C-4 Post-Construction Rehabilitation and Revegetation Plan

Aim and Objective

The purpose of **C-4 Post-Construction Remediation and Revegetation Plan** (PCRRMP) is to outline the management measures for the remediation and revegetation of temporary facilities and associated infrastructure during and post-construction.

As per the ESIA (2019), the PCRRMP provides for remediation as part of the construction phase. It applies to all areas of temporary disturbance to be progressively remediated and revegetated during and after construction of the TRHDP, including surrounding the dam, powerhouse, tunnel, temporary access roads and widened Black Post Road. Rehabilitation at hydropower plant decommissioning (if applicable) will be covered by **D-1 Project Decommissioning Plan** which will be prepared in the future. Additional requirements for the management and monitoring of biodiversity are covered in the **P-2 Biodiversity Management Plan** and associated offset management strategies.

Summary of Impacts and Risks

The Project will result in the clearance of approximately 45.1 ha of vegetation in total, including 23.62 ha to be cleared for permanent infrastructure and 21.48 ha to be rehabilitated and revegetated (refer final figures in the **P-2 Biodiversity Management Plan**). To mitigate for the impacts to the environment, including biodiversity, and to reduce the need for biodiversity offsetting, all temporary facilities shall be removed, and sites remediated and revegetated upon completion of use. This will include the removal of all construction equipment, temporary buildings and waste materials, and the identification and remediation of any contaminated sites. This will help to reduce the short- and long-term impacts of the Project.

Temporary facilities to be rehabilitated include but are not limited to:

- Site office
- Concrete batch plant
- Rock crushing plant
- Explosive magazine
- Temporary access roads (e.g. to tunnel portals, explosive magazine, stockpiles)
- Cleared areas on road edges, around the dam and cofferdams, tunnel portals, pipeline, and powerhouse site not required for operations.

It is understood that the Workers Accommodation Camp will remain and will not be rehabilitated at the end of construction. This is at the request of the community.

Mitigation and Management Actions

#	Issue or Risk	Action	Timing / Frequency	Responsibility
C-4-1.	Topsoil storage	• Topsoil will be stripped and stockpiled separately on site for later reuse in rehabilitation of temporary facilities. As per the ESIA (2019) an estimated 327,900m^3 of topsoil will need to be temporarily stored on the project site, requiring a storage area of approximately 10 hectares.[1] Topsoil will be stockpiled at approved spoil disposal sites.	Vegetation clearance and earthworks	HEC Construction Manager
C-4-2.	General principles including waste minimisation	• The storage and disposal of hazardous and non-hazardous materials resulting from construction demobilisation shall comply with the requirements of the **P-12 Waste Management and Point Source Pollution Plan** and **P-13 Hazardous Waste Management Plan**. • To minimise generation of waste during construction demobilisation, materials shall be sold, transported for use on other projects, gifted to the local community[2], recycled or repurposed. Alternatively, they will be disposed of at the Ranadi Landfill or shipped offshore. • Hazardous materials will be removed for disposal at a hazardous materials disposal facility, if available. Should no hazardous material disposal be available in the Solomon Islands at the completion of construction, hazardous substances shall be shipped offshore for treatment or shall remain on site in a hazardous waste store. • Concrete structures shall be demolished, with resultant material reused as aggregate or disposed of to spoil disposal sites. • Any exporting and transboundary movement of waste and hazardous waste shall comply with the requirements of the Basel Convention (1989).	During and post-construction	HEC Construction Manager
C-4-3.	Temporary buildings, infrastructure and machinery	• Temporary structures and related facilities that are not required for operation (e.g. temporary offices, sheds, and storage buildings) will be demolished and removed. • Construction equipment, heavy and light vehicles (including parts and equipment) shall be sold, gifted to the community, or shipped offshore. • Machinery and equipment will be dismantled and moved off site (e.g. crusher plant, concrete batch plant). • Temporary access roads will be permanently decommissioned and blocked to vehicles as use is no longer required. The road surface shall be broken up and culverts removed in preparation for revegetation. • Erosion and sediment control devices, and concrete washwater treatment systems will be treated, emptied, and stabilised, then infilled • Septic tanks will be completely emptied with effluent taken to the Sewage Treatment Plant, then the tanks shall be treated with lime, and infilled with soil. • All groundwater bores not required for operations will be decommissioned, filled with bentonite (or similar) and capped.	During and post-construction	HEC Construction Manager
C-4-4.	Contaminated soil and groundwater	• Prevention and containment of spills, including proper storage and use of hazardous substances, wide availability of spill kits, and immediate clean up and removal of contaminated soil, is much more effective than remediation a long time after it has occurred. • Where spills have potentially entered soil or groundwater, soil and groundwater will be tested for contamination and rehabilitation completed if applicable. • Contaminated soil shall be excavated and remediated on site or disposed of off-site at Ranadi landfill. • Contaminated groundwater shall be treated according to the volume and nature of the pollutant concerned.	Construction decommissioning	HEC Construction Manager

[1] The previous version of C-9 for Lot 2 and 3 estimated a volume of excavated soil at 862,614 m^3, of which 87,988 m^3 is topsoil. However, this number excludes spoil from the dam, powerhouse and tunnel site.

[2] Items shall only be gifted if the community has requested or expressed interest in the item, and it is in working order. Goods shall not be dumped on the community.

C-4-5.	Site revegetation	• All temporary sites will be actively revegetated. The total area will be specified in the **P-2 Biodiversity Management Plan** but is expected to be in the order of 21.48 ha. • Sites will be rehabilitated progressively over time as activities are ceased and will not be left until the end of construction. • When a site is available for remediation, the following actions will be undertaken: – Recontoured to as natural form as possible and ripped or scarified to reduce compaction, using earthmoving equipment. – Spread with topsoil for a depth of 0.2-0.4 metres (or more on flat topography and where supplies are available). – Planted with rapidly growing non-invasive cover crop(s) such as pueraria (*Neustanthus phaseoloides*), velvet bean (*Mucuna pruriens*), vetiver grass (*Chrysopogon zizanioides*) or similar. More information on cover crops is provided in **Annex C-4-I Bioengineering Slope Protection Report**.[3] – Cover crops shall be planted at a density of ≥1.0 plant per square metre, unless beneath existing canopy where lower density of 0.5 per m^2 may be used. Alternatively, cover crops may be hydroseeded. – Mulch can be applied to improve soil condition, reduce erosion, minimise weed invasion and improve plant establishment. Mulch can be sourced from shredded and chipped material during vegetation clearance activities. – On steep, erosion-prone slopes, plants can be planted into coconut matting (aka coir), jute matting, biodegradable geotextile or similar. – Once sites are stabilised and the cover crop is well established, inter-plant with native shrub and tree species at a spacing of one native tree every 5 square metres (a minimum of 500 native plants per hectare). • Where possible, planting will be timed at the end of the dry season and beginning of the wet season to ensure that plants are sufficiently established to withstand the impacts of major rainfall or drought. Where drought stress occurs, irrigation water from sediment control ponds or the WAC STP can be used. • Adequate erosion and sediment control measures will be implemented at all rehabilitation sites to prevent the discharge of sediment. These controls will be left in place to protect revegetation/rehabilitation works until the site is stabilised and vegetation is well established.	During and post-construction	HEC Construction Manager HEC HSE Manager
C-4-6.	Plant propagation	• A nursery(s) will be established (or contracted) to propagate and grow-on native vegetation for replanting. This could be done in partnership with the local community, who have expressed an interest in supporting the revegetation activities, and/or a local NGO. The nursery(s) will have an adequate supply of soil, water, and equipment supplied by the Project. • With the exception of cover crops, all plant materials used for revegetation (seeds, seedlings, cuttings, saplings) will be sourced from species growing within the Project area. **Annex C-4-II** provides a list of vegetation species identified on site to guide plant propagation and revegetation activities. • Collection of seeds, seedlings and/or cuttings will be done well in-advance of revegetation to ensure adequate quality and quantity of plants. Plant material will be sourced from vegetation clearance areas (as per **P-2 Biodiversity Management Plan** and **C-3 Forest Clearance Plan**) and other areas within Core Land. • Seeds and plants shall be stored and maintained to promote survival, and adequately protected from sun, wind, rain and humidity.	During and post-vegetation clearance During and post-construction	HEC HSE Manager HEC CLOs
C-4-7.	Maintenance, weed and pest control	• Revegetated areas will be monitored at least every three months until a full groundcover is established. • In the case of plant losses creating gaps in revegetation sites, more frequent (monthly) maintenance, including weed control and additional planting with cover crops and native species will be conducted. • Invasive weed and pest species will be controlled, with particular focus on revegetation sites, roadsides and forest edges. Physical, mechanical and/or chemical control methods may be used.	During and post-construction	HEC HSE Manager

Monitoring Requirements

#	Title	Description	Target / Performance Indicator	Timing / Frequency	Responsibility
C-4-A.	Construction demobilisation	• All temporary facilities and structures to be removed off site, with sites to be revegetated and stabilised.	All sites cleared, revegetated and stabilised by COD	By Commercial Operation Date	HEC Construction Manager
C-4-B.	Planting success	• The following will be reported on a quarterly basis: – Number of seeds, plants and/or cuttings collected for propagation, recorded by species – Number of plants planted, recorded by species – Area replanted in hectares. – Fixed photopoint monitoring of revegetation areas. – Labour hours spent in the nursery, replanting, weed and pest control, or other maintenance activities (reported separately) • Other parameters to be monitored in accordance with **P-2 Biodiversity Management Plan** and **M-5 Flora and Fauna Monitoring Plan**.	Adequate supplies of plants are propagated to revegetate temporary sites (approx. 21.48 ha) Full cover of vegetation achieved by COD	During and post-construction Reported in HEC Monthly Project Reports and Quarterly E&S Reports	HEC HSE Manager

Supporting Documents

Annex	Name	Description
C-4-I.	List of Plant Species Recorded at the TRHDP Site	Indicative list of plant species present within the Project area
C-4-II.	Bioengineering for Infrastructure Protection: Slope Protection Report	Proposed method to plant a mix of legume cover crops and Vetiver grass for the purposes of erosion control on slopes.

[3] Note that some of the plant species discussed in this report are invasive to the Solomon Islands and are not recommended.

ANNEX C-4-II LIST OF PLANT SPECIES RECORDED AT TRHDP SITE

Table B.1: List of Plant Species Recorded at the TRHDP Site

Scientific Name	Common Name
Acacia auricauliformis	Acacia
Acalypha grandis	Acalypha
Actinodaphne solomonensis	Actinodaphne
Alpinia oceanica	Ginger
Alpinia purpurata	Ginger
Alpnia purpurata	Ginger
Alstonia scholaris	Milky Pine
Alstonia spectabilis	Milky Pine
Areca catechu	Beetle Nut
Areca macrocalyx	Beetle Nut
Artocarpus altilis	Bread Fruit
Astronidium novae-georgiae	Astronidium
Astronidium salomonensis	Astronidium
Barringtonia procera	Cut Nut
Barringtonia sp	Cut Nut
Boerlagiodendron sp.	
Brachiaria mutica	Para Grass
Broussonetia papyrifera	Paper Mulberry
Brownlowia argentata	Brownlowia
Calamus hollrungii	Ratan
Calamus stipitatus	Ratan
Calamus vestitus	Ratan
Calanthe longifolia	Terrestrial Orchid
Calophyllum paludosum	Calophyllum
Calophyllum peekelli	Calophyllum
Cananga odorata	Ylang ylang, Cananga
Canarium indicum	Ngali nut
Canarium salomonense	Small Ngali Nut
Carica papaya	Pawpaw, Papaya
Cassia alata	Cassia
Celtis philippinensis	Celtis
Citrus limon	Bush lime
Cocos nucifera	Coconut
Colocasia esculenta	Taro
Cominsia gigantea	Cominsia
Commelina diffusa	Commelina
Costus speciosus	Costus
Crinum asiaticum	Crinum, Lilly
Cryptocarya medicinalis	Cryptocarya
Cucurbita sp	Cucurbita
Cyathea brackenridgei	Cyathea, Tree Fern

Scientific Name	Common Name
Cyathea vittata	Cyathea, Tree Fern
Cyathocalyx petiolaris	Cyathocalyx
Cycas seemanii	Cycad
Cyrtosperma johnstonii	Wild taro
Dendrocnide inerme	Poison or Stinging tree
Dioscorea alata	Yam
Diplazium esculentum	Edible Fern
Donax canniformis	Donax
Drymophloeus salomonense	Drymo Palm
Dysoxylum excelsum	Dysox
Elaeis guineensis	Oil Palm
Elaeocarpus sphaericus	Elaeocarpus
Elatostema salomonense	Elatostemma
Euodia elleryana	Euodia
Euodia solomonensis	Euodia
Euphorbia hirta	Milky Weed
Ficus benjamina	Fig
Ficus chrysochaete	Fig
Ficus copiosa	Fig
Ficus longifolia	Fig
Ficus septica	Fig
Ficus variegata	Fig
Ficus virgata	Fig
Ficus wassa	Fig
Flagellaria gigantea	Flagellaria
Flueggia flexuosa	Flueggia
Gymnostoma papuana	Casuarina
Heliconia solomonensis	Heliconia
Hemigraphis reptans	Hemigraphis
Hernandia peltata	Hernandia
Heterospathe minor	Heterospathe palm
Heterospathe salomonensis	Heterospathe palm
Homalomena alba	Homalomena
Hornstedtia lycostoma	Sweet Ginger
Hoya guppyi	Hoya
Hydriastele macrospadix	Gulubia palm
Intsia bijuga	Kwila, Iron wood
Ipomoea batatas	Potato
Ipomoea illustris	Ipomoea
Kleinhovia hospita	Kleinhovia
Leea indica	Leea
Licuala lauterbachii	Licuala palm

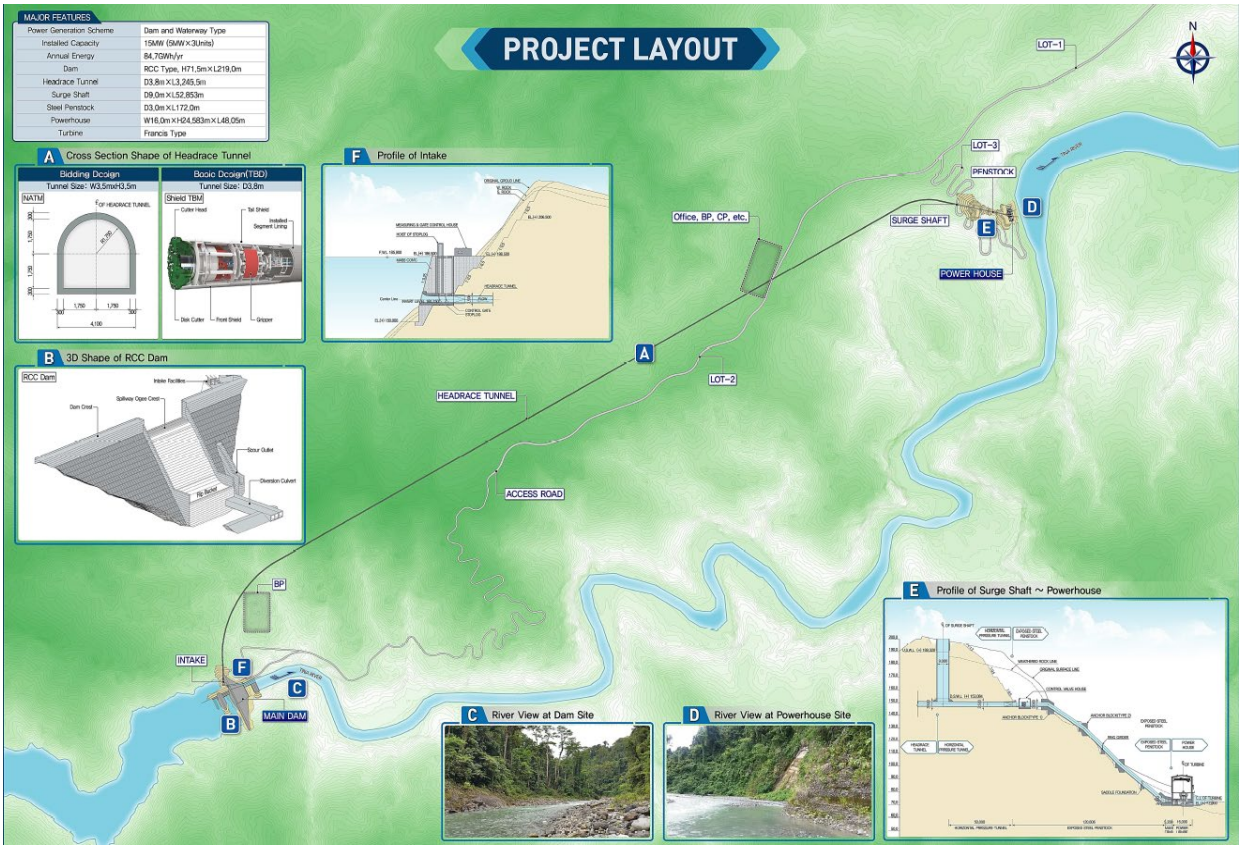
Scientific Name	Common Name
Ludwigia octovalvis	Primrose
Macaranga dioica	Macaranga
Macaranga fimbriata	Macaranga
Macaranga similis	Macaranga
Macaranga tanarius	Macaranga
Mangifera indica	Mango
Manihot esculenta	Casava
Medinilla cauliflora	Medinilla
Melastoma affine	Melastoma
Merremia peltata	Merremia
Metroxylon salomonense	Metroxylon Palm
Mikania micrantha	Mile-a-minute
Mimosa invisa	Sensitive Weed
Mimosa pudica	Sensitive Weed
Mucuna elegans	Mucuna
Musa sapientum	Banana
Mussaenda cylindrocarpa	Mussaenda
Myristica fatua	Myristica
Nastus obtusus	Bamboo
Neonauclea orientalis	Nauclea
Nephrolepis biserrata	Fishbone Fern
Nephrolepis hirsutula	Fishbone Fern
Palaquium firmum	Pencil Cedar
Pandanus compressus	Pandanus
Pandanus sp	Pandanus
Paraserianthis falcata	Albizia
Parinari glaberrima	Tita tree
Paspalum conjugatum	T - grass
Pennisetum polystachyon	Mission grass
Pennisetum purpureum	Elephant Grass
Pholidota sp	Orchid
Phragmites karka	Reed
Piper betle	Piper
Piper wichmanii	Piper
Pipturus argenteus	Pipturus
Planchonella firma	Planchonella
Planchonella thyrsoidea	Planchonella
Pleomele angustifolia	Pleomele
Plerandra solomonensis	Plerandra
Polyscias guilfoylei	Polyscias
Polyscias sp	Polyscias
Pometia pinnata	Pometia, Taun

Scientific Name	Common Name
Premna corymbosa	Premna
Pterocarpus indicus	Rose wood
Ptychosperma salomonense	Ptychosperma palm
Pueraria lobata	Pea
Rhopaloblaste elegans	Palm
Rhus taitensis	Rhus
Rubus moluccanus	Wild Raspberry
Samanea saman	Rain tree
Saurauia purgans	Saurauia
Schizomeria serrata	Schizomeria
Schizostachyum tessellatum	Small Bamboo
Selaginella rechingeri	Selaginella
Semecarpus forstenii	Semecarpus
Sida rhombifolia	Sida
Solanum torvum	Egg Plant
Spathodea companulata	African Tulip
Spathoglottis plicata	Groung Orchid
Starchytapheta jamaicensis	Blue Rat's tail
Stenochlaena palustris	Climbing Fern
Sterculia conwentzii	Sterculia
Syzygium myriadena	Syzygium
Syzygium onesima	Syzygium
Syzygium tierneyana	Syzygium
Tapeinochilus solomonense	Ginger
Terminalia brassii	Brown Terminalia, Swamp Oak
Terminalia calamansanai	Yellow Terminalia
Terminalia sp	Terminalia
Theobroma cacao	Cocoa
Timonius timon	Timonius
Trema orientalis	Trema
Trichospermum psilocladum	Trichospermum
Uncaria appendiculata	Water rope
Viola odorata	Violet
Vitex cofassus	Vitex, Vasa

ANNEX C-4-II BIOENGINEERING FOR INFRASTRUCTURE PROTECTION: SLOPE PROTECTION REPORT

BIOENGINEERING FOR INFRASTRUCTION PROTECTION

Slope Protection Report



SEPTEMBER 2020

Tina Hydropower Limited

HYUNDAI ENGINEERING CO., LTD.

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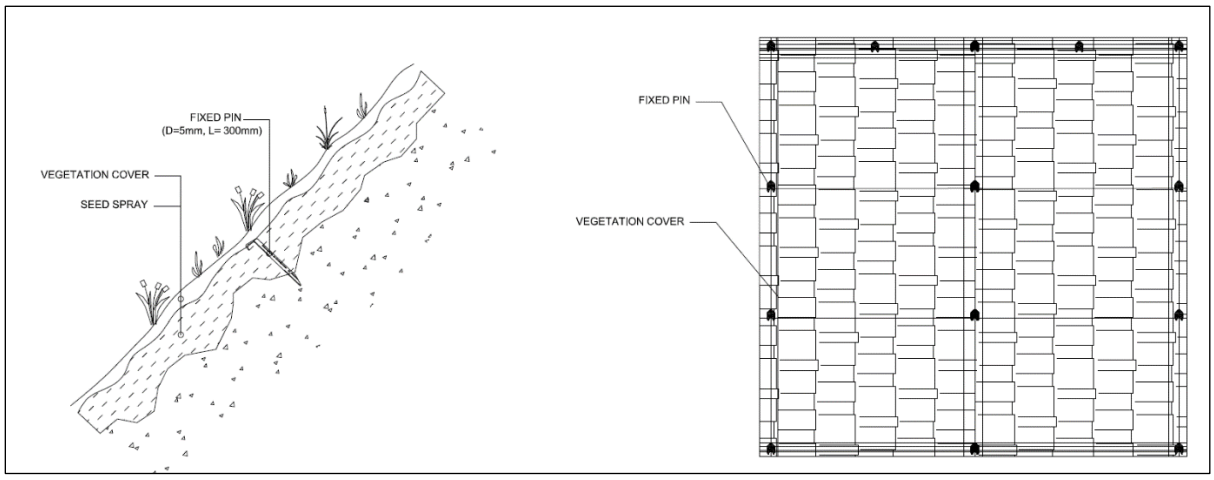
1.0 INTRODUCTION

The Tina River Hydropower Development Project (TRHDP) is expected to be the first major hydroelectric project in the Solomon Islands. Tina River is located 30 km South East of Honiara at the upstream end of the Ngalimbiu River Basin in Malango Ward 20, Central Guadalcanal District. The report contains the methods and type of legumes and grass that will be planted along the access road towards the Dam site and powerhouse area to protect the sloppy areas from soil erosion.

2.0 PURPOSE.

The Contractor is obligated to find an indigenous species (local species) that is suitable for the slope protection of the project site. A species which could tolerate such sloppy construction areas to meet ESMP P-2 BMP. Consultation were made with government authorities and local landscape company's such us Ministry of Agriculture, Kustom garden, New Palm oil limited and with Mr, Myknee Sirikolo, a Solomon Islander Botanist specialist. Mr. Sirikolo advised based on his experience and knowledge of the indigenous plant species and soil texture around Guadalcanal province, more specifically within Gold Ridge/Tina Hydropower project areas recommended to plant a mixer of LEGUME COVER CROPS and VETIVER GRASS for the purposes of avoiding erosion caused by runoff at the slope areas.



2- 1. Shows the simple layout of the slope protection method of planting grass.

- The purpose of selecting Vetiver grass and legume cover crops as the best option for slope Protection is based on their root system, protect the surrounding environment, and give nitrogen to soil.
- Furthermore, Mr. Sirikolo recommended to use the mixture of VETIVER GRASS and legume cover crops like MUCUNA BRACTEATA, CALOPOGONIUM MUCUNOIDES and PUARARIA JAVANICA. This is because they are indigenous/native plant species that are common and grows best on the type of soil within the project site. Mr Sirikolo discourages the use or introduction of foreign plant species as it may introduce invasive species of insects that could destroy the indigenous/native plant species or trees that could result in extinction of our native biodiversity.

2.1 PURPOSE OF LEGUME COVER CROPS.

- Protect the soil
  - Less soil erosion - soil washing away - and less surface crusting.
- Maintain fertility
  - Maintains the organic matter levels in the soil (grass) and, intercropping with leguminous plants adds nitrogen into the soil.
- Weed control
  - A healthy cover crop keeps a paddock free of weeds. (Weed suppression)
- Disease control
  - Can provide a "break crop" that helps reduce disease, nematode, and perhaps pest, levels. For vegetable production, grass cover crops rather than legumes tend to be best for this benefit.
- Mix planting of cover crops species is fine even grass with legume is also available.
- Biological tillage
  - Less cultivation is needed because cover crops loosen the soil.
- Improved paddock access
  - Cover crops can dry out a soil underneath and help farming operations to be timely. This drying out also adds more nitrogen in the soil more available.

Figure 2- 2. Shows the common types of legume cover crops.

2.2 VETIVER GRASS

Has a strong fibrous root system that penetrates and binds the soil to a depth of up to 3 meters and can withstand the effects of tunneling and cracking (Rubinsion.V, Bio- Engineering Infrastructure protection, 2020).

- Perennial and requires minimal maintenance.
- Grows in a wide range of climates. (200-600 mm and -9 to 45 degrees Celsius)
- Erosion and sediments control.
- Steep slope and sediment control.
- Infrastructure protection.

Figure 2 - 3. Shows the example of Vetiver grass for slop protection used in China roads.

3.0 TOTAL SPACE

3.1 LEGUME COVER CROPS

In Access road, design has a seed spray method for slope protection. The Contractor would like to propose LEGUME COVER CROPS to use in seed spray. Total surface to be protected by seed spray method would be 125,000M2 (12.5 ha) approximately. As for the cover crop, approximately 12.5 hectares of land will be covered. Thus requires approximately 75KG of Pueraria Javanica seed and 50KG of Calopogonium Mucunoide and 2 Kg of Mucuna Bracteata to cover the area. It is estimated at approximately 10grams per meter square.

3.2 VETIVER GRASS

However, for Vetiver grass, tillers divided from the mother clump will be used. Vertiver grass has an extensive rooting system with depths of up to 3-4 meters, has seeds but is sterile and does not grow from seeds, therefore it is not a weed. Anything apart from Vetiver seeds will be classified as an invasive species and prohibited into the Pacific Islands. It is rare to find suppliers and the roots are very shallow. Vetiver grass can be planted manually along contour lines to stabilize slopes (cut and fill batters). Slips divided from mother clumps only propagate vetiver. For planting requirement, **4-5 slips per square meter** can be used.

4.0 SPECIES.

The two main species that will be used in this project for slope protection is Legume cover crops and Vetiver grass.

4.1 LEGUME COVER CROPS

a. ***Pueraria javanice (PJ)***

Figure 4 - 1. Shows the photo of Pueraria javanice (PJ) legume cover crops.

Table 4 - 1. Description of Pueraria javanice (PJ)

Legume		
No.	**Name:** *Pueraria javanice (PJ)*	
1	**Plant Character**	Perennial, twining and climbing legume. It is deep- rooted, hairy and a bit woody. Primary stem can grow up to 10m. Secondary stems can grow from the nodes. Mass of foliage is between 60-75cm deep (Daniel, Eurolink Engineering Global Suppliers 2020).
2	**Uses**	Nitrogen fixer, smothers weed growth, controls erosion, retains soil moisture and attracts beneficial organism.
3	**Planting Type**	Monoculture -10Kg/ha. Mixture -4Kg/ ha.
4	**Planting Method**	Spray or in holes.
5	**Growth Habit**	Moderately shade Tolerance, able to survive temporary water logging. Can withstand 4-5 months dry season.

b. Mucuna bracteata

Figure 4 - 2. Shows the pictures of Mucuna Bracteata legume cover crops

Table 4 - 2. Description of Mucuna bracteata

Legume		
No.	**Name:** *Mucuna Bracteata*	
1	**Plant Character**	Perennial, creeping and aggressive climber legume, it spreads fast, thick stems and pseudo tap roots 2-3m depth. Branches from each node. (Daniel, Eurolink Engineering Global Suppliers 2020)
2	**Uses**	Smothers weed, nitrogen fixer, controls erosion, maintains soil moisture and temperature as well as improve soil texture. *Growth Habit* Shade tolerant, slow growth in the first 8 to 10 months. Thereafter, grows profusely.
3	**Planting Type**	Monoculture -85-100g/ha.
4	**Planting Method**	Nursery then field transplanting in points (holes).
5	**Number of Seeds per Kg**	5900-6000 seeds

c. *Calopogonium mucunoides*

Figure 4 - 3. Shows the picture of Calopogonium mucunoids (CM) legume cover crops.

Table 4 - 3. Description of Calopogonium mucuniods (CN)

Legume		
No.	**Name:** *Calopogonium mucunoides*	
1	**Plant Character**	Vigorous annual or short-lived trailing perennial. The stems are succulent, covered with long brown hairs. Rooting is dense and shallow at most 50cm deep. (Daniel, Eurolink Engineering Global Suppliers 2020).
2	**Uses**	N-fixing legume. Controls erosion, reduces soil temperature, improves soil fertility and controls weeds.
3	**Growth Habitat**	Moderately shade tolerant, Warm growing legume, Can withstand flooding conditions, grows better on acidic clay soil (Ph4.5-5) and poor drought tolerant.
4	**Planting Type**	Monoculture -10kg/ha and Mixture-4Kg/ha.
5	**Number of Seeds per Kg**	65,000 – 70,000 seeds.

4.2 VETIVER GRASS

Is a coarse perennial grass found in the tropics of Europe, Africa, Asia and the Oceania and belong to the family Andropogoneae. Vetiver Grass is scientifically known as Chrysopogon zizanioides (formerly known as Vetiveria zizanioides) originally from India (Rubinsion.V, Bio-Engineering Infrastructure protection, 2020).

Vetiver's unique attributes, the root and stem system, combine to work both above and below ground to provide the structural strength and protection mechanisms to address the main causes of slope instability: surface or sheet erosion and internal structural weakness.

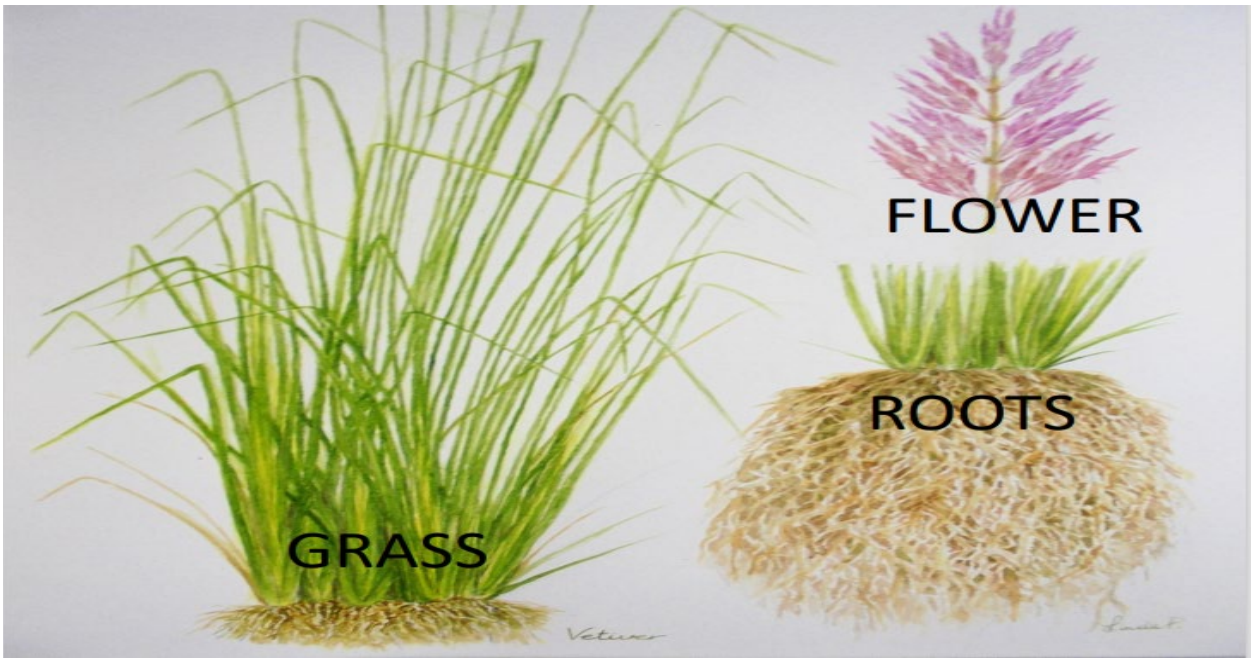


Figure 4 – 3. Shows the example of Vetiver grass, roots and flowers.

Vegetation Works in Three Ways to Address Slope Stability:

- Root reinforcement improves shallow mass stability by increasing the shear strength of the soil.
- Serves to modify the hydrologic activity of the slope, serving as an energy dissipater for water and wind. The grass slows the water flow, allowing the natural INFILTRATION

process to occur, absorbing the excess water and soil moisture, stabilizing internal structural weaknesses.

- The root system penetrates across the soil mantle, into fractures and fissures in the underlying bedrock, residual soil, or transition zones, increasing the soil shear strength.

4.3 TECHNICAL CHARACTERISTICS

- Tensible Strength: 75MPA or 750Kg/cm2 (±1/6 Tensile strength of mild steel.
- Shear Strength: 6- 19 KPA/KG Root/M³ Soil (Compare to tree root 3,2-3,7 KPA/KG root/M³ soil)
- Shear Strength can hold mud/Sediment in erosion controlling process.
- Root grows fast: Reducing ground water level, lowering pore water pressure, improving infiltration and reducing run off and erosion degree (Rubinsion.V, Bio- Engineering Infrastructure protection, 2020).

4.4 CIVIL WORK CHARACTERISTICS

- Highest strength level of all types of grass.
- Can live in sandy, rocky and saline soil.
- Can hold onto stream water = 0.028 M3/SEC.
- Dense and massive root (up to 2-4M).
- Strong and weather resistant.
- Better in aesthetics and co-exist with endemic plants.
- Expected cost is 1/6 –1/8 OF construction cost.

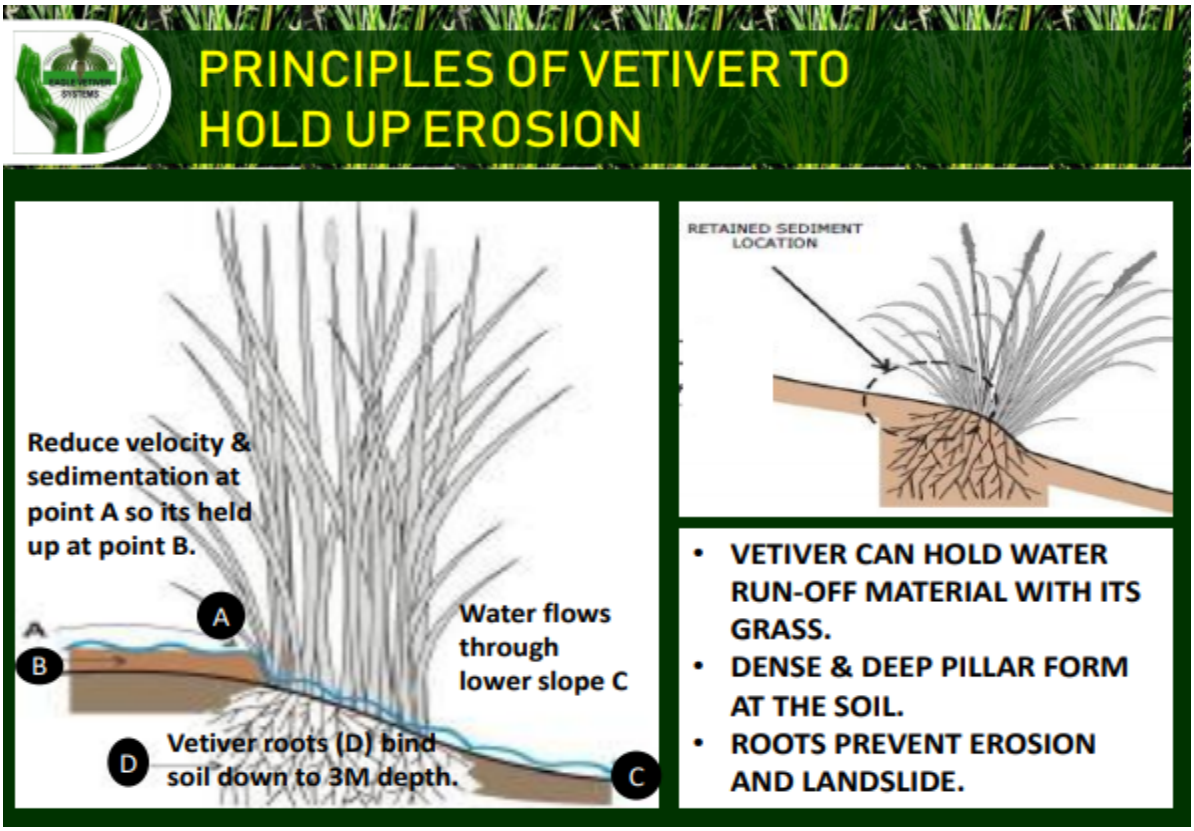


Figure 4 – 5. Shows the principal of Vetiver grass to hold up erosion.

5.0 CONCLUSION

In conclusion, the recommended plant/grass species to be grown at the slope area to protect soil erosion and can be best summarized as follows;

5. 1 VETIVER GRASS

- Eliminates undermining of hard rock structures.
- Effective alternative to hard rock check dams.
- Effective prevention of gully erosion.
- Very cost effective, with savings ranging from 73% for culvert protection to 64% for table drain and miscellaneous protection works and 60% for road shoulder protection.
- In highly erodible soils, the most important advantage of vetiver technology over conventional structures is that rock; structures themselves are not stable and required

constant maintenance to protect the road works, which will add to the overall operating costs of infrastructure in the long term.

5.2 LEGUME COVER CROPS

- Vegetable growers often use cover crops and they should be used more.
- They are very effective at protecting the soil from erosion and they improve soil structure.
- It is not necessary to grow a healthy cover crop to get a good result.

6.0 RECOMMENDATION

Ministry of Forestry and Research

National Herbarium & Botanical Garden Division

P.O. Box G24

Honiara

Solomon Islands

SOLOMON ISLANDS

GOVERNMENT

Phone: **(677)** 26015/ 7512609 **Date: 10 September 2020**

To: Whom it may concern

This is to confirm that the following legume cover crops and a grass species has been recommended for planting at the designated sites along the main road and other potential sites within the Tina River Hydropower Development Project core land area. These plants are: Legume cover crops: 1. Mucuna sp., 2. Pueraria sp. and Calogonium sp. Grass: 1. Vetivar grass.

It was based on the outcome of discussions between my office and staff from Hyundai Engineering Company, regarding the identification of potential species of plants for use in the restoration, revegetation and or rehabilitation of the different sites within the core project area. These initial four (4) plant species, which comprised of 3 legume vines as cover crops and 1 grass are suggested for their suitability as front liners for this purpose. They have the appropriate roots system and leaves that can perform the role of reduction and prevention of soil erosion and soil stabilization.

The legume crops have the capacity to quickly return and fix back nitrogen and other nutrients to the exposed soil and allow the natural regeneration of other plant species to succeed progressively in relation to other favourable environmental factors. They are also able to withstand extreme hot weather, cold, and wet conditions soon after their general establishment on the ground.

Yours faithfully,

Myknee Qusa Sirikolo

(Botanist & Forester)

7.0 PLANTING METHOD

The design will use seed spray method for legume cover crops while Vetiver grass will be planting manually alone the contour lines of the slope area. Legume cover crops is best suit the flat land areas and for slope areas, Contractor will use Vetiver grasses. These is based on their roots differences, so Vetiver grass will be plant along slope areas because its roots can go far depth to one meters. However, in most areas legume cover crops and vetiver grass will be mixed. This means the legume cover crops will be sprayed on the slope then Vetiver grass will be placed manually in between at around one (1) to two (2) meters interval as shown in the diagram below.

• Spraying method

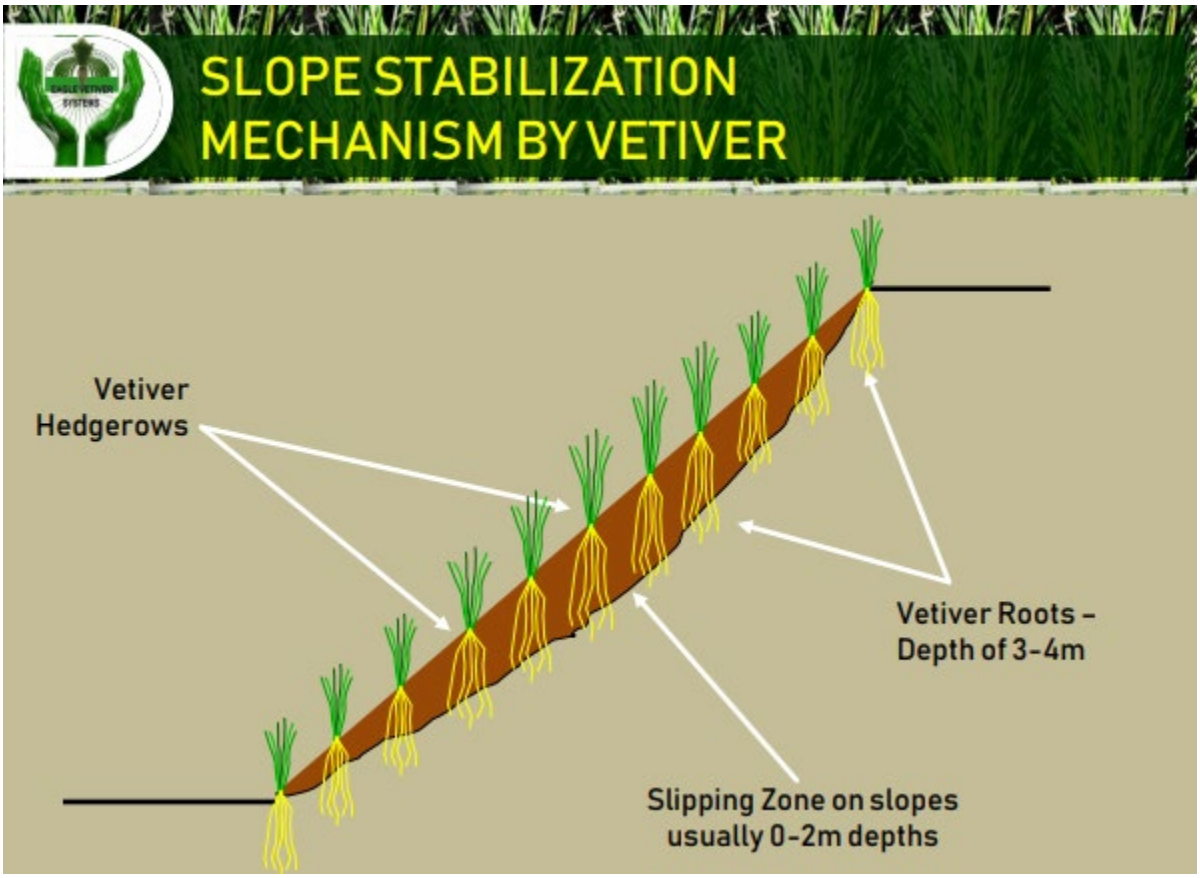


Figure 7 - 1. Shows the Slope Stabilization Mechanism by Vetiver grass.

8.0 References

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9.0 PHOTOES/APPLICATIONS

9.1 LEGUME COVER CROPS

Figure 9 - 1. Shows the example of Mucuna legume cover crops at Gipol plantation (15/08/2020)

Figure 9 - 2. Shows the photos of Calologonium cover crops at Gipol palm oil plantation (15/08/2020)

Figure 9 - 3. Shows the pictures of Pueraria cover crops at Gipol palm oil plantation. (15/08/2020)

Figure 9 - 4. Shows the legume cover crops planted with in palm oil plantation at Gipol 2. (15/08/2020).

9.2 VETIVER GRASS

Figure 9 - 5. Shows the example of Vetiver grass planted in PNG and China including its root system.

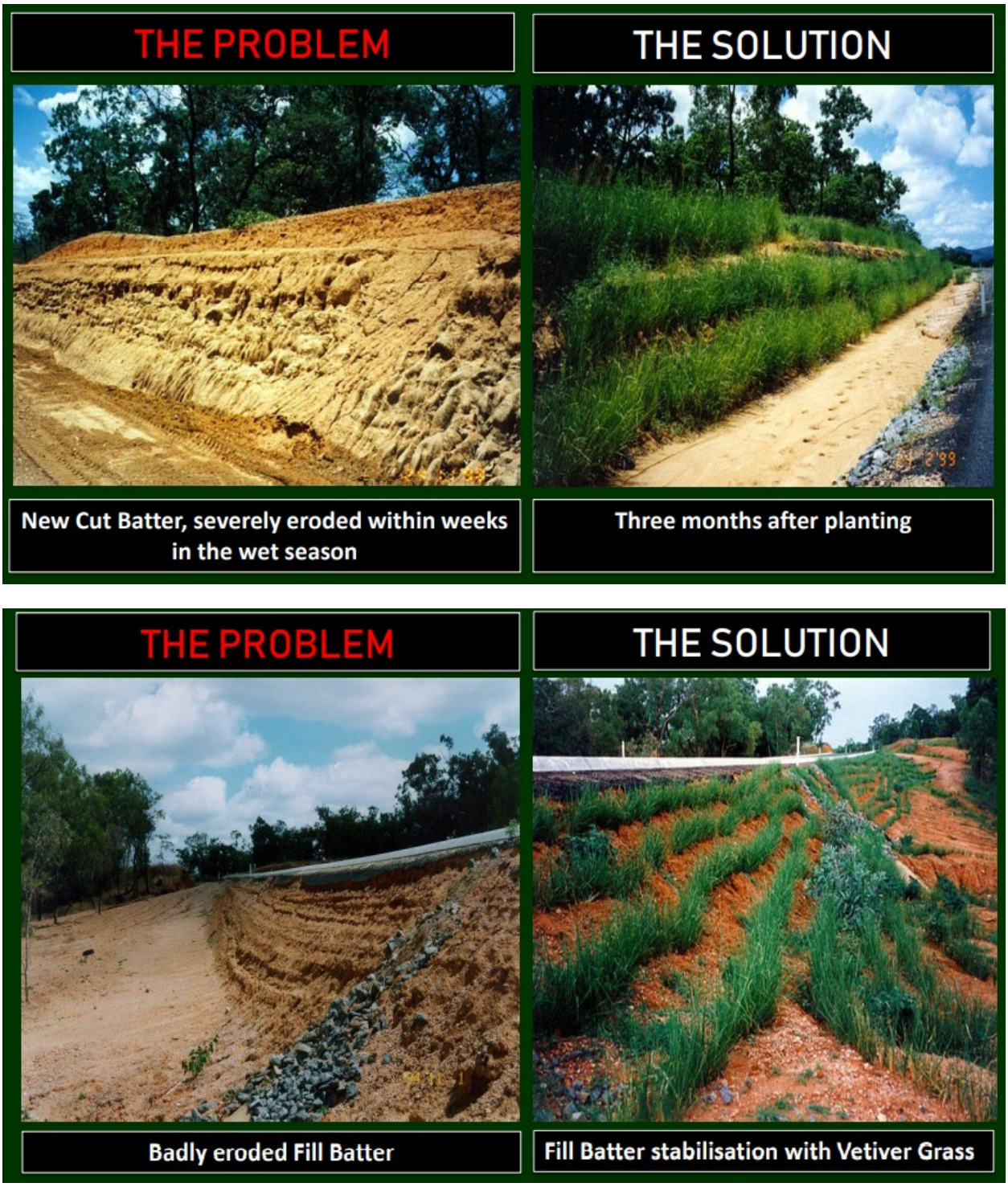

Figure 9 - 6. Shows the Vetiver grass function in protecting the soil erosion.

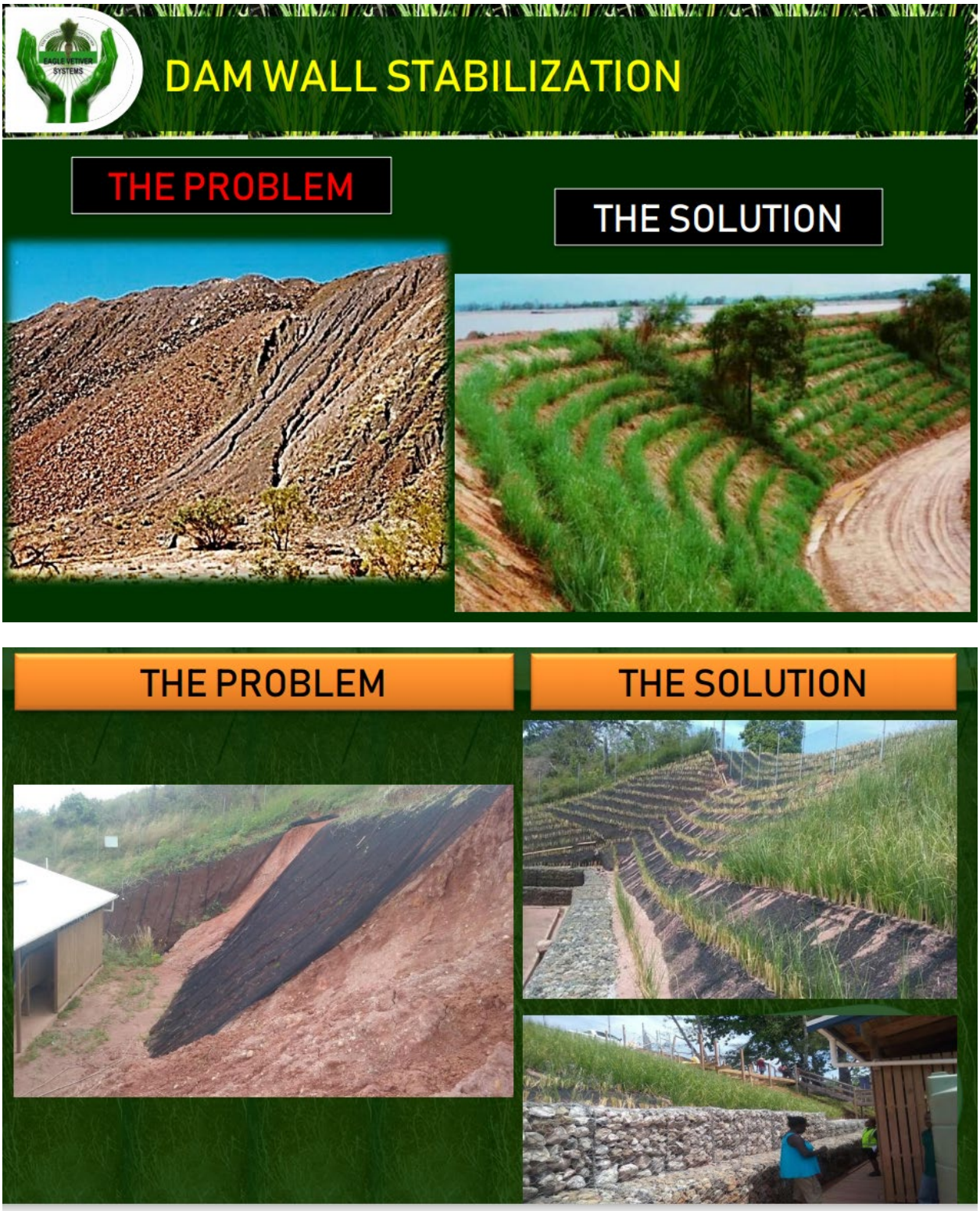

Figure 9 - 7. Shows the Vetiver grass planted as Dam Wall Stabilizer and helps protect the gabions from erosion.

ANNEX C-4-11 PLANT SPECIES PRESENT