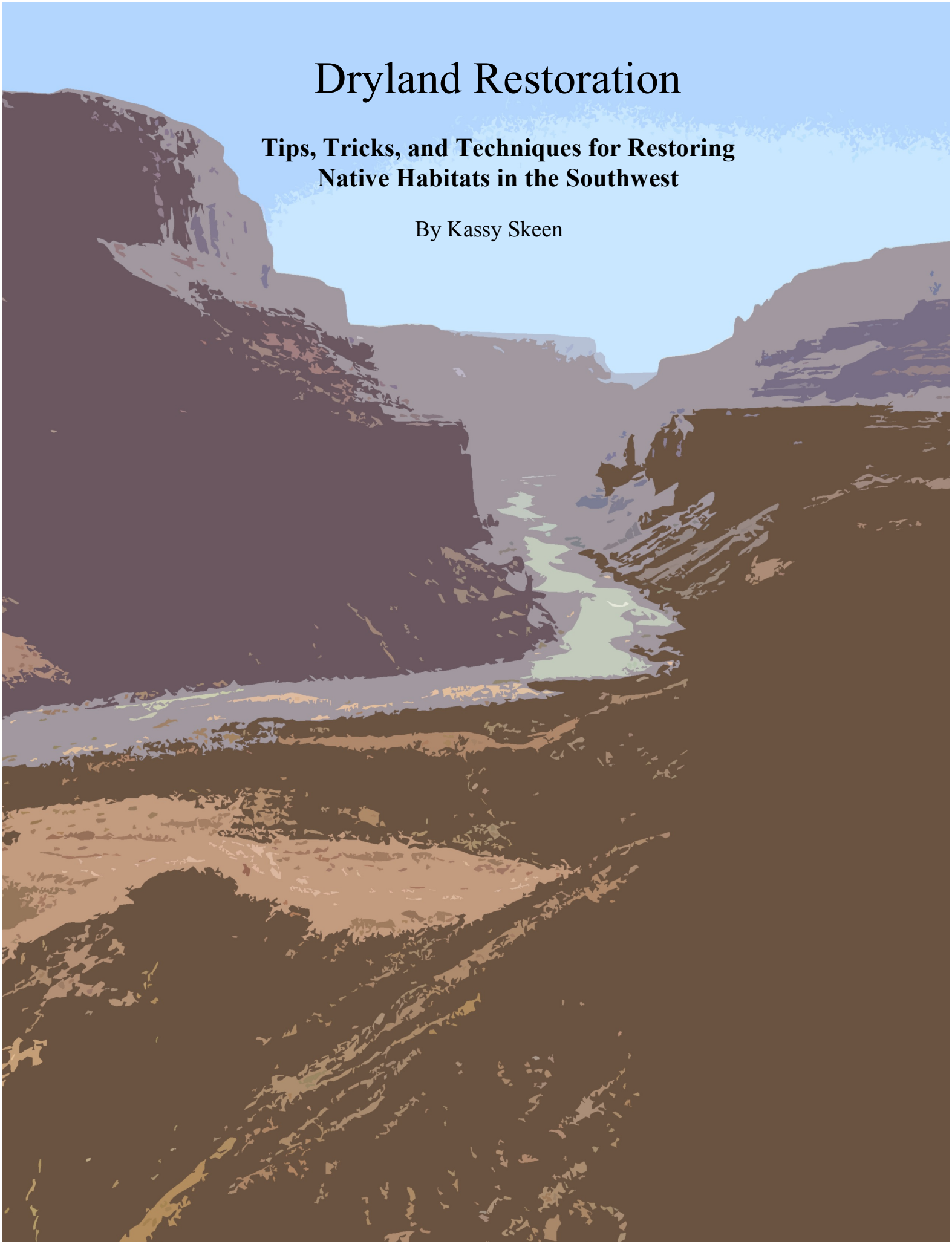
Dryland Restoration

Tips, Tricks, and Techniques for Restoring Native Habitats in the Southwest

By Kassy Skeen



INTRODUCTION

This manual, originally developed at Grand Canyon National Park (GRCA), applies to a broad range of environments. The techniques discussed were used in elevations ranging from 1500 to 9000 feet. Those elevations include the following major vegetation types: Mojave Desert Scrub, Sonoran Desert Scrub, Great Basin Desert Scrub, Pinyon Juniper Woodland, Ponderosa Pine Forest, and Spruce-Fir Forest. Many projects were completed in or near desert riparian areas, while many others were completed on the dry North and South Rims of the park.

The techniques described vary widely in where they can be implemented. The North and South Rims of Grand Canyon are accessible by motor vehicle, which vastly change the array of options available to a manager. Portable water pumps, mechanized equipment for soil preparation, large planting efforts, and immediate access to the park's greenhouse allowed for larger, more intense intervention methods in restoration planning and implementation. Project sites located along the Colorado River and other inner canyon locations are only accessible by raft, helicopter, or foot, making technique options limited in size and scope. In addition, most of the inner canyon of the park is managed as a Proposed Wilderness, which requires that the park staff preserve the wilderness character by refraining from using mechanized equipment, visually offensive signage or structures, or other heavy interventions. This mandate, coupled with limited accessibility, a dry environment, and limited resources required that managers be creative in their approaches to restoring degraded sites, often limiting size and scope with small, but effective restoration interventions.

This manual will detail the very basics of restoration planning, techniques like planting, seeding, and preparing soil, and will also cover topics such as basic trail maintenance techniques that can be used in conjunction with common restoration ideas, as well as mechanized restoration, and more. Most of the restoration work done at Grand Canyon was completed by the Vegetation Program, with large contributions, particularly in the backcountry, by the Trails Program, Visitor Use and Recreation Program, Archaeology, and Visitor and Resource Protection Division. The interdisciplinary team-approach to restoration inspired many creative ideas that ultimately resulted in more effective outcomes.

The fragile desert.

Some of the work completed on the rims of the Park was completed by contractors, but was planned and designed by the Vegetation Program staff. Those projects and techniques are also included in this manual to help managers see the comparisons in completing projects with in-house staff and volunteers, with contractors, or both.

PURPOSE AND AUDIENCE

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The purpose of this manual is not only to serve as a "how-to" guide for specific restoration activities, but also to explain the background information needed for identifying restoration projects and the appropriate level of intervention for particular resource problems. The ultimate goal of the manual is to serve as a repository of knowledge that has been refined over time by multiple generations of land managers to effectively and efficiently restore native landscapes, particularly in the Southwestern United States.

This manual was originally created for a specific geographic location, but has been adapted to a broader audience, in order to serve land managers and restoration practitioners on public and private lands. The techniques described in this manual are all based on real, practical experience, from over 50 restoration projects, ranging in size from a few hundred square meters, to 20 acres, and beyond. While there are scholarly references, this manual was initially written as a technical guide to anyone working in restoration, not just those with an educational or research background in the sciences. While the academic journals and literature will support the theories the techniques are based on, much of the work presented here is a synthesis of institutional knowledge of land managers passed on to individual employees over the course of a career. The scientific validity of the techniques can be found in local data sets at the sites. None of this specific work has been published in any academic journals to date.

WHAT IS RESTORATION AND WHY DO WE DO IT?

According to Webster's Dictionary, the technical definition of restoration is "a return of something to a former, original, normal, or unimpaired condition." By this definition, restoration can mean many things; from pruning the vegetation on a trail back to its original tread, to obliterating a social trail or campsite, to remediating an abandoned mine, or eliminating a stand of tamarisk trees. The location and circumstances can also vary widely, from a project restoring native grasses and forbs along a paved highway to restoring a desert riparian area in the remote wilderness. The definition of what "restoration" means to any project lies in a blend of stakeholder value judgments and scientific information.

The very definition of restoration requires that we understand current conditions and also which conditions we want to achieve. Defining what condition we want is often incredibly difficult and varies based on the type of environment and external pressures. Depending on the project location and scope, there can be management documents, policies, and legislation that mandate managers to achieve certain conditions. Quite often there are any number of stakeholders that have very specific uses for the land, often conflicting in their value judgments. Others may have more leeway in the decision making process, typically those that are managing private lands or reserves. More often than not, there is little quantifiable data that managers can refer to

for what a species assemblage may have been, what a campsite looked like, or what soil conditions were at a particular site. Oftentimes managers set those benchmarks for a resource based on general historical accounts, monitoring programs, or a defined moment in time when conditions were definitively known; trails should have x amount of tread width, no more than x percentage of invasive species should exist at a site, x number of tent pads should exist per beach, or the plant species list should include xx number of species., etc. Restoration practitioners prescribe and implement restoration actions based on those quantifiable benchmarks. Each site or resource issue is unique. The degree to which a site can be restored, given the time and resources available, overriding legal issues, and continued impacts, is decided upon in a collective voice from all resource perspectives. Managers must work together and be inclusive of as many voices as possible, as it is crucial to achieving and maintaining successful restoration projects.

Restoration can also be defined as being active or passive. Active restoration involves implementing specific action like planting or seeding, while passive restoration is the absence of action, except that which is necessary to remove the major stress on the site, such as damaging recreational uses, grazing, or dam control (Morrison and Lindell, 2011). The decision to be active or allow passive restoration depends on time, resources, desired conditions, size of the site, and expertise. Usually, passive restoration requires less monetary investment while active restoration allows the manager to meet specific goals more consistently.

Reasons for initiating restoration activities, whether they are passive or active include (Dorner, 2002):

- To stabilize highly erodible and fragile soils in dam controlled river systems
- To protect threatened and endangered species and their habitats
- To provide high quality visitor experiences by maintaining unimpaired landscapes
- To prevent soil and vegetation damage by providing well constructed and maintained trails
- To protect cultural features and prevent erosion around those sites
- To prevent invasive nonnative species from outcompeting native vegetation
- To restore ecological function and services
- To improve forage
- To recover biodiversity

The reasons listed above have both a scientific basis and a human added value as a driving force. This is in no way a comprehensive list but rather an illustration of how varied the ultimate goal of a project can be.

When do We Consider Restoration an Option?

Three distinct competencies need to be addressed and met before a manager should commit to a restoration project, regardless of size. Those competencies include sound scientific principles, technical expertise, and a deep understanding of the social dynamics of the site (Cairns, 2000). Projects fail when the people who use the site or area don't support the mission of the project or don't feel that their interests were taken into consideration. Likewise, without good planning, initial strong support can wane as people lose faith in the process.

Commitment to restoration should only occur when a sound, reviewed plan with a good basis in current ecological principles has been completed, focusing not just on the structure of an environment but also the services it provides. Is it enough to simply plant 1000 new plants or does the soil biotic community need to be restored in order to support vegetation that will ultimately provide shade to visitors and increase migratory bird nesting habitat? The plan should be able to detail the techniques to be used, but should also allow the managers some latitude in trying new methods. The plan should address how success will be evaluated and when critical decisions will be made regarding the success or failure of certain techniques. And last, but certainly not least, the plan should detail a strategy for engaging the public, which identifies key players and how stakeholders will be involved in the process.

There are no guarantees that all stakeholders in a particular site will support a project. The inclusion of all voices in the scoping and planning process, the engagement of interested parties as volunteers, the dedication to follow up and review, and specific outreach to individuals who throw up opposition are critical to achieving restoration goals.

Restoration is an expensive endeavor. The time, money, expertise, and inputs should only be committed after a thorough investigation of the competencies held by the invested parties.

How Do We Know it Works?

Determining the success or failure of the project and individual techniques based on real scientific evidence, are critical to expanding the body of restoration knowledge at a site.

Managers should develop a monitoring or reassessment plan during initial planning efforts. Monitoring requires at the least a semi long-term commitment in money, staff, and technical resources. There are a plethora of ways to monitor a site, but managers should only choose those that will actually provide sound data to address the original goals of the project and are feasible in terms of time commitment and resources in years to come. Those methods could include permanent photopoints, complete population documentation, mapping, repetitive line transects, soil samples, water quality samples, etc.

Recording accurate data and subsequently using it is the most crucial component in the ability to recognize effective work. Because there are likely to be a variety of people assessing the site over time, consistency in those assessments is crucial. All staff performing any monitoring activities should be at least annually trained on the collection of the data itself and also how to accurately record it on the data sheet or data logger. Seemingly simple tasks of writing down numbers or taking a few photos can be complicated quickly by different styles, small mistakes, and unclear communication. These mistakes can corrupt a dataset and skew results. Complete and accurate data collection is crucial for staff that will be designing work plans from the data collected, especially if those staff can not be in the field at the time of the assessment.

COMPLIANCE FOR FEDERAL LAND MANAGERS

Federal land managers are held to the National Environmental Policy Act (NEPA) process when performing any major actions on federal lands. In addition, they must adhere to cultural laws that protect Native American culture, history, and sites. This includes removing invasive species, performing restoration activities, removing native vegetation, constructing roads and trails, or changing visitor use patterns. Large projects usually go through either the Environmental Assessment or Environmental Impact Statement process to identify potential impacts of the project actions, as well as providing the public time to provide comments and feedback. Typically, agency staff should be aware of how to contact NEPA compliance staff serving their field location. The process can take a significant amount of time. The Bureau of Land Management (BLM) has an excellent training course on-line for NEPA issues called the NEPA Web-Guide on their website.

RESTORATION TECHNIQUES

This manual highlights many active restoration techniques that can be used and adapted to fit a variety of sites. Invasive species management is mentioned throughout the manual, but is not addressed as a separate topic in restoration. Removing invasive species is often a precursor and sometimes even the driver of restoration projects. Due to the number of species, large geographical extent, and varied management techniques, this manual will not focus on invasive species management specifically, but instead will describe follow up interventions and considerations when working in areas with invasive plant species.

PLANTING

Any new restoration planting, regardless of its location, requires careful planning and implementation. New plantings in remote locations need a little extra attention. They need to be self sufficient immediately in order to survive long periods of time with little attention.

To achieve success in new plantings, the first item to address is the plant's water requirements. Some plants will establish on their own, with very little supplemental watering. Others will require a slow drip deep irrigation system to establish. Appendix I outlines some common desert species, where they typically grow, and their water requirements in a remote restoration type project. Refer to the Irrigation and Watering section of this manual for a more in depth description of watering options.

All planting based restoration projects completed at GRCA showed a large benefit to community planting. Community planting consisted of grouping 5 to 20 plants into a common berm, which was approximately 6 to 8 inches higher than the surrounding soil and from 3 to 8 feet across, in varying shapes. Depending on the goals of the project and surrounding vegetation type, groupings consisted of the appropriate ratio of grasses, forbs, shrubs, and occasionally trees. Once the planting ratios were met, supplemental seed was sometimes added to increase diversity or cover, again depending on the goals of the project. Once seeded, communities were mulched

with either duff and litter collected from surrounding areas, or chip/shred mulch from trees that were removed for construction projects throughout the park (see Mulching and Fertilizing section for more details). The communities were then caged with 14 gauge wire fencing, secured with rebar stakes to reduce animal predation, typically elk, deer, beaver, or the wandering human footstep. Watering was then initiated based on the prescription for the site, usually requiring that berm be filled once, allowed to soak in, then filled again for each watering event(see Irrigation and Watering section for more details).

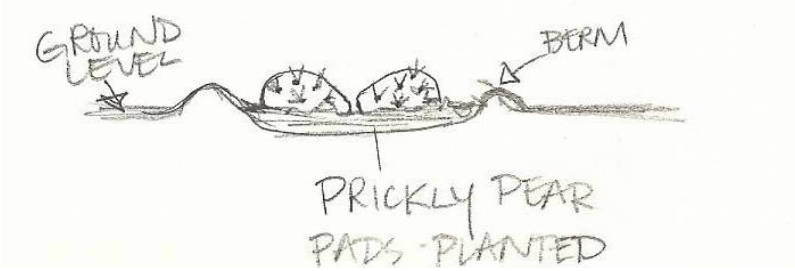
Communities planted in this both increased survival rates over multiple years and improved seeding success, were easier to maintain than individually planted plants, and allowed managers to cover more area with less plants. Communities established more quickly and were able to start self-seeding which filled in the vacant space between berm communities quickly. Crews spent less time hand watering and irrigation systems used less water, which was delivered more efficiently to the grouping. Crews also were able to prioritize invasive species treatments during intense parts of the season by concentrating on removal of invasive plants within the communities, removing those outside the berms when time allowed. Likewise, because only the communities were being watered, the vacant planting space between communities often had much smaller populations of invasive species at the start. The individual plants, while competing to some degree with each other, also benefitted from microclimates created within the communities by the plants themselves or other features like downed logs, large rocks, or small contours created with hand tools. Finally, these communities were also much easier to monitor and track in terms of survival rates due to the ease in mapping groups instead of individuals, as well as the ability to easily relocate the berm in subsequent years.

BASICS OF PLANTING

There are two primary types of planting that you may encounter: direct transplant from on-site stock and direct planting from plants that were propagated in an off site nursery. Generally, you should follow the same planting rules with both types. However, the root structures and immediate needs of the plants will differ. Those transplanted from the site may have freshly cut roots from the transplant, may be larger in aboveground mass, and may suffer from transplant shock as well as planting shock. Those that have come from the nursery will likely be in a potting soil mix, instead of native soil, may not have been hardened off to local temperatures and water regimes, and could have very little root ball or conversely be root bound.

Listed below are the steps you should follow when planting any transplants or container plants.

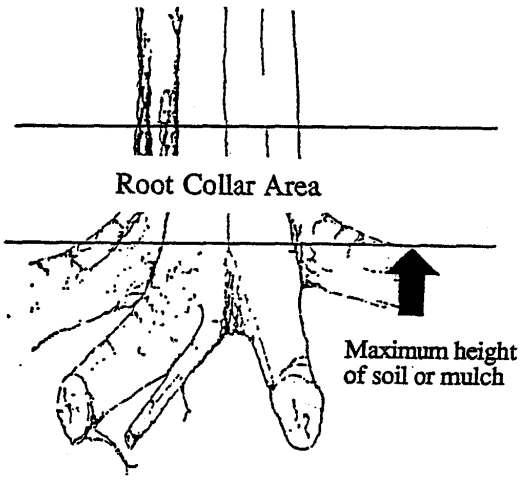
1. The first step in planting is to dig a hole for your plant. The hole should be both larger and wider than the plant you are putting in the ground. You can dig a shallow hole for prickly pad and other cacti, just deep enough to cover one quarter to one third



Cross section sketch of prickly pear planting.

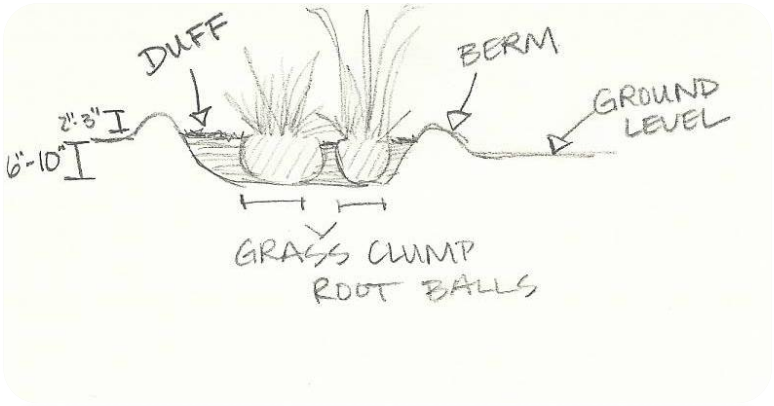
of the entire pad (see drawing above).

2. Add some water to the hole to moisten the sides. Let the water drain completely. This process will help new roots penetrate into the soil at the bottom of the hole as well as reduce transplant shock.
3. While the water is draining, loosen the root ball in its container or pot. This can be done by laying the pot on its side and gently tapping it, then pushing the root ball from the bottom until it slides freely in its pot. Leave the plant in its container. Try not to squeeze the pot to get the plant out, as this can damage the roots and can destroy the root ball. For plants that will be directly transplanted from another area, you will more than likely not have to loosen the root ball. You want to have an intact root ball on transplanted plants, so treat them gently.
4. After the water has drained from the hole, remove the plant from the container by pulling the container off the plant rather than pulling the plant out of the container.
5. Gently loosen the soil on the bottom and sides of the root ball. This encourages the roots to branch out. If the roots at the bottom are spiraled they need to be pulled apart or cut with a pair of hand pruners.
6. Place the plant in the hole so that the level of soil on the plant collar of the root ball is even with the ground. The root collar is the area of the plant where the stem meets the roots (see figure at right).
7. Add and gently tamp some rich, rock-free soil, filling the hole halfway.
8. Add enough water to moisten and settle backfill.



The root collar of a plant.

9. Finish backfilling, alternating soil and water until the entire rootball is covered to the root collar.
10. Continue planting all the plants you have designated for this "berm community" in this way.
11. After you have finished all the plants in the grouping, build a berm of soil, not rocks or mulch, approximately 6 to 8 inches high, at least 1 foot beyond the edge of your planting group. Make sure that the berm wall will hold water (see figure below).
12. Mulch the basin with a healthy layer of native mulch or duff or chip mulch, as prescribed in your planting plan. Make sure to leave some space (an inch or two) between the stem of the plant and the mulch or duff. The space helps to prevent infection from invading your plant by allowing maximum oxygen exchange in the plant tissues.
13. Water thoroughly by filling the entire berm. Patch any leaks you find. After the water has soaked in, fill the berm once more.



Cross section sketch of rootball and berm diagram.

RECORDING/MONITORING PLANTING SUCCESS

Be sure to record planting data for the work completed that day as soon as possible. Be as thorough and accurate as possible. The more time that goes by between planting and recording data, the more inaccurate it becomes. A sample planting data sheet can be found in Appendix II.

Next, monitor the site as often as is needed. This will likely be once a week to once a month during the first growing season and then to a lesser degree in following years. Look for plant mortality and success. Look for additional areas to plant or areas that were unsuccessful in prior salvage/planting attempts. Again, fill out the data sheets quickly and accurately in order to maintain quality site data for future reporting.

The technical definition of salvage is to save from imminent danger by removing and or relocating, in this case, plants. In developed areas, native plants are sometimes dug up from an area that will be impacted by construction and then held over in a type of temporary plant nursery. When construction is complete, the plants are planted in the impacted area to reestablish native plant communities, prevent invasion of exotic species, prevent erosion, and to prevent further human impact to the area in question. In the backcountry, the ultimate reason for salvage is the same: to reestablish native plant communities in impacted areas. The difference in backcountry salvage is that the plant sources are not in imminent danger from some identified pressure. Instead, workers are salvaging, or rather "borrowing" from healthy and established plant communities that can sustain limited losses with little impact.

When considering native plant salvage in the backcountry, you must first evaluate the need and feasibility of salvage at the site in question. A site should meet all of the following criteria before proceeding with salvage and subsequent planting.

- Several donor populations exist that are healthy and vigorous
- As a guideline, for every 1 plant you take, you should be able to leave 20 of the same species (INPS, 2007)
- The planting site has similar habitat qualities as the salvage site
- The species can be easily transplanted
- The donor population can be easily accessed by foot without additional disturbance
- Plants can be immediately planted in their new location
- The species does not require additional water to become established or there is access to slow drip deep irrigation and committed personnel to maintain the watering

If your site does not meet the above criteria, you should not be salvaging and planting live plant material. If however, your site does meet the criteria, you must identify the most appropriate species to plant as well as locate a population of plants that you can salvage and make those explicitly clear to your staff or group. Setting boundaries for salvage is critical to preventing any damage to the donor population. You should not eliminate a healthy population of plants in one area simply to move it to another area where the plants now are subject to stress, lack of water, or further human impacts. You also don't want to invest a large amount of time and energy to salvaging and subsequently planting plants that have little to no chance of survival in their new setting.

When you find an ideal population and have identified your future planting site, you are ready to start with the next steps.

Some shrubs, especially large individuals, may have large and deep taproots, which make them very difficult to salvage. Smaller specimens are the easiest and most successful transplants. In developed areas, large machinery can be useful in salvaging large individual shrubs and trees. Large plants tend to have higher mortality rates over time and are more expensive to salvage.

Salvaged bunch grasses waiting in buckets to be replanted.

In the backcountry environment, large tree salvage is not feasible, nor desirable. Trees require an extensive effort to dig out and care for properly, even with mechanized equipment. The resources needed to perform large tree salvage in backcountry settings are not accessible.

Grasses, forbs, and cacti can be salvaged year round as long as they receive sufficient water. They do especially well in the late fall and early winter when they have been receiving water from seasonal rains. Lower temperatures and higher precipitation will aid in keeping plant stress to a minimum.

Prickly pear species following collection, ready to be planted.

The ideal time for salvaging shrubs is during the fall and early winter. The days are shorter and cooler, so the plants aren't experiencing as much water stress during this time. Unless there is no other option, salvage should not be done during the summer months. If this is the only time possible, the critical element is going to be water. You must have a water source available, and have a commitment from the staff to water the plants for at least six months successively after initial planting. If you don't water, your plants will have little to no chance of success. See the watering section in this manual to determine appropriate watering regimes.

Grasses have fibrous root systems that are typically dense and near the surface of the soil. They do not reach down deep into the soil for water, relying instead on numerous small roots to gather water from the soil surface after rain or watering. It is best to dig several inches deep and all

around a clump of grass, then pop it out on your shovel. In most cases, you should get an intact "root ball" (see figure above) that comes out with the vegetative portion (the green parts) of the plant in one chunk. Again, it is ideal to get as much of the intact root structure as possible.

Forbs and shrubs can have either fibrous roots or tap roots. You should take the same care in removing forbs and shrubs from the soil as grasses. Dig several inches, maybe even feet, down into and all around the plant. Get as much of the roots as is possible, taking special precaution not to break the major roots. You may or may not get an intact root ball with forbs and shrubs. Tap roots and fibrous roots will not hold onto soil that is dry or loose. If you don't get a root ball with your plant, be sure to get some of the loose native soil into a bucket or pot with your plant when transporting it to your planting site. The native soil has microorganisms specially adapted to the environment and to the plants themselves that will increase survival ability.

Prickly-pear like cacti (Opuntia species) are a special type of plant when it comes to salvage. You can actually cut individual pads off of a larger plant and transplant them individually (see figure on page 12) Taking too many pads could drastically decrease the plant's ability to store adequate water and to photosynthesize. Use a pair of hand pruners to make a clean cut in the area where two pads join together. Take special care not to grab the spines of the pad while you move it to its new location. Kitchen tongs are an excellent tool for working with cacti species.

Planting prickly pear with kitchen tongs.

Once you have dug up your plant or obtained your cactus pad, you will need a place to store it and a way to transport it to your new planting site. You will need a bucket or a fabric pot filled partially with moist native soil from your freshly dug hole. You can place your plant in the bucket or pot with the native soil and carry it to your planting location. The moist soil will help to reduce stress on the plant while it is out of the ground.

After you remove your plant from the ground and move it to its new location, you need to repair the hole that your plant came from. Fill it in as much as possible and cover the fresh soil with duff and litter found nearby. The duff and litter will contain some native seed that may aid in natural regeneration. Try to camouflage the former hole by using materials that will blend into the surroundings.

Recording and Monitoring Salvage Success

As described previously, be sure to record planting data for the work completed that day as soon as possible. Be as thorough and accurate as possible. The more time that goes by between planting and recording data, the more inaccurate it becomes. You may want to differentiate plants in your data that have been salvaged versus those that have been direct planted from nursery stock. Survival rates may differ greatly between the two types of plants. A sample salvage data sheet can be found in Appendix III, with planting data sheets in Appendix II.

Next, monitor the site as often as is needed. This will likely be once a week to once a month during the first growing season and then to a lesser degree in following years. Look for plant mortality and success. Look for additional areas to plant or areas that were unsuccessful in prior salvage/planting attempts. Again, fill out the data sheets quickly and accurately in order to maintain quality site data for future reporting.

PLANT MATERIALS COLLECTION

As mentioned earlier, plant materials are not always available on site or will not transplant well during salvage operations. In those instances, plant materials need to be collected which can then later be propagated and grown into larger plants. Plant materials collection should always be directed by a technical expert in plant identification and seed collection so that the correct species, environmental conditions, and target species goals are met. Undirected collecting often leads to inviable seed lots, too much seed, incorrect identification, or donor population damage.

There are many individual species requirements that need extra consideration when planning a materials collection list. For example, certain species do not propagate well from cuttings, rather only from seed. Other species may divide well but not do well from cuttings. Other plants have seeds that are incredibly difficult to collect or even find. The Native Plant Network and Ladybird Johnson Wildflower Center are excellent sources for dryland plant propagation information. Dorn and Dorn's *Growing Native Plants of the Rocky Mountain* is also a very reliable source of information.

Small saltbush plants in the greenhouse, originally from cuttings.

There are also locally adapted species found in areas with extreme environmental and topographical differences in a small geographic location. Before setting out to collect materials, define geographic boundaries that are appropriate to your project. Doing so will allow you to conserve genetic integrity if desired, or to broaden your collection zones to include plant materials that is available in commercial nurseries in your area.

COLLECTING SEED

Once you have identified the species you would like to collect, gathering seed is a very easy process. Seed should be collected from the plant at maximum ripeness. When gently tugged , the seed should fall off the plant into your hand. You should never have to pull hard to get seed. If you have to struggle to get the seeds, it means it's not yet ripe. Collecting unripe seed can lead to rot when the seeds are in storage. In addition, if you spread unripe seed, you may have

absolutely no germination, thus wasting all the energy you put into the collection process as well as reducing the chances of success on your disturbed site. You may collect seed that has already dropped and is lying at the base of the parent plant, while still following the collection guidelines below.

Try to collect seed from at least 50 plants in a population. Collecting seeds from a large number of plants will help to ensure that you are getting wide genetic variation. Genetic variation will increase the chance of germination of your seed and the survival of your seedlings. No more than 20 to 30% of the seed in any given population should be taken. It is important to leave some seed on the plants for natural recruitment around the parent plants. Seeds should be collected and planted within 500 feet of their original elevation (Bainbridge, 2007).

If you are collecting your seed for storage and future use in restoration, the proper storage techniques must be used to ensure that seed is still viable when you want to use it. The two most important items to consider when storing your seed are seed moisture content and seed temperature. The optimum storage container would allow the seeds to dry out, but also keep them cool. Every 1% reduction in seed moisture doubles the life of the seed; each 10 degree drop in seed temperature also doubles the life of the seed. It is important to get the process of drying and cooling started as soon as possible following the initial collection.

You should store most types of seed in paper bags until you reach your storage location. Paper bags will allow the seeds to air dry more quickly than Ziploc bags or any other air-tight containers. It is very important to make sure, however, that the seeds are in an air and water tight container when in transit on rivers or during inclement weather. If water gets into the seed container, the seeds could germinate and die, or rot before the end of your trip. You should try to take the seed bags out of the air-tight container during the day and put them in a place where they can dry and not be blown away. When you reach your final location, be sure to attach and include any data sheets you have filled out to maintain good records of your plant materials.

Honey mesquite seedlings in the greenhouse, originally collected from seed.

There are several pieces of vital information that you should record on the seed container, as well as on a data sheet (see Appendix IV). On the seed container you should record the following information:

Species Code (first three letters of the Genus and first three letters of the Species)
Common Name
Date of Collection
Location of Collection, River Mile, GPS coordinates, or Other

Name of Collector(s)

A collection label may look like the following:

ATRCAN
Four-wing Saltbush
10/10/2014
South Canyon RM 31.5
Kassy Skeen

If you are using a paper bag to collect and store the seed, you can write all the information directly on the bag. If you are using a container that can't be written on, write all the information on a piece of paper and place the paper inside the container with the seed.

Seed Collection Tips and Tricks. Adapted by Kassy Skeen From "An Introduction to Using Native Plants in Restoration Projects," by Jeanette Dorner, 2002.

Tips for collection	Why is it important?
Do match the donor and restoration side 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 area geographically near to the planting site	Locally adapted plants are more likely to succeed at the planting site.
Don't collect in sensitive areas.	Protect sensitive areas.
Do make sure none of the seeds collected are from rare species - contact a State Botanist or other expert for more information about rare species in the area.	Protect rare species.
Don't collect from ornamental plantings or near other exotic species.	Genetic material from outside your site or political boundaries may not be suitable or legal.
Do avoid collecting in exotic plant infested areas. If collection must be done in those areas, be careful not to collect exotic seed.	Helps keep exotic seeds out of the seed mix.
Do obtain permission from the landowner to collect seed on private land or the required permits for public lands.	This is legally required. Contact the land management agency local office for permit information on public lands.
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 willow 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 changes 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 80% 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.	Helps maintain viability for a longer period of time.
Do store cleaned, dried seeds in a paper envelope or a sealed plastic container with desiccant in a refrigerator until needed.	Helps maintain viability for a longer period of time.

CUTTING COLLECTION

Cutting collection follows many of the same rules as seed collection. The difference is collecting live green plant material to be rooted instead of hard, dry seed. When cuttings eventually make it to a green house, they will usually be dipped in a rooting hormone and set up in a mist house in perlite filled trays to develop roots. Once they have rooted, they will be transplanted to soil filled containers. After they reach a reasonable size to be outplanted, they are transported back to the restoration site by whatever means are available. Cuttings provide a quick option for creating reasonably sized plants for outplanting. The entire process usually takes about one growing season, or 9 to 12 months.

Like seed collection, cutting collection is an easy process once you have identified your target collection list. Typically, you will take a cutting from the last 6 to 9 inches of a branch. You want to have this year's growth as well as some of the woody material from last year's growth. If you only take this year's growth, it will not have enough carbohydrate storage and energy to produce roots when placed in the perlite tray.

Again, as with seeds, you want to take cuttings from as many different plants of the same species as possible. You also don't want to take more than 20% of the donor plant in order to ensure its survival. Try to avoid sick or dying plants as material sources.

Cuttings are harder to transport in a backcountry situation than are seeds. They require moisture and cool temperatures to maintain viability. To increase chances of success, after you take cuttings, use a damp paper towel in the bottom of a Ziploc bag. The towel should be touching or wrapped around the base of the cuttings to keep them moist. After you've labeled your bag (using the same method as seed collection) and filled out your respective data sheet (similar to Appendix IV), place your cuttings in a cooler or cool spot in your backpack. Check the cuttings periodically for moisture and heat and add water as needed.

Once you have returned from the field, turn your plant materials over quickly to those in charge of propagating them. Often, you can make arrangements with local nurseries to contract grow materials for you. Federal agencies can also work with the Natural Resource Conservation Service (NRCS) to grow plant materials as well as increase seed lots.

SEEDING

In the right circumstances, direct hand seeding can be very beneficial to the restoration process. Seed is easier to collect than large plants, is easy to transport, and requires little care after it has been spread. Seeds that germinate can help to stabilize the soil and out-compete non-native species. However, desert adapted plants produce seed that often has very specific requirements, which sometimes can limit germination success. On very large projects where the disturbed area exceeds the cost effectiveness of seeding by hand, seeding specifications may be written into the contract for the contractor to perform. It is therefore important to make careful selections when it comes to determining if you should spread seed at your site and which species you should spread.

It is sometimes quite difficult to determine the appropriate seeding rate. The NRCS gives guidance to spread approximately 20 pounds of pure live seed (PLS) per acre on restoration sites. Experience at GRCA demonstrated that a rate ranging from 5 to 10 pounds PLS of a typical grass, forb, and shrub mix was more than adequate to meet the goals of most restoration sites. These sites ranged from freshly disturbed roadsides to backcountry areas disturbed by foot traffic. 20 pounds PLS may be also be cost prohibitive to many land managers. Local seed comes at a great price. Seed that has been hand collected in-house can be very expensive on large scales, but seed purchased from a large commercial company may lack the diversity and quality desired for the project. A blend of the two options may be right for many projects.

There is also considerable debate about the appropriate season to broadcast seed. To maximize germination and growth and minimize additional watering, seeding should be timed with seasonal precipitation. In the desert southwest, that typically means that seeding should be completed during the monsoonal season between July and September, or right before consistent winter precipitation occurs, ideally in late October or early November. Some seed will likely be lost to foraging insects, birds, and small mammals. However, native plants in this area are already timed to naturally release seeds at these times of year. These two precipitation seasons have the ideal conditions for both germination and growth of tender seedlings. Seeds broadcast at other times of year may require you to input consistent and reliable water across large areas for fast germination and growth.

Tractor mounted broadcast seeder.

BASICS OF SPREADING SEED

The appropriate time to spread seed in the restoration process depends on the other techniques that you are using on the site. As a general rule, you should spread the seed after all the major disturbance activities (such as trail building, planting, and salvaging, or road building) have been completed. If you are working down a slope or on an unstable sand bank, you should spread the seed as you move your work down the slope, so that you don't have to walk over your completed work.

The chances of germination will be greatly increased if there is an ideal seed bed. If the work area is compacted, you need to scarify the soil to a depth of at least three inches. Scarifying is accomplished by raking the bare soil surface by hand with a McCleod or similar implement. Large machinery like front-end loaders, graders or skid loaders can also do a great job of scarification if available with a skilled operator. Scarification is important because it loosens the compacted soil surface for an increased chance of root penetration and creates rough soil pockets where both seed and water can collect, thus increasing the chance of germination (see Soils section for more information).

After scarification, you can spread seed by hand or by machine. You should limit seed spreading to non-windy days, ideally in less than 8 mile per hour winds to maximize the number of seeds contacting the soil surface. At Grand Canyon National Park, seeding was most often done by dry broadcast method, versus wet broadcast. In dry broadcast, the seed mix (which can contain either cleaned or uncleaned seed) is mixed with a small amount of sand or kitty litter to provide some weight, and then distributed by hand or in a tractor mounted broadcast spreader.

Wet broadcast usually involves mixing seed in a large truck with water and a slurry of tackifier, fertilizer, and pulp mulch. Dry broadcast was used primarily to ensure that uncleaned seed was evenly mixed throughout the seed mix. The truck tanks with the slurry contain a large agitator which spins inside the tank. Uncleaned seed can clump and be unevenly spread across the landscape when sprayed out. In addition, the wet broadcast method does not allow you to follow seeding with a drag harrow or rake to improve soil contact. This method proved to be highly effective on multiple projects, especially where planting large plants was not feasible (see Appendix V for a case study including seeding). Dry broadcast seeding and scarification can be followed by a hydromulch slurry to take advantage of the mulch benefits across a large area that would be inefficient to mulch by hand.

Tractor mounted broadcast seeder, backing up to a drag harrow, which is lying behind it. The hydromulcher is directly behind the tractor, waiting to spread hydromulch after the tractor operator spreads seed and incorporates it by scarification.

For more information on soil preparation and erosion control techniques used in conjunction with seeding, see the Soils and Erosion Control sections.

With any seeding method, try to seed evenly across the work area, paying particular attention to those small collection pockets where seed and water will have a greater chance of interaction. After you've spread the seed in the desired area, cover it with a light layer of duff and litter or other mulch (see Mulching section below).

How to Monitor Seeded Areas

Make sure you maintain excellent records of seed mixes, application rates, and treatments for all seeded areas of your project. You will hopefully see recruitment of seedlings that can alter the appearance of survival rates in other planted areas.

Monitor the area as often as possible, or when the site has been prescribed for monitoring. Look for both seedling germination and seedling growth. Look for additional areas to seed or areas that were unsuccessful in prior seeding attempts. Again, fill out the appropriate data fields on your data sheets.

Irrigation or some type of supplemental watering system is usually a critical element in dryland restoration projects. Locating water supplies in developed and accessible areas can be a significant challenge. However, it is the backcountry and inaccessible locations that require managers to exercise incredible creativity in developing a reliable watering supply and regime. In either case, irrigation can be either permanent or temporary in nature. The water supplies vary widely, including pumped water from storage tanks, pumped water from rivers, domestic water supplies, reclaimed water supplies, and collected rain water. The delivery systems vary just as widely, from traditional permanent drip lines or sprinklers, to hand watering with hoses, to slow drip Netafim, to old fashioned bucket watering. This section will not include an exhaustive discussion of all of these methods, but will highlight some pros and cons of several systems.

GRCA has long used a simple watering regime in most vegetation types throughout the park. It has proven to be highly effective in establishing vegetation in a timely manner with low mortality rates. That regime is as follows:

- During 1st growing season – water 1 time per week, twice per week in areas with heavy grass plug plantings
- During 2nd growing season – water every other week
- During 3rd growing season – water 1 time per month
- During 4th growing season – no additional water
- Watering begins in May and ceases in November in most years.

Exceptions to this schedule include backcountry and riparian sites. These types of sites typically get watered twice a month for the first two growing seasons, and then follow the normal schedule. Monsoonal precipitation can alter the schedule, as supplemental water may not be needed. Likewise, projects located at higher elevations may only need supplemental moisture June through October, depending on a favorable snow pack and snow melt. Refer to Appendix V for further information on this watering regime in the case studies.

Permanent irrigation systems are a big investment of time and resources, and should only be taken on in areas that quite large and will always be surrounded by development and constant disturbance. GRCA maintains two very large permanent irrigation systems, one located around the South Rim Visitor Center, and the second located around the newest employee housing development. These two sites fit the criteria listed above. They are both fed with reclaimed waste water and are drained every fall to prevent freezing. While these systems both save time by not requiring staff to hand water large planting areas, they consume large amounts of time in the upkeep and operation of timers, poly lines, spray heads, and other aging equipment.

Ollas, or traditional clay pots used in slow, deep irrigation.

One of the permanent irrigation systems did inspire components of a portable system, designed for use along the Colorado River in the backcountry of the park. These systems

used Netafim, an inline emitter, pressure regulated slow drip irrigation hose. The hose was buried in mulch inside the berms of large tree and community plantings with the permanent system. The Netafim lines are offered in multiple flow rates with several options for distance between emitters so that you can alter the water distribution rate. The Netafim performed well buried in wood mulch in high elevation plantings and in sand in river level plantings. The lines were completely hidden in both set-ups and provided a slow, deep watering, penetrating below the root zones of the community plantings, encouraging downward root growth. While the permanent system was fed by a high pressure reclaimed water main line, the backcountry version was powered by a car battery operated pump from the river. The pump and battery could be transported in a 20 mm ammunition can on any raft and could be moved from site to site with ease. The rest of the system remained buried in the sand just a few inches, while providing the slow drip watering when a staff member stopped to water at the site. This portable system was completely temporary in nature and did not detract from the wilderness setting in any way.

Ollas being laid out prior to installation and planting.

GRCA has used several other temporary irrigation systems to fit the needs of a site. One technique is actually an ancient system, where you use "ollas" to provide a slow drip type of watering within a 24 hour period. The ollas were used in backcountry locations only. With this method, you bury unglazed clay pots in the sand, leaving the small opening at the top of the pot exposed to the air (see figure on previous page and figure to the left). You then plant your small shrubs and other plants around the pot, approximately 6 inches away from the edge. You fill the pot with river water and then place a small rock over the opening to prevent debris and or small animals from falling into the pots. Because the pots are porous, water slowly seeps out into the root zone over a day's time. You need to return to fill the pots approximately once per month, depending on the species, until the plants are established. Once the plants are established, you can remove the pots or let them break down in place. This method proved to be highly effective, though on a small scale. The feasibility of transporting clay pots into the backcountry limits which sites you can get to without breakage. Likewise, once installed, in becomes difficult to remove the pot without disturbing the root zones of the surrounding plants. The pots are effective in delivering water and aiding in excellent plant establishment. These work best in small planting areas with less than 200 plants or in areas that may be out of reach of a more conventional irrigation system.

In developed areas, a 500 gallon portable water tank with a small gas powered Honda pump proved to be a reliable method of watering as well. This system could be taken to any planting area that was within 100 feet of a road. Three hose lines could be attached to each pump and run simultaneously. The hoses lines were manned by one or two staff, who could place a hose with a water breaker and wand on each end into a berm in a community planting and move throughout the planting area until all berms had been filled. They would then move through the entire planting site a second time, filling each berm again. While the berms were filling, staff would be

removing invasive species, fixing exclosures, and performing general site maintenance. This method is highly effective and consistently produces excellent results. It does however, have a large time input for staff and requires that they be able to operate a truck with a trailer in tight places to be able to reach many planting sites. This method also requires that there is a water source with which to fill the tank. These tanks were filled with reclaimed wastewater in most cases, which could be done by attaching to a hydrant source for the reclaimed water system. The tanks could also be filled with fresh water from a hydrant, but then also required the use of a backflow preventer to maintain the integrity of the water supply by preventing contamination.

GRCA staff was also able to make use of fresh water fire hydrants by using fire hose reduced down to garden hose size and distributed to community plantings by water breaker and wand, sprinkler, or drip hoses. This system has enough pressure to run multiple lines in large areas. It was however, quite cumbersome to move the heavy hoses and many lines required for this system. More often than not, when this system was in place, a hose lay was left on site in place throughout the growing season to improve efficiency in the amount of time staff needed to complete watering at the site.

Irrigation can take many forms. Many of these systems can be used together to help solve complex watering challenges. Regardless of circumstance, water is usually the main limiting factor in establishing native vegetation on a disturbed site (Allen, 1995).

MULCHING

Plant debris can be used for a variety of purposes within a restoration project. It can be used to aid in the biological process of establishing live plants, but it can also be used in a social engineering aspect to more quickly naturalize the appearance of a site. Reducing the appearance of disturbance in a site often prevents more human impacts to a site such as the elimination or rerouting of a trail. In this section, mulch, litter, and duff are all discussed as agents of restoration in both the biological and social aspects.

MULCH, LITTER, AND DUFF

If used effectively, mulch, litter, and duff can serve many functions in all restoration settings. All are easy to collect, install, and maintain. But what are mulch, litter, and duff technically speaking? Mulch can be considered any plant material that is used in any form as a protective barrier; preventing soil moisture loss, soil erosion, freezing injury, and exotic plant invasion. Mulch can include both live and dead branches, chipped wood, and last season's dry annual grass. Litter is typically defined as leaf drop from last season's growth. It is usually plentiful underneath deciduous trees, but can also be found in large quantities in the form of needle cast from conifer forests. Duff can be considered the decaying and decomposing organic matter above mineral soil. Duff is usually found under shrubs, trees, and grassy areas and often contains native seeds which have fallen from the plants above. Mulch, litter, and duff are highly effective at disguising scarred landscapes, especially social trails and excess campsites. When used in conjunction with other restoration methods, such as trail delineation, rock burying, and

seeding, mulch and duff can be very effective at preventing social trail development and increased erosion (see figures on the following page).

Installing effective mulch and spreading effective duff and litter are sometimes delicate processes. In order to be effective, you need to use plant materials that appropriate to the environment in which you are working. For example, you should not install arrow weed stems in a mesquite – acacia dominated sand dune. Similarly, you should not use Ponderosa Pine forest duff in a Great Basin Desert Scrub location. Installing mulch that doesn't look like it belongs will not be effective at preventing people from reopening a social trail. Vertical mulch, described more fully below, can also be easily knocked over by wind or pulled out by people looking for fire wood if it isn't buried to an appropriate depth. If you are installing vertical or horizontal mulch or spreading duff, be very deliberate and careful in your installation methods, as outlined below.

VERTICAL MULCH COLLECTION

Vertical mulch should be installed in areas where it visually and physically makes sense. Make sure you are familiar with the type of plants already living in the area you want to disguise. Scout outside the camp area and in nearby drainages for quality dead plant material such as logs and branches. If performing other vegetation maintenance in the area, you can use the debris from pruning projects at your site. If there are few dead plant resources available, you can take cuttings from resilient plants such as arrow weed or willow. Taking cuttings simply means using a pruning shears or hand saw and proper pruning methods, as described in Appendix VI. You can cut several stems from the backs or non-visible sides of the plants, making sure that the cuts are not visible from trails or camps. Keep in mind that some areas may require you to use nonnative species branches, such as tamarisk. Invasive, nonnative species can be used to your benefit in the short term, while working on eliminating or reducing other pressures at your site. Using tamarisk branches would fit, as long as you are placing them in tamarisk dominated areas. You may also cut mesquite or acacia branches on a limited basis if you follow proper pruning guidelines, collect from outside high visitor use areas, make non-visible cuts, and limit the quantity of material collected. Always take care not to over-harvest materials and to leave as few impacts as possible when walking throughout the area to collect. Persons working on the project should be careful not to make more social trails and impacts to the site by trying to fix problems.

Installing vertical mulch to resemble native arrowweed.

Little Nankoweap Camp restoration, along the Colorado River. These images are from a small portion of the site, illustrating the appropriate use of mulch, litter, and duff.

Area to be restored, pre-work, November 2008.

Area immediately after restoration, post-work, November 2008.

Monitoring update, February 2009. Note red brome aiding in early stages of restoration.

Improvised lattice work at the top of a hole, made from local materials to stabilize vertical mulch.

VERTICAL MULCH INSTALLATION

Vertical mulch should be installed as securely as possible. Simply poking stems into the sand is not enough to ensure effective function of the mulch. Ideally, you should dig a hole 6 to 12 inches deep. At the bottom of the hole, you can use rocks or other branches to prop up the stems or branches that you intend to make vertical. While arranging the stems, pay particular attention to how the plant would look naturally it if were standing alive or if it were dead. Try to mimic live plant forms as closely as possible. Keep in mind that large weathered logs laying on the surface of the soil or sand can also serve as vertical mulch as long as it blends into the rest of the area.

DUFF AND LITTER COLLECTION

Duff and litter collection and installation follow the same general guidelines as vertical mulching. In fact, it is often times easiest to collect vertical mulching materials and litter and duff materials from the same places. Using duff and vertical mulch together is also necessary to achieve a natural looking site. You should try to match the duff you are collecting to the area you are trying to disguise, as well as to minimize the impact you create by collecting.

Duff and litter will include many types of materials including soil, needles, seed and leaves. You can find duff under the canopies of trees and shrub, as well as around perennial grasses and forbs. Never take more than 25% of the duff material found under a plant, and never scrape down to bare soil. It's important to leave some material where it naturally falls to support seed germination and soil stabilization. Try to collect duff from under native vegetation, in particular mesquite, acacia, cottonwood, willow, or other shrubs and trees. These species shed excellent leaf litter that will turn into duff containing quality nutrients and seed sources. If native vegetation type duff is not available, it is sometimes beneficial to collect from under tamarisk trees. However be careful to minimize or eliminate the possibility of spreading any exotic seed. Check the area thoroughly before collecting from a tree canopy. As illustrated in the figures on page 25, sometimes an invasive species such as red brome, which has colonized the restoration site, serves

Litter and duff collected from under native shrubs and trees.

as a temporary beneficial. In this case, the brome, which was naturally contained in the duff and litter applied to the site, deterred human foot traffic in concert with the dense cactus plantings immediately adjacent to the trail. This site was also seeded with native grass seeds that germinated and established later in the season. The brome provided a long enough window of "greenery" and cover to relieve the site of foot traffic and allow the sites further from the trail to recover with less restoration intervention.

DUFF APPLICATION

Duff should be spread as the last touch up to your site. You do not want to walk on your restoration area after you spread the duff to minimize any disturbance it will receive. You want to spread enough duff and litter to make your restoration site blend into the surrounding undisturbed area (see figures below). You also want to spread enough so that it won't all blow away in one wind event. To help prevent duff and litter from washing or blowing away, it helps to have a rough or uneven soil surface. Creating small furrows or even rake marks will help keep a large portion of the duff and litter in place.

Social trailing at Hance Camp, along the Colorado River in March 2007, prior to work.

Social trail obliteration, post work, March 2007. Note that the trail obliterated here was done primarily with duff and litter that completely blends into the surroundings.

CHIP MULCH

As previously mentioned, chip mulch can be used like duff and litter to provide both biological benefits and social benefits to a restoration site. Mulch is highly effective in increasing water retention, significantly reducing invasive plants, and naturalizing the aesthetics of a newly planted area. At GRCA, contractors and park staff were usually required to chip or shred any woody plant debris that they produced from the clearing and grubbing phase of a project. That mulch was then prioritized for all restoration projects within the park. The vast majority of the chipped or shredded mulch was used in developed areas on the north and south rims.

Staff spreading chip/shred mulch at a construction site.

Typically, chip/shred mulch should be spread to a depth of three inches. If the project area had an unusually high presence of invasive species prior to disturbance, or a species that is particularly difficult to control, mulch should be spread six inches deep. One mulch application usually lasted three years before it need to be replaced. A project was usually covered with mulch twice in the 4 year watering and maintenance cycle of a planting. That length of time was adequate for achieving the goals of most projects.

There is a difference in performance between chipped and shredded mulch. The product you receive is entirely dependent on the equipment available to the crews working the plant debris and also what you request in the contracting process. Shredded mulch tends to make a better interwoven matrix on top of the soil, while chips tend to wash or blow away more easily. Shredded mulch usually has larger pieces and can be slightly harder to spread. Both are effective, though shredded mulch seemingly performs better in longevity.

Chip/shred mulch pile staged at a construction site until it was used around the site following project completion.

HYDROMULCH

It is tremendously important to prepare a good seedbed prior to seeding, as it is equally important to protect seeds once they have been spread. On large construction projects where contractors are expected to seed, they will most likely be expected to cover the dry applied seed with hydromulch. Mulch protects seed from animals, conserves soil moisture, and prevents wind and water erosion.

Hydromulch slurry being applied by truck mounted high velocity spray gun.

Hydromulch should be applied by the contractor within 24 hours of seed broadcast in designated project areas. Using this type of mulch is a more viable option than using chipped mulch spread by hand in large areas. In Arizona, most hydromulch applications follow the Arizona Department of Transportation (ADOT) specifications. Other states may have similar specifications. You can request alternative formulations. As previously mentioned, most contractors like to apply fertilizer, tackifier, mulch, and seed in one dose. As the manager, you can ask them to remove components or add as you see fit. If clearly defined in the request for proposals, contractors should always be able to meet these needs. The following list contains specifications for the hydromulch applications used at GRCA (Skeen, 2013).

- Hydromulch and tackifier should be applied at a rate of 2000 pounds per acre upon completion of seeding operations.
- Hydromulch components:
    - Mulch will consist of 100% Aspen wood fibers
    - Moisture 10% +- 3% PH 5.4 +- 0.1
    - Organic matter (oven dried basis) 99.3% +- 0.2
    - Inorganic Ash (oven dried basis) .7% +- 0.2
    - Water Holding 1,402%
    - A minimum of 50% of the fibers will be equal to or greater than 0.15 inch
    - 75% or more will be retained on a 28 mesh screen.
- Tackifier components: Shall meet the requirements of ADOT 213.02.

Refer to the fertilizer section for a discussion on the necessity of fertilizer applications in dryland soils.

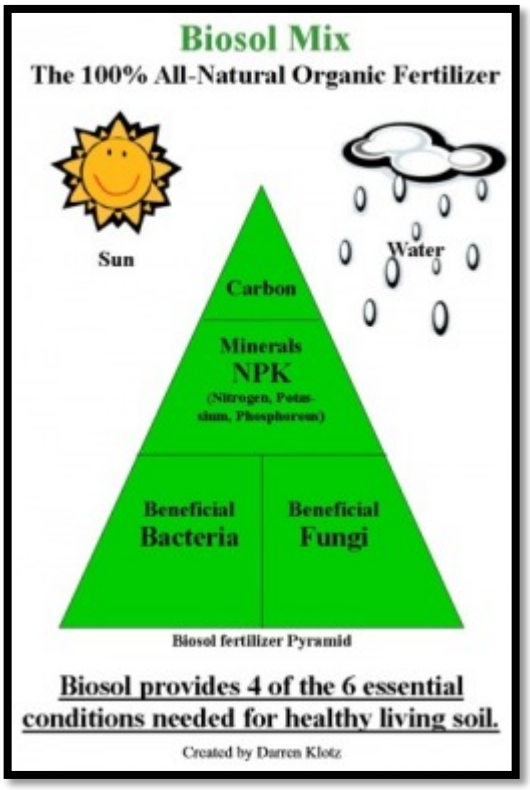
FERTILIZING

Topsoil in the drylands of the US, like Grand Canyon National Park, is typically nutrient poor. Native plants in this environment are adapted to nutrient poor conditions. Adding fertilizer to the soil is usually not necessary and can sometimes lead to the establishment of invasive species, which take advantage of higher nutrient concentrations, especially nitrogen (Dorner, 2002). Fertilizer should only be applied when soil conditions are extremely poor. This may occur when a manufactured topsoil is brought in from outside the local area. It should be applied with native seed, and should be a slow release fertilizer in concentrations no higher than 6-1-2 (N-P-K, or nitrogen, phosphorus, potassium).

The following are specifications for a fertilizer that can be applied with hydromulch (Skeen, 2013).

- Fertilizer: BioSol 6-1-2 or an approved equal.
    - BioSol is a sterilized, weed-free, slow release fertilizer composed of approximately 96% fungal biomass. The nutrient ratio of the fertilizer shall be as follows:

Nitrogen	6%
Phosphorus	1%
Potassium	2%
Nutrient ration:	N-P-K- 6-1-2
Organic Substance	70%
Carbon/Nitrogen ratio	6:1
Nitrogen (total):	>6%
Nitrogen (water soluble)	<0.5%
Phosphorus (P2O5):	1 to 2%
Potash (K2O):	3 to 4%
PH level:	5-6



BioSol is a fungal based fertilizer. It has a strong smell immediately after application, which fades within a few months. If any substitutes are suggested by a contractor for BioSol, be sure they submit specification sheets and provide time for the project manager to to review the alternative product before approval.

SOILS

In general, topsoil in dryland environments is a very precious commodity. A few inches of topsoil or less may be all that is available at the site. Topsoil generation is a slow process in low

moisture environments. Preserving, promoting, and or recovering soil functions in a dryland restoration project are therefore worth a considerable investment of resources.

"A practical definition for topsoil is the top six to ten inches of soil or the depth to which the soil is plowed or cultivated. Topsoil usually differs from the underlying soil by having higher organic matter content, a darker color, better tilth, and higher biological activity in the form of earthworms, bacteria, and fungi. The topsoil is usually less compact than the underlying subsoil and is usually better for the growth of plants." (Rutgers; State University of New Jersey. Cooperative Extension. New Jersey Agricultural Experiment Station)

Topsoil is often not available from any local or regional borrow pit locations. Thus, any topsoil within project boundaries should be conserved. Conservation is best done by scraping the soil into windrows prior to any other disturbance activities that may happen at the site in the early stages of the project. Usually, that can be accomplished at the edge of construction limits, or in a project staging area. Windrows must be no higher than 3 feet. There are no length requirements. The windrows are necessary to preserve the life that exists within the soil, i.e microbes, insects, seed, etc. When put in large piles, heat builds up in the center of the pile and can actually cook the pile, destroying the life inside, sterilizing the soil. Without healthy, living topsoil, disturbed lands cannot establish new native vegetation and will become not only eyesores, but will be left exposed to erosion, invasive species establishment, and continued disturbance by humans activities.

Above the topsoil lie the "litter and duff" layers. The "litter" layer is composed of plant material that has recently fallen from the plants above, which then starts to decompose as it weathers from year to year, turning into the "duff" layer. These layers are important, just as the topsoil is, because they contain not only the organic matter that enriches the topsoil below it, but also contains native seed that will aid in the reestablishment of native vegetation after construction is completed. This layer should also be preserved to the greatest extent possible by raking it aside into piles prior to scraping the topsoil into windrows.

The timing and methods to replace the topsoil to disturbed areas will be particular to each project. There are several guidelines that can be written into contract specification that can generally be applied to most dryland projects. They are as follows (Skeen, 2013):

- Rocks and woody debris larger than 6 inches in diameter should be removed prior to spreading.
- Large rocks from the site can be used to create variation in topography and soil texture, but should only be placed by hand once soil placement is finished.
- Topsoil should never be placed when it is frozen, wet, or in a muddy condition. It should always be placed dry.
- Once topsoil is placed and scarified, it should not be driven over by construction equipment. Only place topsoil when construction is near completion. Driving over topsoil with equipment, especially when wet, will cause severe compaction.
- Topsoil should only be placed when reseeding and or mulching is scheduled to be completed within 10 days. This timing is vital to prevent excessive topsoil erosion while the soil is exposed as well as preventing the opportunity for invasive species establishment.

- Topsoil placement depth depends on project requirements as well as the availability of topsoil at the site. Topsoil should be replaced on high priority areas to be planted or seeded first.
- Clods, and lumps, larger than 6 inches in diameter should be broken up during placement with a harrow, disk or other appropriate equipment.
- Soil should be placed by hand on slopes too steep to safely drive equipment.
- On slopes greater than 3:1, additional soil conservation measures are usually required. See the erosion control section of this document for specifications on erosion control devices.
- In general, soil along roadsides should be placed and then scarified to a depth of 3 inches. In areas that are to be planted, soil should be placed and then scarified to a depth of 10 inches.

If topsoil does not exist at your site, evaluate the benefits and drawbacks of importing it from an outside source. High quality topsoil can be expensive and may have to be transported over a long distance to your site. Be sure to inspect the source and surrounding areas several times prior to importation. It is important to identify unwanted invasive species populations and recommend treatment options to the manager or locate a new source. Have the soil analyzed for nutrient content as well as for loam, sand, and clay components. Universities or State Extension Services usually offer soil testing for a nominal fee. Some sites may not require the addition of topsoil. At GRCA, a 0.75 acre site was restored by planting directly in a local limestone sub-base, which formerly had been a parking-lot for over 70 years. With the addition of duff and litter, supplemental watering, and healthy native plants grown in the local greenhouse, the site overcame deficiencies in initial soil conditions without the addition of an imported topsoil (see Appendix V for more information in Case Studies).

Topsoil replaced that was too wet. Note the large clods before spreading in the left photo and the compacted soil in the right photo. These soils had a tremendous amount of winter snows on top of them while piled in windrows and were not properly dried prior to placement. These soils had to be mechanically re-scarified before seed and mulch could be laid down.

CLEARING AND GRUBBING

In some projects, particularly those that involve some aspect of construction or large earth moving, vegetation may initially have to be cleared or grubbed out (stumps) to set the stage for restoration or to complete the earth moving portion of the project. Whether the plant material is pruned, removed by backhoe, or by blade, it can all be reused creatively. This phase of pre-construction has lasting impacts in how restoration is carried out after major construction has ceased. The following guidelines can be written into contract specifications to help preserve resources (Skeen, 2013).

Topsoil that was properly dried and applied at the appropriate depth. This soil is well scarified and ready for seed and mulch treatment.

- A project manager should meet with contractors or crews on site prior to clearing and grubbing phases to agree on appropriate clearing limits and modifications to those limits. Clearing limits are almost negotiable in some way, sometimes only by a few feet, but sometimes by yards. Getting involved in the early stages may save a large tree that would later be irreplaceable in the restoration phase.
- Contractors should provide temporary barriers (e.g. orange construction fence) to protect sensitive plant species and other existing plant material and critical root zones that are designated to remain but are within the clearing limits. Barriers should be in place before any construction equipment is allowed on site.
- The manager should coordinate with the contractor or crews to allow a window of time for crews to salvage viable plant material after the clearing limits have been identified
- The manager should provide pruning guidelines to the contractor or crews to ensure that any large woody plant material that is pruned for the project will be done properly to prevent infection, root compaction, and subsequent tree death. Basic pruning guidelines can be found in Appendix VI.
- Crews should not use paint on pruned branches or injuries. This is an outdated practice that is not required.
- Crews should not grub (or dig below soil surface) inside the drip line of trees that are to remain. If portions of woody plants within this area extend into construction limits, these should be pruned back to the edge of construction limits.
- Managers should consider any disposable plant materials for other uses. Large straight logs, such as those from junipers are ideal for trail building. All other plant material at the very least can be chipped or shredded and stored in large mulch piles to be used later after seeding and or planting. Stumps can be ground with a tub grinder and added to the chip/shred pile.

Erosion control will likely be needed in any dryland restoration project. There are several small scale techniques that can be used with minimal costs and can be completd with hand labor. On large projects with earth moving and large construction footprints, more aggressive methods requiring the use of heavy equipment will likely be needed. Usually, small slope and trail erosion can be controlled by simply limiting access points and eliminating or rerouting human foot traffic from sensitive areas. When this occurs, vertical mulch, trail delineation, and other techniques discussed earlier in this handbook can stop or slow erosion. On sites with more severe problems, vertical mulching alone will not work. In those places, other techniques such as erosion control fabrics (coconut or jute fibers), check dams, re-contouring slopes with the aid of structures, or sand ladders are necessary. In all cases, on slopes that are 3:1 and greater, vegetation is very difficult to establish. Direct seeding is usually ineffective without supplemental techniques to reduce erosion. These slopes are subject to both wind and water erosion and need stabilization in order to get successful seed germination and subsequent establishment.

RECONTOURING SLOPES

Some highly eroded sites need to be recontoured in order to slow erosion(see figure below). For example, unwanted social trails can severely cut down into sand banks in riparian areas. The trail tread needs to be destroyed in order to eliminate both the visual and physical draw that people have to the established trail. The tread can be raked out or backfilled with sand. When backfilling with sand, it is easiest to find a local source. In many cases with large river systems, sand can be hauled from river level. Hauling from river level ensures that the sand can be replenished by fluctuating water flows. Taking sand from up higher on beaches or slopes can cause additional erosion, expose cultural features, or disturb more vegetation and soil crusts.

Note the deep trail tread and sand bank erosion from this social trail. This site was backfilled with sand from river level to restore the natural grade. The trail was then obliterated with vertical mulch and duff.

When recontouring is needed in a construction zone or over a large area, heavy equipment will be needed. Usually this work involves graders, front end loaders, or skid loaders, driven by skilled operators. The slope design should be done in consultation with an engineer, landscape architect, or other expert in construction management. The contouring work should be completed before laying down any topsoil. This will ensure that the topsoil won't become compacted while large equipment is traveling repeatedly across the slope. Likewise, because quantities of topsoil are bound to be limited, waiting until the subsoil has been contoured will help to conserve precious quantities where they are needed most. Once the contouring and topsoil placement have been completed, you may also choose to perform additional scarification or soil "dimpling" to create pockets for seeding and water collection.

Limits of Construction and Stormwater Protection Plans

Limits of construction are typically demarcated with erosion control fencing or silt fencing, which consists of black plastic and wooden stakes. All states should have an agency that regulates which materials are acceptable to use. Contractors and agencies must submit detailed plans outlining these materials before that agency will authorize a permit to begin construction or earth moving activities. In Arizona, the Department of Environmental Quality (ADEQ) stipulates that either silt fence or erosion control wattles can be used at the edge of construction. Orange construction fence can also be used to protect sensitive resources and mark limits of construction where appropriate. At GRCA, erosion control fencing was eliminated in favor of the erosion control wattles. The change was due to the installation process of erosion control fence, which leaves a large amount of exposed soil on the back side of the fence, outside the limits of construction. This exposed soil and fence is usually left for years following construction, leading to invasion of exotic species and trash build up. Using wattles eliminates these concerns.

Wattles are also typically used to protect storm sewers and downstream drainage areas. They are not a specialty item and are easy to obtain, with less manual labor to install. Look for detailed specifications on your state agency's website to determine which products are acceptable.

Wattles are typically filled with straw, coconut, or aspen fibers. At GRCA, aspen fiber or coconut fiber is required, while straw is prohibited. Straw wattles, despite being certified "weed seed free," do contain viable wheat seed, and can sprout in the right moisture conditions. Aspen and coconut fiber filled wattles do not have any seed component and can thus be used without the concern of introducing a nonnative or invasive species to a restoration project.

Aspen fiber typically decomposes faster that coconut and can remain on-site for several years without breaking down substantially. If the wattles will be removed after a few years, it is more economical to purchase aspen fiber wattles. If the wattle will remain on site for many years and needs to remain functional during that time, coconut fiber wattles will last longer and remain effective in preventing soil erosion by water.

Several manufacturers supply wattles both in coconut coir fiber and aspen fiber. American Excelsior, Western Excelsior, Rolanka, and several others can ship throughout the country.

The following guidelines can be included in contract specifications for both acquiring wattles as well as installing them. Most manufacturer's websites also offer instructions for installing wattles (Skeen, 2013).

- Excelsior fiber, wattles, logs or rolls should consist of curled aspen wood excelsior or coconut coir rolled into a cylindrical shape with a consistent width of fibers evenly distributed throughout the cylinder. The logs should be 12 inches in diameter. They should contain a minimum of 3 pounds of wood fiber per 9 inches encased in a seamless photodegradable or natural fiber tubular netting. All material in the log should be certified weed free. The contractor should also submit a sample prior to installation for approval.

Coconut fiber wattle, with soil apron to catch sediment during a high water flow event.

- Wattles (or sediment logs) should be placed in a shallow trench the depth of which will be no more than 1/3 the diameter of the log. They should be secured every 2 linear feet across the length of the log with a 1 inch diameter wooden stake or landscape pin driven into the ground 24 inches and should remain in place until after all construction is completed (and sometimes longer if required by the state agency issuing the construction permit).
- Wattles should be installed uniformly over sloped areas at approximately 10-15 foot intervals in a staggered overlapping pattern so that an unnatural pattern cannot be detected and the slopes are adequately protected from sheet and rill erosion. Manufacturer's instructions provide specific details on installation, depending on type of wattle used.

Detail of aspen (Curlex) fiber.

Aspen fiber (Curlex) erosion control wattles installed in a drainage.

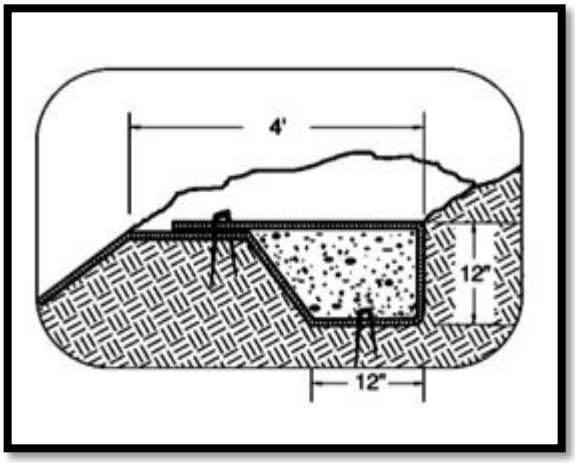
STEEP SLOPES

As previously mentioned, any area that will have a finished slope of 3:1 or greater requires additional protection in order to establish native vegetation. This can typically be accomplished through the installation of an erosion control blanket. These slopes can also be seeded and hydromulched (see Seeding and Mulching sections) prior to installing the blanket. Some locations with 3:1 slopes will be very small, or in an awkward location where a blanket will be difficult to install. Once installed, these blankets can remain on site indefinitely as they will begin to break down on their own as plants grow up through the blanket to stabilize the slope. Removing the blanket may disturb plants that have become established and is not recommended.

Erosion control fabrics are most useful on slopes that are very long (over 50 feet), are tall (over 6 feet), and do not currently have a significant amount of native vegetation already established on them. The fabric needs to be installed with an anchoring trench on both the top and bottom of the slope. Additionally, the fabric needs to be stapled or secured with wooden spikes or landscape staples. Rolls of fabric are very heavy and are very difficult to transport in remote backcountry locations. Though this method is effective, its use should be carefully considered due to the logistical challenges of installation and maintenance.

Coconut coir mat. This product has exceptional longevity and allows crews to seed and plant either before or after installation.

Erosion control blankets can be made of a variety of materials and in a variety of weaves. At GRCA, blankets must be made of coconut coir fabric and contain no synthetic fibers like photodegradable plastic (see figures at right and on following page) Though many other fibers exist, they pale in comparison to the effectiveness of coconut fiber. Coconut fiber has consistently outperformed jute, photodegradable plastics, and aspen fiber blankets in vegetation establishment, longevity, appearance, and weed seed free status. In dryland environments, the photodegradable materials take many decades to break down, and often are still found in large chunks. The natural coconut fiber materials break down slowly, but becomes integrated into the litter and duff layer over time, by facilitating root establishment through their fiber matrices. These blankets are available from most of the same manufacturers as aspen and coconut wattles listed above. Other fibers and weaves can be slightly cheaper, but do have significant drawbacks. See Appendix V for a more thorough discussion in Case Studies.

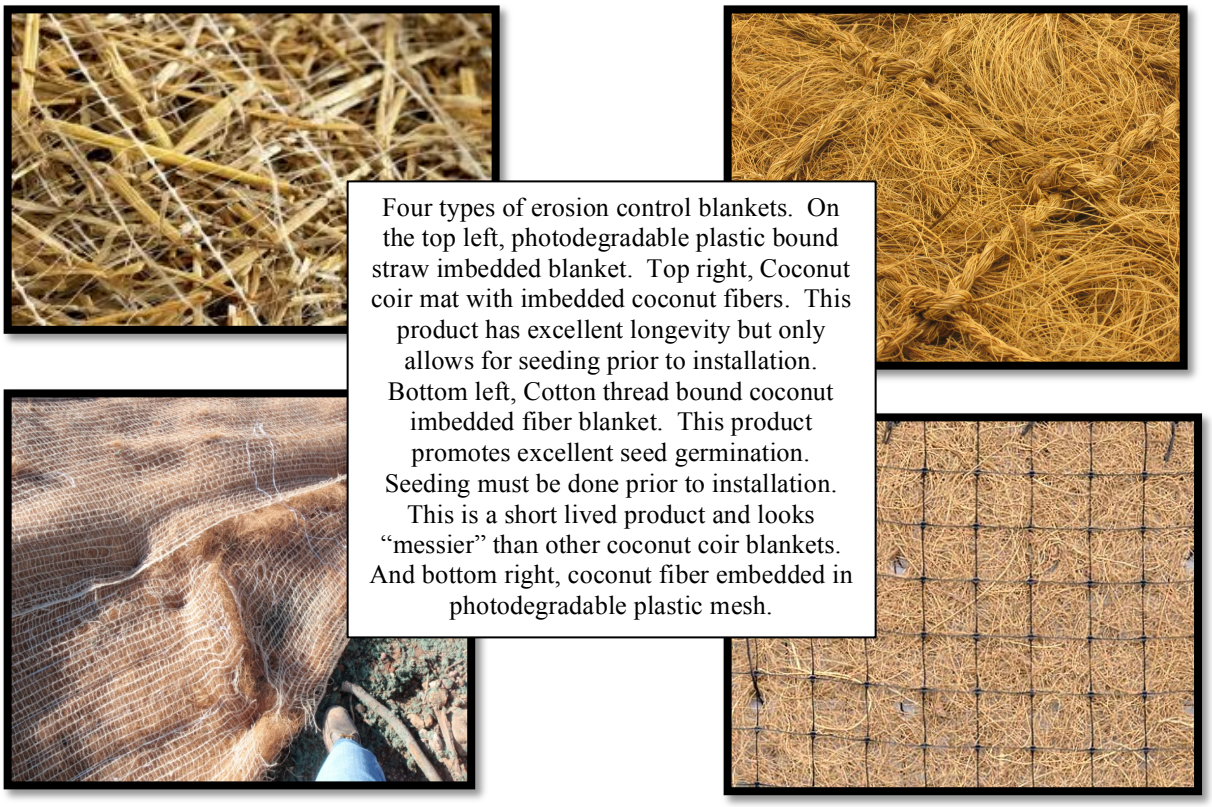


Installation diagram for top of slope anchors. Note that the blanket must be buried in the trench and completely recovered with soil in order to adequately secure the blanket.

To install, the blankets need to be secured with metal landscape staples or wooden stakes. Manufacturers usually include installation instructions on their websites with detailed diagrams. These instructions should be reviewed prior to installation as some modifications can be made and tailored to a specific site (i.e. installing the fabric vertically instead of horizontally, tucking in unfinished edges, etc.).

The following guidelines can be included in contract specifications for installing erosion control blankets (Skeen, 2013).

- Begin at the top of the slope and anchor blankets in a 12 inches deep and 12 inch wide initial anchor trench and anchor with staples at 18 inch spacing.
- The blanket should be unrolled down slope in the direction of the water flow. The blanket should not be stretched but should have full contact with the soil.
- Anchor blanket using staples or stakes. See "Staple Pattern Guide for Slopes" on the below.
- Overlap edges of adjacent parallel rolls by approximately 6 inches and anchor with staples at 24 inch to 36 inch spacing depending on the slope.
- When blankets have to be spliced, place upper blanket end over lower blanket end (shingle style) with 12 inch overlap and anchor with two staggered rows of staples at 12 inch spacing.
- Anchor, fill and compact ends of blankets in 12 inch deep and 6 inch wide terminal anchor trench. Anchor with staples at 18 inch spacing.



Four types of erosion control blankets. On the top left, photodegradable plastic bound straw imbedded blanket. Top right, Coconut coir mat with imbedded coconut fibers. This product has excellent longevity but only allows for seeding prior to installation. Bottom left, Cotton thread bound coconut imbedded fiber blanket. This product promotes excellent seed germination. Seeding must be done prior to installation. This is a short lived product and looks "messier" than other coconut coir blankets. And bottom right, coconut fiber embedded in photodegradable plastic mesh.

A 3:1 slope with seed and hydromulch treatment only, three years after seeding treatment. Note the very sparse vegetation establishment on a slope of this grade.

A 3:1 and greater slope immediately after being covered with coconut coir erosion control blankets. This slope was also seeded and hydromulched with the same seed mix, on the same day as the slope in the photo above.

The same 3:1 and greater slope three years after seed, hydromulch, and blanket treatments. Note the healthy and robust establishment of native vegetation that ultimately stabilized the slope.

SPECIAL BACKCOUNTRY TECHNIQUES

In backcountry settings, erosion control has to be more discreet in appearance and must be feasible to install with the minimum of equipment and labor. Most natural erosional events in a backcountry or wilderness should not or cannot be repaired. They are part of the dynamic nature of a minimally managed system. Those events that are primarily human caused, that are significantly impacting the use of a site, or are creating new use patterns that negatively affect the site should be evaluated for repair.

Erosion control projects in the backcountry can involve built structures that become disguised and used as the stable foundation for planting and seeding. These structures do require time, expertise, and supervision to complete. Trail crews and specialists are excellent additions to restoration project planning staff because of their extensive knowledge of human use patterns, wilderness building techniques, and ability to build using natural materials. They are usually masters of diverting water in dry environments to prevent major erosion in areas that will need to stand up to long-term human use.

CULTURAL RESOURCE CONCERNS

Archaeological related erosion control requires special care. Most cases of erosional events that require control will result directly from an excavation or data recovery, but will also include gullying that exposes undisturbed features in drainages and washes. In all instances, the erosion control methods should be prescribed in conjunction with an archaeologist. While most of the following techniques can be used in culturally sensitive areas in conjunction with seeding and planting, they may need to be modified to maintain the integrity of the cultural site. The utmost delicacy is required to prevent any damage. Culturally relevant concerns should be addressed in the very early planning stages of a restoration project.

SAND LADDERS

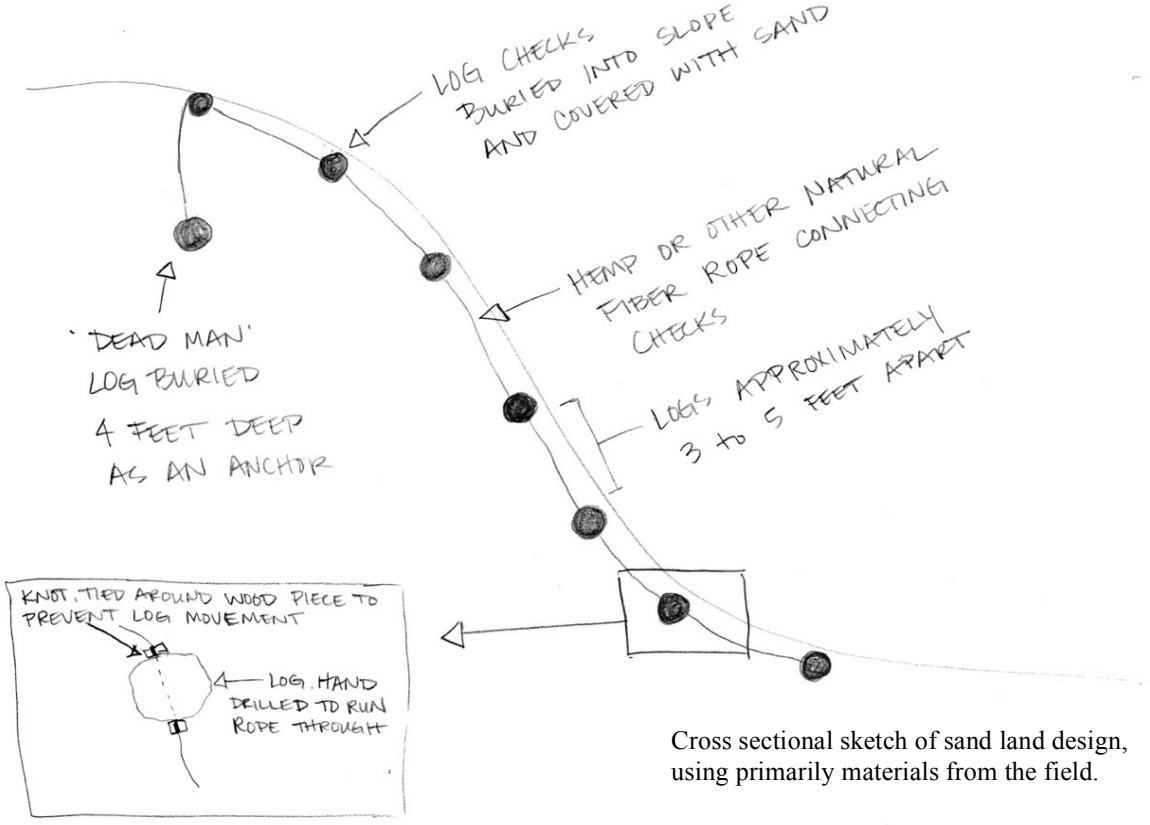
Backfilling with sand in sand ladder construction. Owl Eyes, February 2009.

A sand ladder is an erosion control technique typically used during trail construction in sandy dune type environments. It can also be used for trail obliteration when used with planting, vertical mulching, and the application of duff and litter. On steep sand banks, built trails quickly erode, leading to social trail development. In order to stabilize the site, you must be able to create a trail structure that is anchored into the slope. Sand ladders allow you build an anchor into the top of the sandy slope and provide intermittent wooden steps or checks attached to the anchor with natural rope down the length of the slope (see figure at right and on pages 41 and 42). Sand ladders require a significant amount of construction time, but are very effective at stabilization. You must plan ahead to bring hemp rope or other natural fiber rope, cottonwood drift logs, and have the capacity to haul a significant portion of sand. If the

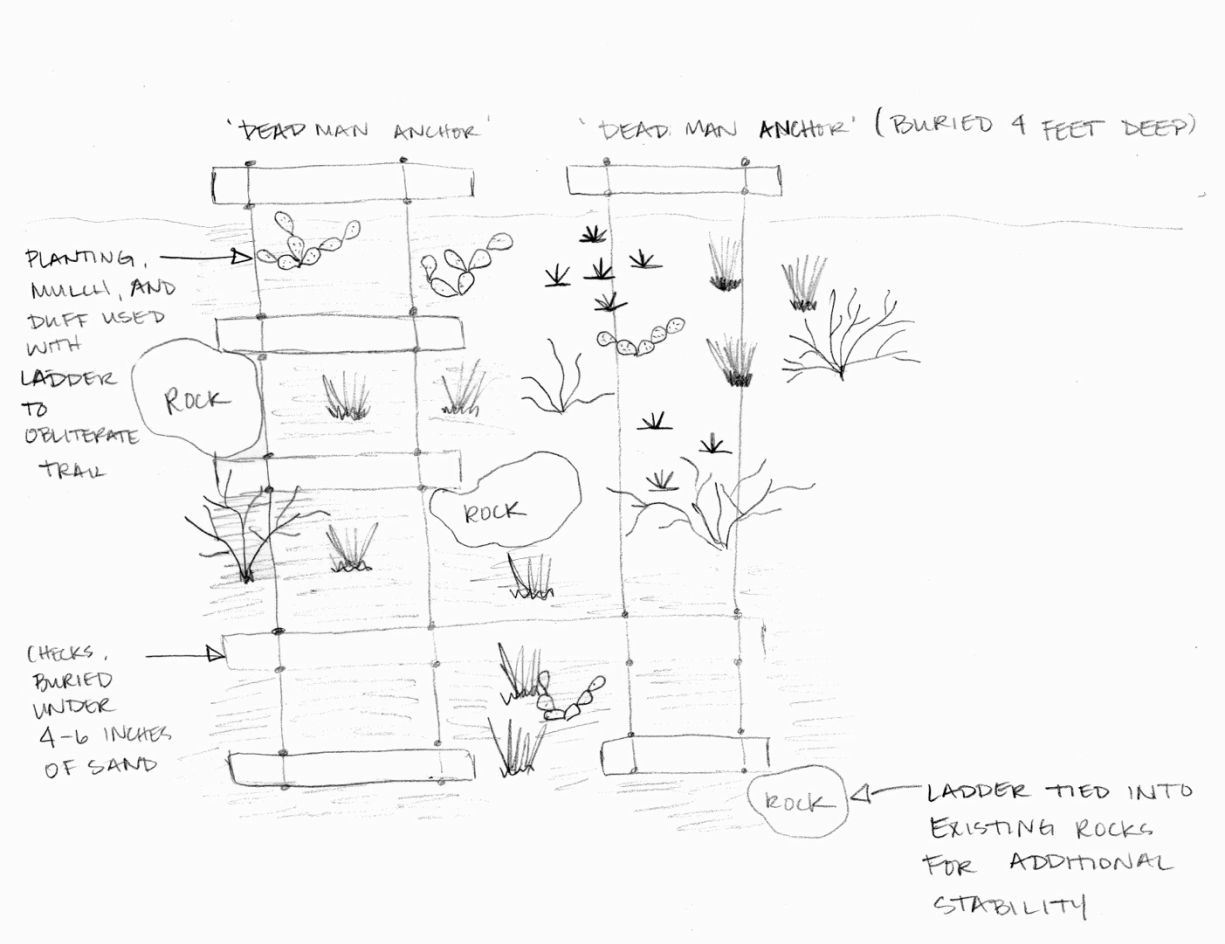
sand ladder is going to be left in place in a remote backcountry location, it should be made of natural materials so that it can degrade over time.

The following is an account of sand ladder construction completed in 2008 at a beach along the Colorado River in Grand Canyon National Park. This ladder was installed on a very steep slope that was being deeply cut by excess social trailing. The ladder stabilized the cut, while vegetation planted in between the log steps aided in total slope recovery and stabilization.

> *"Two three-strand ladders were built of hemp rope and drift logs. The upper-most ladder was anchored into the top of the slope with two "dead man" logs buried several feet into the slope underneath a social trail that was obliterated. Hemp rope and logs were attached moving down slope and anchored into the slope with wooden stakes and pins. The total length of the uppermost ladder was eight meters, and contained 15 log steps. The lower ladder was anchored into the top of the slope with a "dead man" log buried several feet into the slope underneath a social trail that was then obliterated. The hemp ropes running to the lower ladder were buried with little disturbance and covered with vegetation. Hemp rope and logs were attached moving down slope and anchored into the slope with wooden stakes and pins. The total length of the lower ladder was 16 meters, and contained 20 log steps."*



Cross sectional sketch of sand land design, using primarily materials from the field.



Sketch of sand ladder arrangement with plants, mulch, and duff, as a obliteration technique.

CHECK DAMS

Check dams are useful in working dryland environments, especially areas that are prone to seasonal flash flooding. In small washes or gullies, live or dead plant stems can be woven into a horizontal dam and secured with wooden stakes across the width of the wash or gully. Riparian species, such as willows or arrow weed, are flexible enough to create such a structure. The check dam will slow erosion and encourage silt and sand deposition as water flows through and over the dam (see figure at right. Slowly, the dam is built up to the height of the eroded walls. This method is effective, but not permanent. Check dams need to be maintained in order to retain effectiveness. In Alaska, check dams are sometime made entirely with willows and alders

Zuni check dam installed at Soap Creek Camp., along the Colorado River.

that will root easily with consistent moisture. These dams in effect become permanent by aiding in the establishment of live vegetation that will also control erosion. Though not likely to work in ephemeral washes and gullies in a dryland setting, slight modifications could be made that include planting perennial grasses or adding seed to the construction materials. Areas with perennial water sources may be able to make use of this method with the right conditions.

Major natural erosion event with gully formation at Nankoweap Camp, along the Colorado River. No action was taken to mitigate the effects of this erosion event.

BIOLOGICAL SOIL CRUST COMMUNITIES

One of the most important aspects of controlling erosion is maintaining healthy biological soil crusts. Understanding what soil crusts are and why they are important is vital to developing effective restoration plans for any site in the park.

In most arid lands throughout the world, where vegetation cover is sparse, the soil surface is generally covered by a community of highly specialized organisms that form Biological Soil Crusts (BSCs). BSCs consist of algae, cyanobacteria, bacteria, lichens, mosses, liverworts, and fungi. "Crusts help to maintain soil stability, prevent erosion, contribute nutrients for plant growth, fix atmospheric nitrogen into a usable form, retain water in the soil for plants, provide a comfortable bed for seedling germination" (Huisinga et al, 2006). Crusts also help to prevent exotic and invasive species from germinating.

Mature soil crusts on the Colorado Plateau.

BSCs are incredibly fragile. They are concentrated in the top one to four centimeters of soil. Because of the nature of their composition and their location at the very top of the soil surface, BSCs are not resistant to disturbance by foot or other traffic. Full recovery of crust from disturbance is a slow process, particularly for mosses and lichens. Allowing the cyanobacteria and green algae component to recover by excluding disturbance gives the appearance of a healthy soil crust. This visual recovery can be attained in as little as 1 to 5 years, given average climate conditions. However, recovery of the nitrogen fixation capability of soil requires at least 50 years, while recovery of moss and lichen diversity and function from compaction and decreased soil stability is estimated to take several hundred years (Belnap 1993).

People are often harder to control than any other variable affecting resource management. People tend to wander where they want to go, even in the presence of barriers such as fences. People have a greater affinity for open vegetation, as it is easier to walk through; however, these same open sites are generally dependent on soil crusts for stability.

Concentration of recreational use to minimize impacted areas is exceptionally important (see figure at right). Likewise, other management and mitigation activities will become increasingly more important over time. These include but are not limited to designating campsite use, excluding grazers in some areas, delineating defined trails, and educating people to camp on hardened surfaces, such as rocks, and how to hike in areas that lack designated trails, such as in washes, on rock, and fallen logs.

Trailing through BSC communities.

CONCLUSION

This manual has outlined many of the strategies and

techniques used in dryland restoration. As more projects move forward and the natural functioning and appearance of wildlands becomes of high value to the public, these methods should adapt and be refined by the next generation of restoration practitioners.

APPENDICES

Appendix I: Native Plants for Remote Dryland and Riparian Restoration
Appendix II: Planting Site Data Sheet Example
Appendix III: Salvage Data Sheet Example
Appendix IV: Seed Collection Data Sheet Example
Appendix V: Case Study Examples
Appendix VI: Pruning Methodology

** All data sheet examples are adapted from Grand Canyon National Park's Vegetation Program. The key to habitat type, soil types, landform, and rock types is attached to the end of the seeding data sheet, but can be used with all data sheets. These data sheets were made specifically to tie into a custom made database for the GRCA Vegetation Program.

Appendix I. This table highlights species that can be used in a backcountry setting and recommended watering regimes. These plants can also be used in more accesible settings. However, watering regimes should likely be increased as access is easier and resource inputs are not as expensive.

Common Name	**Scientific Name**	**Watering Needs for Establishment and Fast Growth**				**Type of Planting**
		Summer Frequency	Winter Frequency	Type	Duration	Salvage Whole, Split, or From Nursery
Grasses		May - Sept	Oct - Apr			
Indian Ricegrass	*Achnatherum hymenoides*	Monthly	Every other month	Berm	1 season	Salvage/Split
Three Awn	*Aristida species*	Monthly	Every other month	Berm	1 season	Salvage/Split
Side Oats Gramma	*Bouteloua curtipendula*	Monthly	Every other month	Berm	1 season	Salvage/Split
Blue Gramma	*Bouteloua gracilis*	Monthly	Every other month	Berm	1 season	Salvage/Split
Sand Dropseed	*Sporobolus species*	Monthly	Every other month	Berm	1 season	Salvage/Split
Forbs						
Sand Verbena	*Abronia elliptica*	Bi-monthly	Monthly	Slow Drip	2 seasons	From Nursery
Louisiana wormwood	*Artemesia ludovisciana*	Bi-monthly	Monthly	Slow Drip	2 seasons	From Nursery
Twining Snapdragon	*Maurandella antirrhiniflora*	Bi-monthly	Monthly	Slow Drip	2 seasons	From Nursery
Desert Four O'Clock	*Mirabilis multiflora*	Bi-monthly	Monthly	Slow Drip	2 seasons	From Nursery
Evening primrose	*Oenothera species*	Bi-monthly	Monthly	Slow Drip	2 seasons	From Nursery
Twining Milkweed	*Sarcostemma cynanchoides*	Bi-monthly	Monthly	Slow Drip	2 seasons	From Nursery
Globemallow	*Sphaeralcea species*	Bi-monthly	Monthly	Slow Drip	2 seasons	From Nursery
Cacti						
Beavertail	*Opuntia basilaris*	Monthly	Every other month	Berm	1 season	Salvage
Prickly Pear	*Opuntia engelmannii*	Monthly	Every other month	Berm	1 season	Salvage
Grizzly Bear	*Opuntia polycantha*	Monthly	Every other month	Berm	1 season	Salvage
Shrubs						
Acacia	*Acacia greggii*	Bi-monthly	Monthly	Slow Drip	2 seasons	From Nursery
Bigleaf Sage	*Artemesia tridentata*	Bi-monthly	Monthly	Slow Drip	2 seasons	From Nursery
Saltbush	*Atriplex canescens*	Bi-monthly	Monthly	Slow Drip	2 seasons	From Nursery
Emory's Seep Willow	*Baccharis emoryi*	Bi-monthly	Monthly	Slow Drip	2 seasons	From Nursery
Seep Willow	*Baccharis salicifolia*	Bi-monthly	Monthly	Slow Drip	2 seasons	From Nursery
Desert Broom	*Baccharis sarothroides*	Bi-monthly	Monthly	Slow Drip	2 seasons	From Nursery

Common Name	Scientific Name	Watering Needs for Establishment and Fast Growth				Type of Planting
		Summer Frequency	Winter Frequency	Type	Duration	Salvage Whole, Split, or From Nursery
Brickellia	*Brickellia species*	Bi-monthly	Monthly	Slow Drip	2 seasons	From Nursery
Mormon tea	*Ephedra species*	Bi-monthly	Monthly	Slow Drip	2 seasons	From Nursery
Rabbitbrush	*Ericameria nauseosa*	Bi-monthly	Monthly	Slow Drip	2 seasons	From Nursery
Apache Plume	*Fallugia paradoxa*	Bi-monthly	Monthly	Slow Drip	2 seasons	From Nursery
Snakeweed	*Guterrezia sarothrae*	Bi-monthly	Monthly	Slow Drip	2 seasons	From Nursery
Wolfberry	*Lycium species*	Bi-monthly	Monthly	Slow Drip	2 seasons	From Nursery
Arrowweed	*Pluchea sericea*	Bi-monthly	Monthly	Slow Drip	2 seasons	From Nursery
Mesquite	*Prosopis glandulosa*	Bi-monthly	Monthly	Slow Drip	2 seasons	From Nursery
Skunkbush	*Rhus trilobata*	Bi-monthly	Monthly	Slow Drip	2 seasons	From Nursery
Coyote Willow	*Salix exigua*	Bi-monthly	Monthly	Slow Drip	2 seasons	From Nursery

APPENDIX II. Planting Site Data Sheet Example

Restoration Planting/Seeding Data Sheet

Initials_____ Date_____ **Field Checked**
Initials_____ Date_____ **Data Entered**
Initials_____ Date_____ **Verified**

Date of Planting/Seeding: _____ **Observer (s)**: _____ **Planting group(s)**: _____
Location / Canyon Name (circle one): _____
River Mile: _____ **River Side**: _____ **Revisit?** Y N
Planting Site Name: _____
Planting Subsite Name: _____

Site Specific Planting Data (specific to the exact planting site, not the greater polygon):
UTM Easting: __ __ __ __ __ __ **UTM Northing**: __ __ __ __ __ __ __ **GPS Accuracy** (m): _____ **Elevation** (m): _____
(For UTM Easting and Northing, refer to approved site list. All area measurement and UTMs can be found there.)
Slope (degrees): _____ **Aspect** (0-360): _____ **Light Exposure**: open partial-shade full-shade
Surface water within 25m? Y N ***If yes, circle one***: seep spring stream pothole river
Habitat type: _____ **Surface rocks**: (limestone usually) _____
Soil Type: sand loamy sand sandy loam silt loam loam sandy clay loam silty clay loam clay loam sandy clay clay silty clay construction fill n/a
Soil Moisture: dry moist saturated standing water **Landform**: _____ **Topographic Position**: _____
Dominant Species: _____
Associated Species: _____
_____
Site Notes/Comments: _____
_____
_____

(See back of page for Species Specific Planting/Seeding Information.)

Site Specific Work Accomplished:
Reason for Planting (e.g., construction, excavation (cultural resource), campsite mitigation, social trail mitigation, post invasive species removal): _____
Scarification Completed?: Yes No **Depth** (cm): _____ **Area** (m^2) _____
Soil Added?: Yes No **Soil Type**: Fill Potting **Depth** (cm) _____ **Area** (m^2) _____
Mulch Added?: Yes No **Mulch Type**: Chips Duff **Depth** (cm) _____ **Area** (m^2) _____
Rock Lining Added? Yes No **Length:** (m) _____ **Height:** (cm) _____
Fencing/Caging Installed?: Yes No **Exclusion Type**: Fencing Caging **Date to Consider Removal**: _____
# of Cages _____ **Length of Fence Installed:** _____ **Caging Notes:** _____
_____
Water Type: Fresh Non-Potable **Water Method:** Buffy Automated Irrigation Hydrant Spigot Quick Coupler Bucket Other
Date to Cease Watering: _____ **Watering Notes:** _____
(This should be 3 years after the planting date, if different please include notes.)

Site Monitoring Schedule:
(For site monitoring schedule dates, they should begin one year following restoration, and each visit should be 6 months apart.)

Year	Visit	Month/Year
One	1	
	2	
Two	3	
	4	
Three	5	
	6	

Site Totals:
Number of People: _____
Number of Days: _____
Number of Hours per Day: _____
Total Number of Hours: _____
(These hours include the work reported on this form. If exotics removal is part of the restoration, please record them on the volunteer tracking form and in the notes below.)

Total Area Worked on This Visit (m^2): _____
Additional Notes: _____

Restoration Planting/Seeding Data Sheet (continued)

Restoration Area Planted? Y ☐ N ☐ **Restoration Area Seeded? Y ☐ N ☐**

Plant or Seed (P or S)	Species Code	Seed or Plant ID #	Origin of Plant or Seed	# Planted or Weight of Seed Spread (g)	Area Seeded (m^2)	Pot Size	Seed Clean? (Y or N)
			Total Seed Spread:				
			Total Plants Planted:				

APPENDIX III. Salvage Data Sheet Example

Salvage Data Sheet

Initials_____ Date_____ **Field Checked**
Initials_____ Date_____ **Data Entered**
Initials_____ Date_____ **Verified**

Note: When salvaging into flats, record the number of plants you put in a flat, not the number of total flats. On average, a flat should contain 6 individual plants. When you salvage and directly plant at a site without first taking the plant to the nursery, you must still generate a Salvage ID # for that plant to be entered into a database.

Date of Salvage: _____ **Observer (s):** _____ **Salvage group(s):** _____
Location/Canyon Name _____
River Mile: _____ **River Side:** _____ **Revisit?** Y N
Site Name: _____
Reason for Salvage: _____
Dominant Species: _____
Associated Species: _____
Site Notes/Comments: _____

Species Code	# in Flats	1 gallon	4" x 14"	6" x 16"	5 gallon tall	5 gallon	15 gallon		TOTAL	Salvage ID # (S070713_SRV_AGAUTA)
AGAUTA										
ARTTRI										
ASTCAL										
BOUGRA										
CHAMIL										
ESCVIV										
GUTMIC										
JUNOST										
OPU sp.										
PENLIN										
PENPAC										
PINEDU										
PINPON										
POAFEN										
PURMEX										
YUCBAC										

Salvage Data Sheet (continued)

Species Code	Flats	1 gallon	4" x 14"	6" x 16"	5 gallon tall	5 gallon	15 gallon		TOTAL	Salvage ID # (S070708_SRV_AGAUTA)

Grand Total:

Site Totals:

Number of People: _____
Number of Days: _____
Number of Hours per Day: _____
Total Number of Hours: _____

APPENDIX IV. Seed Collection Data Sheet Example

Initials_____Date_____**Field Checked**
Initials_____Date_____**Data Entered**
Initials_____Date_____**Verified**

Seed Collection Data Sheet

Date of Seed Collection: _____ **Observer (s):** _____ **Collecting group(s):** _____
Location/Canyon Name _____
River Mile: _____ **River Side:** _____ **Revisit?** Y N
Site Name: _____ **Location Description:** _____
_____
Reason for Collecting: _____
UTM Easting: _ _ _ _ _ _ **UTM Northing:** _ _ _ _ _ _ _ **GPS Accuracy** (m): _____ **Elevation** (m): _____
Slope (degrees): _____ **Aspect** (0-360): _____ **Light Exposure:** open partial-shade full-shade
Surface water within 25m? Y N ***If yes, circle one***: seep spring stream pothole river
Habitat type: _____ **Surface rocks:** (limestone usually) _____
Soil Type: sand loamy sand sandy loam silt loam loam sandy clay loam silty clay loam clay loam sandy clay clay silty clay construction fill
Soil Moisture: dry moist saturated standing water **Landform:** _____ **Topo. Position:** _____
Dominant Species: _____
Associated Species: _____
Site Notes/Comments: _____

Site Totals:
Number of People: _____ **Number of Hours per Day:** _____
Number of Days: _____ **Total Number of Hours:** _____

Species Code	Merged With ID Number? Y/N	Seed ID Number	Total Weight (g)	Clean? Y or N	Weight Shipped (g)	Shipped to NRCS - Enter Date	Shipped to Other- Enter Date

Note: Describe "Other" shipment details in Comments section. Total Weight=Weight collected that trip.
Note: If only Genus is known write first 5 letter of genus and then lower case spp (Ex. RIBESspp).

HABITAT TYPES: Adapted from Brown et al. (1998)

Habitat Type	Description
Subalpine conifer forest	Engelmann spruce-alpine fir, bristlecone pine-limber pine
Mixed conifer	Douglas and white fir, ponderosa pine, aspen
Ponderosa pine forest	ponderosa pine, Gambel oak, white fir
Great Basin montane scrub	oak-scrub, mountain mahogany, brittlebush, serviceberry
Great Basin conifer woodland	pinyon-juniper series
Great Basin desertscrub	sagebrush, blackbrush, rabbitbrush, winterfat, saltbrush
Mojave desertscrub	creosote, blackbrush, mesquite, saltbush
Alpine/subalpine grassland	bunchgrass (AZ fescue) and sedge-forb-grass association
Semi-desert grassland	grama grass-scrub (*Bouteloua/Pleuraphis*), mixed shrub
Interior wetlands	cattail, rushes, sedges, willows
Riparian	cottonwood-willow, mixed deciduous broadleaf
Developed Area	very clearly a developed area; not good rep. of above

Surface rocks:

Basalt Conglomerate Limestone
Mudstone Sandstone Shale
Granite Schist Gravel Cinders
Asphalt Concrete Other Man-made
Other _____

LANDFORM

Rockpile: uplands composed primarily of jointed and exfoliating granitic outcrops
Drainage channel: bottom not side slope of a drainage confined by banks or a canyon
Side Slope: side of drainage channel
Valley Bottom Fill: usually level places
Ridge: high ground between two opposing slopes
Slick rock: large exposed expanses of bedrock
Terrace: level or gently sloping shelf perched on a slope, often caused by down-cutting rivers
Mesa: level or gently sloping ground surrounded on 3 or more sides by steep down slopes and capped
Butte: similar to a mesa, except with a top that does not have a flat configuration
Cliff: very steep rock slopes
Talus: unsorted material resulting from mass wasting of steep mountain slopes
Sand Dune/Sand Sheet: large accumulations of sand, may be stable or unstable (moving)
Plateau: flat area of great extent and elevation; considerably elevated (>100 m) above adjacent lower-lying terrain (flat area above rim)
Outcropping: exposed bedrock or rock layer at the surface
Road Shoulder: gravel and cinder area sloping away from road surface
Graded Development: area around buildings that has been scraped and graded and landscaped
Paved Development: a clearly developed area, where the ground cover is man-made, e.g., parking lot, road, sidewalk, building perimeter, etc.

SOIL TAXONOMY:

1. Place soil in hand, remove pebbles, and add water very slowly, until it has the potential to have the consistency of putty. Add more soil or water as needed.
   a. If the soil does not remain in a ball, circle "**sand**"
2. If the soil remains in a ball, squeeze the ball between your thumb and forefinger, attempting to make a ribbon of uniform thickness and width pushing up and over your forefinger until it breaks from its own weight.
   a. If no ribbon is formed, record "**loamy sand**"
3. If ribbon forms but breaks before it is 2.5 cm, rub the soil between fingers.
   a. If very gritty, record "**sandy loam**"
   b. If very smooth, record "**silt loam**"
   c. If neither gritty or smooth, record "**loam**"
4. If ribbon breaks between 2.5 and 5 cm, rub the soil between fingers.
   a. If very gritty, record "**sandy clay loam**"
   b. If very smooth, record "**silty clay loam**"
   c. If neither gritty or smooth, record "**clay loam**"
5. If ribbon breaks when it is >5 cm, rub the soil between fingers.
   a. If very gritty, record "**sandy clay**"
   b. If very smooth, record "**clay**"
   c. If neither gritty or smooth, record "**silty clay**"

6.-construction fill is also a soil type.

TOPOGRAPHIC POSITION

APPEDNIX VI. Case Study Examples.

Hermit Road

The Hermit Road project was a major road re-construction project that was completed in 2008. The restoration of the roadsides, major pullouts, and new trails began in October 2008, and were mostly completed by June 2009. A Student Conservation Association (SCA) Corps Team with park staff and other volunteers planted over 16,000 plants at 17 sites along the 7 mile stretch of Hermit Road and the 3 mile stretch of the Greenway. A total of 10.75 acres (43,504 square meters) were planted and or seeded. In FY 2010, 22 additional plants were installed at Hermit's Rest to supplement the small planting already existing there. From March 2009 to November of 2011, staff and volunteers performed site maintenance on all 17 sites, including watering, mulching, removing invasive species, and caging to protect young plants from browsing.

Major restoration operations on the Hermit Road project were completed in 2011. Small supplemental plantings were completed in 2009 and 2010. In 2011, crews removed all protective caging and ceased supplemental watering. In 2012, maintenance was limited to regular invasive species treatment and mortality monitoring. Staff completed extensive monitoring for this project beginning in 2007, and because of the valuable data gained, should continue to monitor until approximately 2018.

Mortality monitoring completed by Vegetation staff in 2009 showed the overall mortality rate to be 3.9%. In 2010, over two growing seasons, the mortality was 7.22%. Monitoring completed in 2011 shows that over three growing seasons, the overall mortality rate is 11%. Vegetation staff continued to monitor in 2012, which was the first season the planting areas did not receive supplemental watering and were also entirely without protective caging. Overall, mortality percentages at different sites became more variable during 2012, ranging from 3.43% to 52%. The 52% site (Hopi Point) is an extreme outlier in the dataset. That site is the most highly visited of all the sites, with no guardrails, fencing, or caging in an area where visitors are frequently seen trampling vegetation to take photos of the canyon view. On average, including the Hopi Point, mortality across all sampled sites was at 17.55%. If Hopi Point is excluded, average mortality rate across sites was 12.01%. This rate was to be expected following 2011 data showing an 11% mortality rate. The Hopi Point site does demonstrate the very high mortality rates commonly associated with highly visited sites. Data from Hopi Point in 2009 shows a 2.56% mortality rate, 2010 data shows 10.3%, 2011 shows 12.8%, and data from 2012 shows 52.1%. The two significant changes between 2011 and 2012 were eliminating supplemental water and removing all protective boundaries around the plants. Other mortality can be accounted for in areas where caging was not installed over the winter due to shortages, where planting sites came very close to the road edge, or where small grass plugs were unearthed due to frost heave or animal browsing.

A summary of lessons learned over the course of the project are listed below:

- Seeding
    - Approximately 9 acres were seeded at 15 lbs. pure live seed (PLS) per acre with primarily *Bouteloua gracilis* and *Poa fendleriana*, with other shrubs, grasses, and forbs.
    - No supplemental water was given to seeded areas.
    - All seed that was spread was wild collected from the Hermit Road area and if grass, was increased by the US Department of Agriculture Plant Materials Center (USDA PMC in Los Lunas, NM).
    - Species composition for the seed mix was based on existing site composition, seed availability, and site conditions.
    - Seeding was done by dry broadcast method with a tractor-mounted auger. The seed was incorporated into the soil with a drag harrow, to approximately 3 inches, and then hydromulched with aspen fiber and tackifier.
    - **Results**: Seedling establishment was very successful. The seeding rate could have been lower. Preliminary seeding work at the Paiute Apartments project, 2 miles from the Hermit Road project, showed excellent establishment at 10 lbs. PLS per acre with a very similar seed mix.
- Salvage
    - Staff and volunteers salvaged approximately 4000 plants prior to construction in the fall of 2007.
    - Results: While salvaging is time consuming, salvaged plants were incredibly valuable as staff did not have seed sources for all species nor did they have the capability at that time of propagating cuttings for every desired species, thus making unlimited plant propagation impossible. Salvaging allowed the project to ultimately to have a greater variety of species.
- Planting
    - Staff and volunteers (about 90% of the labor) planted approximately 16,000 plants over a 3 month period from late September 2008 to December 2008.
    - The crews planted at about 4 plants per square meter. The formula was based on existing plant densities on Hermit Road and an 80% expected survival rate.
    - **Results:** Planting density could be lower. Mortality rates were much lower than expected (11.0% following 3 growing seasons). Though, that number could change significantly after maintenance activities have ceased for a number of years. 2011 was the last year of planned maintenance. Monitoring should continue for at least seven years to determine the 5 year and 10 year survival rates.
    - **Results:** Hermit Road was the first large planting project where "large basins and caging, or community planting" versus the traditional "single berm and caging" planting techniques were employed. This method worked in such a way that multiple plants (5 to 20) were planted together and surrounded with one basin about six to eight inches deep. That entire basin was then protected with one large cage. This method worked very well, and was potentially one of the factors leading to much lower mortality rates than was expected. The larger basins allowed for more thorough watering, increased protection from sun and wind, and increased ability to utilize rainwater. Due to the success of this style, this method

has been employed across the park at all of the large restoration projects with similar success.

- Soil conservation
    - The construction specifications were written so that all topsoil from the project had to be conserved onsite at the edge of construction boundaries. No new topsoil was brought in to plant the former Maricopa Point parking lot.
    - **Results:** Requiring topsoil conservation is also worth the effort. Hermit Road had very little invasive species management issues prior to construction. Native seedling recruitment of plants not in the seed mix was high. In addition, the number of invasive species and actual number of individual invasive plants was manageable by staff and volunteers and was kept low through routine maintenance.
    - **Results:** Crews planted at Maricopa Point in what appeared to be a local limestone sourced sub-base, once the asphalt had been removed. While the planting was difficult at best, the soil was in good enough condition to maintain native plants without supplemental fertilizer. The primary contractor superintendent suggested that based on the texture and appearance of the material, the sub-base (laid down in 1935) was likely from a local quarry, potentially the quarries located just off Hermit Road.
- Mulching
    - All trees that were removed from the project area were chipped and stockpiled for use in restoration areas.
    - All restoration sites, with the exception of Maricopa Point, received 3 to 6 inches of chip mulch, which covered all newly disturbed soil. The mulch was replenished after two years in most locations, since the chips settle or wash and blow away. Maricopa Point received three inches of native collected ponderosa pine duff and litter collected from other locations on Hermit Road
    - **Results:** The mulch (both chip and duff and litter) was highly effective in increasing water retention, significantly reducing invasive plants, and naturalizing the aesthetics of a newly planted area. The effort of collecting and spreading the mulch was vastly outweighed by the benefits of decreased water times, decreased invasive species establishment, reduced mortality, and increased aesthetic value.
- Erosion control devices
    - The specifications called for aspen or weed free straw erosion control wattles, black erosion control fence, and erosion control blankets on slopes greater than 3:1.
    - **Results:** Weed free straw wattles sprouted viable wheat during the summer months and began spreading. Construction crews were asked to remove and dispose of the wattles. As a result, construction specifications for all projects within the park now require aspen fiber wattles.
    - **Results:** The erosion control fence, while effective, has installation drawbacks. The soil that had to be disturbed to install the fence was all placed on the backside of the fence, outside construction limits, where it accumulated invasive species. This fence was not removed immediately after construction, so some populations of invasive species were able to gain a foothold. As a result, all new construction specifications in the park require that either aspen fiber wattles be installed to

control erosion or that all soil is placed on the interior of the fence, to be dealt with inside construction limits.
    - **Results:** On slopes greater than 3:1, staff and volunteers experimented with erosion control fabrics. Three large slopes were used as comparisons to one another; all slopes were approximately 3:1 over the entire course of the slope, all were within one mile of each other, and all were in similar environmental conditions in the same soil. One slope had seeding and hydromulch only; the second had seeding, hydromulch, and jute matting; and the third had seeding, hydromulch, and coconut coir matting. While the transect data is not yet analyzed, visually it is easy to see the far superior results using the seed/hydromulch/coconut fiber method.
- Invasive species management
    - As mentioned earlier, Hermit Road had very few invasive plant populations prior to construction.
    - **Results:** Despite exposure to massive disturbance between March and November of 2008, invasive species issues were very minimal. Russian thistle (*Salsola tragus*) is the largest management issue. The population is found in varying levels of density along the entire course of the road, but is managed annually by volunteer crews. In planting sites, few other invasive species germinated.
    - **Results:** Being diligent about removing Russian thistle while the infestation was very young was worth the effort. Populations have been kept small and manageable.
    - **Results:** Spreading native seed, using chip mulch, retaining native soils, using hydromulch, and using directed manual labor for manageable populations worked very well to prevent large scale invasion.
- Watering
    - The watering regime was instituted as follows:
        - 1st growing season – 1 time per week
        - 2nd growing season – Every other week
        - 3rd growing season – 1 time per month
        - 4th growing season – No additional water
        - Watering begins in May, ceases in November
        - All watering completed by hand with 500 gallon watering tanks with Honda pumps with reclaimed water from South Rim Wastewater Treatment Plant
    - **Results:** This watering regime, which has been standard in the Vegetation Program protocols for quite some time remained effective and appropriate. The only exception to this was at Powell Point on the slope planted with grass plugs. During the first growing season, this small site had to be watered twice per week. During the 2nd growing season, this site was returned to the normal regime.
- Monitoring
    - 19 transects were installed between August 2007 and November 2008 and have been read twice a year to date. These transects will evaluate the change in species composition, cover, and vertical structure over time, pre and post construction, compared to control transects installed in native forest along Hermit Road.

- In addition to transects, every planting site was 100% mapped by hand drawing. In the first year, every site was remapped to obtain a survival rate. In subsequent years, annual survival was calculated using representative samples of those plantings. 1st year survival was 96%, 1st and 2nd year survival was 93%, and 1st, 2nd, and 3rd year survival was 89%.
- **Results:** While the transect data are not yet analyzed, the usefulness is already quite apparent. Visually, differences are already easily noted. The photos at each transect have also been very useful for displaying changes over time.
- **Results:** Survival mapping and the high degree of monitoring are very useful – but also very time consuming. For future projects, less intensive monitoring can be done. This project did provide good data for implementing future projects and establishing protocols.

- Human element
  - One staff member, the Crew Coordinator, was designated as the main contact for this project. Eventually this person became the Restoration Biologist. This person attended weekly progress meetings and visited the site at least three times a week, sometimes more.
  - Results: Building strong relationships with contractors and construction staff early in the process was critical to success. It was sometimes very hard to convince contractors to implement something that isn't industry standard – or isn't something normally done by ADOT, or other major players. Keeping a constant presence during the construction or project process was absolutely necessary. Contractors and cooperators needed daily contact or at the minimum weekly contact to sort out questions, concerns, and project changes.

Powell Point, west exit, in October 2008 (upper) immediately following planting, and in October 2011 (lower). This slope was planted with three species of grass plugs approximately 12 to 18 inches apart and was not seeded.

Pima Point slope with coconut fiber coir mat in October 2008 (upper) and October 2011 (lower).

Paiute Apartments

The Paiute Apartments project was a residential housing project completed in the South Rim Village in 2011. The entire area was completely cleared of all vegetation, thus requiring complete restoration of soils and native vegetation. This site utilized erosion control blankets, dry broadcast seeding, hydromulching, large tree salvage and planting, nursery stock planting, and permanent irrigation installation across a continuous 3.5 acre area. The native vegetation restoration on this site contributed to the Platinum LEED certification of the entire building site, being the only multifamily certified LEED site in the entire state of Arizona and the first for the National Park Service at that time. All restoration work was completed between July and December of 2011 by staff and volunteers. Beginning in April of 2012, the maintenance phase of the project was initiated by the Vegetation staff. Maintenance consisted of removing invasive species, monitoring and repairing irrigation breaks, hand watering in a limited areas, and performing mortality monitoring. The site was maintained primarily by one staff member and many volunteers. Maintenance at this site will be limited in the future as no specific funding source supports this project. That maintenance will consist of changing irrigation programs, removing invasive species, monitoring large tree health, and removing caging as plants become established

Mortality monitoring completed by Vegetation staff in 2012 showed a mortality rate of 12.9% on average, over all sampled sites. Much of this mortality was due to very heavy elk predation, which was not preventable at the site due to the ability of the elk to get inside the larger cage sizes utilized at this project. This mortality rate was much below the 20% mortality rate that was planned for in initial target density calculations. In addition, the entire disturbed area (3.5 acres) was seeded with grasses, shrubs, and forbs in July of 2011. Planted areas also received the seeding treatment. An additional 1000 plants were documented as being from seed origin across the 11 areas that were censused for mortality. Per site, established plants increased between 4% and 250% from originally planted individuals, with most sites having an increase of between 4% and 60%, demonstrating that seeding was a highly effective treatment method. Areas inside basins did have the added benefit of supplemental water, which likely aided in seedling establishment. However, seed and seedlings were disturbed during planting as plants were put in the ground after seeding was completed. Seed was applied at a rate of 10 pounds pure live seed across the entire site.

Roaring Springs

Roaring Springs is located on the North Kaibab Trail in the main trail corridor of the inner canyon. It was formerly a residence for the water pump operator who maintained the water pipeline supplying fresh water to the North and South Rims. The residence and bunkhouse was renovated and converted to temporary staff quarters, as a permanent residence was no longer required due to automation. The site formerly had species that were not native to the park, many of which required permanent supplemental water sources. There were several large invasive trees at the site, in addition to a general degradation of the site as upkeep became less regular over time. The major phases of the Roaring Springs project were completed in September of 2011. The project was funded through a small grant obtained in 2010. In FY2012, Vegetation staff continued maintenance at the site by watering, removing invasive species, and replacing the very limited mortality that occurred at the site. The site was maintained mostly by the North Rim

Vegetation Crew, who hiked to the site during the summer months to maintain irrigation and monitor the site.

This site was unique in that it was only reachable by hiking from either the North or South Rims. All plants and materials had to be flown by helicopter to the site. Smaller plants were packaged in Action Packers, while several box elders were packaged with burlap and flown in an external sling load. Many large cacti were salvaged on site and planted without having to transport.

This site is also aided by the contributions of other divisions of the park, namely the Canyon District of Visitor and Resource Protection and the Trail Crew of the Maintenance Division. These staff members frequently spend time being stationed at Roaring Springs or work from the site as a base camp. They routinely helped with watering, which was the most time consuming part of the maintenance for this project. Running water is typically shut off at the site between mid-October and early May. During these months, the site needed limited water, which had to be obtained from the creek by hauling buckets up to the planting areas.

As part of the Roaring Springs project, staff experimented with replacing a portion of the non-native lawn with different densities of native blue gramma grass plugs, which were propagated in the South Rim nursery. The planting proved to be highly successful, demonstrating the possibility of replacing the entire non-native lawn with native grasses that will require significantly less supplemental water to become established. Once established, the native grasses will require little to no supplemental water and will self seed each year, if not mowed, to keep the lawn a usable and living component of the Roaring Springs landscape.

Photo 5. Experimental native lawn grass plot, immediately following planting in September 2011.

Photo 6. Experimental native lawn grass plot, following one year of maintenance, in September 2012. Note the density and natural seeding.

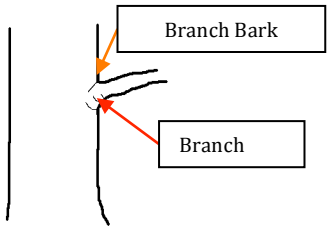
Photo 7. Main portion of Roaring Springs planting, immediately following planting in September 2011.

Photo 8. Main portion of Roaring Springs planting, following one year of maintenance, in September 2012.

APPENDIX VII. Pruning Methodology.

Cutting in the Proper Location

With proper pruning, you want to remove an unwanted branch at its attachment point to the trunk or another branch. Pruning cuts should be made close to, but beyond the branch bark ridge. It is critical that you cut just outside the branch bark ridge and branch collar area so that you will not damage trunk tissues. You should also be sure not to leave a branch stub on the tree. A good rule of thumb is that if you can hang a hat on it, you need to prune close to the trunk or branch. If this cut sounds like a fine line, it should, because it is. Flush cuts (unfortunately a favorite of many) may remove the branch bark ridge and collar and leave a wound larger in size. Together these two factors add up to a longer healing time and a greater exposed surface area that's susceptible to disease organisms.

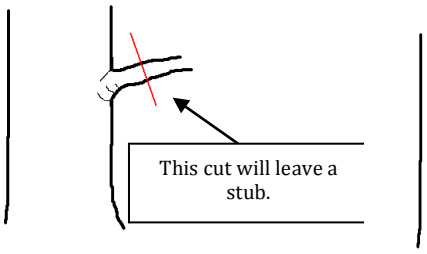


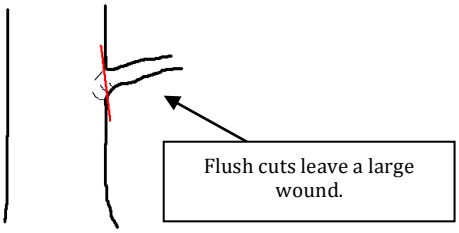
Branch Bark Ridge – area of a tree's crotch where the growth and development of the two adjoining limbs pushes the bark into a ridge.

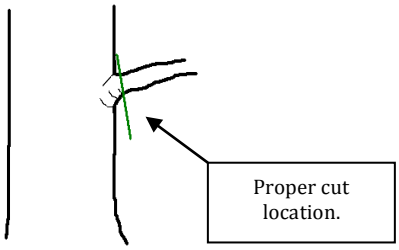
Branch collar – "shoulder" area where a branch joins another branch or trunk created by the overlapping xylem tissues.

The Importance of Cutting in the Proper Location

"The location of the pruning cut is probably the most important aspect of pruning. The location of the cut can influence subsequent growth and minimize the length of time required to callus." Dr. Alex Shigo







Do Not Leave Living Stubs

- Living stubs have no defense system
- Many organisms attack dying tissues and spread

Do Not Flush Cut Trees

- Flush cuts remove the branch collar and the wood where the branch protection zone forms
- Flush cuts expose the trunk wood to infections.
- Flush cuts make a larger wound.

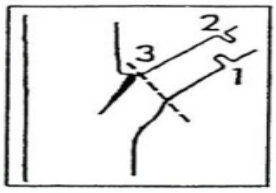
Make Proper Cuts

- The branch collar and branch bark ridge mark the boundary between the branch and the trunk.
- Make the cut where indicated.

Large or Heavy Limb Removal

Use Three Cuts:

- Saw into bottom of limb, one to two feet out on branch about halfway through (this eliminates the chance of peeling bark).
- Top cut branch further out (one to two inches) from undercut. This cut removes limb leaving a stub.
- Remove stub and make proper collar cut (see drawing).



Improper Pruning Causes:

- Insect problems.
- Cracks along trunk.
- Heat injury to trunk and branches.
- Canker or other fungus problems.

Proper Pruning Allows:

- A branch protection zone to develop
- Less chances for secondary damage to occur.
- The remainder of the tree to stay healthy.

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About the Author:

Kassy (Theobald) Skeen has spent all of her life involved with the land around her, beginning with her childhood on a farm. She moved west after earning her Bachelor's of Science degree in Natural Resource Management with a minor in Horticulture from the University of Minnesota. She has worked in and on the mountains, deserts, rivers, and plains of Idaho, Colorado, Wyoming, and Arizona, focusing on everything from fire management to invasive species to restoration to recreation. Much of the last 10 years she spent at Grand Canyon National Park, serving as the Restoration Biologist for the Vegetation Program. During that time, she worked in both the developed and backcountry areas of the park, designing and implementing restoration projects of all shapes and sizes with staff and a thriving volunteer program. Her and her family now live in Wyoming, where she manages the Williams Conservatory for the Botany Department at the University of Wyoming.

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