SAFE HARBOR
ENVIRONMENTAL MANAGEMENT
HABITAT RESTORATION

Stabilizing Slopes, Very Steep Slopes & Coastal Banks

Above: Two images by Gordon Peabody, taken 1 year apart, of steep slope in Brewster, MA. Safe Harbor advocates considering natural system alternatives for stabilization of steep and very steep slopes. Slope cofactors of Geomass and Biomass interact to create successful, sustainable habitat and linkage to scale.

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A word about Safe Harbor: *We provide environmental consulting, permitting, compliance monitoring, mitigation and management services for Restoration, Construction and Invasive Vegetation projects under the jurisdiction of the Massachusetts Wetlands Protection Act; Massachusetts Endangered Species Act; Local Wetlands Bylaws; FEMA Flood and Velocity Zones and Areas of Critical Environmental Concern (ACEC).* ***Safe Harbor*** *specializes in developing stabilization strategies, using low cost/low impact sustainable, natural systems.* ***Safe Harbor Educational Publications*** *are self-funded by Safe Harbor. If you have an interest in supporting our efforts, please contact* ***gordonpeabody@gmail.com*** *or www.SafeHarborEnv.com*

Image by Gordon Peabody. Low impact access and beginning of low profile benching.

I. General Strategies for Stabilization

Sustainable, natural systems for stabilizing steep slopes should always be considered in your Alternatives Analysis. A non-structural, more sustainable solution to steep slope erosion, would use the same gravity causing erosion, to control runoff, with site specific native vegetation systems to control stabilization. Steep, (45 degree) and Very Steep (60 + degree) de-vegetated slopes are fair game for rain-generated storm water erosion. Gravity-driven sheet flow is generated directly by the slope itself and indirectly by contributing, upslope sources. Gravity directs sheet flow downslope, creating accelerating point sources. The weight of this mathematically amplified, liquid-sandpaper transports soil, causing destruction primarily through erosion and secondarily through deposition. Downslope discharge often flows into wetlands. Vegetation growing in groundwater fed wetlands may be sensitive to surface discharge and deposition. Chronic deposition of sediment and silt will smother wetland vegetation. Reduced performance of wetland resources degrades habitat and invites potential regulatory consequences.

1. Assessment: Study the problem and the dynamics between elements of your problem: hydrology; slope; and habitat. Study and identify linkages between primary and secondary sheet flow sources and impacts. Then study adjacent, performing slopes that could be used as a model for your project.

2. Get Measurements: Crest-to-foot and side slope-to-side slope width measurements will assist in calculating materials you will need. We usually divide large areas and long slopes into smaller, easier-to-manage work areas.

3. Address Contributing Flow: the shortest path to successful steep slope erosion control is removing upslope contributions before they reach the slope crest. We recommend "Smart Growth" and "Low Impact Development" (LID) Guidelines for low profile, low impact and low maintenance groundwater infiltration systems such as swales, dry wells, drip lines, filter strips and retention basins. Many of these sustainable, storm water management systems are described in: http://safeharborenv.com/2010/10/03/good-neighbor-storm-water-booklet-now-available/

4. Linkage to Scale: For a system to maintain sustainable performance standards, it should be modeled to mimic nearby, performing habitat models, not only in soil profiles but also in vegetation diversity and density. We recommend excluding upper story and under upper story height plantings.

5. Select Stabilization Technique: Carefully review options (sections II. and III.) for your site. Being able to address site specificity is a key to successful stabilization.

6. Consider Native Transplants: Native transplants have high survivability, if they include the native geomass they are growing in—incorporate the soil mass with compatible microorganism community, pH and nutrient values.

7. Limited Watering: Native vegetation can endure drought but during the first growing season, early root growth is developing. In times of drought, limited watering may be necessary. By the time leaves have begun to droop, damage may have already occurred. The bioengineered system provides a degree of moisture protection to roots. Hand watering is less efficient than timer operated drip hose irrigation but drip irrigation requires more initial effort. Water system decisions are site specific but may need to be "built in" to protect ecological and financial values.

8. Chemical Use: As a matter of policy, Safe Harbor <u>does not use</u> herbicides, pesticides or fertilizers. These <u>unnatural</u> fertilizers create vegetation that is chemically more attractive to insects and encourages invasive plants. <u>They may also</u> destabilize the density of nitrogen-fixing bacteria in roots, making plants "fertilizer dependent". Indigenous compost and mulch, with healthy, diverse microorganism and micro-invertebrate communities, provide a sustainable flow of nutrients. Vegetation consumed as a food source by native insects, small mammals, birds and herbivores, transfers critical ecological energy from plant biomass to animal biomass.

9. Sustainable Vegetation: After three years, bioengineered native vegetation systems will become increasingly more sustainable. This will reflect increased stabilization and infiltration performance. Some reseeding and replanting may be necessary. Sustainable slope stabilization systems mimic the simplicity of natural systems, using infiltration benches and native vegetation, to create high performance results.

10. Managing Invasive Vegetation: Invasive vegetation shows up in recently disturbed areas. Invasives exhibit exceptional growth rates, out-competing slower-growing native vegetation for light, moisture and nutrients. Many types of invasives also chemically interfere using root chemicals (allopathic). During the first year, we often allow invasives to contribute to slope stability, cutting them at the base before they seed and removing root and lower stem by hand when slope vegetation is more stable. Invasive vegetation management should be a component of slope stabilization. Without proper management, invasive canopy will characteristically block sunlight from stabilizing native vegetation at ground level, creating erosion potential.

12. Toe-of-Slope Control: Toe-of-slope mitigations may require temporary use of one or more erosion control systems to temporarily control toe erosion (double-staked straw bales, silt fences with extra stakes, and/or ground stapled biologs).

13. Support Regulations for Storm Water Protection: Uncontrolled upslope development, with impervious roofs, hardscape alterations to grade elevations and impacts to stabilizing vegetation, will alter the nature (direction, volume and velocity) of storm water discharge. Planning and Conservation regulators need support in developing effective storm water management systems. Proper infiltration contributes to sustainable water resources. Low Impact Development (LID) and "Smart Growth" recommends storm water to ground water recharge as close to the source as possible. We recommend using gravity driven, low profile swales and dry wells, instead of more expensive, infrastructure leach pits, which have impacting installation.

II. Techniques for Stabilizing Steep Slopes


Beginning of restoration pictured at left; same area 4 months later at right.

1*. Control Vertical Access*: Vertical foot traffic creates impacts that are avoidable. A person walking downslope, through sand, displaces his or her own bodyweight every ten feet. We recommend using extension ladders to accommodate slope access. Extension ladders easily accommodate slopes 40 to 90 feet long. We recommend using oak stakes to secure the ladders every 20 feet, to prevent sliding. Also consider the option, where possible, of accessing the area from the bottom of the slope and working up.


2. Slope Preparation/Benching: Create "benched" infiltration terraces about a foot wide: we use shovels or boots to level them. These low-impact, horizontal lines of terraces (or benches) should be inclined, to lean back into (or cant into) the slope. This technique will slow down, retain and infiltrate storm water. For 30° slopes, the infiltration lines can be spaced 8 feet apart. A 45° slope can accommodate infiltration lines 6 feet apart. Variable, soil based percolation rates also determining spacing and depth of benches. Each bench wants to retain storm water from the raw slope immediately above it. As the slopes become more vegetated, the benches will also fill in with vegetation, transitioning the slope performance from mitigation to sustainable.

3. Control Horizontal Access: Use these terraces for access. The horizontal, benched terraces provide useful access paths for planting and mitigation work across the width of the slope.

4. Apply Indigenous Compost: Local, indigenous compost (fully decomposed indigenous plant material or compost which has been allowed to heat up enough to neutralize invasive seeds) is spread across the slope and gently raked into the raw, upper two inches of the slope. The profile should reflect native habitat. This layer contributes to sustainability by providing a diverse nutrient/microorganism community. We usually sample core adjacent slopes.

Images by G. Peabody. Absorbent, seed free straw and composted native soil.

5. Do Not Over Compost: More is not better. Excess nutrients will attract invasive vegetation ("like free beer at a party: you never know who will show up"). Over-composting invites downslope problems with nutrient transport.

6. Apply Indigenous Mulch: A thin layer of locally available mulch (semi-composted, indigenous plant material) reflecting the native habitat, should be spread over the compost layer. Straw mulch (*never* hay with seeds) may be used. This creates a bioengineered layer that protects new roots from atmospheric moisture and temperature spikes. Layering also contributes to sustainability by providing micro invertebrate and insect biodiversity.

7. Native Seeding**:** Successful seeding is enhanced by planting during native germination windows. Re-seeding may be required during the first two growing seasons. Sow diverse, locally appropriate seeds into the upper layers. Many native grasses need limited watering and a year, to begin performing.

8. Do Not Over Seed: More is not better. Over seeding will result in nutrient depletion from over competition. This seed mix is only intended as an initial stabilizer. Thick grass performs poorly by encouraging runoff.

9. Stabilize With Jute Netting: Natural fiber jute netting temporarily stabilizes soil structure by performing as a root/stem system and native seed capture grid. We recommend pre-cutting the four foot wide netting in 20 to 30' lengths. Two person installation teams <u>help</u> avoid destabilizing the <u>previously</u> completed surface layers. Install the upper netting edges along the outer edge of each infiltration terrace. On shallow slopes, we may only use a single width of netting, installed directly beneath each terrace.

10. Secure the Netting: Ground staples secure the top, center and bottom edges of the netting. Install staples on the vertical plane, not perpendicular to the slope, at 4-foot offset centers. We use biodegradeable cornstarch staples.

11. A Note on Bioengineering: The upper soil layer will reflect atmospheric moisture and temperature extremes. Intentionally bioengineered, constructed layers provide protective lower, root area layers from these moisture and thermal spikes for stable root growth. Jute netting seems to contribute best when used above the mulch layer and just below any elective, top cover.

12. A Note on Biodiversity and Micro Habitats: Consistent profiles should be avoided. Nature is sporadic; we want to mimic this natural randomness. Thus, inexactness in the application of slope layers, and lumpy, articulated surfaces should be expected. These features create microhabitats, which contribute to plant and insect biodiversity. Site biomass, in the form of downed tree limbs and branches, can also contribute to slope structure and habitat diversity.

13. *Native Plantings:* Planting during seasonal moisture periods mimics native germination windows and enhances survivability. Indigenous plantings and plugs, reflecting native vegetation diversity and density, can be directly dug in. Upslope plantings assist in downslope reseeding.

14. Habitat Restoration Matrix: Site specific, ground cover grass seeds, plugs and woody stems are critical players. Lower understory woody stems should be the limit of vertical articulation. We have also been experimenting with reintroducing native wildflowers to Cape Cod as a matrix component.

15. Use of Top Cover: More is not better. Over covering blocks sunlight, reduces air exchange and redirects rainwater. Randomly spread a thin top covering of leaves, grass, evergreen needles or straw across the netting. 60% cover protects root layers from atmospheric, thermal and moisture spikes.

Images by G. Peabody. Top cover should link restoration to local habitat.

III. Two Techniques for Very Steep Slopes

1. Working on Very Steep Slopes: The interaction of effective infiltration strategy and successful native vegetation is necessary for sustainable stabilization on Very Steep Slopes. We have presented two, proven, illustrated systems for your consideration. We do not recommend mixing these systems. A higher level of attention is necessary when physically performing mitigations on Very Steep Slopes.

2. Control Vertical Access: Vertical foot traffic may create irreversible erosion impacts, which are avoidable. Even walking on the flats of your soles will risk destabilizing surface integrity. Use extension ladders to provide vertical access. They can be paralleled to access sequential areas. Extension ladders easily accommodate slopes 40 to 90 feet long. We recommend using oak stakes to secure the ladders every 10 feet on very steep slopes, to prevent sliding and where possible consider access from the bottom of the slope.


Images by G. Peabody. Using properly secured ladders protects the project.

***3. Very Steep Slopes may be inappropriate for benching*:** Benching may risk destabilizing overall surface performance and integrity.

***4. Control Horizontal Access*:** Use ladders for horizontal access. These need to be carefully set down, using control ropes, as shown in the image. Once these are staked in place every ten feet (stakes driven vertically not perpendicular), they provide a productive work platform. Horizontal and vertical ladders can be joined to create a working grid to access the entire slope without stepping on slope surface

Images by G. Peabody. Proper set up and use of ladders protects workers.

<u>Technique One</u>: Very Steep Slope Stabilization with Fence and Netting:
Lines of thin slat fencing 8-10 inches high are cut from snow fencing. A fifty-foot long roll of 4 foot snow fence will produce five sections (250 feet) of 8-10 inch high fence, with one line of connecting wire per section. Lines of this fencing are set vertically into the slope using rubber mallets. The fence lines are spaced approximately 4-6 feet apart.

Images by G. Peabody. Limited use of very short fencing helps stabilize site.

Several inches of native compost are added gently to the slope. Jute netting is ground-stapled over the compost and over the very short fencing.

Images by G. Peabody. Stages in the bioengineered, slope stabilization process.

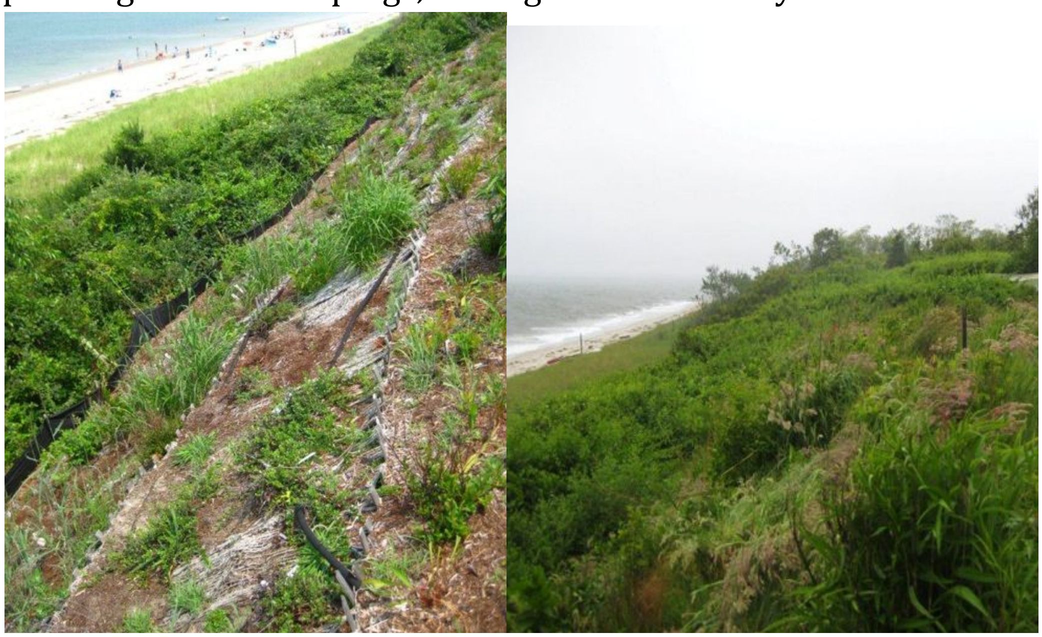
At this point we usually do an initial planting of potted native plants. If social and permitting restrictions require us to work under threat of drought, we include a temporary drip irrigation system, which goes on with a timer, 1 hr. each morning.

Images by G. Peabody. On this site we planted woody stems through netting.

After the first planting and installation of drip hoses we blow in native mulch over the site, about 2 inches thick. Using the mulch blower limits our liabilities from over-activity on very steep slopes. This mulch layer provides a safety envelope to prevent atmospheric moisture and temperature spikes from impacting new root growth on the underneath layers.

Image by G. Peabody. Blowing in mulch significantly reduces site impacts.

Once the bioengineered stabilization system of short fence, compost, netting and mulch is in place, the slope assumes a greater stability and we finish planting with native plugs, mixing soft and woody stems for diversity.



Images by G. Peabody. Same coastal bank site, images one year apart

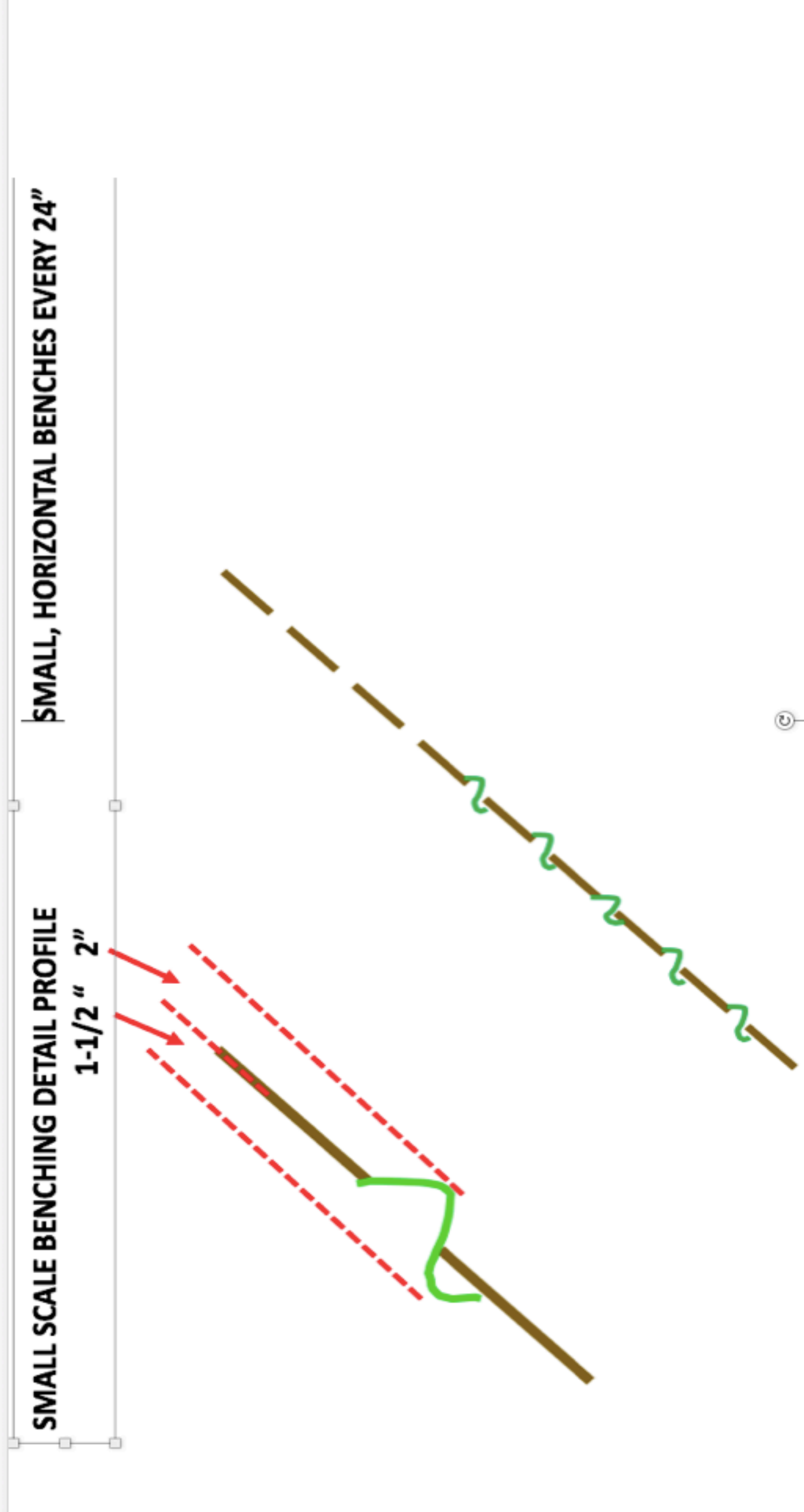
Slope stability and sustainability increases exponentially, during the first few years, as evident in the case study shown here, in Brewster, MA. This is a model and not intended to supersede the requirement for site specificity.

<u>Technique Two</u>: Very Steep Slope Stabilization with Articulation-Shelving:
Very Steep Slopes may be destabilized by benching and we do not recommend attempting that technique. Some coastal habitats are characterized by low-density vegetation but high percolation geomass. Stabilization techniques in these areas should focus on minimizing and mitigating storm water sheet flow. We recommend an innovative technique we refer to as "Slope Articulation", or "Shelving". This innovative technique creates an infiltration matrix of multiple small (24"-36", tilted into slope) shelves, randomly placed over the slope surface. Cumulatively, these articulated areas perform using the same principles as benching, without inviting cross slope consequences.

Images by G. Peabody.24" shelving, using a trowel, forms downslope berm.

We often utilize the random shelving, to plant native vegetation. This enhances storm water retention and infiltration performance. This shelf could use more back slant.

Technique 3: Minimal benching strategy



Technique 3: Minimal Benching with more frequent mitigation points to maintain close control of slope runoff