SOIL & SLOPE REVEGETATION (Flatter than 2:1)

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition

Stabilizing exposed soils on slopes through revegetation in order to minimize or prevent the erosion of soil by wind or rain and sedimentation problems

An urban environment slope revegetated and protected with a coir mat
© Aussie Erosion

When land is disturbed at a construction site, or the natural vegetation cover is retired, the erosion rate may increase significantly. Proper planning and use of erosion control prevention and mitigation measures can reduce the impact of human-caused erosion.

A well-established vegetative cover is one of the most effective methods of reducing erosion. Vegetation protects soil surfaces from rain generated splash erosion and can help slow runoff flows across a site of ground disturbance. In addition, plants establish root systems, which stabilize soil and prevents soil erosion against weathering forces.

Even though mud, dirt and sand are natural, they are still serious pollutants that must be prevented from entering the waterways, including the storm water drainage systems, which discharge to creeks, waterways, rivers and beaches. That is why this vegetation coverture should be established on construction sites as soon as the slopes are finished.

The four most common soil erosion prevention methods through revegetation are:

- Stabilizing slope soil by hydro-seeding,
- Erosion control mat,
- Covering with mulch,
- Surface roughening

Different variants existing

=> Stabilizing exposed soils by hydro-seeding

Control of erosion and soil management on natural slopes or embankments and cut slope (on construction sites)

The most common way to stablish a vegetal coverture is by seeding. The goal of the erosion control by seeding is to have a rapid establishment and a dense fibrous root system.

- **Hydroseeding**: is an alternative to the traditional process of broadcasting or sowing dry seed. It is very effective for hillsides and sloping lawns to help with erosion control and quick planting. Water, seed, fertilizer and protective mulch is mixed in a tank and sprayed onto the ground (3).

Embankment hydroseeded in Madrid-Galicia high-speed railway
© Acciona I+d+i

- **Seeds selection**. Seed mixes are developed for specific climatic zones to match the optimum growing conditions for each species.

Another plant characteristic of importance is how the grass develops, grows and spreads (for instance rhizomatous grass that send out runners that will start new growth). Rooting depth is important, the mixture of rooting depths provides optimum support for soils and best enables the removal of water by the roots at the various zones in the soil. Seed used in a hydroseeder does not need to be any specific ones. Nearly any seed can be used and at the same application rate as other seeding methods.

- **Water** in the mix acts as a carrier and the contact of the seed and the water will jump-start the growth process. When extra fast germination is desired, it is also possible to pre-germinate seed for even faster growth.
- **Fertilizer** is usually used in the mix. A high phosphorus "starter" fertilizer that will stimulate root growth is the most commonly used.
- **Mulch**. Fiber mulch accelerates the growing process by maintaining moisture around the seeds thereby increasing the rate of germination (1).
- **Other additives**. Other products that may be added to a hydro seeding mix are products called tackifiers (guar gum and copolymers) acting like a glue to hold mulch in place that help hold the materials on a hillside in rainy conditions. The site also determines some additives as can be a lime based product added if the pH needs correcting. Other products such as co-polymers that hold 400 times their weight in water and slowly release it as the moisture is needed, or growth stimulants or symbiotic mycorrhizas, etc.

Hydro seeding restauration in L'Horta, Spain
© Acciona Ingeniería S.A.

=> Covering with mulch

Mulch is a name given to a group of organic and inorganic materials (such as decaying leaves, bark, or compost) that are spread on the soil surface to prevent the erosion of soil by wind or rain. These plant based materials are usually considered temporary and are intended to degrade after the establishment of permanent vegetation.

Applying a layer of mulch to the soil top protects it against rain impact and allows the soil to slowly soak up water. It can encourage seeds to sprout and protect seedlings and thus helping with erosion prevention.

The biggest limitation for use it in embankments and cuttings is that it is unstable with high slopes, needing the combination with other techniques such as cells.

Straw and wood fibres (wood chips) are the most common materials applied as loose mulch. Straw mulch can be used as light mulch (wheat or oat straw). Wood chip mulches are useful for weed control. Typical ground covers such as grass have difficulty growing through heavy woody material because of its weight and also as this high-carbon material decomposes, it removes plant nutrients from the soil (through microbial processes), resulting in low soil fertility (4). Application of a nitrogen rich fertilizer maybe required. Nevertheless, bark chips mulch does not require additional nitrogen fertilizer but it has to be considered that pine barks reduce the PH of soil, so should not be used on low PH soils.

- Minimizes erosion by providing a protective cover over disturbed, bare, reseeded or revegetated soils
- Minimal thickness protects soils form splash erosion while thicker layers are effective for additional sediment control.
- Protect seeds and seedlings favouring the cover of the soil with vegetation and avoiding erosion
- Heavy mulch reduces weeds by preventing germination of weed seeds
- Retains moisture by reducing evaporation, thereby reducing the need for watering
- Last but not least, a mulched surface looks much better than bare soil

Bark mulch and Mypex slope
©Lynch garden design

=> Erosion control blankets, (ECBs) or mats

Erosion control blankets are mats comprised of 100% organic fibers (biodegradable). ECBs are used to stabilize disturbed surfaces and to promote the establishment of vegetation. There are two main types of erosion control mats; jute mat and coir mat. With these natural fibers can be weaved an open geotextile.

There is another type of mat or a composite geotextile incorporating UV-sensitive netting for improved short-term stability..

Straw blanket with synthetic netting
© Titan

Using these mats like an erosion control tool is an effective method because it holds the root of vegetation and stabilizes soil. When used in conjunction with growing vegetation, it is even more effective.

The key to successful revegetation is good soil condition, good surface preparation and intimate contact between the blanket and the soil. (5)

When vegetated, it has the mechanical strength necessary to hold soil in place and prevent erosion. The netting breaks up runoff from heavy rains and dissipates the energy of flowing water and wind. Mesh promotes the growth of new vegetation by absorbing water and preventing the topsoil from drying out.

Natural fiber mesh together with revegetation
© Fullservice Green solutions

- Prevent erosion from exposed soils on slopes with medium runoff
- Typically used when a vegetative cover cannot be achieved due to soils, time of year or where slopes are too steep for mulch.
- Mats can be biodegradable (organic material) or ultraviolet degradable (synthetic material) and have different grades for different duration of protection, ranging from 2 months to 36 months
- Synthetic reinforcing net can entrap wildlife such as lizards, snakes and birds

Placement of an coir mesh
© Aussie Erosion

=> Surface Roughening

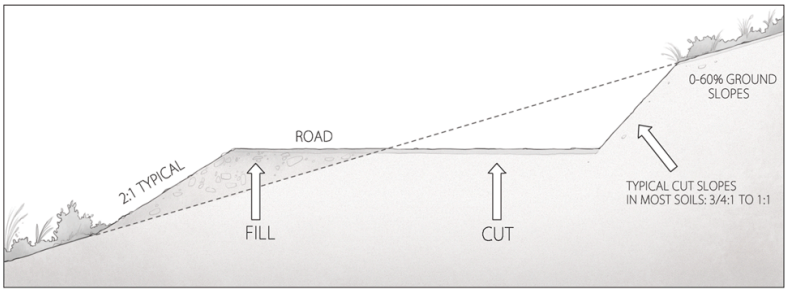
Surface roughening is a temporary erosion control practice where the soil surface is roughened by the creation of grooves, depressions, or steps that run parallel to the contour. It can also be used to help establish vegetative cover by reducing runoff velocity and giving seed an opportunity to take hold and grow by reducing runoff velocity and allowing soil infiltration and acting as a sediment trap.

Surface roughening

© Massachusetts Department of Environmental Protection

However, this practice alone is not sufficient to stabilize a slope for long periods, that is why it is normally used in combination with other erosion control measures such as mulching and seeding or planting. Roughening alone as an erosion control measure is of limited effectiveness in intense rainfall events. If roughening effects are washed away in a heavy storm, the surface will have to be roughened again and new seed and mulch applied.

Roughening methods may include tilling, disking or harrowing, which must be done across the slope along the contour. Tracking, by contrast, must be done up and down the slope. The main factor to choose one method or the other depends on the origin of the slope; cut slope or fill slope.



Examples of fill slope and cut slope

© Noah Kroese/2014/08/

- **Fill slopes** roughening (7)

Fill slopes are not as stable as cut slopes, no matter how much compaction is applied. Therefore, slopes which are steeper than 3:1 (H:V) should be avoided.
Use grooving or tracking to roughen the face of the slopes as necessary. Operate tracked machinery up and down the slope to leave horizontal depressions in the soil.
Apply fertilizer, mulch, or other soil amendments as necessary prior to grooving or tracking. Do not blade or scrape the final slope face. Seed and mulch roughened areas to obtain optimum seed germination and growth. (7)

- **Cut slopes** roughening (7)

Cut Slopes are much more stable than fill ones.
Consider the use of steeped slopes or terraced slopes.
Tilling, disking, and harrowing are also acceptable methods of roughening a cut slope. Groove the slope using machinery to create a series of ridges and depressions that run across the slope and on the contour.
Excessive roughness is undesirable where mowing is planned.

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	02| Water management and quality > 02-1 Urban water management 04| Biodiversity and urban space > 04-1 Biodiversity > 04-2 Urban space development and regeneration > 04-3 Urban space management 05| Soil management > 05-1 soil management and quality	- Avoiding water system drainage problems due to the accumulation of eroded sediments. Intercept rainwater. - Soil conservation promotes vegetation growth, provides habitat for insects and animals and in consequence biodiversity - Avoiding soil erosion and the loose of its potential productivity
Co-benefits and challenges foreseen	01| Climate issues > 01-2 Climate adaptation 07| Public Health and well-being > 07-2 Quality of life 10| People security > 10.2 Control of extraordinary events.	- Contribute to urban heat island mitigation. - Aesthetic value. A poorly managed and eroded soil is always unsightly. - Vegetated slopes are more stables against landslides after heavy rains.
Possible negative effects	07| Public Health and well-being 04| Urban space management	- It could become a shelter for undesired and unhealthy animals. - There is more fire risk during dry seasons that is why these surfaces require the maintenance of these green areas, which implies more costs.

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	Entity - Private houses, - Public residential areas - Building construction sites for commercial or industrial areas planned for development or redevelopment, - Cut or fill embankments on infrastructure construction sites
Impacted scales	Neighbourhoods
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	It is usually the time to establish permanent, stabilizing vegetation and depends of types of the selected plants: - Grass: it takes about three months, - Shrubs: 1 to 2 years - Trees: 2 to 3 years
Life time (5)	- Vegetation; from 12 months to 20 years - Light Mulch: no longer than 1 year - Heavy Mulch: from 1 to 2 years - Erosion control blankets: from some months to 3 years - Soil roughening: few months
Sustainability and life cycle	- Plants and light mulch can be composting or recycling in most of the cases. - Erosion control blankets finish degraded naturally after few years. - Heavy mulch is a natural product that can be revalorized to fuel or reuse it.

Management aspects (kind of interventions + intensity)	- Stabilize disturbed slopes as quickly as possible. - Any necessary maintenance and repair must be made prior to leaving the site. - once finished the work and after few months, review the slope situation to ensure that erosion and sediment control measures are in working order - Check the irrigation system once per year - 1-2 vegetation maintenance interventions per year.

II.3 Stakeholders involved

Stakeholders involved in the decision process	- Owners, co-owners of infrastructure or construction site - Municipality (in case of municipal properties) - Private owners, eventually an isolated neighbour
Technical stakeholders & networks	- Soil scientist - Landscape architects - Irrigation system designers - Specialized green spaces management firms and gardeners.
Social aspects	- Raise awareness among private owners that stabilizing slopes is necessary to avoid erosion problems. - Revegetated slopes implies more aftercare although it is more pleasant

II.4 Design / techniques/ strategy

Knowledge and know-how involved Or key points for success	- Geotechnics knowledges, - Designers of environmental corrective measures			
Materials involved	**Hydroseeding** - Seed selection - Water - Fertilizer - Mulch Tackifiers - Hydro-seeding-pump	**Mulch** - Light mulch: straw from wheat or oat - Heavy mulch: wood chips + nitrogen fertilizer Or pine barks - Selected plants - Irrigation system	**ECBs** - 100% biodegradable mesh: Jute fiber or coir fiber - Composite geotextile: - Retaining pins - Selected mix of plants - Irrigation system	**Soil roughening** - Machinery - Selected mix of plants

II.5 Legal aspects related

It is illegal for any substance other than rainwater to enter the storm water system. Soil can damage storm water drainage system and damage the environment, so private owners, builders or developers are subject to control this kind of erosion problems.
Company's inability to manage a construction site correctly can cause fines (even his disqualification), the same as for private owners damaging storm water drainage.

II.6 Funding Economical aspects

Range of cost (Prices are from Spain 2016 and it must be considered the scale impact on prices. These are prices for big works not for private plot works)	**Hydro-seeding** 1,66 €/m^2	**Heavy Mulch, supply and implementation** Pine barks (35€/m^3): 5 €/m^2 Wood chips: 9 €/m^2 Selected plants: (4 perennials and 1 sap tree): 40 €/m^2 average	**ECBs, supply and implementation** Coir fibre mesh (350g/m^2): 5 €/m^2 Jute fibre mesh: 3 €/m^2 Selected plants: (4 perennials and 1 sap tree): 40 €/m^2 average	**Soil roughening implementation** 0,7 €/m^2 Selected plants: (4 perennials and 1 sap tree): 40 €/m^2 average
Origin of the funds (public, private, public-private, other)	- Private land owners or co-owners - Infrastructure manager - City councils			

	- Construction companies

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

=>.Rock mulch together with wood fiber mulch:

Cost: gravel mulch (5 cm height) over anti-weed mat (5,22€/m^2)

© Lawn-wranglers.com

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors

Success factors-

- Choose the correct NBS based on the slope gradient, soil characteristics, local climate conditions and final expected aspect,
- Choose a mixture of plants adapted to the local environment,
- Good soil surface preparation,
- Mulch is unstable with high slopes,
- Blanket Correct installation making sure the blanket is flush with the soil surface.
- Set up the maintenance keeping plants in the right conditions

Limiting factors	- Steep of the slope - The type of soil (organic material, PH, texture etc.) - Geotechnical soil conditions (fill or cutting slope) - Soil water availability - Pest - Fire risk

III.2 Comparison with alternative solutions

Grey or conventional solutions counterpart	**=>.Retaining walls** Slope can be stabilized with retaining walls. Traditional retaining walls can be made out of corrugated steel sheet-pile, steel gabion baskets filled with rock, articulated cement blocks, polyethylene geocells, cut stone, brick, timber or even geofoam.

Anchor Highland Wall - Bull Run

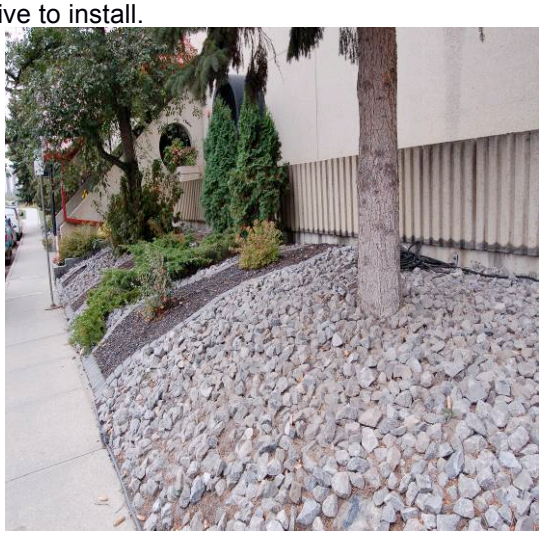
© Allied concrete

Gabions used as soil retainer on a sloping soil surface

© gabion1.com.au

=>.Rock mulch:

There are many different types of rock to use as mulch. Rock mulch is heavier to handle and apply than bark mulch. It is also a more permanent landscape installation, not decomposing into the soil or adding organic matter. Nevertheless, it requires a weed barrier underneath to keep weeds from growing up through the rock layer and more expensive to install.



Rock mulch used as soil retainer

© Bistrodre.com

Close NBS	**=> Slope revegetation Steeper than 2:1** **=> Soil structuration**

IV/ References

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