An introduction to using native plants in restoration projects.

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WHY USE NATIVE PLANTS?

A native (indigenous) species is one that occurs in a particular region, ecosystem, and habitat without direct or indirect human actions (Kartesz and Morse 1997; Richards 1998). Species native to North America are generally recognized as those occurring on the continent prior to European settlement.

Although only about 737 native plant species are protected by the Endangered Species Act, it is estimated that nearly 25 percent of the 20,000 native plant species in North America are at risk of extinction. It is becoming generally recognized that in order to preserve individual species, their plant communities must be preserved. This includes the preservation of native plants that are not yet in danger of extinction, but still play an important role in native ecosystems.

As the public becomes more concerned about the environment, the interest in the preservation and restoration of native plant communities increases as well. Native plants are valued for their economic, ecological, genetic, and aesthetic benefits in addition to the growing societal belief in their intrinsic value as living species.

In 1969 Congress passed the National Environmental Policy Act (NEPA) that provides statutory protection of natural ecosystems on federal lands, and also offers the public the opportunity to consider the environmental implications of revegetating federal landscaped with introduced versus native plants (Richards 1998). Then in 1995, 9 federal agencies and 53 organizations created the Native Plant Conservation Initiative National Strategy for the protection of native plants. Work on the National Strategy is continued today by the Plant Conservation Alliance.

Using native plants to restore the landscape or as a substitute for exotic ornamental plantings can help to reverse the trend of species loss. Although the methods may differ, native plants require the same level of care in installation and establishment as do ornamental plants. If the environment has been altered significantly through human activities, some work will be necessary to recreate an environment more hospitable to natives. However, in the long run, natives will, in most cases, form self-sustaining plant communities that do not require much maintenance. Because they are adapted to a local region, they tend to resist damage from freezing, drought, common diseases, and herbivores if planted in that same local region.

Native plant species provide the keystone elements for ecosystem restoration. Native plants help to increase the local population of native plant species, providing numerous benefits. There are specific associations of mycorrhizae with plants, invertebrates with woody debris, pollinators with flowers, and birds with structural habitat that can only be rebuilt by planting native plants.

Advantages of native plants:

- add beauty to the landscape and preserve our natural heritage
- provide food and habitat for native wildlife
- serve as an important genetic resource for future food crops or other plant-derived products
- help slow down the spread of fire by staying greener longer
- decrease the amount of water needed for landscape maintenance
- require very little long-term maintenance if they are properly planted and established
- produce long root systems to hold soil in place
- protect water quality by controlling soil erosion and moderating floods and droughts

PLANNING A NATIVE PLANT PROJECT

Once a decision has been reached to use native plants in landscaping or in a restoration project, there are a number of important factors that should be considered. In order to have a successful project, these factors should be examined during the planning process long before plants are brought onto the site.

It is very important to consider carefully the time it will take to implement the project. Working with plants creates specific needs because certain phases of a project can only be done at certain times of the year. Lack of foresight in this area can be disastrous. The first section on "*Establishing a Realistic Timeframe*" explains some of the features of native plant projects that require proper timing in order to develop an effective project. It is also helpful, when beginning to plan the project, to have a clear idea of the project goals and objectives. Information on doing so can be found in the section on "*Determining Project Targets.*" After setting goals, take the time to understand the planting site thoroughly with the aim of anticipating and addressing possible problems as outlined in the section on "*Evaluating The site.*" Finally, good planning will entail carefully deliberated decisions on what native plants will be used and where or how they will be acquired. There are a number of sections following "*Evaluating The site*" that can help in completing that phase of the project.

While the following sections are mainly intended as a guide for native plant restoration projects, many of the same concepts apply to using native plants in landscaping. Consequently, there is useful information in this guide for anyone who is planning to use native plants.

Establishing a Realistic Timeframe

Native plant restoration projects must be planned well in advance. It is not practical for most projects to begin in January and expect to install plants in the ground in March or April. There is much that needs to happen between the time that the project is identified and the time the plants are ready to go into the ground.

Taking time at the beginning to thoroughly evaluate the site and develop a well-thought out site preparation and planting plan is an important first step to planning a successful project. This may require evaluating the site during different seasons to understand how the site changes over time. Also, identifying a natural model or referencing a preserve can add relevant information. This understanding will help in avoiding costly mistakes such as planting plants in a place where they cannot survive the environmental conditions.

Using native plants in a restoration project often involves the collection of locally-adapted plant material or commercially grown local ecotypes. Materials are often not immediately available in the quantities and quality required from native plant suppliers. If this is the case, make sure there is enough lead time to collect and propagate the plant material required – either using project staff or contracting with a supplier. The only time this might not be the case is if there is already a high demand for the native plants needed and the native plant suppliers have accurately anticipated that demand. Advanced planning and ordering of the plant material will ensure the availability of desired species with proper hardening of the stock or harvesting of the seed.

If seeds are to be collected there is usually only a short window during the year when seeds are ripe and available for collection. Often, a series of collections is needed to reflect the diversity of the seasons. After the seeds are collected, some require special treatment, such as several months of cold hardening or after-ripening, before they will germinate. If plants need to be propagated from plant cuttings, a general rule of thumb is to allow 18-30 months from the time the parent plants are located in the summer to the time rooted cuttings are of sufficient size to survive transplantation into the restoration site. To be absolutely sure of plant availability, containerized seedlings should be ordered 1-2 years prior to planting and bareroot seedlings should be ordered 2-4 years prior to planting (Colorado Department of Natural Resources 1998). Commercially grown seed also requires ordering ahead of time.

Involving local experts in the design and development of the restoration project will also require advance planning. Assistance might be needed from experts in several fields, such as hydrology, geology, soil science, horticulture, biology, and wetland ecology. Coordinating among numerous people always requires more time than originally expected.

Although it may seem more economical to coordinate a native plant project on a shorter time schedule, usually the results will not be very good. In order to ensure the greatest long-term success of the project, it is well worth investing time at the beginning to evaluate the site and to ensure that all the plants or seeds needed for the project can be obtained.

Determining Project Targets

When starting a native plant restoration project it is important to clearly determine the project targets.

Defining the Problem

The first question to answer is: what are the problems with the site? Is the problem soil erosion due to a lack of vegetation, low native biodiversity due to a near monoculture of one or two invasive weeds, increased flooding problems due to a reduction in the ability of the ecosystem to regulate water flow or some other problem related to vegetation? Asking specific questions and considering all aspects are essential to identifying problems at the site.

Setting Goals and Objectives

Once the site's problems have been identified, it is easier to set clear goals and objectives. A goal is more overarching and an objective is more specific. Setting clear goals and objectives will help in making good decisions as the planning process continues. Clear goals and objectives are also essential for defining a monitoring plan that will quantitatively evaluate the long-term success of the project. Each objective should relate to some measurable criterium.

Some examples of goals, related objectives and measurable criteria:

Goal: increase available wildlife habitat
Objective: plant native plants that can provide food for local wildlife
Measurable Criterium: establish greater than 50% cover of native plant species that are providing food for wildlife

Goal: improve water quality
Objective: plant native species that require less fertilizers and pesticides than non-native plants, reducing chemical run-off into local streams
Measurable Criterium: reduce the quantity of commercial fertilizers used on site by 90%

Goal: reduce soil erosion
Objective: plant native species that will develop strong extensive root structures to hold soil in place
Measurable Criterium: reduce soil loss to less than 5 Mg/ha per year

With careful planning, the project can address multiple goals. Ideally, a project should aim for a holistic approach toward solving multiple problems by reaching several goals rather than a result benefiting a single goal.

Evaluating the Site

The site condition is a critical factor in the success of a restoration project. Plants that are ill suited to a site's growing conditions will have difficulty surviving. Consequently, the conditions of the site need to be known before making a detailed restoration plan. Remember also that the site can look very different at different times of the year. It may be completely dry in the summer, but look like a pond in the winter. Try to evaluate the site during all seasons or find out from others that are familiar with the site how it might change over the course of a year.

Important characteristics to consider include the following:

- soils
  - history of residual herbicides and/or pesticides
- topography
- hydrology
- existing ecological communities
  - presence of exotic plant species
  - abundance or lack of native plant species
- disturbances
- climate and microclimate
  - frost-killing dates

Ideally, the assistance of specialists such as soil scientists or hydrologists should be obtained to evaluate some of these characteristics in order to make a more accurate determination of the existing site conditions.

Soils

Soils are one of the most important factors that can influence plant survival on the site. A few of the major characteristics of soil and examples of how they can affect plant health and survival are listed below.

- **texture** – affects moisture levels and nutrient exchange
- **pH** – affects the ability of plants to take up nutrients
- **organic matter** – affects nutrient and moisture availability
- **compaction** – makes it difficult for plant roots to penetrate the soil; affects nutrient cycles & beneficial organisms
- **residual herbicides or pesticides** – can affect plants and associated insects

For general soils information contact the local Natural Resources Conservation Service (NRCS) office or the local Conservation District. Referring to the published soil survey for the site's area will be an important first step. Some soils information can also be found on-line at the National Soil Survey Center's web site at http://soils.usda.gov/.

In evaluating specific project site soils, having a professional soil scientist provide assistance would be the preferred course of action. If there are none on the project team, try contacting NRCS, the county Cooperative Extension office of the state's land grant university or an environmental consulting firm. However, there are also a few things that can be done without a soil scientist on staff to get a basic idea about the type of soil on the site

The first step in examining the soils at the site is to collect some soil samples. The method of collection for soil samples can affect the results of tests, so it is important to consider a few basic collection guidelines. Soil samples are usually collected with some type of soil probe that can collect a core cylinder sample of soil. These soil probes can be purchased through most forestry or agronomic supply catalogs (Appendix A).

The recommended depth of the sample is variable depending on the type of site and the type of analysis. It is best to get the advice of a soil scientist. However, if an expert opinion is not available, samples are often collected to a depth of around 20 centimeters. Deeper samples are often obtained if woody plants are part of the restoration project.

Sampling location should also be considered carefully. Samples should be taken at a number of different places in the site in order to determine soil variability. Composite samples consist of a minimum of three soil cores from a single area to get a representative sample. While agronomists traditionally composite samples, an understanding of the heterogeneity of both disturbed areas and reference areas is very important for predicting the desired result or likelihood of success of the project. When sending in non-composite samples, indicate to the lab that field replicates instead of composites are being submitted. Try and sample areas that may have different soil types. Different soil types can be indicated if the vegetation is varied from one location to another and if the water relationships are different from one part of the site to another. If the soil chemistry or texture is different in different parts of the site, that is an important factor that will need to be considered during site preparation and the planting design phase.

If samples will be stored or transported before doing a chemical analysis (pH, organic matter, or nutrients), they should be placed in a plastic bag at the site, closed with a ziplock or a twist tie, labeled with a permanent marker, and kept cool during transport. After transport most samples should immediately be air-dried by spreading out each soil sample into a thin layer on separate labeled pieces of clean butcher paper. However, certain tests, such as those for plant-available nitrogen, require fresh samples to be processed as soon as possible after collection, so the lab should be consulted beforehand.

If the services of a soil testing laboratory are to be used, be sure to talk to them about their specific guidelines for sample collection. It is also important to let them know that the soil is from a disturbed area. In most cases, these labs run tests and interpret results for farmers. Tests results will be interpreted differently if viewed in the context of a disturbed area rather than an agricultural area.

The following characteristics of soil are considered a part of good project planning.

Soil Texture

Soil texture is important because it influences both water availability and nutrient availability. For a rough idea of the texture, moisten the soil a little and then feel the texture by rubbing and rolling some of it between fingers. Is it very sandy and not able to stick together much or is it mostly fine material that can be molded like clay? Clay-dominated soils will also tend to stain skin whereas sandy or silty soils will rub off more easily. Soils that are very sandy tend to be drier because they allow water to drain quickly. Clay-dominated soils are often associated with wetlands because of their poor drainage.

Soil pH

The soil pH has a major effect on nutrient availability. Test the soil pH using the following steps:

1. Use a 2 mm sieve to remove all soil particles greater than 2 mm.
2. Mix approximately 20 to 25 grams of the sieved soil with a 1:1 or 2:1 ratio of water to soil to make the soil into a wet paste. Add just enough water to saturate the soil (when forming a depression in the sample, water just begins to move into the hole and puddle).
3. Let the paste sit for half an hour to equilibrate.
4. Stir the paste again.
5. Measure the pH of the paste with a pH meter or pH paper.

Make sure a several different samples from different places at the site are tested to be sure of accuracy and that the pH does not vary throughout the site. The range of pH values is from 0 to 12. The classification of the pH of soils is:

pH	**Classification**
< 5	strongly acid soils
5 – 6.5	moderately acid soils
7	neutral soils
7 – 8.5	alkaline soils
8.5 or higher	strongly alkaline soils

Knowing the pH will help guide plant selection as certain plants prefer more acid soil conditions and others prefer more alkaline soil conditions. If the site has elevated concentrations of heavy metals, it will be necessary to keep the soil pH greater than seven for the restoration program to be successful. This can be accomplished through limestone application.

Electrical Conductivity

Salt concentration of the soil is measured using a conductivity meter. These are similar to pH meters and are easily used. Generally, an electrical conductivity measurement of greater than 2 deciSiemans per meter is an indication of a potential salt problem.

Organic Matter

Organic matter is typically defined as a combination of recognizable organic material (roots, insects, etc.) and decayed organic material that is no longer recognizable (humus) in the soil. The terms “duff” and “litter” are also used in some literature and by some resource managers. There are a number of beneficial effects of organic matter in the soil, including increased water holding capacity and increased nutrient exchange.

There are a few field methods for detecting organic matter which do not require an intricate setup. However, these do not produce accurate assessments or estimates. They include:

1. Visual assessment - dark color of soil
2. Floating - floating off organic matter by shaking a soil sample in a jar of water

Soil organic matter can be estimates using a muffle furnace that can heat soil to very high temperatures. Follow these steps to determine the soil organic matter content:

1. Use a 2 mm sieve to remove all soil particles greater than 2 mm.
2. Dry the soil sample at 105°C overnight.
3. Weigh the sample and record its weight. This is the initial dry weight.
4. Burn the sample in the muffle furnace at 450°C for four and a half hours.
5. Weigh the sample and record its weight again. This is its final weight.
6. Calculate the percentage of organic matter in the soil using the following equation:

$$\frac{\text{(Initial dry weight - Final weight)}}{\text{Initial dry weight}} \times 100 = \text{\% organic matter}$$

The typical range of organic matter percentages ranges from trace amounts in sandy desert soil to up to 20 or 30 percent in some forest soils. Organic soils with greater than 30 percent organic matter, such as peat, are mainly found in wetlands or former wetlands.

The estimation of percent organic matter can sometimes be an indicator of nutrient availability in the soil. However, having a professional soil lab test the soil for available nutrients will be a more accurate determination. This information can be used to check if appropriate nutrient amounts are available for the desired plant community. It is also important to find out what the organic matter content is in nearby soils that have not been disturbed. This can be done by consulting the local NRCS office or the soils testing lab of the state's land grant university. These places would also be a good place to ask about sources of organic matter should the site require additional material. If the soil has lower total organic matter than comparable nearby soils, adding organic matter to the soil will improve the chances for success in plant restoration.

Soil Compaction

Another soil characteristic to consider is soil compaction, especially if the site has previously been subjected to a lot of heavy traffic (vehicular, livestock, bicycle, foot). Compacted soil can make it difficult for plant roots to penetrate, thus decreasing their ability to grow and survive. Just trying to dig in the soil gives a rough idea of the compacted level. Soils with higher clay contents tend to become compacted much more easily than soils with high sand and silt contents. However, a more quantitative way to evaluate soil compaction is to measure the bulk density of the soil. There are bulk density soil samplers, also called core soil samplers, available through forestry supply catalogs (Appendix A) that can be used to collect a known volume of soil. However, as long as a known volume of soil is collected it need not involve a bulk density sampler. One alternative to a bulk density sampler is to collect a sample, then place a waterproof plastic bag in the hole left by collection, fill the bag with water until the level is at the same level as the soil surface with the bag pressed against the sides of the hole, and the water is poured into a graduated cylinder to measure its volume. The soil sample should then undergo the following steps.

1. Carefully collect a soil sample of a known volume.
2. Dry the soil in a 105°C oven to remove any moisture.
3. Weigh the dried soil sample.
4. Use the following equation to calculate bulk density:

dried soil weight / known original volume of sample = bulk density

The point at which the soil becomes compacted enough to impact root growth is a bulk density of 1.6 Mg/m^3. If bulk density is too high, a good way to decrease it and improve the growth environment for plants is to incorporate organic matter into the soil. Addition of manure, composts or municipal biosolids will improve soil aggregation and decrease bulk density, but may also add significantly to problems with invasive plants. For more information on the use of these type of amendments see the separate paper on "*Using Biosolids for Reclamation and Remediation of Disturbed Soils*."

Other Resources

Another good way to get more information about the soils at the site is to find the Soil Survey reports for the area. These can often be obtained through the local NRCS office, cooperative extension offices, libraries or city or county planning departments. Maps in the soil survey can cover the classification of the site soils and usually will include a detailed description of the characteristics of that soil.

<u>Topography</u>

The topography of a site can also play an important role in restoration design. For example, steep slopes are more likely to have soil erosion problems and low areas are more likely to be inundated with water for part of the year. Topography can be assessed a number of ways including visual inspection, use of survey equipment, aerial photographs, and U.S. Geological Survey quadrangle maps.

When restoring a wetland, this aspect should be paid close attention. Many wetland plants are only successful at very specific microelevations with respect to a wetland because they tolerate only certain levels of water inundation. Planting them at the wrong microelevation, where they might receive too much or too little water, could result in a considerable amount of plant loss.

Steep slopes greater than 2:1 may require the addition of erosion control materials such as matting, weed-free straw or mulch. A local soil scientist should be able to assist with selecting appropriate solutions.

Hydrology

As stated above, different plants prefer different levels of moisture. The hydrology of the site will determine the amount of water available to plants at different times of the year. Consequently, the choice of native plant species and the locations for planting should be heavily influenced by the hydrology at the site.

The information about soil types as outlined in the soils section will begin to suggest something about the typical hydrology of the site. Soils that are fine textured and classified by the soil survey as "hydric" soils are typically associated with wetlands, and the site should be expected to be flooded at least seasonally. Other factors to assess when doing a hydrologic survey are the locations of any springs or streams, depth to groundwater, the amount of rainfall or snowmelt that the site receives, any type of periodic flooding events, and any disturbances of the historical hydrologic regime.

For more help with finding hydrologic information about the project site, try contacting the local U.S. Geological Survey's Water Resources Division Office. Visit their website (http://water.usgs.gov) and go to the local information section to find the local contact. If they don't have the information needed, then they can probably offer good advice on where to get assistance. The website also has some good information available on topics such as stream flows and water quality that may be relevant.

If dealing with a complicated hydrologic site such as a wetland, it would be wise to hire a professional hydrologist to conduct an assessment of the site. While important in any restoration project, understanding the hydrology is especially critical in wetland ecosystem restoration. Many wetland plants must be planted in very specific places according to the hydrology of the system and will die if planted in the wrong place. It may be important to restore site hydrology before plantings can be successful.

Existing Ecological Communities

Knowing what is already living on the site can help predict what species are likely to succeed on the site and what potential problems may need to be addressed before native plants are reintroduced. If assistance is needed in identifying the plants on the site, there are a number of places that may be able to provide assistance in finding someone. These include the local conservation district office, the local office of the Natural Resources Conservation Service, the botany department of a local university, the county Cooperative Extension offices of land grant universities, the state Department of Natural Resources, the state Natural Heritage Program (Appendix A) or an environmental consulting firm.

Conducting an inventory of the plant species that are present on the site is useful for several reasons. First, if native plants are still found on part of the site, they are species that should probably be included in the restoration plan. The only exception to this would be if the rest of the site was very different in character from the place where natives were growing; in which case they would be unlikely to survive in the new area. Secondly, the inventory may find exotic species that are considered noxious weeds or invasive plants that can spread quickly and outcompete native species. These are species that should be removed or contained before new plants are planted. A third use of the inventory would be to identify any indicator species. Indicator species are plants that are known to prefer certain types of growing conditions such as wet soils, compacted soils, high nutrient levels or low light levels. Finding these types of species can help predict the probable growing conditions at the site. To find this information, consult the local flora or speak with a native plant expert in the area. Finally, having an idea of what is growing on the site is also a good indicator of what types of seeds are in the soil. This can be useful if there is the potential for a lot of native seeds to be present or can be a problem if there are a lot of weed seeds that could grow and reestablish themselves after the mature plants are removed. Prior to starting soil or herbicide impacts on prairie sites, conducting a prescribed burn on a site can sometimes rejuvenate suppressed native plants.

Making a list of native plant species that are found coming into old or new disturbances in the surrounding areas can be helpful. These native plants are the early colonizers and grow well in disturbances similar to the potential restoration site. They will eventually be replaced by the indicator species.

In addition to a plant survey, a wildlife survey can be useful to determine what is already present at the site. It can indicate what type of habitat already exists at the site and what kinds of habitat modifications might be useful to the wildlife already present. Be sure to include arthropods (insects and spiders) as they are excellent indicators of the site's biological health. Some wildlife can also play a crucial role in determining the success of a restoration project because of the potential for them to damage young plants that have not yet become established. Entire restoration projects have been destroyed in a day by geese pulling up and eating all the tender young shoots that were so carefully planted the day before. In other projects, rodents have caused many of the planted young trees to die because they gnaw on the bark at the base of the trunk. There are many ways to design a restoration project to minimize wildlife damage to new plants, such as fencing or tree protection bands. Knowing what potential wildlife problems are present can help in planning the type of protection needed.

When examining the ecological communities on the site, don't forget to look at the nearby ecological communities. There may be an intact native community nearby that could be used as a reference site as the restoration project is designed. When environmental conditions are similar, the reference site's inventory list may be used when defining the project site's species list. There may also be nearby areas with invasive plant species that could potentially invade the restoration site. If an important goal of the restoration is wildlife habitat, it will be important to look at the wildlife corridors that exist between the site and other natural areas. Good advice about where to get useful information on local wildlife can be obtained from the local office of the U.S. Fish and Wildlife Service (http://www.fws.gov/) or from the state's wildlife agency.

<u>Disturbances</u>

Disturbances play a very important role in shaping the ecological communities found on the landscape. Some communities are damaged by certain types of disturbances and other communities are dependent upon certain types of disturbances for their continued survival. One example of damage to a community caused by a disturbance is intensive grazing which favors species that can survive grazing pressures and eliminates those that are sensitive to grazing. Other consequences of detrimental disturbances include accelerated rates of erosion, loss of developed soil, declines or loss of nutrient cycling, and adverse impacts on natural hydrologic pathways. An example of a positive relationship between a community and disturbance are prairie communities that are dependent on fire. The periodic fires in the prairies kill off young invading woody species and create bare patches for new prairie seedlings to germinate and grow.

If a native plant community is to be reestablished on a degraded site, disturbance patterns that will harm these plants will need to be eliminated as much as possible and disturbance patterns that the community requires will need to be reinstated to the highest extent possible. Consequently, it is important to understand what types of disturbances have taken place in the past that may have affected the local community, what disturbances may take place in the future that could affect the ecological balance, and what disturbances may be necessary to maintain the desired ecological community.

Examples of types of disturbances include:

- chemical contamination
- fire or suppression of fire
- flooding
- fragmentation and roads
- grazing
- hurricanes
- invasive species
- landslides
- mechanical disturbance
- tilling
- trampling and off road vehicle use
- urbanization
- wind

Climate and Microclimate

The general climate of the area and the specific microclimate of the restoration site are also important factors to consider. Both affect the water availability, amount of sunlight, and maximum and minimum temperatures each plant will experience. All of these factors will influence the ability of each plant to grow and survive.

Some general climate factors to consider:

- maximum and minimum temperatures (daily, monthly, yearly)
- number of frost-free days
- seasonality of precipitation (e.g. wet winters, dry summers)
- total average yearly precipitation

Some microclimate factors to consider:

- aspect of site (e.g., north-facing or south-facing)
- range of topography (e.g., small changes in elevation such as dips in the landscape)
- shade
- total pavement area or area of impervious surface nearby (which can increase local temperatures and amounts of surface water runoff)

To get a general sense of the local climate in the area of the site, visit the National Climactic Data Center's website (http://lwf.ncdc.noaa.gov/oa/ncdc.html). The site also has access which allows retrieval of specific weather history information for the weather data collection site nearest the project site (See Appendix A). This section allows the choosing of information parameters and which data site will be viewed, and then graphs the information for the years that data is available.

Choosing the Appropriate Plant Species

Once clear goals and objectives have been set for the project and a thorough site evaluation has been conducted, native plant species that will be appropriate for the site should be chosen. Choose native species that will match restoration site conditions by keeping in mind the three most important variables for plants: water, light, and nutrient availability. For instance if the site has sandy, well-drained soils and full exposure to the sun, it would not be a good idea to plant species that require moist, shady conditions. This may sound obvious, but a surprising number of native plant projects have made this kind of mistake.

In developing a plant list, remember that species are typically found together in certain groupings, referred to as plant associations or plant communities. These associations will suggest other plant species that may be appropriate. Planting species together based on their typical associations is a good idea because they will all be adapted to the same site conditions. They may also have symbiotic relationships, a relationship where each helps the other in some way. Some species may also be dependent on the presence of certain other species. If one of the goals of the project is to restore self-supporting native flora and fauna communities there is a greater chance of success through using typical associations to develop the plant list. This is a much better method as opposed to picking individual species without considering their interactions.

Also, keep in mind that the final community desired on site that must be created or restored may not be the one that is initially planted. For example, if the goal is to restore a native hardwood forest community on a site that has been cleared of trees, it would not be appropriate to plant herbaceous understory species that are shade-tolerant or intolerant to high light levels. Until the shady environment is created, those understory species will not survive and efforts and resources will have been wasted.

To help in selecting the most appropriate species, different resources are advantageous.

- native species are already on site
- reference sites
- local plant experts
- literature on local plant communities
- historical records of the site

The best indicators of appropriate plant species may be native species that are already growing on the site, if there are still some left. An exception would be if the site has been altered enough for new native species adapted to different conditions to grow, rather than the originally present native species. In this case an evaluation of which native plant community is desired at the site: the original community or one adapted to the new site conditions. The challenge is to determine the factors keeping native species from growing throughout the entire site.

Another very helpful method of determining what native species to use is to identify a reference community. A reference community is the same type of ecological community as the project plans to have at the restoration site. It is always located in environmental conditions similar to the restoration site and provides an idea about what plant species to use for restoration. If there is enough historical data available, the reference community could be the community that was historically found at the site. However, if it is unclear what native species used to be present at the site, a reference community can also be an intact community of native species located near the restoration site in similar site conditions.

Local native plant experts and literature on local plant communities are two other resources that should be taken advantage of if the restoration team is not familiar with the native plants of the site's region. Historical records of a site, including include localized floras, local herbaria, aerial photographs, and first-hand accounts, can provide another good source of information. Many of these experts and information resources at the local conservation district office, the local office of the NRCS, the botany department of local universities, the county Cooperative Extension office of the state's land grant university, the state's Department of Natural Resources, the state's Natural Heritage Program (Appendix A) or an environmental consulting firm.

The plants in any restoration are part of an ecosystem which includes animals as well as plants. Especially in highly disturbed or developed areas, the plant community which is being replicated may no longer exist locally. For that reason, a thorough search of historic information is imperative to assure restoration to the correct plant community. Often there are small landscape scale differences in the composition of native plant communities of which only local native plant experts are aware. Having their assistance can help in avoiding the use of plants that may be native to the region, but are not appropriate to the particular planting site. Literature on local plant communities can also be helpful when determining appropriate plant species for the site's conditions. Plant books or articles may suggest native plant species that prefer certain types of environmental conditions.

When landscaping within an urban area, it does not matter as much where the native plant species come from as long as they are native plants to that region or area. For areas near public lands, National Forests or state lands with few introduced plants, first preference should be given to obtaining local native plant species from local plant materials. These concerns are based on genetics issues which are outlined in the next section. If local native plant materials are not available, consider using a non-persistent annual such as weed-free barley or cultivated oats to act as a soil stabilizer until native plants in the area can recolonize a site. Another option for small restoration sites, without noxious weeds or invasive plants nearby, would be to not seed at all and allow the local native plants to recolonize a site on their own.

Understanding the Importance of Genetics

There has been a growing awareness recently of the importance of plant genetics in restoration projects. Genetic variation within plant species can influence their long-term chances of survival and growth. An ecotype is a certain population of plants within a species that, due to different genetics, has a different form (height, leaf size, etc.), flowering time, resistance to diseases/pests or hardiness that is adapted to certain local environmental conditions. Plant ecotypes are not different species because they can still interbreed. Taking plant species that are of one ecotype and moving them to an area with different environmental conditions, such as different freezing stresses or different moisture levels, can result in poor growth or death.

These types of genetic concerns have long been recognized in the forestry industry. Tree seed zones have been developed for specific tree species based on an understanding of their genetic variation across the landscape. Seeds are only planted in the same tree seed zone they were collected from, in order to increase the plants' chances of survival and adaptability. However, it is only recently that some scientists have begun to examine the genetic variation of herbaceous or shrub species across the landscape. Consequently, there is very little information available about what might be the appropriate distance one could safely relocate native plant species when considering the gene pool.

In addition to concerns about the ability of the planted species in restoration projects to survive and adapt, some people are concerned that the introduction of new genetic material in an area can damage local populations of native species. The thought is that new genetic material could result in the weakening of local populations' ability to survive and adapt to environmental pressures. This particular concern is still being debated. However it is clear that without a better understanding of the genetic variation of the species, it is a safer option to avoid as much as possible introducing non-adapted genetic material that may have unanticipated detrimental effects. Also, because plant genotypes may contain very different chemical compounds, using the wrong genotype of a plant species can also cause death or injury to herbivorous species who depend on the plant (Longcore 2000).

Depending on the genetics, there may be very different strategies for the appropriate places to collect propagation material for specific species. A general rule to follow is, if information is not available on the plant species' genetic variation, try to use plant material of local genetic source whenever possible. There is no universal agreement as yet on the exact guidelines for "local" sources. However, selecting a plant material source where the following factors are the same or similar to the site can serve as a general rule of thumb.

- aspect
- associated vegetation
- ecoregion
- elevation
- frost dates
- hydrology
- rainfall
- slope
- soil type
- temperature patterns
- watershed

Because there are very few sources from which native plant material can be obtained, it may be difficult to get plants that are from as local a genetic source as desired. First, consider where the restoration project will be located, in an urban area or near public lands with very few introduced plant species. If the site is located near the latter, a broad guideline to follow is to ensure that the native plant materials originated from at least from the same ecoregion. There are a few different ecoregion classifications of the United States that have been developed. One popular classification is Bailey's ecoregions, a product of a cooperative effort among several federal agencies and The Nature Conservancy. These regions are areas that have been defined as having similar natural communities, geology, and climate (Appendix A). If local native plant materials are not available, it sometimes can be better to seed with non-persistent annuals such as weed-free barley or cultivated oats, rather than introducing non-local native plant seed from another area into the gene pool. For more information about how to determine if the native plant or seed supplier has the type of genetic stock preferred, see the section on "*Selecting a Suitable Supplier*."

Active Reintroduction of Natives or Let Them Return Naturally?

Once the project's list of native plant species has been decided, the next step is to determine how they will be restored to the site. There are two major choices: allow natives to return naturally or reintroduce natives by direct seeding or planting grown plants. The choice can be made to use one approach or a combination of these options.

To decide which option is most appropriate for a particular project, consider the site conditions and the needs of the plants wanted. Seek information on successes and failures of similar projects. Good sources of information include journals like *Restoration Management Notes* or consulting with other local projects.

First it must be understood why native plants are no longer present on the site. This can best be determined by using the data collected during the site evaluation. Researching prior management practices and use history of the area is vital to determining which plants will come back on their own to the site. Is there anything the site evaluation found that would be a probable cause for the lack of native plants? For example, is there a disturbance such as the presence of grazers that has been preventing the return of native plants or have the soil conditions changed in some way so that they are not hospitable to native plants? If the restoration project changes the site conditions, such as removing the grazers or reconditioning the soil, sometimes that is enough to allow native plants to return naturally.

One of the advantages of allowing native plants to return naturally is the low cost; however, there are other important questions that should be answered before deciding to use this method. Perhaps the most important question is whether there is an adequate source of native plant reproductive material on or near enough the site to facilitate their return. There should either be native seeds in the soil seed bank or a nearby stand of intact native plant material that will be able to reproduce and expand into the site through seed production and germination or vegetative propagation. However, except in large tracts of wildlands, human disturbances have impoverished the soil seed bank.

The presence of noxious weed or invasive plant species on or near the site could mean that they reinvade along with the native species. Although an ideal and inexpensive method, relying upon native seeds in the soil seed bank is vanishing because the invasive species are more likely to appear. If the natural return of native plants is still the desired option and there are noxious weeds or invasive plants present, there should be a plan for active control of these weeds until the native plants have a chance to establish themselves enough to outcompete the weeds.

Finally, when considering the option to allow the natural return of native plants, the rate at which the natives may return and reestablish on the site should be compared with the project's desired timeline. The enhancement of natural revegetation includes creating seed catchments, mulching, and removing disturbances. Even using these enhancements, natural return is usually associated with a slow return rate which may increase the chances of failure if other factors are not controlled such as weedy plants or grazers. In this case, it may be more efficient to pursue a more rapid reintroduction of natives through seeding or planting rather than using time and resources for weeding and predator protection while waiting for the natives to reestablish. However, most projects will use a combined approach of active reintroduction and natural return of native plants because there is no single approach that will fulfill all the needs of a site.

Active Reintroduction: Seeds or Plants

If active reintroduction of natives seems to be necessary for the project, the next step is to determine whether seeding or planting would be most successful. There are advantages and disadvantages to both and, again, it may be most useful to try a combination. For each site and plant community, different strategies will be appropriate.

Seeds are an attractive option because they are less expensive than plants and are easier to distribute in a large restoration site. However, they also have a number of disadvantages. Seeds are more susceptible to predation from birds or rodents when they are first scattered. This is less of a problem if they are drill seeded. Seeds can take several years to establish especially if they are tree or shrub seeds. They are more likely than planted plants to be overcome by weedy species, especially at the early stages of germination and as young seedlings. Finally, if seeds have specific germination requirements that are not met they may not establish at all, or they may establish years later when requirements such as freeze-thaw cycles are met.

Propagated plants may be preferred because they establish themselves more rapidly, increasing the chances of success in a project. If project species are difficult to germinate, using plants that have already passed that stage ensures better establishment and survival. However, using plants will be more expensive than seeds. It is also more labor intensive to install plants rather than doing a direct seeding. Considerations should also include the time and labor that will be needed to maintain an outplanting project due to supplemental irrigation, protective cages, and other measures.

If planting or seeding on arid sites, keep in mind that provisions must be made for irrigation when natural water fails to occur. When using containerized plants on arid sites, irrigation will almost always be necessary until the plants are established. Establishment occurs when plant roots have grown sufficiently out of the container root ball into the native soil for the plant to be able to reach available soil water.

Ultimately, it depends on the needs of the specific plant species for the site. People who are working to restore plant communities dominated mainly by herbaceous species that don't have strict germination requirements, such as prairies, tend to use seeds. On the other hand, people working to reintroduce woody plants, which may be slow to establish or are difficult to germinate, tend to use plants instead of seeds. Sometimes a combination of techniques is most useful, such as seeding those plants that will germinate and establish easily from seed and then, after a few years, using seedlings for the other plants that have a more difficult time establishing from seed or planting overstory plants first and seeding understory plants later as conditions allow.

Sources of Seeds

There are a number of different options for obtaining the required native seeds. These options include

- using donor soil from a similar intact native plant community or development site (e.g., building construction or roadcut)
- weed-free wild hay from a native grassland or wetland
- collecting seeds
- buying local native seeds from a supplier or grower

The method chosen will depend on the type of plant species wanted, the availability of the seeds needed, and the resources available.

One option especially used in some wetland restoration projects is to find an intact native plant-dominated wetland from which some soil can be removed as donor soil (Galatowitsch and van der Valk 1994). This soil will usually have a number of native wetland plant seeds in it. To plant the seeds, the donor soil is spread in a thin layer across the restoration site. However, if this method is used, *care should be taken not to damage the intact wetland* unless it is about to be destroyed, disturbed or is in need of salvage.

If the donor site is slated for development (or a roadcut), the top 8 to 10 inches of soil can be removed and transported to the restoration site. If the donor site is to remain intact, then small amounts of soil can be removed from different zones and spread thinly in specific areas at the restoration site. If there is variation within the donor site in terms of vegetation types present and hydrology, probably the greatest success to be found would be to take the donor soil from the different areas separately and place them in the most similar places in the restoration site. In wetlands, it is important to remember that different plant species prefer different types of water inundation levels so an effort should be made to match up donor soil to the same water inundation levels in the site. Also, it is important to remember that not all the plants desired for reestablishment may have seeds in the seed bank, so using this method along with other methods will help to ensure greater plant diversity. For more information about this technique refer to the book *Restoring Prairie Wetlands, An Ecological Approach* (Galatowitsch and van der Valk 1994).

A second similar approach, used to acquire seed mainly for grassland restoration projects, is to collect weed-free wild hay from a native grassland or wetland. Hay is collected when the seeds of the native species have developed and matured, but have not yet fallen. When using this method it is important to find a site that does not also have the seed of undesirable invasive species that may cause problems at the restoration site. It is also important to closely monitor the flowering and maturation of seed of the native species at the collection site to ensure that the hay is harvested at the optimum time. Remember, however, that different species' seeds will mature at different times, so a series of smaller harvests at different times to capture more of the diversity of the site should be considered. Once collected, the hay can then be spread over the prepared restoration site. Also, remember it is an important collection ethic to leave enough native seed at the collection site so that the donor plant community's ability to reproduce and maintain itself is not damaged. If there are no noxious weeds or invasive plants nearby, native plant litter and seeds can also be raked in from the edges of a small restoration site.

Both using donor soil or weed-free wild hay as a source of seeds for the desired native plants can be attractive options because it is much easier to collect these types of materials rather than collecting the seeds of all the desired species individually. Another advantage of these methods is that the types and relative abundances of native species will usually be close to a typical local native plant community. The drawbacks of these two methods, however, are that it may be difficult to find a suitable collection site that has the desired species and very few undesirable species. In addition, as mentioned previously, sometimes these methods will miss some of the species that are desired, either because they do not produce as much seed or they produce it at a different time than the time that collections take place.

If the previous two methods are not appropriate for the project, but the use of seeds is still warranted, then collecting or buying them should be considered. Collection may be a preferable option for ensuring that the seed sources are local. With experience in native seed collection present, it is possible to have the project team gather the seed. Otherwise a professional native seed collector can be contracted to collect for the project.

If the decision is made to collect seed, keep in mind the amount of lead time required to do so. Seed can only be collected during the limited time that it is ripe - usually from less than a week to a month. If this window is missed, collection must wait until the next year or next growing season. It is very important to factor in this extra time when developing the schedule for different phases of a native plant project.

There are a number of important considerations to keep in mind when collecting seed. The guiding principles for collection should be ones that help ensure that the best seeds for the project are being collected while protecting the intact native populations from which they are being collected. The seed collection guidelines below are good for most types of native seed. However, there are a few types of seed that are more difficult to collect and store because they have unique handling requirements. If the types of seeds being collected are not familiar, make sure to check with an experienced seed collector before following these procedures.

Do's and Don'ts of Seed Collection	Why?
Do match the donor and restoration site conditions as much as possible: slope, aspect, hydrology, soil type, frost dates, temperature patterns, elevation, etc.	Plants adapted to similar environmental conditions are more likely to succeed at the planting site.
Do collect in an area geographically near to planting site.	Locally adapted plants are more likely to succeed at the planting site.
Don't collect in sensitive areas.	Protect sensitive populations.
Do make sure none of the seeds collected are from rare species – contact the state Natural Heritage Program for more information about rare species in the area (Appendix A) .	Protect rare species.
Don't collect from ornamental plantings or near other exotics.	Ornamental varieties of the same species may not have the environmental adaptations needed for establishment at the planting site.
Do avoid collecting in weed infested areas. If collection must be done in those areas, be careful not to collect weed seed.	Helps keep weed seeds out of the seed mix.
Do obtain permission from the landowner to collect seed on private land or the required permit(s) for public lands.	This is legally required, as well as common courtesy.
Do try to collect dry seeds on a dry day. Wet fruits such as berries can be collected on wet or dry days.	Collected seeds with high moisture content will lose their viability more quickly than drier seed.
Do make sure to collect when seeds are mature. The seed should not dent under a fingernail and should detach easily from the plant.	Increases germination success.
Do use paper bags or other "breathable" containers for dry seeds. Berries and fruits can be collected in plastic buckets.	Helps the seed dry out more quickly so it will retain its viability longer.
Do collect from large populations.	Helps increase genetic diversity, thus increasing the chances of successful establishment.
Don't concentrate on one small area of the plant population, instead collect from a wider area.	Helps increase genetic diversity, thus increasing the chances of successful establishment.
Do collect from different microhabitats within the site.	Helps increase genetic diversity, thus increasing the chances of successful establishment.
Do know the factors affecting seed viability of the species before collecting and processing them.	Short-lived seed such as willows and alders need to be planted immediately after collection, and kept cool until planting.
Do collect a few seeds from many plants rather than many seeds from a few plants.	Helps increase genetic diversity, thus increasing the chances of successful establishment. Also protects intact populations.

Do collect from a wide range of plants: short or tall, scrawny or robust.	Helps increase genetic diversity, thus increasing the chances of successful establishment.
Do leave at least 2/3 of the available seeds.	Protect natural populations.
Do communicate with other local collectors about where collections are taking place.	Important to protect the intact natural population to make sure one site is not getting collected from too many times.
Don't harm donor populations.	Protect natural populations.
Do immediately clean and dry seeds after collection or treat wet fruits appropriately. *Dry seeds:* Spread out on paper or tarp in a dry place for a few days. *Wet fruits:* 1.) Separate seeds out of fruit by pressing through a metal screen. Put the mashed fruit in a bucket of water and float off the pulp (viable seeds should sink to the bottom). Then dry the seed by spreading out on paper or tarps. OR 2.) Plan to store these fruits intact in a cool environment; then macerate fruit, float off seed and plant immediately upon cleaning without prior drying.	Most cleaned and dried seeds have a higher viability rate. Seeds of many species of wet-fruited plants such as Baneberry (*Actea rubra*) and Toyon (*Heteromeles arbutifolia*) will often go into complex dormancies when cleaned and dried.
Do store cleaned, dried seeds in a paper envelope or a sealed plastic container with desiccant in a refrigerator until needed.	This will help maintain viability for a longer period of time.

Finally, if it is not feasible for project staff to do the collecting, a contract can be made with a professional seed company to collect the seed or seed can be purchased from companies that already have that seed in stock. The advantages to contracting the seed collection is that collection can be tailored to make sure that collected seed is locally appropriate for the project. Ask the contractor if they follow the above guidelines when they collect seed. Keep in mind however, that sites will have to either be located by project staff or the contractor will need enough lead time to find the appropriate sites to collect the requested species and to wait until the seeds are mature and ready to collect. This may take at least one year. Contract collection may be the only way to get seed of particular species if it is not otherwise commercially available.

If local native plant seed is commercially available, this may be a more desirable option than contract collection because there is no reason to wait until the right season for collection. Many native seed suppliers keep careful records about the collection locations so it is still possible to match the seed collection locations to the project site.

One method of getting information about the original source of the seed collected is to request Yellow Tagged Source Identified Seed; however, this is not available yet in all states. The yellow tag indicates that the seeds were collected from a stand that was not bred for cultivation, either a natural stand or a production field where no breeding has taken place. The source identification lists the geographic genetic origin of the seed. The location listed is not consistent, but is usually either a county, a group of counties or a state.

It may also be useful to request an analysis label with each bag of seed. This label should state the species' scientific name, the purity of the seed (actual seed of the species present vs. other plant material, weed seeds, etc.), the amount of weed seeds present, the germination rate for the seed, and the amount of Pure Live Seed (PLS). PLS is the percentage of actual pure seed multiplied by the percentage of that seed that will actually germinate. However, keep in mind that, for many native species, currently there are no established testing techniques so germination test results may not always be completely accurate. The information provided on the analysis label can also help in comparing seed prices between different suppliers. One supplier may offer a lower price for their seed, however it may be due to the fact that it hasn't been cleaned as thoroughly, resulting in less actual seed per volume.

If there are concerns about the quality of the seed being purchased, testing can be done by an independent seed testing laboratory that has been approved by the Association of Official Seed Analysts (http://www.aosaseed.com/), keeping in mind that many of their methods have been developed for agricultural seeds. If the lab is not familiar with the germination requirements of the native species being tested, their results may not be accurate.

Be sure to check the identity of all seeds before growing them out, whether seeds have been collected by project staff, collected through a contract or commercially purchased. Some seeds being sold commercially are not accurately identified and their use may compromise the integrity of the restoration.

Sources of Plants

If plants are a better option or part of a combined approach for the project, to find the sources of native plants required the following options cover the various methods that can be used singly or in combination.

- contract with a native plant supplier to grow the plant material
- salvage plants from a site that is about to be destroyed
- collect and propagate the plant material using project staff
- buy already grown plants from a nursery

Contract with a Native Plant Supplier

Contract growing is favored by many experienced project managers that have the necessary amount of lead time to plan native plant projects. This option provides the flexibility to work with a supplier to determine which of the desired species can be propagated. Also it is the best way to ensure that all the species needed can be propagated and will be available for the project. Contracting a grower presents the opportunity to be more selective as to the original source of plant material used for the project.

Salvage Plants

Salvaging plants is a popular option in some parts of the country. Some established programs exist that salvage plants from areas slated for development, such as the King County Native Plant Salvage Program (Appendix A). These programs then make the plants available for restoration projects. Plants that survive the salvaging process best tend to have a shallow, compact root system, can tolerate a broad range of habitat conditions and are adapted to disturbance. This includes succulents and grass clumps. It is also important to take proper care of the roots of salvaged plants. Native soil should be kept intact with the rootball and transplanted with the salvage plant. The roots should be cut cleanly when first salvaged and then the rootball should be kept moist. If the plants cannot be planted immediately at the restoration site, there needs to be a good holding facility which can keep the plants moist and healthy until it is the right time to replant them. **Remember that plants should never be dug up from an intact native plant community that is not about to be developed. Salvaging is a technique used only to save plants that otherwise would be destroyed.**

Collect and Propagate the Plant Material Using Project Staff

This is an option that in most cases, should only be used if project staff are already experienced in plant propagation or will have the assistance of a plant propagator. However, there are a few cases when some plants are easy enough to propagate that it may be an attractive option.

One example of this is plants such as willow trees or red-osier dogwoods that are easily propagated from cuttings. This is a common technique used in stream or wetland restoration projects in some parts of the country. When the plants are dormant in the fall and winter, sections approximately four feet long and around half an inch in diameter can be harvested from straight branches of mature plants located near the site. The lateral branches and twigs are trimmed from the sides of the branch, and then it is planted at the restoration site (right side up) by pushing it into the soil until half is underground. It is important to keep the end of the cutting moist if the cuttings are not planted on the same day as they are cut. Also, make sure that, once planted, the soil is pressing against the cutting so root production is triggered. In the spring successful cuttings will begin sprouting branches and leaves. If working in a dry climate, always make sure the soil is moist or water the cuttings at the time of planting.

Buy Already Grown Plants from a Nursery

If the native species required for the project are a type that are commonly available in local native plant nurseries and there is enough available stock, this may be an attractive option for those who wish to acquire plants more rapidly. It is important to follow the suggestions in the sections on "*Selecting a Suitable Supplier*" and "*Evaluating Plant Material*" to ensure the nursery provides high quality plants. Nurseries should be contacted long before the plants are needed to allow them to make arrangements to have sufficient quantities available. In temperate regions, many nurseries will need to have an order in December to make sure plants are available for spring or summer planting.

Selecting Plant Product Types

Plant material is available in a variety of forms, each with advantages and disadvantages for native plant project planning. Nursery grown native plants can be grown in a wide assortment of containers, usually dependent on which species is grown, its growth habit (tree, woody shrub, annual, perennial, etc.) and its natural habitat. Ideally, the container chosen and the conditions in which the plant are grown simulate natural conditions as much as possible. For example, wetland plants can be grown in specialized beds that allow the soil medium to be saturated much of the time instead of completely draining. This mimics natural wetland conditions.

The following is a list of commonly available nursery stock types:

- ***BALLED-IN-BURLAP or "B&B"*** The plant is grown in the field, dug up with its roots and surrounding soil, and wrapped in a protective material such as burlap.
- ***BARE-ROOT*** The plant is sold without any soil around its roots.
- ***CONTAINERS*** The plant is sold in a container of soil with drainage holes. Sizes and shapes of containers vary, but they are usually plastic. Examples of common sizes are: 4" pots, 6" pots, and 1, 2 or 5 gallon containers.
- ***CUTTINGS or WHIPS*** A piece of branch, root or leaf that is separated from a host plant and is used to create a new plant. These may be placed in a rooting medium or stuck directly into the ground for planting.
- ***LINERS*** A small grafted plant, rooted cutting or seedling that is ready for transplanting. They are often used for herbaceous plants and grasses.
- ***PLUGS or TUBELINGS*** These are similar to liners, but they are individual cylindrical or square planting containers that are longer than they are wide. The longer shape provides room for a plant to build root mass for transplanting.

COMPARISON OF PLANT MATERIAL FOR RESTORATION PLANNING		
TYPE	**ADVANTAGES**	**DISADVANTAGES**
BALLED-IN-BURLAP	• Well-developed root systems increase chances of survival on site • Provide shade and earlier establishment of upper canopy on site	• Expensive • Large and heavy to transport
BARE-ROOT	• Less expensive • Easier to transport to site, lightweight to carry around for planting • Roots have not been restricted by containers	• Require care not to let root systems dry out before planting • Difficult to establish in dry sties or sites with warm, sunny spring seasons
CONTAINER	• Well-established root systems with intact soil • Provide "instant" plants on site • Available in a variety of sizes, many are available year-round	• Native soil not used in nursery, transplant shock may occur when roots try to move in to native soil • Can be expensive • Can be difficult to transport to and around site if large amount is used • Can be difficult to provide irrigation until established, may actually require more maintenance than plugs
LINERS/ PLUGS/ SEEDLINGS	• Well-established root systems with intact soil • Easy to transplant, plant material pops out of containers easily	• Same as above • Smaller plants may take longer to establish, require more initial maintenance
CUTTINGS	• Inexpensive to produce • Cuttings may easily be taken on site or from nearby site • Easy and light to transport • Known to work well in rocky areas or areas difficult to access	• No established root systems • Timing of taking cuttings and planting them is important, varies among species
SEED	• Inexpensive compared to plant material • Variety of seed available commercially • Easier handling than plant material	• Seeds of different species have different germination and storage requirements • Potential losses from birds, small mammals, etc. eating seeds on site • Slower establishment on site
SALVAGE*	• Can use plant material that would otherwise be destroyed • Plant material could be local to site • Relatively inexpensive • Small or young salvage plants often adapt more readily to transplant than do mature specimens	• Different native plants respond differently to being dug up, some loss could be expected • Requires fairly intensive measures to protect plants and ensure they have adequate irrigation

* "SALVAGE" refers to the process of removing native plants from a site before ground disturbance at that site occurs. See the previous section, "*Sources of Plants*" to read more about plant salvaging techniques and requirements.

Timing, as mentioned in previous sections, is an important element when considering which types of plant material to use. Local seed could be collected to match site conditions, but different species produce seed at different times of the year, and have different storage requirements. If any of the work is to be contracted, advance planning is crucial so that a suitable, qualified contractor can be found. As more native plant nurseries become established and more nurseries begin to grow out local native plants, a wider variety of plant material types and species become available. Some nurseries will grow out specific plants under contract. If plant material is to be propagated from site-specific stock or seed, a few years may be necessary to grow the plant material.

Another consideration is the optimum size of the plants that are being used. Big plants seem preferable to some who would like to see some large plants established quickly. In some sites where maintenance after planting was not possible, planting larger plants helped to increase total survival. However, others have found that more mature plants sometimes have difficulty adjusting to their new environment and may not survive. Also big plants can be very expensive. For many, smaller plants are a more attractive option because they are inexpensive, easier to handle, and they often can more easily adapt to the new site conditions. However, it does take longer to develop large established plants on a site and they may require more initial maintenance.

Micropropagation

Micropropagation, or tissue culture, is a vegetative method for multiplying plants in which a whole plant is produced from a very small piece of plant tissue. Although not always economical or as desirable for many native plant species, it can be the desired form of native plant production in specific instances, such as:

- seeds are not available (in the case of some rare native plant species, very little seed is produced)
- seeds are difficult to handle or propagate
- cuttings are vulnerable to disease and/or require too much care
- cuttings have a low survival rate
- existing shortage of stock plants from which to take cuttings

During the micropropagation process, a piece of a plant (e.g., stem, root, leaf, bud, single cell) is placed in a test tube or another form of culture that has been supplied with the nutrients and growth hormones the plant needs. In a controlled environment, the new plant material, known as a plantlet, develops tiny roots, shoots, and leaves similar to a seedling. When the plantlet is large enough, it is transferred to soil outside of the laboratory where it produces leaves of normal size and assumes the likeness of the parent plants.

While micropropagation enables the production of many plants in a short period of time, there is concern about the lack of genetic variability in the cultured plants. Since new plants are being created from the tissue of old plants without the mingling of genes that is associated with non-vegetative or sexual reproduction, no new genetic variation is being added to the population. In other words, clones are being produced.

For many native plant species, vegetative reproduction occurs naturally and frequently. So, the concern about limited genetic variation does not apply to all species, especially those that are widespread and abundant. However, it is important to approach micropropagation for restoration purposes in a conservative manner when genetics are considered. One way to increase the genetic variation in the new plant population is to culture tissue from numerous stock plants and grow only a few plantlets per stock plant. Similar to seed collecting guidelines, remember to use a wide range of stock plants (short, tall, scrawny, and robust) in order to increase genetic diversity.

Selecting a Suitable Supplier

It is an ideal situation if the expertise, equipment, and staff are available to produce propagated native plant material or native seed on site for the restoration project. However, this is usually not feasible. Often a suitable supplier must be chosen to perform the work. Native plant material is available from retail or wholesale nurseries or specialized growers. Native seed is available from commercial seed suppliers. Some nurseries, growers, and seed collectors may specialize in native plants and some may only include them as part of their business. Choosing a supplier who specializes in native plants and seeds is desirable, but is not always an option. Checking with a state's native plant society can sometimes yield a list of suppliers who specialize in native plants.

Again, **timing** is extremely important in this phase of restoration planning. It is virtually impossible for suppliers to keep a giant inventory of native plants and seeds on hand at all times. Suppliers try to anticipate needs for variety and quantity of native plants and seeds, but it is difficult. Also, it can take several years to grow plant material or collect seed for a specific project. This is very important to remember when searching for a supplier to help with acquiring the plants or seeds needed.

Plant Material Suppliers

Select nurseries or plant growers that have experience working in the site's ecoregion and carry plant materials or can collect plant materials from the project area (within the same ecoregion). The supplier should have staff knowledgeable about local native flora. If specific plants are to be grown for the restoration project, interview the grower about their knowledge of propagating all planned species. Ask them to send catalogs and/or price lists if available.

Find out where and how the plants being sold have been grown. Plants may have been grown in a very different part of the country and consequently, would not be well-suited for the restoration site. Make sure plant material has never been dug from the wild and removed from its natural habitat. Unfortunately, this practice does occur and has negative far-reaching effects on natural systems and native plant populations. Nursery owners and growers should assure the customer that all plants have been "nursery propagated." This means that staff have collected only seeds or cuttings from the wild, and have not removed whole plants from the wild. Also request that the supplier supply information about the original location of the parent plant material to aid in determining how locally adapted the plants might be. Good native plant nurseries will have this type of information on record. If plants have been salvaged, ask the staff person where and how they were salvaged. Ethical salvage occurs when plants are removed before some type of construction or destruction takes place and always with the landowners' permission.

Plan to visit the nurseries. Nursery grounds should be clean and orderly. Survey plant material for general vigor and health. Note the presence or absence of weeds on the grounds or in container plants. Some weeds are acceptable, since it is extremely difficult to completely control weeds in nurseries. Many nursery operators are trying to reduce their pesticide use and may therefore be weeding everything by hand, which is time-consuming. Note how well equipment on site is maintained and cared for such as tractors, greenhouse systems, and irrigation systems.

Nurseries and growers may advertise membership in professional trade organizations such as the American Association of Nurserymen, International Society of Arboriculture or their state Nursery and Landscape Association. Although these trade memberships are not required for operation, they show that the owners care about keeping abreast of current issues, regulations, technology, product improvement, and other pertinent information in the nursery trade.

Seed Suppliers

Many of the considerations for choosing plant material suppliers also apply to choosing seed suppliers. Again, try to choose a seed supplier that operates in the same geographic ecoregion as the restoration site, as that supplier is most likely to have native seed suitable for that area. There are companies which specialize in native seed collection, processing, and growing. These companies can have a wealth of knowledge about native plants and seeds. Ask them to send catalogs and/or price lists if available.

It is helpful to become familiar with several terms when ordering seed to assist in making informed decisions:

Certified Seed (blue tag)
This certification only applies to seed produced through cultivation, not seed collected in the wild. The seed certification system promotes the production and purchase of seed of known genetic identity and is used widely in the traditional agricultural field. Only cultivated, named varieties can be certified. Each state has a certification agency that inspects field conditions and regulates how the seed is produced, harvested, and cleaned. The seed is also subject to a variety of laboratory tests. If the seed passes these tests, it is certified by a state agent with a blue tag. This certification process guarantees the seed has the same genetic potential to perform in the field as the original seed did when it was released for production. This type of seed will only be available from the larger seed companies. Sometimes it is necessary for native seed suppliers to cultivate native seeds if the amount of seed needed is greater than what could be harvested in the wild without impacting native populations. However, it is important to consider how growing all the seed together in a cultivated area may have altered the genetics of the seeds. They may no longer be as adapted to the environmental conditions they may experience on the planting site. Native plants grown from certified seeds may also hybridize with local native plants and pollute gene pools. In light of this, not all projects accept cultivars for planting.

Source Identified Seed (yellow tag)
The Association of Official Seed Certifying Agencies (AOSCA) has an approved seed certification class for native seed collection called the “Source Identified Class.” Seed that was harvested following approved guidelines for this seed class will receive a yellow certified seed tag. The tag confirms to the purchaser that the location of seed harvest was verified by the certifying agency. This yellow certification is not available yet in all states.

Pure Live Seed (PLS)
Pure live seed is a measure describing the percentage of a quantity of seed that will germinate. It is a way to standardize quality so the purchaser can compare the quality and value of different lots of seed. One lot may be cheaper, but may not have as high a PLS as another lot, and so therefore may not be a better deal financially because it would have fewer seeds that would actually germinate. See the section on “*Seeding Restoration Sites*” for more information on calculating the PLS.

Seed Testing and Labeling
Seed companies should include a clear label on each bag of seed that shows the results of purity and germination tests, and the scientific name of the species. The Association of Official Seed Analysts oversees these tests. Purity of the seed is the percentage of the labeled species by weight. The percentages of other crop, weed, inert material, and the percentage of dormant or hard seed should also be included. The label should also show the percentage of the seed count that will germinate. Keep in mind however that many seed labs are still not that familiar with native seed germination requirements and so may not accurately estimate the germination percentage. New tests need to be developed.

Customized Mixing
Some companies offer custom seed mixing services that involve creating a seed mix from species chosen by the customer. However, the drawback of purchasing pre-mixed seeds is that it becomes difficult to confirm the identity, purity and quality of the seed being purchased.

Site Adapted Custom Seed Collection
Some seed companies also may offer collection services where they will harvest seed from sites the customer specifies. This is a preferred way to go for many that want to ensure that their seed is from local sources.

Seed companies offer a variety of shipping alternatives that can be arranged upon ordering. Again, it is a good idea to interview the staff about the seed company’s harvesting methods to ensure ethical collection has taken place. See the seed collection guidelines in the “*Sources of Seeds*” section to learn more about ethical seed collection practices.

Evaluating Plant Material

All plant material is not created equal. Quality plant material is an important ingredient in a successful restoration implementation. It is important to evaluate plant material before deciding to purchase it from a commercial supplier or accepting material that has been grown specifically under contract for a project. Plants come in all shapes, sizes, and life forms, but understanding some basic characteristics of nursery grown plants will help project managers make informed decisions about purchases.

There are written specific guidelines for nursery stock entitled "The American Standards for Nursery Stock" (American National Standards Institute 1986). However, these standards pertain specifically to woody landscaping materials only and are not necessarily appropriate for native plant material. The nursery stock standards include acceptable specifics for height to caliper ratio, taper, crown configuration, and branching pattern. These specifics are included because, in the landscape industry, uniformity of plants is a desirable trait. However, in the native plant world, diversity is a more desirable trait because it is an indicator of genetic diversity.

Having good mental images of the growth habit and form native plant species have in their natural habitats will help in the evaluation process. There are several general characteristics to consider when examining plant material. The negative characteristics mentioned are not necessarily fatal to the plants, some can be corrected, but if all or most of the plant material examined has potential problems, it may be better to look elsewhere for plant material.

Vigor
This is a subjective assessment of how healthy plants appear, and can differ depending on time of year or the physiological state the species is in at the time. Generally, plants with green, turgid leaves and robust stems are vigorous. The plant should be able to stand upright on its own without stakes or supports. Spindly growth, dry or discolored leaves or tissue or insect damage are all examples of signs of weak plants. Conversely, bright green, soft plants of extremely vigorous growth which have been grown with constantly high levels of nitrogen fertilization may not be able to survive the rigors of the native site without a hardening-off treatment.

Injury
Plants should generally be free of injuries, wounds or insect damage. Mechanical damage includes such injuries as broken off shoot tips, cuts or digs in the stems, and severe pruning.

Pests
Not all organisms or indications of their presence are necessarily harmful, but generally plants should be free of insects, signs of disease, galls, cankers, fungus, or weeds growing in the potting soil.

Species Labels
At least one plant, ideally all, in a lot should be clearly tagged with the correct botanical scientific name of that plant.

Heterogeneity
Native plant material need not be exactly the same height and width. Landscape nurseries usually strive for this likeness among plants because customers are assured that one plant is as good as another. However, variability is a desirable characteristic in native plants in their genetic, and thus physical, makeup.

Roots

A healthy root system is extremely important for plants since roots provide the mechanism by which plants absorb nutrients and water from the soil to survive and grow. The top of a plant may appear healthy, but the plant could have root problems in the container. This could threaten its survival later. It is easy to inspect the root systems of bare-root plants. To inspect the root systems of container plants, randomly select several plants and turn them upside down so they pop out of their containers. The root system should have healthy main roots and plenty of smaller fibrous roots. The plant and its rootball should come out of the container as a unit and the rootball should hold most or all of the soil together. If the plant can be pulled out without any intact soil, it is not well rooted in its substrate.

ROOT CHARACTERISTICS TO EXAMINE (Hummel)

Circling or kinked roots	• plant may have remained in its container too long • if these types of roots are at the periphery of the root zone they could be root pruned before planting, if they occur close to the main stem and/or in the central root zone, they are difficult to correct and could eventually girdle the plant
Root tip color	• white-root tips are healthy and actively growing • brown/discolored-roots may have been injured (frozen, salt, over watering, poor drainage, disease, etc.)
Circling roots at bottom of container	• plant may have been under watered • top of the plant may not be balanced with the root system
Roots mostly at top portion of container	• plant may have been over watered • container may not have been well-drained so there was little oxygen available at the bottom of the container
Roots mostly on one side of container	• temperatures may have been too hot for roots on the other side of the container (e.g. may have always been exposed to the southwest and strong sunlight)
Roots all swept to one side in a "J" shape	• roots may not have been spread out and centered when planted into the container
Roots coming out of drainage holes in the bottom of containers	• oxygen, water, and nutrient resources may be limited inside the container (taken up by other roots) • potting medium is too wet inside the container so little oxygen is available

<u>Aftercare</u>

Plants should be handled carefully and protected during transport from the nursery. If they are to be transported in a truck, for example, it would be best if the truck had a canopy, sideboards or an enclosure of some kind (e.g. a tarp) to protect the plants from the elements. Plants transported in an open truck at high speeds can be severely damaged by the high wind conditions. Temporary storage before planting should be sheltered from wind, extremes in hot and cold temperatures, and potential injury. Bare-root plants should be kept in a dark, cool, moist location to prevent the roots from drying out. The roots could be wrapped loosely in moist burlap, where air could still circulate around the roots. Plants in dark containers should also be kept in a cool location, as direct sun can greatly increase the temperature in the container and damage fragile roots. Plants should also be watered regularly. A nursery employee could explain what watering schedule the plants have been on recently.

It is beneficial to allow plants to “harden off” before they are planted. This is a horticultural term that refers to the acclimation of a plant to its new environment. Conditions at the restoration site could be extremely different than the nursery setting in terms of temperature, exposure, and elevation. Plants should still be watered, but allowing more time between waterings will help harden the plants off. Plants could be allowed to remain on site for a few weeks for this process to be effective depending upon the differences in conditions between the nursery and restoration site. It is important to water plants properly to avoid crown rot.

Writing Specifications for Obtaining Plants from a Commercial Grower

The quality of the plant material used in a restoration project is as important to the ultimate success of the project as the proper planning, site preparation, and site maintenance. To ensure high-quality plant material is obtained from a nursery or contract grower, very detailed information about the species and characteristics of plants needed must be specified in a written contract. As applied to native species, the concept of plant specifications is new because, until very recently, specifications were only used for ornamental plants in traditional landscaping applications. Consequently, there are no hard and fast rules regarding specifying native plant material from a commercial grower. However, some basic dos and don'ts that will help to ensure quality plant material are outlined below. Information on writing specifications for seed collection is provided in the next section, "*Writing Specification for Seed Collection or Field Production*."

Do:

- **Order ahead.** One year ahead for seed and 3 years ahead for seedlings or larger plants.

- **Specify that only locally-adapted plant material be collected and that the exact collection locations be documented.** The collection locations should be documented regardless of whether they have been selected by project staff or the nursery.

- **Provide exact information on the number of each species and size of each plant that is required.** Size should be specified by container size (in gallons) or pounds, a range of plant heights, and a range of stem diameters when appropriate. Take care to ensure the range of heights and diameters are appropriate for the natural growth habit of the particular species requested. Make sure there is enough flexibility in the ranges to ensure plenty of genetic diversity.

- **For containerized seedlings or balled-in-burlap plants, specify that the root ball stay together when removed from its container or burlap and that the root ball fills the container.**

- **Specify that containers are weed free.**

- **Know the species.** Knowing the species that is being worked with will allow for better and more cost-effective specifications. For example, groundcover species have shallow roots so they do not need large pots. Also, tap-rooted species and species sensitive to root disturbance should be grown in deeper pots and should not be specified as ball and burlap or bare root.

- **Specify planting media, fertilizer regime, and desired mycorrhizal inoculation.** Residual chemical fertilizers may create weed problems or water quality problems at the site. Certain soil mixtures may be excessively drained or hard to keep moist at the restoration site. Inoculation with mycorrhizae at the earliest possible stage of nursery production may promote a higher transplant success rate.

- **Inspect a small sample before accepting all of the plant material.** To do so, pull out a sample and check the roots. If the plant is root bound or has severely circular roots, then do not accept it. Also look underneath the leaves with a hand lens for insects and disease. Also, inspect species to verify proper identification.

Don't:

- **Use ornamental or cultivated varieties of native species.** The ornamental varieties have been bred for aesthetic values, not to be adapted to certain environmental conditions. It is best to avoid using them if at all possible.

- **Accept "equivalent" species.** It is common practice in landscaping to substitute an "equivalent" species when the requested species is not available. This may be acceptable in an ornamental landscape but it is <u>not</u> acceptable in a native plant project. Specifically indicate in the contract that substitutions are not allowed unless specifically agreed upon.

- **Specify that there be very little insect damage or disease.** Some damage from insects and a small amount of disease (such as fungal spots) should be accepted and will not result in decreased survival of the plants. Otherwise the choice of plant material will be more limited and probably more expensive.

Writing Specifications for Seed Collection or Field Production

It is important to write clear specifications for a seed collection contract in order to get good results and maintain clear expectations and communication between the participating parties.

- **Decide what species will be collected, the amounts of each species, and the form they should be in.** The species should be specified by its scientific botanical name including variety, if applicable. The amounts should be specified in pounds, bushels or other such specific units. The form should be specified using botanical terms for fruiting bodies of plants for example, clean seed, pods, capsules, utricles, achenes, seed head or fleshy fruits. Be familiar enough with the species so that the specifications make sense. Consulting with a local native plant expert or a supplier can help if more information is needed on a species.

- **Will the collection areas be chosen by the project staff or will the contractor be responsible for identifying them?** If the contractor is responsible for identifying seed collection areas, the contact cost may be more expensive because extra time will be involved to accomplish this. However, if areas are identified by project staff, be sure that these are areas which will provide enough seed for the project without causing damage to the donor population. General areas for collection should still be specified for seed collection such as within certain watershed boundaries, elevation bands, slope, and aspect.

- **If possible, include a questionnaire in the contract asking the bidder to outline their related experience.** Ask questions regarding seed collection and processing experience, plant identification skills, and tools and equipment that will be used to accomplish the task.

- **Will seed cleaning be done by the supplier, project staff or another facility/contractor?** Clean seed will be more expensive, but a finished product would be received at the end of the contract.

- **How will seed be stored prior to delivery?** Certain species require cool moist storage or viability is lost.

- **Write specifications for what is deemed viable, vigorous seed.** Acceptable seed should be ripe without any evidence of insects, diseases, environmental or other types of damage.

- **How will the seed be accepted upon delivery?** What type of containers or bags should it be delivered in? Generally, seed should be accepted completely dried only, unless the plan is to dry it using project facilities. How will the seed be weighed and inspected? Will there be an established level of acceptable chaff (extraneous leaves, twigs, dried flower parts, etc.) that may require the seed to be cleaned upon delivery? It should be transported and stored in cool, dry conditions and packaged to protect the seed from the elements, rodents, insects, and disease. Or transported accordingly due to wet fruits and their specific needs.

- **How is the contractor required to record information about each seed lot?** At a minimum, two tags should be filled out for each seed lot in case one is lost or damaged. One could be placed inside each bag of seed and one stapled on the outside. The species name, place of collection, estimated number of parent plants collected from, elevation, date of collection, and name of collector should be recorded for each lot. In addition, maps of collection sites and daily logs of the contract progress are extremely useful.

- **Do not allow contractor to collect in wilderness or protected natural areas of any kind.** If collecting on any private land, make sure the owner's permission is granted. Specify arrangements for any specific permits needed.

- **Include a section on genetic diversity.** Seed lots should be kept separate according to species and collections site. Collections should be made from a large number of unrelated plants. Collecting should be dispersed throughout the collection site and not concentrated in one area. Collectors should not remove all of the seed from any given site, and ideally should leave at least two-thirds of the seed for natural reproduction.

- **Provisions should be written to cancel or reduce the amounts requested in case it is a bad seed crop year.** A range can be specified as acceptable for each species beginning with zero (in case that species does not produce an acceptable seed crop) up to a maximum amount acceptable. This protects both parties if good seed is not available. Often, substitutions can be made if another desired species is producing ample seed. These provisions should be agreeable to both parties and specified in the contract.

- **Decide payment methods and procedures.** Normally, contractors are paid by the pound or bushel for their efforts, and not hourly. However, this may not be feasible for collection of site-specific native seed. If species are not growing in monocultures or collections need to be done at many diverse populations, collection may be very time-consuming.

- **Arrange a pre-work meeting before the contract begins so a schedule can be created along with a method of communication.** Decide how to monitor progress of the contract through reports, regularly scheduled meetings or other communication methods.

- **If possible, monitor seed development of each species to assess seed production and vigor, in case any changes need to be made in the contract.**

- **Plan ahead for provisions to process, store or plant the seed once delivered.**

PREPARING THE SITE

Before reintroducing native plants into the restoration site, it is important to ensure that the site conditions are what the plants need to grow and survive. If the site's soil is too compacted, has the wrong moisture levels or there are thriving invasive species, it will be difficult to establish a successful, self-maintaining native plant community. These are problems that should have become apparent during the site evaluation phase of the project. This section addresses some of the more common problems that restoration projects should address before planting or seeding begins.

One important factor to consider when making any kind of site modification is the importance of site complexity. Ensuring that the site is complex means that there will be a greater diversity of habitats available for species to use. For example, when preparing the site for planting, instead of smoothing out the surface of the soil, it may be desirable to purposely create a rough site. This can help to create little shallow depressions, which can act as microsites that capture moisture and protect small seedlings that are germinating. On a larger scale, complex sites may have a few different kinds of habitats such as a wetland, meadow, and a forest adjacent to each other. This diversity of habitats may be important to some types of wildlife that like to forage in the meadow, require the wetland for drinking water, but use the nearby forest to hide from predators.

A complex restoration site has a much greater chance of supporting a higher level of biodiversity and is less likely to suffer from catastrophic losses due to unexpected disturbances. Nature itself is complex and unpredictable. Diversity will help to create a site that functions as much as possible like a natural site so that it can be resilient to environmental stress. Every possible contingency cannot be anticipated when designing a restoration project. However, creating a complex restoration site will give the project a greater chance of success in becoming a self-sustaining diverse community of native species.

Noxious Weeds and Invasive Plants

The greater the amount of weeds that can be removed from the site prior to planting, the greater the chance that the restoration project will succeed. The most effective weed removal methods will differ for various types of weeds. Sometimes a combination of two or more of the removal methods is most effective. For example, one commonly used combination of weed control for herbaceous weeds is to shallowly till the site, allow the weeds to begin growing, spray with glyphosate, wait ten days, then spray again if weeds resprout. Also note that if an herbicide is used, a non-residual should be chosen to prevent detrimental effects on the site later.

Invasive plants are always a problem and the site will need continual monitoring. In one of the most monitored restorations – Curtis Prairie in Madison, Wisconsin – the invasive weeds that were a problem 55 years ago continue to be a concern today.

Below is a list of most of the typical methods used for invasive plant and noxious weed removal:

Physical Removal
- pulling
- mowing
- burning
- tilling

Smothering
- artificial mulch: plastic, landscape fabric, cardboard, newspaper
- biological mulch: hay, wood chips, compost
- cover crop: growing a sterile (non-reproducing) annual that will outcompete weeds then die off
- hot water: pouring hot water over noxious weeds or invasives

Chemical Control
- pre-emergent herbicide (prevents seeds from germinating)
- post-emergent herbicides (kills plants after they begin to grow)
  - contact: kills the surface part of the plant that it comes in contact with
  - systemic: affects the whole plants' internal biochemical pathways
  - selective: only harms specific plant types (e.g. only broadleaf grasses)

Ecological Control
(changing an ecological function to discourage weed growth):

- shade
- flood
- change disturbance patterns
- change available nutrient levels
- change soil pH

Reduced Soil Function

Often in disturbed soils there is a loss of nutrients, soil structure or ability to retain moisture. In these cases soil amendments can be used to repair these damaged soil functions. Typical soil amendments include topsoil, organic fertilizers, peat and lime.

A common concern in restoration sites is soil nutrient availability. If there has been excessive removal or disturbance of topsoil, there may not be sufficient levels of nutrients to support a native plant community. Soil amendments can add nutrients to the soil. However, before doing so, a good understanding of the typical nutrient levels in an undisturbed soil of that area is necessary. Some native plant communities are adapted to low nutrient levels and the addition of nutrients may encourage the invasion of weeds. In that case it may even be desirable to reduce the amount of nutrients available in the soil in order to discourage weed growth. For example, accumulated organic matter as a result of management may need to be raked from the site.

If the topsoil has been removed from the site or damaged, one option may be to replace topsoil on the site. This topsoil can be salvaged from the site prior to disturbance or removed from another site prior to its disturbance. When acquiring topsoil, keep in mind that a major value of topsoil is in its living component – the microbes and invertebrate animals that cycle nutrients, maintain the soil structure, and aerate the soil. Topsoil should be stored in small, shallow piles that allow air to circulate through the soil. It should also be used as quickly as possible to prevent organism mortality or soil loss due to erosion. In addition, in order to preserve soil structure, topsoil should not be salvaged when it is very wet or very dry. Moving excessively wet or dry soil will cause it to lose its soil structure, reducing soil aeration and killing off soil organisms. If the topsoil is from a different site, it should also be checked for weeds or weed seeds before it is transported to the restoration site. Topsoil with a lot of weeds should not be used (Colorado Natural Areas Program 1998).

If topsoil is not available or does not seem like the most appropriate option, but there is still a need to improve soil function, a commonly recommended method is to add some type of organic matter. Organic matter such as biosolids (sewage sludge) or compost can provide a slow release of nutrients while helping the soil retain moisture and develop soil structure. The slow nutrient release helps to prevent a sudden flush of nutrients that could encourage weed invasion. Slow nutrient release also means that the nutrient levels will be maintained for a longer period of time, giving the new ecological community time to establish its own nutrient cycle.

Using commercial fast-release fertilizers is not usually recommended to amend the soil. Typically these fertilizers will add too many nutrients at once, leading to an increased invasion of weedy species and possible fertilizer burn of young native species.

If the soil pH is not appropriate for the desired plant community, there are soil amendments that can be used to alter the pH. Copper sulfate, elemental sulfur, peat, shredded pine bark or pine needles can be used to reduce the pH (increase acidity). Addition of organic amendments, such as biosolids, will also decrease soil pH as they decompose. If the soil is too acidic, lime can be added to raise the pH.

Soil Contamination

Restoration of a native plant community on a site that had previously been contaminated can pose additional complications. If the removal of contaminants has changed the soil structure or soil chemical properties, soil amendments may be required before a vegetative cover can be established. Several of the variables to check for have been previously outlined. They can include soil pH, electrical conductivity (EC), and soil structure.

In some cases, compounds can be added to remediate a soil that will alter soil pH. Bringing the soil pH back to normal levels, either through the addition of lime (to increase pH, or increase alkalinity) or elemental sulfur (to decrease soil pH, or increase acidity), may be necessary. If high rates of material are required to correct soil pH, the soil solution may be too salty to permit plant growth and a waiting period that includes rain events or irrigation may be required. Salt concentration of the soil is measured using a conductivity meter. These are similar to pH meters and are easily used. Generally, an EC measurement of greater than 2 deciSiemans per meter is an indication of a potential salt problem. If remediation has disturbed the soil structure, addition of organic matter (in the form of manure, biosolids or composts) will rapidly improve soil physical properties.

In many cases, soil remediation will involve addition of large amounts of organic material or lime. Under these circumstances, plants that would normally be appropriate to use on a site may not readily establish. If surrounding naturally occurring soils are acidic, low in organic matter or nitrogen, plants adapted to these conditions are not appropriate for restoration. To provide a temporary cover until soil conditions return to what would be considered normal for the site, an annual cereal such as rye or wheat grass may be appropriate. If the soil needs to remain calcareous as part of the remediation, it will be necessary to identify plants that are adapted to highly alkaline soils as opposed to acidic soils.

If the soil had been contaminated with an organic material, it is important to determine if the compound is toxic to plants (phytotoxic), and if so, if it is toxic to all plants. If it is not phytotoxic, then there should be no additional obstacles to revegetation. However, if particular plant species have been used for remediation, then removal of these species and replacement with tolerant natives will be required.

If a phytotoxic compound such as an herbicide is the source of contamination, it may be possible to establish a plant cover on the site if the herbicide was specific to a particular family of plants.

In this case, selection of appropriate species will be limited to those that are not affected by the herbicide. As the contaminant is broken down in the soil, volunteer species of the targeted families may start growing.

Soil Compaction

While some native prairie seed needs a firm seed bed in order to establish well, most soils that have been compacted to the point at which it is difficult for plant roots to penetrate the ground need to be loosened. This is usually accomplished through the use of a sharp metal implement such as a ripper or a chisel that can be attached to the rear of a tractor and pulled through the compacted soil. However, this method will only provide temporary relief from soil compaction. Repeated plowing to reduce compaction on agricultural fields will generally increase soil compaction over time. This method should be used with caution. If it is used in a site with a lot of rhizomatous invasive weeds, its use can spread the rhizomes, and thus the weeds, making weed control more difficult. Also, some mechanical methods of reducing soil compaction can have a detrimental effect on soil structure, making the soil more susceptible to erosion or less able to provide the necessary nutrients and moisture. Addition of organic matter with its accompanying soil fauna and plants to the soil will reduce compaction, as well as improve soil structure. This is the preferred alternative to simply plowing the soil.

Soil Erosion

If soil erosion is an issue at the site, there are some structural adjustments that can be made. If previous disturbance at the site has resulted in unnaturally steep slopes, the slopes should be regraded to decrease the chance for soil erosion. Ideally, to minimize soil erosion, slopes should be complex (rough and uneven, instead of smooth) or concave on the surface, low gradient, and short in length. Complexity is not only valuable in minimizing soil erosion, but increases the site's chance of supporting a diverse ecological community.

If steep slopes cannot be regraded or there is still some soil erosion taking place, then physical barriers to slow or stop the loss of soil can also be used. There are many types of erosion control mats available that can be placed on top of the bare soil to keep soil in place until vegetation can reestablish itself. It is best to use ones that are made with some type of natural biodegradable material such as coconut fiber, straw or wood shavings that will decompose after a few years. In addition, using physical barriers such as hay bales or silt fences can help prevent soil from being washed off the site. Straw of hay should be certified free of weed seed to avoid introducing weeds to the site. Mulching with weed-free straw or local native weed-free hay which contains up to 2 pounds of local native seed per bale can also help minimize soil erosion. Installation of such control measures may be required due to local ordinances for on site work to proceed, please check for this when planning the project.

If a long period of time is required for the native vegetation to reestablish itself, another method to minimize soil loss would be the use of a temporary cover crop. Usually some type of sterile non-persistent member of the grass family specifically developed for this purpose (REGREEN, Barley, cultivated oats) can be quickly seeded and established on the site but will die off in a year or two when the native vegetation begins to take hold.

Improper Hydrology

While the hydrology of the site is important in any restoration project, it is especially critical if the restoration involves some type of aquatic ecosystem. Many wetland plants are adapted to specific degrees of soil saturation, water depth, and duration and frequency of inundation. If the current hydrology of the site does not provide the conditions necessary for the desired plant species, it will need to be altered.

Altering the hydrology of the site is a complex undertaking and should be done with the assistance of a professional hydrologist. It should also be kept in mind that a successful long-term restoration project is one that can function as a natural system with a minimum of continuous human intervention. Consequently, if the hydrologic system can be altered by taking advantage of natural patterns of water flow, this would be preferable to alterations which require construction of artificial flow control structures.

One simple way to alter hydrology is to reshape the contours of a site. Gently sloping shorelines surrounding lakes or wetlands are preferable to steep slopes. A gentler gradient means larger areas can be created that have similar levels of soil saturation or water depth, allowing a larger area for certain plant species to establish themselves. Steep slopes make it more difficult to identify the particular microelevation where planted plant species will be able to grow and survive.

Often at a wetland restoration site, the hydrology had been previously altered in some way to make the land available for other uses. Common examples of this are wetlands that were drained or river flow that was diverted so that the resulting drier land could be used for agriculture. In order to restore the original hydrology of these types of sites, these flow alterations must be reversed. This could include rediverting flow of a river or stream back through the wetland, removing flood control structures or removing artificial drainage systems.

For more management intensive projects, water levels in the wetland can also be controlled through the construction of a water level control structure. However, it should then be kept in mind that there should be some long-term plan for maintenance of that control structure.

Finally, when altering hydrologic patterns at the site, it is important to take into consideration periodic flooding events. Flooding is a natural part of any aquatic system. Its occurrence should be expected and perhaps may even be necessary for the success of the restoration project.

Detrimental Disturbance Patterns

As was explained in the section concerning site evaluation, disturbances can be either detrimental or beneficial to a native plant community, depending on the requirements of that particular community. If a native plant community is to be reestablished on the site, disturbance patterns that will harm these plants will need to be eliminated as much as possible and disturbance patterns that the community requires will need to be reinstated. Try to minimize the amount of ground disturbance for each project, especially in areas such as alpine tundra where microbiotic soil crusts and alpine plant communities take a long time to recover.

PLANTING THE SITE

Once the site has been prepared and native plants have been determined as not to reestablish on their own, it is time to begin planting the native plant material. Make sure, whether planting seeds or plants, to know the time of the year most appropriate to do so for the particular species and type of material being used. For example, if the seeds require cold winter weather before they are able to germinate, and artificial exposure to those types of conditions will not occur before planting, they should be planted in the fall. Or, in temperate areas, rooted plants are typically planted in the spring, after the harsher weather of winter has finished. This gives them a whole growing season to establish themselves before winter sets in again.

The following sections detail some of the things that should be considered when seeding or planting the site.

Seeding Restoration Sites

If seeding is a good option for the particular species of native plants desired at the site, there are a number of things that should be considered when seeding the site. See the previous on "*Active Reintroduction: Seeds or Plants*" for the advantages and disadvantages of seeds versus plants.

Timing

Since seeds require moisture to germinate, seeding at a restoration site usually should take place at the time of year when a lot of moisture is available. For many areas, this is fall or spring. Summer plantings are possible if irrigation is available for that season. This will vary from region to region; different regions appear to have better results with certain seasons. Because native plants are not agricultural crops, they should not be planted on the same calendar. For instance, warm season grasses can thrive in June and July plantings.

Seed germination requirements should also influence the timing of the seeding. Different species may need to be planted during different seasons in order to maximize germination. If the seeds require stratification before germination they should be seeded at a time when they will receive that stratification. For example, many seeds in temperate climates require a cold, moist stratification. These seeds could be planted in the fall so that they are stratified during the winter and then will germinate in the spring. However, this method exposes the seeds to possible predation and other stresses for a longer period of time, so some restoration practitioners recommend artificially stratifying the seed and then planting when it is ready to germinate.

Seeding should take place soon after any final grading, contouring or other major site work is completed to minimize soil erosion and invasion by weedy species. Consequently, this work should be done just before the time of year when the seeds should be planted. If it will be a while before the seeds will germinate, it may be wise to consider using a cover crop or mulching the site to prevent excessive erosion before the site begins to revegetate.

Staggering the seeding of species over a series of years is another option that might be considered. Some restoration project managers recommend a phased seeding plan to introduce a few species first that can quickly establish. Then, in the following years or seasons of the year, other species can be interseeded to increase native plant diversity. In some cases, a “nurse plant” introduced first actually facilitates establishment of other species that are planted later.

Site Preparation

Appropriate site preparation is important for increasing the chance of establishment and survival. If the seeds will be broadcast sowed, previous to sowing the site should have some type of surface preparation to the topsoil to create roughness for maximum germination success. Common techniques include the use of agricultural equipment to plow, harrow, chisel, disk, rip or gouge the soil surface parallel to natural contours (Munshower 1994). These techniques increase water infiltration and retention into the soil, increase soil aeration, and reduce soil erosion. Site preparation should take into consideration the fact that using the least possible soil disturbance is key to reducing weed competition.

An overly soft seedbed risks the chance of seeds being planted too deep. One rule of thumb that can be used as a field test is that a site should be firm enough for a 200 pound adult to not sink into the soil any more than ¾” with the heel of their boot. This may vary depending on the type of plant community being restored.

If the seeds will be drill seeded it is recommended to use a cultipacker or similar device to pack the soil, ensuring good seed to soil contact which is important for germination success (Morgan 1997). This should be done just before the seeds are drill seeded. Whenever equipment is to be used at the site, the tires and undercarriage should be thoroughly cleaned with high pressure spray to remove dirt and potential weed seeds from other job sites. If the seeds are broadcast sown, the packing should take place after the seeds are sown. An alternative method used with prairie seed is to firmly prepare the soil before drill or broadcast seeding, and then follow up seeding with a light drag or harrow to enhance soil to seed contact.

Seed Mixes

Effective seed mixes should consider a number of different factors (Diboll 1997):

- budget
- each species' ecological behavior
- efficiency of seeding technique
- germination rates and reliability of each species
- grass-to-forb ratio for herbaceous seed mixes
- restoration goals
- season of planting
- seed quality
- seeding rates and seed size
- site environmental conditions

Also, genetic considerations should factor into the selection of seed mixes. See the section on "*Understanding the Importance of Genetics*."

The seeds in the mix should be appropriate to the environmental conditions of the place where they will be sowed. If there are varying conditions in different parts of the site then it may be better to develop multiple seed mixes by matching species that are adapted to the specific environmental conditions. For example, if there is part of the site that is lower and moister and part of the site is higher and drier, separate seed mixes should be developed for the two different locations.

Of course, the mix should also reflect the goals of the project. The choice of plant species was discussed at length in the section on "*Choosing the Appropriate Plant Species*."

Since quite a few seed mixes are for restoration of native herbaceous species, another consideration should be the ratio of grasses and grasslike species to forbs (herbaceous plants that are not grasslike). For maximum diversity a mix with forbs making up 50 to 60 percent of the total weight is recommended (Diboll 1997). This may vary however depending on the particular plant community being restored and the cost of different forbs. For example, many native prairie sites species have a ratio of forbs over grasses even greater than 60 percent. For larger projects these ratios may be too expensive.

Seed quality is usually expressed as PLS (Pure Live Seed). This is a combination of how pure the seed is (amount of seed vs. amount of chaff, other non-viable plant material, and weed seeds), and what the germination rate is of the seed. For example, seed with a 90 percent purity and a 50 percent germination rate would have PLS calculated as shown:

$$\text{PLS} = \frac{\text{(percent purity) * (percent germination rate)}}{100} = \frac{90 * 50}{100} = 45\ \%\ \text{PLS}$$

To get the desired amount of seeds to germinate, seeds with a lower PLS will need to be applied at higher rates than seeds with higher PLS values.

Seeding rates are sometimes expressed as the number of seeds or weight of seed per unit area (acre, hectare, etc.). There is little conclusive information available to determine correct seeding rates for particular native species because restoration sites and goals can vary greatly. Much of the information available is anecdotal. Seeding rates may be estimated from recommended seeding rates for similar commercially available species, from the number of plants expected per unit area, and/or by speaking with restoration professionals. Seeding rates should be increased for harsh sites (poor soils, steep slopes, low moisture, etc.) where germination and plant survival will be lower due to the harsh conditions. Seeding rates should also increase if competition from weedy species is expected. It may be desirable to seed natives heavily so they may establish to eventually outcompete weeds. In native plant communities, grasses generally establish more competitively than forbs, forbs more than shrubs, and shrubs more than trees (Munshower 1994). Some seed loss to birds, squirrels, rodents, and other fauna should be expected. Some seeds will simply not germinate because they were buried too deeply, dried out on the soil surface or were not viable from the beginning. Some seeds may be blown away by wind or washed away by water.

The seeding rate can be calculated using the PLS, the number of seeds per pound for that species, and the number of germinating seeds desired per square foot. Use the formula below to calculate the rate:

$$\frac{\text{\# of seeds/square foot desired * 43560 feet/square acre}}{\text{seeds/pound * PLS/100}} = \text{pounds/acre of seed required}$$

To calculate the amount of lbs/acre for each species by the proportion desired the number of germinating seeds per square feet can be multiplied by each desired percentage.

For example using the information given below and the formula just described the total number of pounds per acre of two species, A and B, can be calculated:

Total number of germinating seeds per square foot desired: 50

Species	**A**	**B**
% desired proportion	60	40
seed per sq. ft.	30 (60 percent of 50 seeds)	20 (40 percent of 50 seeds)
PLS	45 percent	51 percent
# of seeds per pound	60,000	80,000

Species A:

$$\frac{\text{30 seeds/square foot * 43560 feet/square acre}}{\text{60,000 seeds/pound * (45/100)}} = \textbf{48.4 pounds/acre of seed required}$$

Species B:

$$\frac{\text{20 seeds/square foot * 43560 feet/square acre}}{\text{80,000 seeds/pound * (51/100)}} = \textbf{21.4 pounds/acre of seed required}$$

Remember that this final number of pounds per acre has already taken into account the purity and germination rate of the seed. With all the factors required to calculate the seeding rate, there is no truly accurate method of determining seeding rates at this time.

Some species are easier to seed than others. Certain species are more likely to seed successfully if some of the other plants have already germinated and established. These are seeds that should not be included in the initial seed mix, but could be seeded after two or three years.

Consider also how the species will interact with one another. Some species may be more aggressive than others. If these aggressive species are not adjusted to a smaller proportion of the total seed mix, they could end up outcompeting the less aggressive species in the mix.

The seeding rate should also be adjusted based on the type of seeding method to be used. Hand seeding is usually less efficient than mechanical seeding. Consequently, it is probably a good idea to increase the seeding rate if hand seeding will be the method used (Diboll 1997).

Seasonal differences in the seed germination rates should also be considered. Not all species germinate at the same time. If the project has seeds that have different optimal seasons for germination, perhaps the seeds should be divided up into different mixes, such as a spring mix and a fall mix. Availability of seed species will limit the mix as well.

Finally, budget will always play a role in determining species mixes. Some species are much more expensive than others, depending on their availability and the difficulty involved in collection and cleaning. It is never an easy decision to determine whether some species are not cost effective. This is where an understanding of the plant community being created becomes important. What role do those species play in the community? Are they a matrix species? Are they an important wildlife habitat plant? Are other plants in the community dependent on this species to help maintain the community balance? Please take into account that sometimes costly specifications are not expensive due to the diversity of a long species list, but because of an overly heavy seeding rate based upon agricultural methods for pastoral grasses using around 50 lbs/acre.

Seeding Techniques

The most important goal for seeding a site is to place the seed at the proper soil depth that will ensure its germination and successful growth (Munshower 1994). Different seeds have different light, moisture, and temperature requirements. Therefore, the optimal placement depth in the soil is different for different seeds as well. Generally, smaller seeds germinate more readily close to the surface, while larger seeds can be buried more deeply. Because native seeds vary so widely in their germination requirements, it is difficult to choose the best conditions for all species in one single seeding technique (Munshower 1994). Therefore, it is ideal to estimate average conditions for seed mixes with a variety of species or to do a few different seeding treatments if possible. There are a few types of seeding techniques commonly used for restoration:

Drill Seeding
Drill seeding is normally used for species with large seeds and may be accomplished with specialized agricultural equipment or with hand-held seed drills. In either case, the seed is placed below the soil surface so it has protection and potential for good soil water contact. The advantages of using drill seeders is that due to their ability to place the seeds at a precise depth, they have a higher germination rate and so can be more efficient. The disadvantages can be the cost of purchasing a drill seeder or the difficulty of renting one for the correct time, their need for very clean seed to operate effectively, and the fact that the seeds planted are in straight rows, creating a less natural look (Morgan 1997).

Broadcasting
Broadcast seeding places seed on the soil surface instead of underground. This can also be accomplished with agricultural equipment like fertilizer spreaders or by individuals operating

hand spreaders. Adding an inert carrier such as horticultural vermiculite, perlite or sand to the seed mix can help make the seed mix easier to spread and help to track where the seed has already fallen (Morgan 1997), although some disagree with these additions and do not use them in projects. Normally the ground is raked or harrowed before seeding to break up the surface and after to allow seeds to fall into crevices which help retain moisture for germination. The ground can then be packed with a cultipacker to press the soil in against the seeds. It is not recommended to use this method on a windy day as a lot of the seed might blow away. Broadcast seed application rates normally need to be higher than drilled seed rates because they have a lower germination rate. However, the advantage of broadcast seeding is that it is cheaper, easier, and creates a more natural look.

Hydroseeding
This is a type of broadcast seeding in which seed is applied to the soil surface in a liquid (usually water) from specialized high pressure equipment. This method is often used for steep or rocky slopes, and otherwise difficult terrain. Mulch may also be applied in this manner as hydromulch, but it is recommended to apply this after seed is applied so the seed does not end up on top of the mulch where it could dry out and fail to germinate (Munshower 1994). It is also key that this mulch does not form a mat that shades out emerging seedlings. “Tackifiers” are often used to help the seed or mulch “stick” to the soil surface.

Aerial Seeding
This is another type of broadcast seeding in which seed is dropped from a fixed-wing aircraft onto the soil surface. This is most effective for extremely large or otherwise inaccessible areas (Munshower 1994).

Local Native Hay Seeding
This is a type of seeding where local native grass (weed-free) is cut and baled with the seedheads still intact. Up to 2 pound of local native seed per bale would be seeded on the site when the local native hay is spread out as mulch.

<u>Mulch</u>

Adding weed-free mulch to the site after it has been seeded offers many benefits for successful seed germination:

- provides physical substrate for the seeds so they are not blown or washed off site
- provides physical protection for the seeds from extremes in temperature, light, and moisture
- provides additional source of local native seed if local native hay is used
- retains moisture which is important for successful germination
- reduces soil erosion

Mulch can take many forms (organic and inorganic), and all have advantages and disadvantages that vary widely between restoration sites. Some examples of mulch materials are: bark, wood chips, weed-free straw, leaves, weed-free local native hay, crushed stone, black plastic, newspaper, and erosion control fiber mat materials. The mulch should be applied in such a way as to not suppress seed growth when the seeds start to germinate. In other words, it should be applied in a thin enough layer so that the seeds (especially small ones) would not be buried too deeply.

Cover Crop

Sometimes it may be useful to use a cover crop to help protect the site from soil erosion as well as provide safe sites for seedling germination until the native plants that were seeded are able to establish. Cover crops are usually some type of sterile annual weed-free grain that will grow rapidly, establish for the first year, and then fade out as the natives become established. Oats, barley or REGREEN are recommended over wheat or some types of rye because the wheat and rye have been found to have a more competitive effect on the seeded natives. However, early successionals such as Canada Wild Rye, a cool season native grass, are also useable. If possible, to help ensure that the grain does not persist at the site, it is recommended that it be mowed before it produces seed.

Planting Young Plants

Careful and correct planting techniques are critical to the survivability of young transplants. Environmental conditions will vary widely among sites, but the following general guidelines should help ensure success.

- **Choose a day with moderate weather conditions.** Try not to plant on days with extreme heat, cold, moisture or wind.

- **Minimize root exposure before planting.** Do everything possible to prepare for planting before removing the plant from its container or other root protection. Collect all necessary tools, distribute plants around the site to their expected locations, prepare the water supply, dig the holes, and any other arrangements necessary.

- **Make each planting hole twice the diameter and just slightly deeper than the height of the container or rootball.** Planting holes for bare-root plants need to be large enough so the roots are not crowded together in the hole. The cross-section of the planting hole should be bowl or lens shaped instead of cylindrical because the roots need to spread horizontally to the surface to take advantage of available oxygen. The larger and wider the planting hole, the better.

- **Roughen the sides and bottom of the planting hole with the sharp edge of a shovel or other implement.** One of the greatest difficulties for transplant roots to overcome is to breach the planting hole/new soil interface. Roughening the surfaces of the planting hole provides easier access for the developing root to enter the new soil. When working in an arid climate, watering the planting hole thoroughly prior to planting will assure the availability of soil moisture to plant roots as they grow down into the native soil.

- **Place some of the backfill soil into the bottom of the hole in a mound and firm it down.**

- **Remove the plant from its container, wrapping, burlap, wire basket or other covering.** Once the plant is removed from the container, it should be planted immediately to prevent death of roots.

- **Prune off any broken, twisted, dead, circling or diseased roots.** Loosen and brush off soil around the periphery of the root ball.

- **For container-grown plants, "butterfly" the bottom half of the root ball by spreading the roots apart.** Lay the root ball on its side and slice with a sharp implement two-thirds of the way up the root ball starting from the bottom. Fan the two cut halves out to the sides. This is recommended to help plant establishment and reduce the chance of root girdling.

- **Place the plant in the hole so that the roots are spread out over the mounded soil and the base of the stem is slightly above the soil line.** If necessary, hold the plant suspended in the hole to keep it upright while backfilling with the other hand.

- **Generally, adding amendments such as organic material or fertilizer just to the soil used to refill the hole is not thought to aid in plant establishment.** (Pellet 1971; Whitcomb 1979a; Corley 1984; Davies 1987; Hodge 1990 in Harris 1992) Ideally, the native plants will acclimate to the soil conditions of the site and survive without additional nutrients in the planting hole. Nitrogen is the most common nutrient lacking in soils, so a nitrogen fertilizer could be added at the surface and watered in. It is not recommended to place fertilizer in the planting hole because it could burn the roots.

- **Backfill soil around the roots firming it using hands or feet after every few inches**. Take care not to damage the roots and be sure the roots are still spread out.

- **Do not bury the stem of the plant, make sure it is still at or above the soil surface.** The soil surface in relation to the stem of the plant should be at the same level as it was in the container. Continue until the hole is filled with firm soil, gently pulling up and settling down the plant to eliminate air pockets.

- **Create a berm around the perimeter of the planting hole that will hold water**.

- **Water the plant**, **wetting the entire planting hole basin.** Be sure to let water flow downward and soak into the soil, then water again. The first watering flushes air from the soil pores; it is the second watering that will provide water available for the plant's use.

- **If possible, mulch around the base of each plant.** This will reduce weed competition, mediate soil temperature extremes, and reduce moisture loss from the soil. Mulch should not be allowed to touch the trunk or crown of plants and should be placed at least 1" away.

Depending upon the environmental conditions at the restoration site, measures may need to be taken to help new transplants survive. Staking plants, especially in windy areas, may be necessary. Protective tubing, netting or screening may be utilized to protect young plants from herbivory, harsh sun, wind, cold, or machine or foot traffic. There are a wide variety of products for these purposes available from nursery supply catalogs. It is important to remove any protective devices when they are no longer needed so they do not impede the growth of plants.

To encourage the roots to spread out from the container soil into the native soil, it is important that sufficient water is applied to wet the area of native soil outside and below the rootball and container's potting soil. The amount of water the new transplants need will again depend on the site conditions and the weather patterns. Some native plants will initially require watering until they have become established at the site. Whatever watering regime is decided, the frequency of watering should decrease over time to allow the plants to acclimate to the site and eventually survive without any additional watering.

Using Volunteer Labor

Using volunteers for a restoration project can be extremely valuable. In addition to providing much needed labor, the public can be educated about the value of ecological resources, the need for restoration, and the importance of good land stewardship practices. It also may provide them

with a stronger feeling of connection to their local environment. By instilling in them that sense of "ownership" of a restoration site, they become more inclined to continue to visit the site and provide information about disturbances and detrimental changes occurring there. However, it is also important to remember that volunteers do require adequate training and supervision to ensure that the work is done correctly. Using volunteers as a cheap source of labor without adequately supporting them could be detrimental for the project.

When using volunteers in a restoration, here are some basic guidelines to follow:

- Be organized and know, before they arrive, what work the volunteers will be doing.
- Inform volunteers that their efforts (sweat equity) develop project ownership so they treat and enjoy the site as their own.
- Use color-coded flags to mark the planting locations of individual plants. Use a different color for each species or write the initials of the species on each flag. Marking individual locations eliminates the chance that volunteers will plant a particular species in an inappropriate location.
- Provide adequate, clear training and supervision. Keep in mind that the volunteers will have varied backgrounds, with some needing more information and training than others.

Make sure that all volunteers are provided with enough information and training to ensure successful implementation or management of the restoration project. Written or graphical training materials are usually appreciated and well-received.

- If the same volunteers will be working at a site over a long period of time, be sure to provide enough training and encouragement so that they want to return. Remember, they are providing a much-needed service at no cost.

- Show appreciation. If the budget allows, providing food and/or t-shirts is always a popular. Otherwise, a simple “thank you” goes a long way.

To find volunteers, contact the extension agency, local native plant or gardening clubs, other community organizations or advertise in the local media. Also, look to nearby neighborhood primary and secondary schools, as well as universities, for student volunteers of all ages.

CARING FOR THE SITE

Following installation of the native plants, continued maintenance and care for the site is often required to ensure a successful project. The amount and duration of care – mostly watering, fertilization, and insect pest control – will depend on the particular environmental conditions and location of the restoration site.

Watering

During the planning phase of the restoration project, it should be determined if it will be necessary to water the plant material for a given time period following the initial installation. The basis for this decision should include considerations of weather, site topography, plant water requirements, logistics, and cost-effectiveness. Also, in general, larger plants require more water to survive than do seeds and smaller plants. If a restoration project is conducted on a very large scale or is in a remote location, then it may not be possible, both logistically and economically, to water the site. When this is the case, one should take advantage of seasonal rainfall patterns and plant seeds and/or plants either right before or during the rainy season. Hydroseeding (or hydraulic seeding), a technique in which seed, water, and nutrients are sprayed over the ground in the form of a slurry, may also be an option on very large sites. Other options to pursue if irrigation is cost-prohibitive include site preparation to remove all competing vegetation (which brings with it other complications such as increased erosion) or mulching to conserve water.

To determine if water is needed at the restoration site, a visual inspection of the plants will usually suffice. Most plants wilt noticeably when water is limited. Leaves can become dull and fade in color, turn yellow, and, in extreme instances, die. Some species of native plants will wilt earlier than others, so these can be used as an early-warning sign of drying conditions. If water does need to be added to the site, only apply an amount equivalent to the average annual rainfall in that area. Anything above that amount would be extraneous to the needs of the native species and an unnecessary cost.

Watering needs are different in dry areas with low humidity. Container plants will usually die if natural water regimes are relied upon during the first year. Potting mixes are prone to drying out quickly in arid climates, and once artificial soil mixes are dry, they resist moistening, resulting in plant death. Plants in arid climates will require irrigation on a regular basis until established, usually until the end of the first growing season. Irrigation should be sufficient to moisten the soil below the bottom of the planting hole.

Methods for water application include basin (flood), furrow, sprinkler, and low-volume, high-frequency (e.g., drip, minisprinkler, or soaker) systems (Harris et al. 1999). The basin and furrow methods offer a low-tech solution to irrigation and can be installed during the site preparation and/or planting phases of the restoration project. With both methods, water is provided to the plants only when the basin or furrows are filled. Sprinkler systems, when properly designed and maintained, can provide uniform water distribution on both flat and hilly terrain. Sprinklers are best used early in the day, when there is little wind and foliage will be able to dry throughout the day. The drying factor is especially important for plants susceptible to water-related diseases. Drip and minisprinkler irrigation apply water slowly and in such a way that only a portion of the soil within the dripline becomes wet. Drip emitters apply water more slowly and to a smaller area than minisprinklers and are better suited to smaller, slow-growing or widely-spaced plants. They also, however, have a greater tendency to clog than do the higher-pressure minisprinklers. With any type of sprinkler or drip irrigation system, equipment breakdown may cause stress on the plants.

Erosion Control

The benefits of vegetation in preventing erosion are well documented – their roots stabilize and anchor the soil and live plants and litter increase the absorptive capacity of the soil. However, before the newly-installed native plants become established, erosion of exposed soil could be a problem. One easy and economical way to prevent erosion during the time of plant establishment is to use weed-free mulch. This is especially true on slope plantings. Weed-free mulch protects the seeds and seedlings against rain and wind and also reduces loss of moisture during dry periods. A variety of mulch types can be used, which include hay or straw, jute netting, wood fiber or fiber netting. Other considerations regarding erosion prevention are:

- buffering or filter strips
- diverting surface water runoff away from disturbed soils
- keeping heavy equipment off exposed soil during heavy rain
- planting native grass along drainage channels to slow the rate of runoff
- planting temporary vegetation cover (e.g., annual grasses) on sites that remain exposed during the rainy season

Invasive Species Controls

Following installation of new native plants, controlling the recruitment and spread of invasive plant species is one of the most important elements to ensure the success of a restoration project. Once established, invasive species can outcompete native species, form dense stands, and eventually dominate an entire plant community. Restoration projects that involve earth-moving or alterations to hydrology are particularly vulnerable to the influx and spread of invasive species (WADOE 1993).

Specific methods for invasive species control and eradication are detailed in the "Invasive Weeds" section. It is critical and cost-effective to prevent establishment and spread of new weed invasions during and after the initial site work has been completed. Methods of doing so include the following:

- early detection and eradication of new weed invasions
- containing neighboring weed infestations
- minimizing soil disturbances
- planting native species of the local ecotype
- managing for healthy native plants
- test plots

Early detection and eradication of new weed invasions. If a new infestation is detected at an early stage and the plants are removed before seeds are produced, efforts and resources will be saved. Even if some plants are detected after seed production, but before a large population increase, less work is required than in a full-blown invasion. One method commonly used to prevent weed invasion is to regularly survey the restoration site, removing individual weed plants before they become better established and begin seed production. The weed infestation area should be identified on a map of the site, marked in the field, and continually monitored during subsequent surveys.

Containing neighboring weed infestations. Since restoration sites do not exist in a vacuum and often are situated within a larger disturbed landscape, there is a good chance that weed populations will be found in areas adjacent to or nearby the site. One approach to controlling the spread of invasives is to spray the borders of the infested area with an herbicide. Containment programs are typically designed only to limit the spread of a weed population, and thus can require a long-term commitment to herbicide application.

Minimizing soil disturbance. Most weed species have developed characteristics, such as rapid growth rates and high seed production, that enable them to move into a bare ground site quickly and aggressively. They often are able to outcompete native species in occupying disturbed soil. Because this is the case, it is important to minimize soil disturbance in a restoration project wherever possible.

Planting native species. Eliminating a weed can leave environmental resources available for the reinvasion of the same or different weed species. Revegetation with native plants can prevent reinvasion of undesirable species and can also contain the spread of remnant weed populations.

Managing for healthy native plants. In areas where native species have been planted, it is important to manage the landscape properly so that the native plants remain healthy and strong and weed encroachment is limited.

Test plots. If the project time frame allows, it may be cost effective and worthwhile to carry out recommended treatments on test plots of a smaller scale to see if desired results can be obtained. Monitoring test plots is an excellent planning tool for large-scale restoration attempts.

Fertilization

Following the initial planting, fertilizing native plants is only necessary in extreme cases when the condition of the soil is still in need of repair. This would be in places such as contaminated sites or abandoned mine sites where the topsoil has been completely removed or destroyed. In those instances where the soil is not yet conducive to supporting native plant populations, the revegetation aspect of the restoration plan should be postponed until soil conditions can be improved. This is described in detail in the previous section on "*Reduced Soil Function*." Once the desired soil environment (e.g., pH, nutrient levels, diversity of microorganisms) has been created or restored, then the native plants, being adapted to those particular soil conditions, should not require additional fertilization.

Applying nutrients to a restoration site without first knowing if the soils are deficient can cause adverse effects such as salt buildup in the soil, inhibition of mycorrhizae formation, growth of invasive species, and water pollution. It has also been reported that the addition of even mild fertilizers can cause root dieback and shoot burning in many native species, particularly those that are drought tolerant. If it is decided that fertilization is an option, first take soil samples to determine what nutrients are limited. It is important to keep in mind that the pH of a soil, among many other factors, can greatly affect nutrient levels. Iron and manganese may be less available in alkaline soils, and phosphorous may be limited in acid sandy or granitic soils. Potassium levels may also be low in acid sandy soils. Always remember to keep in mind the specific needs of the native plant community being restored. These plants may be adapted to particular low nutrient conditions. In these cases adding nutrients can reduce the ability of the native species to outcompete weedy species.

Pest Management

It is a good idea to regularly inspect the plants at the restoration site for signs of insect pest damage. Before doing so, however, it is a good idea to find information about what pests have the greatest potential for infesting the site. Knowledge about the host plants will provide much of this information, since the large majority of pests are host-specific. Keep in mind, though, that some pests are host-specific only at certain times of the year. For example, the woolly apple aphid infests American elms in the winter and then moves to apple trees in the spring and summer; the woolly elm aphid infests serviceberries in the summer and then spends the rest of the year on elms (Harris et. al. 1999).

To inspect plants for pest problems, go out to the restoration site on a regular basis and systematically check plant foliage for pests and damage symptoms. A routine should be developed that is efficient for each particular restoration site. As was mentioned before, learn about the problems common to the species on the restoration site and be able to recognize signs of damage caused by pests. Also, it is important to be able to clearly distinguish the pests from beneficial organisms. The use of appropriate tools, such as a hand lens and reference materials, can aid in pest recognition.

If a pest population increases to some level that can no longer be tolerated, then it may be necessary to implement some control practices. Before spraying or introducing a predator population, it is strongly encouraged that the advice of the local extension agency be sought.

Continuous Protection of Restoration Site

Following installation of the native plants in a restoration project, it is necessary to consider what will happen to the site once the project team walks away from it. For example, if the restoration site exists in a rural area or even some urban areas, it is highly probable that there are wildlife populations nearby waiting to forage on all of the newly-installed plant material. As has been documented time and time again, grazing or browsing by domestic or wild animal populations can severely inhibit establishment of native plant populations. Other considerations for protecting the restoration site include erosion control and adapting the management plan to suit changing environmental conditions.

Protection from Grazing or Browsing

Although some matured prairie plantings benefit from occasional or light grazing (effects similar to those produced by prescribed burning), most sites should be protected from grazing or browsing. The most effective method of controlling grazing or browsing of native plant material by wildlife is to prevent access to it. For larger animals, such as deer and cows, fencing the site, plant communities or individual plants can restrict access. The fences should be tall enough to prevent deer from jumping over them and sturdy enough to withstand the weight of the animals leaning or pushing against them. Building fences of chicken wire can also prevent waterfowl grazing, but the exclosures must be small enough so that they are unable to fly in and out of them. It may also be necessary to construct a cover of fencing or other material over the site to keep out smaller birds.

Plants can also be individually protected by installing some sort of physical barrier immediately around their base. For tree seedlings, tree shelters are often used. These are tubes of translucent plastic that fit around the bottom portion of the plant. Tubes of rigid netting are also used. To protect mature trees, chicken wire or hardware cloth can be wrapped around the base of the tree. For protection from rodents which like to eat the bark at the base of young trees, aluminum foil can be wrapped around the base of each tree to a height of around 9 inches.

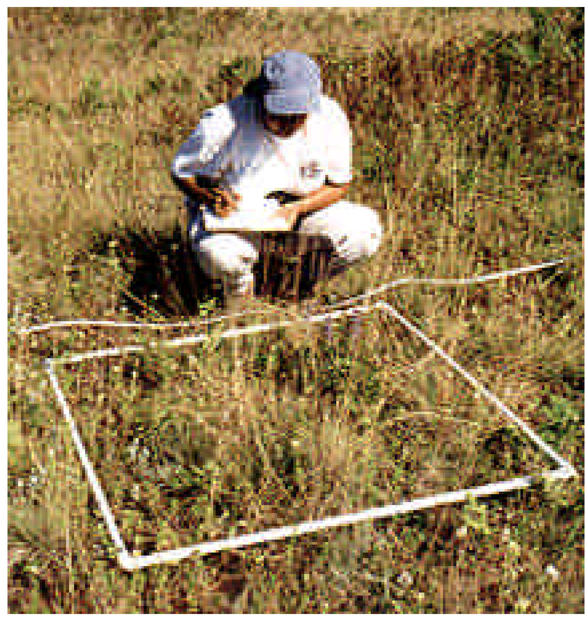
All protective fences and barriers should be removed later, once the plants have established.

Monitoring

Monitoring is the means by which it may be determined how well the native plant project meets goals and objectives. It also serves a critical function, alerting managers to possible maintenance needs to ensure continued success of the project.

Development of a monitoring program requires much planning and consideration of one's specific goals and objectives. In fact, all monitoring data should be evaluated relative to the goals and measurable criteria established at the onset of the restoration project. Take for example a goal of increasing available wildlife habitat with measurable criteria as the establishment of greater than 50 percent cover of native plant species that are providing food for wildlife. The monitoring efforts would be directed at measuring the change in percent cover over time of those native plant species known to be a food source for wildlife. The success of the restoration project would then be evaluated based on a greater-than-fifty-percent or less-than-fifty-percent-cover of native species, which would have been measured through monitoring.

Monitoring has the dubious honor of being the most forgotten or left-out element in restoration projects. Many restoration projects are resource intensive in the early stages, which makes it easy to commit all of the project budget to planning the project, purchasing the plant material, procuring equipment, site preparation, and putting the plants or seeds into the ground. All too often, not enough thought is given to what might happen to the restoration site after the plants or seeds are installed, and project failure can be the unfortunate result. Monitoring provides a long-term look at the ecological changes occurring after the initial restoration project and enables proactive management to prevent failure of the project. Some examples of factors that can interfere with the success of a restoration project include invasion of noxious weeds or invasive plants, intense browsing or grazing by wildlife, failure of introduced plantings due to drought conditions, acts of nature that severely damage restored areas, and damage resulting from human trespass.



Techniques for vegetation monitoring can include a cursory visual inspection of installed plants or a more detailed study of plant species or groups of similar plant species using randomly or systematically-placed quadrats or other sampling units. A combination of both techniques may be appropriate for most planting sites: monthly site checks to quickly ensure that plants are healthy and are not being harmed by something, and more detailed assessments once or twice a year to examine vegetation health, growth, and establishment in order to monitor project development and success.

The choice of specific monitoring methods for the more detailed assessment will depend on the type and density of vegetation that is being restored. If the planting involved mainly woody vegetation where it is easy to relocate individual plants, assessments may involve counting numbers of surviving versus dead individuals and measurements of growth such as height, stem width, and numbers of new branches. If the project involved planting of herbaceous plants or mainly seeding, it may be better to establish monitoring plots throughout the site. Ideally all the monitoring plots combined should cover at least five percent of the total project area. They should be placed so that they can provide a fairly accurate picture of the success of the overall site. This may mean stratifying the site (dividing it up into different sections based on site differences) and then randomly placing a proportional number of sampling plots within each section. Within the plots some of the measures of vegetation that could be used include diversity, density, percent cover, frequency, and biomass. Each of these is explained briefly below. They should be evaluated in comparison with reference areas and take into consideration the natural dynamics of an ecosystem over time.

If time and funding prevent intensive monitoring of a restoration site, at least take photographs of before and after restoration at the same spot. These photos can also be retaken in future years to help chart the progress of a site.

Diversity

Diversity measures both the absolute number of species in an assemblage, community or sample, as well as their relative abundance. Low diversity refers to few species and/or unequal abundances, while a measure of high diversity corresponds to many species with equal abundances.

Density

Density is the number of individuals in a given unit of area. While density is a commonly-used metric due to its being easily obtained and understood, it does have some limitations. The major limitation is that the critical unit of measurement is the individual plant, which may be difficult to identify in some instances. For example, rhizomatous perennials grow by vegetative spread, making it difficult to determine whether one or several stems belong to a single individual. Therefore, it is important to first determine the individual unit of interest, making sure it is a unit easily identifiable in the field.

Percent Cover

Percent cover typically refers to the vertical projection of vegetation or litter onto the ground surface when viewed from above. This measure is considered as an approximation of the area over which a plant exerts its influence on other parts of the ecosystem, or its dominance relative to other plants or species. Variations of this concept include vegetation cover, the total cover of vegetation on an area; crown cover, the spatial extent of tree or shrub canopies; ground cover, the cover of plants such as shrubs, grasses, and herbs as well as cover of litter, bare ground, and rock; and basal cover, the cover of the basal portion of plants. Percent cover is one of the most commonly measured vegetation attributes and provides a quantitative measure for species that can not be easily or accurately measured by density or biomass. When the cover of individual species or species guilds are measured separately, the total cover within a sample may exceed 100 percent due to overlap of the plant crowns or foliage.

Frequency

Frequency is the proportion of time a species or guild occurs within a given number of samples. It is a useful means of detecting differences in vegetation structure between two or more plant communities and is sensitive to change over time (The Nature Conservancy 1997). If a species has a frequency of 20 percent, then it should occur once in every 20 quadrats examined. The measure is obtained simply by recording whether a species is present in a series of quadrats. A major benefit to collecting frequency data is the ability to collect a lot of data within a relatively short time period. However, the information gathered from this method is limited such that it does not provide an idea about the relative dominance and abundance of a species in the community.

Biomass

Measuring biomass in vegetation monitoring is used infrequently mostly since it involves some degree of destructive sampling. It can, however, provide a good measure of seasonal and annual changes in growth.

Maintenance Using Prescribed Burning

Future management of restored prairie and other fire-dependent plant communities can utilize prescribed burning as a tool. Planning ahead for using fire requires a firebreak. Many times this can be done by planting a green break, or short cool-season grasses around the perimeter of the project site. Green breaks have proven to be valuable in reducing the time and expense of maintaining these sites.

Adaptive Management

Adaptive management is a systematic approach for improving management by learning from past mistakes. Management objectives and actions are continuously adjusted as new information is gathered through monitoring and more is known about which management techniques work and which do not. This approach to management is especially applicable in a restoration context, where environmental conditions are changing rapidly and there still is much uncertainty about how to design and implement a successful project. For example, a restoration site existing in a highly urbanized area was planted with native species, and, due to the absence of wildlife in the area, no plans for protection of the plant material from wildlife were made. Then in the second year of the project, some deer moved onto the site and proceeded to graze on the tender shoots that had been planted the year before. If the original project management plan was not modified to install fencing or some other physical barrier around the site, then chances are good that the deer would cause considerable damage to the new plant material. Adaptive management of a restoration site can lead to more effective decision making and increase the likelihood of project success.

FINAL THOUGHTS

Planning, implementing, and maintaining a native plant project can be a considerable undertaking. As is detailed in this manual, there are many important considerations that project managers should be aware of before deciding to use native plants. Using native plants can ensure that, over time, low-maintenance vegetation is established on a site. However, it is not as easy as buying a few plants that the local nursery labels as native, planting them in the ground, and walking away. It is clear that, in order to be successful, careful thought should be used in selection of plant species, installation of those species, and maintenance of those species until establishment. For those that are concerned about losses of native species diversity, using native plant species in their projects is a worthwhile and rewarding endeavor. The final product, a restored native community of plants and wildlife, is well worth the effort.

APPENDIX A: SELECTED WEBSITES

Please note: *The Plant Conservation Alliance does not control and cannot guarantee the relevance, timeliness, or accuracy of the materials provided by other agencies or organizations, nor does it endorse other agencies or organizations, their views, products or services.*

Bailey's Ecoregions & Other Ecoregions

- http://www.epa.gov/bioindicators/html/usecoregions.html
- http://www.fs.fed.us/institute/ecolink.html
- http://www.fs.fed.us/land/ecosysmgmt/ecoreg1_home.html
- http://www.ngdc.noaa.gov/seg/eco/cdroms/gedii_b/datasets/b03/bec.htm

Forestry or Agronomic Supply Catalogs

- Ben Meadows Company (http://www.benmeadows.com)
- Cole-Parmer (http://www.coleparmer.com)
- Forestry Suppliers Inc. (http://www.forestry-suppliers.com)

National Climactic Data Center

- http://lwf.ncdc.noaa.gov/oa/climate/onlineprod/tfsod/climvis/main.html

Natural Heritage Programs

- http://www.natureserve.org/nhp/us_programs.htm

Successful Salvage of Native Plants

- King County (Washington state) Native Plant Salvage Program (http://dnr.metrokc.gov/wlr/PI/salvage.htm)

Other Restoration, Revegetation & Native Plant Websites

- Fire Effects Information System (http://www.fs.fed.us/database/feis/)
- Society for Ecological Restoration (http://www.ser.org)
- Plant Conservation Alliance (http://www.nps.gov/plants/)
- Native Plants Journal & Native Plants Network (http://www.its.uidaho.edu/nativeplants/)

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