DOS AND DON'TS OF SUCCESSFUL REVEGETATION WITHPRE-PLANTED COIR BLANKETS[1]

Paul B. Hook,[2]and Jeffrey M. Klausmann[3]

Abstract. When installed correctly, pre-planted coconut fiber products can facilitate wetland and riparian revegetation and increase chances of success on challenging sites. Pre-planted coir blankets, for example, use efficient sod-style installation, provide some immediate erosion control, and contain relatively mature herbaceous wetland plants with well developed root systems and high shoot cover. This can greatly accelerate ecological and aesthetic results, reduce weed problems, and allow newly installed vegetation to tolerate less than ideal hydrologic conditions better than individual nursery-grown plants. Pre-planted products are not foolproof, however. Due to their obvious robustness, it is tempting to overestimate what they can tolerate and to neglect important details of planning and execution. As with other wetland and shoreline revegetation techniques, most problems result from failing to match plants with hydrology or failing to provide suitable water levels during initial establishment and for the long-term. Understanding site hydrology and species' environmental requirements is central. Grading design and construction, plant selection, soil specifications, and timing of installation must address hydroperiod carefully; inches or weeks can mean the difference between sufficient water, lethal drying, or excessive flooding, and these consequences depend on soil type and plant species. During installation surface irregularities must be limited to achieve good root-soil contact. If project delays push installation outside the target period for hydrology, supplemental irrigation may be required. Potential herbivory and trampling should be evaluated and barriers installed where needed. Adequate temporary anchoring is required and must match site hydraulic conditions; pre-planted coir is not an instant erosion control system and depends on rooting for effective stabilization. In our oral presentation, we will present case studies illustrating problems as well as successful, well executed projects.

Additional Key Words: sod, wetland, riparian, restoration, erosion control, streambank bioengineering, plant selection, hydrology, site preparation.

---

[1] Paper was presented at the 2006 Billings Land Reclamation Symposium, June 4-8, 2006, Billings MT and jointly published by BLRS and ASMR, R.I. Barnhisel (ed.) 3134 Montavesta Rd., Lexington, KY 40502.

[2] Paul B. Hook, Wetland and Watershed Scientist, and Jeffrey M. Klausmann, Principal, Intermountain Aquatics, Inc., Driggs, ID 83422. [3]Presenting author

Proceedings America Society of Mining and Reclamation, 2006 pp 375-397
DOI: 10.21000/JASMR06010375

http://dx.doi.org/10.21000/JASMR06010375

Introduction

Pre-planted coir blankets combine the characteristics of coconut-fiber erosion control mats and well-developed plants in one revegetation product. Together the fiber blanket and plants allow efficient sod-style installation and provide immediate erosion control and ecological and aesthetic benefits in wetland and streambank settings. With good project design and correct installation, pre-planted coir blankets can also increase the probability of success on challenging sites. This technique is not foolproof, however; success depends on thoughtful evaluation of site hydrology and plant ecology during project design, as well as attention to numerous details during project implementation.

This paper presents a brief introduction to pre-planted coir blankets and summarizes what we have learned about how to use them successfully. Since 1999 we have worked with this technique in various roles – as researchers comparing it to other revegetation methods (Klausmann and Hook, 2001), as restoration and revegetation practitioners using it in our own projects, as consumers buying pre-planted coir from others, and as growers supplying pre-planted coir to other practitioners and advising them in its use. Our purpose here is to share practical knowledge about a technique that most revegetation and stream restoration professionals have not experienced directly. We hope that readers will gain a better understanding of the appropriate uses of pre-planted coir blankets and learn from our mistakes as well as our successes.

What are Pre-Planted Coir Blankets?

Pre-planted coir blankets are essentially a nursery-grown sod consisting of a coconut fiber base and native herbaceous plants (Fig. 1). The coir base is the growth medium and the “carrier” that holds plants together during transport and handling. At our Native Sod Solutions nursery in Rexburg, Idaho, we use 1×5 m (3.3×16.4 ft) mats consisting of a fiber core approximately 5-8 cm (2-3 inches) thick that is enclosed in a mesh envelope. Individual plants of various native species are inserted directly into the coir at high density and grown hydroponically in shallow, lined ponds until relatively high root and shoot cover are achieved (Fig. 2). Greenhouse or nursery-grown planting stock is typically used, but bare-root plants, wild-collected transplants, and seed may also be used if appropriate for the desired species. Typically the plants are sedges, rushes, bulrushes, spikerushes, and grasses. Specifications and production methods may differ among suppliers, and there are other pre-planted coir products such as coir rolls with small shrubs. This paper only addresses blanket or mat type materials.

This technique was tested by the U.S. Army Engineer Waterways Experiment Station at least as early as 1983 for stabilizing coastal sites (Knutson et al., 1990; Allen and Leech, 1997). Use of pre-planted coir has increased in the United States and internationally over the last two decades but remains quite limited compared to other planting methods. It has been installed in a wide range of settings: wetland, stream, pond, or coastal; low to high energy; wildland to urban; and naturalistic to highly landscaped (Fig. 3 and 4, and photographs in later sections).

Figure 1. Pre-planted coir blankets in nursery pond. Left: Top view of a single piece. When ready to install, plants are well developed but above-ground cover is not completely filled in. Right: A piece of pre-planted coir rolled for shipping. Rolled pieces are easiest to handle using hay hooks. Rolled pieces are usually carried to their planting location, then unrolled in place.

Although it can no longer be considered an experimental technique, it remains unfamiliar to many involved in wetland, streambank, and shoreline revegetation, and products and practices are still evolving. Commercially produced pre-planted coir has been available for over a decade in the U.S. and Europe, but is not locally available in all areas. We are aware of U.S. producers in East Coast, Upper Midwest, Rocky Mountain, and Pacific Northwest states. Pre-planted coir blankets are sometimes called mats or pallets and are marketed under various trade names.

Pre-planted coir differs from natural, salvaged wetland sod in several ways. It is soil-less and, consequently, lighter to transport. The coir base provides more predictable physical characteristics that enhance handling, installation, and erosion control. Without soil it is free of the soil's reservoir of weed seeds but also lacks the desirable native seed bank sometimes present in salvaged topsoil. Nursery-grown coir sod can be planted to order and does not depend on having a local source for salvaging native sod, which would typically be a wetland that is being disturbed by the same or another project. The options for sourcing plants for pre-planted coir are the same as for planting techniques that use individual transplants; unless local plants or seeds are specifically collected and propagated, the genotypes will be those that are represented in the native plant marketplace.

Figure 2. Well developed roots and rhizomes contribute to several strengths of pre-planted coir blankets: rapid establishment and growth, erosion control, and a degree of tolerance to herbivory and non-ideal hydrology.

Compared to more conventional planting techniques that use seeds or individual plants, pre-planted coir blankets offer a number of potential advantages. Efficient sod-style installation can simplify and reduce labor costs for planting. Properly staked, the coir blanket provides some immediate erosion control. Having been grown out in a nursery, the plants are relatively mature and have well developed root systems and high shoot cover. This can greatly accelerate ecological and aesthetic results, reduce weed problems, and allow newly installed vegetation to tolerate less than ideal hydrologic conditions better than small individual plants. Simple installation, reduced weed control requirements, and shorter times to achieve vegetation objectives can streamline project management and completion. Many of these advantages apply even when comparing pre-planted coir to methods that use identical raw materials (coir blankets and individual nursery-grown plants) but place bare mats in the field and then plant them. Growing time in the nursery gives plants a head-start under favorable, controlled conditions.

Pre-planted coir has important limitations, most of which are similar to those for other revegetation and bioengineering approaches. Site hydrology and water and soil chemistry must be suitable for the plants used. In shoreline applications, hydraulic forces must not be excessive for the overall approach used whether it is primarily bioengineering or combines “soft” and “hard” armoring. Survival and performance depend on proper installation and adequate plant care before installation and during the establishment phase. Perhaps due to its robustness, many people tend to overestimate what pre-planted coir can do and tolerate, and they neglect important details of design, planning, and execution.

It is best to think of pre-planted coir as one more tool in the revegetation and bioengineering "tool box" and to use it selectively and in combination with other methods and materials. Each one has capabilities, limitations, conveniences, and costs. Their relative merits depend on the situation. Pre-planted coir is not a one-size-fits-all solution.

Figure 3. Examples of relatively natural and landscaped shorelines revegetated with pre-planted coir blankets. Top: A hemi-marsh area created to enhance shorebird and waterfowl habitat in Teton Valley, Idaho. Bottom: a pond created for a residence in Jackson Hole, Wyoming.

Figure 4. Pre-planted coir was used to revegetate filled areas in this project that narrowed an over-widened spring creek in south-central Idaho. Individual transplants had failed previously. From top to bottom: before installation, immediately after installation at the beginning of June, 2005, and in September, 2005.

Dos and Don’ts for Success

The keys to success with pre-planted coir blankets are largely the same ones that apply to all types of wetland and shoreline revegetation and bioengineering: understanding hydrology and soils, selecting appropriate plants, scheduling installation for an appropriate time of year and advantageous hydrologic conditions, integrating the revegetation plan with engineering or geomorphic design, using plant material that is really ready for planting, installing material correctly, and caring for plants before and after installation. Some details are specific to pre-planted coir blankets. The suggestions below are a mixture of seemingly obvious considerations – which are nonetheless ignored at times – and some less obvious insights.

<u>Planning and Design Understand and plan for site hydrology and soils</u>.

It is surprising how often projects suffer due to lack of adequate attention to the site’s hydrologic regime. Regardless of the planting techniques used, hydrology and associated environmental conditions experienced by plants are the foundation for any wetland or shoreline revegetation project. Water depth at the time of installation and throughout the ensuing growing season are most important, but long-term conditions should also be considered. It is critical to have as accurate and complete information as possible about the range of water levels at the project site, the seasonal timing of fluctuations, and the predictability or inter-year variation of water levels. When project budget and timeline allow, collect as much hydrologic monitoring data as possible beforehand. In our experience, this is especially important for pond or wetland systems that rely on groundwater to support surface water features; water levels can fluctuate widely between seasons and years – often much more than assumed – and unlined ponds or depressions may lose water to seepage at very high rates, making it impossible to maintain desired water levels by pumping groundwater or diverting a surface water source. In engineered systems fed by runoff, such as stormwater channels and wetlands, hydrologic analyses should address ambient water levels, not just the major runoff events that are usually emphasized in channel and basin design.

Pre-planted coir can be used successfully under a wide range of hydrologic conditions, but plant selection, installation schedules, and monitoring and maintenance plans will differ greatly among them. Examples of common situations are: ponded with relatively steady water levels; streams with a distinct seasonal snowmelt or rainfall runoff peak; spring creeks with an attenuated snowmelt peak or a mid-growing-season peak induced by dense aquatic macrophytes; or intermittently wet channels or basins, such as areas receiving stormwater. In each of these cases there are ecologically significant differences in the hydrograph including the range of water levels, typical and base levels, and the duration and seasonal timing of high or low water periods. These will affect the installation schedule, the drought or flooding stresses plants are subjected to during the establishment phase and during future wet or dry years, and the possible need for supplemental irrigation.

Any available hydrologic and climate data should be examined, particularly USGS or other stream or tide gauge records for the project area or for comparable, nearby locations. If necessary, it may be possible to estimate base and peak flows indirectly from watershed characteristics and statistical relationships or to estimate hydrographs from simple hydrologic models. Observations by individuals with local experience can be invaluable; these may include residents, irrigators, natural resource professionals, recreational water users, or construction contractors involved in stream, pond, and irrigation system work. Visual signs such as bankfull indicators, water-borne debris, and silt lines may be useful. Finally, there is no substitute for solid knowledge of hydrology within the design team and, ideally, experience with closely similar systems; the less site-specific information is available, the more important sound professional judgment becomes.

Many sites are affected by human water management through impoundments, irrigation diversions, irrigation return flows, transfer of water between watersheds, and engineered stormwater drainage and storage systems. Any ability to control water levels artificially should be explored; if this involves diversion or impoundment, water rights and authorization to impound water and alter water levels should be confirmed (Figure 5). For projects involving engineered ponds, wetlands, or stormwater basins, there should be a good estimate of the water budget that integrates surface and groundwater flows, evapotranspiration, and seepage losses. If the project involves major alterations to the hydrologic system, such as redirection of surface water or creation of a new pond, it may be appropriate to consider contingency plans for differences between designed and realized hydrology.

Starting with an informed estimate of surface water dynamics, it is necessary to consider how this will interact with site grading, shallow groundwater systems, and soils. The effects of existing topography and grading are straightforward: differences in shoreline or soil surface elevations result in wetter or dryer conditions. Differences in depth and duration of inundation, or depth to free water when the surface is not inundated, can be estimated directly from a hydrograph and site elevations. Where hydraulic conductivities are high, the surface water hydrograph may also describe conditions at some distance from a water body; however, this

Figure 5. Pre-planted coir blankets installed at this site required temporary irrigation because target water levels (level of vegetation in photograph) were not reached on schedule. Water for the pond was supplied by a large irrigation canal that had more than adequate capacity to fill the pond on time, but withdrawals by upstream irrigators during warm weather delayed filling more than anticipated.

simple relationship sometimes can break down even at very short distances. Where hydraulic conductivities are low, riparian groundwater levels may not be tightly linked to stream or pond levels except when there is a direct surface connection via overflow. The low-conductivity barrier may be remarkably thin and not at all obvious, such as where fine sediments have sealed a channel bed; in such cases, riparian and surface water hydrographs may be quite different even if the channel and the floodplain are both dominated by coarse materials with high conductivities such as sands and gravels. Artificial liners will have similar effects.

Soil or sediment texture modifies how fluctuations in surface water levels translate to the root-zone environment experienced by plants. Finer soils promote greater capillary rise, resulting in temporary extension of moist conditions when water levels drop below the surface. They also retain more water from precipitation or irrigation. By contrast, coarse substrates retain little available water above the water table or after irrigation or rain, so plants are more likely to experience desiccation when the surface is not flooded. Finer substrates, particularly if lacking in structure, generally have lower air diffusion rates when exposed, which may result in a longer period of anoxia, which can stress plants depending on species and developmental stage. Differences in texture, structure, and organic matter content will also affect cohesion, ability to anchor coir, surface deformation by trampling, soil-root contact, fertility, and other factors. All of these should be considered whether using existing, amended, or imported substrates.

<u>Match plant species to site hydrology and project objectives</u>.

As with any wetland or shoreline revegetation technique, plant selection and placement is central. Many problems result from choosing plants that are not well matched to a site's hydrologic environment. A basic understanding of species' environmental requirements and tolerances is essential. There is no substitute for a sound understanding of wetland plant ecology and experience working with wetland plants. Of course, plant selection must also consider aesthetics, plant diversity, and functional objectives such as erosion control, weed inhibition, and habitat enhancement for targeted wildlife species.

Even when site hydrology is not fully known, an approximate description can narrow the plant list to species with good odds of success. There is a substantial body of information about the natural hydrologic environments occupied by plants. Sources include plant material guides from conservation agencies' and nurseries, tables of species' wetland indicator status, and books and articles on wetland and riparian ecology. Figure 6 shows typical hydrologic environments for some of the species we work with most often. Both the species list and the distributions of individual species can vary considerably from place to place, but each species has a characteristic hydrologic range and each environment has a limited list of common candidate species.

Reference sites with relatively undisturbed and functional plant communities can provide excellent guidance for plant selection. This approach uses nature as a template. On-site reference communities are ideal, but nearby sites with similar environments can be used. Many wetland plant communities occur as nearly monospecific stands sorted out by subtleties of hydrology. Reference sites can be used to make sure that locally dominant species are included in the mix.

It is best not to get too clever with installation patterns. The match between plants and hydrology generally needs to be reasonable rather than precise. Uncertain hydrology, variations in site elevations, and plants' ability to tolerate a range of conditions all favor an approximate approach. We typically plant each piece of coir with one to three species. In many settings, such as sloped banks comprising a range of elevations, coir with different species mixes can be used at different elevations, and more than one species can be included in each piece of coir to address more subtle spatial differences in hydroperiod (Fig. 7). On a 3:1 slope, the upper edge of a 1m wide piece of coir will be about 0.3 m (1 ft) higher than the lower edge, which can represent a large difference in hydroperiod. Differences in environment across this range can be accommodated by planting individual pieces with a species mixture that includes plants with slightly difference hydrologic preferences, such as Nebraska sedge/beaked sedge/Baltic rush. There is also the potential more complex mixtures, but we have found that using three species balances flexibility of application and efficiency of production.

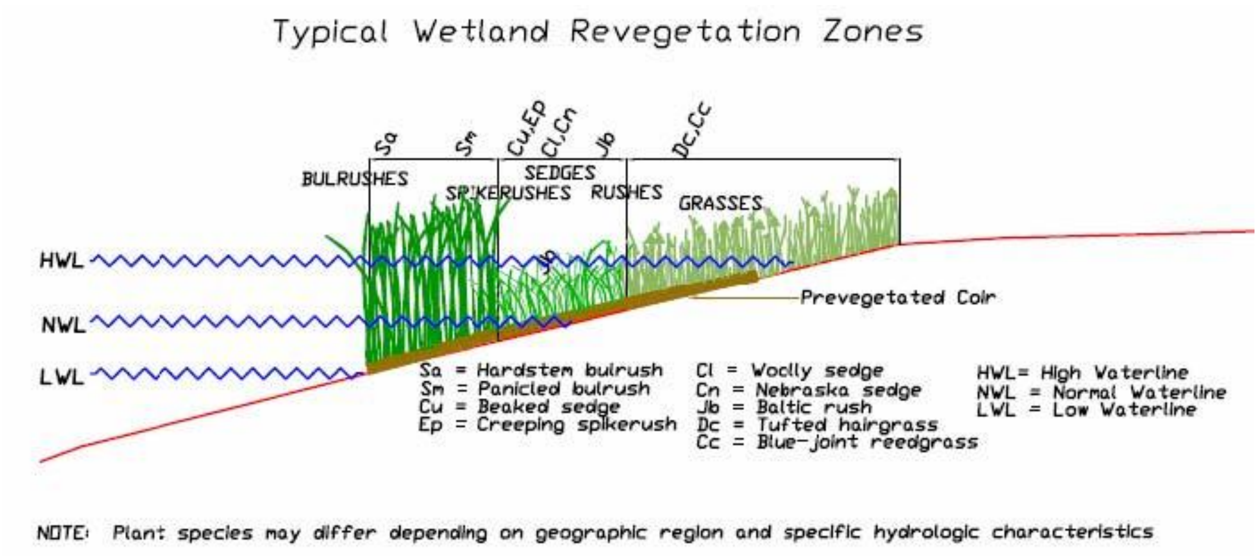

Figure 6. A typical example of hydrologic zones and plant species for wetland and streambank revegetation. Details will differ among regions and wetland or stream types.

<u>Schedule installation or control hydrology to provide suitable water levels</u>.

The relatively mature plants in pre-planted coir are generally more tolerant of flooding or drying than small seedlings or transplanted plugs, but their tolerances are not unlimited, especially during the first weeks after installation. Therefore, it is important to provide the most favorable water levels feasible during initial establishment. In situations with uncontrolled and variable water levels, installation should be scheduled based on the expected hydrograph. The lowest risk strategy will depend on the nature of the growing-season hydrograph. For example, one stream may have very low base flows and brief, intense snowmelt runoff while another is characterized by abundant base flows and significant increases in water levels during the growing season. In the first case, one concern would be risk of desiccation before roots penetrate far enough to tap groundwater as it drops. In the second case, the main concern would likely be excessive flooding and oxygen deprivation before plants are acclimated to their new environment and well rooted (Fig. 8). Too much water can be as stressful as too little water.

Figure 7. Two different species mixes have been installed on upper and lower zones of this streambank. The two vegetation zones, each 1-m wide, differ in color and texture; the wooden stake (lower center) is near their boundary. Photograph was taken late in the first growing season. Plant distribution and abundance will adjust to site conditions over time.

It may be necessary to reschedule an installation if site hydrology does not behave as expected. As the appointed date approaches, information about snowpack or weather forecasts might lead to adjustments based on anticipated shifts in the hydrograph. Unpredictable changes may occur within days of planned installation. The ideal installation window may also be missed because of unforeseen construction or permitting delays. Getting the best possible conditions involves planning, luck, and flexibility. Because changes in plan may be required, it is important to know the expected hydrology at all times during the year, not just the ideal time.

It is critical to have an irrigation strategy if installation will proceed when conditions are dryer than ideal, whether this is due to low runoff, project delays, or other factors. Be prepared to irrigate or raise water with portable dams where appropriate. Situations with artificially controlled hydrology are easier to plan for, but simplicity should not be taken for granted. Control is often less absolute than assumed. For example, a water right may be sufficient, but exact timing of supply may require coordination with other water users (Fig. 5).

Figure 8. Revegetation using individual transplants failed due to high water levels during the growing season on this spring creek in south-central Idaho. Filled areas were exposed when planted in 2003 but inundated by approximately 0.5 m (1.6 ft) water level increases from early to late growing season. In 2004, plants were dying from flooding stress (left photograph). By the end of May, 2005, only plants on the highest microsites survived (right photograph). Pre-planted coir blankets were installed in early June, 2005, and thrived throughout the growing season even as water levels rose (Fig. 4).

Understand and plan for site hydraulic forces.

Where flowing water or waves will subject a shoreline to significant erosive forces, both short and long-term stability of vegetation should be evaluated realistically. If hydraulic analysis or professional judgment suggests that erosive forces will increase the risk of physical failure, it may be necessary to incorporate more features that confer strength and resilience. The same analytical tools that are used with other shoreline bioengineering approaches should be used for projects incorporating pre-planted coir – mainly hydraulic analyses, geomorphic analyses, channel engineering methods, and the insights of professionals experienced with these tools and with bioengineering.

While the formal analyses can seem arcane, many of the risk factors are commonsense: in streams, gradient, depth, velocity, angle of current against banks at channel bends, and presence of features likely to create localized turbulence; in pond or lakes, exposure, wind fetch, and direction of prevailing winds; in tidal systems, frequency and magnitude of tides, currents caused by the tides, and exposure to waves. The forces of flowing water and tides are intuitive to most people, but the erosion risk in ponds and lakes is often underestimated (Fig. 9).

Steady water levels and absence of a current do not guarantee a peaceful, low energy environment; wind-generated waves can undermine sediment beneath coir, pull coir and roots away from the surface, or tear at edges of coir pieces. Risk of damage is typically greatest at the water line – which may not be constant – but surging pressure acting on coir and unconsolidated fill can cause damage below the waterline and lead to slumping. In both stream and pond settings, the effects of hydraulic forces may be modified by bank slope and composition and degree of consolidation of the substrate. Rapidly falling or fluctuating water levels can also trigger slumping because banks remain temporarily saturated, heavy, and weak, but are no longer supported by standing water (Fig. 10).

Figure 9. Even gentle wave action can be destructive on unprotected shorelines. On this shoreline, topsoil was placed over an artificial liner and planted with individual tubelings. When this photograph was taken, minimal waves caused by moderate winds had started to erode soil and dislodge plants at the waterline (e.g. at arrow). Other shoreline areas at the same site that were protected with pre-planted coir tolerated larger waves.

Figure 10. Slumping of pre-planted coir blankets on this pond shoreline resulted from fluctuating water levels and insufficient depth of fill over a synthetic liner. Slumping exposed the band of soil indicated by the arrows. Poor growth and drying of plants also reflects the inadequate soil depth, which was less than specified in the design. Fill and vegetation both had to be replaced.

Pre-planted coir blankets occupy an intermediate position on the spectrum of shoreline and channel revegetation and engineering approaches. Pre-planted coir is much better able to resist erosion than designs that use individual transplants alone or with lightweight erosion control fabrics (ECF). In some situations such as soft, unconsolidated banks exposed to wave action, the combination of a heavy coir mat and relatively robust plants anchored in the coir can succeed where individual plants fail to establish (Knutson et al., 1990; Allen and Leech, 1997); this reflects both the erosion control and plant development characteristics of pre-planted coir. In many medium to high-energy situations, however, it is necessary to use additional practices to enhance short or long-term stability. To stabilize unconsolidated fill and protect it from erosion at breaks between coir pieces, it may be necessary to cover the bank with continuous sheets of ECF and to key the ECF into the bank (Fig. 11). Any number of designs are possible that combine pre-planted coir blankets with other streambank engineering techniques and materials, such as rock revetments, coir rolls, or embedded logs (Fig. 12). Of course, less expensive revegetation methods may be adequate in less exposed settings, even a short distance from the shore. Thus pre-planted coir will often be used just in a narrow band 1-2 m wide along the waterline, while individual plantings or seeding are used landward of this (Fig. 7, 10, and 12).

Pre-planted coir is not a complete, instant erosion control system and depends on rooting for effective anchoring; the established plant community ultimately provides long-term bank or shoreline stability. Un-secured pre-planted coir should not be expected to sustain unrealistic flow rates or wave energy immediately after installation. Although the coir blanket does provide significant erosion protection initially, this can only be effective with adequate temporary anchoring. The specific type and amount of anchoring and the decision to use erosion control fabric or other materials must match site hydraulic conditions (Fig. 13). On stream banks we recommend installation just after peak flows, when water levels are gradually dropping. Supplemental irrigation may be required to fully establish the vegetation, but it will generally be fully rooted and ready for high water the following spring. The time required for roots to provide adequate anchoring depends on growing conditions including heat, light, and moisture. In our experience, it is virtually impossible to pull up rooted coir manually after as little as 2-3 weeks at warm, low elevation sites or 4-5 weeks at cooler, high elevation sites. Although there is little data on initial or long-term performance of pre-planted coir in high energy channel environments, we have worked on projects where installed material was exposed to intense flows from storm runoff within several weeks after installation and was not dislodged or damaged (Fig. 12).

Figure 11. This bend in the Teton River, Idaho, was rebuilt with a gentler slope and protected with erosion control fabric before installing pre-planted coir blankets. Two lifts of soil are protected by separate pieces of ECF, each with its lower edge buried before folding it back over the soil "burrito-wrap style". Fencing protects young shrubs on bank from browsing.

Figure 12. In the Butte Metro Storm Drain Reconstruction project, pre-vegetated coir blankets were a small but important feature of a complete design. The form and size of the large trapezoidal channel used standard hydrologic analyses and engineering methods to design for flashy urban runoff, and the entire bottom of the channel was armored with coarse aggregate before placing topsoil. The small, sinuous pilot channel in the center is designed largely for aesthetics and carries a low, seasonal base flow. Pre-planted coir was used on the banks of this pilot channel in many areas, but other materials such as rock revetments were also used. Erosion control fabric was installed over all top-soiled areas. Areas away from the channel banks were seeded, and woody species were planted on upper side-slopes. This channel handled a large runoff event successfully just 10 days after pre-planted coir was installed (Hook 2006).

Figure 13. In the Butte Metro Storm Drain Reconstruction project, pre-planted coir blankets were staked at relative high density, with stakes angled to help secure the coir against currents.

Arrange material orders well ahead of time.

While supplies of many native plants are limited, the available inventory and production capacity for pre-planted coir is even more restricted. Lead times for custom orders are also longer. For pre-planted coir started with containerized nursery stock, production times include several months after planting the coir blankets, in addition to the previous time taken growing seedlings and, for some species, pre-treating seeds to satisfy germination requirements. Growing time in ponds is typically 10 weeks to several months, but some species are inherently “slow starters” and require an entire growing season to reach the same degree of readiness. For some species mixes total production time from seed pretreatment to installation can exceed 12 months. Custom materials will typically require a minimum 6-month lead-time. Lead times are not constant because they depend on timing relative to annual production cycles for containerized plants and relative to the outdoor nursery growing season. It may be necessary to place orders as much as a year in advance for large quantities or custom-grown orders. At Native Sod Solutions nursery, stock mixes that we grow routinely are usually available upon request from fall through early summer; specific plant mixes and quantities can become limited as the peak summer planting season nears.

Before, During, and After Installation

Coordinate readiness of plant material, project, and site. The advantages of pre-planted coir are greatest when plants are well developed and really do have a significant head-start compared to individual plants. No one likes to pay a gallon-pot price for a 3-cubic-inch tubeling that was just transplanted into the larger container and has not grown into it; it is just as unreasonable to pay pre-planted coir prices if plants have not filled in adequately. Criteria for initial plant spacing and for readiness to install are not standardized in the industry; judging readiness is inherently subjective and semi-quantitative at best. Nonetheless, it is fair to expect a supplier to describe their criteria for readiness using words or example photographs. It is also reasonable to check on development of material, particularly after a deposit has been placed on a substantial order. Finally, although rolling and transporting pre-planted coir necessarily causes minor and transient damage to plants, conditions during transport should protect plants from unnecessary damage.

It is equally important that the site and project are ready for planting. Project delays happen for many different reasons, and hydrologic conditions usually cannot be predicted perfectly. If installation will be delayed, it is best to delay delivery of the material too. Storing material at the supplier's nursery can add to project costs because use of limited nursery space preempts new production and some continuing care is required. It is not trivial for the supplier to hold material and reschedule delivery, but storing pre-planted coir on-site is inefficient and can result in material damage. Even while still rolled up, the material must be watered to prevent desiccation, root damage, and plant death. Due to shading, crushing, and disease concerns, the acceptable time for storing pre-planted coir rolled up is measured in days not weeks and is very sensitive to weather. Because supply is limited, especially for custom grown material, it may not be possible to replace damaged material immediately. Therefore, it is critical to minimize storage times for rolled coir and to keep unrolled coir well-watered if stored on-site. An appropriate place for storing the material may not be available on-site or may require unloading material at a distance from the project site and having to load and move it later. It is most efficient and best for the plants if pre-planted coir is installed as soon as possible after delivery.

Plan adequate labor, supervision, and oversight. Installation of pre-panted coir is manual rather than mechanized and is physically demanding. Adequate crew size helps both efficiency and quality of installation. The 1×5 m pieces that we use are rolled for transport. At approximately 70 kg (150 pounds), depending on plant size and degree of saturation, and the size of a 205-L (55-gallon) barrel, the rolled blankets can be awkward to handle (Figure 1). Two workers using hay hooks can usually handle the rolls efficiently. Labor needs average about 0.3 to 0.5 labor hours for unloading, locating, unrolling and staking each piece. Times may be greater if it is necessary to transport material manually over long distances from the delivery point. Additional labor may also be required if ongoing watering in is necessary.

Although installation is relatively simple, adequate oversight is critical. Someone must verify that the correct quantities and species mixes have been delivered and that the material is in good condition. Someone familiar with the design should direct material placement to the correct locations and elevations and see that it is installed properly. The need for artificial irrigation should be re-evaluated, and the people responsible for irrigation should be given clear direction; these may be people who do not work directly for the designers or installers and who may not be familiar with pre-planted coir.

No specialized equipment or supplies are needed. Essentials include hay hooks (2 per worker), hand sledges (1 each), gloves (coir can be abrasive), and stakes (6-12 per mat). Depending on prior site preparation, shovels and rakes may be needed to smooth the soil surface. At some sites, a hand cart, four-wheeler and trailer, or small boat may be useful for moving pieces to their destinations.

<u>Establish good root-soil contact and secure mats well</u>. One of the chief advantages of pre-planted coir is advanced root development, which accelerates permanent anchoring and plant establishment. Roots within the coir blanket or on its bottom surface are vulnerable to desiccation and generally will not grow across dry voids. The planting surface should be prepared to limit irregularities that would result in voids under mats. Large obstructions should be removed and localized voids filled. Unroll coir carefully, avoiding air pockets by smoothing out irregularities, and tuck loose roots at edges under the coir. In addition to pressing and staking pieces down, watering can help weigh down the coir and press roots against soil.

Coir blankets should be staked in place for temporary stability during the establishment phase. The size and number of stakes will depend on conditions and require judgment. In our experience, 6-12 stakes 0.4-0.6 m long (16-24 inches) are sufficient for each 1×5 m piece in most cases. Driving stakes at an angle can enhance anchoring against swift currents, waves, or flotation. In tidally influenced wetlands, innovative anchoring devices may be needed to address repeated tidal lifting of coir off the substrate; pieces of rebar bent over at the top end have been effective. If a synthetic liner is present and is only shallowly covered, it may be necessary to anchor coir at the top of the slope above the liner.

<u>Protect site to limit potential wildlife, livestock, and human trespass damage</u>. Livestock, wild ungulates, waterfowl, and rodents can impede revegetation efforts by depleting plant carbohydrates, retarding growth, and crushing or dislodging plants. Human foot or vehicle traffic can also disrupt newly planted sites. Pre-planted coir tolerates trampling and herbivory better than most revegetation methods, but it is best to limit these impacts as much as practical.

As with erosion control, the initial advantages of pre-planted coir involve both plants and coir. Because the plants have relatively well developed rhizomes when installed, they can tolerate herbivory better than small, individual transplants. However, heavy, ongoing grazing can stress and eventually kill vegetation, especially if too wet or too dry. One of the most common problems with individual transplants is that geese pull plants out of the soil, leaving them to die. With pre-planted coir, extensive rhizome and root systems lock plants into the coir base so that plants cannot be dislodged. This also prevents ejection of plants by frost heaving, a common problem with newly-planted plugs. The coir and dense root systems also spread out physical pressure so that trampling causes less soil deformation and churning. Coir on fine, unconsolidated fill can still be vulnerable to localized damage or lateral movement by trampling, especially on steeper slopes.

Potential for herbivory and trampling should be evaluated and barriers installed where needed. Although it will tolerate some trampling and grazing, pre-planted coir should be shielded from heavy animal and human traffic during the initial establishment phase. If intense herbivory is expected as a site, installation may be scheduled to minimize it. At the Hagerman Wildlife Management Area, for example, the Idaho Fish and Game Department timed installation of pre-planted coir to coincide with periods of relatively low waterfowl use. The need for protection will often be dictated by other revegetation practices used in combination with pre-planted coir. String or net barriers may be needed to deter waterfowl from grazing and pulling out individual plugs of herbaceous plants in adjacent areas, or fencing may be required to protect young woody plants from browsing (Figure 11). Following installation, damage to vegetation or fencing should be monitored and repaired as needed.

Monitor and manage weeds. Compared to many conventional revegetation techniques, pre-planted coir can resist weed establishment remarkably well, and we consider this one of its greatest advantages (Klausmann and Hook, 2001). Once again, this is due to both the coir and the well-developed vegetation. In our plot-scale research and in full-scale projects, weed recruitment from the seedbank is mostly suppressed by pre-planted coir, which completely covers the soil. Aggressive weeds such as reed canarygrass will still require management during the establishment phase and into the future to maintain target plant community composition. The effort required may be significant where there are residual weed populations next to the planted site.

In general, weed management costs and effort are likely to be less for pre-planted coir than more conventional revegetation practices, but weed management remains a routine concern and cost savings should not be exaggerated. Pre-planted coir is not weed-proof, so it is still important to monitor and treat weeds as needed. And because pre-planted coir is often used on just part of a revegetation project, the frequency of weed monitoring and treatment and associated transportation and labor costs will be determined largely by areas that are more vulnerable to weeds.

Monitor water levels during the establishment phase and modify as needed. The plants in pre-planted coir blankets are at greatest risk during the first weeks and months after installation. In the nursery, hydrology is optimized and plants are not subjected to desiccation or extreme oxygen deprivation. In the field, water levels may be either to too low or too high. While the relatively advanced growth of the plants in pre-planted coir makes them more robust than small plugs under non-ideal conditions, they can still be damaged or killed. Plan on several trips to the site to check water levels and plant condition. During the early establishment phase, plant growth and survival can be determined by differences of inches of water depth or days to weeks of exposure or inundation. The range of acceptable water levels will become wider after roots and shoots are fully grown.

The optimal water level during establishment is slightly above or below the coir surface, with shoots in air and roots in water. Many wetland plants rely on oxygen uptake by shoots to meet their belowground oxygen needs. To limit anoxia, shoots should not be completely submerged during the establishment phase, or for excessive periods after establishment.

For roots, desiccation is the main concern. At installation, roots are entirely in the coir or at the coir-soil interface. In the absence of standing water, the coir retains a limited amount of water, typically enough to remain moist from less than a day to several days depending on weather. If dry, roots will not grow into the soil and may die. Newly installed material typically requires a period of inundation to establish. Water levels can safely drop below the surface only to the extent that soils, weather, or irrigation allow roots to stay moist. The minimum acceptable water level will depend in part on the height of capillary rise for a given soil, but capillary wetting should not be relied upon for new material; moist soil alone cannot supply enough water, especially in dry, windy conditions. If natural or controlled water levels leave plants exposed during early establishment, irrigation is critical. Once a significant amount of roots has grown into the soil, the moisture retention and capillary qualities of the soil may reduce the risk of desiccation provided that the soil is not too coarse. Ultimately, full development of the root system will allow plants to tap shallow groundwater when water levels are below the surface.

For many projects, favorable water levels can be achieved by coordinating the design, installation schedule, and site hydrology. Ideally, water levels should be as near to optimum at planting time and rise or fall gradually to minimize plant stress and maximize growth and spread. For example, on a streambank where water levels are uncontrolled, installation shortly after peak runoff can allow root growth to keep up with falling water levels if stream flows recede gradually. A similar sequence of conditions can be created artificially in cases where water levels are managed. Because many installations are on sloping banks, it may not be possible to have ideal conditions throughout the planted area without controlled water-level fluctuations or irrigation. Short-term artificial fluctuations can be used in lieu of irrigation to ensure that plants on upper slopes remain moist without drowning out lower plants.

Where irrigation is necessary, various methods can be used depending on site characteristics, the area to be irrigated, and availability of equipment and labor. For small areas and short periods, it can be practical to water manually using a pump and hose or by bailing stream water directly with a bucket. Tarp dams can be used to raise water levels in small channels; Butte-Silver Bow County crews used this approach effectively in a stormwater channel with minimal base flows, moving dams frequently to keep all areas moist during establishment (Figure 14). If the area is large and tarp dams are not practical, sprinkler irrigation may be the best option, especially if sprinklers are already present for agriculture or landscaping.

Summary

If used appropriately, pre-planted coir blankets can be an exceptionally effective revegetation technique. Their main advantages include efficient installation, initial erosion control and weed suppression, accelerated development of vegetation, and a degree of tolerance to herbivory and non-ideal hydrology. While the tough, flexible coir base and the well-developed vegetation make pre-planted coir a relatively forgiving technique, sound design and installation are still essential. Keys to success include understanding site hydrology and matching species selection to hydrologic conditions, timing installation for favorable water levels, achieving good root-soil contact during installation, providing temporary anchoring appropriate to site hydraulic conditions, controlling water levels or irrigating as needed during establishment, and limiting herbivory and trampling.

Finally, it is important to treat pre-planted coir blankets as part of a total design, not a stand-alone or one-size-fits-all solution. Pre-planted coir is just one of the tools in the revegetation tool box. When it is used, it will usually be one of several revegetation and bioengineering techniques, and it will be used where its strengths address specific needs or priorities. In our experience, there are situations where a lower cost approach has been proven reliable and adequate, and spending more for pre-planted coir is not justified. There are other situations where pre-planted coir is more effective than alternatives and a realistic cost comparison (including material, labor, management, maintenance, and monitoring costs) shows that it is also economically competitive.

Figure 14. Temporary tarp dam used to raise upstream water levels to irrigate newly installed pre-planted coir blankets in the Butte Metro Storm Drain. A pipe or pole supports one edge of the tarp across the channel, and rocks are used to hold the tarp against the channel bottom and sides. At this site, base flow is artificially controlled but limited. The photograph was taken when the channel was drained to allow dams to be moved.

Acknowledgements

This paper benefited from the observations, ideas, and insights of many colleagues, collaborators, and clients over the entire time we have worked with pre-planted coir.

Literature Cited

Allen, H. H., J.R. and Leech. 1997. Bioengineering for streambank erosion control; Report 1, Guidelines. Technical Report EL-97-8, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. http://www.wes.army.mil/el/wetlands/pdfs/el97-8.pdf

Hook, P.B. 2006. Pre-vegetated coir achieves rapid results in reconstructed stormwater channel. Land and Water 50 (1): 7-11.

Klausmann, J.K., and P.B. Hook. 2001. Comparison of Seven Methods for Revegetating Sedge-

Dominated Rocky Mountain Wetlands. Project completion report for USEPA Region 8 104(b)(3) Wetlands Protection Grant to Teton County, WY. Intermountain Aquatics, Inc., Driggs, ID.

Knutson, P. L., H.H. Allen, and J.W. Webb. 1990. Guidelines for vegetative erosion control on wave-impacted coastal dredged material sites. Technical Report D-90-13, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. http://el.erdc.usace.army.mil/elpubs/pdf/trd90-13.pdf