Land Management Program

Erosion Control Techniques and Permitting Processes

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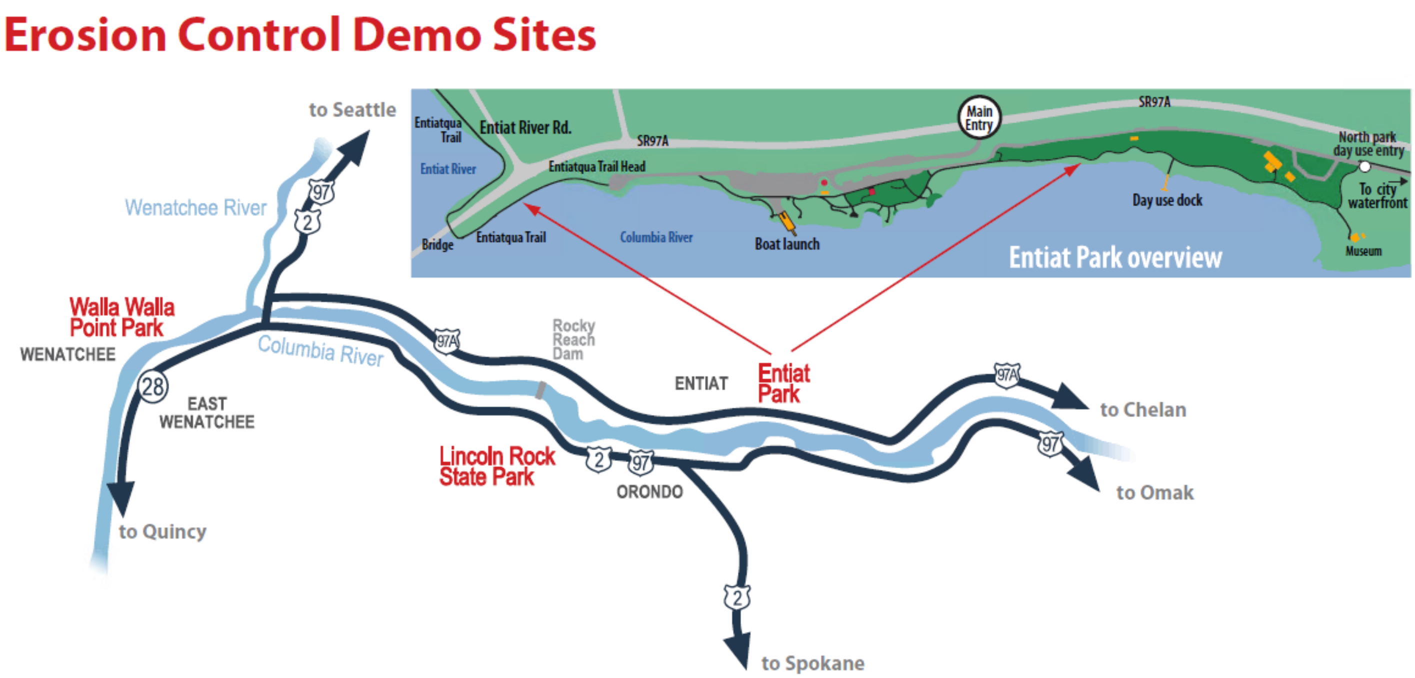
APPENDICES

SECTION 1: PURPOSE AND INTRODUCTION

The intent of this report is to aid landowners in planning and obtaining permits for erosion control work that may be needed on their property. To accomplish this aim, this report provides information, current at the time the report was prepared, on generally accepted erosion control techniques and on the process that landowners must go through to obtain permits for such work.

It is not the intent of this report to provide complete, detailed information on design of erosion control work, or to provide designs that are pre-approved by permitting agencies. There is enough variation from one site to the next that some adjustment of details will likely be required based on a thorough knowledge of the principles involved in the design. Similarly, because of variations between sites and changes in regulations over time, it is not feasible for permitting agencies to pre-approve a design for any site.

Per Chapter 1: Rocky Reach Shoreline Erosion Management Plan of the Rocky Reach Comprehensive Plan, the Public Utility District No. 1 of Chelan County (Chelan PUD) is required to "…select four sites at which to perform erosion control work with the intent of demonstrating a variety of appropriate, permissible techniques to the public" during the first 20 years of the current license term. The four demonstration sites are located at Entiat Park, Entiatqua Trail, Lincoln Rock State Park, and Walla Walla Park. The four sites are accessible easily by the public, which was important for selecting these sites. Erosion control work has been completed at all demonstration sites. At each location, information is provided on an interpretive sign detailing the methods used and how to access more information regarding erosion correction and control methods. Information provided includes figures demonstrating bio-engineering erosion control techniques, causes of erosion, a brief description of bio-engineering erosion features and environmental benefits, and the Chelan PUD webpage address for public access to this document.



SECTION 2: PERMITTING AGENCIES AND PROCESS

Landowners wishing to repair shoreline erosion or take steps to prevent further erosion must obtain permits or approvals from several agencies, including the Washington Department of Fish and Wildlife (WDFW), the Chelan County Planning Office (Chelan County) or the Douglas County Planning Office (Douglas County), Washington Department of Ecology (Ecology), and the U.S. Army Corps of Engineers (USACE). These agencies are required to uphold county, state and federal regulations dealing with construction or earthwork near or below the normal high water line. Some are also required to consult with, or follow, requirements of other agencies.

One of the first steps in obtaining permits needed for erosion control work is to arrange for representatives of WDFW and USACE to visit the site to discuss the planned work and alternatives for accomplishing it. The WDFW's requirements are explained on their web page. Starting with this step, rather than with submitting an application, can save the time and effort needed to revise and resubmit an application after the agency staff visit the site. After visiting the site with WDFW and USACE staff, the landowner should have a better understanding of what requirements need to be addressed in the permit application.

The number of agencies involved, and the fact that each agency may be interested in a slightly different aspect of the work, can make the permitting process seem daunting to many landowners. Fortunately, the agencies involved have developed a common permit application form called the Joint Aquatic Resource Permits Application (JARPA). The JARPA form can be used to apply for Hydraulic Project Approvals (WDFW), Shoreline Management Permits (local county), Water Quality Certifications (Ecology), and USACE Section 404 permits. Filling out and submitting this form will allow the landowner to address the information needs of multiple agencies with a minimum of effort. The form and instructions are available on-line from any of the permitting agencies.

SECTION 3: SELECTING A METHOD

There may be several methods that could be used to control erosion on any given site, but not all will be equally effective or equally acceptable to the owner. To select the best method, the landowner must consider the goal of the work, available resources, site characteristics, and the goals and requirements of permitting agencies.

The goal of the work may be stated in terms of the desired degree of protection or repair of the site. The landowner must consider whether it is sufficient to provide protection for a slope's toe, with the idea that if the toe is protected from further erosion, higher parts of the slope will stabilize over time. Alternatively, a more complete, immediate stabilization and rehabilitation of the entire slope may be needed. The more complete approach might include more effort directed toward slope stabilization and revegetation above the high water line and may be more appropriate in situations where minimizing additional loss of land is critical. This must be balanced with resources available to support the work. Protection only at the toe may be more appropriate where resources are limited and it is acceptable to wait for the upper parts of a slope to reach a stable angle and stabilize.

Site characteristics that are useful in planning and designing erosion control efforts include such things as wave height and direction, the presence of surface runoff or seepage, steepness and configuration of slopes, soil type, and anticipated use of the site. The importance of each of these factors is discussed briefly below.

Wave height and direction are important because wave energy increases with height. As a result, larger waves require larger rocks to resist movement. Also, larger waves reach higher on the shore (wave run-up). Protection should extend above the level commonly reached by waves. Wave direction is also important because waves that strike the shore squarely have a greater impact on the shoreline than those that strike it obliquely. Since some techniques are appropriate for sites with smaller waves, but not for sites with larger waves, it is worthwhile to observe and consider carefully how waves typically approach a site and to measure or estimate common maximum wave heights.

Surface runoff and seepage can make a significant difference in erosion and must be dealt with separately from wave erosion. Surface runoff from natural drainage, irrigation, roads or other sources can remove soil from slopes and prevent establishment of vegetation, making efforts to stabilize the slope’s toe and face more difficult and less effective. Provisions should be made to direct surface runoff away from eroding slopes, to control its velocity, and to dissipate its energy in harmless ways, such as using splash blocks.

Whether from natural groundwater or irrigation water, seepage exiting a slope can destabilize a slope or eroding face. The saturated soil is heavier and weaker than it would otherwise be which can lead to slumping or sloughing of soil from steep slopes. Also, seepage can remove fine soil particles, gradually weakening soil slopes. Seepage can be addressed in some cases by diverting water higher on the slope before it infiltrates the ground. In other cases, it can be drained from the slope in a safe, controlled manner before it reaches the surface. This may require drilling or constructing drains and can be relatively expensive. Seepage can also be addressed by adding a filter and a berm of free-draining material at the slope’s toe. The filter allows water to leave the slope while holding soil particles in place, and the berm increases stability of the slope.

The steepness and configuration of slopes above and below the high water line are important in selecting and designing an erosion control method. Specifically, the height of the eroding face, the slope angles of the face, and the areas above and below it are useful information in selecting and designing erosion control measures. Eroding faces that are relatively high and steep or undercut may require methods that provide support to improve their stability. Faces that are relatively low with upper slopes that are gently sloping may require only protection from the impact of waves and little support to improve their stability.

Sites with broad, gently sloping beaches benefit from the fact that the gently sloping shore absorbs wave energy. As a result, these sites can be treated using techniques suited to smaller waves. Sites with steep slopes in the drawdown area do not benefit from as much energy dissipation and so require more substantial toe protection. The soil type in the drawdown area can give a good indication of whether the site gains protection from a gentle slope. Gently sloping beaches that offer this protection will typically be sandy rather than covered by gravel or cobbles. Slopes covered with gravel, cobbles and boulders are typically steeper and offer less protection from approaching waves.

Soil type affects how easily soil is eroded and the slope angle at which it is stable. For example, soils that are predominantly sands and silts usually erode more easily than either clay soils or coarser soils that are mainly gravel and cobbles. Also, soils with higher density or composed of coarser, angular particles will remain stable at steeper slope angles than loosely packed soil or soil with smaller, rounded particles. As a result, the soil type influences how well a site must be protected from waves and what slope angle it can reasonably be expected to maintain.

Site use should be considered in selecting and designing erosion control measures. Designs for heavily used recreation sites must take into account the impact of additional foot traffic and also possible hazards to people on foot, swimmers and boaters. Such considerations are much less relevant at more remote sites that are seldom visited.

SECTION 4: THINGS TO AVOID

Impermissible designs: The list of things to avoid starts with the pitfall of planning work based on techniques that are not permissible. Before starting detailed planning and design, it is worthwhile to talk with representatives of WDFW and USACE to make sure that the approach being considered can be permitted. Such pre-planning conversations are a good investment of time because the regulations that the agencies must enforce change periodically. As a result, methods that were accepted a few decades ago, or even a few years ago, may not be permissible now.

Bulkhead walls: A prime example of how regulatory standards have changed over time is the vertical or near-vertical bulkhead wall. A few decades ago, these were considered acceptable and were preferred by many landowners for a variety of reasons. Within the past several years, however, as bulkhead walls became more and more common, their drawbacks became more obvious and more of a problem both to landowners and to agencies responsible for protecting the aquatic environment.

Vertical walls do not absorb wave energy, but reflect it. As a result, they tend to cause scouring of the area in front of the wall and, unless they are designed appropriately, undercutting of their own foundations. They may also encourage higher erosion rates on adjacent parts of the shoreline. These are problems for landowners. The scouring action tends to remove the finer soil particles from in front of the wall and the shape of the wall makes the edge of the water very abrupt, with no shallow water and fewer irregular surfaces than a natural shore. These are problems for permitting agencies because they reduce the quality of key parts of aquatic habitat.

For this reason, construction of new bulkhead walls is not being permitted, and even replacement-in-kind of existing walls is being discouraged, except with modifications to address some of the drawbacks. To be successful in obtaining permits to build a vertical wall, a landowner will have to be able to persuade agency staff that there are valid reasons for use of this approach and that other approaches will not work or are not appropriate for the particular site. Further, if a wall is permitted, the landowner should be prepared to include items in the design that will make up for (mitigate) the negative effects of the wall. Similarly, any erosion control method with a steep face can be used only if it can be justified for the particular site and if appropriate mitigation is included.

<u>Gabions</u>: Gabions, another impermissible approach, are wire baskets, rectangular or tube-shaped, which are filled with rocks to form a larger mass. They allow a large mass to be constructed in areas where large rock, or equipment to handle it, are not available. Their use below the normal high water line is not favored by some permitting agency staff due to fears of possible fish stranding and also because of the poor performance of past gabions installations that were poorly designed or constructed. If gabions are used, care should be taken to select the appropriate type and to use them in accordance with the manufacturer's recommendations.

<u>Plants alone:</u> In researching erosion control techniques, you are likely to encounter the term "bioengineering." This term is used to describe a wide variety of methods. One of the concepts it is used to denote is the idea that erosion should be controlled by means of plants alone. In some settings, this approach may be appropriate, but few plants can hold their own against the waves. Logs or rocks (rocks last longer) should generally be included in designs to absorb wave energy and provide some protection for plantings. The possible exception may be a site with a broad, very gently sloping beach which can absorb most wave energy before it reaches the high water line. Also, plants generally will not provide an overall remedy for a slope that is unstable.

<u>Methods unsuited to the site</u>: A great deal of information on bioengineering and erosion control methods is available in books, from the Internet, and from permitting agency staff. Most of the methods and designs presented were developed for stream banks or, at best, for lakeshores with relatively gentle slopes.

One factor that affects suitability is that methods developed for stream banks are designed with the load of river currents in mind. Also, along many streams, the slopes being protected are relatively flat, with substantial soil deposits. Logs and other components can be anchored by being partially buried so they project out of the bank into the stream. The shoreline of local lakes and reservoirs is often relatively steep and, even where enough soil exists to allow for such burial, the excavation needed could easily destabilize the slope, resulting in more of a problem than the erosion.

<u>Too-small rock</u>: In placement of riprap for erosion protection, care should be taken to select a size of rock that will be stable under the impact of waves present at the site. Small rock is easier to handle, but also easier for waves to move. As a result, repairs with rock that is not large enough will not last.

<u>Lack of filtering</u>: A factor that is easily overlooked in design and construction is that of filtering to keep underlying soils in place. If large rock is placed on a sandy bank that is eroding, waves and runoff can still wash smaller soil particles out between the larger rocks and undermine the repair. To make the repair last and perform well, it is critical to place something between the underlying soil and the riprap to "filter" those small soil particles and keep them in place. The filter may consist of layers of intermediate-sized soil (sand or gravel of appropriate sizes) and/or filter fabric. Filtering based on sand and gravel with the right gradation requires some careful design and construction work. A simpler approach is to use filter fabric (non-woven geotextile) covered by a layer of gravel. The gravel protects the fabric from the large rock and from sunlight, but does not have to meet strict gradation requirements as it would if it were serving as the filter. The advantage of filtering using layers of sand and gravel is that it facilitates inclusion of plants in the design, which is more difficult where filter fabric is used.

Ends and edges: The stability of some erosion control techniques is dependent on maintaining continuity. These repairs can be unraveled by waves, starting at an edge or at any gap. It is particularly important to carefully plan and construct the ends and lower edge of repairs using such techniques. As an example, consider a wall of hand-placed rock. Such a wall is built of rocks that may be smaller than the ideal simply to allow handling and placement of the rocks. Individually, many of the rocks used could be moved by waves at the site, but together they can withstand the wave action. There are examples of such walls around the area that have survived for decades, however, rocks at the edges of such repairs are more susceptible to being moved. Similarly, any gap created in such a repair provides new “edges” for waves to work on. Where such materials are used, it is important to place the bottom edge below grade or protect it with an apron, and to curve the ends into the shore. Also, rocks along the edges should be as large as possible to avoid unraveling.

Even where techniques are used which are less susceptible to unraveling, they can still be undermined if inadequate attention is paid to toe protection. This can take the form of placing the bottom edge below grade, placing an "apron" in front of the structure to blend it into the existing surface, or both.

Lack of maintenance: Any erosion control method should be assumed to need periodic inspection and maintenance. A careful inspection should be made at least annually, and a conscious effort should be made to notice and evaluate any changes each time the site is visited. It is much easier to make minor repairs to address problems while they are small than to reconstruct an entire structure that has failed due to neglect.

Resources

Permitting: Washington Department of Ecology provides a great deal of helpful information on permitting requirements and possible designs.

Bioengineering: University of Nebraska, provides helpful information.

Streambank and Shoreline Protection, Chapter 16 of the National Engineering Handbook (NEH), Part 650, National Resources Conservation Service, USDA, 1997.

APPENDIX A: SUMMARY OF TECHNIQUES

This appendix provides a summary of several erosion control techniques in an effort to provide information that will assist landowners in selecting methods most appropriate for their site and in avoiding impermissible designs. **This information should not be considered adequate for final design of erosion control work and the inclusion of a method here should not be considered to imply that the technique will be automatically permitted for a given site.**

It is not the intent of this report to provide complete, detailed information on design of erosion control work, or to provide designs that are pre-approved by permitting agencies. There is enough variation from one site to the next that some adjustment of details will likely be required based on a thorough knowledge of the principles involved in the design. Similarly, because of variations between sites and changes in regulations with time, it is not feasible for permitting agencies to pre-approve a design for any site.

The techniques included are:

- Plants only
- Live fascine
- Anchored logs
- Riprap
- Rock wall
- Cribwall
- Perched beach
- Drift sills

A.1 Plants Only

Description and applications: The use of plants, without other materials, to prevent or resist erosion is attractive in many ways, but does have its limitations. Once established, plant roots tend to stabilize the soil in which they grow, and their stems impede soil particle movement and slow the flow of water. This approach is useful along streams or drainage channels at levels which are reached by intermittent flow.

Sites where plants alone can make a significant contribution are those with very broad, flat slopes in the drawdown zone. These beaches absorb much of the energy of waves approaching the high water line so plants at that level are somewhat protected. Small trees or shrubs at the high water line on such sites can provide significant protection to the toe of the slope behind them, and also improve the site's appearance by hiding any eroded slope that is present.

Even at the locations at which plants alone are successful in slowing erosion, the results would be improved with the addition of some other materials to protect the plant roots. For this reason, information on use of plants emphasizes their use in conjunction with other techniques. Please see Appendix B for more information.

Resources

U.S. Department of Agriculture: database of plant information.

The home page for the Natural Resources Conservation Service and the page for Washington State provide helpful technical information on plants and erosion control techniques.

NRCS associated with WSU in Pullman, WA Plant Materials Center.

A.2 Live Fascine

Description and applications: Live fascine (rhymes with machine) is a term used to denote bundles of stems or limbs taken from live trees or shrubs, commonly willows or red osier dogwood. These are anchored at the high water line, along the toe of a slope very much like logs. Initially, the bundles provide some protection from waves similar to a log and, over the course of a few years; the live limbs take root and establish a thick stand of willows and/or other plants. They could also be used effectively in combination with logs.

Like logs, live fascine is expected to be most appropriate for protection of sheltered sites or sites with relatively flat slopes in the drawdown area. Unlike logs, they include the benefit of providing some re-vegetation and, where successful, being self-sustaining.

This method is not appropriate for very steep sites where waves reach the high water line with little loss of energy. At such locations, live fascine would be expected to provide some benefit, but may not last. The other possible limitation of this method is it produces a shoreline lined with willows or similar trees. This may not be ideal for all sites, but may be dealt with by periodic heavy pruning, which also keeps the plants vigorous.

Materials and equipment: Required materials include bundles of fresh live limbs and stakes or other means of anchoring them in place until they take root. Equipment needed includes shovels, hammers, and a backhoe or excavator, if desired, to assist in handling bundles.

Design factors: Factors to consider are similar to those for anchored logs. The live fascine should be anchored at approximately the high water line, at the toe of the eroding face. The bundles are often anchored using 2 foot to 3 foot long tapered stakes. Bundles should be large enough in diameter to block most waves at a site. To handle wave run-up, bundles should extend above the ground an amount roughly 1.25 times the wave height at the high water line. This means that if 1 foot waves commonly reach the high water line at a site, bundles about 15 inches in diameter, or multiple bundles, are preferable for blocking wave run-up. For sites with large enough waves, this will become impractical and another method should be selected.

Maintenance: Bundles that fail to take root should be replaced. Regular inspections should be made to watch for areas being undercut so they can be protected using rocks or logs. As plants mature, significant pruning or periodic cutting back to stumps may be helpful in maintaining vigorous growth.

Resources

Live Fascines: Construction guidelines for placing long bundles of live woody vegetation in shallow entrenchments parallel to the flow of the stream. Ohio Department of Natural Resources.

Franti, T. G. 2013. Bioengineering for Hillslope, Streambank and Lakeshore Erosion Control. NebGuide, University of Nebraska.

A.3 Anchored Logs

Description and applications: Logs anchored along the high water line have been used successfully to resist erosion at several sites.

At sites with relatively low eroding faces and gentle slopes in the drawdown area, or sites that are well sheltered from large waves, logs anchored at the high water line may provide the necessary protection to control erosion of the toe and allow the shoreline to stabilize. At sites with steeper slopes and larger waves, logs may not be sufficient, but can still be beneficial in absorbing some wave energy.

Logs can be easier than riprap to walk on and harder for people to move, though logs can become slick when wet. Their main disadvantage may be that they don't last as long as rocks.

Materials and equipment: In addition to logs, materials needed include some way to anchor the logs. This may be done using soil anchors suitable for driving into or burying in rocky soil, and chains or cables for connecting the anchors and logs. Alternatively, large rocks may be used to anchor logs, but some means of connecting the two is still useful. This can be done using eye-bolts with expansion shells or grout, as are used to anchor bolts in concrete.

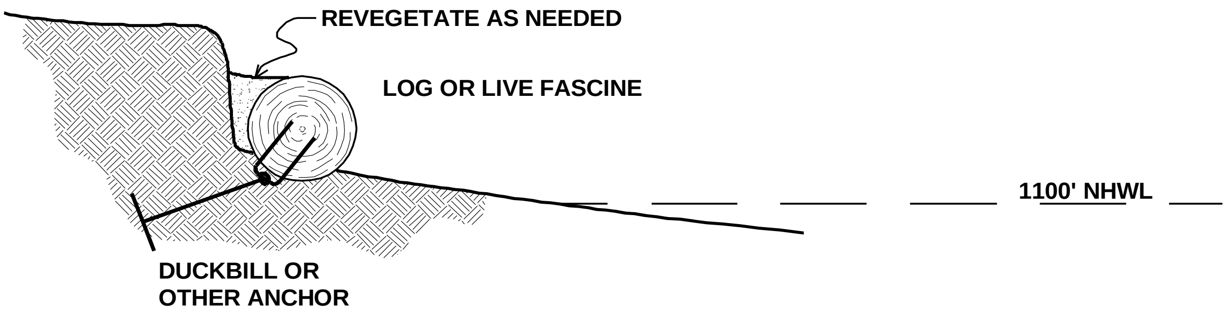
In most cases, an excavator or similar equipment will be needed to handle the logs, including partial burial. An excavator can also be helpful in placing anchors or handling large rocks if those are used as anchors. If rocks are used for anchors, a hammer drill will be needed to drill holes for inserting eye-bolts.

Design factors: Logs should be chosen with a diameter sufficient to block most waves at a site. To handle wave run-up, logs should extend above the ground an amount roughly 1.25 times the wave height at the high water line. To protect against undercutting, roughly 1/3 of the log's diameter should be buried. This means that if 1 ft waves commonly reach the high water line at a site, a log almost 2 ft in diameter is preferable for blocking wave run-up. If this is not feasible, 2 or 3 logs can be bundled together to form a larger mass. For sites with larger waves, this will become impractical and another method should be selected. The logs should be placed at approximately the high water line, at the toe of the eroding face.

Maintenance: Regular inspections should be made to watch for signs of anchors working loose and to keep track of deterioration of logs with time.

Resources

Bioengineering for Streambank Erosion Control; Report 1: Guidelines, Allen, H., and Leech, J. R. (1997), Technical Report EL-97-8, U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS, page 29.



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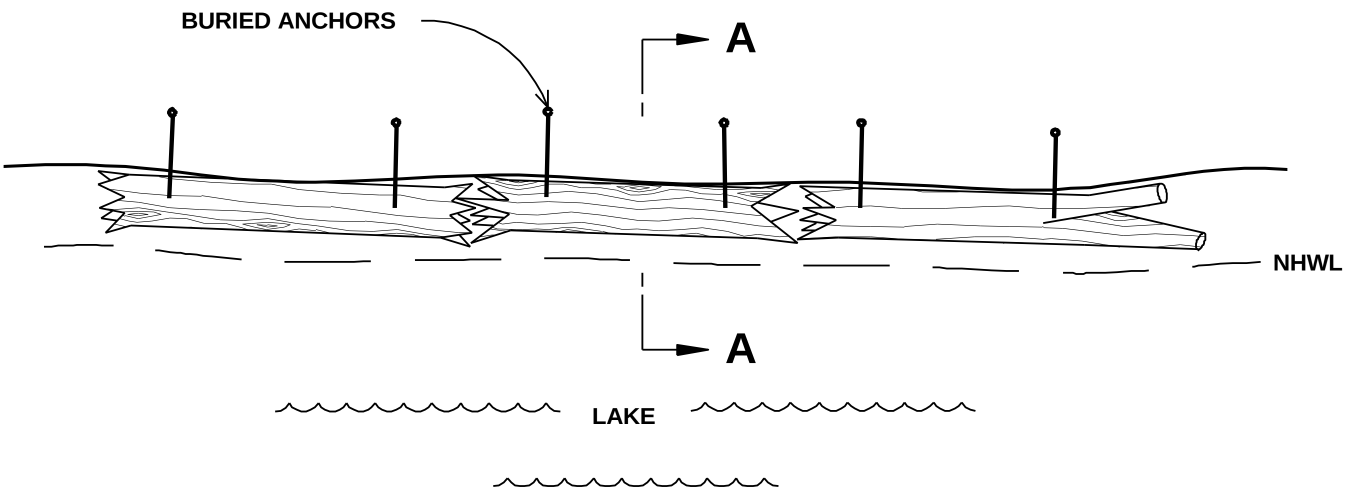


PLAN VIEW (NTS)

ANCHORED LOGS
LIVE FASCINE

A.4 Riprap Revetment

Description and applications: A riprap revetment relies on a layer of large rocks to absorb wave energy and protect the soil beneath it. The rock can be placed and fitted together by machine, by hand, or by a combination of the two. Beneath the layer of large rocks is a layer of smaller cobbles and gravel which cushions a layer of filter fabric. The filter fabric allows drainage but prevents water from removing soil particles between the larger pieces of rock and undermining the riprap. The final slope of the rocks is variable, but is generally required to be 2H:1V or flatter. Slopes of 3H:1V or flatter are preferable.

Riprap has the advantages of being able to handle large waves and steep slopes, being placeable largely by machine, and being flexible so that it can accommodate some deformation with time. It is suited for steeply sloping sites, though it does require a sufficiently flat and stable toe area to avoid sliding or rolling of the rocks at the base. It is also well suited to very exposed sites subject to large waves. For very gently sloping sites subject to smaller waves, other techniques may be more cost-effective.

Despite its appearance, well-placed riprap is not just dumped. During placement of riprap, care should be taken to work the pieces into place to avoid leaving loose pieces that can rock or shift easily to leave gaps. This effort makes the riprap more stable under the impact of waves and also more stable, and safer, when people walk or climb on it.

Some variations on riprap as described above include hand-placed riprap, and grouted riprap or grouted boulders. Hand-placed riprap is very much like a sloping rock wall. It requires less heavy equipment, can have a neater appearance and is less likely to include loose pieces since each rock is placed individually. Rock placed by hand may not withstand waves as large as those tolerated by machine-placed rock, simply because rock placed by hand must be smaller.

Grouted riprap or grouted boulders also leave no loose pieces because the individual pieces are placed in a bed of mortar. The result can look very much like a rock wall or regular riprap, but the pieces are not as subject to shifting. For this reason, grouted riprap may be preferred at some high-traffic sites. This method is not as tolerant of deformation as regular riprap since any movement causes the mortar to crack. It may also be more difficult to obtain permits for this technique and use of grout or mortar adds substantially to the complexity of construction.

The current emphasis on “bioengineering” affects riprap by including vegetation among the rocks above the high water line. Willows or other phreatophytes are well suited to this and can be planted as cuttings during the riprap placement.

Materials and equipment: Materials include filter fabric, gravel and cobbles for a cushioning layer, correctly sized, sound rock, plant cuttings for inclusion above the high water line, and pipes to facilitate planting. Sound rock implies rock that will not break down as a result of handling or freeze/thaw cycles. Since a riprap layer depends on rock size and weight to function, rock that breaks down will lead to failure of the riprap installation.

Riprap placement typically requires use of heavy equipment such as excavators and loaders to grade the site (if needed) and to place the gravel layer and riprap. Shovels, hammers and utility knives are needed for placement of the filter fabric.

Design factors: Relevant factors include slope, wave size, filtering, and rock soundness.

- Riprap is commonly placed on slopes as steep as 1.5H:1V, however, permitting agencies strongly prefer slopes of 2:1, 3:1 or flatter because of their greater stability and usefulness as aquatic habitat. In some cases, regrading the site or making the layer of riprap thicker at its base may be necessary to provide this final slope.
- Riprap must be sized according to the size of waves it will experience, layer thickness, slope, rock density, and a few other factors. Angular rock is best. Also, the height to which riprap is placed must be selected to account for wave run-up.
- Riprap layer thickness typically ranges from 1.5 to 2.25 times the average rock size.
- Filter fabric, and a cushioning layer of gravel and cobbles to protect it, are needed to keep native soil in place beneath the riprap layer. As waves surge into and out of the riprap layer, the water can remove finer soil particles and undermine the riprap unless something is done to hold the soil in place. Filters, whether fabric or graded sand and gravel, do this. Fabric is assumed in the sample design because it is simpler to use.
- Rock used for riprap must be sound (hard and dense) in order to resist the impact of waves and the freezing and thawing it will experience. Rock that is not sufficiently sound will break down and require replacement.

Maintenance: Riprap should be inspected regularly so that gaps or thin spots can be repaired early. Riprap does not typically fail suddenly, but does require some maintenance to prevent progressive deterioration.

Resources

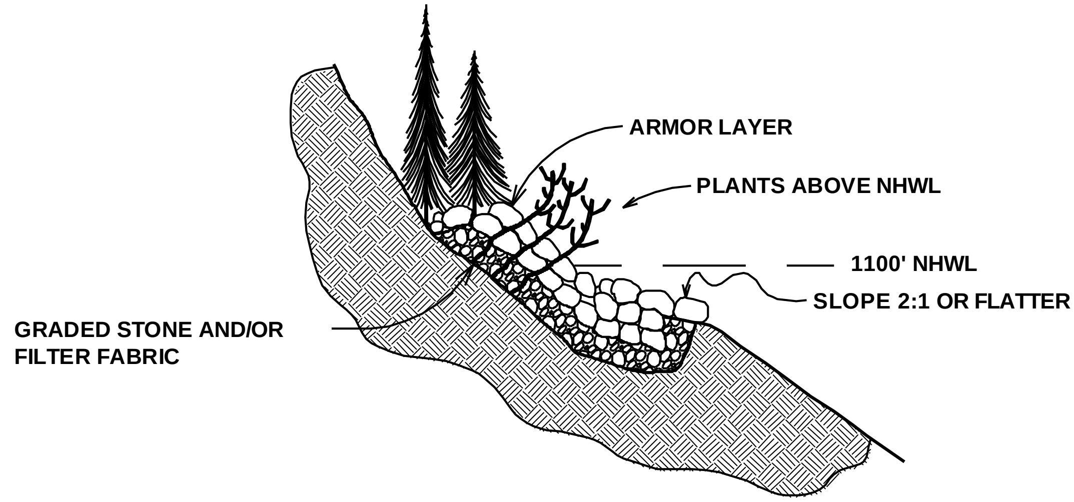
Design of Coastal Revetments, Seawalls, and Bulkheads, USACE EM 1110-2-1614

Engineering and Geotechnical Techniques for Shoreline Erosion Management in Puget Sound, Coastal Erosion Management Studies, Volume 4, Washington Department of Ecology Report 94-77, June 1994.

Streambank and Shoreline Protection, Chapter 16 of the National Engineering Handbook (NEH), Part 650, National Resources Conservation Service, USDA, 1997.

Riprap for slope protection against wave action, Technical Release 69, Soil Conservation Service, USDA, 1983.

Gradation Design of Sand and Gravel Filters, Chapter 26 of Part 633 National Engineering Handbook, NRCS.



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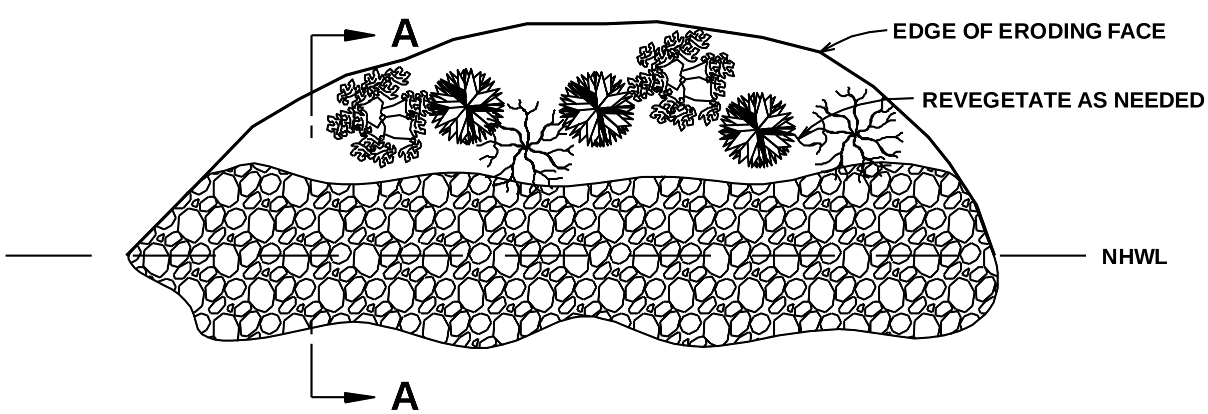


PLAN VIEW (NTS)

RIP RAP REVETMENT

A.5 Rock Wall

Description and applications: Rock walls are structures of carefully stacked rocks, placed by hand or by machine. They are similar in many respects to riprap, but are typically more nearly vertical, with face slopes as steep as 75° to 80°. As with hand-placed riprap the rocks used are generally smaller so that they can be handled by workers. Rock walls are preferred by some landowners as their neater appearance and steep face can make them better suited to some site uses. Rock walls are well suited to sites with steep eroding faces that need to be supported to preserve site features higher on the slope. They can be designed to improve slope stability in addition to protecting the slope's toe from wave action.

Rock walls may be disliked by permitting agencies because steep faces are considered less beneficial for aquatic habitat than an eroding shoreline or some other repair types. As a result, such walls are likely to be allowed only at sites where they can be justified based on the site's use for recreational activities or the shape of the site. Where they are permitted, some mitigation work is likely to be required. Rock walls are also labor-intensive and so can be more expensive than other methods. Finally, constructing a high-quality rock wall is not as simple as it might seem. Fitting rocks together well requires careful work and more skill than might be assumed by the casual observer.

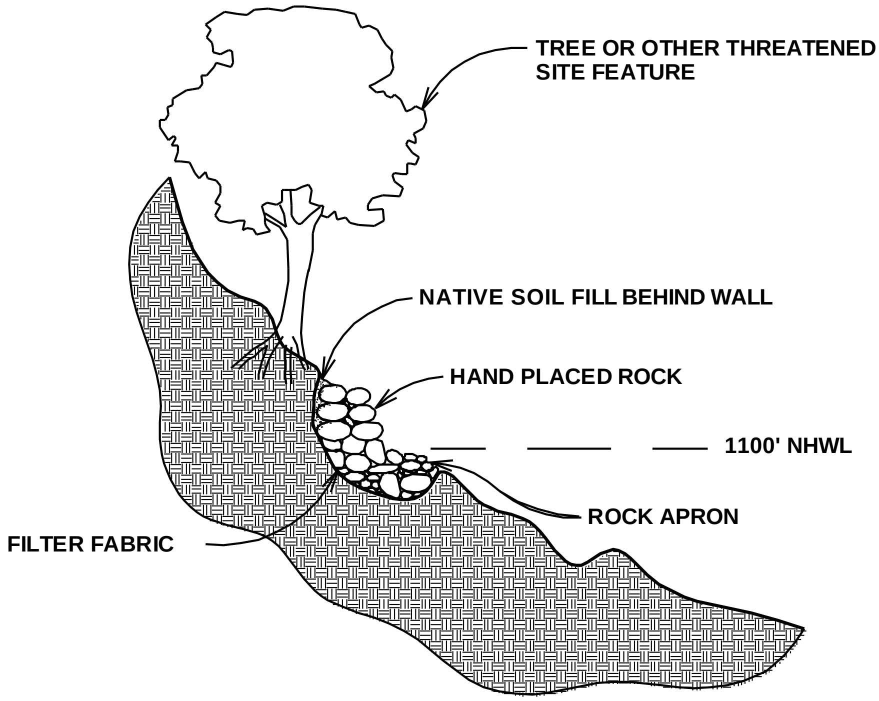
Materials and equipment: Necessary materials include rocks, filter fabric, and soil to fill behind the wall. Excavation equipment can greatly speed up foundation preparation and filling behind the wall. Placing smaller rocks as chinking on the wall's back side is best done by hand.

Design factors: Rock walls can be constructed of rocks placed by hand, machine-placed rock, or a combination. As a result the rock may not be sized for wave height, however, bigger rocks are still better. Walls should be designed for wave run-up and their toes should be protected from undercutting as with all walls. Extending the wall roughly 1.5 times the design wave height above the high water level is generally adequate to address wave run-up. To prevent undercutting, the wall can be extended about 0.5 wave heights into the foundation soil and/or an apron of rocks can be placed in front of the wall. This is especially important on sites where the wall will be founded on more easily eroded soils.

Drainage of water from behind rock walls is also critical, as pressure from accumulated water can destabilize the wall. For this reason, the use of filter fabric on the native soil slope and free-draining fill behind the wall is very important.

Where the wall is also intended to support a marginally stable slope, it must be founded on sound material and it is important to slope the back side of the wall so that the slope's soil rests on it, tending to push it downward. In cases where the wall is expected to make an important contribution to slope stability, design by an engineer is a good investment.

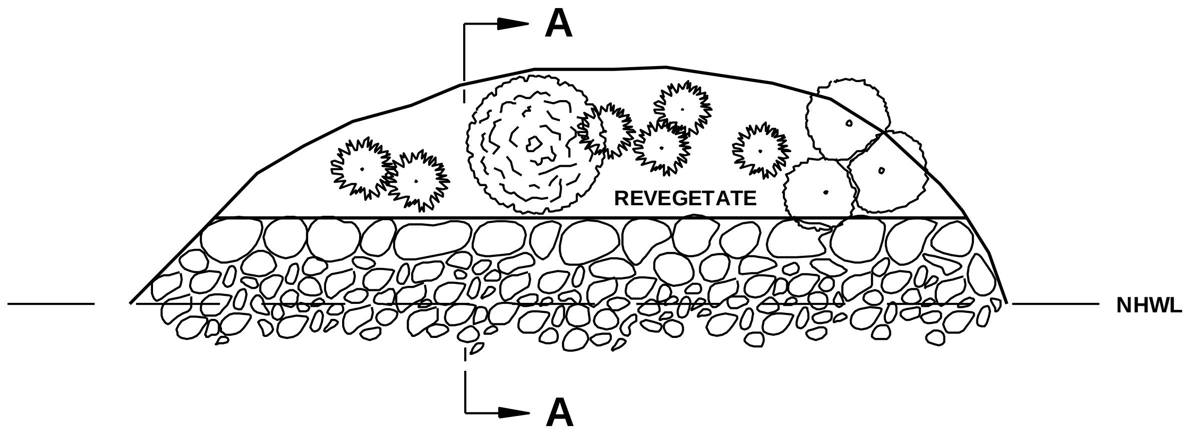
Maintenance: Rock walls require periodic inspection and maintenance. Many of the rocks in hand-placed rock walls are smaller than would be ideal to resist wave energy so it is important to watch for signs of failure at the edges and for missing rocks in the middle. Small failures or missing rocks should be repaired immediately since they can create weak points in the structure and lead to much larger failures.



SECTION A-A

NOTES:

- MINIMIZE SPACE BETWEEN WALL AND EXIST. SOIL FACE.
- FLATTER SLOPE ON FRONT OF WALL IS STRONGLY PREFERRED. SLOPE STEEPER THAN 2:1 ALLOWED ONLY IN SPECIAL CIRCUMSTANCES AND WITH MITIGATION



PLAN VIEW (NTS)

ROCK WALL

A.6 Cribwall

Description and applications: A cribwall is a structure of logs, wood beams, or concrete "ties" that are interlocked to form a retaining structure. They can be constructed so that gaps are left between logs or to minimize gaps. One set of logs forms a face parallel to the shoreline and other logs (tiebacks) project into the shoreline to anchor the cribwall to the fill material behind it.

Cribwalls are suited to steep sites where rock walls would be used, but make use of different materials. They can also be used at sites which lack flat toe areas if the cribbing is anchored to bedrock or other large, stable rocks. They have many of the same advantages and disadvantages as rock walls. Where wood is used, the materials will not last as long as rock. Where gaps are left between the pieces, care must be taken to use fill behind the wall that cannot be washed through the gaps and filtering behind that coarse fill.

Because the face of a cribwall is steep, it is likely to be permitted only for sites where more desirable alternatives are clearly not workable. Mitigation measures are likely to be required with a cribwall.

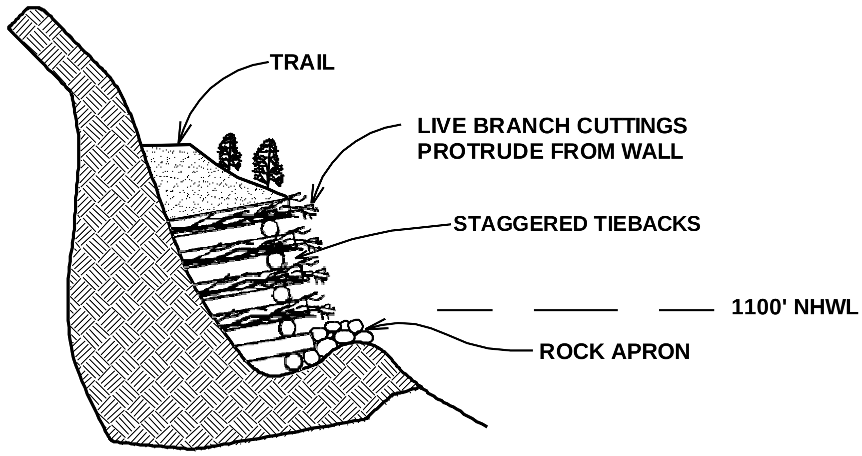
Materials and equipment: The pieces of the cribwall can be wood timbers, logs, or concrete beams. Coarse fill and filtering material are needed behind the cribwall. Also, depending on the material and design used, some means of fastening the pieces together may also be required. Rocks are also helpful to form an apron at the base of the wall to prevent undercutting. Foundation preparation, wall placement and backfilling can be completed using hand tools, but can be facilitated by excavation equipment.

Design factors: A cribwall is probably one of the more demanding methods presented in terms of skill required to obtain good results. This is especially true if good appearance is desired. A cribwall and the fill placed behind it form a structure. The wall cannot perform without the support and anchoring of the fill and the fill cannot stay in place without the protection of the wall pieces. This must be borne in mind in planning and constructing a cribwall. The pieces that project into the fill serve to tie the wall and fill together. If the wall and fill are not stable as a unit, this approach will not work. The rules of thumb for wave run-up and protection of the toe are the same as for rock walls.

Maintenance: Cribwalls require regular inspection and maintenance. Things to watch for in particular include loss or settlement of fill behind the wall and deterioration or shifting of the wall's pieces. The connections between pieces on the face and those anchored in the fill are critical. Protecting the toe from undermining is also critical since it can cause instability of the wall as a whole or a loss of fill from behind the wall.

Resources

Ohio Department of Natural Resources, Ohio Stream Management Guide, Live Cribwalls, Guide No. 17.
Ohio Department of Natural Resources, Office of Coastal Management, Chapter 4: Erosion Control Structures.
Streambank and Shoreline Protection, Chapter 16 of the National Engineering Handbook (NEH), Part 650, National Resources Conservation Service, USDA, 1997.

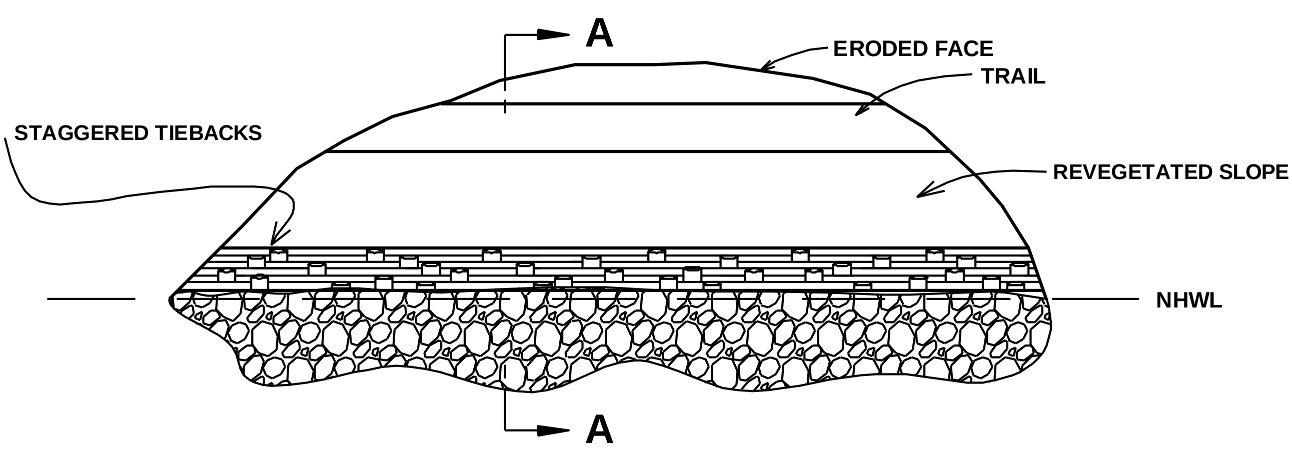


SECTION A-A

VEGETATED CRIB WALL

NOTES:

- THIS METHOD MAY BE SUITED TO VERY STEEP SITES THAT REQUIRE EROSION REPAIR TO MAINTAIN FEATURES SUCH AS TRAILS.



PLAN VIEW (NTS)

CRIB WALL

A.7 Perched Beach

Description and applications: A perched beach consists of sand or gravel fill placed at a stable slope to a level above the high water line. It effectively raises the river bed slightly so that waves impact on a beach rather than reaching the toe of the eroding face at the high water line. Depending on the existing slope and material used, it may require a rock berm placed some distance below the high water line to retain the sand or gravel.

Perched beaches may be appropriate for sites where the slope below the high water line is moderately gentle and for sites where the perched beach can be bracketed on its ends by existing structures or bedrock. It is not appropriate for sites with steep slopes in the drawdown area or for sites where it would form a new peninsula projecting from the current shoreline.

Because of the amount of material required, a perched beach is likely to be a relatively expensive type of repair. It does have some potential benefits, including improving access and providing shallow water for aquatic habitat.

Materials and equipment: If a rock berm is needed to retain the beach, it should be made of sound rock, as would be required for riprap, and will require filter fabric to prevent smaller soil particles from being washed out between the larger rocks. Sand or gravel is required for the beach material. See more of the requirements under design factors. Earthmoving equipment will be needed for efficient placement of the rock berm and beach fill. Depending on access, the material may have to be brought to the site by barge.

Design factors: The rock berm design should take into account the same factors considered in designing riprap. The front face of the berm will need to be 2H:1V or flatter and the rock should be sized to withstand waves at the site. In addition, the backslope of the rock berm, which will be buried by the beach fill, should be sloped at about 1:1 or flatter to improve its stability for supporting the beach.

There is a definite relationship between wave size, soil gradation, and stable slope of a beach. For the same wave size, finer soils will require flatter slopes to be stable. This is one reason why the sandy beaches around the area are flatter than the cobble and boulder slopes. A graph included in Appendix C illustrates this relationship. Consideration must be given to the steepness or flatness of slope that will fit in the space available, and what gradation of material will be stable on that slope when exposed to waves. The choice of beach material is critical to the complexity and cost of the work because the resulting beach slope will ultimately dictate the size of or need for a rock berm. Courser beach material will likely result in a lower cost, overall.

Allow for wave run-up. To be effective, the new beach surface must extend far enough above the high water line that waves do not continue to reach the toe of the eroding slope.

Plants above the high water line improve the stability of the beach and are likely to be required as mitigation for the repair.

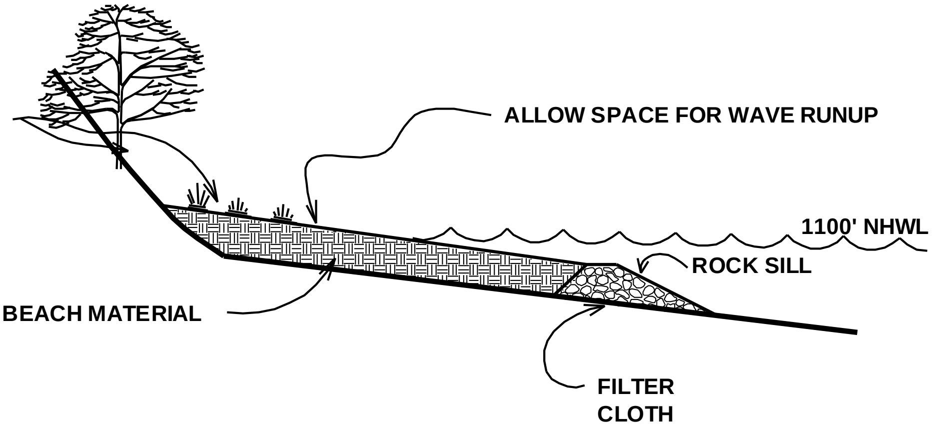
Maintenance: Perched beaches require periodic inspection and maintenance. The rock berm should be inspected and maintained similar to any riprap installation. The beach fill should be inspected to see whether it is being lost and for what reason.

Resources

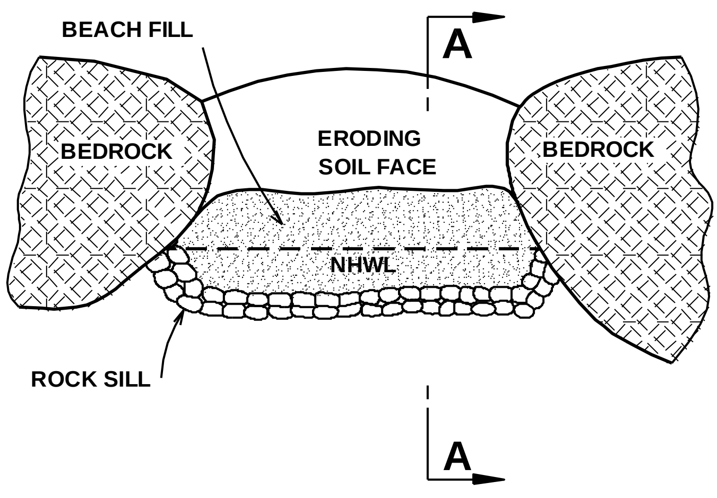
Engineering and Geotechnical Techniques for Shoreline Erosion Management in Puget Sound, Coastal Erosion Management Studies, Volume 4, Washington Department of Ecology Report 94-77, June 1994.

Design of Beach Fills, U.S. Army Corps of Engineers, EM 1110-2-3301, May 31, 1995.

Low Cost Shore Protection, a Property Owner's Guide, U.S. Army Corps of Engineers, 1981. See also, Low Cost Shore Protection, a Guide for Engineers and Contractors.



SECTION A-A



PLAN VIEW (NTS)

NOTES:

- **RAISE BEACH GRADE TO ABSORB WAVE ENERGY BEFORE WAVES REACH THE ERODING FACE**
- **SELECT FINAL BEACH SLOPE AT WHICH MATERIAL USED IS STABLE UNDER WAVE IMPACT.**

PERCHED BEACH

A.8 Drift Sills

<u>Description and applications</u>: Drift sills are rock berms placed perpendicular to the shoreline. They differ from groins in that they do not reach the high water line and can be relatively pervious to waves. Their purpose is different than the other techniques listed in this appendix. They do not provide as much direct protection of the shoreline. Instead they are intended to slow the movement of sand through the site due to littoral drift and to help retain sand in areas that might otherwise not be able to retain sand due to wave energy that is too high. The berms work by absorbing part of the energy from waves that do not approach the shoreline squarely. Also, as they slow the drift of sand through the site, the sand serves to absorb more energy from waves approaching the shore.

<u>Materials and equipment</u>: The material for drift sills consists of rock, such as would be used for riprap. Excavation equipment is required to place drift sills efficiently.

<u>Maintenance</u>:
Drift sills require periodic inspection and maintenance. Most of the maintenance will consist of reshaping berms or adding rock as previously placed rock sinks into the subgrade.

<u>Resources</u>

<u>Coastal Groins and Nearshore Breakwaters</u>, U.S. Army Corps of Engineers, EM 1110-2-1617, August 20, 1992. This manual does not deal explicitly with drift sills, but contains information on similar methods.

APPENDIX B: NATIVE PLANTS FOR EROSION CONTROL

Revegetation is considered an important aspect of erosion control for a variety of reasons.

- Inclusion of appropriate vegetation in erosion control efforts can make them more effective and extend their benefits over a greater area. For example, riprap can protect against erosion at the high water line, but vegetation can be used more efficiently, and at lower cost, higher on the shoreline.
- Plant roots help hold soil in place despite the influence of gravity and surface runoff.
- Vegetation as part of erosion control efforts can be very helpful in addressing the aesthetic impact of erosion.
- Inclusion of plants in erosion control works improves their benefits and value as terrestrial and aquatic habitat. For this reason, inclusion of appropriate vegetation can make it easier to obtain permits for erosion control plans. The concept of bioengineering continues to gain in popularity and a key part of it is inclusion of vegetation in erosion control works.

Given the benefits listed above, it is worthwhile to include plants in planning erosion control work. It is important to select plants that are suited to the site conditions and uses of the site.

A Property Owners Guide to the Use of Native Plans for Erosion Control

Produced by Calypso Consulting
For PUD #1 of Chelan County

October, 2000

Why use native plants in erosion-prone areas?

"Native plants" are plants which are the same species as those which grow wild in nearby areas. Examples of native plants in the area vary from the magnificent Ponderosa pine to wild roses, showy purple lupines, and tiny annual wildflowers. "Non-native" plants are the plants one usually finds planted in our gardens, like petunias, lilacs, cotoneasters, and hydrangeas. "Weeds" are almost always non-native plants, but these plants are usually undesirable for most gardeners and invade both gardens and natural areas. Weeds, like mullein, cheatgrass, knapweed, toadflax, and others, present serious problems for homeowners and land managers, are often unattractive, and provide few benefits for erosion control or anything else.

In general, the long term stability of a slope benefits from a healthy cover of vegetation. Traditionally, fast growing seed mixtures of non-native grasses were used to stabilize steep slopes. However, plants that are native to an area are adapted to local climate and site conditions, and can persist and form self-sustaining plant communities without continued inputs of water and fertilizers. Native plants provide habitat for birds, wildlife, and beneficial insects. Many native plants of the area also have showy flowers and foliage. Additionally, seed mixtures of non-native plants, like "wildflower" mixes, can contain seeds of weedy species that can eventually dominate the erosion control site and even spread to surrounding areas.

Erosion prone slopes in arid areas are harsh environments. It can be difficult to establish new plantings, and plants will tend to grow slowly and often have high mortality in the first few years. However, native plants are likely to outperform non-native plants in the long run. In areas of low rainfall, plants are unlikely to form a solid surface across the slope, but the root systems of even widely spaced plants will help bind and stabilize the slope.

We recommend the use of native plants for erosion control. This document provides guidance and recommendations for:

* site evaluation
* choosing appropriate plants for your site
* recommended native plants
* plant propagation and seed collection
* site preparation
* planting methods, and
* maintenance of your plantings.

We also provide a list of other resources: books, organizations, nurseries, seed companies, and environmental restoration consultants that grow or work with native plants. This list does not constitute an exhaustive list or an endorsement of these sources, nor does this document provide a complete how-to manual for using native plants for erosion control. However, it does provide basic knowledge and resources to begin your project.

Site evaluation

The first step in any erosion control project is a thorough evaluation of the site. Site conditions will affect all of your decisions, from the placement of physical structures to the selection of plants and the site preparation prior to planting. Without an initial evaluation, you may spend a lot of money on plantings that fail and die on your particular site. An evaluation should include, at a minimum, information about *the microclimate of the site, soil chemistry and texture, topography, and surrounding vegetation*. Some questions can be answered by careful observation, while others may require professional services.

The following questions should be addressed before attempting revegetation:

Does your site need physical structures to protect the slope or the base of the slope? Contact a geological engineering company if you suspect the need for physical structures.

What is the average rainfall in your area, and how is it distributed throughout the year?

What is the length of your growing season?

What direction does your slope face? South facing slopes are much dryer than north facing ones.

Is your site unusually windy?

What is the slope of the site? Slopes steeper than 75% may be too steep for most vegetation.

Does the site have a uniform slope, or does it have gullies or benches?

What is the total area of your site?

What is the soil pH, available nitrogen, phosphorus, potassium, and organic matter? This can be obtained by sending a sample to a soil lab or by testing with a home soil test kit. *Optional.*

What is the soil texture? Sandy, rocky, clay? Soil labs will also provide this analysis, but even a general sense is helpful in plant selection.

What vegetation is already growing on the site, if any? Are there weeds on the site?

What native vegetation is growing on nearby stabilized slopes that are similar to your site?

Does the site have a perennial, or an intermittent creek, or are there established drainage areas?

Choosing appropriate plants for your site

Once the site evaluation is complete, and you know the types and locations of physical erosion control structures that may be needed, you are ready to consider the appropriate plants for the site. There are a number of considerations involved in this choice. All the questions in the site evaluation are relevant to the choice of plants, but the most important part of the site evaluation is the list of native plants that are growing on nearby sites that resemble yours. This list of nearby plants represents plants that are most perfectly adapted to the microclimate, soils, and slopes of your site. A county extension agent, Forest Service biologist, or local Washington Native Plant Society chapter may be able to help in the identification of nearby native plants. There are also a number of popular books of eastern Washington native plants. Sagebrush Country, by Ron Taylor, is quite helpful. You can also hire a professional botanist to develop a list of appropriate native plants for your site.

Other considerations in choosing plants for your site include cost, availability, aesthetics, and height at maturity, ease of planting, and stress tolerance. In general, we recommend a diverse mix of shrubs, herbaceous plants, and grasses. Natural mortality or stress may kill some species chosen for the slope, but if you have a mixture of plants, others may survive and thrive. Also, plants with different rooting systems provide different kinds of soil stabilization: fibrous roots, which are characteristic of grasses, prevent surface soil movement; deep taproots help to anchor deep soil layers; and rhizomatous root systems, like those of sumac, form a complex network of roots that prevent gullying. Trees can cause problems on eroding slopes. Although their extensive root systems provide great stability, if they become uprooted they can destabilize an entire slope. Annuals, like the plants in many “wildflower” seed mixes, or many weedy species, do very little to stabilize a slope.

Native plant landscaping is a relatively new field, so most nurseries and landscapers have little or no experience with or access to native plants. The list of specialty nurseries and seed sources at the end of this document may be helpful. We do not recommend using plants that came from other parts of the United States, even if they are the same species that grow here, since these plants may not be adapted to this area, and may even affect the genetic integrity of wild native plants in the area.

You can collect seed or cuttings from nearby plants (with permission), or you can contract with a native plant nursery to collect seed and/or grow plants for you into “tubelings”. In contract growing the nursery will collect plant material from the area and grow it in their greenhouses to the size you need. This may be initially expensive, but, especially for large projects it’s likely to pay off in the end with increased plant survival and vigor.

Recommended native plants

The following native plants occur widely in the area. Several have also been widely used for erosion control in other areas. Other native plants not mentioned here may also be appropriate for your site, especially if they grow nearby. For a full list of plant species, you may contact the wildlife department of the Chelan PUD.

Grasses

Bluebunch wheatgrass *(Agropyron spicatum or Pseudoroegneria spicata)*
Bluebunch wheatgrass is a large, attractive bunchgrass with fibrous roots and flowering stalks up to three feet tall. It can grow on north or south facing slopes, and is most commonly found with sagebrush or bitterbrush. It is highly drought tolerant and can grow in fine or coarse soils. It is considered a good forage grass for wildlife. It is generally grown from seed. Seed can either be collected or purchased and sown in the fall at a depth of ¼ to ½ inch, 15 seeds per square foot, or seed can be grown into ”plugs” in a greenhouse and planted out. *Recommended methods: sow seed directly or buy/contract transplants and plant out in fall or early spring.*

Pinegrass *(Calamagrostis rubescens)*
Pinegrass is a grass with rhizomatous (trailing) roots that, as its name implies, often grows with Ponderosa pine. It can grow quite densely, but does not flower every year. It would be best on cooler, north facing, less disturbed slopes. It is considered a good forage grass for wildlife. Seed can either be purchased or collected and sown in the fall at a depth of ¼ to ½ inch, 15 seeds per square foot, or seed can be grown into ”plugs” in a greenhouse and planted out. It may also be possible to divide adult plants from other sites and plant the divisions. *Recommended methods: direct seed in fall or buy/contract transplants and plant out in fall or early spring.*

Herbaceous Plants

Yarrow *(Achillea millefolium*)
Yarrow is perennial plant in the sunflower family that can grow up to three feet high and has gray-green, aromatic, finely divided leaves and clusters of cream colored flowers throughout the summer. It has rhizomatous roots and can form single plants or dense mats. It is considered a good plant for erosion control, since it is drought resistant and capable of growing in highly disturbed sites. It would be appropriate for either north or south facing slopes, and would be a good plant to try on the steepest, harshest slopes. It can be grown from seed or propagated by division from adult plants in spring. *Recommended method: direct seed.*

Balsamroot *(Balsamorhiza species)*
There are two species of balsamroot in the area: arrowleaf balsamroot (*B. sagittata*) and Carey’s balsamroot (*B. careyana*). Both are large perennials in the sunflower family with large green leaves and very showy yellow flowers in the spring. They have deep taproots and are used widely for soil stabilization. They grow naturally on steep, open, droughty slopes, particularly on the south facing slopes, and are considered important wildlife forage plants. They can be grown from seed (sow seed in the fall, and cover firmly) or seed can be grown in a greenhouse to one year old plants and planted out. It may take several years for

balsamroot to flower after planting. *Recommended method: sow seed directly on site in fall or buy/contract transplants and plant on site in fall or early spring.*

Goldenrod *(Solidago canadensis)*
Goldenrod is a perennial in the sunflower family with rhizomatous roots and multiple flowering stems up to four feet high that produce beautiful sprays of golden flowers in early fall. Goldenrod generally grows close to water level, so it would be appropriate as a planting at the toe of a slope. It can form mats several feet across. Goldenrod can be grown easily from seed or even more easily from pieces of the rhizome of adult plants. *Recommended method: transplant rhizomes on site in fall or early spring or buy/contract transplants.*

Silky lupine *(Lupinus sericeous)*
Silky lupine is a perennial in the pea family that grows up to 2 ½ feet high and has clusters of bright blue flowers in the spring. It often grows naturally with balsamroot. It has fibrous roots and like most members of the pea family, can "fix" nitrogen in the soil. This quality makes it a very important plant for revegetation, since most soils are low in nitrogen. It is a good forage plant for deer, birds, and small mammals. It may be difficult to establish silky lupine on highly disturbed or barren sites. It can be grown from seed that is directly sown on the planting site or one can take cuttings from side shoots in the early spring, root them, and plant them out. Seed should be treated with rhizobium (that allows the plants to fix nitrogen) prior to planting. Rhizobium is widely available at nurseries. *Recommended method: buy/contract transplants*.

Other herbaceous plants:

Phlox *(Phlox hoodii)* - a showy, hardy plant, but providing little erosion control

Wormwood *(Artemisia ludoviciana)* - a gray, aromatic plant for near water line

Low shrubs

Chelan penstemon *(Penstemon pruinosus)*
Chelan penstemon is a mat forming perennial in the figwort family with leathery leaves and many spikes of dark blue flowers in early summer. It does well in rocky habitats and would be a good choice for planting on or near rock or other erosion control structures, though it can also thrive on open slopes with herbaceous plants. It can be grown from seed in a greenhouse or from cuttings taken in early August and planted out the following early spring. *Recommended method: contract "tubelings".*

Bearberry, kinnikinnik, manzanita (Arctostaphylos species)

There are three species of bearberry that grow in the area: *A. nevadensis* (pinemat manzanita), *A. uva-ursi* (kinnikinnik), and *A. patula* (greenleaf manzanita). The most common is pinemat manzanita. Pinemat manzanita and kinnikinnik are very low trailing shrubs that form large mats on the ground surface. Greenleaf manzanita is a medium-size shrub. All are in the huckleberry family and have attractive foliage, small white flowers in early spring, and red berries that are important for birds and mammals as a food source. Pinemat manzanita and kinnikinnik are excellent for erosion control, and can cover large areas of steep, open ground. They will establish most easily on the north-facing slopes, but could also be grown on the south-facing slopes. The easiest way to grow these plants is by layering (bending living branches down to the ground and staking, then waiting for the branch to root, cutting the connection to the parent plant, and transplanting) or by stem cuttings. Kinnikinnik can also be grown from fall cuttings. Growing from seed can be difficult. *Recommended method: layering and transplanting to site.*

Snow buckwheat *(Eriogonum niveum*)
Snow buckwheat is a perennial member of the buckwheat family that forms low mats of silvery leaves surmounting a deep taproot and produces clusters of white flowers in mid to late summer. It is an excellent choice for the most extreme sites, and has been released by the Soil Conservation Service as a plant for use in erosion control. It is also an important winter food for big game. It prefers open, gravelly habitats, and would be best on south-facing slopes. Plants are easily grown from seed and transplanted out, and it may be possible to direct seed on site. *Recommended method: buy/contract transplants and plant in fall or early spring, or try direct seeding in fall.*

Other low shrubs:

Oregon-grape *(Berberis aquifolium)* - a showy, drought-tolerant plant with bright yellow flowers

Parsnip-flowered buckwheat *(Eriogonum heracleoides)* - bears large clusters of cream-colored flowers in the spring

Shrubs and small trees

Smooth sumac *(Rhus glabra)*
Smooth sumac is sometimes considered an undesirable species, but it is an easily grown, outstanding native plant for erosion control. It is a tall deciduous shrub that tends to form “thickets” due to its long rhizomatous roots. It has divided leaves that turn brilliant red in the fall and dark red fruits that are an important wildlife food source. It prefers open habitats, and could be grown on either north or south facing slopes. It would do particularly well on lower slopes or in small drainages. It is difficult to grow from seed, but can be grown easily from root or stem cuttings. It roots so vigorously that it may be possible to plant cuttings

directly on to a slope. *Recommended method: try root or stem cuttings directly on site in fall or early spring, or buy transplants and plant out in fall or early spring.*

Big sagebrush *(Artemisia tridentata)*
Big sagebrush is the naturally dominant shrub on most south facing slopes. It is a medium-sized aromatic shrub with a deep taproot and silvery leaves. It is highly drought and disturbance tolerant and would be a good choice for a steep, south-facing slope. It can be grown from seed in the greenhouse, from cuttings on upper twigs, or from young transplanted seedlings. *Recommended methods: transplant seedlings or buy transplants and plant out in fall or early spring.*

Bitterbrush *(Purshia tridentata)*
Bitterbrush is a very common shrub in the area. It is a medium-sized shrub (3-7 ft.) in the rose family with a deep taproot, small dark green leaves and small yellow flowers in the spring. It is a major food source for mule deer, and is moderately tolerant of steep, droughty, unstable slopes. It can be grown easily from seed sown in the fall (do not plant deeper than 1 inch), or from cuttings or by layering (see bearberry for description of layering). *Recommended method: seed sown in fall, or buy/contract transplants and plant in fall or early spring*.

Oceanspray *(Holodiscus discolor)*
Oceanspray is a tall, many-stemmed deciduous shrub (5-10 ft.) in the rose family with graceful sprays of cream-colored flowers in mid to late summer. It colonizes disturbed areas naturally, can tolerate gravelly and rocky soils, and tends to spread slowly by suckers from the parent plant. Its roots also have good soil-binding characteristics. Seed viability is low, though seeds can be collected in fall, kept cold 4-5 months, then grown into seedlings in a greenhouse. It may be more effective to take suckers from adult plants or to take dormant cuttings in January and February. *Recommended method: buy/contract transplants and plant out in fall or early spring.*

Chokecherry *(Prunus virginiana)*
Chokecherry is a small deciduous tree (up to 15 feet tall in the area) that often forms small thickets or has a multiple-stemmed form due to its rhizomatous root system. It has long clusters of white flowers in the spring and its fruit is a valuable food source for birds. It generally grows best in semi-moist environments, so it would do well in small swales or at the edge of the water. Seed can be planted directly ½ inch deep into moist, well-drained soil in the fall. Plants can also be grown from cuttings of the rhizomes or from stem cuttings of new growth in the spring or early summer. *Recommended methods: fall direct seeding or buy/contract transplants and plant out in fall or early spring.*

Red-osier dogwood *(Cornus stolonifera)*
Red-osier dogwood has become a favorite, along with willows, for erosion control on moist sites or near water level. Red-osier dogwood is a many stemmed shrub that can grow up to 15 feet tall and can form small thickets. The bright red stems

are attractive in winter and early spring, as are the flat-topped white flowers in spring. Red-osier dogwood is an important winter browse for big game and the fruit is a food resource for birds. Cutting plants back every few years encourages branching and suckering. Red-osier dogwood does best in swales and prefers north-facing. Plants are very easily grown by layering adult plants or by taking 3 ft long cuttings in early spring. On very moist sites these cuttings can be planted directly on site. *Recommended method: plant cuttings or rooted plants from layering directly into moist soil in fall or early spring. This plant is also readily available from nurseries.*

Other shrubs and small trees:

Slide alder *(Alnus sinuata)*- for near water line on the upper parts of the .

Douglas maple *(Acer glabrum var. douglasii)*- for north facing slopes.

Serviceberry *(Amelanchier alnifolia)*- attractive white flowers in spring.

Coyote willow *(Salix exigua)* -for near water line - cuttings can be placed directly into the soil.

Rose species *(Rosa nootkana and R. woodsii)* - two native pink flowering roses with a wide tolerance for sun or partial shade.

Rabbitbrush *(Chrysothamnus nauseosus) and C. viscidiflorus* - for dry south facing slopes.

Obtaining plants for your site

There are many options for obtaining plant material for your site, several of which are described below. You may find that a combination of sources will be most cost and time efficient. One effective strategy is to transplant shrubs and sow the seeds of grasses and herbaceous plants. In general, the more disturbed and harsh the site, the more it may be necessary to use transplants rather than seeds or cuttings directly on to the site. There will almost certainly be some mortality of transplants, especially on a harsh site. Very large transplants may not do well. Exercise consumer prerogative and request that local nurseries start to stock more native plant species grown from local seed sources. The stocking of natives is becoming more commonplace in some areas.

Hiring a professional restoration company: There are companies, such as Bitterroot Restoration (see list of resources) that can evaluate your site, collect seed from nearby plants, grow them to the right size in their greenhouses, prepare your site, plant out the seedlings, and design the maintenance for them. This is the most expensive option, but a reputable company could save a lot of time and expense in the end, especially on large or technically complex projects.

Contract growing: In contract growing, a nursery agrees to gather local seed and grow a specified number of seedlings for planting on your site. Most contract growers do not plant the seedlings; you would need to do that yourself or hire a landscaper to plant them. Unfortunately, many landscapers do not have experience with native plants. Finding one that does will almost certainly increase the survival of your plantings. Depending on the size of the project, contract growing may be less expensive than buying plants from a nursery, and you will have plants that are from the area. In contract growing, you will generally receive plants as “tubelings”, plants in long, narrow pots that encourage tap root growth. Tubelings have a higher survival rate than bare-root or container-grown transplants, especially in arid areas, since they encourage long taproot growth.

Buying plants from a native plant nursery or other sources of native plants: There are a few nurseries in eastern Washington that carry a large selection of native plants (see list of resources), and even a small nursery may have a few species of native plants. Your local Soil Conservation District or Washington Native Plant Society chapter may also have some bare-root native plants for sale in the spring. Be sure to find out the source of the seed, and avoid plants that have been grown from seed gathered in other states - these plants may not be well adapted to Eastern Washington conditions. Plants may come either in containers or “bare root”. Bare root plants are the least expensive but they dry out very quickly if not planted in fall or early spring and as soon as possible after purchase. Keep bare roots in a moist environment until planting.

Buying seed: There are a number of seed companies that carry native plant seed (see list of resources). If you buy seed that can be sown directly on the site or if you are willing to grow the seed to transplantable size, this may be a good option. Again, avoid seed that comes from non-Eastern Washington sources and try to find seed from areas similar to your site in elevation and aspect.

Gathering seed: Seed can be gathered from plants in the area, although be sure to ask permission before collecting on private property and inquire with the local U.S. Forest Service office before collecting on National Forest land. Collecting is not allowed on lands managed by the National Park Service. In general, collect seed in the summer for spring flowering plants and in the fall for summer flowering plants. Be a “messy” seed collector and leave enough seed on the plant or on the ground for wildlife and plant reproduction. Many seeds need a period of chilling before they can germinate, and only a few species can be directly sown. Most do best if grown to a transplantable size in containers. For more information on growing plants from seed, see the books in the list of resources.

Layering: Layering is a process by which adult plants are encouraged to produce a new set of roots from a branch that has been bent down to the ground. Many shrubs do this quite readily. With landowner permission, stake a branch so that it comes into contact with the ground. Come back a few months later. If the branch has produced a good root system, you can cut the branch from the parent plant, with its new root system, and transplant it to your site. Be aware that some species may require a full year to produce adequate roots. Layering is also a good way to increase the number of plants on an erosion control site after the initial plantings have been established.

Cuttings: Cuttings can come from roots or branches. Each species has its own requirements for cuttings. A few, like willows and red osier dogwood, can be grown by simply taking a cutting from a branch in fall (after leaves fall) or early spring (before the plants leaf out) and sticking it into moist ground. These are called “live stakes”. Most require cuttings at particular times of year or require that the cuttings be dipped in a rooting hormone solution and planted in a pot until the roots develop before being transplanted to your site. Plants with rhizomatous roots can often be grown easily from root cuttings, though usually the root cuttings must be kept uniformly moist until shoots develop.

Divisions: Grasses and perennials, like many garden plants, can often be divided in early spring and the division can then transplanted to the site.

If you choose to collect seeds, cuttings, or divisions from the wild, please observe the following guidelines:

* Before collecting on public lands, obtain necessary permits.
* Get permission from private property owners before entering or collecting on private property.
* Collect only as much as you can actually use.
* When collecting cuttings, do not collect more than 1/20th of the plant.
* When collecting seed, do not collect more than 1/20th of the seed in an area, and collect from many different plants rather than just one.
* Collect whole plants only from sites where the native plants will be destroyed, by construction projects or other destructive actions.
* Collect cuttings or seed only from plants you can identify: there are rare plants in the area.

Site preparation

Site preparation requirements will depend on the qualities of the site. In general, steeper, actively eroding, and/or south facing sites will need the most preparation. The site evaluation will reveal the major issues of the site. The plants that are recommended above grow naturally in difficult conditions, so site preparation is simpler than what might be necessary for non-native plants.

Weeds: Most eroding slopes without native vegetation will have one or more weedy species growing on the slope. The most likely are cheatgrass, knapweed, and mullein. If weeds are a serious problem on the site, pull them or use a non-soil-accumulating herbicide like Rodeo (for near aquatic areas) before planting native plants. At a minimum, weeds should be kept clear in a three foot radius around any transplant. For more information, contact the Chelan County Noxious Weed Control Board or your local agricultural extension office (see list of resources).

Soil chemistry: Soil tests may have revealed deficits in nitrogen or other nutrients that can be remedied at the time of planting by using fertilizers or compost. These should be used judiciously, since native plants are well adapted to low nutrient soils and fertilizers will encourage weed growth.

Soil stability: Any major slope instability should be corrected before planting, since it will be several years before the plants on the site will provide much erosion control. If surface run-off and gullying is a problem, this should also be dealt with prior to planting or at the time of planting.

Geotextiles: Almost all erosion-prone slopes will also need some form of "geotextile", or erosion control fabric, in place before planting. Erosion control fabrics are woven mats or meshes that simulate a vegetation cover and keep the surface layers of soil, along with seeds and transplants, from washing downslope and eventually into the water. There are many types of geotextiles and erosion control fabrics. Some are made of synthetic material and do not biodegrade over time. The biodegradable ones are made from a variety of materials, including jute, straw, coconut fiber, and coir. They come in rolls and are pegged into place on the slope, before planting seeds or transplants. These are highly recommended on any steep site, since they both protect surface layers and provide a good microenvironment for seedlings and transplants. They can also be used to hold mulch in place on the slope. The list of resources gives some sources for geotextiles.

Contouring: It may also make some sense to contour very steep slopes. Contouring creates a series of terraces or ledges on a steep slope. If the contours are stable, the flat surface will encourage water retention and provide an improved microhabitat for seedlings and transplants. The coastal property owner's manual published by the Washington Department of Ecology (see list of resources) describes several methods of contouring.

As a rule of thumb, 30% slopes are the steepest slopes on which machinery can be used, and 50% slopes are the upper limit for easy revegetation. It may be possible to revegetate slopes up to 75% with proper preparation and maintenance.

Moisture: We do not recommend installing underground sprinkler or irrigation systems. Native plants will need supplemental water only for the first one to two seasons, and extra water will encourage weed growth. However, a temporary drip or soaker irrigation system may be appropriate.

Planting methods

Seeding: Planting methods for seeding include broadcast seeding and drill seeding. Seeding is most effective and efficient on mild slopes. If you are using geotextiles, most seed will do best if in contact with the soil and covered by the fabric. In drill seeding an implement is used that deposits the seed at the correct depth in the soil. This is particularly recommended on slopes without geotextiles. Many native plants will germinate more successfully if seeded in the fall, and if the soil is kept moist in the spring and throughout the first growing season. Slightly roughening the surface of the soil before planting will also increase germination, especially for seeds that are broadcast on top of the soil. Bear in mind that it may take 5-10 years for woody vegetation grown from seed to reach a size that will provide protection to the slope. Walking on steep slopes to seed can be dangerous and can also destabilize the slope.

Transplanting: Most transplants from seed are planted on site when they are between one and three years old. Cuttings may be grown in the greenhouse for six months to a year. "Tubelings" are the easiest to plant, though you may also be planting bare root or potted plants. It is critical to plant in the fall or early in the growing season, when soil moisture is highest and temperatures are relatively low. Minimize the time between the nursery and planting, especially with bare-root plants. Adding compost to the planting hole may be beneficial. Plantings should be spaced 3-9 feet apart, depending on the eventual size of the adult, although plants can also be planted in groups. Make sure there are no weeds within a three feet radius of the transplant, and if the slope allows, mulch the area immediately around the transplant. Pruning the plant after planting sends energy to the roots and will help it survive its first season. Geotextiles are placed before planting, and a hole is made for the transplant. It may also help the survival of the transplant to add water holding materials to the hole, or to create a small ledge on the slope on the downslope side of hole to catch water.

If portions of the slope are too steep for planting, you may be able to stabilize the edge of the slope with geotextiles or by planting a band of vegetation on the flatter ground along the top edge. Plants that form thickets and have rhizomatous root systems may be most effective. Eventually plants may seed into the steep slope.

Cuttings of willow, red-osier dogwood, and sumac may be able to survive if planted directly on to the slope, especially if there is some natural moisture on the slope. The cuttings are buried so that only a few inches are above the ground surface. These are called "live stakes". The King County Department of Natural Resources Web site (see list of resources) has a good description of collecting and planting live stakes. Generally, live stakes are planted in the fall after the leaves drop. Due to the dry, hot summers of the area, live stakes may have a high mortality rate.

Maintenance of your plantings

Although native plants need less care than most garden plants, the first few seasons after planting are critical in terms of seedling and transplant survival. Most slopes will need some supplemental watering and weeding in the first two years. Since many native shrubs are attractive to deer and rabbits, it may be necessary to use a chemical deer repellent (see list of resources) or wire fencing around young plants. There are also a variety of commercially available tree shelters that protect plants from both animals and wind and sun. Even a ring of medium-sized rocks placed around the base of the transplant will protect it from wind, smaller animals, and temperature fluctuations.

After shrubs are well established, deer browsing will only keep them well pruned. Some replanting may be necessary, since transplant and seedling mortality are to be expected. After three seasons, most native plantings should be self-sufficient, though it may be several more years before plants bloom and begin to spread across the slope.

Conclusion

Planting and encouraging native trees, shrubs, flowers, and grasses may seem daunting at first. However, with a little effort you will be richly rewarded by a low-maintenance landscape which stabilizes slopes, provides habitat for birds and wildlife, and bursts into bloom each spring and summer. Enjoy!

Resources

Books and pamphlets on native plants and on erosion control

Biotechnical and Soil Bioengineering Slope Stabilization by Donald Gray and Robbin Sotir. Wiley-Interscience, New York, New York. 1996.

Gardening with Native Plants of the Pacific Northwest by Arthur Kruckeberg. University of Washington Press, Seattle, Washington.

The Northwest Gardeners Resource Directory by Stephanie Feeney. Cedarcroft Press, Bellingham, Washington.

Plants of Southern Interior British Columbia. Lone Pine Publishing, Renton, Washington.

Propagation of Pacific Northwest Native Plants by Robin Rose, Caryn Chachulski, and Diane Haase. Oregon State University Press, Corvallis, Oregon. 1998.

Sagebrush County by Ron Taylor. Mountain Press. 1992.

Seeds of Woody Plants in North America by James Young and Cheryl Young. Dioscorides Press, Portland, Oregon. 1992.

Slope Stabilization and Erosion Control, a bioengineering approach edited by R. Morgan and R. Rickson. Chapman and Hall, New York, New York. 1995.

Slope Stabilization and Erosion Control Using Vegetation: a manual of practice for coastal property owners. Washington Department of Ecology publication number 1993-30, Olympia, Washington. 1993.

Eastern Washington nurseries and seed companies that carry native plants

Firstline Seeds
11703 Road 1 SE
Moses Lake, WA 98837
509-765-1772

Grassland West
1392 Port Drive
Clarkston, WA 99403
509-758-9100

Moses Lake Conservation District Nursery
1775 Southeast Hwy 17
Moses Lake, WA
509-765-5333

Methow Natives
Winthrop, WA
509-996-3562
methownatives@methow.com

Kinder Gardens Nursery & Landscaping
1137 S. Highway 17
Othello, WA 99344
509-488-5017

Plants of the Wild
PO Box 866
Tekoa, WA 99033
509-284-2848
plants@eznet.com
nursery plants

L&H Seeds
4756 W Highway 260
Connell, WA 99326
509-234-4433

Rainier Seed Company
PO Box 187
Davenport, WA 99122
1-800-828-8873

Milestone Nursery
PO Box 907
Lyle, WA 98635
509-365-5222
contract growing

Rainshadow Nursery
641 Camion Road
Ellensburg, WA 98926
509-968-4778
rainshdw@sisna.com
contract growing

Revegetation/restoration consultants

Bitterroot Restoration
445 Quast Lane
Corvallis, MT
406-961-4991
http://www.revegetation.com/index/htm

Geotextiles and erosion control fabrics

Bitterroot Restoration (see above)

RoLanka International
6474 Mill Court
Morrow, GA 30260
404-961-0331

Deer repellent and other plant protection aids

Ben Meadows Company
P.O. Box 20200
Canton, GA 30114
http://www.benmeadows.com/cgi-bin/SoftCart.exe/scstore/
1-800-241-6401

Web-based resources

Using live stakes: http://www.kingcounty.gov/environment/stewardship/nw-yard-and-garden/live-stake-plantings.aspx

Native plant sources of the Pacific Northwest:
http://www.kingcounty.gov/environment/stewardship/nw-yard-and-garden/native-plant-resources-nw.aspx

Washington Native Plant Society: http://www.wnps.org

Other resources

Chelan County Conservation District
301 Yakima St. Rm. 307
Wenatchee, WA 98801
509-664-0265

Hortus West: a western North America native plant directory and journal
PO Box 2870
Wilsonville, OR 97070
1-800-704-7927

PUD #1 of Chelan County
Wildlife Department
PO Box 1231
Wenatchee, WA 98801
509-663-8121

Washington Native Plant Society
Wenatchee Valley Chapter
Pam Camp, president
509-665-2100

WSU Cooperative Extension Service, Chelan and Douglas County
400 Washington Street
Wenatchee, WA 98801
509-664-5540

Chelan County Noxious Weed Control Board
303 Palouse Street
Wenatchee, WA 98801
(509) 664-5550

APPENDIX C: RULES OF THUMB AND BASIC DESIGN INFORMATION

C.1 Typical Winds and Waves

The wind and waves to be protected against are key factors in many of the erosion control designs. Owners should observe the characteristics of their particular sites to see whether less extreme design conditions may be appropriate. For example, on sites with gentle slopes below the high water line, large waves will not be able to reach the shoreline because of the shallow water. A relationship between slope, depth and size limit for waves is shown by Figure C-1. An indication of such gentle slopes is given by finer, sandy material in the drawdown area because the sandy material would typically not stay on steeper slopes.

C.2 Typical Unit Weights and Design Parameters

There are several numbers that may be useful in design of structures for erosion control. The numbers below can be used as an initial approximation of these parameters. Final designs should not be done based on these numbers without independent confirmation.

Unit weights in pcf (pounds per cubic foot)

Water	62.4 pcf
Concrete	150 pcf
Rock	160 to 170 pcf
Sand or gravel	100 to 130 pcf (depends on gradation, compaction and moisture content)

C.3 Sources of figures:

Figures C-1 and C-3: “Low Cost Shore Protection…a Guide for Engineers and Contractors”, U.S. Army Corps of Engineers, 1981.

Figure C-2: “Low Cost Shore Protection…a Guide for Engineers and Contractors”, U.S. Army Corps of Engineers, 1981, after Weggel, J.R., “Maximum Breaker Height”, Journal of the Waterways, Harbors and Coastal Engineering Division, ASCE, Vol. 98, No. WW4, Paper 9384, 1972.

Figure C-4: Kamphuis, J.W., et al, Calculation of littoral sand transport rates, Coastal Engineering, Vol. 10, pp. 1-21, 1986.

Figure C-5: Naval Facilities Engineering Command, NAVFAC DM-7.1, Soil Mechanics, May 1982.

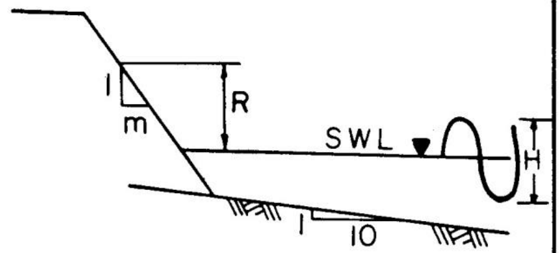
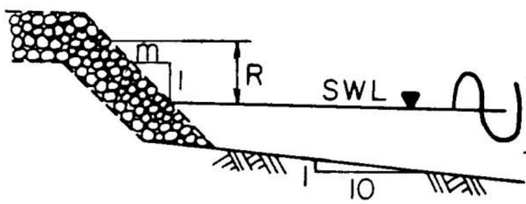
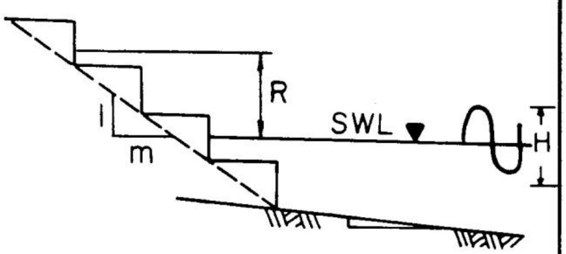
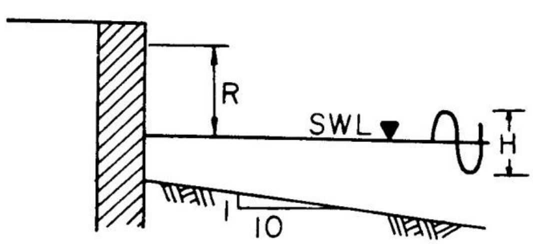
	m	R
 SMOOTH FACE	1.5 2.5 4.0	2.25H 1.75H 1.50H
 ROUGH FACE	1.5 2.5 4.0	1.25H 1.00H 0.75H
 STEPPED FACE	1.5	2.00H
 VERTICAL FACE	—	2.00H

Figure C-1: This figure will aid in estimating wave run-up for various slopes and surfaces.

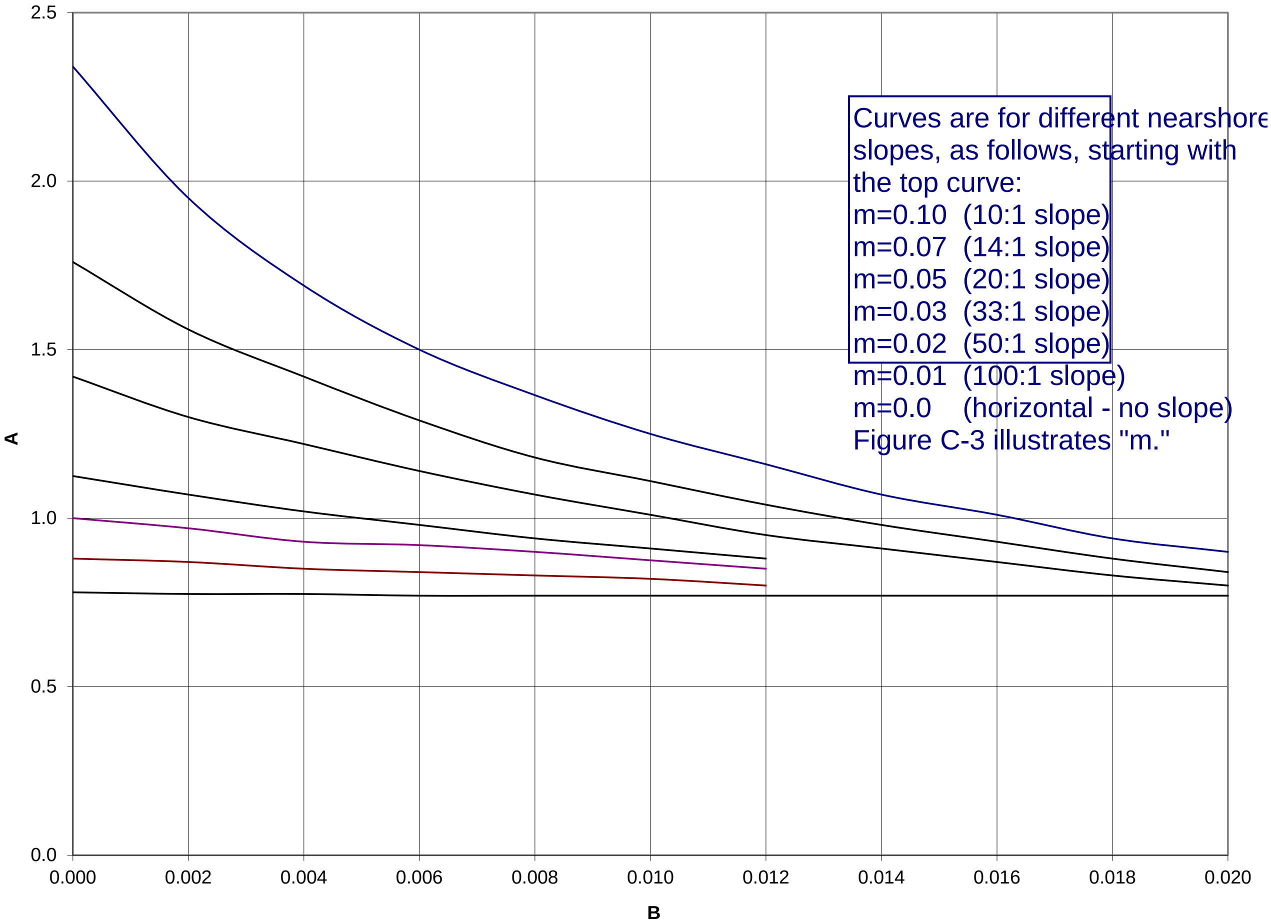


Figure C-2: This graph of possible nearshore wave height illustrates that relatively flat beach slopes and shallow water limit the wave size which must be taken into account in design. $A = H/d_s$ and $B = d_s/gT^2$, where H is wave height, d_s is water depth at shoreline (see Figure C-3), g is acceleration due to gravity (32.2 ft/sec^2), and T is wave period.

Example: d_s = 1.74 ft and T = 3 sec would yield B = 0.006. For a 10:1 beach slope (top curve), A = 1.5, so the design breaking wave height would be H = (1.5 x 1.74) ft = 2.6 ft.

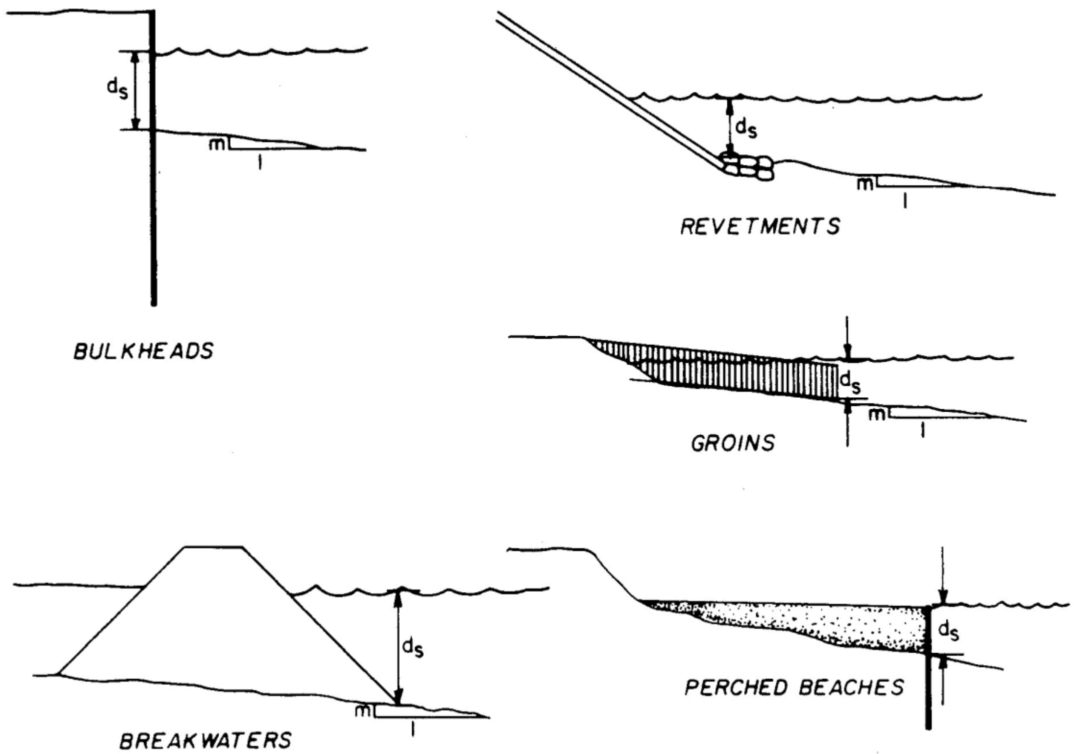


Figure C-3: Illustrates definitions of d_s and m used in Figure C-2.

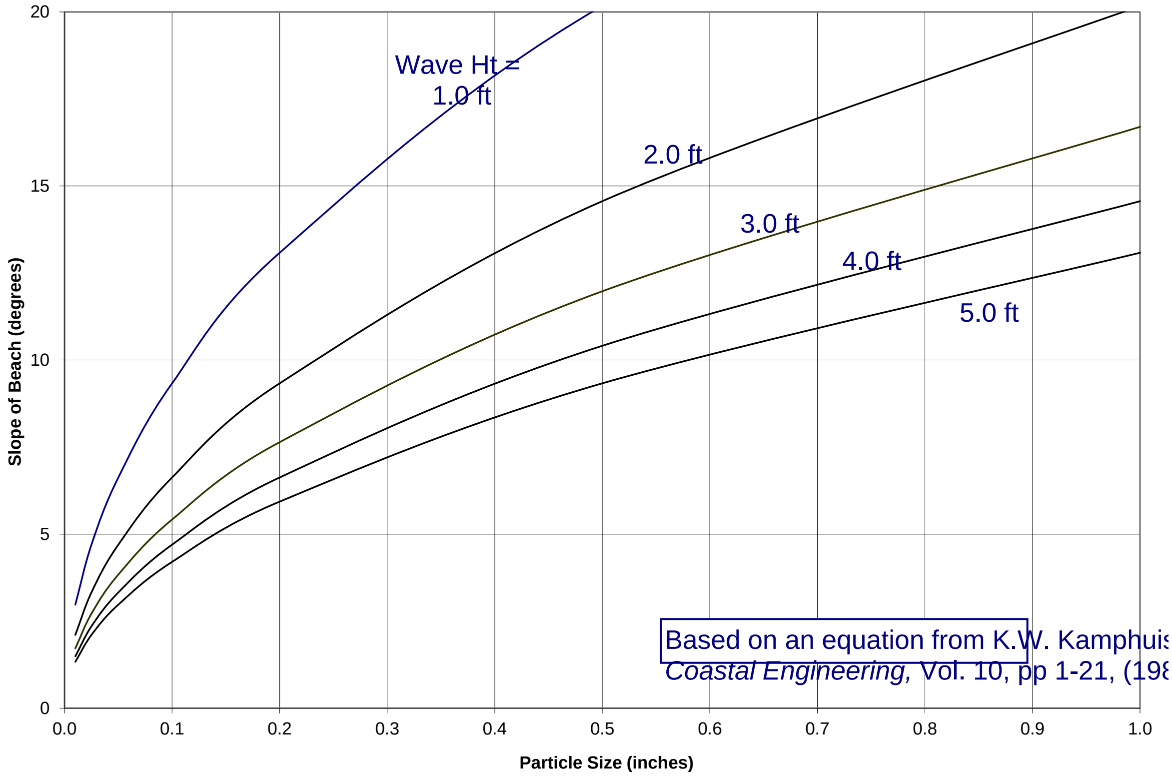


Figure C-4: At a given wave height, soils with smaller particle size will form flatter slopes. For example, subjected to 3 ft waves, a soil with an average particle size of 0.5 inches would be expected to form a slope of about 12°, while a soil with 0.2 inch particles (coarse sand or fine gravel) would be expected to form a slope of about 7° to 8°. This is a particularly important consideration in selecting materials for a perched beach.

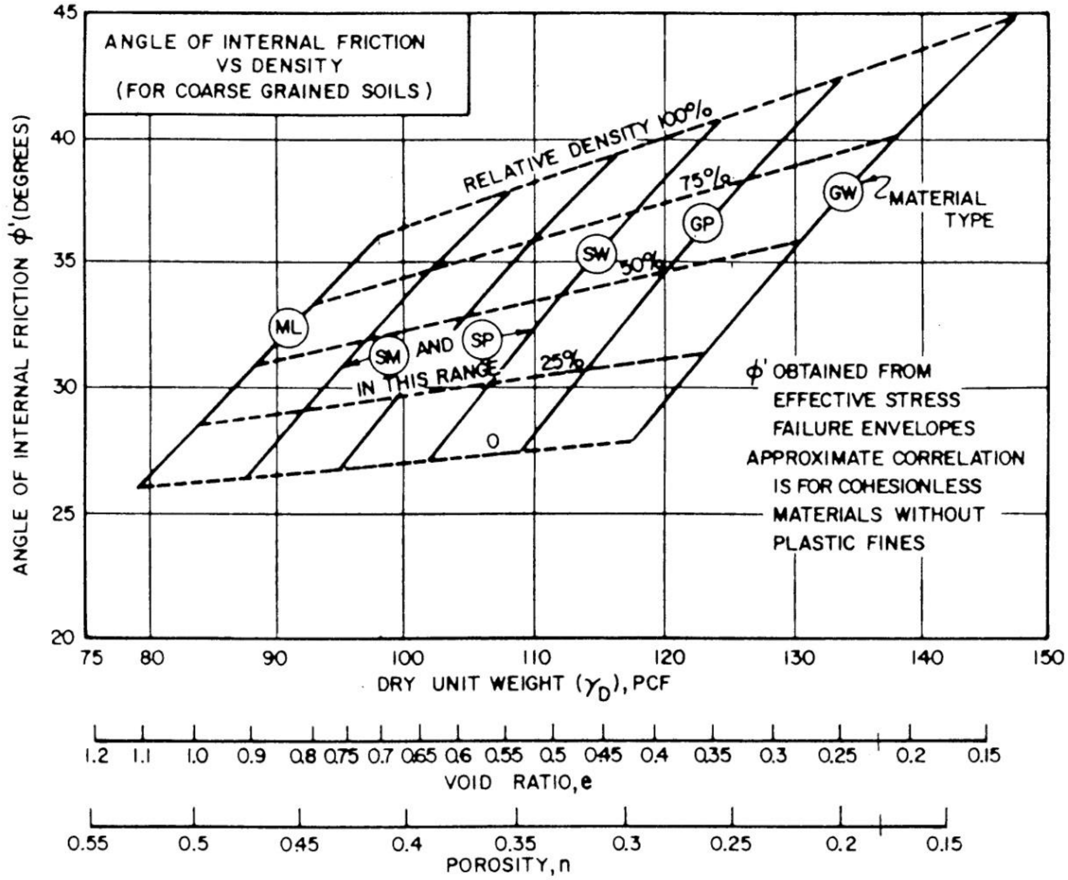


Figure C-5: Generalized density and strength information for granular soils

APPENDIX D: GLOSSARY

Wave height: Vertical distance from the crest to the trough of a wave. If the wave crest is 1 feet above the calm water surface, the wave height is 2 feet.

Wave run-up: Vertical distance above the calm water surface that waves travel up the shoreline. This depends on slope angle and roughness, but is often about 1.5 times the wave height.

Upslope: In this report, refers to the portion of the slope above the eroding face.

Face, eroding face: Portion of the slope above the high water line where shoreline erosion has affected slope stability

Downslope, drawdown area: The ground surface below the high water line.
High water line: The high water line

Sand, gravel, cobble, boulder: These terms refer to different soil particle sizes and are defined according to the Unified Soil Classification System.

- Sand: from 0.003 to 0.19 inches (0.074 to 4.76 mm)
- Gravel: from 0.19 to 3.0 inches (4.76 to 76.2 mm)
- Cobble: from 3.0 to 12 inches (76.2 mm to 30.5 cm)
- Boulder: greater than 12 inches (30.5 cm)

Gradation, particle size: This refers to the range of particle sizes in a soil, including the percentage of each size. Soils are classified based on the size of most of the particles; e.g., a soil in which particles larger than 0.19 inches make up more than 50% of the weight is classified as gravel.