001. Invasive plants and fire in the deserts of North America. In K.E.M. Galley, and T.P. Wilson, eds. Proceedings of the Invasive Species Workshop: The Role of Fire in the Control and Spread of Invasive Species. Tall Timbers Research Station Miscellaneous Publication No. 11: 1-14.

Bushey, C. 1995. Fire effects on noxious weeds within the Columbia River Basin. Science report, Interior Columbia Basin Ecosystem Management Project. Available online at: http://www.icbemp.gov (under "Science Contract Reports, September 7, 1999").

Carpenter, A.T., and T.A. Murray. 1998b. Element Stewardship Abstract for *Centaurea diffusa*. The Nature Conservancy Wildland Invasive Species Program. Available at: http://tncweeds.ucdavis.edu/index.html

CDFA (California Department of Food and Agriculture. 2003a. Baby's breath [*Gypsophila paniculata*]. California Department of Food and Agriculture, Plant health and Pest Prevention Services. Available online at: http://pi.cdfa.ca.gov/weedinfo/GYPSOPHI2.html

Coombs, E.M., G.L. Piper, and L.M. Wilson. 2002. Biological Control. In William, R.D., D. Ball, T.C. Miller, R. Parker, J.P. Yenish, T.W. Miller, D.W. Morishita, and P.J.S. Hutchinson. 2002. Pacific Northwest Weed Management Handbook. Oregon State University. pp. 4-7.

CNAP (Colorado Natural Areas Program). 2000. Creating an Integrated Weed Management Plan: a Handbook for Owners and Managers of Lands with Natural Values. Colorado Natural Areas Program, Colorado State parks, Colorado Dept. of Natural Resources, and Colorado Dept, of Agriculture, Division of Plant Indiustry, Denver, CO. 349 pp.

DiTomaso, J.M., 2000. Invasive weeds in rangelands: Species, impacts, and management. Weed Science 48: 255-265.

Evans, J.R., J.J. Nugent, J.K. Meisel. 2003. Invasive Plant Species Inventory and Management Plan for the Hanford Reach National Monument.

Grace, J.B., M.D. Smith, S.L.Grace, S.L. Collins, and T.J. Stohlgren. 2001. Interactions between fire and invasive plants in temperate grasslands of North America. In K.E.M. Galley, and T.P. Wilson, eds.

Proceedings of the Invasive Species Workshop: The Role of Fire in the Control and Spread of Invasive Species. Tall Timbers Research Station Miscellaneous Publication No. 11: 40-65.

Hager, A, and C. Sprague. 2000. Herbicide formulations and calculations: Active ingredient or acid equivalent. University of Illinois Pest Management and Crop Development Bulletin. Available online at: http:"www.ag.uiuc.edu/cespubs/pest/articles/200002j.html

Lajeunesse, S. 1999. Dalmatian and yellow toadflax. In R.L. Sheley and J.K. Petroff, eds., Biology and Management of Noxious Rangeland Weeds. University of Oregonb Press, Corvallis, OR. Pp. 202-216.

Mack, R.N., D. Simberloff, W. Mark Lonsdale, H. Evans, M. Clout, and F. A. Bazzaz. 2000. Biotic invasions: Causes, epidemiology, global consequences, and control. Ecological Applications 10: 689-710.

McNeely, J.A. 2001. The Great Reshuffling: Human Dimensions of Invasive Alien Species. IUCN, Gland, Switzerland and Cambridge, UK. 242 pp.

Moody, M.E. and R.N. Mack. 1988. Controlling the spread of plant invasions: the importance of nascent foci. Journal of Applied Ecology 25: 1009-1021.

Morishita, D.W. 1991. Dalmatian toadflax, yellow toadflax, black henbane, and tansymustard: Importance, distribution, and control. *In* James, L.F., J.O. Evans, M.H. Ralphs, R.D. Child, eds. Noxious Range Weeds, pp. 399-407. Westview Press, Boulder, CO.

NWCB (Washington State Noxious Weed Control Board). 2003b. Weed Information. Washington State Noxious Weed Control Board website. Available online at: http://www.nwcb.wa.gov/INDEX.htm

Randall R. 2001. Garden thugs, a national list of invasive and potentially invasive garden plants. Plant Prot Q:16: 138-171.

Randall, J.M. 1996. Weed control for the preservation of biological diversity. Weed Technology 10: 370-383.

Rees, N.E., P.C. Quimby Jr., G.L. Piper, E.M. Coombs, C.E. Turner, N.R. Spencer, and L.V. Knutson (eds). 1996. Biological Control of Weeds in the West. Western Society of Weed Science in cooperation with USDA Agricultural Research Service, Montana Department of Agriculture, and Montana State University.

Renz, M.J. 2000. Element Stewardship Abstract for *Lepidium latifolium.* The Nature Conservancy Wildland Invasive Species Program. Available at: http://tncweeds.ucdavis.edu/index.html

Robocker, W.C. 197O. Seed characteristics and seedling emergence of dalmatian toadflax. Weed Science 18: 720-725.

Roche, C.T., and B.F. Roche Jr. 1999. Diffuse knapweed. In R.L.Shelley and J.K. Petroff eds., Biology and Management of Noxious Rangeland Weeds. Oregon State University Press, Corvallis, OR. Pp. 217-230.

Roche, C.T., and B.F. Roche Jr. 1988. Distribution and amount of four knapweed (*Centaurea* L.) species in eastern Washington. Northwest Science 62:242-253.

Schirman, R. 1981. Seed production and spring seedling establishment of diffuse and spotted knapweed. Journal of Range Management 34: 45-47.

Senese, F. 2002. General Chemistry Online. Available online at: http://antoine.frostburg.edu/chem/senese/101/solutions/faq/percentage-by-volume.shtml

Sheley, R.L., B.E. Olsen, and L.L.Larson. 1997. Effect of weed seed rate and grass defoliation level on diffuse knapweed. Journal of Range Management 50: 39-43.

Snyder-Conn, E. 2001. Memorandum on Conditional Approval of Pesticide Use Permits R1-01-13700-01, - 04, and -10 for use of Transline, Arsenal/Rodeo, and Oust at Hanford Reach National Monument and Saddle Mountain National Wildlife Refuge. National Pest Management Coordinator, U.S. Fish and Wildlife Service, Division of Environmental Quality. 12 pp.

Tu, M. 2001. A success story, Tom McCall Preserve, Northeast Oregon. The Nature Conservancy Wildland Invasive Species Program. Available at: http://tncweeds.ucdavis.edu/index.html

Tu, M. and B. Meyers-Rice. 2002. Site Weed Management Plan Template. The Nature Conservancy Wildland Invasive Species Program. Available at: http://tncweeds.ucdavis.edu/index.html

USFWS, U.S. Fish and Wildlife Service. 2001.

Watson, A.K., and A.J. Renney. 1974. The biology of Canadian weeds *Centaurea diffusa* and *C. maculosa*. Canadian Journal of Plant Science 54:687-701.

William, R.D., D. Ball, T.C. Miller, R. Parker, J.P. Yenish, T.W. Miller, D.W. Morishita, and P.J.S. Hutchinson. 2002. Pacific Northwest Weed Management Handbook. Oregon State University. 420 pp.

Youtie, B. 1997. Weed control as the first step in protecting and restoring native plant communities on Northeast Oregon natural areas. In T.N. Kaye, A. Liston, R.M. Love, D.L. Luoma, R.J. Meinke, and M.V. Wilson, eds. Conservation and Management of Native Plants and Fungi. Native Plant Society of Oregon, Corvallis. Pp 78-82.

Youtie, B., and J. Soll. 1994. Non-chemical control of diffuse knapweed (Centaurea diffusa). Washington State University Cooperative Extension Knapweed Newsletter 8: 2-3.

Zamora, D.L., and D.C. Thrill. 1999. Early detection and eradication of new weed infestations. In R.S. Sheley and J.K. Petroff, eds., Biology and Management of Noxious Rangeland Weeds. Oregon State University Press, Corvallis, OR. pp. 73-84.

Zimmerman, J.A.C. 1997. Ecology and distribution of *Centaurea diffusa* Lam., Asteracea. USGS Biological Resources Division , Colorado Plateau Field Station-Flagstaff, Arizona.

Internet 02/16/98. Available: http://www.nbs.nau.edu/FNF/Vegetation/Exotics/diffusa/diffusa.html

Personal Communications

Mark Woodward. Wildlife Biologist. Grant County Public Utility District. Beverly, Washington.

Appendix A

Comprehensive List of Invasive Plant
Species Occurrences

Dimensions. Length and width are entered for point and line occurrences only. Perimeter length is entered for polygon occurrences only.

Coordinates. All coordinates are in UTM datum NAD27. For occurrences mapped as polygons, the coordinates given are the centroids of the polygons. Two sets of coordinates -- the start point and the end point -- are displayed for line occurrences only.

Weed Name	Year Recorded	Occurrence Type	Coordinates		Dimensions			Area (m2)
			E	N	Length (m)	Width (m)	Perimeter	

Appendix B

Washington State Weed Law: Noxious Weed Classes

II. Washington State Noxious Weed Classification (NWCB 2003a)

Class A

Class A noxious weeds are non-native species with a limited distribution within the state. State law requires eradication of Class A weeds.

Class B

Class B noxious weeds are non-native species that are established in some regions of Washington, but are of limited distribution or not present in other regions of the state. Because of differences in distribution, treatment of Class B weeds varies between regions of the state. In regions where a Class B noxious weed is unrecorded or of limited distribution, the species is classified as a 'Class B Designate': prevention of seed production is required. In regions where a Class B species is already abundant or widespread, control is a local option. In these areas the species is a 'Class B Non-designate'; containment, gradual reduction, and prevention of further spread are the chief goals.

Class C

Class C noxious weeds are non-native species that are already widely established within the state. Control measures are not required by state law, but are a local option.

Monitor List

The Monitor List is maintained for non-native species that may be invasive in Washington or which exists in an adjacent state or province or occurs on an adjacent state or province's noxious weed list and is not known from Washington. Additional information is needed on distribution, abundance or biology.

Appendix C

Threat Matrix

201_ Activities Ranking Chart

Site Risk Assessment for Threats to Northern Wormwood

High (H) 3 points, Medium (M) 2 points, Low (L) 1 point, +/- worth 0.5 point

	Area			**Scoring: Total points**
Threat	**Northern**	**Core**	**Hawk's Pole**	
Dalmation toadflax				
Diffuse knapweed				
Other species				
Scoring: Total points				

*Current Threat Matrix was developed by the Wormwood Workgroup in MONTH YEAR to guide invasive species management efforts for the following year.

**Threats rated as "High" were viewed as detrimental by the Wormwood Workgroup immediately and need to be addressed as soon as possible. Threats rated as "Low" were viewed as insignificant to the Northern wormwood population at this moment and should be prioritized below other threats.

Appendix D

Explanations of Selected Chemical Terms

1. Herbicide Formulations and Calculations: Active Ingredient or Acid Equivalent?

Aaron Hager and Christy Sprague. 2000. Tables and figures not included: See http://www.ag.uiuc.edu/cespubs/pest/articles/20002j.html.

Most people who routinely use pesticides are familiar with the term active ingredient. The active ingredient of a pesticide formulation is the component responsible for its toxicity (phytotoxicity for herbicides) or ability to control the target pest. The active ingredient is always identified on the pesticide label, either by common name (atrazine or bentazon, for example) or chemical name (2,4-dichlorphenoxy acetic acid or diglycolamine salt of 3,6- dichlor-o-anisic acid, for example). The active ingredient statement may also include information about how the product is formulated and the amount of active ingredient contained in a gallon or pound of formulated product. For example, the Basagran label indicates the active ingredient (bentazon) is formulated as the sodium salt, and one gallon of Basagran contains 4 pounds of active ingredient.

Usually when an herbicide trade name is followed by a number and letter designation (4L, 75DF, 7EC, etc.), the number indicates how many pounds of active ingredient are in a gallon (for liquid formulations) or pound (for dry formulations) of the formulated product. The formulation designations for Basagran 4L, AAtrex 90DF, and Prowl 3.3EC indicate Basagran 4L contains 4 pounds of active ingredient (bentazon) per gallon of formulated product, AAtrex 90DF contains 0.90 pound of active ingredient (atrazine) per pound of formulated product, and Prowl 3.3EC contains 3.3 pounds of active ingredient (pendimethalin) per gallon of formulated product, respectively.

Some herbicides (atrazine, for example) have specific maximum-per-year application rates that cannot be exceeded. These maximum-per-year application rates are generally presented in terms of the total amount of active ingredient that can be applied per year. How would you calculate the pounds of active ingredient applied at a given product use rate? There are several calculations that can be used to determine the amount of active ingredient applied at a given product use rate. One of the easiest calculations is

lbs. active ingredient (a.i.) per acre = gallons or lbs. product applied/ acre x lbs. a.i./ gallons or lbs. product

Using this equation, we can calculate the amount of active ingredient (bentazon) that is applied when we apply 2 pints (0.25 gallon) per acre of Basagran 4L:

Sometimes, however, the numbers preceding the formulation designation (L, EC, DF, etc.) do not indicate pounds active ingredient per gallon or pound but rather the acid equivalent per gallon or pound. The term acid equivalent is one that many people are less familiar with. Acid equivalent may be defined as that portion of a formulation (as in the case of 2,4-D ester, for example) that theoretically could be converted back to the corresponding or parent acid. Another definition of acid equivalent is the theoretical yield of parent acid from a pesticide active ingredient that has been formulated as a derivative (esters, salts, and amines are examples of derivatives). For instance, the acid equivalent of the isooctyl ester of 2,4-D is 66 percent of the ester formulation but 88 percent of the ethyl acetate ester formulation. Why would an herbicide (one that has the acid as the parent molecule) be formulated as a derivative (ester, salt, amine, etc.) of the parent acid?

An herbicide molecule may sometimes be altered to impart some property other than herbicidal activity. Herbicidal activity refers to the ability of a particular herbicide to effectively bind to a target site within the plant and exert some type of lethal effect (i.e., you apply the herbicide to the plant and the plant eventually dies). Such alterations are possible with herbicide molecules that are acids (for example, molecules that have a carboxyl group as part of their structure). The acidic carboxyl hydrogen is replaced by the desired ions to form a salt or reacted with an alcohol to form an ester. Why would this be done? For example, due to the chemical characteristics of a particular herbicide molecule, the parent acid may not be readily absorbed into a plant, because it's not able to effectively penetrate the waxy cuticle covering the leaf. Somehow altering the parent acid may increase the ability of the herbicide to penetrate through the leaf much more effectively. For some postemergence herbicides, formulating the parent acid as an ester or salt is frequently done to facilitate absorption through the leaf. Other formulations or derivatives of the parent acid may increase the water solubility of the herbicide. 2,4-D (2,4-dichlorphenoxy acetic acid) is commonly formulated as an ester or amine. The ester formulation increases the lipid solubility of the herbicide, which allows it to more easily penetrate the waxy cuticle of the plant leaf. The amine formulation greatly increases the water solubility of the herbicide, which may be desirable if the product needs to be moved into the soil solution for root uptake (brush control, for example).

If an herbicide is formulated as a derivative of the parent acid, it is important to remember that the parent acid is the herbicidally active portion of the formulation. The parent acid is what binds to the herbicide target site within the plant and causes plant death. The salt or ester portion of the formulated product may allow for greater absorption into the plant but plays no role in binding to the herbicide target site. For example, when an ester herbicide penetrates the cuticle, enzymes convert the ester back to the parent acid, so following absorption, the ester part of the formulation plays no role in herbicidal activity. Modification of the parent acid (formulation as a salt, ester, or amine) may increase the amount of active ingredient in a formulation, because the amount of active ingredient listed on a product label includes both the weight of the parent acid and the weight of the salt or ester. Modification does not always, however, increase the amount of acid (herbicidally active portion) in the formulation. The acid equivalent represents the original acid portion of the molecule and is used for "apples-to-apples" comparisons of different formulations containing the same acid. Another example will hopefully alleviate some the confusion.

2,4-D can be formulated as various esters. The chain length of the ester can be varied but is most commonly eight carbon atoms long (isooctyl ester). Let's assume we have two ester formulations of 2,4-D: the first has only two carbon atoms forming the ester, and the second has eight carbons forming the ester. The parent acid is the same in these two formulations; the only difference is the length of the ester. These can be visualized in the following diagrams.

The structure on the left is the parent acid of 2,4-D. The second diagram is the parent acid, formulated with a 2-carbon side chain (the two added carbons are in bold text), and the third diagram is the parent acid, formulated with an 8-carbon side chain (again, the added carbon atoms are in bold text). While these added carbon atoms may modify some aspect of herbicide performance (the isooctyl ester is the most commonly used ester formulation of 2,4-D), it is the parent acid (the one depicted in the left diagram) that acts at the target site within the plant. The added carbon atoms of the esters add weight to the formulation and may increase the amount of active ingredient of a formulation, but they do not increase the amount of parent acid in the formulation. If these two formulations were commercially available, and someone wanted to know how much of the parent acid each formulation contained, the calculation to use would be based on the acid equivalent of the formulations, not the active ingredient of the formulations.

Let's assume that both the 2,4-D 2-carbon ester formulation and the 8-carbon ester formulation were commercially available and each contains 4 pounds of active ingredient per gallon. The application rate on the label is 1 pint per acre of either formulation. Since the application rates and the pounds of active ingredient per gallon are identical for each formulation, the amount of active ingredient applied would be the same for each formulation. If you doubt this, plug in the appropriate numbers for each formulation in the formula given previously for calculating the amount of active ingredient applied. Even though the amount of active ingredient applied is the same for each formulation, the amount of acid applied is not the same. Remember that it is the parent acid that binds to the target site to control the weed; the ester portion of the formulation is not involved in binding to the target site. How would we calculate the amount of acid applied?

The first step is to determine the amount of acid equivalent contained in a gallon of formulated product. Some labels indicate both the amount of active ingredient and acid equivalent contained in the formulation, while others list only active ingredient. If the pounds acid equivalent is specified on the product label, all you need to do to determine the pounds acid equivalent applied per acre is substitute pounds acid equivalent for pounds active ingredient in the equation presented previously for calculating the pounds active ingredient applied. For this example, however, let's assume that neither of these 2,4-D ester formulation labels indicates the amount of acid equivalent.

The formula that can be used to calculate the amount of acid equivalent contained in a gallon of formulated product is acid equivalent (a.e.) = molecular weight of the acid/ molecular weight of the salt or ester x 100

We now need to provide some molecular weights (i.e., how much the molecule weighs) to complete these calculations. The molecular weight of the parent 2,4-D acid is 221.04. The molecular weight of the 2-carbon ester formulation is 29.02 (weight of the two carbons and five hydrogens) + 221.04 (weight of the parent acid) = 250.06. The molecular weight of the 8-carbon ester formulation is 333.25.

The acid equivalent of the 2-carbon ester formulation is acid equivalent = 221.04 – 1/ 250.06 x 100 – 88%

So the amount of acid equivalent in 1 gallon of formulated product is

88% a.e. x 4 lbs. active ingredient (a.i.)/ gallon = 3.52 lbs. a.i.

The acid equivalent of the 8-carbon ester formulation is:

a.i. = 221.04 – 1/ 333.25 x 100 – 66%

So the amount of acid equivalent in 1 gallon of formulated product is:

66% a.e. x 4 lbs. a.i./ gallon = 2.64 lbs. a.i.

Again we applied 1 pint (0.125 gallon) per acre of each formulation, and because they both contain 4 pounds active ingredient per gallon, the amount of active ingredient applied is equal. The amount of acid applied (that part of the formulation that actually controls the weed) for each formulation is not equal.

The amount of acid applied per acre with the 2-carbon ester formulation is:

0.125 gallons of product applied/ Acre x 3.52 lbs. per acre/ gallon of product – 0.44 lbs. applied per acre

The amount of acid applied per acre with the 8-carbon formulation is:

0.125 gallons of product applied/ Acre x 2.64 lbs. per acre/ gallon of product – 0.33 lbs. applied per acre

This example demonstrates that there was more acid applied with the 2-carbon ester formulation than with the 8-carbon formulation. In practical terms, more of the part of the formulation that actually controls the weeds was applied with the 2-carbon ester formulation. To compare the herbicidally active portion of two ester, salt, or amine formulations, product equivalents should be based on the acid equivalent of a salt or ester formulation.

This exercise was done to illustrate that, to calculate equivalent rates of salt or ester formulations, the acid equivalent calculation should be used. If there is only one formulation of a salt or ester product commercially available, it wouldn't really matter if you calculated active ingredient or acid equivalent. For example, Pursuit is formulated as the ammonium salt of imazethapyr, but currently only one manufacturer markets Pursuit. There are, however, several commercial formulations of 2,4-D and glyphosate. Referring to Table 5, you can see there are over 30 different commercial formulations of glyphosate available today, and more will likely be available in the future. Not all these formulations contain the same amount of acid equivalent, so if you want to determine equivalent rates of two glyphosate-containing formulations with respect to how many molecules of glyphosate are applied, you must calculate these rates based on acid equivalent. Table 6 lists some calculations of acid equivalents, based on an application rate of 1 pound active ingredient per acre. This table illustrates that, when calculations are based on equivalent active ingredient, the amount of acid applied may not always be equal. It is the acid portion of a salt formulation that binds at the target site.

The purpose of this article is to illustrate how to calculate differences in formulations based on either active ingredient or acid equivalent. Will differences in the amount of acid equivalent applied between two formulations result in weed-control differences? You might argue that, if the difference in amount of acid applied is large enough, differences in weed control might result and might be noticed on weeds against which the herbicide is "marginal." However, it is difficult to make an all-inclusive statement that weed-control differences will always result if differing amounts of acid are applied, especially when the difference in amount of acid applied is small.

Labeled application rates are established by herbicide manufacturers based on product testing. It does not seem likely that a herbicide manufacturer would market an herbicide at an application rate that would consistently result in reduced weed control compared to a competitive formulation.

2. How are percentages by volume calculated?

Fred Senese. 2002. Available online at: http://antoine.frostburg.edu/chem/senese/101/solutions/faq/percentage-by-volume.shtml

Volume-to-volume (vol/vol) percentage is calculated as:

$$\text{Volume \%} = \frac{\text{Volume of substance}}{\text{volume of total solution}} \text{ X } 100\%$$

For example, to prepare 100 ml of 5% (v/v) solution of ethanol, pipette 5 ml of ethanol into the bottom of a 100 ml flask and dilute to the mark with water. Careful, though. The denominator specifically says volume of total solution and NOT volume of solvent. This makes a difference, because volumes are not additive. 5 ml ethanol plus 95 ml of water does NOT equal 100 ml of solution!

Appendix B
Grant PUD Agency Response Table

Submitting Entity	Date Received	Paragraph #	Agency Comment	Grant PUD Response
USFWS (Tara Callaway)	10/25/2018	1	Here are my comments and edits for this draft. I really appreciate you all taking our thoughts and ideas into consideration in this plan. I really hope (and believe!) that this plan will accomplish a great deal of conservation for this species.	Grant PUD has incorporated and included the comments and edits into this final NWW Conservation Plan.
WNHP (Walter Fertig)	11/21/2018	1	I just realized I neglected to send you comments on the final draft of the wormwood document. I thought it looked pretty good and that you had already incorporated most of my thoughts from the very first draft – so I don’t really have anything to add.	Comment noted.
USBOR (Edna Rey-Vizgirdas)	11/29/2018	1	Thank you for the opportunity to review the Northern Wormwood Conservation Plan. On behalf of Reclamation's Ephrata Field Office, we greatly appreciate Grant County PUDs continuing efforts to conserve habitat for this species.	Comment noted.
USBOR (Edna Rey-Vizgirdas)	11/29/2018	2	We support the Conservation Plan, and hope these measures will be successful in recovering this extremely rare plant species. Please keep my staff informed of any meetings or site visits relating to Conservation Plan implementation.	Grant PUD has appreciated the USBOR participation in previous conservation activities for Northern wormwood and will continue to ensure all parties remain informed through participation in the Northern Wormwood Working Group routine meetings and site visits.

From:	Callaway, Tara <tara_callaway@fws.gov>
Sent:	Thursday, October 25, 2018 1:51 PM
To:	Mike Clement
Cc:	Gregg Kurz; Hoff, Gina; Fertig, Walter (DNR); Mark Woodward; Debbie Firestone; Lewis, Stephen
Subject:	Re: [EXTERNAL] 2018_10_16 Final Draft NWW PVA_CA Report
Attachments:	2018_10_16 Final Draft NWW PVA_CA Report_TC comments.pdf

---

Hi Mike and Mark,

Here are my comments and edits for this draft. I really appreciate you all taking our thoughts and ideas into consideration in this plan. I really hope (and believe!) that this plan will accomplish a great deal of conservation for this species.

Thank you everyone!

Tara

On Thu, Oct 18, 2018 at 10:31 AM, Mike Clement <Mclemen@gcpud.org> wrote:

> All,
>
> For your review and/or comment please see attached final draft of Grant PUD's Northern Wormwood PVA and Conservation Agreement. Please send any comments you may have to Mark or myself at Mwoodwa@gcpud.org by November 18th so we can incorporate them into the final version. Also, a big thank-you to those whom have previously provided comments which we have incorporated into this version. We look forward to implementation of the Conservation Agreement and initiating the Northern Wormwood Working Group early next year.
>
> Thanks, Mark

--

Tara Callaway
Endangered Species Biologist
U.S. Fish and Wildlife Service
Central Washington Field Office
215 Melody Lane, Suite 103
Wenatchee, WA 98801
Office: (509) 665-3508 ext. 2004

Debbie Firestone

From: Rey-Vizgirdas, Edna <ereyvizgirdas@usbr.gov>
Sent: Thursday, November 29, 2018 3:32 PM
To: Mike Clement
Cc: Hoff, Gina; Clyde Lay
Subject: [possible spam] Northern Wormwood Conservation Plan

Please take care when opening links, attachments or responding to this email as it originated outside of Grant.

Mike,

Thank you for the opportunity to review the Northern Wormwood Conservation Plan. On behalf of Reclamation's Ephrata Field Office, we greatly appreciate Grant County PUDs continuing efforts to conserve habitat for this species.

We support the Conservation Plan, and hope these measures will be successful in recovering this extremely rare plant species.

Please keep my staff informed of any meetings or site visits relating to Conservation Plan implementation.

Regards, Edna Rey-Vizgirdas

--

Sincerely,
Edna Rey-Vizgirdas
Resource Management Supervisor (acting)
Ephrata Field Office, **Pacific Northwest Region**
Bureau of Reclamation
W: 509-754-0231
<>*<>*<>*<>*<>*<>*<>*<>*<>*<>*