Appendix A

Preliminary Revegetation Plan
Cattle Point Improvement Project
January 2010

The purpose of this report is to present viable revegetation strategies and measures that would be used to revegetate disturbed sites associated with the Cattle Point Road Improvement Project if an action alternative is selected. This is a *preliminary* revegetation plan which means that it will be modified as the road plans evolve, depending on which alternative is chosen following completion of the NEPA process. Since the current road plans are in a very preliminary stage, many design elements will change during planning. A *final* revegetation plan will be completed when road plans are at the 70% design. The preliminary revegetation plan will be used to begin the process of obtaining seeds and seedlings from appropriate genetic sources for plant material production.

The report is structured as follows:

Objectives

Road Objectives

The objectives of the Cattle Point Road Improvement Project are to "maintain vehicular, bicycle, and pedestrian road access to the Cattle Point area through the San Juan Island National Historical Park" and "provide safe and pleasant roadway experiences for residents and visitors". The preferred alternative (Alternative B) in the Draft Environmental Impact Statement developed by the Federal Highway Administration and the National Park Service (2010) proposes to realign 4,950 feet of the Cattle Point Road to the north of the existing road and to restore the portion of the existing Cattle Point Road, that would be abandoned in the process, so that it blends into the surrounding topography. The road construction would create about 10 acres of new cuts and fills and about 3 acres of reclaimed abandoned road, which would be revegetated. In addition, the staging area, which would occupy approximately 1 acre, would likely need to be revegetated.

This plan outlines preliminary revegetation strategies based on the preferred alternative (Alternative B). If a different alternative is chosen, the revegetation strategies would be the same; however, the details of the plan would be altered to reflect the chosen alternative and final road design details.

Revegetation Objectives and DFCs

The revegetation objectives are the foundation for which strategies for reestablishing vegetation are based. The desired future conditions (DFCs) are created from revegetation objectives and become the monitoring criteria used for measuring the success of the revegetation project. The following are the main revegetation objectives and DFCs identified for the Cattle Point Improvement Project.

<u>1) Stabilize disturbed soils</u>. NPDES (National Pollution Discharge Elimination System) permit requires that disturbed soils associated with construction be stabilized to reduce the potential of surface erosion (including wind and storm runoff) and sloughing of cuts and fills. It also requires establishment of a uniform vegetative cover with a density of 70% of the background plant cover.

DFC: *Less than 20% of soil will be exposed 12 months after road construction and at the end of three years, basal cover*[1] *of vegetation (native and non-native species) will cover 70% of the soil surface*. The "Soil Cover" protocol outlined in the Roadside Revegetation technical guide (Steinfeld and others 2007) will be used to monitor this parameter.

<u>2) Reestablish native vegetation</u>. Disturbed areas associated with this project offer a unique opportunity to create an extensive native plant community that currently exists only in small, isolated remnants throughout the prairie/grassland habitat of the American Camp unit. By establishing native plants in the reclaimed road section, a long corridor of native plants will transect a portion of the Park, serving as an anchoring point for the reestablishment of desirable species into the surrounding area. This would achieve a San Juan Island National Historical Park vegetation management goal of restoring native vegetation to the historic landscape and at a broader level, the National Park System's fundamental goal of restoring and enhancing park lands to preexisting natural conditions. The proposed action also offers the opportunity to test revegetation treatment methods that could be used for future restoration efforts in the park.

DFC: *By end of third year, native plants will occur on 70% of the project area.* The "Species Presence" protocol, using a 0.1 square meter quadrat frame, will be used for monitoring the presence of native plants. This protocol is described in the Roadside Revegetation technical guide (Steinfeld and others 2007).

<u>3) Control aggressive non-natives</u>. Reducing the presence of aggressive non-native species is a management goal for San Juan Island National Historical Park. Bare soils resulting from road construction activities will open up sites to invasion by noxious weeds. This plan will propose an Integrated Pest Management approach to reducing the presence of these species.

DFC: *Less than 1% of the quadrats will have bull thistle, Canada thistle, tansy ragwort, Fuller's teasel, spotted knapweed, California poppy, common mullein, cutleaf and Himalayan blackberry, oneseed hawthorn, quackgrass, orchard grass, ripgut brome (Bromus rigidus), or tall fescue (Lolium arundinaceum) and less than 5% of the quadrats will have Queen Anne's lace, common St. Johnswort, common velvetgrass, or hairy catsear.* The "Species Presence" protocol using a 1.0 square meter quadrat frame will be used to monitoring the presence of noxious weeds.

<u>4) Establish host plants for the Island Marble Butterfly</u>. The DEIS requires the establishment of host species for the Island Marble Butterfly (*Euchloe ausonides insulanus*) as a mitigating measure for the enhancement of this species. According to Pyle (2004), this butterfly "represents one of the most dra-

[1]Basal cover refers to the area that the base of plants occupy at ground line and involves clipping grasses and forbs at one inch above the ground surface during monitoring.

matic examples in the North America fauna of a narrowly endemic taxon...and its entire future seems to depend upon management within the Park". Its host plants are tall tumblemustard (*Sisymbrium altissimum*), field mustard (*Brassica campestris; renamed Brassica rapa*) and Menzies' pepperweed (*Lepidium virginicum var menziesii*).

The first two mustards are introduced species and the pepperweed is native. Since National Parks are prohibited from intentionally propagating non-native species, only the Menzies' pepperweed can be considered for propagation in this plan however, the other two species will not be eradicated if they reestablish on their own. Several other native plant species will be investigated as potential host plants for the Island Marble Butterfly. These include Eschscholtz's hairy rockcress (*Arabis eschscholtziana*) and tower rock cress (*Arabis glabra*) which are found on San Juan Island but not in the park. Common pepperweed (*Lepidium densiflorum var. densiflorum*) is a native host plant for the Large Marble butterfly (*Euchloe ausonides*), a conspecific of the Island Marble Butterfly, that inhabits the mainland. Small trials to evaluate butterfly preferences of known and potential host plant species will be conducted by park resource management staff in 2010/11, but propagating plant species other than the pepperweed, will be deferred until more information is obtained about these plant-butterfly relationships.

DFC: *Until more is known, 10 patches per acre of native host plants, containing at least 20 plants per patch, will be established on disturbed sites three years after construction*. Monitoring this DFC will be accomplished by mapping these populations.

5) Maintain and enhance the presence of California buttercup. The California buttercup (*Ranunculus californicus*) is classified by the state of Washington as threatened and critically imperiled because there are less than six known occurrences in the state. During the spring 2005 field survey, the National Park Service (NPS) identified 33 groups (consisting of 2 to 260 individuals) of California buttercup within the project area, occupying a total area of approximately 0.5 acres. The new road construction will seek to minimize ground disturbance to avoid as many California buttercup groups as possible. Nevertheless this action could potentially impact approximately 4 to 5 known groups. Plants in these areas will be salvaged prior to ground disturbance and relocated. Restoration of the abandoned road segment, as well as roadway cuts and fills, will provide an opportunity for increasing California buttercup populations.

DFC: *The California buttercup will increase by 15 population groups by the third year after construction*.

Site Inventory

The Cattle Point project area is unique in its environment and aside from possibly portions of nearby islands (Long Island and Charles Island), it appears to stand alone in terms of soils, climate, and vegetation.

Climate[2]

Wind. High winds have strongly influenced the development of soils, geomorphology, and subsequently the vegetative patterns and plant growth observed in the project area. Slopes have a southern exposure that receives the direct effects of storms blowing across the Strait of Juan de Fuca. These winds have scoured a half mile portion of the park between Pickett's Lane and Cattle Point Road, as it

[2]The data sets presented in the climate section were derived using the PRISM climate mapping system, USDA's official climate data. PRISM uses data from weather stations, a digital elevation model, and expert knowledge of complex climatic extremes, including rain shadows, coastal effects, and temperature inversions to estimate monthly temperatures and precipitation for any set of coordinates. The decimal degrees location used for this analysis was 48.4524 and -122.9724. The analysis evaluated data from 1970 to 2008.

funnels around the Mt Finlayson ridge, creating sand dunes and an eroded landscape (see Figure 1B). Winds are also responsible for the two-foot deposit of fine loess sands that blanket an extremely gravelly subsoil.

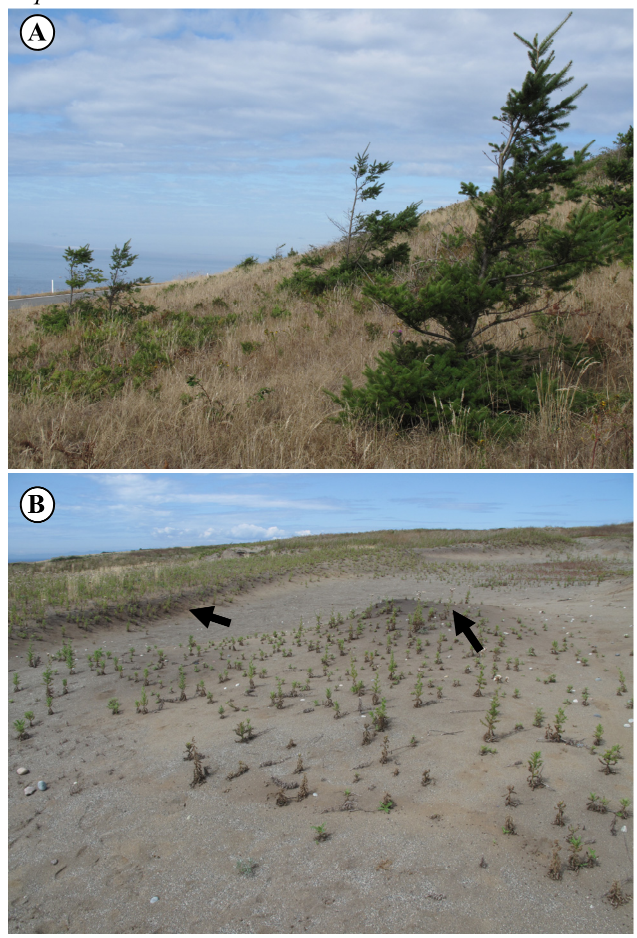


Figure 1. Wind Effects. *The few trees present in the project area have been deformed by strong winds (A). Winds have also scoured a portion of the park landscape, removing the topsoil and depositing in dunes. Arrows in the bottom picture (B) show areas of remnant topsoil.*

The degree that an area is protected from high winds will strongly influence the development of the plant community. The most obvious example of this is the dramatic change from grasslands to forests at the Mt Finlayson ridgeline. While some young trees have become established on the windward side of the ridge, the impacts from winds have reduced tree and shrub growth substantially (see Figure 1A).

High winds will affect revegetation efforts by stressing newly planted seedlings or seed as they are germinating. These effects will be greatest during the summer months but should diminish as daily temperatures decline in the fall. Desiccating winds occurring during the early establishment of vegetation will be one of the main limiting factors for successful revegetation, therefore some degree of wind protection during the first several years of establishment should be considered when implementing this plan.

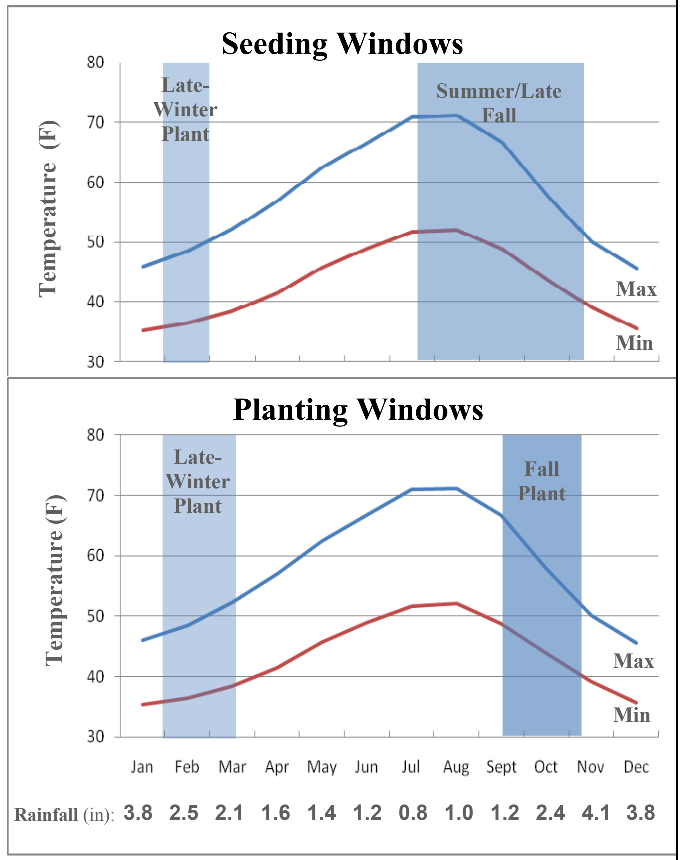
<u>Precipitation.</u> Cattle Point receives an annual rainfall of approximately 26 inches with more than half occurring from November through February. Precipitation from late spring through the end of summer is sparse, averaging approximately an inch of rainfall a month (see Figure 2). This is not enough rainfall to wet a dry topsoil and therefore the lack of precipitation in the summer is considered one of the main limitations to plant establishment on this project. The arrival of the first rainstorms in late September to October determines the earliest that seedlings can be planted in the fall.

<u>Temperatures</u>. Temperatures are quite favorable for plant growth during much of the year as long as soil moisture is available. Optimum temperatures for plant growth occur from June through September, but this is also the period when precipitation is at its lowest. Fall temperatures are mild with a warming trend over the last thirty years. October and November are favorable months for plant establishment because the mild soil temperatures are ideal for new root growth. This is also a period of the year when many seeded species, including weed seeds, germinate before winter arrives.

Winter temperatures are cool but don't frequently fall below 32 degrees, reducing the risk of freeze thaw effects on planted seedlings and germinating seeds. While some root growth takes place during December and January, most plant growth is limited during this period because of low solar radiation. Warming of soils and increased day length in February initiates new roots on most plants and by early March, most established plants have begun to develop new shoots. Seeds of species requiring stratification that were sown in the fall also begin to germinate by late February.

Planting Windows. Planting windows are dictated by temperature, precipitation, and soil conditions (Figure 2). The optimum time to plant at Cattle Point is from mid-September to early November when topsoils are at field capacity (typically this occurs after one or two substantial rainstorms). The earlier that containerized seedlings are planted in the fall (soil moisture permitting), the longer they will be exposed to warm soil conditions and the greater the chances of establishment. Warm soils increase the likelihood that roots will quickly grow out from the plugs and occupy the topsoil before non-native species begin to germinate. New root growth decreases in the late fall and winter months with declining temperatures but picks up again in February. By early spring, when non-native germinants are just beginning to put down roots, the planted native species will be well on their way to occupying most of the below and above ground environments.

Figure 2. Seeding and Planting Windows. *The best time to seed and plant is in the fall because soil moisture is high, soil temperatures are mild, and soil conditions favorable for ground-based equipment. Planting and seeding during this time leads to seedlings that are established by early spring.*



Seedlings can be planted after mid-October, but the likelihood of more frequent and substantial rainfall events increase. For hand-planted seedlings this is not a problem (hand-planting can be done from November through March), but for ground-based planting equipment, wet soils will limit equipment operations and potentially cause soil puddling and compaction.

The late-winter planting window is less favorable than the fall planting window because there is less time for roots to grow out from the plug before precipitation becomes limiting in late May. Sites that are planted in late winter have the added problem of competing with seeds of non-native species that have germinated in the fall and are now beginning to grow, in which case there is a greater chance that non-native species will outcompete the planted seedlings for the site. While rainfall is less in February than the preceding months, there still will be many days when soils will be too wet to operate equipment.

Seeding Windows. The optimum time to seed at Cattle Point is from mid-July through early November. Depending on the species and seed covering method, most seeds sown during this period will germinate by late fall. Seeds applied through hydroseeding equipment should be applied later in the seeding window (October) to avoid excessive exposure of seed to the elements. Seeds being covered with soil or mulch can be sown earlier in the seeding window. The reason for applying seeds in the summer months when construction slopes are ready is to reduce the potential that non-native seeds will "get there first".

For example, leaving a site unseeded until October increases the likelihood that non-native seeds will blow onto the bare soils and compete with the germinating native seeds. Mulching over the native seeds further reduces the potential that non-native seeds will germinate prior to native seedling establishment.

Soils

The soils of the project area have been mapped as San Juan Sandy Loam series with three phases based on slope gradient: 2 to 8 Percent Slopes, 15 to 35 Percent Slopes, and 30 to 60 Percent Slopes (Natural Resources Conservation Service and National Park Service 2005). The soil profile is made up of very distinct horizons (see Figure 3). The base horizon, or parent material, is composed of gravels and cobbles and holds very little water and nutrients for plant growth. By itself, the parent material is not suitable for growing plants. Overlaying the parent material is a thick windblown layer composed of a topsoil and subsoil. The topsoil is rich in organic matter and nutrients. Sandwiched between the topsoil and parent material is the subsoil which is approximately 8 inches deep and considered less productive than the topsoil but far more productive than the parent material.

The soils of the project area are productive and support a predominantly non-native grass/forb plant

Figure 3. Soil Profile. *The San Juan Sandy Loam soil series is the predominant soil in the project area.*

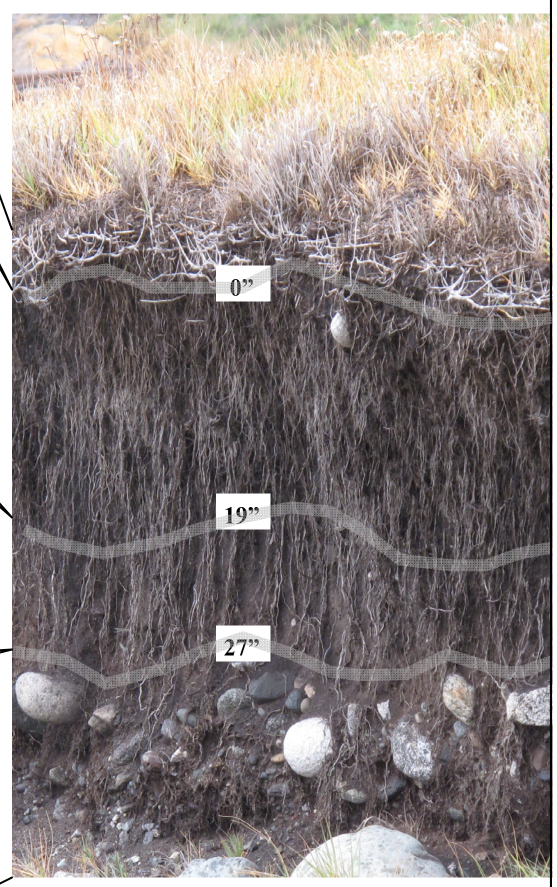
San Juan Sandy Loam Soil Profile

Organic Layer is composed of grass and forb plants, thatch, and leaf litter. Thickness varies by vegetation but can be several inches thick.

Topsoil is a dark, friable sandy loam, high in fine roots. It has a moderate water holding capacity of 1.1 to 1.6 inches per foot of soil. Organic matter is very high in the top 12 inches of soil (6 to 12%) but declines with depth (3 to 6% at 12 to 19 inches). Permeability is rapid, ranging from 2 to 20 inches per hour. pH ranges from acid (5.1) at the surface to neutral (6.5) near the bottom of the horizon.

Subsoil is a brown gravelly loamy coarse sand (30% gravels). It has a very low water holding capacity of 0.1 to 0.7 inches per foot. Organic matter varies from 1 to 4 %. Permeability is rapid, ranging from 6 to 20 inches per hour. pH is near neutral (6.1 to 6.5).

Parent Material is a dense, extremely gravelly coarse sand with 80% gravels and cobbles. It holds a fraction of water (0.1 to 0.5 inches per foot water holding capacity). Organic matter is scant (<1%) and nutrients are very low. Permeability is very rapid ranging from 6 to over 100 inches per hour. pH is neutral (6.6 to 7.3). This a very deep layer.



community. This project offers an opportunity to create a functioning native plant community through the application of appropriate restoration methods, practices, and strategies on sites that have been disturbed through road construction activities. Key to the success of such project will be: 1) salvaging, 2) storing, and 3) reapplying of topsoil. The challenge when building the new road section will be to excavate as much topsoil as possible, while mixing only minor amounts of subsoil and no parent material into the salvaged material. If parent material is inadvertently removed with the topsoil, then the result will be salvaged topsoil high in gravels and cobbles, and the quality of the material as a growing medium, will be reduced. Further confounding the operation will be the removal and disposal of the top several inches of topsoil prior to salvage to keep from introducing unwanted non-native seeds and plants. Topsoil storage conditions will also have to have a high degree of oversight to assure that soil quality is maintained. Finally, the attention to how topsoil is reapplied to sites is very important to assure that soils are not overly compacted during compaction. These three phases of topsoil transfer will be discussed in more detail in this plan (pages 10-12)

In addition to the undisturbed soils described above, this project also has soils that have been highly disturbed when the road was first built, yet recovered in recent years. They include the fill slopes of the Cattle Point Road. While these soils have not been investigated, it is suspected that they are high in gravels and cobbles because when they were placed, the horizons, including the parent material, where undoubtedly mixed. Material from the fill slopes should be investigated during road construction to assess where they can be used in the project.

The main limiting factor for revegetation that is associated with soils on this project will be the topsoil depth. While there are no disturbed reference sites to evaluate, it appears that 12 inches of topsoil over an uncompacted subsoil containing less than 35% gravels should be sufficient for reestablishing native vegetation. Where this is not possible, composts or other organic amendments will be applied to the soil to increase its productivity. Another limiting factor to native plant revegetation will be soil disturbance caused by rabbits when they create their warrens. Large areas of soils are exposed by this type of disturbance and become sites where non-native species become established.

Figure 4. Plant Communities. *The Cattle Point project area includes several remnant native polygons (green polygons) which are composed of four dominant native vegetation communities. Surrounding these polygons is non-native prairie composed primarily of the Holcus lanatus vegetative community (Bivin 2009).*

Vegetation

The American Camp prairie falls within the Xeric Grassland with Shrub Islands vegetation type described by Peterson (2002). The prairie is roughly 704 acres in area and contains an astonishing variety of native species. In a recent plant survey of the American Camp prairie, Bivin (2009) found that of the 109 species identified in this vegetative type, 60 were native species and 49 exotic. In this survey, areas that were dominated by native plants were located and mapped (Figure 4). These areas, or polygons, range from less than 0.01 acres to 4.5 acres and make up approximately 12 percent of the prairie. Islands of native diversity will provide the ecological information and plant materials necessary for developing successful revegetation strategies for this project. Restoration efforts that expand into these communities will provide greater ecological connectivity and habitats within the prairie.

Bivin also identified 12 vegetation communities making up the prairie, five of which were surveyed in, or adjacent to, the project area (Figure 4). Of these vegetation communities, four were dominated by native species. These native vegetation communities, which are named after the dominant species, are: *Festuca roemeri*, *Bromus sitchensis*, *Leymus mollis*, and *Lupinus littoralis*. Figure 5 shows the most common species occurring in these communities. The composition of species in each of these vegetation communities will be used as a guide in the selection of species for revegetating this project. It is important to note that while these plant communities are dominated by native species, they also have a component of non-native species, some of which are aggressive or undesirable.

The remaining 85 percent of the project area is composed of non-native vegetation, with *Holcus lanatus* being the primary vegetation community. While the *Holcus lanatus* plant community is dominated by *Holcus lanatus* (41% cover), over 25 percent of the plant cover is composed of native species which include *Carex inops*, *Elymus glaucus*, and *Pteridium aquilinum* (Figure 6). Understanding the *Holcus lanatus* vegetation community will provide ecological insights into the selection and use of the species for this revegetation project.

Figure 6. Non-native Plant Community. *Most of the project area is of the Holcus lanatus vegetation community which is composed of the percentage of species shown in this table. Green cells are native and salmon cells are undesirable species.*

Holcus lanatus		
	Holcus lanatus	41
	Poa pratensis	15
	Carex inops	11
	Elymus glaucus	10
	Pteridium aqualinum	7
	Bromus hordeaceus	4
	Hypochaeris radicata	5
	Cirsium arvensis	4
	Rumex acetosella	4
	Vicia sativa	4

Figure 5. Native Plant Communities. *Four native plant communities (Festuca roemeri, Leymus mollis, Bromus sitchensis, and Lupinus littorallis) are found within or adjacent to the project area. These communities are dominated by native species (species in green-shaded cells) however, within these communities are species that have been identified as aggressive and undesirable (salmon-shaded cells).*

Festuca roemeri		
	Festuca roemeri	57
	Holcus lanatus	14
	Carex inops	8
	Vicia sativa	6
	Pteridium aquilinum	5
	Rumex acetosella	5
	Poa pratensis	4
	Aira caryophyllea	2
	Camassia quamash	3
	Danthonia californica	3
	Hypochaeris radicata	3
	Rubus ursinus	0.5
	Luzula multiflora	2

Leymus mollis		
	Leymus mollis	33
	Rubus ursinus	12
	Pteridium aquailinum	11
	Bromus sitchensis	10
	Festuca rubra	9
	Cirsium arvense	5
	Aira caryophyllea	5
	Poa pratensis	4
	Vicia hirsuta	2
	Vicia sativa	1

Bromus sitchensis		
	Bromus sitchensis	27
	Bromus hordeaceus	27
	Poa pratensis	25
	Vicia sativa	10
	Bromus rigidus	10
	Holcus lanatus	6
	Pteridium aquilinum	6
	Cirsium arvense	4
	Hypochaeris radicata	3
	Geranium molle	3

Lupinus littoralis		
	Lupinus littoralis	35
	Bromus rigidus	22
	Pteridium aquilinum	6
	Rumex acetosella	6
	Bromus sterilis	6
	Leymus mollis	5
	Cirsium avense	4
	Hypochaeris radicata	4
	Festuca roemeri	3
	Abronia latifolia	3

The numbers in the columns to the left of the species name is the percent cover.

Revegetation Units

The project area is broken into four revegetation units: 1) gentle cuts and fills, 2) steep cuts and fills, 3) reclaimed road, and 4) staging areas. Each unit has its own revegetation strategies and set of treatments.

Unit 1. Gentle Cuts and Fills

The middle portion of the proposed road is located on gentle terrace slopes with gradients ranging from 5 to 30 percent and encompassing less than 3 acres. The cuts and fill slopes that are created in this area will be minimal in size and offer a greater variety of revegetation treatments because of the gentle slopes. Specifically, gentle slopes can be planted with seedlings using ground-based equipment, which opens the opportunity of establishing many forb species. This area is important because it is the part of the project where topsoil will be salvaged and reapplied on the cuts, fills and on the old road section. Because of the potential lack of topsoil on this project, it is important that as much "clean"[3] topsoil is obtained from this area as possible.

Figure 7. Unit 1. *General vicinity of gentle cuts and fills.*

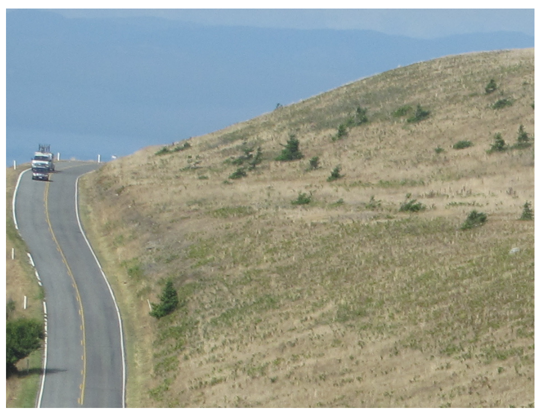
The following are the main revegetation strategies that will be followed:

- Salvaging and storing topsoil (page 10)
- Applying topsoil to gentle slope gradients (page 11)
- Planting methods—Seedlings (page 19)

Unit 2. Steep Cuts and Fills

Steep cut and fill slopes will be created at the beginning and the end of the proposed new road alignment. These slopes will range from 30 to over 50 percent and create approximately 5 to 7 acres to revegetate. The long, steep slopes will eliminate the use of ground-based mechanical restoration methods. Salvaging topsoil on steeper slopes will be more difficult than on gentler slopes nevertheless, since topsoil is at a premium, care must be taken to obtain as much clean topsoil as possible. Placing salvaged topsoils on steep cuts and fill slopes will have to be done during construction using an excavator or stone slinger. While some hand-planting of grass and forb seedlings can be done on these slopes, most of the revegetation will have to be accomplished using seed.

Figure 8. Unit 2. *Steep cuts and fills at north end of project.*



[3] "Clean" refers to topsoil free of gravels and cobbles from the parent material and non-native plant reproductive propagules (seeds, plants, roots) from the surface horizon.

The following are the main revegetation strategies that will be followed:

- Salvaging and storing topsoil (page 10)
- Applying topsoil to steep slopes (page 12)
- Seeding methods (page 16)
- Applying mulch (page 12)
- Applying compost (page 13)

Unit 3. Reclaimed Abandoned Road

Figure 9. Unit 3. *Section of Cattle Point Road that will be obliterated after new road is constructed.*

When the new section of road has been constructed, the existing road will be obliterated. The road asphalt and road base will be removed and the road fill pulled into the road prism and recontoured to blend in with the surrounding landscape. Salvaged topsoil, obtained during the construction of the new road, will be placed over the reclaimed abandoned road section. Approximately 2.4 acres will be restored to native vegetation.

Revegetation methods will depend on the steepness of the reclaimed surfaces. There will be more opportunities to plant forb and grass seedlings with ground-based equipment on gentler slope gradients; whereas the steeper sections of reclaimed road will have to be seeded with native grass species. The following are the main revegetation strategies that will be followed:

- Applying topsoil to gentle and steep slopes (page 11-12)
- Seeding methods (page 16)
- Planting methods (page 19)
- Applying mulch (page 12)

Unit 4. Staging Areas

The staging areas have not yet been identified.

Revegetation Strategies

Salvaging and Storing Topsoil

Topsoil is critical for reestablishing native vegetation on cuts, fills, and the reclaimed road. It is an achievable goal to obtain all topsoil from the 12.4 acre footprint of the new road so that topsoil does not have to be brought in from outside sources. It is also important that topsoil be free of non-native plant propagules (seeds, roots, and plants) that might reestablish and outcompete native plant reestablishment on this project. For these reasons, detailed attention needs to be given to how topsoil is salvaged.

When topsoil is removed from the new section of road, some or all of the following measures can be used to prevent contamination of topsoil with non-native plant propagules.

1. Remove organic layer and 3 to 6 inches of surface topsoil without mixing this material into lower topsoil horizons (Figure 3). The material from this layer is full of seeds, roots, and litter from non-native

species and must be stored in separate piles. This layer will be referred to as the "organic topsoil" to differentiate it from the material below it which will be referred to as "clean topsoil".

2. Monitoring the removal of the organic topsoil during salvage is important to insure that the proper depth of this layer is removed and not mixed into the lower topsoil layers. Removal of this layer should be done without disturbing the lower horizons. Equipment such as a tilt bucket attached to an excavator is preferred for exact removal of soil horizons.

3. The organic topsoil material excavated from this operation will produce between 5,000 to 10,000 cubic yards of material. This material must be kept separate from the clean topsoil pile. A location for storing the organic topsoil will need to be identified.

4. Since the organic topsoil will be high in organic matter, it will compost to some extent in the piles. If the piles reach high enough temperatures (greater than 180°F), then most seeds and plant parts will be killed and the resulting composted organic topsoil could be used on the project as a lower horizon. Adding high organic matter, such as chipped woody debris and yard waste, to these piles will increase the composting process.

5. After the organic topsoil layer has been removed, a 12 to 24 inch deep section of clean topsoil will be excavated. This should be done when soils are relatively dry. A soil scientist or other trained personnel should be on site when this work is done to assure that soil horizons are being removed correctly. Some subsoil will be excavated with the clean topsoil, but no more than 15% gravels will be allowed in the total volume of clean topsoil removed.

6. The clean topsoil that will be used on the gentle cut and fill slopes can be stored in windrows above cuts or below the fill slopes. The clean topsoil must be placed on plastic to prevent non-native propagules present on the undisturbed soil surface from contaminating the salvaged soil. When enough soil to cover the cuts and fills to a depth of 12 to 18 inches has been placed in windrows, then the clean topsoil must be covered with plastic to prevent erosion, reduce the potential for non-native seeds to blow onto the soil, and keep the soils relatively dry.

7. The clean topsoil that will be applied to the reclaimed abandoned road will be stored offsite on the road from Pickett's Lane to the Redoubt. Clean topsoil will be placed in long windrows on one side of the road, leaving enough room for one-lane vehicular access. Topsoil will be stored in piles no higher than 15 feet high and in a manner that does not overly compact or damage the soil. Soil will not be driven on by heavy equipment.

8. The clean topsoil will be covered with plastic to prevent erosion, to reduce the potential for weed seeds to blow onto the piles and to keep the piles relatively dry. Soils should not remain uncovered for any length of time during the seed dispersal window (summer through early fall) to prevent contamination of windblown seed.

9. Construction equipment will be steam-cleaned prior to excavating clean topsoil. When construction equipment is used in areas high in weeds, it will be steam-cleaned prior to working in clean topsoil areas.

Applying Topsoil to Gentle Slope Gradients

Applying salvaged topsoil to low gradient slopes is much easier than on steeper slopes. The wider range of equipment that can be used on these slopes, results in lower costs and often better results.

1. The placement of clean topsoil must be done during or just before the optimum seeding or planting windows (Figure 2).

2. Clean topsoil must be placed on non-compacted slopes. If sites are compacted prior to topsoil placement, they must be loosened to a depth of 18 to 24 inches. This is preferably done with an excavator bucket or the teeth of an excavator bucket. Clean topsoil placed over non-compacted soils increases rooting depth and increase the potential for successful revegetation.

3. Clean topsoil will be applied with equipment that does not compact or mix the soil during or after

placement. Such equipment includes excavators, manure spreaders, or stone slingers, but not ground-based equipment because of the potential risk of compaction and mixing clean topsoil with lower soil layers.
4. Placement of topsoil will be monitored by a soil scientist or trained personnel to assure that it is applied at a minimum depth of 12 inches and not mixed in with the surfaces below. Compaction will be measured with a soil penetrometer.
5. Since the high quantities of organic topsoil are unsuitable as salvaged topsoil, this material could be applied as a base, then covered with 6 to 12 inches of clean topsoil. This will depend on the condition of the organic topsoil, such as how much composting has taken place, and other factors which a soil scientist will determine at that time. Using the organic topsoil will increase the amount of topsoil for the project as well as dispose of the material.
6. The final slope shape will be left somewhat uneven to create different niches for plant establishment. Sculpted or uneven surfaces produce microsites that are protected from the wind which should result in better establishment of vegetation.
7. The soil surface will be left in a roughen condition after application. This can be accomplished during application through instructions to the operator or by using equipment designed for surface imprinting. After topsoil application, soils will not be driven on with high ground pressure equipment. If equipment must be used for revegetation efforts, then only equipment with ground pressures of less than 5 psi will be used.
8. Seeding, mulching, or planting seedlings will be done as soon after placement of clean topsoil as possible to get a jump on non-native plant reestablishment. This will be especially important if topsoil placement is done during the optimum period of weed seed dispersal.

Applying Topsoil to Steep Slope Gradients

Application of topsoil to steep slopes is more difficult and the application methods more limited.

1. The ground surface must be sculpted or have an irregular surface prior to application of clean topsoil. This will minimize the risk of topsoil sloughing after placement.
2. Clean topsoil will be applied with equipment such as an excavator or a stone slinger in a manner that will not mix the clean topsoil with the lower materials.
3. The placement of clean topsoil must be done during or just before the optimum seeding or planting windows (Figure 2).
4. Placement of topsoil will be monitored by trained personnel to assure that it is applied to a minimum depth of 12 inches, not mixed in with the surfaces below, and not overly compacted.
5. The soil surface will be left in a roughen condition after application. This can be accomplished during application through instructions to the operator or by using equipment designed for surface imprinting.
6. The final slope shape will be left somewhat uneven to create different niches for plant establishment. Sculpted or uneven surfaces produce microsites that are protected from the wind which should result in better establishment of vegetation.
7. Seeding, mulching, or planting seedlings should be done as soon after placement of clean topsoil as possible to get a jump on non-native plant reestablishment. This will be especially important if topsoil placement is done during the optimum period of seed dispersal.

Applying Mulch

Applying a mulch over soils that have been seeded should be considered especially if: 1) the slope gradients are steep, 2) the soil surface is prone to wind or water erosion, or 3) if a mulch is needed to reduce the establishment of unwanted species.

1. Use clean, high quality mulch, free of seeds. Source will be certified "weed-free".
2. Use only sources of mulch originating on San Juan Island. This would involve working with local businesses that specialize in compost and mulch production, such as the San Juan Sanitation Co., several years prior to project implementation to assure that appropriate material and quantities are available.
3. Perform weed surveys of material before accepting. Material should be certified weed-free by a botanist.
4. Use long-fiber mulch, not wood chips.
5. Place over seeded areas at a depth of 0.8 inches for large seeded species (most grass and some forb species) and at a depth of 0.25 inches over small seeded species (most forb and some grasses such as Roemer's fescue).
6. Investigate using a tackifier over mulch to prevent movement of the mulch by high winds.

Applying Compost

Where clean topsoil is not available, an option is to cover the soil surface with an imported compost that is free of seeds. The thick layer of compost will bury weed seeds present in the soil surface and prevent them from germinating. Obtaining compost on the island however, will be very expensive, so this option should only be used as a last resort.

1. Use high quality compost, free of seeds, and meeting US Composting Council standards (for example of standards see Steinfeld and others 2007 page 225). The compost must be fertile, fine textured, and demonstrate that it is capable of growing vegetation. Source will be certified "weed-free".
2. Use only composts originating on San Juan Island. This would involve working with local business, such as the San Juan Sanitation Co., several years prior to the project to insure that appropriate material and quantities are available.
3. Perform weed surveys of compost material before accepting. Material should be certified weed free by a botanist.
4. Place compost at a minimum of a 2 inch depth, but deeper depending on the amount and type of non-native species that are present in the topsoil.
5. Use a tackifier in the compost.
6. Schedule the placement of compost right before seeding or planting to reduce the risk that non-native seeds will blow in from surrounding areas.
7. Place compost with a stone slinger or mulch blower, instead of tractors or excavators, to assure a uniform application.
8. Be certain that equipment is free of seeds and vegetative parts by steam cleaning or other methods.

Species and Genetic Source

The isolation of San Juan Island created conditions where plant species evolved independently of their counterparts on the mainland and adapted to the unique characteristics of the soils and climate of the prairie ecosystem. It is important that these unique traits are conserved in the park. For this reason, only locally collected native plant materials will be used for propagation in this revegetation project.

The species that could potentially be propagated for this project are shown in Figure 10. The selection of these species was based on their presence in the four native plant communities (Figure 5), propagation experience, and project objectives. Of these, only a portion will be used in large amounts. These are referred as workhorse species and they will form the backbone of the native plant communities that will be reestablished. The list in Figure 10 will change as more experience is gained in the next few years from propagating these species by the San Juan Island National Historical Park personnel and by others.

The makeup of the native plants found in the four native plant communities shown in Figure 5 will be used as a guide in developing several seed and seedling mixes. The appropriate composition of species in a mix will be developed in the next few years. One approach is to develop four seed and seedling mixes that correspond to the makeup of each of the four native plant communities shown in Figure 5. If four mixes are developed, then it will be important to understand where they will be applied. Another approach is to develop seed and seedling mixes that are composed of a hybrid of these native plant communities. A third approach is to have a seed and seedling mix that is predominately composed of one or two native grass species. This approach has been tested in several fields at American Camp. A field below the Redoubt was planted several years ago with Roemer's fescue at a 1-foot spacing with very good results (Figure 11). Another field, near the American Camp Visitor Center, was planted with two species, blue wild rye and Sitka brome with good results.

Information Needs. Whichever seed and seedling mixes are developed, testing how each performs will be important to know prior to implementing the revegetation project.

Propagation and Installation of Plant Materials

There are many ways to reestablish the plant species shown in Figure 10. The most common, and typically least expensive propagation and installation method, is direct seeding. Yet for many forb and shrub species, direct seeding is not the best method for achieving plant establishment. Other methods can be more successful and they include propagating from nursery-grown seedlings, bulbs, wildlings, and in some cases, sprigs. Each of these propagation methods has advantages and disadvantages as discussed in the following section.

Seeds

Seeding is the most common method of reestablishing native grasses on restoration projects because it is relatively inexpensive compared to other propagation methods. Most grass species do well when seeded and it can be assumed that this will be the case for the grass species selected for this project. There is less experience with seeding forb species and for this reason the primary method of propagating forbs should be from planting containerized seedlings. Nevertheless, seeding trials using forb species should be initiated to understand how well they might reestablish using this propagation method.

Seed Production. This project will require larger quantities of seeds than can be efficiently obtained through hand collection. Obtaining large quantities of seeds is typically done through seed-increase contracts. Under these contracts, hand-picked seeds that have been cleaned at a seed extractory are sent to farmers who specialize in growing native grass and forb seeds. The farmer receives the "starter" seeds in the late summer, sows them in the fall, and harvests new seeds from the established beds the following summer. Beds can remain in production for several years or more producing large quantities of seeds. To obtain enough seed for this project, seed beds need to be established two to three years prior to direct seeding. The seeds harvested from these beds must be cleaned, packaged, and held under controlled storage conditions until needed for the project. This will necessitate that "starter" seeds from species listed in Table 10 are available for seed-increase contract. The Park has already collected many of these species and has these in seed storage. Some of these species are being propagated for seeds through the Natural Resources Conservation Service (NRCS) Plant Materials Center in Corvallis, Oregon. Larger seed increases can be made through the U.S. Forest Service which contracts its seed pro-

*Figure 10. **Species Propagation.** The following table identifies those species that will be considered for propagation. The species highlighted in green are considered workhorse species which means that they will be the backbone of the species mix. The blue highlighted cells are "specialty" species, which are those species that meet specific project objectives. The "propagation" column indicates if a species has been successfully propagated by either the San Juan National Historic Park or by others. Information for this table was obtained from a review of each species on the Native Plants Network (www.nativeplants.for.uidaho.edu) and the Plants Database (www.plants.usda.gov).*

			Stocktype				
Grasses		**Propagation**	**Containers**	**Bulbs**	**Seeds**	**Sprigs**	**Wildlings**
Sitka brome	Bromus sitchensis var. sitchensis	1,2	y		y		
Jepson's blue wildrye	Elymus glaucus ssp. jepsonii	1,2	y		y		
Roemer's fescue	Festuca roemeri	1,2	y		y		
California oatgrass	Danthonia californica	1,2	y		y		
slender wheatgrass	Elymus trachycaulus ssp. trachycaulus	1	y		y		
Alaska oniongrass	Melica subulata var. subulata	1	y		y	y	
American dunegrass	Leymus mollis ssp. mollis		y			y	
long-stolon sedge	Carex inops ssp. inops		y			y	
Lemmon's needlegrass	Achnatherum lemonii	1,2	y		y		
red fescue	Festuca rubra ssp. rubra	1	y		y		
Forbs							
barestem biscuitroot	Lomatium nudicaule	1	y				
common camas	Camassia quamash	1	y	y		y	y
checker lily	Fritillaria affinis var. affinis		y	y			y
meadow deathcamas	Zigadenus venenosus var. venenosus	1	y	y			y
western yarrow	Achillea millefolium var. occidentalis	1	y		y	y	
western pearly everlasting	Anaphalis margaritacea	1	y		y		
Canadian goldenrod	Solidago canadensis var. salebrosa	1	y		y	y	
Sierra pea	Lathyrus nevadensis var. pilosellus		y				
miniature lupine	Lupinus bicolor ssp. bicolor	1	y		y		
American vetch, purple vetch	Vicia americana ssp. americana		y		y		
tapertip onion, taper-tip onior	Allium acuminatum	1	y	y			y
fireweed	Chamerion angustifolium	1	y				
bracken fern	Pteridium aquilinum var. pubescens	1	y			y	
Henderson's shooting star	Dodecatheon hendersonii		y				
California buttercup	Ranunculus californicus	1	y				y
wild strawberry	Fragaria virginiana	1	y			y	y
Nootka rose	Rosa nutkana var. nutkana	1	y				
hookedspur violet	Viola adunca var. adunca	1	y				
seashore lupine	Lupinus littoralis		y		y		
common woodrush	Luzula multiflora var. multiflora		y				
hyacinth brodiaea	Triteleia hyacinthina	1	y	y			
Eschscholtz's hair rockcress	Arabis eschscholtizana		y				
Menzies' pepperweed	Lepidium virginicum var. menziesii		y				
Common pepperweed	Lepidium densiflorum var. desiflorum		y				
Shrubs							
common snowberry	Symphoricarpos albus var. laevigatus		y				
trailing blackberry	Rubus ursinus ssp. macropetalus		y			y	y

Propagation: 1 - propagated by others, 2 - propagated by the SJHNP

duction through farmers in the Columbia Basin. Bulk seeds need dry, cool, and rodent-free conditions for storage. Bulk seed storage facilities can be either located on the island or at the U.S. Forest Service Bend Pine Seed Extractory in Bend Oregon.

Seeding Methods. There are a variety of seeding methods which will be used depending on the species being sown and site conditions. Hydroseeding is a method where seeds are hydraulically delivered to the surface of the soil through a slurry composed of wood fibers and a tackifier. The advantage of this system is that seeds can be applied in a very short period of time without the need for ground-based equipment. For many small-seeded forb species that require light to germinate, hydroseeding has an advantage over other seeding methods, because forb seeds in this method are barely covered with wood fiber, directly exposing them to sunlight. Unlike broadcast seeding, where seeds can move off the site through wind and surface erosion, hydroseed mixes contain a tackifier that keep small forb seeds in place until germination. While hydroseeding can be advantageous for small-seeded species, large-seeded species, such as grasses and some forbs (e.g., lupines), need to be covered either by soil or mulch for good germination. This fact does not preclude using hydroseeding to place the seed but it will require that once seeds are placed, they are covered by mulch or soil.

Other seeding practices include hand-seeding, drilling, and harrowing. Hand-seeding has an advantage over other seeding methods where the placement of a single species or a specialized seed mix on the project is critical. Hand-seeding assures that seeds are placed in the exact locations and at the appropriate seeding rates. The disadvantage of hand-seeding is that the surface-applied seeds are exposed to wind or water erosion which could move the seeds before or while they are germinating. To compensate for this, hand-applied seeds must be immediately covered with either soil or mulch to keep them in place and to create a favorable environment for germination.

Seed drilling requires specialized equipment that is pulled behind ground-based equipment. The advantage of using the seed drill is that seeds can be placed at the appropriate depth in the soil surface to correspond to the seed size and germination requirements (e.g., grasses will have a deeper setting than most forb species). Some seed drills have several hoppers that can hold more than one seed mix, and each hopper can be calibrated to the specific requirements of the seed mix. The disadvantage of seed drilling is that it is limited by the slope gradients that the ground-based equipment can effectively and safely operate without disturbing the soil. Specialized low ground pressure tractors, including track tractors, can work on slopes up to 30% and often steeper slopes, and should be considered for this type of operation.

Seed harrowing is a seed application system where seed is broadcasted on the soil surface and then immediately mixed in the soil by a “toothed” chain dragging behind the seeder. This system has less accuracy than seed drilling because the seed is mixed throughout the top layer of soil and not placed at a specific depth. Like seed drilling, harrowing is also limited by slope gradients. Nevertheless, it has advantages because it can be used under conditions not favorable to seed drills (e.g., rough surface conditions and narrow strips).

A less typical way of seeding is to mix seeds with compost (page 13). In this operation, seeds are injected into the compost as it is blown onto the surface of the soil. The disadvantage of this method is that compost is expensive and must come from offsite producers.

Mulching is a method to cover seeds once they are sown (page 12). The advantages of mulching are that seed covering depths can be accurately controlled and mulch creates an optimum environment for seed germination. As with compost, the disadvantage of using mulch is that it must be created at the project site or delivered from offsite producers in large quantities (typically 100 to 135 yards per acre).

A seeding strategy will be developed in the final revegetation plan that uses some or all of the above seeding methods in combination or separately. Seed mixes and seeding rates will be developed for the different seeding methods and revegetation objectives. High seeding rates will be used for areas where seed germination is predicted to be low or the threat of weed infestation high.

Some considerations when seeding are:

1. Seed during optimum seeding windows (Figure 2).
2. Seed immediately after topsoil placement.
3. Use high seeding rates to "flood the system" with native species and reduce the potential that non-native seeds, if present, can establish on the site.
4. If seeds are sown in late winter or early spring, pre-germinate seeds prior to sowing.
5. Do not apply fertilizer with seed since nutrient levels should be high in clean topsoil (reassess need for fertilizers once plants have become established).
6. Apply mycorrhizae in case populations have been reduced during topsoil storage. This can be applied with the seed.
7. Seed applied by hand must be immediately followed with a surface application of long-fibered mulch (page 12).
8. Seed applied with a seed drill must be pulled by low ground pressure equipment and placed at a depth of 0.25 to 1.0 inch below soil surface depending on the size of the seed.
9. Seed applied with a seeder/chain harrow must be pulled by low ground pressure equipment. Higher seeding rates should be used with this equipment since some seeds will not be covered and some will be buried too deeply.
10. Unless covered with mulch, seed application using hydroseeding equipment, should be scheduled later in the fall when there is a greater chance that the surface soil will stay moist for longer periods.
11. To insure plant establishment in critical areas, supplemental irrigation using hydroseeding equipment should be scheduled.
12. If forb seeds are used, develop seed mixes that are low in grass seed to reduce the competition from grasses.

<u>Information Needs:</u> Direct seeding over bare soil has not been investigated in the Park so there is little actual knowledge how well this treatment would do under project site conditions. The concern with seeding is that the non-native seed bank, if present, will outcompete any native seeds applied to the site. A trial could be established that would evaluate which methods would work best for controlling non-native vegetation while succeeding in establishing native species. This trial could evaluate 1) how well workhorse species establish from seed, 2) how well native species grow when competing with non-native species, and 3) which method of seed cover is most effective – mulch covering or soil cover.

Seedlings

The advantage of establishing vegetation from nursery-grown seedlings is that the germination and early growth phase (the most critical period in plant development) takes place under a controlled nursery environment. This not only results in less seed being used (because most seeds develop into plants) but more importantly, the larger seedlings, when planted in the field, have a 3 to 4 month growing advantage over non-native species starting from seed. Planting seedlings at close spacing (e.g. one foot apart) easily develops into a desirable stand of native species within a year (Figure 11). The disadvantage of using containerized seedlings is the high costs of seedling production, transportation, and planting. Using seedlings requires a higher degree of coordination since plants can not be stored for long periods like seeds. A higher degree of scheduling orders, growing contracts, seedling delivery, short-term storage, and planting is important for successful plant establishment.

The National Park Service has had very good success in establishing native grasses from nursery-grown seedlings. In the last several years, they have established blue wildrye (*Elymus glaucus*) and Sitka brome (*Bromus sitchensis*) in small fields near the American Camp Visitor Center and Roemer's fescue (*Festuca roemeri*) near the Officer's Quarters at the Redoubt from small containerized plants instead of from seed (Figure 11). These fields have demonstrated that planting containerized plants is a viable method of reestablishing native grasses at a production scale.

Figure 11. Seedling Establishment. *As NPS has demonstrated in a field below the Redoubt, planting Roemer's fescue grass plugs at 1 foot spacing can lead to quick native plant cover, low in non-native species.*

Seedling Production. Grass and forb seedlings can be grown outside or in greenhouses. The advantage of growing seedlings outside is the lower production costs and the greater opportunities to grow seedlings closer to the project site. As the NPS has demonstrated, temporary seedling growing areas can be set up to produce large quantities of seedlings relatively inexpensively (Figure 12). If the NPS decides to take on the role of growing some or all of the containerized seedlings on site, then it will be important that there are trained personnel dedicated to overseeing the crop seven days a week during the growing season. It is also very important that outdoor production facilities have a good irrigation system, one that evenly distributes water to all containers. Uneven irrigation will create an inconsistent crop.

While most grass species can be grown outside, forb species might need to be started in a greenhouse environment and then moved outdoors. Nursery grass and forb production from offsite facilities will require the development of a contract for growing containers, or a contract for growing and planting containers. The NPS is learning how to grow a variety of forb species and what is being learned will help in establishing how large quantities of forb seedlings will be produced.

Some considerations for seedling production are:

1. Schedule nursery sowing so that grass plugs have not outgrown the containers by the time they are needed for planting. For most grass species that are sown in 6 cubic inch or smaller containers, sow seed 6 to 10 weeks prior to outplanting.
2. Most forb species take longer to grow in containers than grasses. Scheduling of forbs will be on a species specific basis.
3. Use a 5 to 6 cubic inch volume container for most grass species. Larger container sizes will increase costs.
4. Use potting media without perlite.
5. Unless fertilizers can be injected into the irrigation system during watering, apply slow-release fertilizer to plugs prior to sowing to assure that nutrients are available during production.
6. Apply mycorrhizae to plugs in nursery or in outplanting to assure mycorrhizae are present on the roots.

Figure 12. Seedling Propagation. *Propagating native grasses in containers can be done simply as the NPS has shown at American Camp.*

Planting Methods. Seedlings can be planted manually or mechanically. The NPS contracted the planting of containerized seedlings in the fields near the Redoubt and American Camp Visitor Center. These seedlings were planted with a 4-gang transplanter pulled by a tractor. Planting rates can be very high with this type of system, however this system will not work on steep slopes. On steeper areas, hand planting will be the preferred method. Hand planting can also be used where small clumps of a single forb species are desired (Figure 13). Hand planting can be done with shovels, augers, and dibbles.

Some considerations when planting seedlings are:

1. Plant seedlings during planting windows (Figure 2) and after soils have reached field capacity (i.e., after several major rainstorms). Planting can be done later in the season with hand crews, but ground-based planting equipment will be limited by wet soil conditions from mid-November through February.
2. Do not plant during hot spells or dry winds. Plant when weather outlook for 7 to 10 days after planting is favorable for plant establishment.
3. Protect plants from wind by planting on the upwind side of micro-relief features (this assumes the site is hand planted, not machine planted).
4. Pull seedling transplanters with low ground pressure equipment.
5. Thoroughly wet up plugs right before transplanting.
6. For grass species, plant at one-foot spacing.
7. Spacing for forb plants will be based on species characteristics. Design the location for forb plugs to minimize the competition with grass species. Many forb species grow in large populations or clumps and plantings should reflect the natural distributions.
8. Assure the top of the plug is not exposed to drying by covering the surface of the plug with 0.5 to 1.0 inches of soil.
9. Do not apply fertilizer to site after planting. Assess need for fertilizers only after plants have become established. Soils with salvaged topsoil should have enough nutrients without fertilizer application.
10. To assure plant establishment in critical areas (i.e., establishment of important species, steep cut slopes etc), supplemental irrigation using hydroseeding equipment in the late summer following planting could be used.

Information Needs**.** Grass seedlings are relatively easy to grow, but propagating many of the native forb species in containers will require some literature review and testing to develop an understanding on how well they grow and how long they will take to propagate. The NPS is growing some of these species on site and at the Plant Materials Center in Corvallis Oregon, but more work needs to be done in the next couple of years. Outplanting forb species in test plots will help establish the optimum planting densities for each species.

While planting seedlings is a very effective way of establishing desirable vegetation, it can also be expensive. A cost effective method of growing and planting seedlings needs to be investigated for gentle slopes and steep slopes. Each site condition will require different planting equipment.

Bulbs

Several forb species in Figure 10 can be grown from bulbs. The advantages of establishing plants from bulbs are that they have wider planting windows than seedlings, they are easy to plant, and they can be stored for long periods of time. The disadvantage of bulb propagation is that to produce bulbs large enough in size for transplanting can take 2 to 4 years, which increases production costs substantially.

Bulb Production. Bulbs are typically started from seed either sown in containers or bareroot nursery beds. The plants that develop are grown for several years until the bulbs are harvested. Bulb production works well at bareroot nurseries because these facilities have the equipment and experience to lift roots from the ground. Bulb production is similar to growing bareroot seedlings, except there are no tops on the plants at the time of harvest. Harvesting bulbs is done in the winter and requires bareroot lifting equipment that loosens the soil and brings the bulbs to the surface where the are hand-picked. In contrast, when bulbs are grown in containers the bulbs must be removed from the container and then extracted from the media. Harvested bulbs are stored in coolers until they are needed, however the duration that the bulbs of species shown in Table 10 can remain in cold storage and still be viable is uncertain and should be investigated if long-term bulb storage is anticipated.

One of the unique advantages of growing bulbs is that there are multiple stocktypes that can be derived from a single crop. Bulb-producing species, grown in containers, can produce seeds, bulbs, or seedlings. When grown in bareroot beds for several years, these plants will produce a seed, as well as a bulb crop. In addition, multiple bulb harvests can be made from a single bareroot bed if, during bulb lifting, only large bulbs are harvested and smaller bulbs left to continue to grow and produce a crop the following year.

Planting Methods. Bulbs can be planted with some of the same methods and equipment used to plant seedlings (e.g., shovels, dibbles, and transplanters), however other methods should be considered. One method is to apply bulbs to the topsoil during placement which would eliminate the need to plant bulbs in a separate operation. This method of restoration is not common, so some investigation in terms of potential damage to the bulb and the depth that bulbs should be placed would have to be conducted.

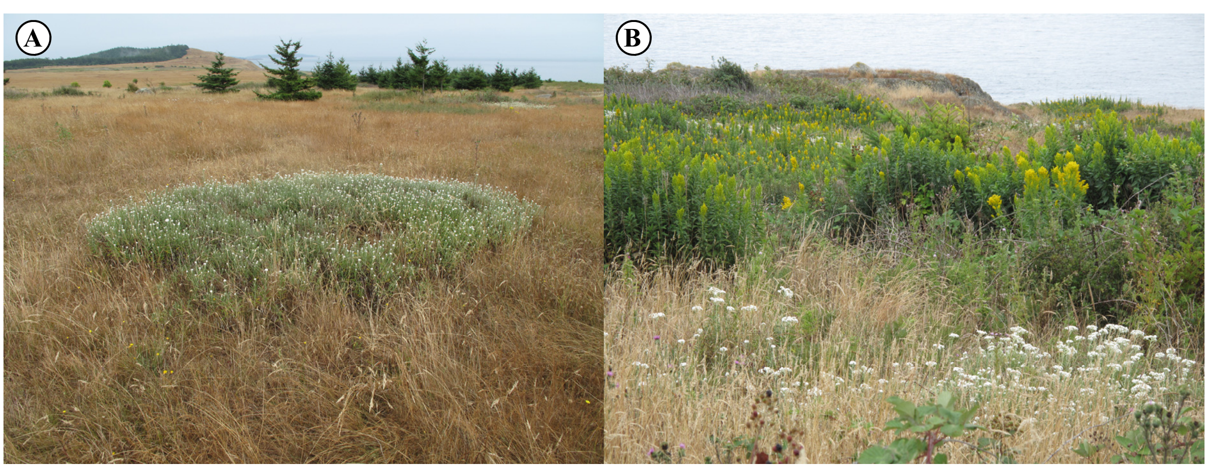
Information Needs. Culturing and planting practices for bulb installation should be investigated if bulbs are going to be used. Locating bareroot nurseries that would want to grow bulb crops should also be investigated.

Sprigs

Sprigging is a method of establishing rhizomatous grasses from small stems or rhizome segments (called "sprigs"). In this process, sprigs which contain three or more nodes are broadcasted over the site and covered with soil. When soil moisture and temperature conditions are right, the sprigs grow roots and leaves. Propagating grasses from sprigs is a method used in the turf grass industry, especially in the establishment of golf greens, however sprigging has seldom been used in restoration projects.

Sprig Production. At least six species have been identified in Table 10 as having the potential to be grown from sprigs. While there is no experience in propagating these species from sprigs, some trials

Figure 13. *Many forb species, such as western pearly everlasting (A) and Canadian goldenrod (B) grow in dense populations or clumps.*



could be established to investigate the feasibility of propagating and installing sprigs. One production method could use bareroot nurseries or seed production facilities to grow these grasses in beds and then during dormancy (summer, fall, or winter) the plants would be lifted from the soil and cut into sprigs. The advantage of using bareroot nurseries is that these facilities have equipment specialized for lifting plants. In addition, a sprig bed could also produce a seed crop if the bareroot nursery is equipped for harvesting seeds. The golf industry has developed equipment to lift and separate sprigs for planting.

Planting Sprigs. There are several possible ways of planting sprigs. Sprigs could be hand or mechanically broadcasted over the soil, then lightly disked or crimped into the surface. Sprigs could also be placed in with the clean topsoil while it is being applied. This method would eliminate the need for a separate spreading operation.

Information Needs. There is little written in the restoration literature on sprigging, so there would need to be some investigation into this methods of propagation and planting if it were to be used on any scale. A place to begin would be to review the work that has been done by the golf industry.

Wildlings

Plants obtained from digging individuals from the wild are called wildlings. Using wildlings in restoration projects has the advantage over the previously discussed methods in that the plant material does not need to be propagated, it is just excavated and moved to a new location. The construction of the new road will offer a large source of wildlings for this or other local projects. For projects where species are hard to establish or where just a few plants of one species are needed, salvaging wildlings can be a very good method. The disadvantages of salvaging wildlings are 1) the high costs of excavation, transportation, and installation of the plants and 2) the risk of excavating and replanting weed species that might be growing in or near the plants to be salvaged.

Most of the species in Table 10 can be reestablished by salvaging wildlings however, for only those species where other propagation methods are not practical or economical, should this method be considered. The populations of California buttercup within the road construction footprint should be considered for movement to new locations because of importance of maintaining and enhancing this species (see Specialty Species section).

Salvaging wildlings is a three phase operation of excavating, transporting, and planting. Complications arise when the sites where the wildlings are being moved are not ready for planting. This will most likely be the case for this project and will require that wildlings be moved to a temporary growing area while sites are being prepared. Keeping the wildlings alive during this period will require constant monitoring and irrigation during the growing season. The planting window for wildlings and care during and after planting are similar to those for container seedlings.

Specialty Species

California buttercup (*Ranunculus californicus*). Propagation of the California buttercup can be done from either wildlings obtained prior to road construction or from seedlings. Salvaging plants from the 4 to 5 potentially impacted populations will begin before construction (within the framework of National Environmental Policy Act (NEPA) and NPS policies) to assure that plants will be available by the time the sites are ready for planting. Prior to salvaging plants, a survey will be conducted to locate all populations that will be disturbed. Salvaging plants from these populations will involve digging a portion of the plants and moving them to a temporary growing area (this could be on the Park premises). While being grown in this area, individual plants will be transplanted into large containers (0.5 to 1.0 gallon size containers) and grown for at least a year.

Starting the buttercup from seeds will involve first obtaining seeds from local sources. Collecting seeds should begin as soon as possible. Seed should be sown in small containers first to conserve space and once germinated, moved to larger containers, such as 0.5 to 1.0 gallon size to assure high success in plant establishment. Washington State Department of Natural Resources (DNR) has recently propagated California buttercup in containers from seeds and planted them on state lands at Cattle Point. Based on work with similar species, they expect that it should be easy to establish this species from seedlings. To produce a seedling large enough in size for outplanting should take 1 to 2 years.

Once the site is ready, plants can be hand-planted in clumps, mimicking the size and shape of the natural populations. Mulching the surface of the soils around each plant will reduce the potential of other species competing with the California buttercup.

Host species for the Island Marble Butterfly. Menzies' pepperweed (*Lepidium virginicum var. menziesii*) is a known host plant and Eschscholtz's hairy rockcress (*Arabis eschscholtizana*), tower rock cress (*Arabis glabra*), and common pepperweed (*Lepidium densiflorum var. desiflorum*) are potential host plants for the Island Marble Butterfly. Seeds from these four species will be collected as soon as possible and the NPS will begin evaluating propagation methods using both direct seeding and seedling production. The NPS will also be conducting trials to determine if the Island Marble will utilize the three potential host plants and if larvae will survive and thrive on them. Pending the results of these trials, only known and documented native host plants will be propagated for the project.

Integrated Pest Management

Overview

There are 49 exotic species found in the American Camp prairie (Bivin 2009) and of these, 18 species are considered aggressive or undesirable by the NPS (Figure 14). These species are undesirable for many reasons: how well they repopulate disturbed soils, how aggressively they move into areas already established with native plants, their longevity on a site, and the difficulty of eradicating them.

The NPS will use an integrated pest management (IPM) approach to weed control. IPM consists of a series of pest management evaluations, decisions, and controls that will be developed for each of the 18 species of concern (EPA 2009). This approach uses information on the life cycles of each weed and their interaction with the environment to control them economically, and with the least possible hazard to people, property, and the environment. Within the framework of IPM, the NPS emphasizes the judicious use of pesticides. IPM is a four-step process: 1) prevention, 2) set action thresholds, 3) monitor, and 4) control.

Prevention

The basic strategy for weed prevention is:

1. Start with weed-free soil by salvaging and applying "clean" topsoil (pages 10-12).
2. When possible, schedule the application of topsoil after the optimum weed dispersal window.
3. Apply native seeds or plants at high densities immediately after topsoil placement (pages 14-22).
4. Where appropriate, apply "clean" mulch immediately over native seeds or plants (page 12).
5. Steam-clean all equipment used on the project with special attention given to equipment used in topsoil salvage and placement, revegetation equipment, and hydroseeding tanks.

Other prevention methods include controlling wind-borne seeds originating downslope from the new road and the abandoned road. This can be done by mowing the meadows in a 100 foot swath parallel to each road before weed seeds become mature.

Action Thresholds

The action threshold is the point at which pest populations or environmental conditions indicate that pest control action must be taken. The action threshold for each weed species is shown in Figure 14. They are based on the stated desired future conditions stated in Objective 3 on page 2

Monitoring

Monitoring will be conducted before, during, and after construction. Prior to construction, an inventory of the weeds identified in Figure 14 will be conducted on cut and fill slopes of the existing road and in the footprint of the proposed road. The "Species Presence" protocol using a 1.0 square meter quadrat frame will be used for monitoring the presence of weed species of concern (Steinfeld and others 1997).

Sites under construction will be visually monitored for presence of weeds and on a monthly basis, top-soil piles will be monitored visually for the presence of weeds. After revegetation has taken place, the project will be monitored periodically, beginning in the late winter after construction. The monitoring schedule will be developed according to the weed species and severity of invasion.

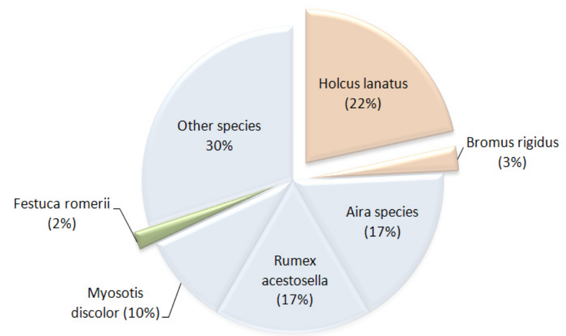
Figure 14. Weed Species of Concern. *Of the non-native plants identified in the project area, the 18 weeds shown in this table are considered aggressive or undesirable. Most of the species are perennial or biennial (Duration column: P = perennial, B = biennial, A = Annual). Some species are on the Washington Noxious Weed list (Weed Class column). The action threshold column is the percent of plots having a species of concern at which an action will be taken.*

Species	Common Name	Duration	Weed Class	Action Threshold (% Presence)
Bromus rigidus	ripgut brome	AP		1
Centaurea stoebe	spotted knapweed	BP	B	1
Cirsium arvense	Canada thistle	P	C	1
Cirsium vulgare	bull thistle	B	C	1
Crataegus monogyna	oneseed hawthorn	P		1
Dactylis glomerata	orchard grass	P		1
Daucus carota	Queen Anne's lace	B	B	5
Dipsacus fullonum	Fuller's teasel	B		1
Elymus repens	quackgrass	P		1
Eschscholzia californica	California poppy	AP		1
Holcus lanatus	common velvetgrass	P		5
Hypericum perforatum	common St. Johnswort	P	C	5
Hypochaeris radicata	hairy cat's ear	P	B	5
Lolium arundinaceum	tall fescue	P		1
Rubus armeniacus	Himalayan blackberry	P		1
Rubus laciniatus	cutleaf blackberry	P		1
Senecio jacobaea	tansy ragwort	P	B	1
Verbascum thapsus	common mullein	B		1

Control

Once monitoring has indicated the action thresholds of any of the weed species of concern have been exceeded, then an array of control measures will be considered, a decision made, and action taken. Weed control measures include hand weeding, flaming, steaming, covering, spot herbicide spraying, and broadcast herbicide spraying. Each of these treatments has some degree of effectiveness that varies with the type of species shown in Figure 14.

Figure ***15. Weed Seed Bank.*** *Germination tests of the seedbank samples taken in the prairie showed that 70% of the germinants were from the six species shown in this chart. Only Festuca romerii was native at 2%, while two undesirable species, Holcus lanatus and Bromus rigidus, were present on 25% of the plots.(Bivin 2009).*



IPM Plan

It is not in the scope of this revegetation plan to identify the effectiveness of each control measure for each species shown in Figure 14. This should be addressed in an IPM plan developed specifically for the implementation of this project. The development of the plan will require a thorough review of the effectiveness of weed control measures for each species in Figure 14. It would outline measures that will be taken if monitoring indicates a threshold for any species has been exceeded.

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