Slope Protection Designs and Specifications

Guidelines from Trials in Northern Viet Nam

TA 8102-VIE: Promoting Climate Resilient Rural Infrastructure in Northern Viet Nam

Technical Report No. 18

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TR-1	Launch Workshop	February 2013
TR-2	Inception Workshop	April 2013
TR-3	Knowledge Development and Communications Plan	November 2013
TR-4	Vulnerability Assessment and Adaptation Response Workshop	November 2013
TR-5	Approaches to Building Climate Change Resilience in Rural Infrastructure	December 2013
TR-6	Feasibility Study: Demonstration Measures at Sub-project 4, Bac Kan	May 2014
TR-7	Feasibility Study: Demonstration Measures at Sub-project 32, Son La	October 2014
TR-8	Bioengineering Workshop: Design and Construction (Riverbanks)	July 2015
TR-9	Feasibility Study: Demonstration Measures at Sub-project 34, Thai Nguyen	December 2015
TR-10	Feasibility Study: Bioengineering Demonstration Measures to Protect Slopes at Nhau Pass at Sub-project 31, Son La	March 2016
TR-11	Initial Monitoring Report for Riverbank Demonstrations at SP4 Bac Kan and SP32 Son La	April 2016
TR-12	Bioengineering Workshop: Design and Construction (Roadside Slopes)	June 2016
TR-13	Lessons Learned Workshop	October 2016
TR-14	Demonstration Effectiveness Audit	May 2017
TR-15	Training Completion	May 2017
TR-16	Construction Completion	May 2017
TR-17	Field Guidelines for Slope Protection	May 2017
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More information: www.icem.com.au | info@icem.com.au
ICEM - International Centre for Environmental Management
6A Lane 49, To Ngoc Van Street,
Tay Ho, Hanoi,
Viet Nam

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1 INTRODUCTION

This document provides the detailed technical designs of selected bioengineering and associated engineering options used to protect and increase the resilience of roadside slopes and riverbanks against surface erosion and shallow failure. It is one of the knowledge products that the Asian Development Bank (ADB) capacity development technical assistance (TA) project TA 8102-VIE Promoting Climate Resilient Rural Infrastructure in Northern Viet Nam project has prepared as part of the long term purpose of establishing a critical mass of trained engineers and technicians able to use bioengineering as a low-cost, climate resilient tool. The project is funded by the Global Environment Fund (GEF) and administered by ADB, and provides technical assistance to the Ministry of Agriculture and Rural Development (MARD).

The document includes the drawings and specifications for 16 techniques that were physically demonstrated at five sites in four locations in three provinces of northern Vietnam, namely: Thanh Mai Commune, Bac Kan Province; Lien Minh Commune, Thai Nguyen Province; and Thom Mon Commune and Phong Lap Commune, Son La Province. It is to provide a developing knowledge base and source of design material that can be further expanded and updated for the use of bioengineering practitioners, and to support the knowledge transfer process to the key stakeholder groups.

For detailed practical application of the summarised options this document should be used in conjunction with TA 8102-VIE report TR17 Field Guidelines for Slope Protection and report TR14: Demonstration Effectiveness Audit.

All of the techniques use locally available materials, particularly indigenous plants. The list of plants used in the demonstration sites is given in Table 1, and the list of bioengineering and associated engineering options is summarised in Table 2.

As developed by this project under the support of the GEF and ADB, there are two main purposes for the use of bioengineering on slopes and riverbanks.

- ***Protection*** of surfaces against erosion and shallow landsliding under normal conditions.
- ***Resilience*** against damage by exceptional rainstorms, floods or other climatic events, either now or in the future.

Consequently this document refers to both ***protection*** and ***resilience***, as the purposes for the use of bioengineering in conjunction with standard civil and geotechnical engineering structures.

Table 1: Initial list of recommended plants for use in bioengineering and mixed techniques

Plant	Scientific name	Locations of use		
		Cut slope	Embankment	River bank
Vetiver grass	*Vetiveria zizanioides*	√	√	
Willow-leaved water croton	*Homonoia riparia*			√
Weeping fig	*Ficus benjamina*			√
Tiger grass	*Thysanolaena latifolia*	√	√	
Golden dewdrop	*Duranta erecta*	√	√	
Blanket grass	*Axonopus compressus*	√	√	
Indian willow	*Salix tetrasperma*		√	√
Randia tomentosa	*Randia tomentosa*	√		

Table 2: Recommended site types for bioengineering and engineering techniques

Ref.	Option	Locations for use		
		Cut slope	Embankment	River bank
A.1	Large grass planting	√	√	
A.2	Short cover grass planting	√	√	
A.3	Grass seed + mulch + mesh	√		
A.4	Brush layers	√	√	√
A.5	Palisades	√		
A.6	Live fences		√	√
A.7	Fascines		√	√
A.8	Live poles and truncheons		√	√
A.9	Live check dams	√		
A.10	Shrub or tree planting			
B.1	Vegetated rip rap			√
B.2	Vegetated gabions			√
B.3	Concrete frame + large grass	√		
C.1	Concrete frame + stone infill	√		
C.2	Stone-lined drains	√	√	
C.3	Gabion cascades	√	√	
C.4	Gabion mattresses			√

2 CLIMATE RESILIENCE

Climate change has always occurred at different time scales and in future is likely to be an increasing feature of global environmental conditions. Although the nature of accelerated climate change is still very difficult to determine, there is increasing evidence that the variability of weather patterns is changing. Even without that, much of human life is already sometimes affected by climatic-induced events (rainstorms, droughts, typhoons, etc.) of exceptional severity, and at levels occasionally experienced historically. It is obvious that, even if future climate changes are not significantly more severe, the future management of infrastructure will benefit from greater in-built resilience to the kind of events already seen. If that can be achieved in a cost-effective way, then the benefits will be greater.

Bioengineering offers a number of opportunities to make infrastructure more resilient for both current and possible future climatic extremes. There are several ways in which this can be done, but the common theme is that any bare soil surface must be treated with bioengineering techniques. As this document shows, these are very affordable within the overall scope of infrastructure project budgets.

Beyond small areas, the only way to protect slope surfaces from erosion is through the use of vegetation. In most cases, plants will gradually colonise bare surfaces, and eventually a full cover of vegetation will be achieved. Left to itself, this vegetation will be random. One of the purposes of bioengineering is to *engineer* the vegetation so that it is as strong as possible. To do this usually requires more than one technique to be used. That is why it is important to assess each site carefully and to implement a range of measures. An example might be for an embankment to have a cover of planted grass to armour the surface against erosion, and also to have live poles inserted, from which will come strong, woody roots that reinforce the soil and increase its resistance to shear. What this means is that the incorporation of vegetation in engineering – bioengineering – is not just good in protecting roads from current climatic problems like heavy rainfall, but also important to make them more resilient against greater extremes of rainfall, drought or flood.

A range of vegetation also increases the biodiversity. This is not so much through the vegetation itself – only a few species are used in bioengineering works – but more through the encouragement of colonisation of the site by other plants and animals which can come into the habitat created by the initial bioengineering species. Greater biodiversity is a benefit in itself, but it is also important to achieve it wherever possible because healthy ecosystems contribute to environmental resilience in the wider landscape.

In rural areas, vegetation can be restored quickly by the local community, who are familiar with the species and how to manage them. This is particularly the case where the bioengineering scheme is designed to be managed in part by the local community for productive purposes. Through this process, the protection of roads can be more resilient and easier to restore following an extreme climatic event.

At a local level, the presence of vegetation itself helps to modify the climate. Bare surfaces become hot and dry, but vegetation provides shade, keeping it cooler and maintaining soil moisture for longer. It also captures carbon and transpires oxygen, contributing in at least a small way to climate amelioration.

Figure 1: Current and future climate fluctuations make engineering more uncertain in hilly areas

3 GENERAL PROCEDURES

Effective and sustainable slope protection and stabilisation need to start with understanding the nature of any actual or potential slope problems and their causes. To identify and build up an understanding of the problem, slope inspection needs to be conducted carefully and systematically, to identify the basis for the next steps. A risk-based approach can be used to determine the best way to allocate resources between different sites.

Figure 2 outlines the decision-making process for site inspection, through which practitioners can plan for and design appropriate solutions.

If any potential slope problem is identified, it is important to carry out detailed planning of the necessary steps to address the problem.

Figure 3 shows the progression of the steps for slope stabilisation and protection, starting from planning and moving to design, implementation and lastly, maintenance.

A key part of the planning process is the detailed assessment of each site. The recommended approach for this involves a careful inspection of the site, completing a data collection exercise. The intention is to understand what processes are causing the problems that are making the site unstable, and working out how they can be resolved most cost effectively.

Figure 4 gives a simple format for the systematic assessment of roadside and riverbank slope problems.

Choosing the appropriate engineering techniques, either geotechnical or bioengineering, depends on site conditions. Each slope problem requires one or more solutions to perform different functions. Bioengineering can deal with surface protection and shallow slope instability. Therefore, knowing which bioengineering technique is suitable for each slope problem is crucial for applying this approach.

Figure 5 shows how to select the best technique, to give the best arrangements for protection and resilience.

After site construction is completed and all of the bioengineering techniques are put in place, it is vitally important to perform maintenance activities correctly and at the right times. A handbook on maintenance has been published by this project's Technical Assistance team and was distributed to contractors and communities: this is incorporated in report TR14 in the same series as this document.

Technical Notes

The following notes provide additional information and explanation in support of Figures 3, 4 and 5.

Note A: Site Segments. A slope segment can be defined as a length of slope with a uniform angle and homogeneous material that is likely to erode or fail in a uniform manner. In most cases, the engineering response will be different for different parts of a site. The segment is the unitary area of treatment on the site.

Note B: Material Drainage. This relates to the internal porosity of soils and the likelihood of their reaching saturation, losing cohesion and starting to flow. Materials with poor internal drainage tend to have more clay than sand. They are prone to slumping at a shallow depth (e.g. < 500 mm) if they accumulate too much moisture. In such a case, stabilisation requires some kind of drainage in addition to other functions.

Note C: Site Moisture. The moisture regime of the entire site must be considered, although in the field this can only be estimated. In assessing sites, it is necessary to determine into which of four categories each segment falls.

- Wet: permanently damp sites (e.g. north-facing gully sites).
- Moist: sites that are reasonably well shaded or moist for some other reason.
- Dry: generally dry sites.
- Very dry: sites that are very dry; these are usually quite hot as well (e.g. south-facing cut slopes).

Figure 2: Decision-making process for slope inspection and maintenance

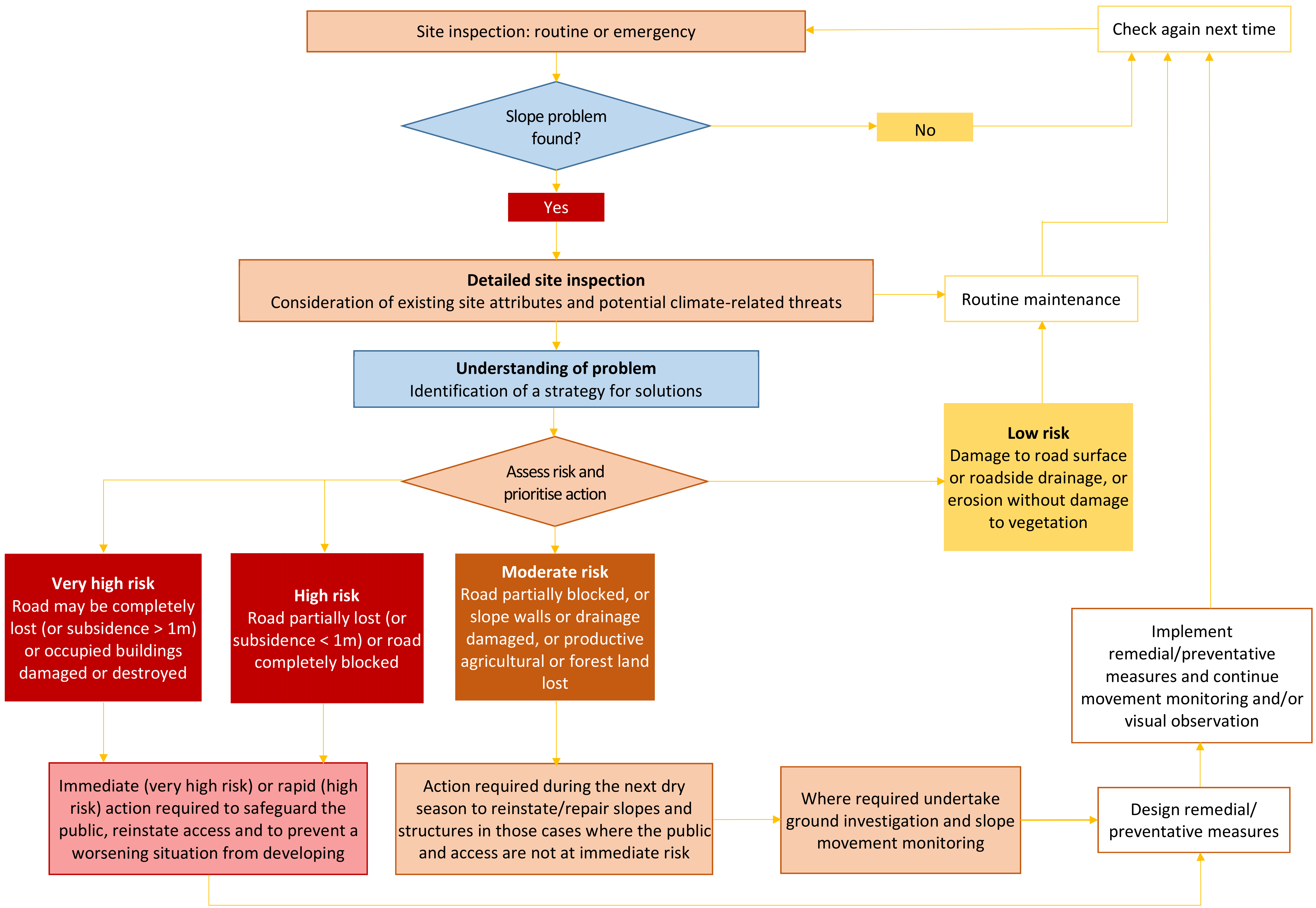


Figure 3: Flow chart to show the progression of the steps for slope stabilisation and protection

PHASE	STEP	ACTION TO BE TAKEN	RESULT / OUTPUT EXPECTED	LOCATION
Planning	1	Make an initial plan of the year's works	List of sites requiring treatment	Office
	2	Prioritise the work	List of sites in priority order (see Figure 1)	Roadline
	3	Initial site appraisal	Divide the sites into segments for assessment (see Note A)	Sites
	4	Assess the site	Detailed plan of site with problems identified (see Figure 3)	Sites
	5	Determine combination of works required	Initial plan of civil and bioengineering techniques (see Figure 4)	Sites
	6	Choose the optimal techniques for the site	List of techniques to be designed in detail, with measurements	Sites
Design	7	Design the civil and bioengineering works	Detailed designs for all required works	Office
	8	Select the species to use	List of the actual species of plants to be used	Office
	9	Calculate the required quantities and rates	Table of quantities, rates and costs for all required works	Office
	10	Finalise priority against available budget	Final list of site works to be completed within available budget	Office
	11	Plan plant needs	Determination of the actual sources of bioengineering plants	Office
	12	Prepare documents and arrange implementation	Draft contract documents and arrange procurement	Office
Implementation	13	Prepare for plant propagation or procurement	Arrangements made for provision of all required plants	Nursery/source
	14	Make the necessary site arrangements	Contracts and other procurement and logistical arrangements	Office/sites
	15	Prepare the site for work	Site access and safety provisions completed	Sites
	16	Implement the civil engineering works	All earthworks and hard engineering completed	Sites
	17	Implement the bioengineering works	All bioengineering works completed	Sites
	18	Monitor the works	Regular inspections undertaken to ensure works are functioning	Sites
Maintenance	19	Maintain the works	Repairs, cleaning and refinements undertaken as necessary	Roadline/sites

Figure 4: Site assessment and treatment procedure

SITE ASSESSMENT PROFORMA

Complete one proforma per site. Use additional forms if there are more than 3 segments on the site

Site location:

Date of assessment: **Assessor's name:**

Site type

[_] Above road [_] Below road [_] Riverbank [_] Other (specify)

Sketch of site [Label segments]

Scale: Orientation:

(a) Segment number	**(1)**	**(2)**	**(3)**
(b) Erosion and failure processes			
(c) Oher factors			
(d) Slope angle(s)			
(e) Slope length			
(f) Material drainage			
(g) Segment moisture			

Assessment criteria

(a)	Slope segments.	Identify each part of the slope with a uniform angle, material and failure process(es).
(b)	Erosion and failure processes.	List the erosion or failure processes. State their size and severity.
(c)	Other factors.	List any physical factors which might affect the site. State their size and severity.
(d)	Slope angle(s).	Measure and place in one of 3 classes: < 30º, 30 – 45º, or > 45º.
(e)	Slope length.	Measure and place in one of 2 classes: <15 metres or > 15 metres.
(f)	Material drainage.	Assess and place in one of 2 classes: good or poor.
(g)	Segment moisture.	Assess and place in one of 4 classes: wet, moist, dry or very dry.

SITE TREATMENT PROFORMA

Complete one proforma per site. Use additional forms if there are more than 3 segments on the site

Site location:

Date of assessment: **Assessor's name:**

Sketch of proposed treatment – Segment 1	**Treatment list**
Sketch of proposed treatment – Segment 2	**Treatment list**
Sketch of proposed treatment – Segment 3	**Treatment list**

Additional notes on site treatment

Figure 5: Choosing bioengineering techniques for slope protection and resilience

START (a) SLOPE ANGLE	→ (b) SLOPE LENGTH	→ (c) MATERIAL DRAINAGE	→ (d) SITE MOISTURE	→ (e) PREVIOUS / POTENTIAL PROBLEMS	→ (f) FUNCTIONS REQUIRED	→ (g) PRIMARY TECHNIQUES – PROTECTION	→ (g) SECONDARY TECHNIQUES – RESILIENCE
> 45^0	> 15 metres	Good	Damp	Erosion, slumping	Armour, reinforce, drain	**Diagonal lines of large grass planting**	Diagonal palisades at wide spacing
			Dry	Erosion	Armour, reinforce	**Contour lines of large grass planting**	Contour palisades at wide spacing
		Poor	Damp	Surface slumping, erosion	Drain, armour, reinforce	**1. Downslope grass lines and vegetated stone pitched rills** or 2. Chevron grass lines and vegetated stone pitched rills	None available – consider more hard engineering measures with good drainage
			Dry	Erosion, surface slumping	Armour, reinforce, drain	**Diagonal lines of large grass planting**	Diagonal palisades at wide spacing
	< 15 metres	Good	Any	Erosion	Armour, reinforce	**1. Diagonal lines of large grass planting** or 2. Bamboo mesh and planted grass	Diagonal palisades at wide spacing
		Poor	Damp	Surface slumping, erosion	Drain, armour, reinforce	**1. Downslope lines of large grass planting** or 2. **Diagonal lines of large or short grass planting**	None available – consider more hard engineering measures with good drainage
			Dry	Erosion, surface slumping	Armour, reinforce, drain	**1. Bamboo mesh and short grass planting** or 2. Contour lines of large grass planting or 3. Diagonal lines of large grass planting	Contour palisades at wide spacing
30^0 - 45^0	> 15 metres	Good	Any	Erosion	Armour, reinforce, catch	**1. Downslope grass lines and vegetated stone pitched rills or** 2. Site planted grass, mulch and jute or bamboo mesh	Live poles or truncheons
		Poor	Any	Surface slumping, erosion	Drain, armour, reinforce	**Site-specific drainage system and shrub/tree planting**	Nothing further required
	< 15 metres	Good	Any	Erosion	Armour, reinforce, catch	**1. Brush layers of woody cuttings** or 2. Contour lines of large or short grass planting or 3. Contour fascines or 4. Palisades of woody cutting or 5. Large grass planting and jute or bamboo mesh	Short cover grass planting between brush layers, palisades and fascines Live poles between grass lines
		Poor	Any	Surface slumping, erosion	Drain, armour, reinforce	**1. Diagonal large grass planting lines** or 2. Diagonal brush layers or 3. Site-specific drainage system and shrub/tree planting	Shrub or tree planting
< 30^0	Any	Good	Any	Erosion	Armour, catch	**Contour lines of large grass planting**	Shrub or tree planting Live poles or truncheons
		Poor	Any	Surface slumping, erosion	Drain, armour, catch	**Diagonal lines of large grass planting**	Shrub or tree planting Live poles or truncheons
Special conditions							
Any loose sand		Good	Any	Erosion	Armour	**Bamboo mesh and planted grass**	Live poles or truncheons
Any "laterite"		Poor	Any	Erosion, surface slumping	Armour, drain	**Diagonal lines of grass and shrub/tree planting**	Nothing further required
Gullies ≤ 45^0	**Any gully**			Erosion (major)	Armour, reinforce, catch	**1. Live check dams or** 2. Vegetated stone pitching	Nothing further required

≠ Only the common potential problems are given here. "Any loose sand" is defined as any slope in a weak, unconsolidated sandy material; such materials are normally river deposits of recent geological origin. "Any laterite" covers any reddish soil with a high clay content. It is normally of clay loam or clay texture, and formed from prolonged weathering; it may not show all the characteristics of laterite. Techniques in bold type are preferred.

4 COST NORMS

To support planners, developers and practitioners in estimating the labour requirements for constructing bioengineering techniques in different areas, the project recorded in detail the labour inputs required to build the demonstration sites. These are summarised in Table 3, and the details are given at the end of this document: Table 7 for SP4 in Bac Kan Province, Table 8 for SP32 and Table 10 for SP31 in Son La Province, and Table 9 for SP35 in Thai Nguyen Province

These figures need to be treated with caution, for the following reasons.

- The findings are based only on demonstration sites, so these data are from a research environment, and not from the setting of a regular mainstream activity.
- For no activity was there a sample of more than four demonstrations.
- A large proportion of the activities (18 out of 38) were each only undertaken at one site.
- Site conditions vary considerably between locations, so that bids and costs are also likely to have varied between the sites.
- Contractors were new to these activities, and so the bidding rates might not be particularly representative of the actual true costs.
- The sites were individual locations, and so there was no economy of scale for the contractors' mobilisation to cover a number of sites.

Because of these limitations in the data that are currently available on bioengineering works in Viet Nam, Table 3 includes columns to show the range of values that were found between the sites. This allows the user to see the range of variation easily, and thereby to see how much variability was experienced between the sites.

Nevertheless, Table 3 shows that there is a reasonable concurrence for some activities, particularly those for bioengineering. It also gives the upper and lower limits that might be expected, giving users at least some guidance in calculating the inputs required.To support planners, developers and practitioners in estimating the labour requirements for constructing bioengineering techniques in different countries and different areas, the summaries of detailed labour inputs to build the five demonstration sites are included in Table 7 for SP4 in Bac Kan Province, Table 8 for SP32 and Table 10 for SP31 in Son La Province, and Table 9 for SP35 in Thai Nguyen Province.

Figure 6. A rehabilitated valley side slope on a mountain road in Sa Pa. The project's demonstration trials show that one worker can plant 4 m^2 of large grasses per day.

Table 3: Summary of information regarding the labour requirements for different slope protection activities

Ref.	Item	Unit	Average labour requirement (days/unit)	Range	
				Lowest labour requirement	Highest labour requirement
	Improvement/repair of access road (about 1000 m)	Lump sum	**187.50**	105.00	270.00
	Temporary tents & storage (5% of other construction costs: 1 + 3a + 4 to 15)	Lump sum	**86.50**	70.00	103.00
	Site clearance including disposal	m^2	**5.36**	0.01	16.00
	Compensation for trees (official rate 1,950,000, doubled for contingency)	Lump sum	**5.50**	3.00	8.00
	Earthworks (Cut) for slope formation of medium soil including disposal locally or up to 1 km away	m^3	**0.26**	0.21	0.31
	Earthworks (Cut Slope) for slope formation / trimming	m^3 of cut	**0.37**	0.16	0.58
	Earthworks (Fill) for slope formation including compaction to K85	m^3	**0.52**	0.50	0.54
	Earthworks (Fill Slope) for slope formation / trimming	m^3 of fill	**2.23**	0.35	4.10
	Earthworks for slope surface preparation (trimming and making ready for planting and/or rock works)	m^2	**0.02**	0.01	0.03
	Disposal of debris and surplus materials locally or within 1 km including any fees	m^3	**0.69**	0.10	1.75
	Transportation of materials from road to site	m^3	**1.31**	n.a.	n.a.
A.1	Construction of Vetiver Grass Lines	m^2 of planted area as designed	**0.23**	0.10	0.30
A.2	Construction/planting of Short Grass	m^2 of planted area	**0.19**	0.18	0.21
A.3	Construction of wide-mesh Jute Net with grass seeding	m^2 of constructed area	**0.62**	n.a.	n.a.
A.4	Construction of Brush Layers	Linear m of terrace	**0.21**	0.09	0.29
A.5	Construction of Live Palisades	Linear m of planted row	**0.56**	0.32	0.80
A.6	Construction of Live Fences	Linear m of row	**0.23**	0.07	0.41
A.7	Construction of Fascines	Linear m of row	**0.32**	0.08	0.56
A.8a	Construction of Live Poles	Linear m of row	**0.11**	0.08	0.14
A.8b	Construction of Truncheon Cuttings	Linear m of row	**0.38**	n.a.	n.a.
A.9	Construction of Live Check Dam	Piece (1 constructed dam)	**2.00**	n.a.	n.a.
B.1a	Construction of Vegetated Riprap Type 1 (K0 – K5)	Linear m as designed	**2.55**	n.a.	n.a.
B.1b	Construction of Vegetated Riprap Type 2 (K8 – K10)	Linear m as designed	**2.50**	n.a.	n.a.
B.1c	Construction of Vegetated Riprap (C7 – C10)	Linear m as designed	**2.76**	n.a.	n.a.
B.2	Construction of Vegetated Gabions (C5-C7 & C12-C13)	Linear m as designed	**1.19**	n.a.	n.a.
B.3	Construction of mortared masonry frame with grass planting	m^2 of constructed area	**1.49**	n.a.	n.a.
C.1	Construction of mortared masonry frame with dry stone revetment	m^2 of revetment	**1.63**	n.a.	n.a.
C.2a	Construction of dry stone pitching for drainage channel at base of fill slope (including earthworks for trimming)	linear m of channel	**0.43**	n.a.	n.a.
C.2b	Construction of mortared masonry-lined channel on cut slope (includes earthworks for trimming)	linear m of channel	**0.94**	n.a.	n.a.
C.2c	Construction of mortared masonry drains at roadside and 1st level (including earthworks for channel trimming)	linear m of channel	**0.94**	n.a.	n.a.
C.3a	Construction of gabion cascade	m^3 of gabion cascade	**2.85**	1.41	4.29
C.3b	Construction of Gabion (1st layer, C2-C7 & C10-C13)	Linear m as designed	**2.15**	n.a.	n.a.
C.3c	Construction of mortared rock side wall for gabion cascade	m^3 of stone side wall	**11.82**	3.09	20.55
C.3d	Construction of additional steps to existing cascade	m^3 of masonry	**4.00**	n.a.	n.a.
C.4	Construction of Gabion Mattress (C2-C7 & C10-C13)	Linear m as designed	**4.29**	n.a.	n.a.
	Construction of Toe Riprap (K0, K6, K7)	Linear m as designed	**2.08**	n.a.	n.a.
	Construction of concrete slope revetment at slope toe (including earthworks for slope trimming)	m^2 of revetment	**1.63**	n.a.	n.a.

n.a. – not applicable – is used where the activity was used on only one site

5 VEGETATED TECHNIQUES

Where a slope is subject to erosion or very shallow slope failure, vegetated methods of slope protection are appropriate. This involves the use of living plants or cuttings to reduce erosion and shallow-seated instability on slopes. In these applications while there is an element of slope stabilisation the primary focus is on slope surface protection.

Vegetation is a highly appropriate means of providing slope protection for reasons of its availability, relatively low cost, local resource based installation techniques and compatibility with a rural environment. It is particularly appropriate in situations where large areas of slope are affected, a common situation on road cuttings and unstable hill terrain. The enhancement of road-side vegetation increases resilience to extreme climatic events, and can also have a positive effect both visually and through economic returns from plant usage.

Vegetative techniques protecting riverbank at SP4 in Bac Kan Province

Vegetative techniques protecting fill slope at SP35 in Thai Nguyen Province

A.1 LARGE GRASS PLANTING

LARGE GRASS PLANTING (1)

A1

This procedure applies to a range of large grass species, but it is based on Vetiver grass, which is widely used in bioengineering works throughout south-east Asia.

Site Preparation

a. The site is prepared to the desired slope before the day on which planting will take place. Debris is removed, depressions are filled in and humps are levelled off to attain a linear profile.

b. Using a measuring tape and string, the lines to be planted shall be marked by pegs starting from 750 mm beyond the top of the slope and then at 300 mm down the slope.

Plant Preparation

a. Plant cuttings must be prepared and planted within 12 hours.

b. Vetiver (Vetiveria zizanioides) clumps shall be dug out from the nursery using a spade or hand trowel.

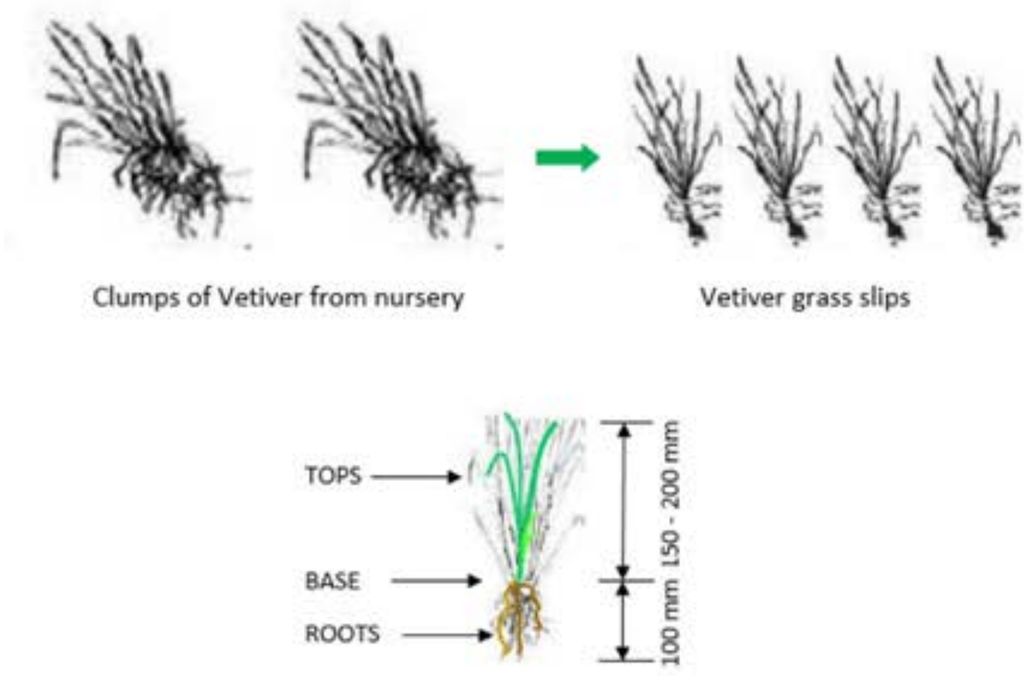
c. A handful of grass, including the roots, is carefully separated by pulling it away from the rest of the clump. This is called a 'slip' of Vetiver grass. It must consist of at least two shoots with live growth buds and at least five roots with live growth buds.

d. The top (leaves) of the slip are cut off about 150 mm to 200 mm above the base of the plant (i.e. the point where the above ground shoots meet the roots).

e. The roots are cut off at 100 mm below the base. See Fig. A.1.1.

f. The slips are then wrapped in wet jute sacks and kept in the shade while they are transported to the site.

Fig. A.1.1: Preparation of grass slips



Clumps of Vetiver from nursery

Vetiver grass slips

Cut slips

TA 8102-VIE: PROMOTING CLIMATE RESILIENT RURAL INFRASTRUCTURE IN NORTHERN VIETNAM				
SP4 - BAC KAN RIVERBANK WORKS				
LARGE GRASS PLANTING PROCEDURE				
ICEM TAY HO, HANOI, VIET NAM	DRAWING ID: AAS1206/C-323/F003	DESIGNER:	DAVID ROJAS JR.	
		DRAWER:	PHAN TIEN AN	
PHILKOEI INTERNATIONAL INC, PHILIPPINES (PKII)	SCALE: NO SCALE	CHECKED:	NGUYEN TRAN THUAT	
	DATE: 10/5/2014	APPROVAL:	JAMES RAMSAY	

LARGE GRASS PLANTING (2)

A1

Planting Process

1. The first line to be planted is along the top of the slope, then working downwards.
2. Dig holes 100 mm deep and 75 mm in diameter at 100 mm centres along the top row. See Fig. A.1.2.
3. Place the grass slip into the hole, making sure that the roots are not tangled or curved back to the surface.
4. Fill the hole with soil and firm gently with the fingers leaving no air pockets by the roots.
5. Firm along the whole row using careful foot pressure.
6. If it is available, place a few handfuls of compost or manure around each grass line.
7. Proceed to the next row down and repeat steps 2 to 6. Note that the grasses in each row should be offset from the one above. See Fig. A.1.3.
8. If no rain is expected in the next two days, pour water carefully by hand over each grass plant.

Fig. A.1.2: Site prepared for grass planting, showing the marker pegs for the rows and the locations of planting holes

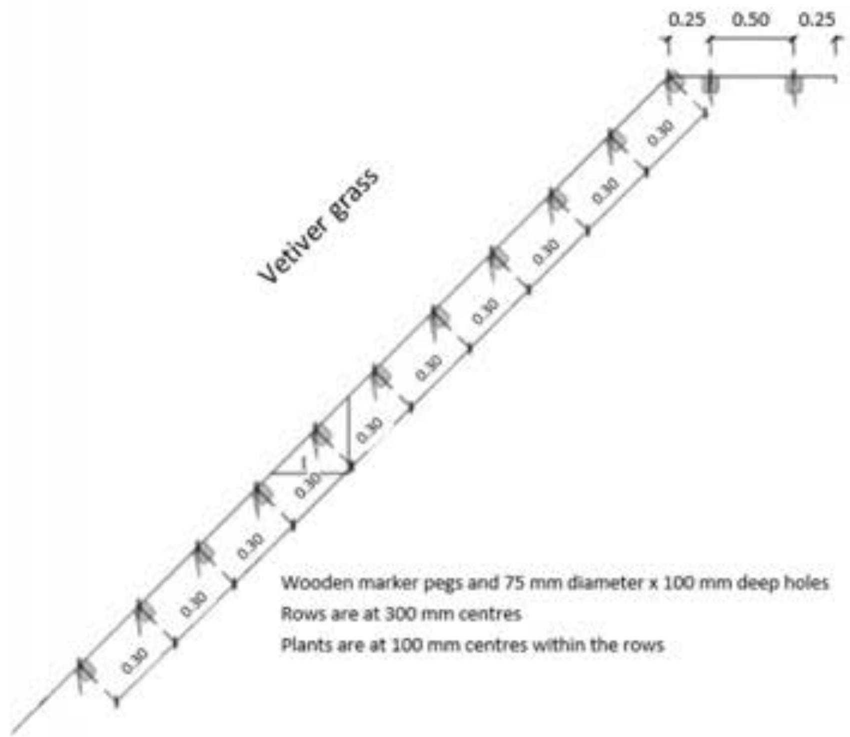
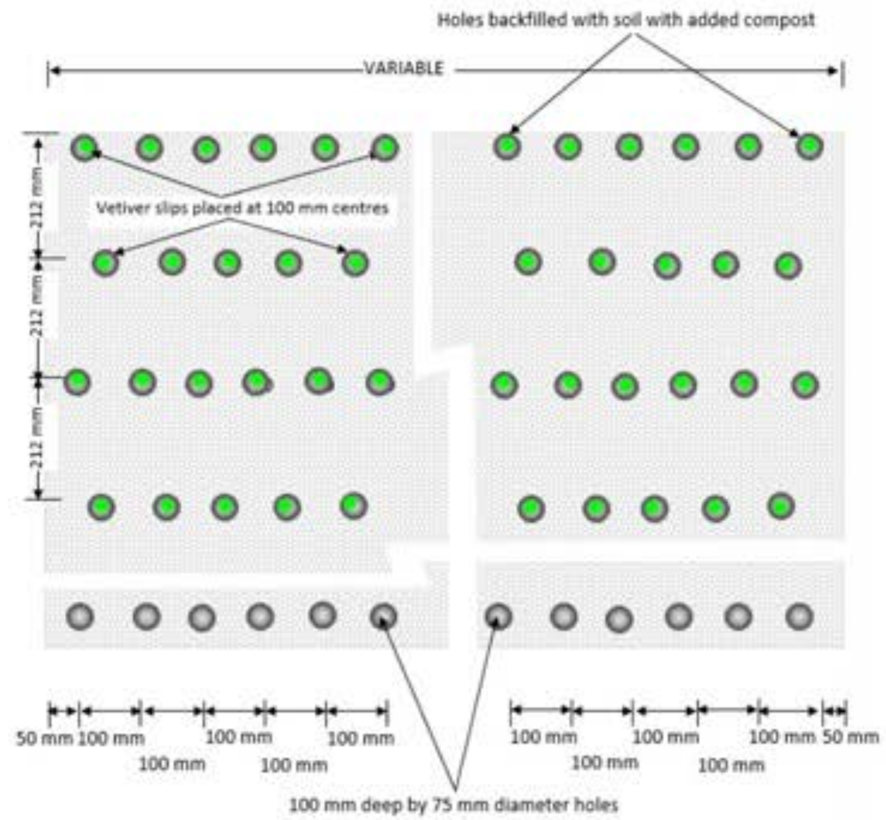


Fig. A.1.3: Plan layout of large grass planting



TA 8102-VIE: PROMOTING CLIMATE RESILIENT RURAL INFRASTRUCTURE IN NORTHERN VIETNAM			
SP4 - BAC KAN RIVERBANK WORKS			
LARGE GRASS PLANTING PROCEDURE			
ICEM TAY HO, HANOI, VIET NAM	DRAWING ID: AAS1206/C-323/F003	DESIGNER:	DAVID ROJAS JR.
		DRAWER:	PHAN TIEN AN
PHILKOEI INTERNATIONAL INC, PHILIPPINES (PKII)	SCALE: NO SCALE	CHECKED:	NGUYEN TRAN THUAT
	DATE: 10/5/2014	APPROVAL:	JAMES RAMSAY


Planting Vetiver grass in riverbank embankment site at SP32 in Son La province


Vetiver grass lines in riverbank embankment at SP32 in Son La Province three months after plantation


Operation and maintenance of Vetiver grass in riverbank embankment at SP4 in Bac Kan Province


Vetiver grass lines on fill slope embankment at SP35 in Thai Nguyen Province three months after plantation

A.2 SHORT COVER GRASS PLANTING

SHORT COVER GRASS PLANTING (1)

A2

This procedure applies to a range of large grass species, but it is based on lesser spear grass or "Mackie's pest" (Chrysopogon aciculatus), a short cover grass which is common in Viet Nam.

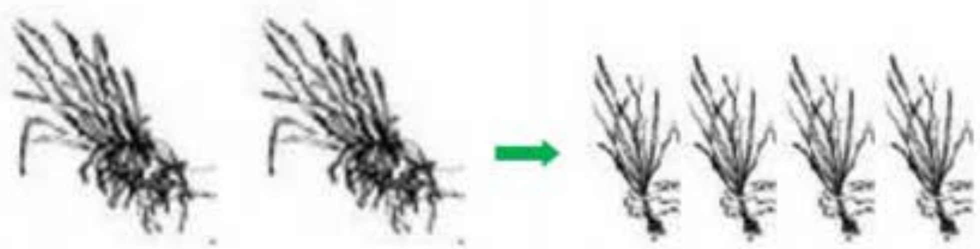
Site Preparation

a. The site is prepared to the desired slope before the day on which planting will take place. Debris is removed, depressions are filled in and humps are levelled off to attain a linear profile.
b. Using a measuring tape and string, the lines to be planted shall be marked by pegs starting from the top of the slope and then at 500mm (354mm vertical) down the slope.

Plant Preparation

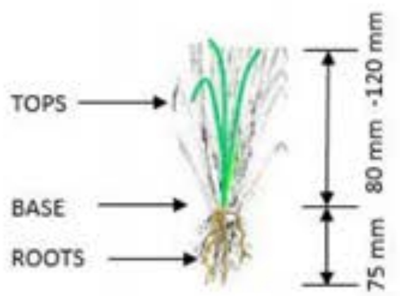
a. Plants must be prepared and planted within 12 hours.
b. Lesser spear grass (Chrysopogon aciculatus) clumps shall be dug out from the nursery using a spade or hand trowel.
c. A hand full of grass, including the roots, is carefully separated by pulling it away from the rest of the clump. This is called a 'slip' of spear grass. It must consist of at least two shoots with live growth buds and at least five roots with live growth buds. See Fig. A.2.1.
d. The top (leaves) of the slip are cut off about 80 mm to 120 mm above the base of the plant (i.e. the point where the above ground shoots meet the roots).
e. The roots are cut off at 75 mm below the base. See Fig. A.2.1.
f. The slips are then wrapped in wet jute sacks and kept in the shade while they are transported to the site.

Fig. A.2.1: Preparation of grass slips



Clumps of spear grass from nursery

Spear grass slips



A prepared grass slip

TA 8102-VIE: PROMOTING CLIMATE RESILIENT RURAL INFRASTRUCTURE IN NORTHERN VIETNAM				
SP31-SON LA ROAD SLOPE PROTECTION WORKS				
THI CÔNG TRỒNG CỎ BẢN ĐỊA NGẮN / LOCAL SHORT GRASS CONSTRUCTION				
ICEM TAY HO, HA NOI, VIET NAM	DRAWING ID: AAS1206/S - 036 /V01	DESIGNER:	DAVID ROJAS JR.	
		DRAWER:	PHAN TIEN AN	
PHILKOEI INTERNATIONAL INC, PHILIPPINES (PKII)	SCALE:	CHECKED:	NGUYEN TRAN THUAT	
	DATE:	APPROVAL:	JAMES RAMSAY	

SHORT COVER GRASS PLANTING (2)

A2

Planting Process

1. The first line to be planted is along the top of the slope, then working downwards.

2. Dig holes 80 mm deep and 80 mm in diameter at 100 mm centres along the top row. See Fig. A.2.2.

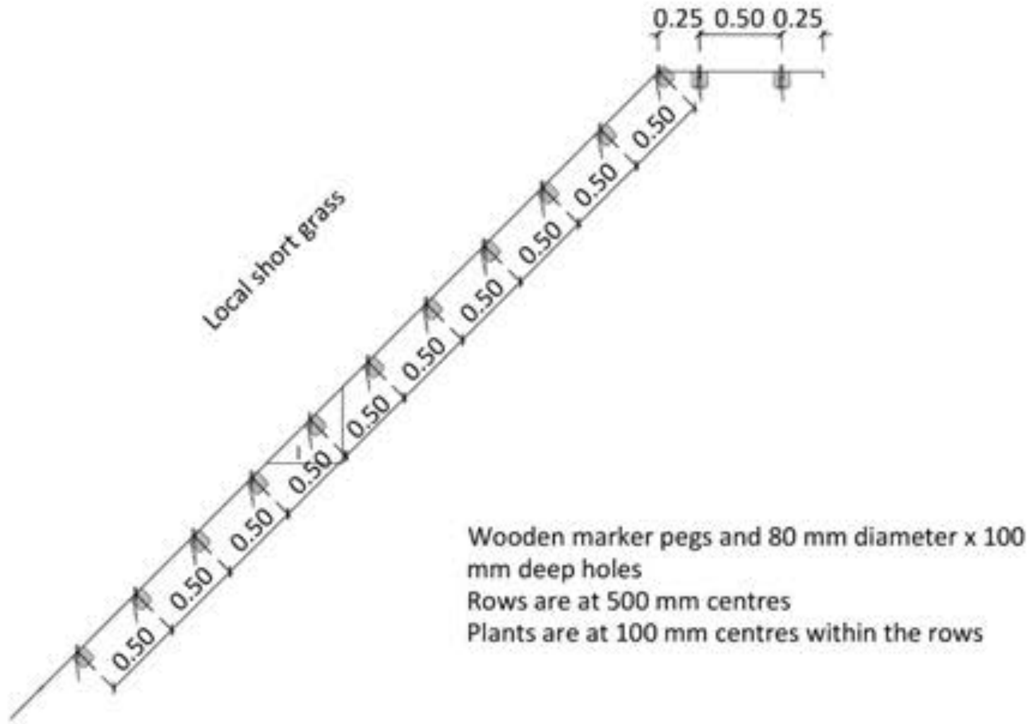


Fig. A.2.2: Site prepared for grass planting, showing the marker pegs for the rows and the locations of planting holes

3. Place the grass slip into the hole, making sure that the roots are not tangled or curved back to the surface.

4. Fill the hole with soil and firm gently with the fingers leaving no air pockets by the roots.

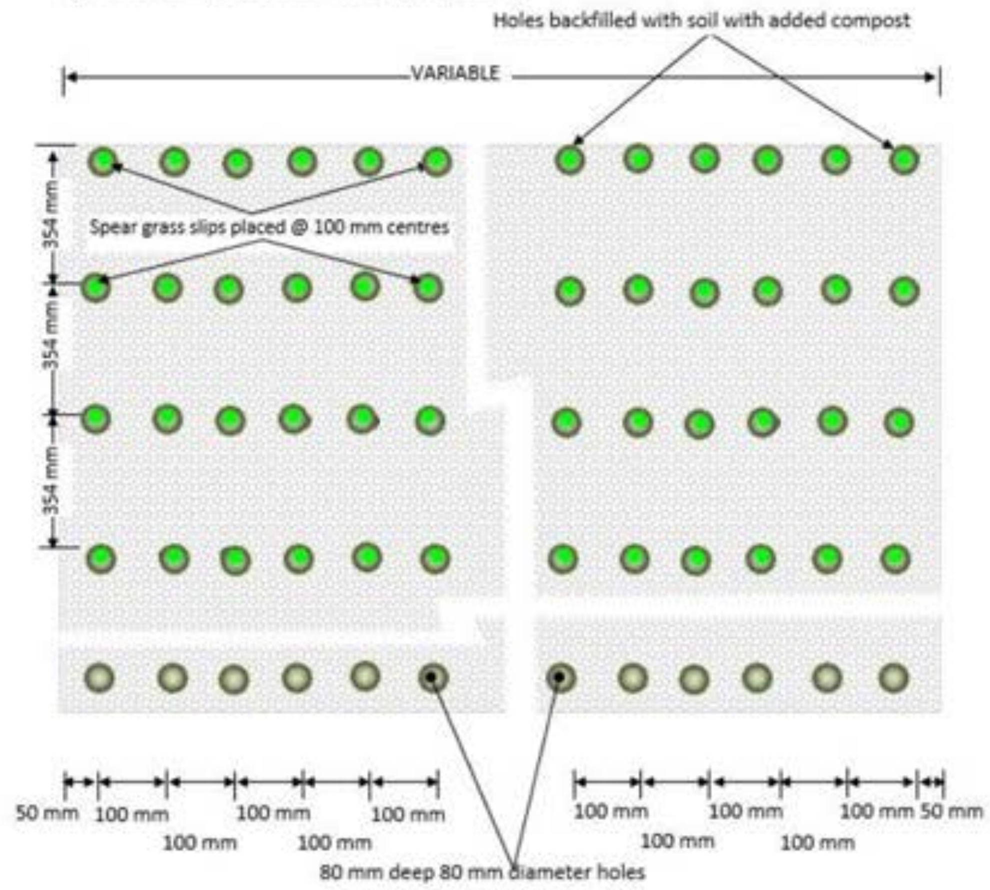
5. Firm along the whole row using careful foot pressure.

6. If it is available, place a few handfuls of compost or manure around each grass line.

7. Proceed to the next row down and repeat steps 2 to 6. Note that the grasses in each row should be offset from the one above. See Fig. A.2.3.

8. If no rain is expected in the next two days, sprinkle water by hand over each grass plant.

Fig. A.2.3: Plan layout of small cover grass planting



TA 8102-VIE: PROMOTING CLIMATE RESILIENT RURAL INFRASTRUCTURE IN NORTHERN VIETNAM				
SP31-SON LA ROAD SLOPE PROTECTION WORKS				
THI CÔNG TRỒNG CỎ BẢN ĐỊA NGẮN / LOCAL SHORT GRASS CONSTRUCTION				
ICEM TAY HO, HA NOI, VIET NAM	DRAWING ID: AAS1206/S - 036 /V01	DESIGNER:	DAVID ROJAS JR.	
		DRAWER:	PHAN TIEN AN	
PHILKOEI INTERNATIONAL INC, PHILIPPINES (PKII)	SCALE:	CHECKED:	NGUYEN TRAN THUAT	
	DATE:	APPROVAL:	JAMES RAMSAY	


Planting short grass on cut slope at SP35 in Thai Nguyen Province


Newly planted short grass on cut slope at SP31 in Son La Province


Short grass covering soil surface on fill slope at SP35 in Thai Nguyen Province


Short grass on cut slope at SP35 in Thai Nguyen Province two months after plantation

A.3 GRASS WITH MULCH AND MESH

GRASS WITH MULCH AND MESH (1)

A3

This technique assumes that grass seed will be used. However, if that is not available, the site can be planted with short cover grass instead, following technique A.2.

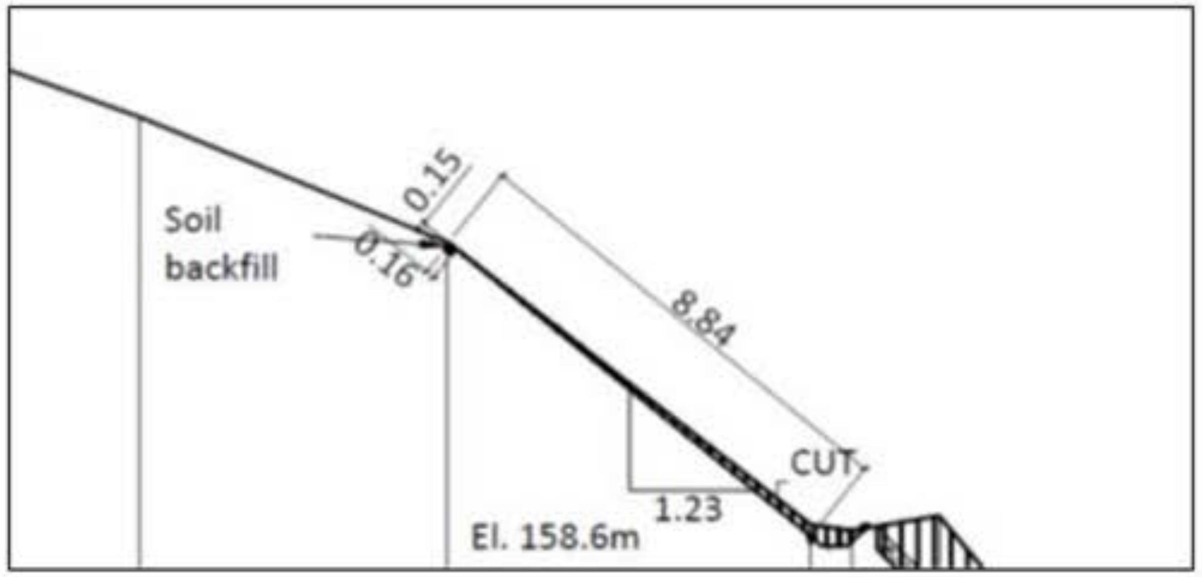
Preliminary Preparation

a. Prepare mulch from fallen leaves and bark chips of local trees, rice straw, clippings of grass leaves, wood chips or any locally available removed plant part deemed appropriate by agronomists for making mulch compost for the site.
b. Procure rolls of jute net (at least 1600 mm gross width and mesh width 30 to 40 mm). If not available locally, an alternative is a flexible bamboo mat of similar width and mesh size.
c. Procure or prepare anchor pins made from galvanised iron and bent into a J-shape, with a minimum diameter of 5 mm and length of 300 mm.
d. Procure seeds of a local grass species. The amount required should be specified by an agronomist, but a general rule is to use 25 grams per square metre.
e. Transport all materials to the site once slope preparation is completed.

Site Preparation

a. The site is prepared to the desired slope before the day on which planting will take place. Debris is removed, depressions are filled in and humps are levelled off to attain a linear profile. See Fig. A.3.1.

Fig. A.3.1: The slope is prepared, graded and smooth.



b. Using a measuring tape and string, mark lines across the slope at 250 mm intervals.
c. Scratch shallow horizontal trenches across the slope, following the marked lines. The trenches should be 100 mm wide and 50 mm deep.

TA 8102-VIE: PROMOTING CLIMATE RESILIENT RURAL INFRASTRUCTURE IN NORTHERN VIETNAM				
SP34-THAI NGUYEN ROAD SLOPE PROTECTION WORKS				
VỊ TRÍ CÔNG TRÌNH Ở XÃ LIÊN MINH - LOCATION OF SITE IN LIEN MINH COMMUNE				
ICEM TAY HO, HA NOI, VIET NAM	DRAWING ID: AAS1206/T- 047 /V01_1/2	DESIGNER:	DAVID ROJAS JR.	
		DRAWER:	PHAN TIEN AN	
PHILKOEI INTERNATIONAL INC, PHILIPPINES (PKII)	SCALE:	CHECKED:	NGUYEN TRAN THUAT	
	DATE:	APPROVAL:	JAMES RAMSAY	

GRASS WITH MULCH AND MESH (2)

A3

Planting Process

1. Mix together the mulch and grass seed according to an agronomist's instructions. If specialist advice is not available, mix together 25 grams of grass seed and 0.05 cubic metres of dry mulch per square metre of slope surface.
2. Carefully spread the mixed seed and mulch into the shallow trenches across the slope area that will be covered by the first roll of jute or bamboo. See Fig. A.3.2.
3. Anchor the top end of a roll of jute netting (or bamboo mesh) to the slope above the top shallow trench using anchor pins placed at 100 mm centres across the end of the roll.
4. Roll the jute net down the slope, putting anchor pins on the sides and middle at 1500 mm intervals.
5. All anchor pins should be placed perpendicular to the slope.
6. At the bottom of the slope, place the last row of anchor pins below the bottom trench and at 250 mm intervals across the mesh roll. Then cut off the remaining mesh. See Fig. A.3.3.
7. Move to the adjacent slope area and repeat steps 1 to 6. The mesh rolls should have an overlap of 150mm. See Fig. A.3.4.

Fig. A.3.2: Mulch, grass seed and jute or bamboo mesh are laid on the slope.

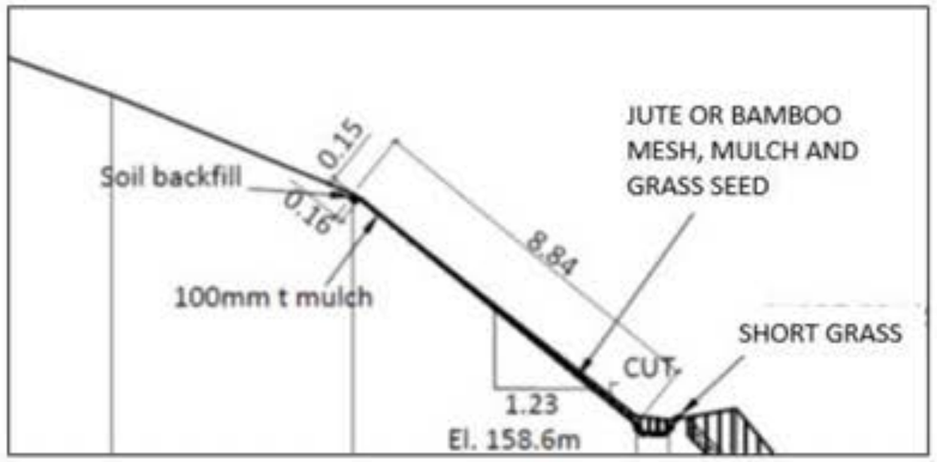


Fig. A.3.3: The jute or bamboo mesh is anchored using galvanised iron pins.

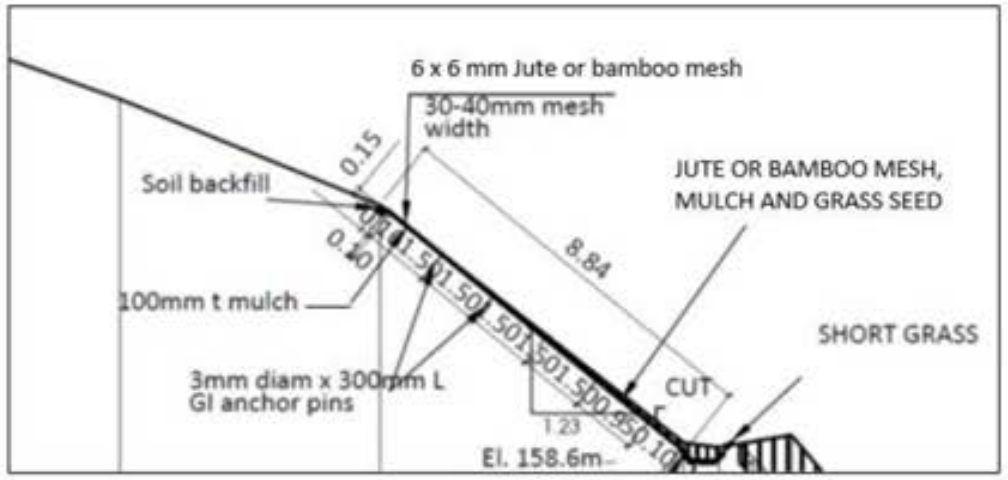
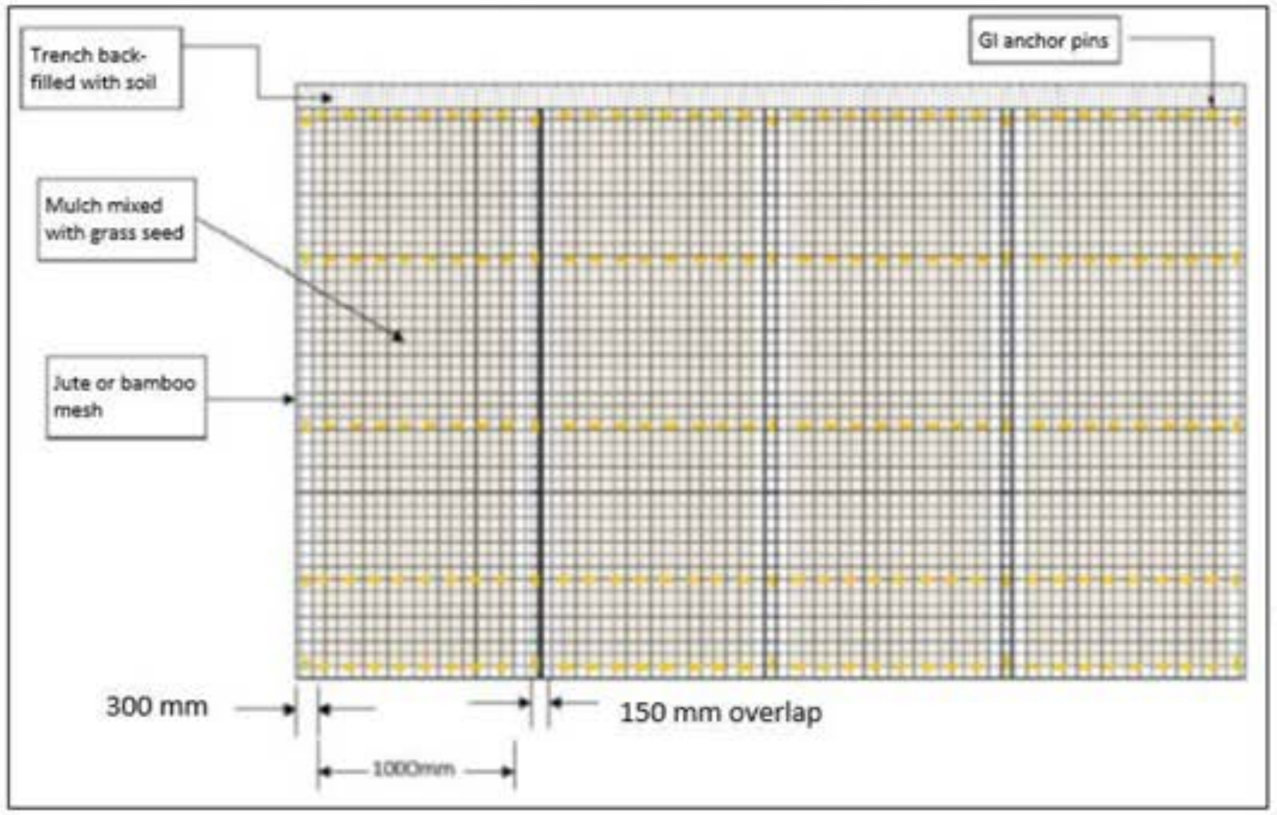


Fig. A.3.4. Plan layout of the completed slope treatment.




Bamboo mesh laid out on cut slope at SP35 in Thai Nguyen Province


Bamboo mesh and short grass in early development on cut slope at SP35 in Thai Nguyen Province


Bamboo mesh and short grass one month after plantation on cut slope at SP35 in Thai Nguyen Province


Bamboo mesh and short grass ten months after plantation on cut slope at SP35 in Thai Nguyen Province

A.4 BRUSH LAYERS

BRUSH LAYER (1)

A4

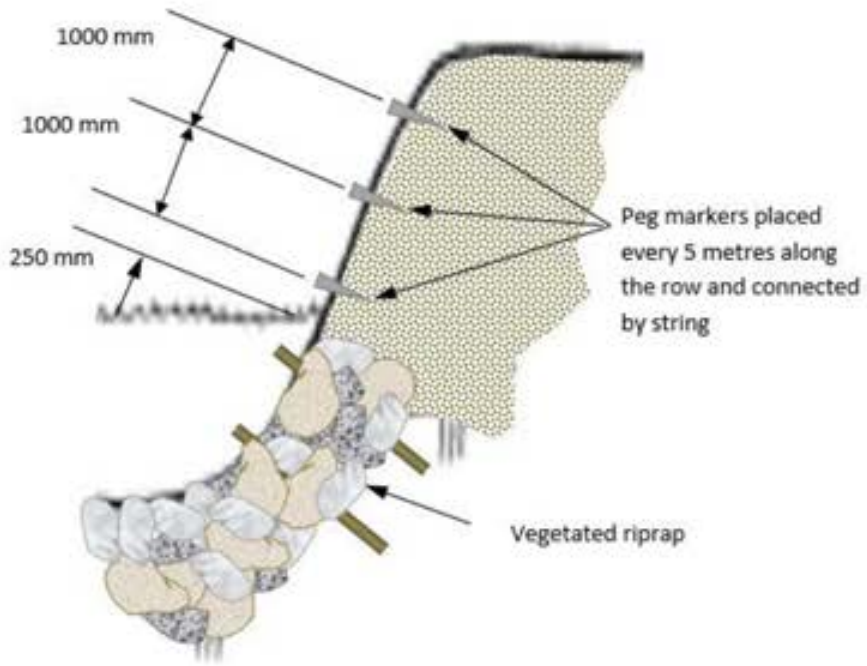
This procedure applies to the use of cuttings from a range of shrub or tree species, but it is based on cuttings from Puou trees, which are common in northern Viet Nam.

Site Preparation

a. The site is prepared to the desired slope before the day on which planting will take place. Debris is removed, depressions are filled in and humps are levelled off to attain a linear profile.

b. Using a measuring tape and string, the lines to be planted shall be marked by pegs starting from 250 mm above the toe of the slope, and then at 1000 mm centres up the slope. See Fig. A.4.1.

Fig. A.4.1: The lines for brush layers have been marked on the slope to be treated. [Note that the vertical dimension is exaggerated.]



Plant Preparation

a. Plant cuttings must be prepared and planted within 12 hours.

b. Cuttings from puou trees shall be used, or from another shrub or small tree that is suited to the site and shows the correct habit for an ability to grow from cuttings i.e. many shoots coming from the stump).

c. Cuttings shall be made cleanly using sharp tools, with no damage to the bark.

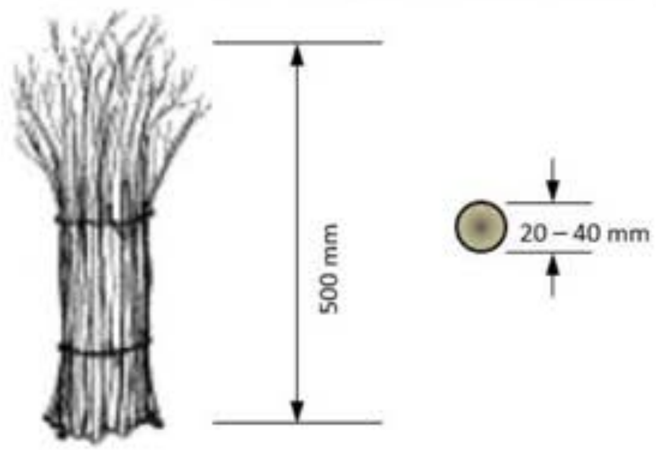
d. Cuttings shall be from woody material that is 6 to 18 months in age.

e. Cuttings shall be 20 to 40 mm in diameter and 500 mm long. See Fig. A.4.2

f. The lower end of each cutting shall be cut at 45 degrees and the tops cut perpendicular to the stem. Side branches shall be trimmed off carefully, using sharp tools.

g. Once made, the cuttings are wrapped in wet jute sacks and kept in the shade while they are transported to the site.

Fig. A.4.2: A bundle of cuttings prepared for brush layering.



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SP4 - BAC KAN RIVERBANK WORKS			
BRUSH LAYER CONSTRUCTION			
ICEM TAY HO, HANOI, VIET NAM	DRAWING ID: AAS1206/C-319/F003	DESIGNER:	DAVID ROJAS JR.
		DRAWER:	PHAN TIEN AN
PHILKOEI INTERNATIONAL INC, PHILIPPINES (PKII)	SCALE: NO SCALE	CHECKED:	NGUYEN TRAN THUAT
	DATE: 10/5/2014	APPROVAL:	JAMES RAMSAY

BRUSH LAYER (2)

A4

Planting Process

1. The first line to be planted is along the bottom of the slope, then working upwards.
2. Starting at the bottom, a terrace 400 mm wide and sloping 1 V: 5 H to the back shall be cut into the slope. See Fig. A.4.3.

Fig. A.4.3: Excavation of the trench for the first brush layer.

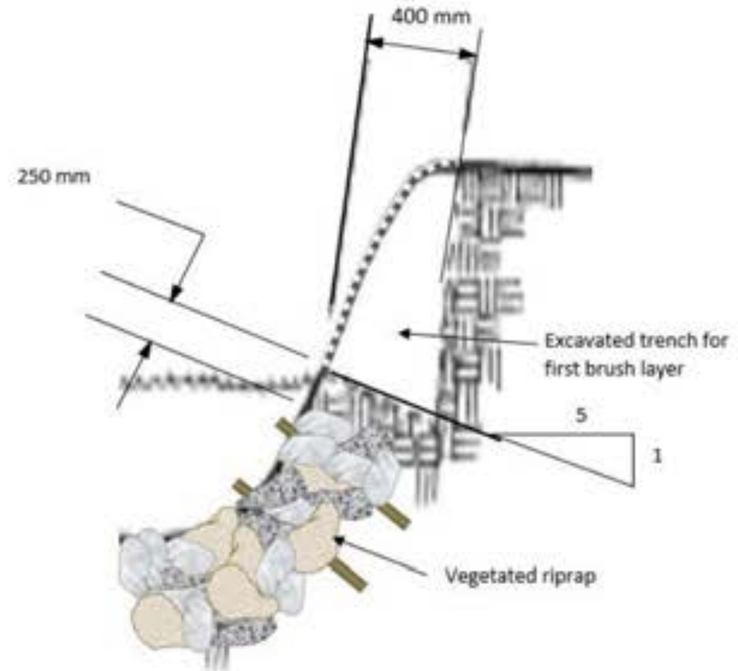
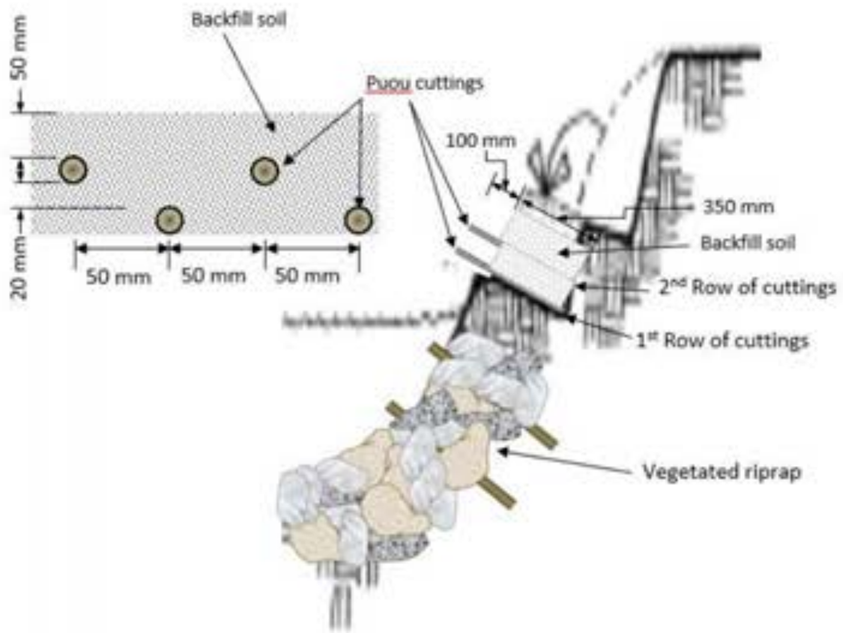
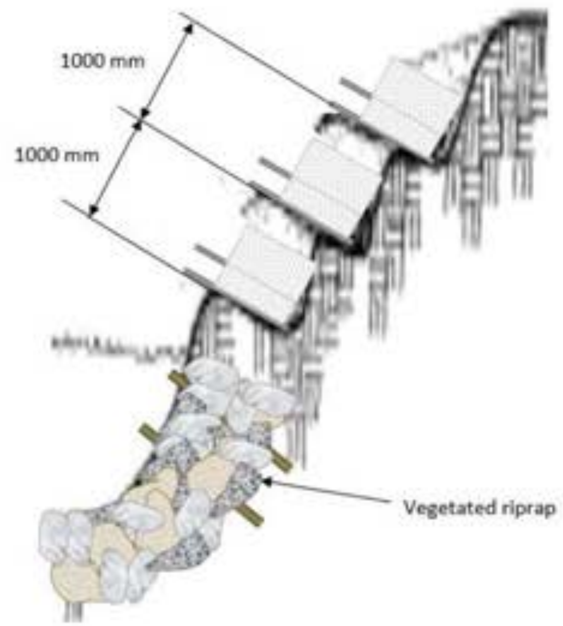


Fig. A.4.4: The first brush layer completed and backfilled.



3. Puou cuttings shall then be placed on the terrace at 100 mm centres with the branch growing tips pointing outward. Not more than 100 mm of each cutting should protrude beyond the edge of the terrace.
4. Once all the cuttings are placed, a 20mm layer of soil is placed above this first row cuttings.
5. A second row of cuttings is then placed above the soil layer at the same spacing as the first row but staggered between the first row of cuttings.
6. The terrace is backfilled with a 50 mm soil layer and with 400 mm length of cuttings covered by soil and the remaining 100 mm protruding out. The backfill shall be compacted reasonably well by foot pressure. See Fig. A.4.4.
7. Each of the next terraces shall be cut from the slope at 1000 mm above the preceding terrace and steps 3 to 6 repeated. See Fig. A.4.5.

Fig. A.4.5: The example slope completed with three brush layers installed and backfilled.



TA 8102-VIE: PROMOTING CLIMATE RESILIENT RURAL INFRASTRUCTURE IN NORTHERN VIETNAM			
SP4 - BAC KAN RIVERBANK WORKS			
BRUSH LAYER CONSTRUCTION			
ICEM TAY HO, HANOI, VIET NAM	DRAWING ID: AAS1206/C-319/F003	DESIGNER:	DAVID ROJAS JR.
		DRAWER:	PHAN TIEN AN
PHILKOEI INTERNATIONAL INC, PHILIPPINES (PKII)	SCALE: NO SCALE	CHECKED:	NGUYEN TRAN THUAT
	DATE: 10/5/2014	APPROVAL:	JAMES RAMSAY


Newly planted brush layers in riverbank embankment at SP4 in Bac Kan Province


Brush layers on cut slope at SP35 in Thai Nguyen Province two months after plantation


Brush layers in riverbank embankment at SP4 in Bac Kan Province four months after plantation


Brush layers on fill slope at SP35 in Thai Nguyen Province three months after plantation

A.5 PALISADES

PALISADES (1)

A5

This procedure applies to the use of cuttings from a range of shrub or tree species, but it is based on cuttings from golden dewdrop or Thanh quan (Duranta erecta) trees, which are common in northern Viet Nam.

Site Preparation

a. The site is prepared to the desired slope before the day on which planting will take place. Debris is removed, depressions are filled in and humps are levelled off to attain a linear profile.

b. Using a measuring tape and string, the lines to be planted shall be marked by pegs starting from 250 mm above the toe of the slope, and then at 1000 mm centres up the slope.

Plant Preparation

a. Plant cuttings must be prepared and planted within 12 hours.

b. Cuttings from Thanh quan trees shall be used, or from another shrub or small tree that is suited to the site and shows the correct habit for an ability to grow from cuttings (i.e. many shoots coming from the stump).

c. Cuttings shall be made cleanly using sharp tools, with no damage to the bark.

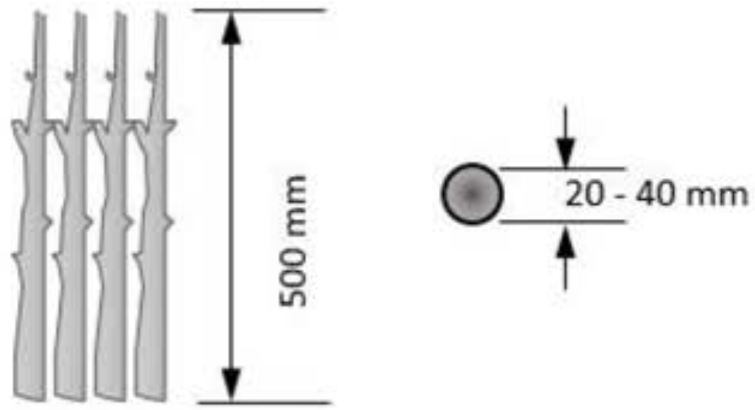
d. Cuttings shall be from woody material that is 6 to 18 months in age.

e. Cuttings shall be 20 to 40 mm in diameter and 500 mm long. See Fig. A.5.1.

f. The lower end of each cutting shall be cut at 45 degrees and the tops cut perpendicular to the stem. Side branches shall be trimmed off carefully, using sharp tools.

g. Once made, the cuttings are wrapped in wet jute sacks and kept in the shade while they are transported to the site. Optionally, they may be immersed in water for one or two days (see Fig. A.5.2).

Fig. A.5.1: Preparation of cuttings for palisades.



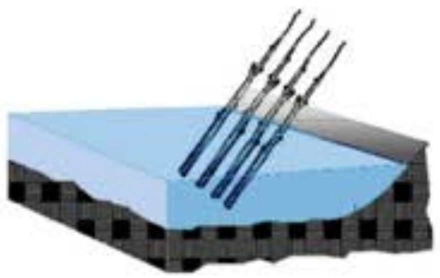


Fig. A.5.2: Cuttings for palisades may optionally be immersed in water for one or two days after they have been taken

TA 8102-VIE: PROMOTING CLIMATE RESILIENT RURAL INFRASTRUCTURE IN NORTHERN VIETNAM				
SP34-THAI NGUYEN ROAD SLOPE PROTECTION WORKS				
LOCATION OF SITE IN LIEN MINH COMMUNE				
ICEM TAY HO, HA NOI, VIET NAM	DRAWING ID: AAS1206/T- 039 /V01		DESIGNER:	DAVID ROJAS JR.
			DRAWER:	PHAN TIEN AN
PHILKOEI INTERNATIONAL INC, PHILIPPINES (PKII)	SCALE:		CHECKED:	NGUYEN TRAN THUAT
	DATE:		APPROVAL:	JAMES RAMSAY

PALISADES (2)

A5

Planting procedure

1. Always start at the top of the slope and work downwards.
2. Using a pointed bar, make a hole in the slope that is bigger than the cutting (i.e. about 50 mm in diameter) and deep enough to take at least two-thirds of its length (i.e. 350 to 400 mm deep).
3. Carefully place the cutting in the hole, so that at least two-thirds is buried. Firm the soil around it, taking care not to damage the bark. Ideally, only one node of the cutting or about the top 100 mm should protrude from the soil.
4. Make the next hole 50 mm along the row and offset by 25 mm. See Fig. A.5.3.
5. Repeat steps 2 and 3 all along the row. Then move down to the next row. See Fig. A.5.4.

Fig. A.5.3: Placement of a standard double palisade row.

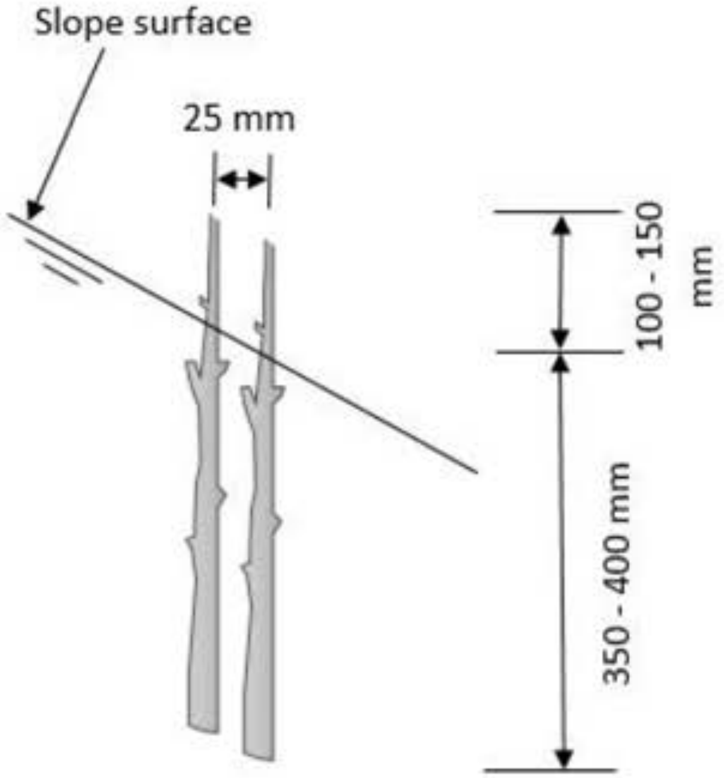
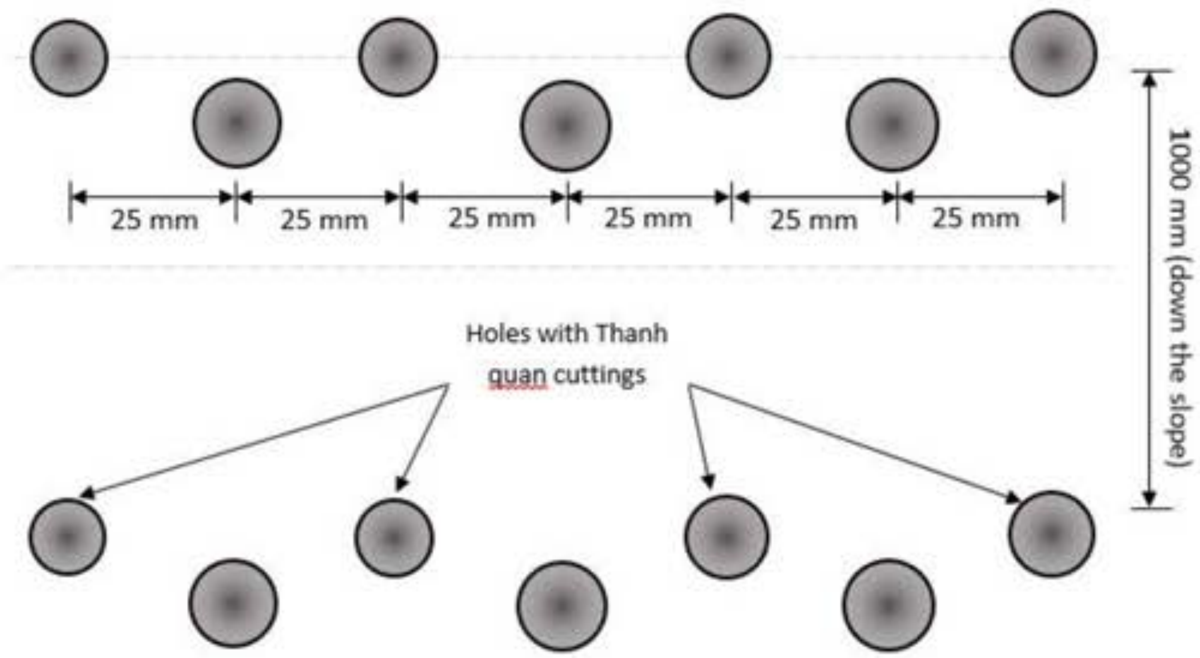


Fig. A.5.4. Plan layout of two palisade lines (not to scale



TA 8102-VIE: PROMOTING CLIMATE RESILIENT RURAL INFRASTRUCTURE IN NORTHERN VIETNAM				
SP34-THAI NGUYEN ROAD SLOPE PROTECTION WORKS				
LOCATION OF SITE IN LIEN MINH COMMUNE				
ICEM TAY HO, HA NOI, VIET NAM	DRAWING ID: AAS1206/T- 039 /V01	DESIGNER:	DAVID ROJAS JR.	
		DRAWER:	PHAN TIEN AN	
PHILKOEI INTERNATIONAL INC, PHILIPPINES (PKII)	SCALE:	CHECKED:	NGUYEN TRAN THUAT	
	DATE:	APPROVAL:	JAMES RAMSAY	

Newly planted palisades on cut slope at SP35 in Thai Nguyen Province

Palisades on cut slope at SP35 in Thai Nguyen Province one month after plantation

Watering palisades on cut slope at SP31 in Son La Province

Palisades on cut slope at SP35 in Thai Nguyen Province ten months after plantation

A.6 LIVE FENCES

LIVE FENCES (1)

A6

This procedure applies to the use of cuttings from a range of shrub or tree species, but it is based on cuttings from Si (Ficus benjamina) trees, which are common in northern Viet Nam.

Site Preparation

a. The site is prepared to the desired slope before the day on which planting will take place. Debris is removed, depressions are filled in and humps are levelled off to attain a linear profile.

b. Using a measuring tape and string, the fence lines to be planted shall be marked by pegs starting from 200 mm above the toe of the slope, and then at 1000 mm centres up the slope.

Plant Preparation

a. Plant cuttings must be prepared and planted within 12 hours.

b. Cuttings from si trees shall be used, or from another shrub or small tree that is suited to the site and shows the correct habit for an ability to grow from cuttings (i.e. many shoots coming from the stump).

c. Cuttings shall be made cleanly using sharp tools, with no damage to the bark.

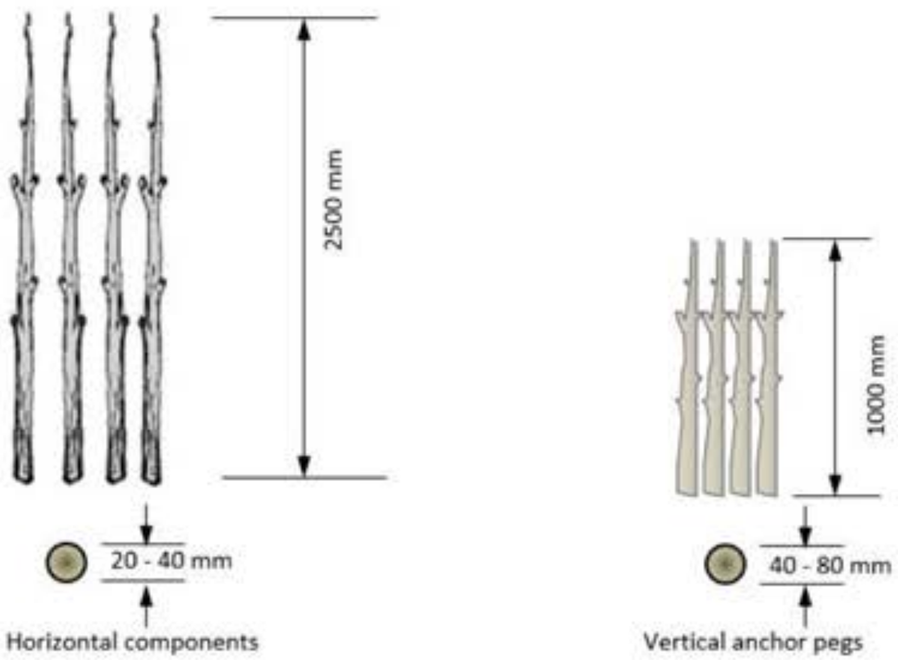
d. Cuttings shall be from woody material that is 6 to 18 months in age.

e. Cuttings shall be 40 to 80 mm in diameter and 1000 mm long for the vertical components of live fences, and 20 to 40 mm in diameter and at least 2500 mm long for the horizontal components. See Fig. A.6.1.

f. The lower end of each cutting shall be cut at 45 degrees and the tops cut perpendicular to the stem. Side branches shall be trimmed off carefully, using sharp tools.

g. Once made, the cuttings are wrapped in wet jute sacks and kept in the shade while they are transported to the site.

Fig. A.6.1: Cutting dimensions for live fences.



Planting Procedure

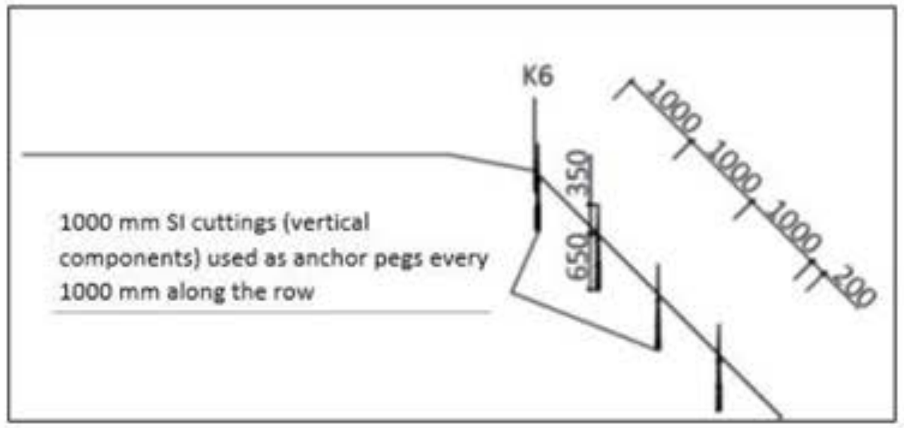
1. Always start at the top of the slope and work downwards.

2. Begin the construction by inserting the vertical posts of the fence.

3. Using a pointed bar, make a hole in the slope that is bigger than the cutting (i.e. about 80 to 100 mm in diameter) and deep enough to take at least two-thirds of its length (i.e. 650 to 700 mm deep).

4. Carefully place the cutting in the hole, so that at least two-thirds is buried. Firm the soil around it, taking care not to damage the bark. Ideally, only about the top 350 mm should protrude from the soil. See Fig. A.6.2.

Fig. A.6.2: Cross-section of slope with vertical components in place.



TA 8102-VIE: PROMOTING CLIMATE RESILIENT RURAL INFRASTRUCTURE IN NORTHERN VIETNAM				
SP4 - BAC KAN RIVERBANK WORKS				
THI CÔNG RÀO CHẮN BẰNG CÂY TƯƠI/LIVE FENCES CONSTRUCTION				
ICEM TAY HO, HANOI, VIET NAM	DRAWING ID: AAS1206/C-322/F003	DESIGNER:	DAVID ROJAS JR.	
		DRAWER:	PHAN TIEN AN	
PHILKOEI INTERNATIONAL INC, PHILIPPINES (PKII)	SCALE: NO SCALE	CHECKED:	NGUYEN TRAN THUAT	
	DATE: 10/5/2014	APPROVAL:	JAMES RAMSAY	

LIVE FENCES (2)

A6

Planting Procedure (continued)

5. Make the next hole and insert the next vertical post 1000 mm along the row. Repeat steps 3 and 4.

6. Make three more holes in between the two posts already installed, at 250 mm centres, and insert intermediate vertical posts by repeating steps 3 and 4.

7. Continue all along the row, repeating steps 3 to 6. See Fig. A.6.3.

8. The 2500 mm cuttings to form the horizontal components are placed with their lower ends under at least 150 mm of soil in a small trench scraped out along the row. They are then woven between the vertical posts and attached to the vertical posts by string. See Fig. A.6.4.

9. There should be 4 to 8 horizontal cuttings woven into the live fence, with them overlapping by at least 25%.

10. Partially cover the fence by placing some excavated soil on the higher side. Compact the soil gently but firmly using foot pressure. See Fig. A.6.3.

11. Move down to the next row and repeat the procedure.

Fig. A.6.3: Layout of the vertical components of live fences.

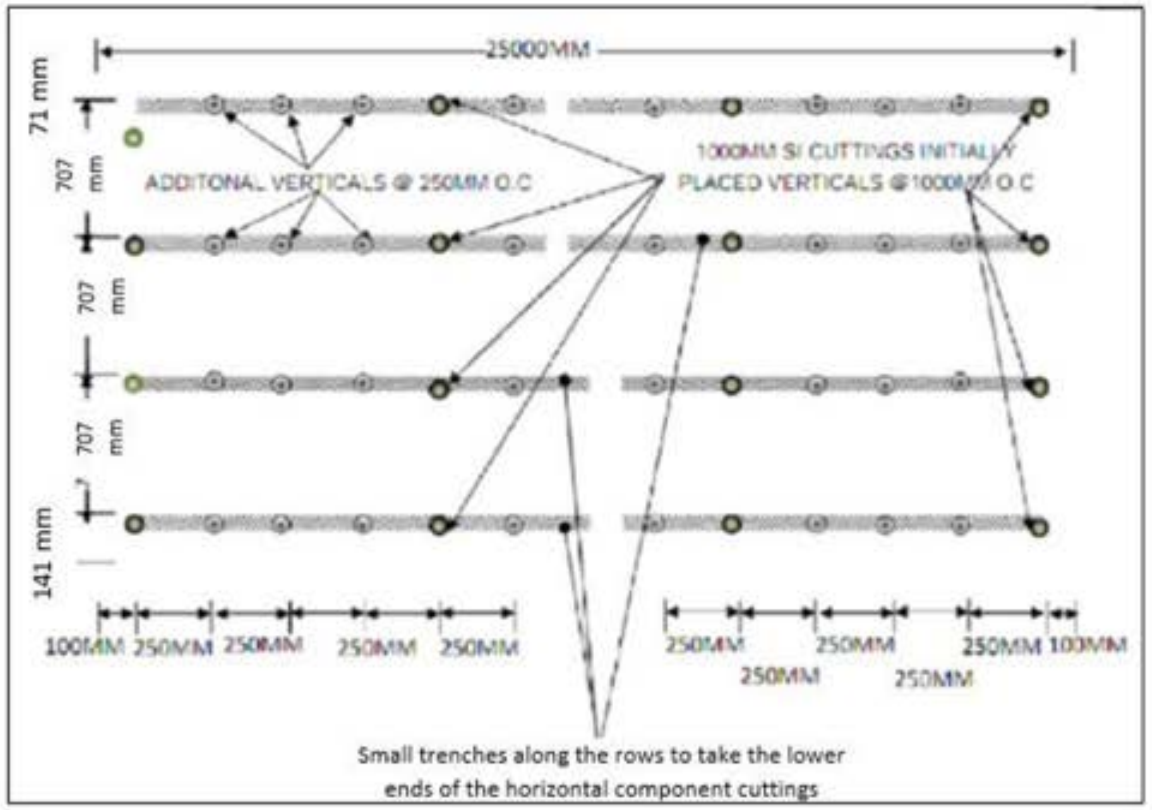
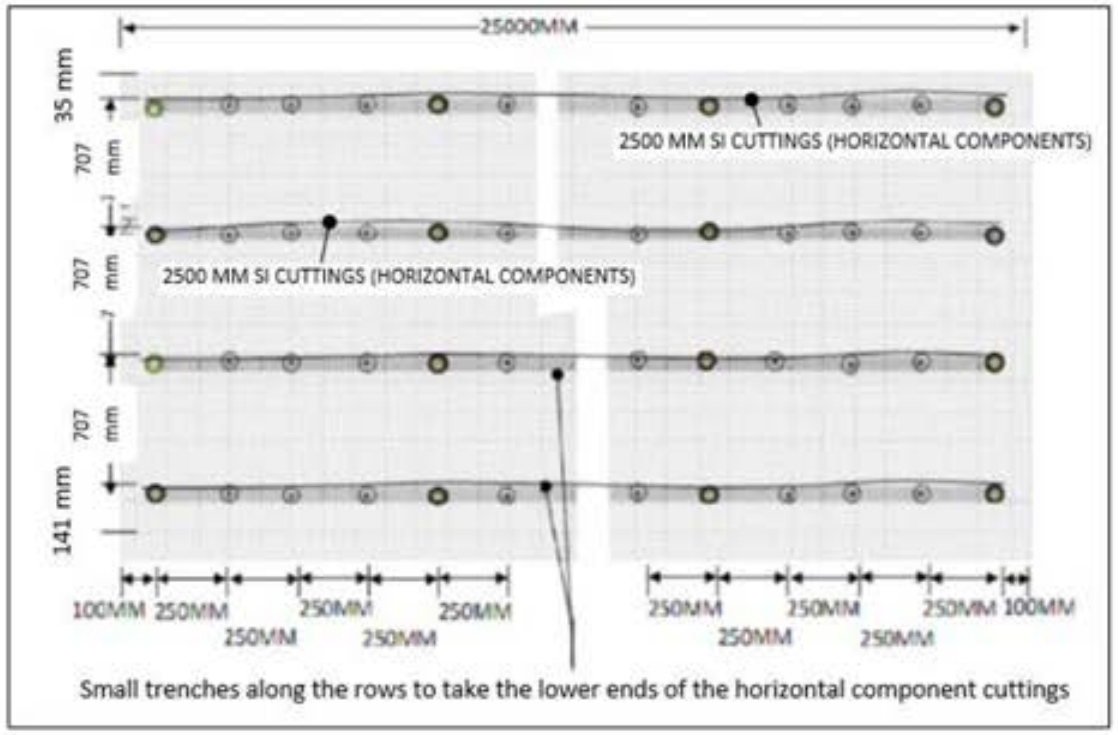


Fig. A.6.4: Layout of the live fences with the horizontal components woven in between the vertical posts.



TA 8102-VIE: PROMOTING CLIMATE RESILIENT RURAL INFRASTRUCTURE IN NORTHERN VIETNAM			
SP4 - BAC KAN RIVERBANK WORKS			
THI CÔNG RÀO CHẮN BẰNG CÂY TƯƠI/LIVE FENCES CONSTRUCTION			
ICEM TAY HO, HANOI, VIET NAM	DRAWING ID: AAS1206/C-322/F003	DESIGNER:	DAVID ROJAS JR.
		DRAWER:	PHAN TIEN AN
PHILKOEI INTERNATIONAL INC, PHILIPPINES (PKII)	SCALE: NO SCALE	CHECKED:	NGUYEN TRAN THUAT
	DATE: 10/5/2014	APPROVAL:	JAMES RAMSAY


Constructing live fences in riverbank embankment at SP32 in Son La Province


Live fences on fill slope at SP35 in Thai Nguyen Province three months after plantation


Live fences in riverbank embankment at SP32 in Son La Province after 14 months and three flood seasons


Live fences on fill slope at SP35 in Thai Nguyen Province 11 months after plantation

A.7 FASCINES

FASCINES (1)

A7

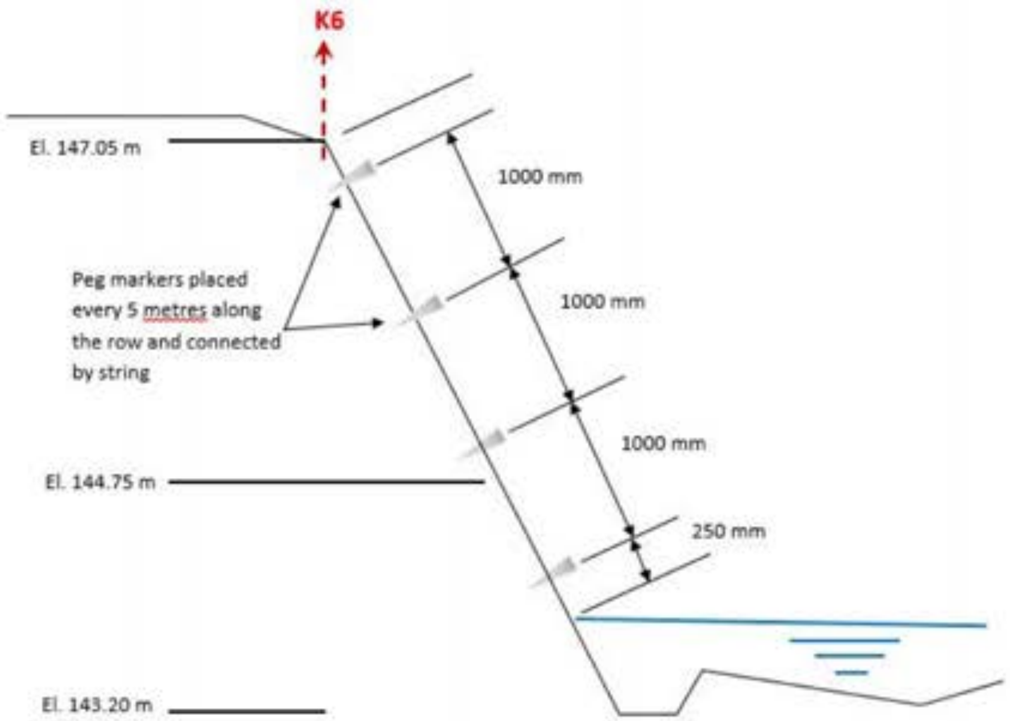
This procedure applies to the use of cuttings from a range of shrub or tree species, but it is based on cuttings from Si (Ficus benjamina) trees, which are common in northern Viet Nam.

Site Preparation

a. The site is prepared to the desired slope before the day on which planting will take place. Debris is removed, depressions are filled in and humps are levelled off to attain a linear profile.

b. Using a measuring tape and string, the fascine lines to be planted shall be marked by pegs starting from 250 mm above the toe of the slope, and then at 1000 mm centres up the slope. See Fig. A.7.1.

Fig. A.7.1: The lines for fascines have been marked on the slope to be treated. [Note that the vertical dimension is exaggerated.]



e. Cuttings shall be 25 to 40 mm in diameter and 1000 mm long for the anchor pegs of fascines fences, and 20 to 40 mm in diameter and at least 2500 mm long for the horizontal components of the actual fascine bundles. See Fig. A.7.2.

f. The lower end of each cutting shall be cut at 45 degrees and the tops cut perpendicular to the stem. Side branches shall be trimmed off carefully, using sharp tools.

g. Once made, the cuttings are wrapped in wet jute sacks and kept in the shade while they are transported to the site. Optionally, cuttings may be immersed in water for a few days once they have been taken (see Fig. A.7.3).

Fig. A.7.2: Cutting dimensions for fascines.

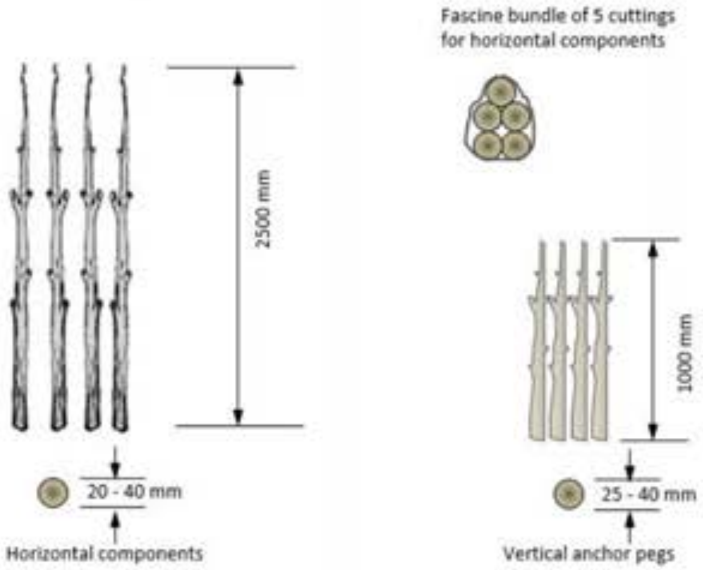
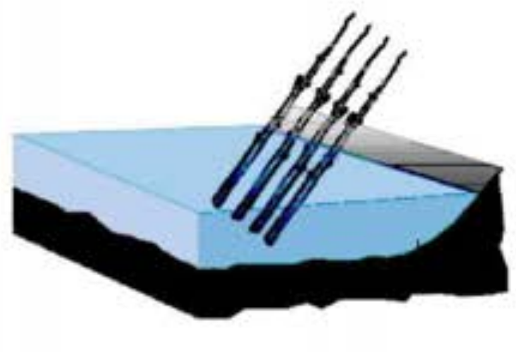


Fig. A.7.3: Optionally, cuttings may be immersed in water for a few days after they have been taken



Plant Preparation

a. Plant cuttings must be prepared and planted within 12 hours.

b. Cuttings from si trees shall be used, or from another shrub or small tree that is suited to the site and shows the correct habit for an ability to grow from cuttings (i.e. many shoots coming from the stump).

c. Cuttings shall be made cleanly using sharp tools, with no damage to the bark.

d. Cuttings shall be from woody material that is 6 to 18 months in age.

TA 8102-VIE: PROMOTING CLIMATE RESILIENT RURAL INFRASTRUCTURE IN NORTHERN VIETNAM				
SP4 - BAC KAN RIVERBANK WORKS				
THI CÔNG CỪ BÓ HOM CÂY TƯƠI/FASCINES CONSTRUCTION				
ICEM TAY HO, HANOI, VIET NAM	DRAWING ID: AAS1206/C-320/F003	DESIGNER:	DAVID ROJAS JR.	
		DRAWER:	PHAN TIEN AN	
PHILKOEI INTERNATIONAL INC, PHILIPPINES (PKII)	SCALE: NO SCALE	CHECKED:	NGUYEN TRAN THUAT	
	DATE: 10/5/2014	APPROVAL:	JAMES RAMSAY	

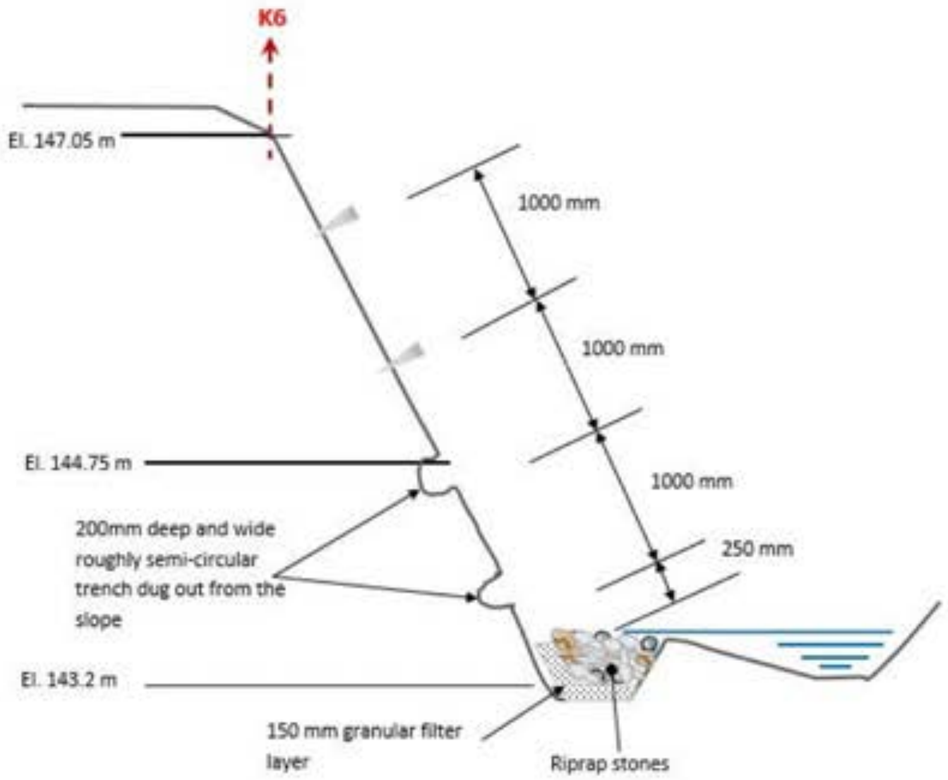
FASCINES (2)

A7

Planting Procedure

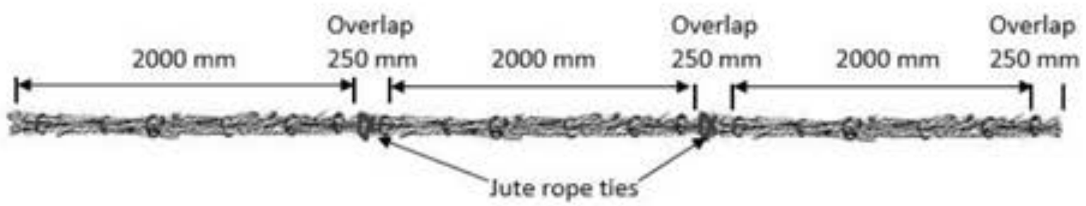
1. Always start at the bottom of the slope and work upwards.
2. Starting from the bottom line, a roughly semi-circular trench of approximately 200 mm in depth and width shall be dug out from the slope. See Fig. A.7.4.

Fig. A.7.4: The trenches for the first two fascines have been excavated on the slope being treated. [Note that the vertical dimension is exaggerated.]



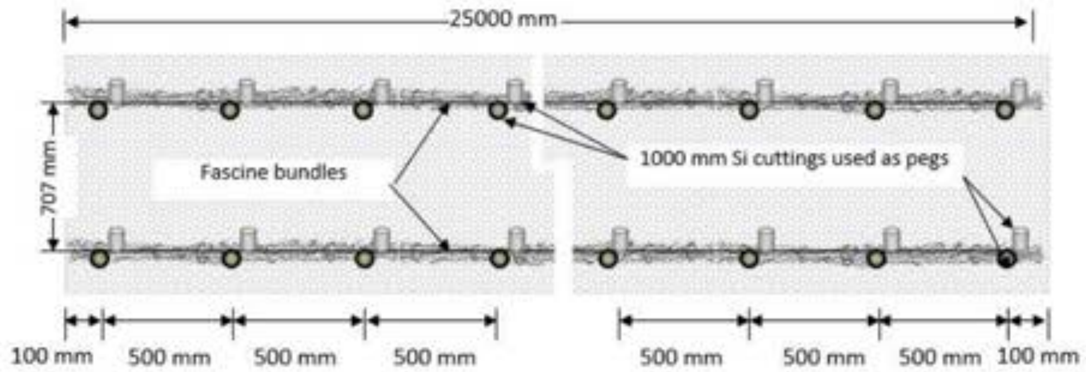
3. The long cuttings are then laid in the trench in a bundle of five pieces placed one after the other with an overlap of at least 250 mm. They are tied together with twine or jute rope. See Fig. A.7.5.

Fig. A.7.5: Fascine bundles are tied together with at least 250mm overlap between cuttings



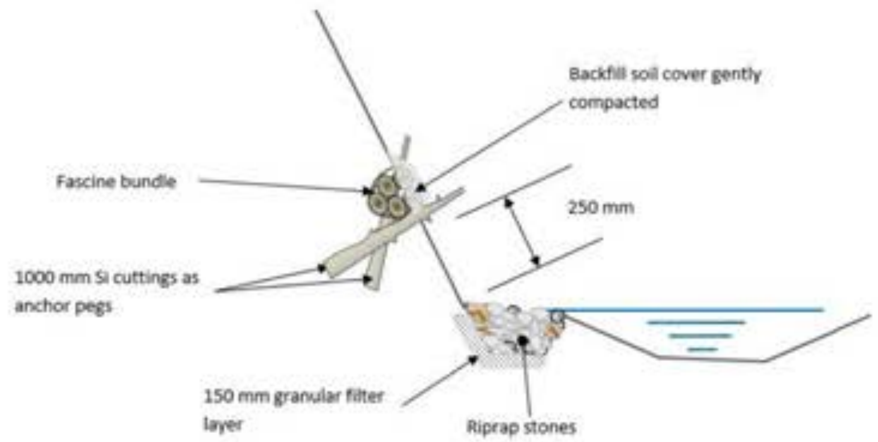
4. The bundle shall then be pegged every 500 mm with two 1000 mm vertical anchor pegs. This is done by making vertical holes using a pointed bar, that are bigger than the cutting (i.e. about 50 mm in diameter) and deep enough to take at least two-thirds of its length (i.e. 650 to 700 mm deep). Carefully place the cutting in the hole, so that at least two-thirds is buried. Firm the soil around it, taking care not to damage the bark. Ideally, only one node of the cutting or about the top 100 mm should protrude from the soil. See Fig. A.7.6.

Fig. A.7.6: Fascines are staked with anchor pegs at 500 mm centres.



5. The whole trench is then backfilled with the excavated soil. It is gently but firmly compacted over the bundle using foot pressure. The soil cover shall be 50 mm to 100mm thick. See Fig. A.7.7.
6. Move up to the next row and repeat the procedure.

Fig. A.7.7: Cross-section of a completed fascine



TA 8102-VIE: PROMOTING CLIMATE RESILIENT RURAL INFRASTRUCTURE IN NORTHERN VIETNAM			
SP4 - BAC KAN RIVERBANK WORKS			
THI CÔNG CỪ BÓ HOM CÂY TƯƠI/FASCINES CONSTRUCTION			
ICEM TAY HO, HANOI, VIET NAM	DRAWING ID: AAS1206/C-320/F003	DESIGNER:	DAVID ROJAS JR.
		DRAWER:	PHAN TIEN AN
PHILKOEI INTERNATIONAL INC. PHILIPPINES (PKII)	SCALE: NO SCALE	CHECKED:	NGUYEN TRAN THUAT
	DATE: 10/5/2014	APPROVAL:	JAMES RAMSAY


Fascines in early development on fill slope at SP35 in Thai Nguyen Province


Fascines on fill slope at SP35 in Thai Nguyen Province three months after plantation


Golden dewdrop used to construct fascines on fill slope at SP35 in Thai Nguyen Province


Fascines on fill slope at SP35 in Thai Nguyen Province 11 months after plantation

A.8 LIVE POLES AND TRUNCHEONS

LIVE POLES AND TRUNCHEON CUTTINGS (1)

A8

This procedure applies to the use of cuttings from a range of shrub or tree species, but it is based on cuttings from si (Ficus benjamina) trees, which are common in northern Viet Nam.

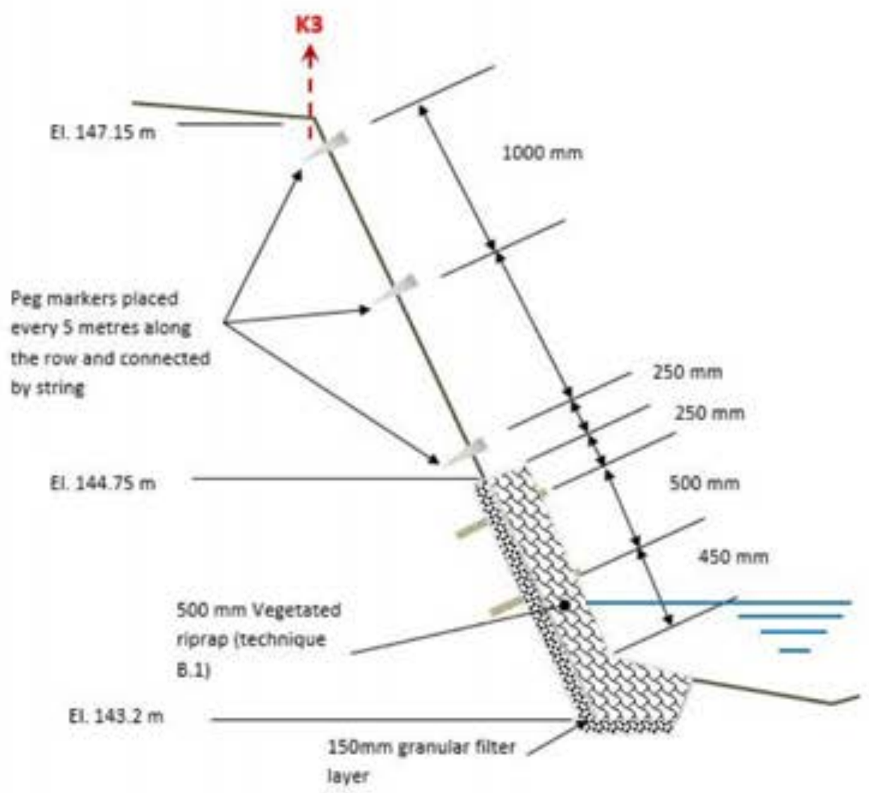
Site Preparation

a. The site is prepared to the desired slope before the day on which planting will take place. Debris is removed, depressions are filled in and humps are levelled off to attain a linear profile.

b. Using a measuring tape and string, the lines to be planted shall be marked by pegs starting from 250 mm above the toe of the slope.

c. For both live poles and truncheons, the lines shall normally be at 1000 mm centres up the slope. See Fig. A.8.1.

Fig. A.8.1: The lines for live poles or truncheons have been marked on the slope to be treated. [Note that the vertical dimension is exaggerated.]



d. Cuttings for live poles shall be from woody material that is 6 to 18 months in age.

e. Live pole cuttings shall be 40 to 50 mm in diameter and 1000 mm long See Fig. A.8.2.

f. Cuttings for truncheons shall be from woody material that is 12 to 36 months in age.

g. Truncheon cuttings shall be 50 to 100 mm in diameter and 2000 mm long. See Fig.A.8.3.

h. The lower end of each cutting shall be cut at 45 degrees and the tops cut perpendicular to the stem. Side branches shall be trimmed off carefully, using sharp tools.

i. Once made, the cuttings are wrapped in wet jute sacks and kept in the shade while they are transported to the site. Optionally, cuttings may be immersed for a few days after they have been taken. See Fig.A.8.4.

Fig. A.8.2: Cutting dimensions for live poles.

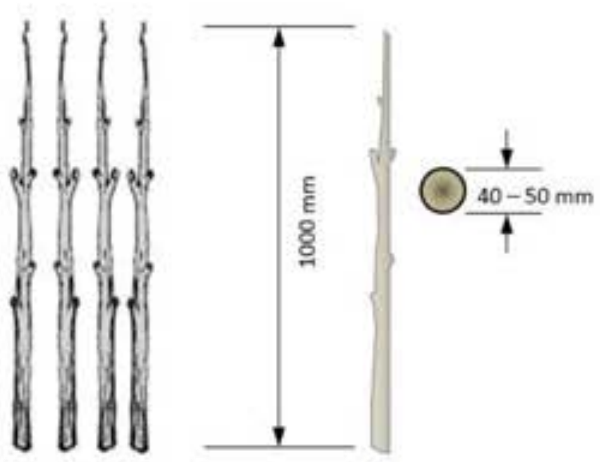


Fig. A.8.3: Cutting dimensions for truncheon cuttings.

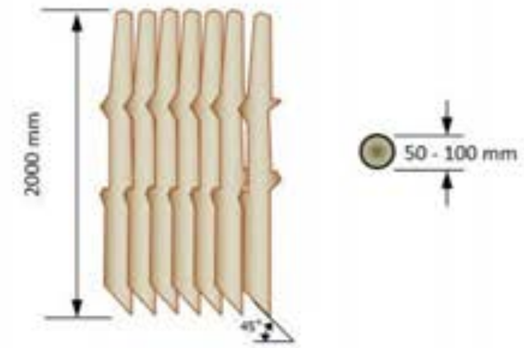
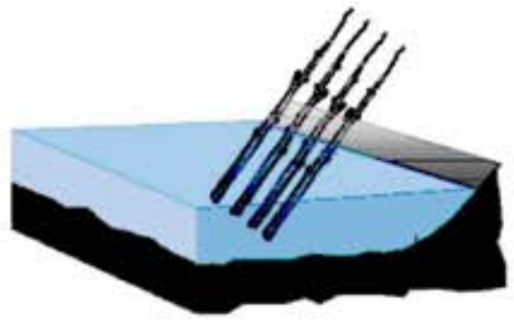


Fig. A.8.4: Optionally, cuttings may be immersed in water for a few days after they have been taken.



Plant Preparation

a. Plant cuttings must be prepared and planted within 12 hours.

b. Cuttings from si trees shall be used, or from another shrub or small tree that is suited to the site and shows the correct habit for an ability to grow from cuttings (i.e. many shoots coming from the stump).

c. Cuttings shall be made cleanly using sharp tools, with no damage to the bark.

TA 8102-VIE: PROMOTING CLIMATE RESILIENT RURAL INFRASTRUCTURE IN NORTHERN VIETNAM			
SP4 - BAC KAN RIVERBANK WORKS			
THI CÔNG HLIVEOM CỌC CÂY TƯƠI/POLE PLANTING CONSTRUCTION			
ICEM TAY HO, HANOI, VIET NAM	DRAWING ID: AAS1206/C-321/F003	DESIGNER:	DAVID ROJAS JR.
		DRAWER:	PHAN TIEN AN
PHILKOEI INTERNATIONAL INC, PHILIPPINES (PKII)	SCALE: NO SCALE	CHECKED:	NGUYEN TRAN THUAT
	DATE: 10/5/2014	APPROVAL:	JAMES RAMSAY

LIVE POLES AND TRUNCHEON CUTTINGS (2)

A8

Planting Procedure: Live poles

1. Always start at the top of the slope and work downwards.
2. Using an auger or steel bar, create holes slightly larger than the diameter of the cuttings, approximately perpendicular to the slope and at 500 mm centres along each line. The holes should be 850 to 900 mm deep. See Fig.A.8.5.
3. The cuttings are then placed into the holes with the branch growing tips pointing outward and with approximately 100 mm to 150 mm of each live pole protruding above the ground. See Fig. A.8.6.
4. The space around the pole shall be filled with fine soil and lightly compacted with foot pressure.
5. The succeeding row of holes is created 1000 mm downslope from the preceding row. The holes of the next row shall be staggered from the previous row for greater surface area protection. See Fig. A.8.7.

Fig. A.8.5. Holes bored in the slope ready for the insertion of cuttings. [Note that the vertical dimension is exaggerated.]

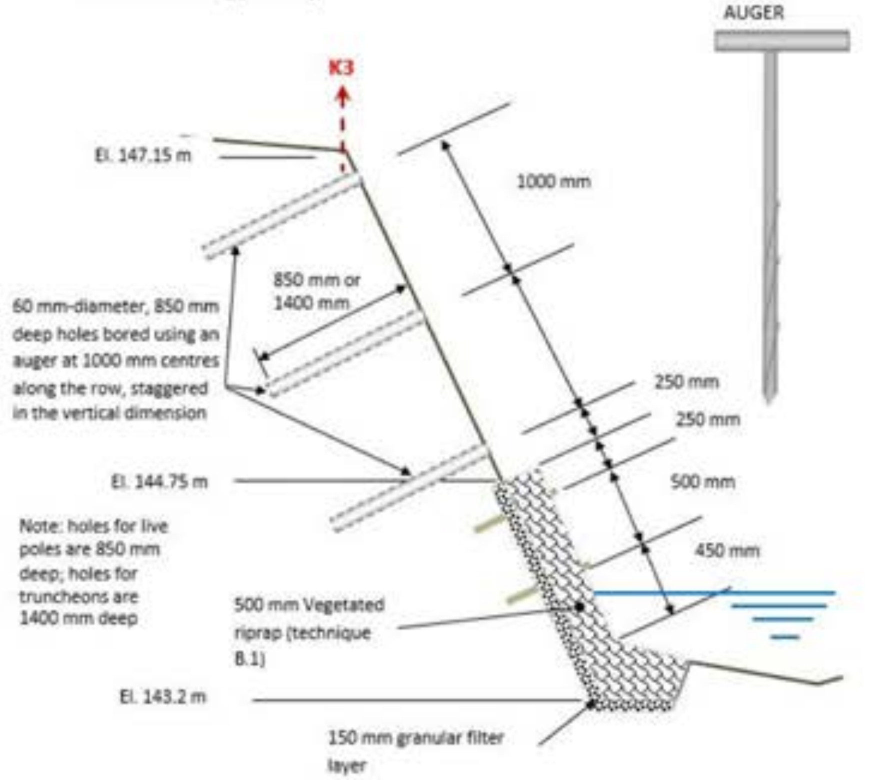
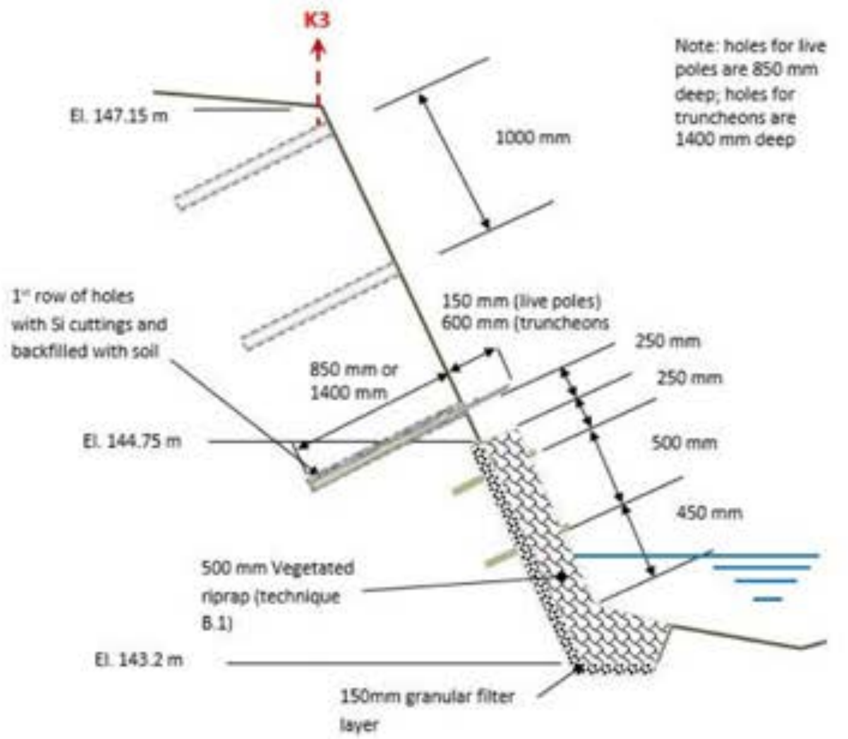


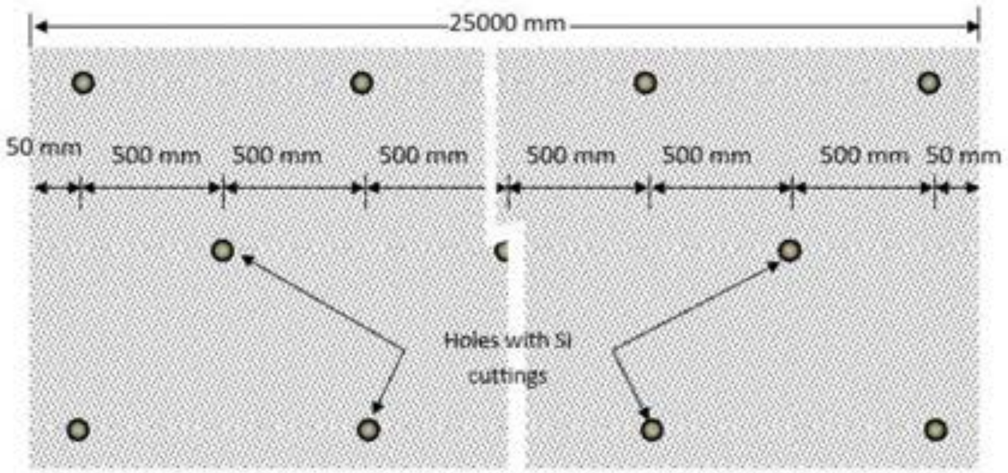
Fig. A.8.6. The first row of cuttings inserted into the holes in the slope and backfilled. [Note that the vertical dimension is exaggerated.]



Planting Procedure: Truncheons

1. Always start at the top of the slope and work downwards.
2. Using an auger or steel bar, create holes slightly larger than the diameter of the cuttings, approximately perpendicular to the slope and at 1000 mm centres along each line. The holes should be about 1400 mm deep. See Fig. A.8.5.
3. The cuttings are then placed into the holes with the branch growing tips pointing outward and with approximately 600 mm of each truncheon protruding above the ground. See Fig. A.8.6.
4. The space around the truncheon shall be filled with fine soil and lightly compacted with foot pressure.
5. The succeeding row of holes is created 1000 mm downslope from the preceding row. The holes of the next row shall be staggered from the previous row for greater surface area protection. See Fig. A.8.7.

Fig. A.8.7: Plan layout of the slope with inserted live poles of truncheons.



TA 8102-VIE: PROMOTING CLIMATE RESILIENT RURAL INFRASTRUCTURE IN NORTHERN VIETNAM				
SP4 - BAC KAN RIVERBANK WORKS				
THI CÔNG HLIVEOM CỌC CÂY TƯƠI/POLE PLANTING CONSTRUCTION				
ICEM TAY HO, HANOI, VIET NAM	DRAWING ID: AAS1206/C-321/F003	DESIGNER:	DAVID ROJAS JR.	
		DRAWER:	PHAN TIEN AN	
PHILKOEI INTERNATIONAL INC, PHILIPPINES (PKII)	SCALE: NO SCALE	CHECKED:	NGUYEN TRAN THUAT	
	DATE: 10/5/2014	APPROVAL:	JAMES RAMSAY	


Newly planted live poles in riverbank embankment at SP32 in Son La Province


Live poles in riverbank embankment at SP4 in Bac Kan Province 18 months after plantation


Live poles in riverbank embankment at SP32 in Son La Province after one year and two flood seasons


Willow-leaved water croton used to construct live poles in riverbank embankment at SP4 in Bac Kan Province

A.9 LIVE CHECK DAMS

LIVE CHECK DAMS (1)

A9

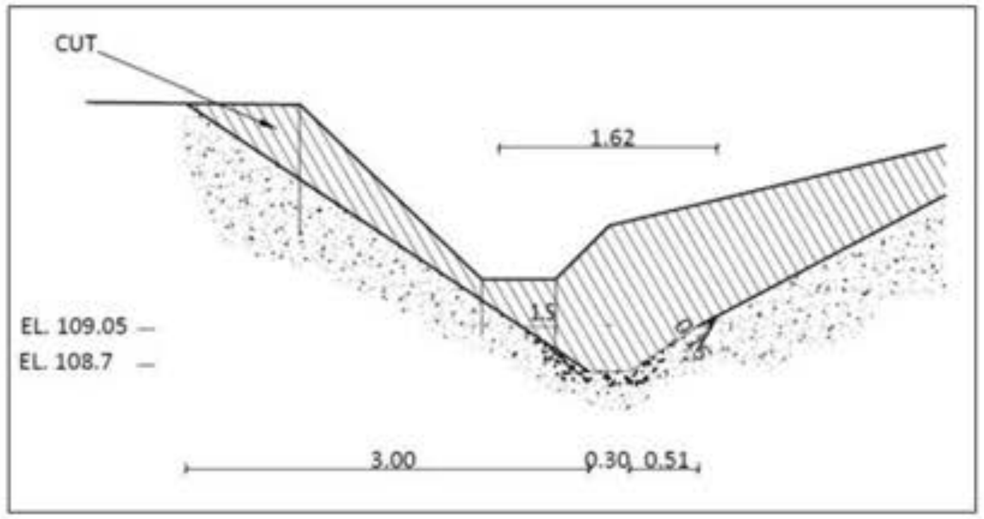
This procedure applies to the use of cuttings from a range of shrub or tree species, but it is based on cuttings from golden dewdrop or Thanh quan (Duranta erecta) trees, which are common in northern Viet Nam.

Site Preparation

a. The site is prepared to the desired slope before the day on which planting will take place. Debris is removed, depressions are filled in and humps are levelled off to attain a linear profile. See Fig. A.9.1.

b. Using a measuring tape and string, the locations chosen for live check dams to be planted shall be marked by pegs starting from 1000 mm above the toe of the slope, and then at 2000 to 5000 mm centres up the gully.

Fig. A.9.1: Preparation of site for live check dams.



Plant Preparation

a. Plant cuttings must be prepared and planted within 12 hours.

b. Cuttings from thanh quan trees shall be used, or from another shrub or small tree that is suited to the site and shows the correct habit for an ability to grow from cuttings (i.e. many shoots coming from the stump).

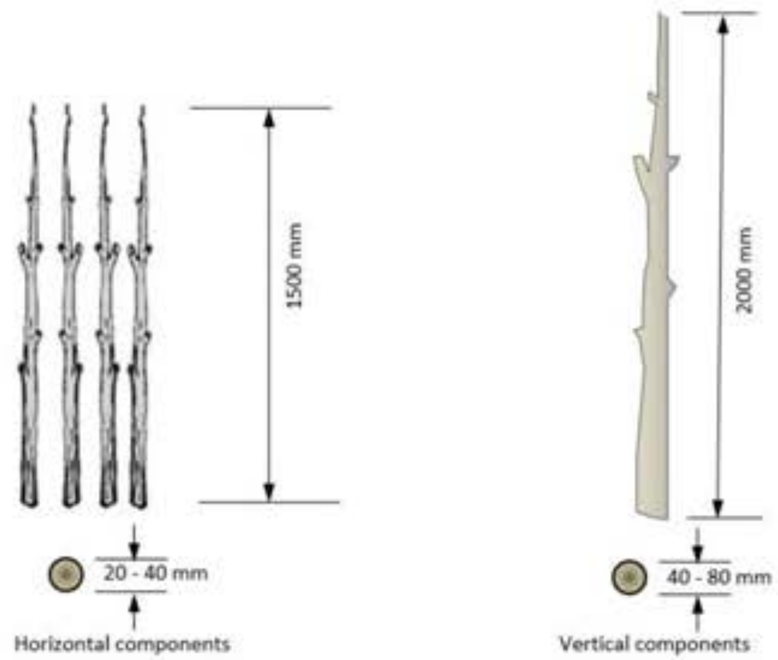
c. Cuttings shall be made cleanly using sharp tools, with no damage to the bark.

d. Cuttings shall be from woody material that is 6 to 18 months in age.e. Cuttings shall be 40 to 80 mm in diameter and 2000 mm long for the vertical components of live check dams, and 20 to 40 mm in diameter and approximately 1500 mm long for the horizontal components. See Fig. A.9.2.

f. The lower end of each cutting shall be cut at 45 degrees and the tops cut perpendicular to the stem. Side branches shall be trimmed off carefully, using sharp tools.

g. Once made, the cuttings are wrapped in wet jute sacks and kept in the shade while they are transported to the site.

Fig. A.9.2: Cutting dimensions for live check dams.



TA 8102-VIE: PROMOTING CLIMATE RESILIENT RURAL INFRASTRUCTURE IN NORTHERN VIETNAM				
SP34-THAI NGUYEN ROAD SLOPE PROTECTION WORKS				
VỊ TRÍ CÔNG TRÌNH Ở XÃ LIÊN MINH - LOCATION OF SITE IN LIEN MINH COMMUNE				
ICEM TAY HO, HA NOI, VIET NAM	DRAWING ID: AAS1206/T-048 /V01	DESIGNER:	DAVID ROJAS JR.	
		DRAWER:	PHAN TIEN AN	
PHILKOEI INTERNATIONAL INC, PHILIPPINES (PKII)	SCALE:	CHECKED:	NGUYEN TRAN THUAT	
	DATE:	APPROVAL:	JAMES RAMSAY	

LIVE CHECK DAMS (2)

A9

Planting Procedure

1. Always start at the top of the slope and work downwards.
2. Excavate a trench 150 mm deep and 300 mm wide across the gully in the location where the check dam will be built. See Fig. A.9.3.
3. Begin the construction by inserting the vertical posts of the live check dam.
4.This is done by placing two rows of live posts at a spacing of 300 mm between rows and 300 mm centres along each row. There will be 5 vertical posts in each row, with the central three posts 1700 mm long and the two outer posts 2000 mm long. Only 350 mm of the single central post will be above ground; 550 mm of the next two posts will be above ground; and 300 mm of the two outer posts will protrude above the ground.
5. Holes are made using a pointed bar. The hole is made bigger than the cutting (i.e. about 50 to 100 mm in diameter) and deep enough to take at least two-thirds of its length (i.e. around 1200 mm deep).

Fig. A.9.3: Excavation of the foundation for a live check dam.

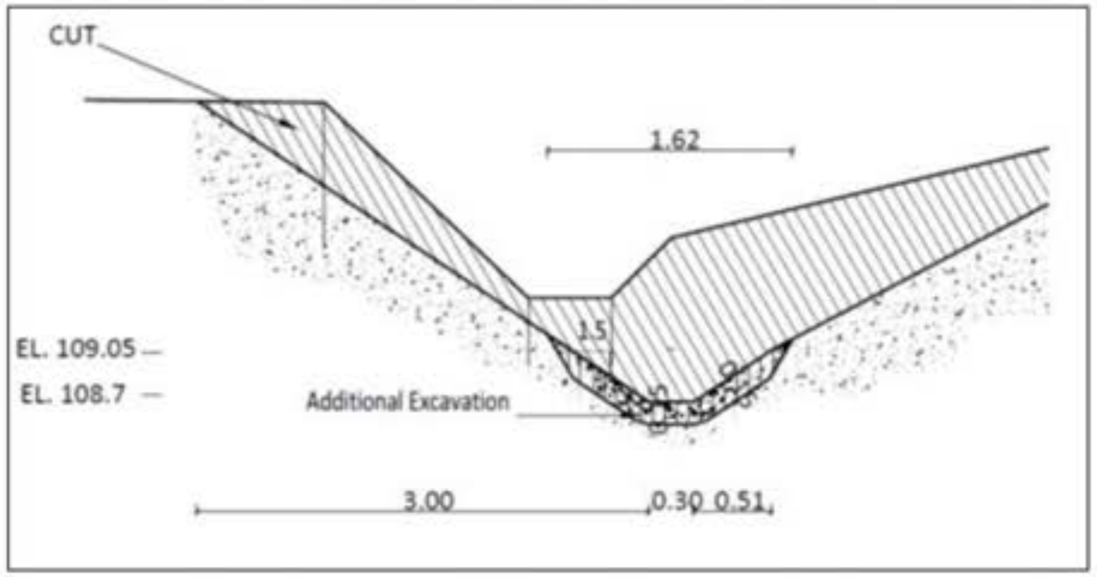
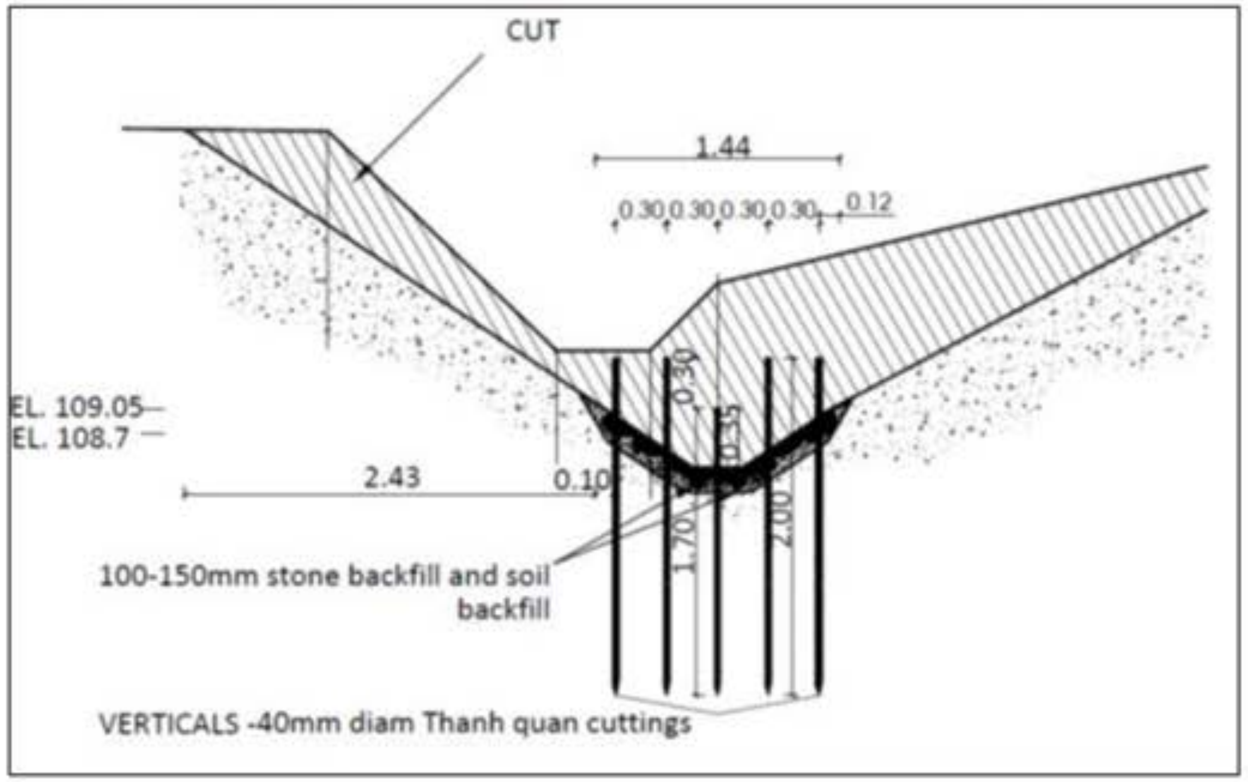


Fig. A.9.4: Planting of the vertical components of a live check dam.



6. Carefully place the cutting in the hole, so that at least two-thirds is buried. Firm the soil around it, taking care not to damage the bark.
7. After placing the two rows of vertical posts, soil and stone (~100 to 150 mm diameter) is backfilled in the excavated trench. Stone shall be on top of the soil. Press the soil and the stones firmly by foot or a flat wooden tamper. See Fig. A.9.4 for the completed vertical components.

TA 8102-VIE: PROMOTING CLIMATE RESILIENT RURAL INFRASTRUCTURE IN NORTHERN VIETNAM			
SP34-THAI NGUYEN ROAD SLOPE PROTECTION WORKS			
VỊ TRÍ CÔNG TRÌNH Ở XÃ LIÊN MINH - LOCATION OF SITE IN LIEN MINH COMMUNE			
ICEM TAY HO, HA NOI, VIET NAM	DRAWING ID: AAS1206/T- 048 /V01	DESIGNER:	DAVID ROJAS JR.
		DRAWER:	PHAN TIEN AN
PHILKOEI INTERNATIONAL INC, PHILIPPINES (PKII)	SCALE:	CHECKED:	NGUYEN TRAN THUAT
	DATE:	APPROVAL:	JAMES RAMSAY

LIVE CHECK DAMS (3)

A9

Planting Procedure (continued)

8. Place the horizontal components at both sides of the vertical posts in the two rows. The horizontal cuttings are tied to the vertical posts by jute rope. The lowermost horizontal cutting shall be 70 mm above the base level of the channel. The succeeding horizontals are placed at 100 mm centres.
9. The lower ends of the horizontal cuttings should be buried into the soil of the trench on one side of the check dam, under at least 150 mm of soil.
10. There should be 4 to 8 horizontal cuttings in the live check dam, with them overlapping by at least 25%.

Fig. A.9.6: Plan layout of a live check dam.

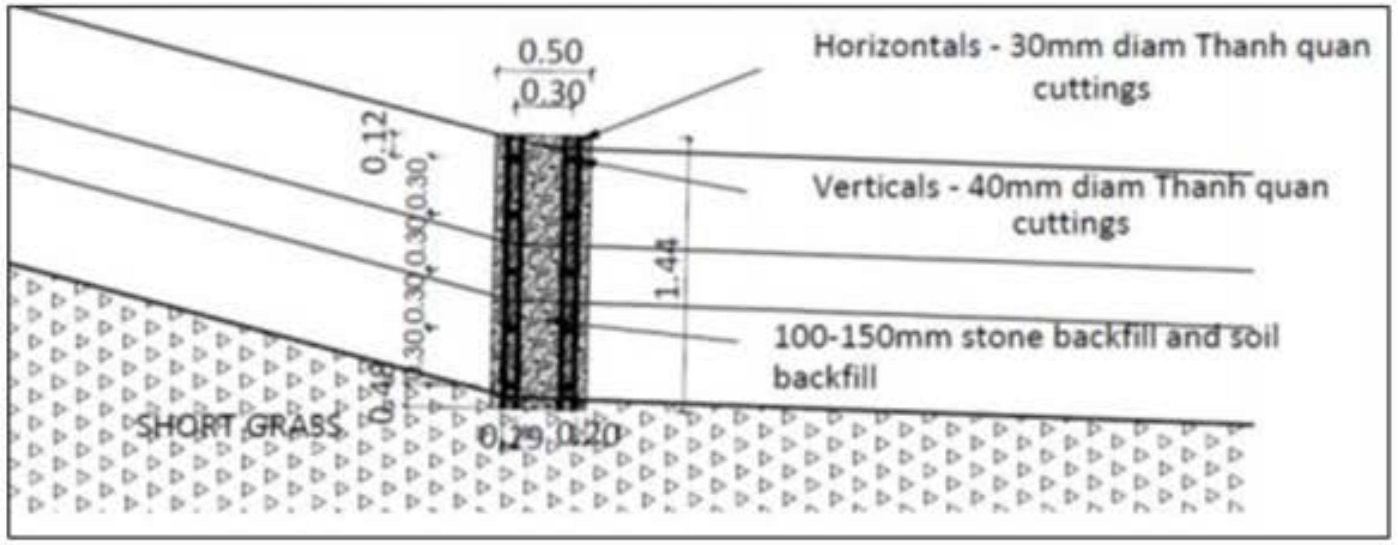
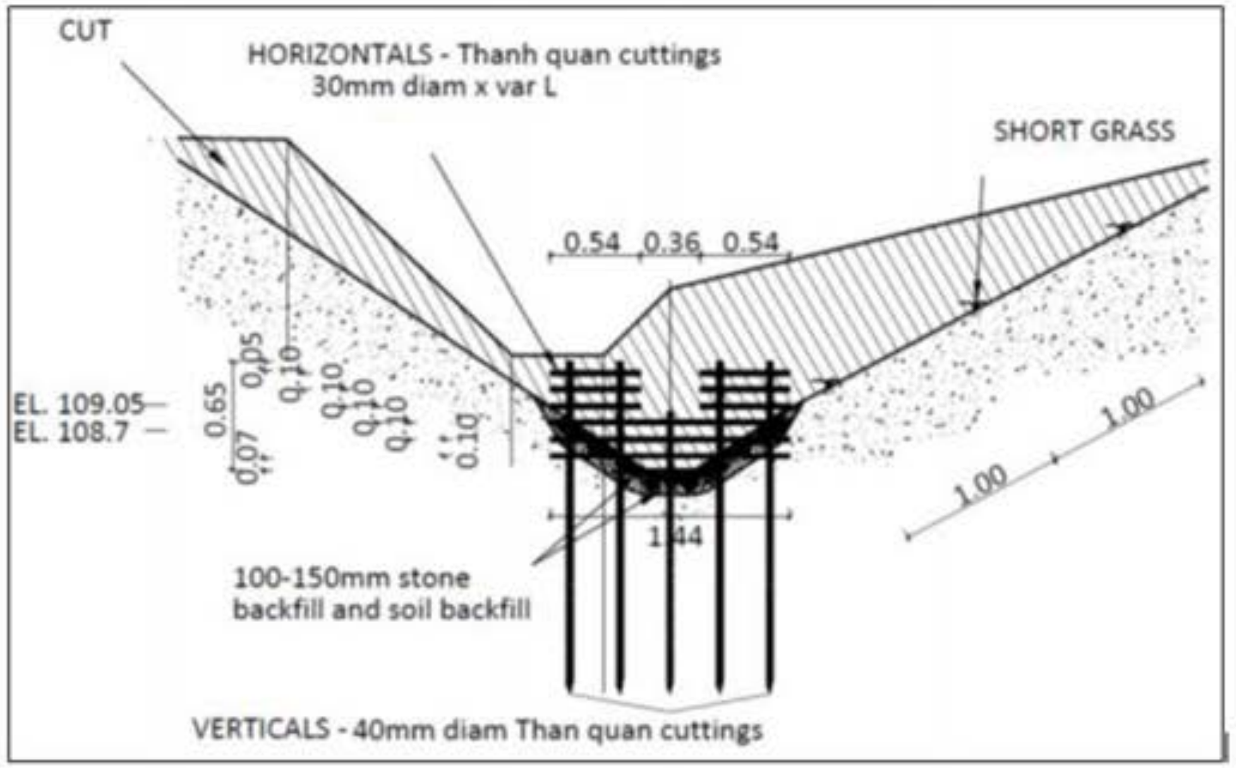


Fig. A.9.5: Planting of the horizontal components of a live check dam.



11. After placing the horizontal components between both rows of vertical posts, soil and stone (~100 to 150 mm diameter) is backfilled in the space in between. Stone shall be on top of the soil. Press the soil and the stones with careful foot pressure. See Fig. A.9.5 for the completed horizontal components. Fig. A.9.6 shows a plan layout view.
12. It is important to ensure that the lowest point of the check dam is in its centre, as shown in Fig. A.9.5.
13. Move up to the next check dam location and repeat the procedure.

TA 8102-VIE: PROMOTING CLIMATE RESILIENT RURAL INFRASTRUCTURE IN NORTHERN VIETNAM			
SP34-THAI NGUYEN ROAD SLOPE PROTECTION WORKS			
VỊ TRÍ CÔNG TRÌNH Ở XÃ LIÊN MINH - LOCATION OF SITE IN LIEN MINH COMMUNE			
ICEM TAY HO, HA NOI, VIET NAM	DRAWING ID: AAS1206/T- 048 /V01	DESIGNER:	DAVID ROJAS JR.
		DRAWER:	PHAN TIEN AN
PHILKOEI INTERNATIONAL INC, PHILIPPINES (PKII)	SCALE:	CHECKED:	NGUYEN TRAN THUAT
	DATE:	APPROVAL:	JAMES RAMSAY


Newly constructed live check dam at the base of fill slope at SP35 in Thai Nguyen Province


Replanted live check dam on fill slope at SP35 in Thai nguyen Province


Live check dam on fill slope at SP35 in Thai Nguyen Province after replantation


Live check dam on fill slope at SP35 in Thai Nguyen Province five months after replantation

6 MIXED TECHNIQUES

There are several choices for slope protection, but in general the two main groups of options are:

- "Hard" measures such as retaining walls and revetments or
- Bioengineering (i.e. vegetation-based) measures.

These two types of solutions should not be viewed as an "either-or" option, but rather they can be more effectively considered as a spectrum of solutions to solve specific problems. Therefore, a combination of the two is often the best way to deal with slope protection issues.

In many circumstances, physical engineering measures can be supported by the addition of vegetation and vice versa. In a rural infrastructure environment, bioengineering can be utilised to minimise cost, but it takes time to establish and can only be suitable for dealing with shallow erosion. Low cost hard options can provide immediate protection in the most vulnerable points whilst the bioengineering plants develop their full strength. On the other hand, adding vegetation to civil engineering work can provide additional resistance to erosion through layers of vegetation on the surface and deep rooting throughout the soil mass. It also provides habitat value, creates a more natural appearance, and becomes less visually intrusive than a structural treatment alone. It must also be recognised that there will be many sites where a combination of the two groups of techniques is required simply because of the variable nature of soils and rocks at those sites.

Masonry framework with grass on cut slope at SP35 in Thai Nguyen Province

Vegetated gabions protecting riverbank at SP32 in Son La Province

B.1 VEGETATED RIPRAP

VEGETATED RIPRAP (1)

B1

This procedure applies to the use of cuttings from a range of shrub or tree species, but it is based on cuttings from Si (Ficus benjamina) trees, which are common in northern Viet Nam.

Site Preparation

a. The site is prepared to the desired slope before the day on which construction and planting will take place. Debris is removed, depressions are filled in and humps are levelled off to attain a linear profile.
b. Using a measuring tape and string, the area to be installed with riprap and planted shall be marked by pegs.
c. The required volume of angular rocks or boulders for riprap, and also sand and pebbles for filter layers, shall be procured and brought to the site.
d. The rocks for riprap shall have a median diameter D50 = 30 mm and a thickness of 300 mm at the starting cross-section K0 to 5 m downstream where the slope is gentle (1v:5h to 1v:2h); and a D50 = 300mm and a thickness of 600 mm where the slope is steeper than 1v:2h up to 1v:1.25h.
e. The filter layer shall have a median diameter D50 = 40 mm and a thickness of 200 mm.
f. The rock riprap material and the granular filter material shall have grain size distribution according to Table B.1 below.

Plant Preparation

a. Plant cuttings must be prepared and planted within 12 hours.
b. Cuttings from si trees shall be used, or from another shrub or small tree that is suited to the site and shows the correct habit for an ability to grow from cuttings (i.e. many shoots coming from the stump).
c. Cuttings shall be made cleanly using sharp tools, with no damage to the bark.
d. Cuttings for live poles shall be from woody material that is 6 to 18 months in age.
e. Cuttings shall be 50 to 100 mm in diameter and 2000 mm long. See Fig. B.1.1.
f. The lower end of each cutting shall be cut at 45 degrees and the tops cut perpendicular to the stem. Side branches shall be trimmed off carefully, using sharp tools.
g. Once made, the cuttings are wrapped in wet jute sacks and kept in the shade while they are transported to the site.

Fig. B.1.1: Cutting dimensions for vegetated riprap.

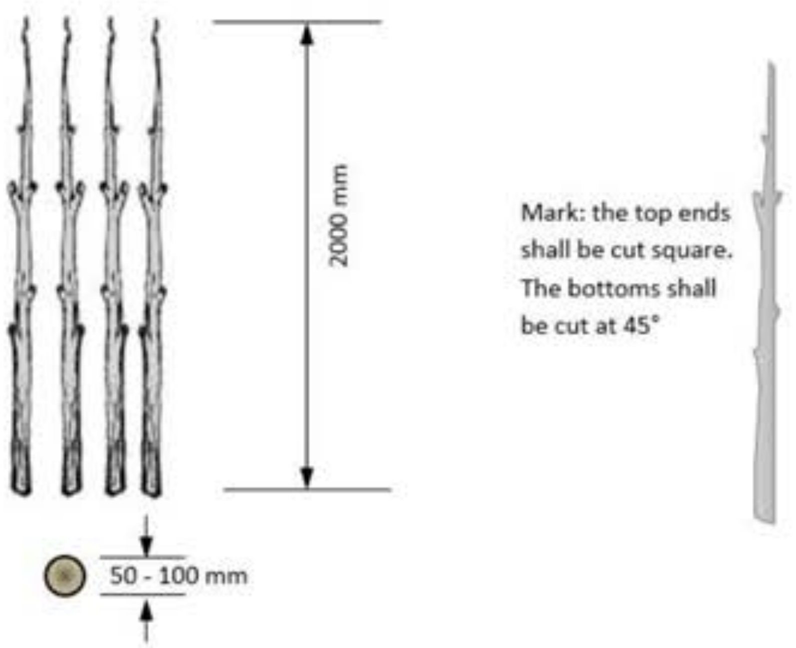


Table B.1: Size distribution requirements for riprap rock and filter materials

% Passing	Grain size distribution, mm	
	Rock	Granular filter
100 %	600	80
85 %	470	62
75 %	420	56
60 %	360	50
50 %	300	40
30 %	240	28
15 %	190	14
10 %	120	5

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SP4 - BAC KAN RIVERBANK WORKS
VEGETATED RIPRAP CONSTRUCTION

ICEM TAY HO, HANOI, VIET NAM	DRAWING ID: AAS1206/C-324/F003	DESIGNER:	DAVID ROJAS JR
		DRAWER:	PHAN TIEN AN
PHILKOEI INTERNATIONAL INC, PHILIPPINES (PKII)	SCALE: NO SCALE	CHECKED:	NGUYEN TRAN THUAT
	DATE: 10/5/2014	APPROVAL:	JAMES RAMSAY

VEGETATED RIPRAP (2)

B1

Construction and Planting Procedure

1. Riprap shall be constructed in a series of strips, each 1000 mm wide. The filter layer for the whole area is laid first. Then the first strip of rocks shall be laid, then a line of cuttings, then the next strip of rocks, and so on.
2. Place two (2) 100-mm filter layers on the slope area where the riprap is being installed, as shown in Fig. B.1.2.
3. The grain size distribution of the layers shall be as indicated in Table B.1.
4. Immediately after the filter layer has been prepared, the stones shall be placed manually, starting from the bottom.
5. The contractor must ensure that the stones are fitted firmly and a stable compact mass is attained. The stones must be placed properly at all times during the construction.
6. The surface of stonework shall not vary from the average slope profile or the specified average channel invert by more than 30 mm.
7. After completing the first strip of riprap to the height specified in the design, a line of holes shall be bored using auger rods along the edge of the rock strip. The holes shall be 100 mm in diameter, 1400 mm deep and spaced at 1000 mm centres, and shall be approximately perpendicular to the slope.
8. A tree cutting is placed carefully into each hole to a depth at which there is a protrusion of 100 to 150 mm above the finished riprap rock profile.
9. The space around the pole below the rock layer shall be filled with fine soil and lightly compacted with foot pressure.
10. The portion of the cutting within the riprap rock thickness shall be covered by hessian jute before the next year layer of stones is placed. See Fig. B.1.3.
11. The next 1000 mm strip of riprap is then placed, repeating steps 5 to 10.
12. Each row of cuttings shall be staggered or offset by 500 mm along the horizontal from the preceding row below.
13. The top of the riprap is then backfilled with the excavated soil, which is then gently but firmly compacted. See Fig. B.1.4.

Fig. B.1.2: Placement of the filter material.

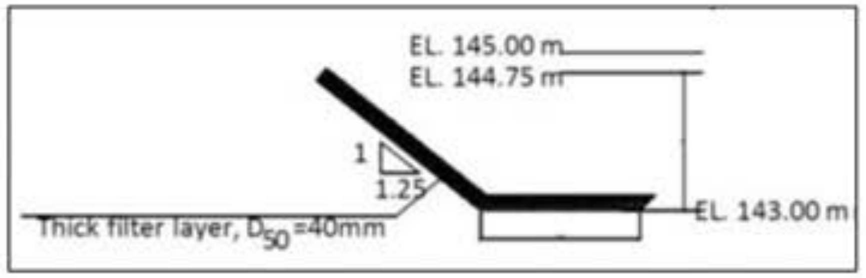


Fig. B.1.4: Vegetated riprap completed, with two lines of cuttings and three strips of rocks.

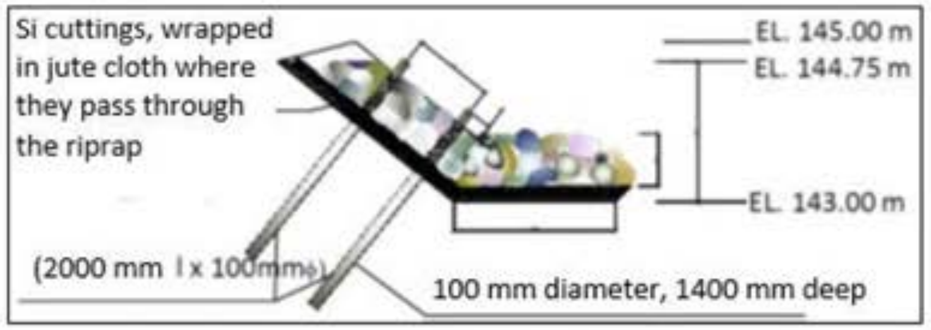
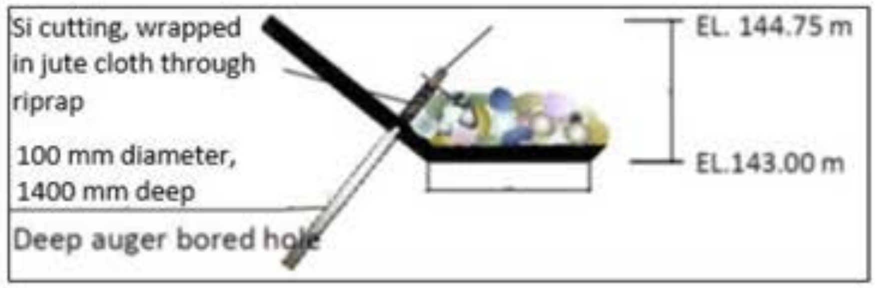


Fig. B.1.3: Placement of the first strip of riprap rock and the first line of cuttings.



TA 8102-VIE: PROMOTING CLIMATE RESILIENT RURAL INFRASTRUCTURE IN NORTHERN VIETNAM			
SP4 - BAC KAN RIVERBANK WORKS			
VEGETATED RIPRAP CONSTRUCTION			
ICEM TAY HO, HANOI, VIET NAM	DRAWING ID: AAS1206/C-324/F003	DESIGNER:	DAVID ROJAS JR
		DRAWER:	PHAN TIEN AN
PHILKOEI INTERNATIONAL INC. PHILIPPINES (PKII)	SCALE: NO SCALE	CHECKED:	NGUYEN TRAN THUAT
	DATE: 10/5/2014	APPROVAL:	JAMES RAMSAY


Vegetated riprap in riverbank embankment at SP4 in Bac Kan Province four months after plantation


Vegetated riprap protecting the toe of riverbank at SP4 in Bac Kan Province


Vegetated riprap protecting the toe of riverbank at SP4 in Bac Kan Province 13 months after plantation


Vegetated riprap protecting the toe of riverbank at SP4 in Bac Kan Province 23 months after plantation

B.2 VEGETATED GABIONS

VEGETATED GABIONS (1)

B2

This procedure applies to the use of cuttings from a range of shrub or tree species, but it is based on cuttings from May chay (Salix tetrasperma) trees, which are common throughout South-east Asia.

Site Preparation

a. The site is prepared to the desired slope before the day on which construction and planting will take place. Debris is removed, depressions are filled in and humps are levelled off to attain a linear profile.
b. Using a measuring tape and string, the area to be installed with gabions and planted shall be marked by pegs.
c. The required volume of angular rocks or boulders for gabions, and also sand and pebbles for filter layers, shall be procured and brought to the site.
d. The rocks shall have a median diameter D50 = 430 mm.
e. The filter layer shall have a median diameter D50 = 50 mm and a thickness of 200 mm.
f. The gabion rocks and the granular filter material shall have grain size distribution according to Table B.2 below.
g. Gabion baskets of the specified size and wire material are procured, delivered and assembled at the site. Step-by-step procedures for the assembly of gabion baskets are provided by suppliers. Typical unassembled and assembled gabion baskets in Fig. B.2.1.

Table B.2: Size distribution requirements for gabion rock and filter materials

% Passing	Grain size distribution, mm	
	Gabion	Granular filter
100 %	910	90
85 %	700	81
75 %	620	72
60 %	520	60
50 %	430	50
30 %	374	32
15 %	280	16
10 %	200	6

Fig. B.2.1: Gabion basket layout

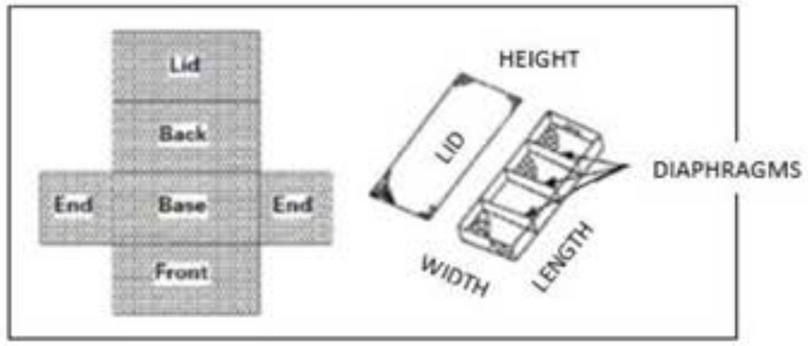
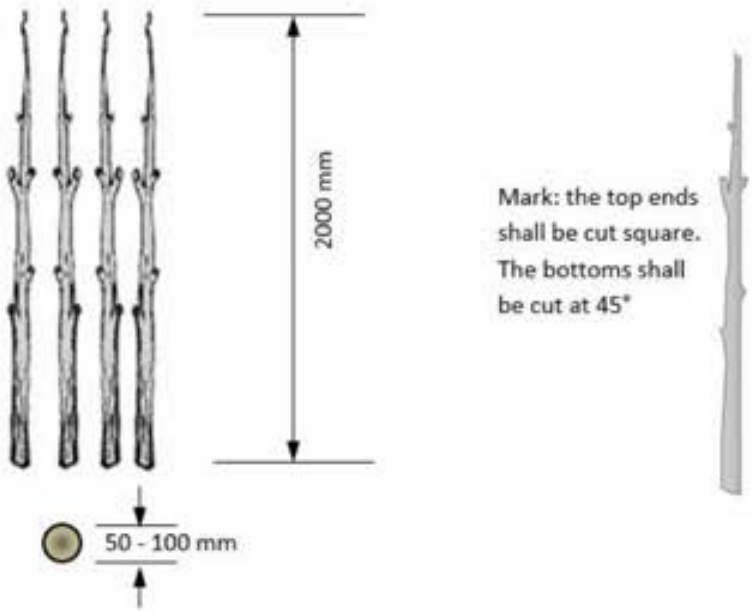


Fig. B.2.2: Cutting dimensions for vegetated gabions



Plant Preparation

a. Plant cuttings must be prepared and planted within 12 hours.
b. Cuttings from May chay trees shall be used, or from another shrub or small tree that is suited to the site and shows the correct habit for an ability to grow from cuttings (i.e. many shoots coming from the stump).
c. Cuttings shall be made cleanly using sharp tools, with no damage to the bark.
d. Cuttings for live poles shall be from woody material that is 6 to 18 months in age.
e. Cuttings shall be 50 to 100 mm in diameter and 2000 mm long. See Fig. B.2.2.
f. The lower end of each cutting shall be cut at 45 degrees and the tops cut perpendicular to the stem. Side branches shall be trimmed off carefully, using sharp tools.
g.Once made, the cuttings are wrapped in wet jute sacks and kept in the shade while they are transported to the site.

TA 8102-VIE: PROMOTING CLIMATE RESILIENT RURAL INFRASTRUCTURE IN NORTHERN VIETNAM			
SP32 - SON LA RIVERBANK WORKS			
VEGETATED GABION CONSTRUCTION			
ICEM TAY HO, HANOI, VIET NAM	DRAWING ID: AAS1206/C-320 (1)/F003	DESIGNER:	DAVID ROJAS JR.
		DRAWER:	PHAN TIEN AN
PHILKOEI INTERNATIONAL INC, PHILIPPINES (PKII)	SCALE: NO SCALE	CHECKED:	NGUYEN TRAN THUAT
	DATE: 10/5/2014	APPROVAL:	JAMES RAMSAY

VEGETATED GABIONS (2)

B2

Construction and Planting Procedure

1. This procedure describes the construction of a gabion wall with a gabion mattress extending in front of it.
2. Place a filter layer of at least 200 mm thickness on the slope area where the gabion is being installed, as indicated in the design.
3. Immediately after the filter layer has been prepared, the baskets for the gabion mattress are laid out on the prepared surface. They are fixed in place using 1000-mm metal stakes at the four corners and three to five stakes in the middle portion.
4. Adjacent gabion baskets are laced (i.e. bound with wire) together securely. See Fig. B.2.3.
5. The gabion mattresses are filled with rock manually in such a manner that the stones are fitted firmly and a stable, compact mass is attained. The Contractor must see to it that the stones are placed properly at all times during the construction process. The baskets must not bulge or move out of position.
6. Once the mattress baskets are filled, the lid is placed on top and laced properly on all four sides. See Fig. B.2.4.
7. The baskets for the gabion wall are placed on top of the filled gabion mattresses at an offset of 300 mm. The gabion boxes are laced to the mattresses on the four overlapping edges.
8. Each box is then filled with rocks up to 1/3 height. Stiffeners are then placed horizontally across the basket in each dimension to support the sides and prevent bulging. The boxes are filled again up to the 2/3 level and stiffeners are again attached across the basket. Filling of the box is then completed
9. Once each basket is filled, the lid is placed on top and laced properly on all four sides. See Fig. B.2.4.
10. The filter layer at the back slope is then placed and the slope backfilled up to the level of the top of the first gabion box.
11. [If the design is for a single gabion box, the next step is to backfill the soil to the final slope angle and then to prepare the top slope for the specified bioengineering technique as per the appropriate technique.]
12. The baskets for the next layer of gabions are then placed on top of the first, offset backwards into the slope by at least 300 mm (depending on the design) and offset sideways by 500 mm. The baskets are laced securely to the baskets below, along all connecting edges.
13. May chay cuttings shall then be laid through the mesh at the bottom of the second gabion basket, with the base of the cutting into the slope and the top end protruding 150 mm in front of the second gabion basket. The portion of the cuttings in contact with the gabion box shall be protected by wrapping in jute cloth. Cuttings shall be at 1000 mm centres along the length of the gabion structure.
14. The portion of the cuttings behind the gabions are then immediately buried in soil to stop them drying out.
15. Steps 8 to 10 are then repeated for the completion of the second gabion layer.
16. Steps 12 to 15 will then be repeated for each further layer of gabion, until the design height of the wall has been completed. See Fig. B.2.5.

Fig. B.2.3: Placement of the filter material and first layer of gabion boxes

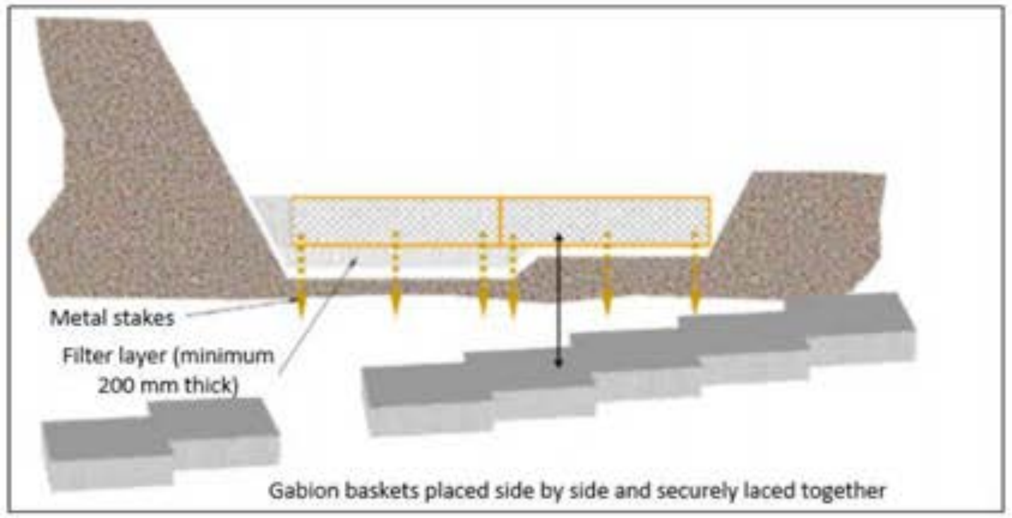


Fig. B.2.4: Filling a gabion basket and lacing on the lid

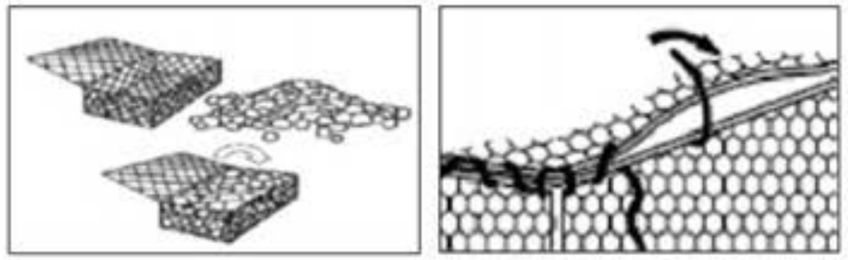
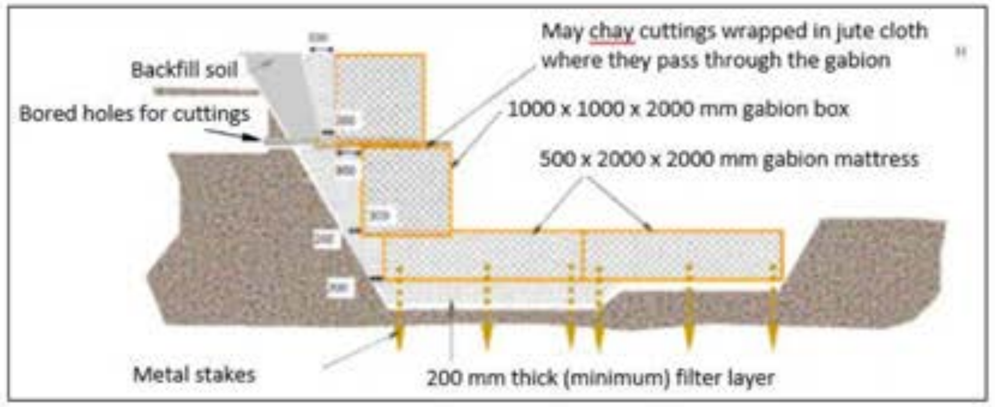


Fig.B.2.5: The completed structure of vegetated gabions



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SP32 - SON LA RIVERBANK WORKS				
VEGETATED GABION CONSTRUCTION				
ICEM TAY HO, HANOI, VIET NAM	DRAWING ID: AAS1206/C-320 (1)/F003	DESIGNER:	DAVID ROJAS JR.	
		DRAWER:	PHAN TIEN AN	
PHILKOEI INTERNATIONAL INC, PHILIPPINES (PKII)	SCALE: NO SCALE	CHECKED:	NGUYEN TRAN THUAT	
	DATE: 10/5/2014	APPROVAL:	JAMES RAMSAY	


Constructing vegetated gabions in riverbank embankment at SP32 in Son La Province


Completed vegetated gabions in riverbank embankment at SP32 in Son La Province


Vegetated gabions in riverbank embankment at SP32 in Son La Province after one year and two flood seasons


Vegetated gabions in riverbank embankment at SP32 in Son La Province after 21 months and three flood seasons

Vegetated gabion technique protecting riverbank together with live poles and live fences techniques at SP32 in Son La Province

Plants growing through layers of rock in vegetated gabion technique at riverbank embankment at SP32 in Son La Province, providing flexible binding to the structure once the wire has corroded

B.3 CONCRETE FRAME WITH LARGE GRASS PLANTING

CONCRETE FRAME WITH LARGE GRASS PLANTING (1)

B3

This procedure applies to a range of large grass species, but it is based on Tiger grass (Thysolaena latifolia), which is found widely throughout South-east Asia.

Site Preparation

a. The site is prepared to the desired slope before the day on which construction and planting will take place. Debris is removed, depressions are filled in and humps are levelled off to attain a linear profile. See Fig. B.3.1.

b. Stones or boulders with width (B) and thickness (C) ranging from 75 mm to 100 mm and length (A) ranging from 120 to 150 mm shall be procured or gathered and transported to the site. See Fig. B.3.2.

c. Prepare at least 12 pieces each of 0.5 m thick x 1.75 m high x 2.63 m wide and 0.5 m thick x 1.15 m high x 1.73 m wide rectangular framework made of 6 mm thick wood plank or plywood. This will serve as the formwork for the openings of the 6 m high mortar framework and 4 m high mortar framework, respectively.

Plant Preparation

a. Plants must be prepared and planted within 12 hours.

b. Tiger grass (Thysolaena latifolia) clumps shall be dug out from the nursery using a spade or hand trowel.

c. A hand full of grass, including the roots, is carefully separated by pulling it away from the rest of the clump. This is called a 'slip' of tiger grass. It must consist of at least two shoots with live growth buds and at least five roots with live growth buds.

d. The top (leaves) of the slip are cut off about 150 mm to 200 mm above the base of the plant (i.e. the point where the above ground shoots meet the roots).

e. The roots are cut off at 100 mm below the base. See Fig. B.3.3.

f. The slips are then wrapped in wet jute sacks and kept in the shade while they are transported to the site.

Fig. B.3.1: Cross-section of the prepared slope.

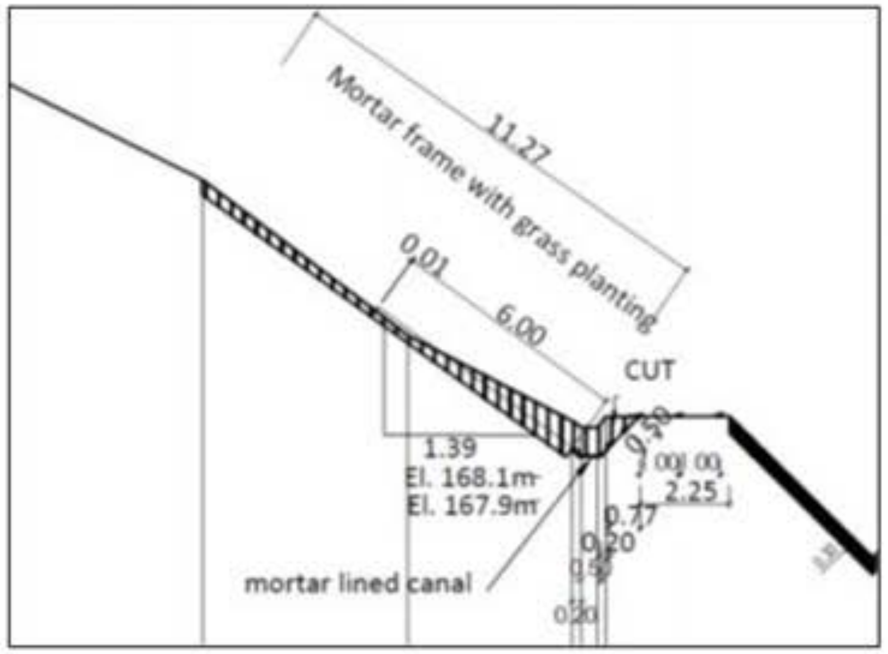
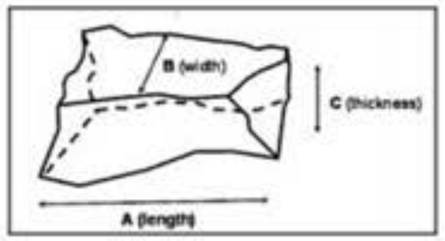


Fig. B.3.3. Preparation of grass slips.

Clumps of Tiger grass from nursery | Tiger grass slips | CUT SLIPS

Fig. B.3.2: Rock dimensions (see text).



TA 8102-VIE: PROMOTING CLIMATE RESILIENT RURAL INFRASTRUCTURE IN NORTHERN VIETNAM			
SP34-THAI NGUYEN ROAD SLOPE PROTECTION WORKS			
LOCATION OF SITE IN LIEN MINH COMMUNE			
ICEM TAY HO, HA NOI, VIET NAM	DRAWING ID: AAS1206/T- 045 /V01	DESIGNER:	DAVID ROJAS JR.
		DRAWER:	PHAN TIEN AN
PHILKOEI INTERNATIONAL INC, PHILIPPINES (PKII)	SCALE:	CHECKED:	NGUYEN TRAN THUAT
	DATE:	APPROVAL:	JAMES RAMSAY

CONCRETE FRAME WITH LARGE GRASS PLANTING (2)

B3

Construction and Planting Procedure

1. This procedure is for two layers of concrete framework and grass planting. For this technique, the "hard" works (i.e. the concrete framework) should be constructed during the dry season and may be built weeks or even months before the "soft" works (i.e. the planting), which must be done early in the wet season.
2. Starting from the bottom, construct the mortared masonry framework (0.3 m thick x 6 m high x 7.88 m wide) with 4 rectangular open panels (1.75 m high x 2.63 m wide) as shown in Fig. B.3.4.
3. Allow the frameworks to cure / harden for at least 2 to 3 days. Remove the open panel formworks after curing. Place 10 mm thick x 300 mm wide compressible joint filler (mat made of bamboo or locally available material) between each framework.
4. Fill the panels between the framework with soil, and firm and smooth it ready for planting.
5. Using a measuring tape and string, the lines to be planted shall be marked by pegs starting 300 mm from the top of the panel and then every 500 mm down the slope.
6. The first line to be planted is along the top of the slope, then working downwards.
7. Dig holes 100 mm deep and 100 mm in diameter at 100 mm centres along the top row.
8. Place the grass slip into the hole, making sure that the roots are not tangled or curved back to the surface.
9. Fill the hole with soil and firm gently with the fingers leaving no air pockets by the roots.
10. Firm along the whole row using careful foot pressure.
11. If it is available, place a few handfuls of compost or manure around each grass line.
12. Proceed to the next row down and repeat steps 7 to 10 or 11. Note that the grasses in each row should be offset from the one above. See Fig. B.3.5.

Fig. B.3.4: Construction of the first concrete framework level.

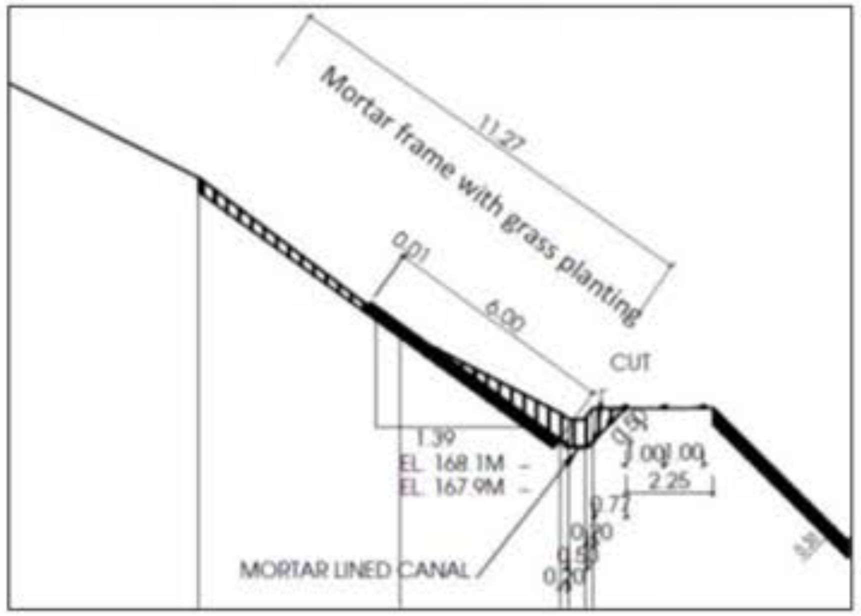
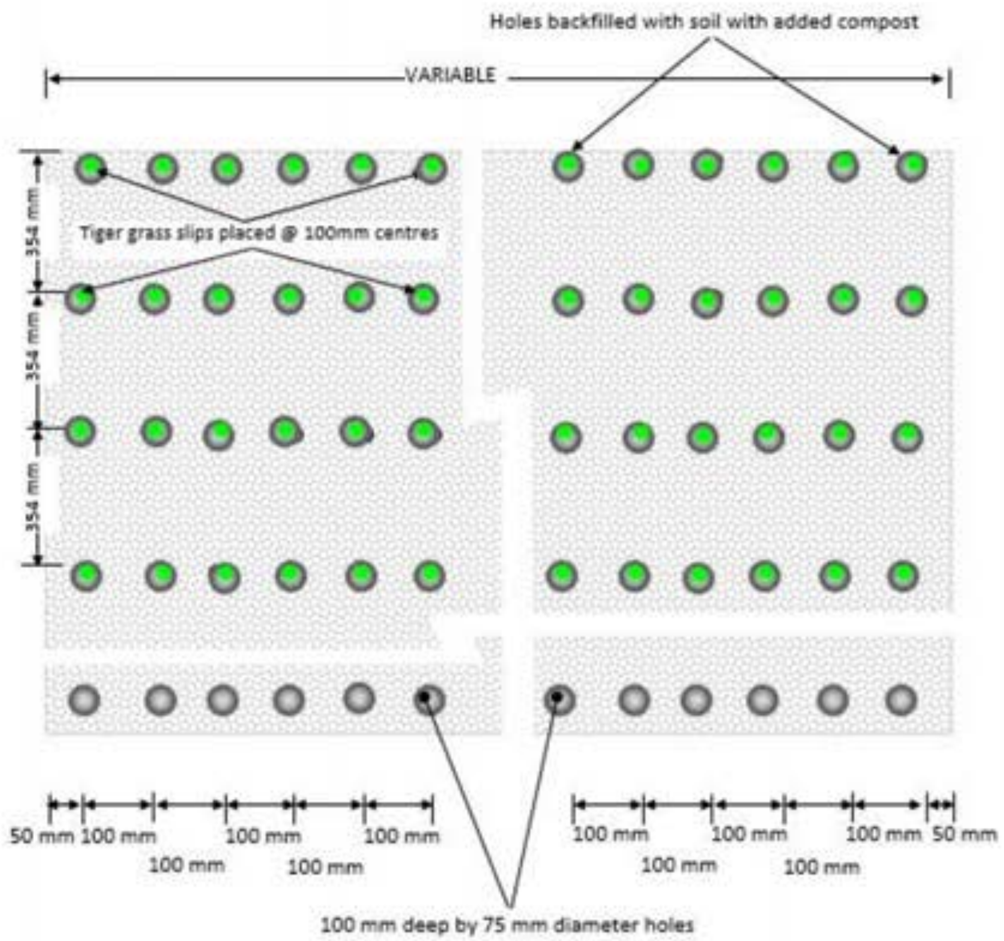


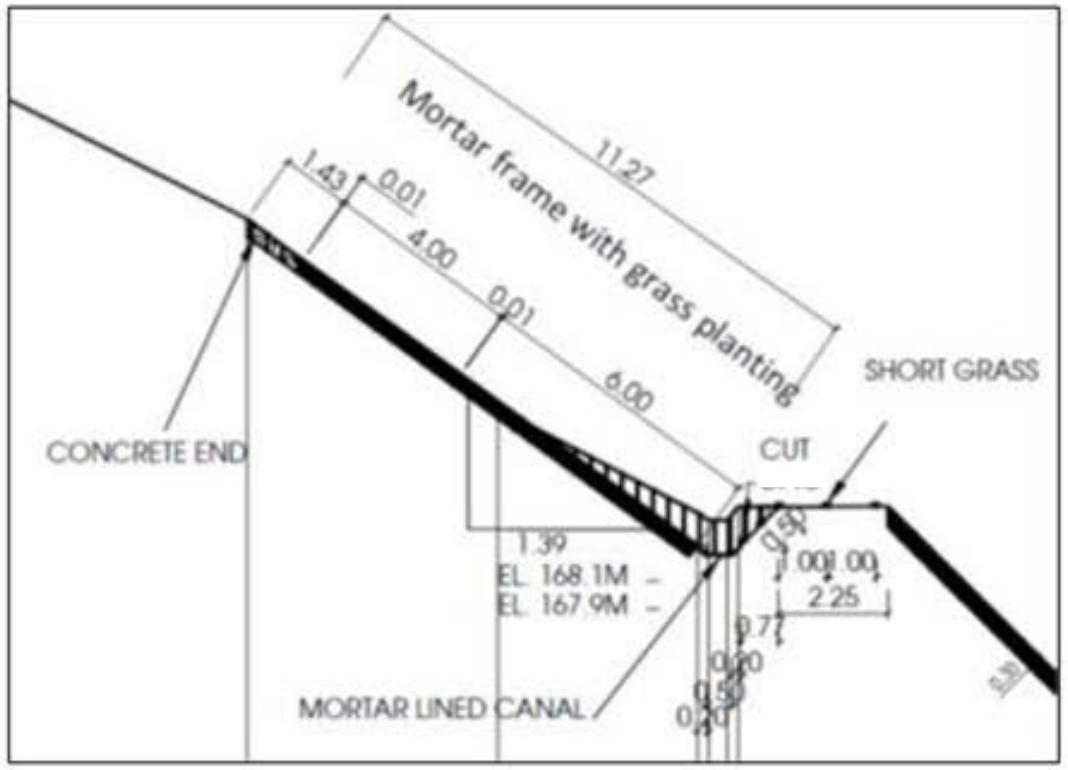
Fig. B.3.5: Planting arrangement for the soil panels.



CONCRETE FRAME WITH LARGE GRASS PLANTING (3)

B3

Fig. B.3.6: Cross-section of the completed slope.



Construction and Planting Procedure (continued)

13. If no rain is expected in the next two days, pour water carefully by hand over each grass plant.
14. Construct the upper mortared masonry framework (either 0.3 m thick x 6 m high x 7.88 m wide or 0.3 m x 4 m high x 5.18 m wide) with 4 rectangular open panels (dimensions depending on the framework size). Allow the framework to cure / harden for at least 2 to 3 days. Place 10 mm thick x 300 mm wide compressible joint filler (mat made of bamboo or locally available plant material or fibre) between frameworks. In the excess area on top, place concrete to seal the slope.
15. Repeat steps 4 to 11 for infilling with soil and tiger grass planting.
16. Drawings of the completed slope protection works are shown in Fig. B.3.6, Fig. B.3.7 and Fig. B.3.8.

Fig. B.3.8: Plan layout of the completed slope: 4-metre lift framework.

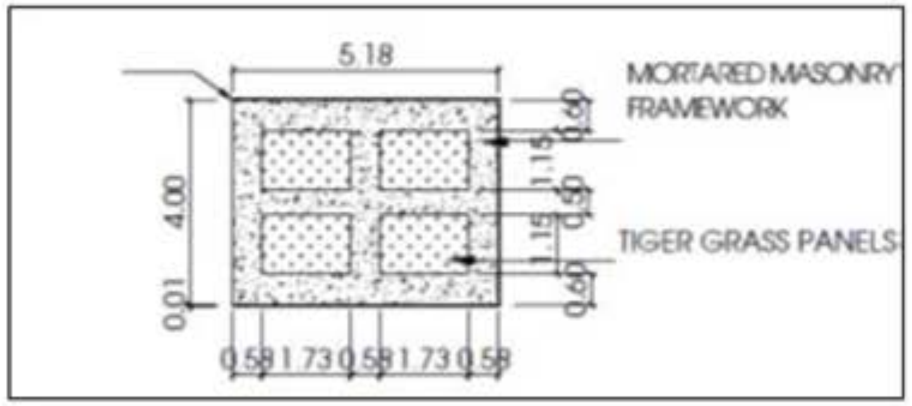
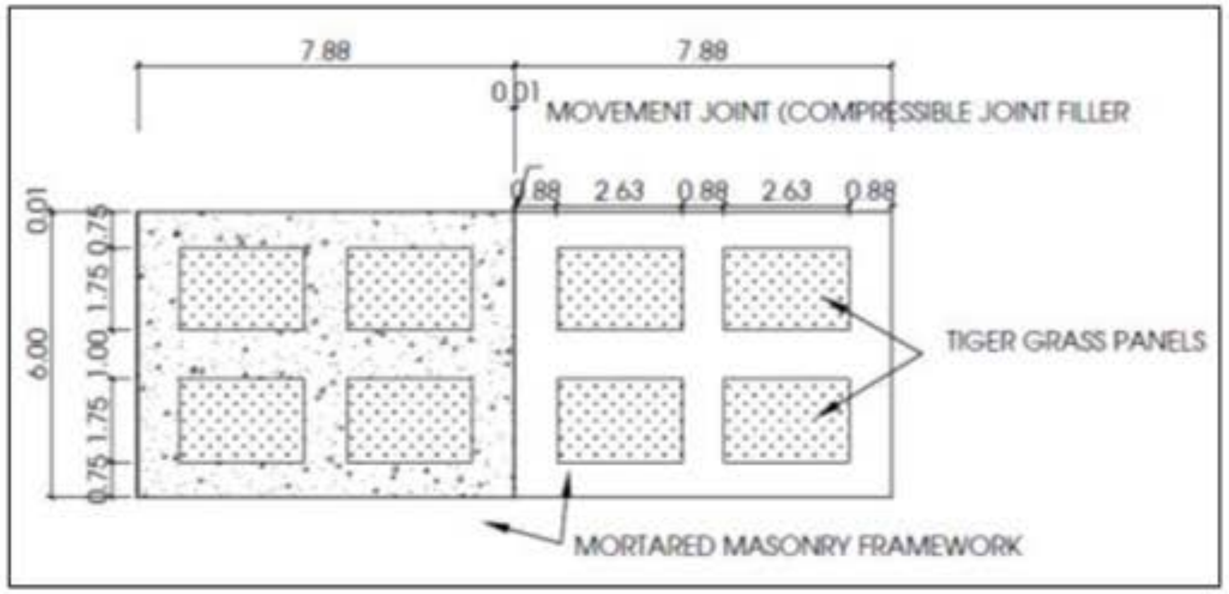


Fig. B.3.7: Plan layout of the completed slope: 6-metre lift framework.



TA 8102-VIE: PROMOTING CLIMATE RESILIENT RURAL INFRASTRUCTURE IN NORTHERN VIETNAM				
SP34-THAI NGUYEN ROAD SLOPE PROTECTION WORKS				
LOCATION OF SITE IN LIEN MINH COMMUNE				
ICEM TAY HO, HA NOI, VIET NAM	DRAWING ID: AAS1206/T- 045 /V01	DESIGNER:	DAVID ROJAS JR.	
		DRAWER:	PHAN TIEN AN	
PHILKOEI INTERNATIONAL INC, PHILIPPINES (PKII)	SCALE:	CHECKED:	NGUYEN TRAN THUAT	
	DATE:	APPROVAL:	JAMES RAMSAY	


Constructing masonry framework with grass on cut slope at SP35 in Thai Nguyen Province


Masonry framework with grass on cut slope at SP35 in Thai Nguyen Province one month after plantation


Masonry framework with grass on cut slope at SP35 in Thai Nguyen Province two months after plantation


Masonry framework with grass on cut slope at SP35 in Thai Nguyen Province five months after plantation

7 HARD TECHNIQUES INCLUDING DRAINAGE

Bioengineering is not a substitute for civil engineering. It can protect slopes against surface erosion and can improve resistance to shallow slope failures in many situations. However it is not effective in fresh to moderately weathered rock environments and cannot deal with slope instability greater than about 0.5m deep. In the cases when deep slope instability occurs, physical engineering (hard techniques) are required. They are particularly common in hilly and mountainous areas but are also frequently employed as a riverbank protection option.

Management of surface and subsurface water is a key issue in mitigating slope problems. Therefore, constructing appropriate drainage plays a vital role in slope protection, and hard engineering options such as stone mortared drains and gabion cascades can be substituted for the use of costly concrete measures, where suitable stones are readily available from nearby sources.

Hard techniques protecting slope in national highway from Hoa Binh Province to Son La Province

Conventional revetment protecting riverbank at SP4 in Bac Kan Province

C.1 CONCRETE FRAME WITH STONE INFILL

CONCRETE FRAME WITH STONE INFILL (1)

C1

Site Preparation

a. The site is prepared to the desired slope before construction will take place. Debris is removed, depressions are filled in and humps are levelled off to attain a linear profile.

b. Stones or boulders with width (B) and thickness (C) ranging from 75 mm to 100 mm and length (A) ranging from 120 to 150 mm shall be procured or gathered and transported to the site. See Fig. C.1.1.

c. Prepare at least 12 pieces each of 0.5 m thick x 1.75 m high x 2.63 m wide, 0.5 m thick x 1.5 m high x 2.25 m wide and 0.5 m thick x 0.8 m high x 1.25 m wide rectangular framework made of 6 mm thick wood plank or plywood. This will serve as the formwork for the openings of the 6-metre high mortar framework and 4 m high mortar framework, respectively.

d. Pegs are placed on the slope to mark the locations for the formwork, as per the dimensions shown in Fig. C.1.2.

Fig. C.1.2: Preparation of slope and marking-out dimensions.

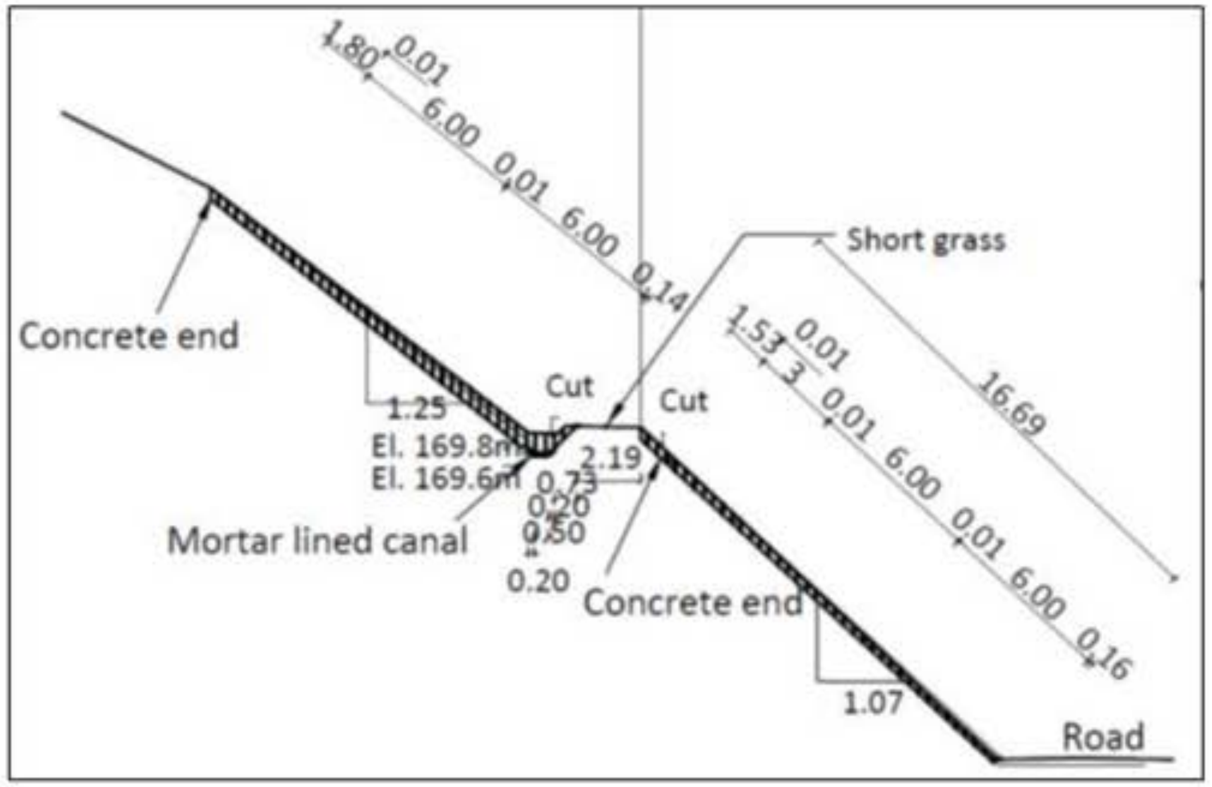
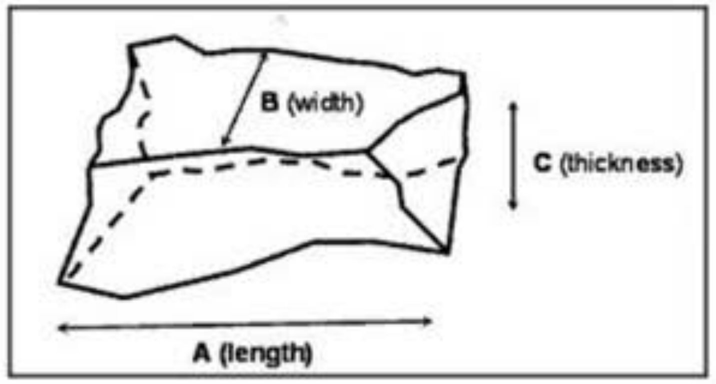


Fig. C.1.1: Rock dimensions (see text).



TA 8102-VIE: PROMOTING CLIMATE RESILIENT RURAL INFRASTRUCTURE IN NORTHERN VIETNAM			
SP35-THAI NGUYEN ROAD SLOPE PROTECTION WORKS			
LOCATION OF SITE IN LIEN MINH COMMUNE			
ICEM TAY HO, HA NOI, VIET NAM	DRAWING ID: AAS1206/T- 034 /V01	DESIGNER:	DAVID ROJAS JR.
		DRAWER:	PHAN TIEN AN
PHILKOEI INTERNATIONAL INC, PHILIPPINES (PKII)	SCALE:	CHECKED:	NGUYEN TRAN THUAT
	DATE:	APPROVAL:	JAMES RAMSAY

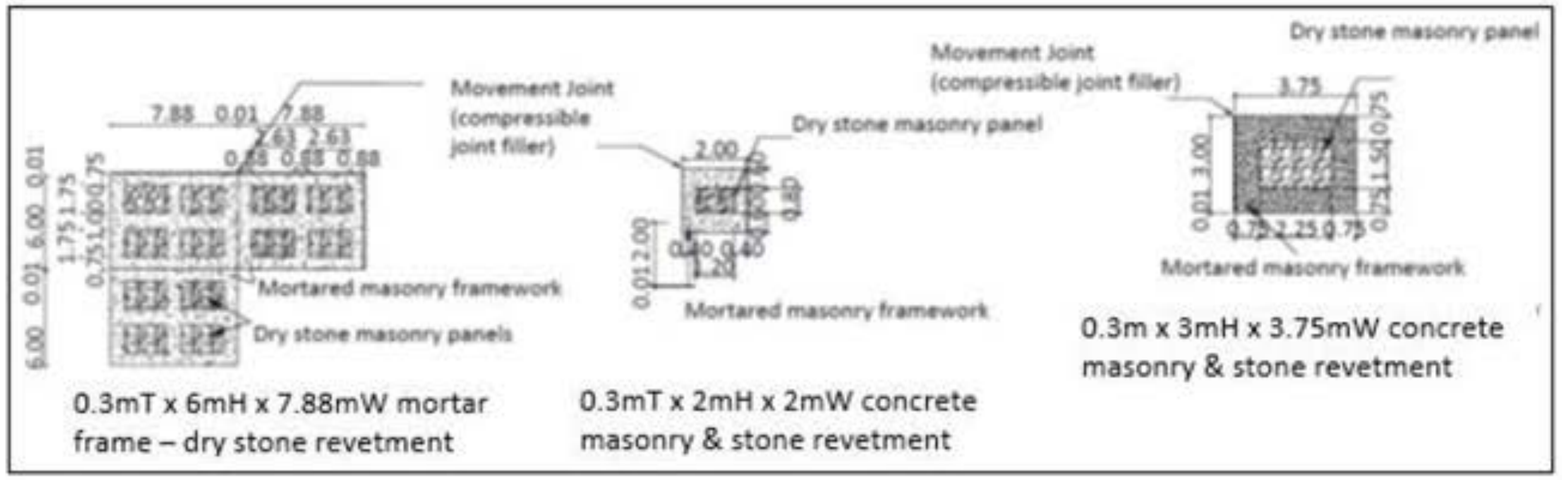
CONCRETE FRAME WITH STONE INFILL (2)

C1

Construction Procedure

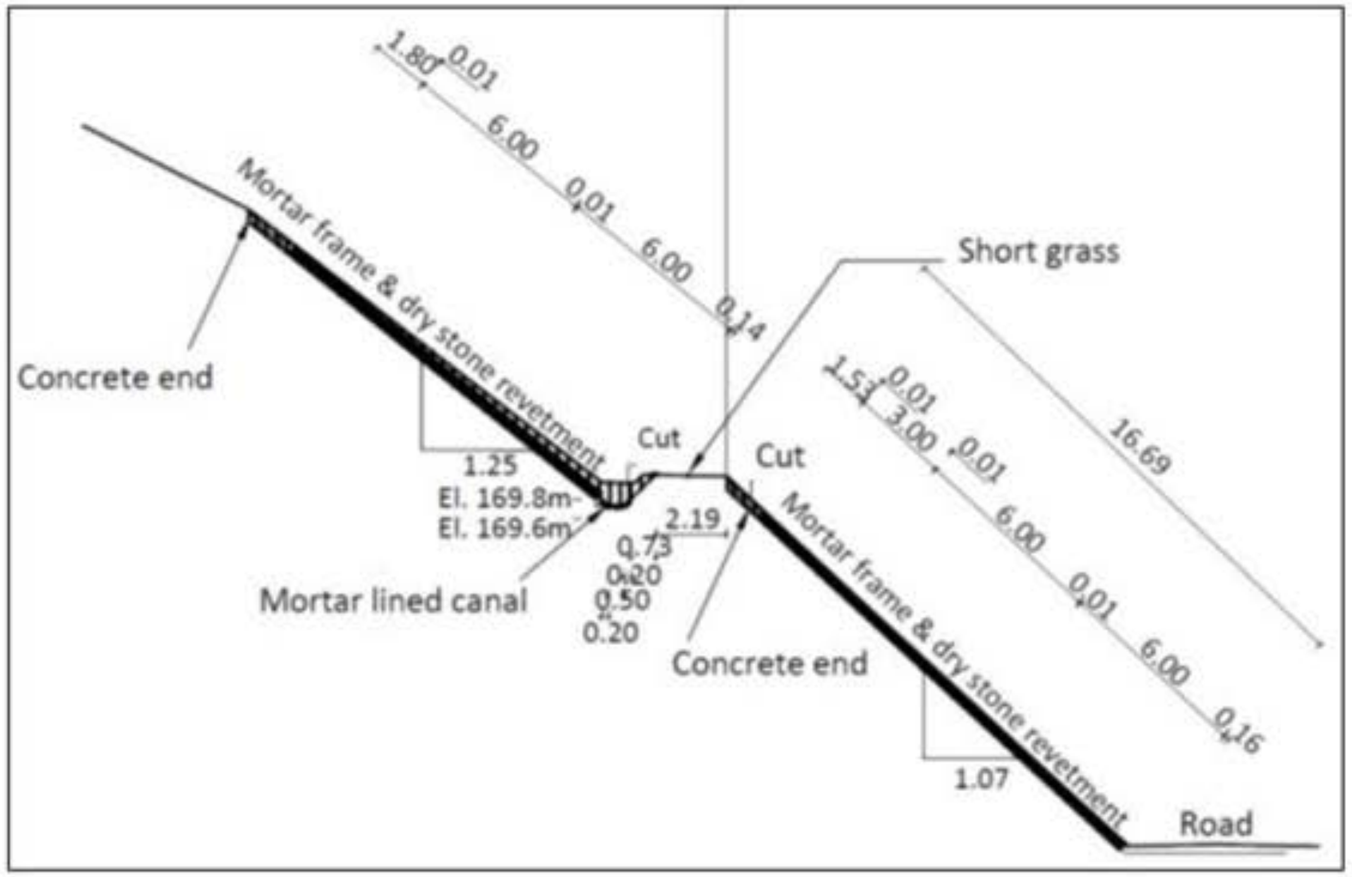
1. This procedure is for two layers of concrete framework, with dry stone infill in the panels. Construction must be done during the dry season.
2. Starting from the bottom, construct the mortared masonry framework (0.3 m thick x 6 m high x 7.88 m wide) with 4 rectangular open panels (1.75 m high x 2.63 m wide) delineated by formwork. This as per the left hand plan view in Fig. C.1.3.

Fig. C.1.3: Plan layout of the different framework dimension options.



3. Allow the frameworks to cure / harden for at least 2 to 3 days. Remove the open panel formworks after curing. Place 10 mm thick x 300 mm wide compressible joint filler (mat made of bamboo or locally available material) between each framework.
4. In the open rectangular panels, ensure that the foundation conditions are sound and firm. Then place the dry stone packing carefully, by hand, to form a tight arrangement. Fill the voids between stones with soil.
5. Construct the upper mortared masonry framework (0.3 m thick and one of 6 m high x 7.88 m wide, or 3 m high x 3.75 m wide, or 2 m high x 2 m wide) with rectangular open panels (dimensions depending on the framework size). This will be determined by the design. Fig. C.1.3 shows the dimensions in plan view.
6. Repeat steps 3 and 4 for the second lift.
7. If there are additional lifts, repeat the process again. Fig. C.1.4 shows the final slope.

Fig. C.1.4: Completed concrete and drystone framework slope protection, with dimensions.




Masonry framework with dry stone infill on cut slope at SP35 in Thai Nguyen Province


Dry stone infill used on cut slope at SP35 in Thai Nguyen Province


Masonry framework with dry stone infill on cut slope at SP35 in Thai Nguyen Province


Masonry framework with dry stone infill on cut slope at SP35 in Thai Nguyen Province

C.2 STONE-LINED DRAINS

STONE-LINED DRAINS (1)

C2

Site Preparation

a. The drainage channel line is prepared to the desired slope, length and width several days before construction. This will be based on a detailed survey and design drawings.

b. Debris and rocks are removed, depressions are filled in and humps are levelled off to attain a linear profile. See Fig. C.2.1.

c. Undertake additional excavation along the bed of the channel to create the foundation for the dry stone pitching. This excavation shall normally be 150 to 300 mm in depth. See Fig. C.2.2.

d. Stones or boulders with width (B) and thickness (C) ranging from 75 mm to 100 mm and length (A) ranging from 120 to 150 mm shall be procured or gathered and transported to the site. See Fig. C.2.3.

Fig. C.2.1: General site preparation for a stone-lined drain.

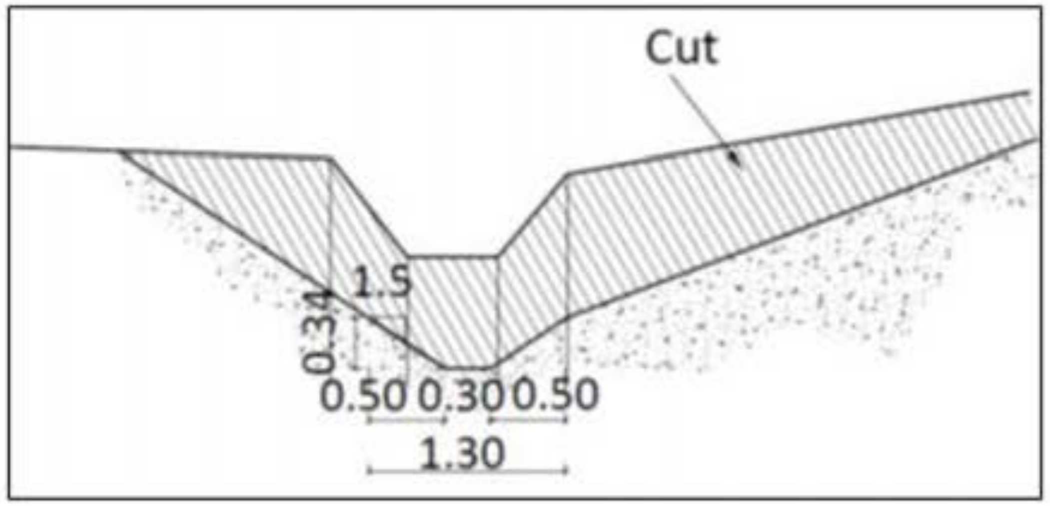


Fig. C.2.2: The additional excavation required for drain foundation development.

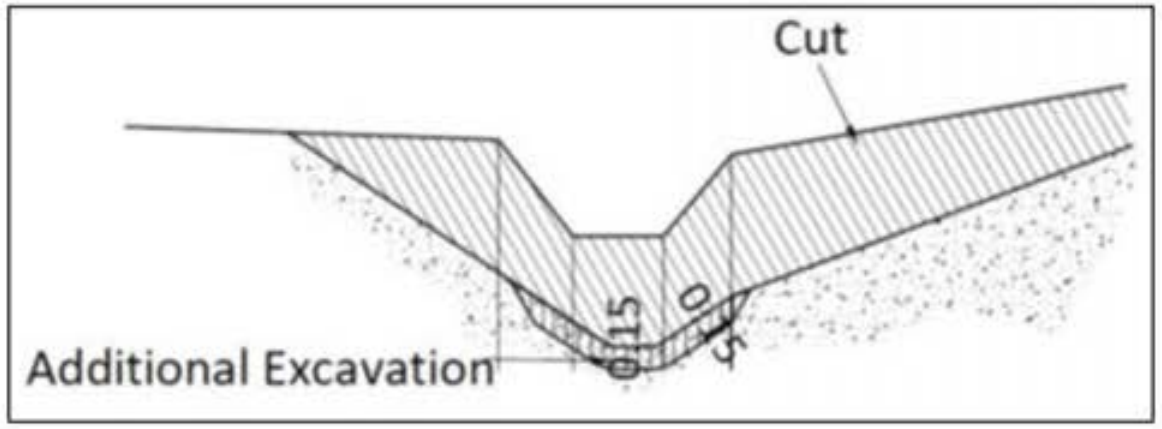
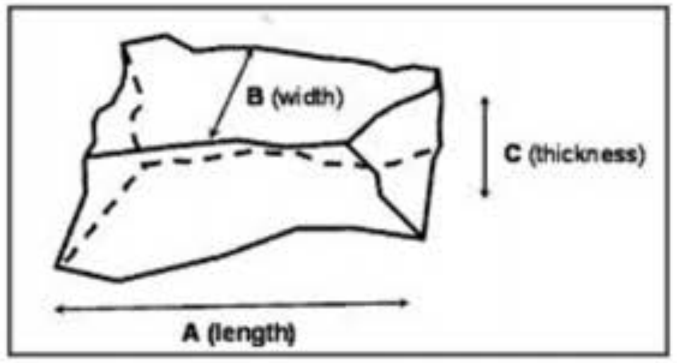


Fig. C.2.3: Rock dimensions (see text)



TA 8102-VIE: PROMOTING CLIMATE RESILIENT RURAL INFRASTRUCTURE IN NORTHERN VIETNAM				
SP35-THAI NGUYEN ROAD SLOPE PROTECTION WORKS				
LOCATION OF SITE IN LIEN MINH COMMUNE				
ICEM TAY HO, HA NOI, VIET NAM	DRAWING ID: AAS1206/T- 035 /V01	DESIGNER:	DAVID ROJAS JR.	
		DRAWER:	PHAN TIEN AN	
PHILKOEI INTERNATIONAL INC. PHILIPPINES (PKII)	SCALE:	CHECKED:	NGUYEN TRAN THUAT	
	DATE:	APPROVAL:	JAMES RAMSAY	

STONE-LINED DRAINS (2)

C2

Construction Procedure

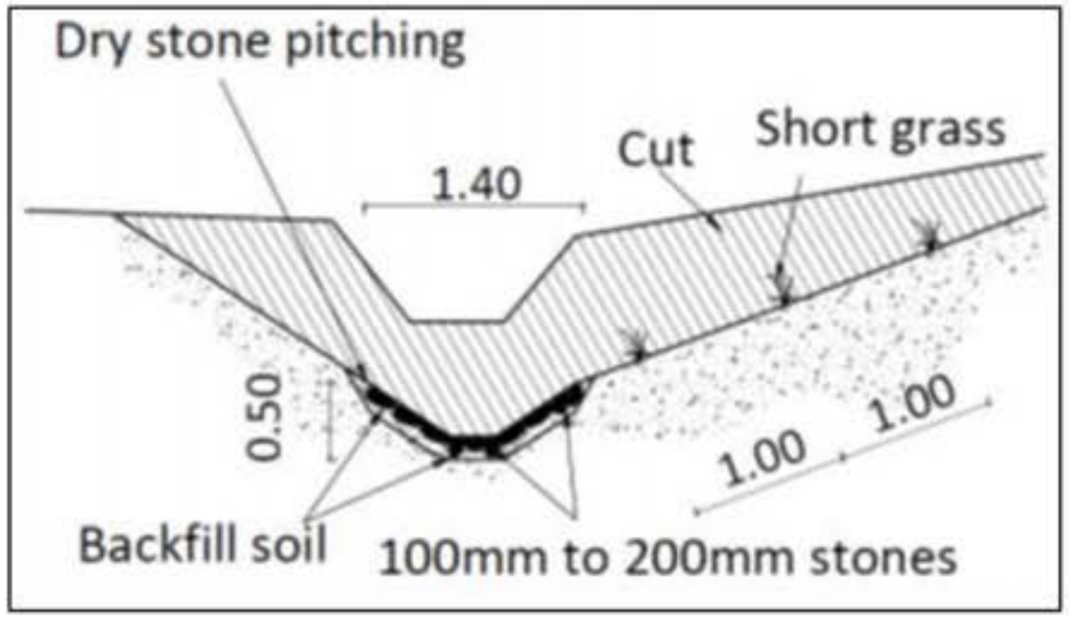
1. Backfill about 50 mm of soil in the foundation excavation and press firmly by foot or a flat wooden tamper.

2. Place the stone tightly on top of the backfilled soil. Each stone must be placed manually in such a manner that the stones are fitted firmly and a stable, compact mass is attained. Each one is pressed firmly by foot. The contractor must ensure that the stones are fitted firmly and a stable, compact mass is attained. The stones must be placed properly at all times during the construction.

3. The surface of stonework shall not vary from the average slope profile or the specified average channel invert by more than 30 mm.

4. Backfill the gaps between the stones with soil and again press firmly by foot or a flat wooden tamper until a relatively even surface is obtained in the channel. See Fig. C.2.4.

Fig. C.2.4: Installation of stone pitching to create a stone-lined drain



TA 8102-VIE: PROMOTING CLIMATE RESILIENT RURAL INFRASTRUCTURE IN NORTHERN VIETNAM				
SP35-THAI NGUYEN ROAD SLOPE PROTECTION WORKS				
LOCATION OF SITE IN LIEN MINH COMMUNE				
ICEM TAY HO, HA NOI, VIET NAM	DRAWING ID: AAS1206/T- 035 /V01	DESIGNER:	DAVID ROJAS JR.	
		DRAWER:	PHAN TIEN AN	
PHILKOEI INTERNATIONAL INC. PHILIPPINES (PKII)	SCALE:	CHECKED:	NGUYEN TRAN THUAT	
	DATE:	APPROVAL:	JAMES RAMSAY	


Dry stone pitching to drainage channel at the toe of fill slope at SP35 in Thai Nguyen Province


Dry stone pitching to drainage channel at the toe of fill slope at SP35 in Thai Nguyen Province


Dry stone pitching to drainage channel at the toe of fill slope at SP35 in Thai Nguyen Province


Dry stone pitching to drainage channel at the toe of fill slope at SP35 in Thai Nguyen Province

C.3 GABION CASCADES

GABION CASCADES (1)

C3

Site Preparation

a. Twenty-one (21) Thanh quan wooden poles of about 100 mm diameter (80 to 120 mm) and 1500 to 2000 mm long shall be gathered, bundled and transported to the site. The posts shall be tied together by twine or jute rope to form a bundle. See Fig. C.3.1.

b. The slope is prepared to the desired configuration at the start of construction. This will depend on the site-specific design, but normally for a gabion cascade there will be a series of steps down the course of the cascade.

c. The required volume of angular rocks for gabions shall be procured and brought to the site. The rocks shall have a median diameter D50 = 150 mm.

d. The required volume of sand and pebbles for filter layer shall be procured and brought to the site. The filter layer shall have a median diameter D50 = 30 mm and a thickness of 200 mm.

e. The gabion rocks and the granular filter material shall have grain size distribution according to Table C.3.

f. Gabion baskets (Macafferi or equivalent quality) of the specified size and additional binding wire are procured, delivered and assembled at the site. Step-by-step procedures for the assembly of gabion baskets are provided by suppliers. A typical unassembled and assembled gabion basket is shown in Fig. C.3.2.

Fig. C.3.1: Wooden post dimensions for reinforcing gabion foundations

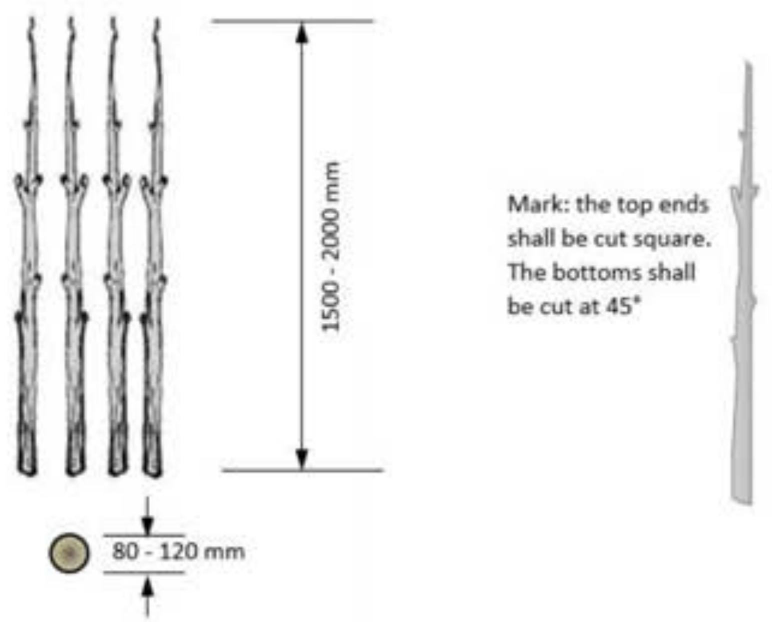
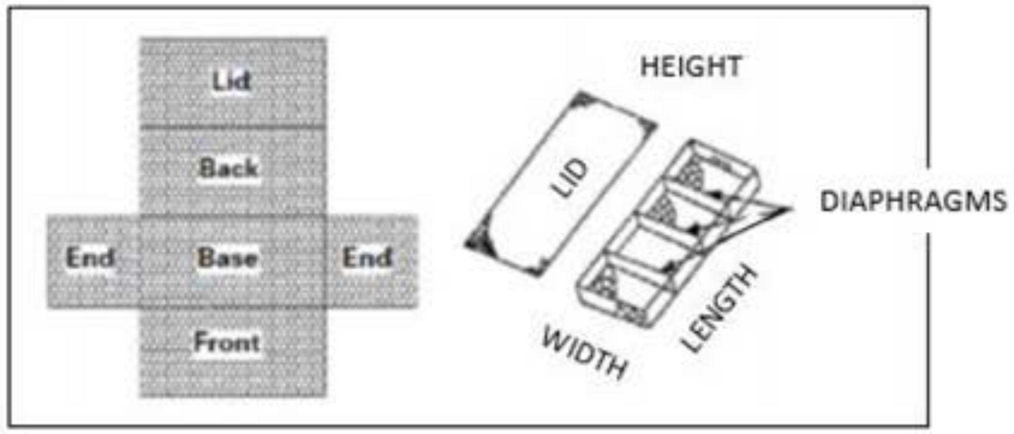


Table C.3: Size distribution requirements for gabion rock and filter materials

% PASSING	Rock	Granular Filter
100%	300	70.00
85%	230	55.00
75%	200	50.00
60%	180	35.00
50%	150	30.00
30%	140	20.00
15%	120	12.00
10%	100	5.00

median diameter

Fig. C.3.2: Gabion basket layout



TA 8102-VIE: PROMOTING CLIMATE RESILIENT RURAL INFRASTRUCTURE IN NORTHERN VIETNAM

SP35-THAI NGUYEN ROAD SLOPE PROTECTION WORKS

LOCATION OF SITE IN LIEN MINH COMMUNE

ICEM TAY HO, HA NOI, VIET NAM	DRAWING ID: AAS1206/T- 036 /V01	DESIGNER:	DAVID ROJAS JR.
		DRAWER:	PHAN TIEN AN
PHILKOEI INTERNATIONAL INC, PHILIPPINES (PKII)	SCALE:	CHECKED:	NGUYEN TRAN THUAT
	DATE:	APPROVAL:	JAMES RAMSAY

GABION CASCADES (2)

C3

Construction Procedure

1. Excavate the holes for the wooden pole supports and place the wooden poles. Backfill the space in the holes.
2. Place the filter layer (at least 200mm thick) on the bottom step of the cascade as indicated in the design. The grain size distribution of the layer shall be as indicated in Table C.3.
3. After the filter layer has been placed, the gabion mattresses are laid out on top of it. The mattresses are fixed in place using 1-metre metal stakes (at the four corners and three to five stakes in the middle portion). Adjacent gabion baskets are laced (i.e, bound securely using wire) together properly and securely.

Fig. C.3.3: Filling a gabion basket and lacing on the lid

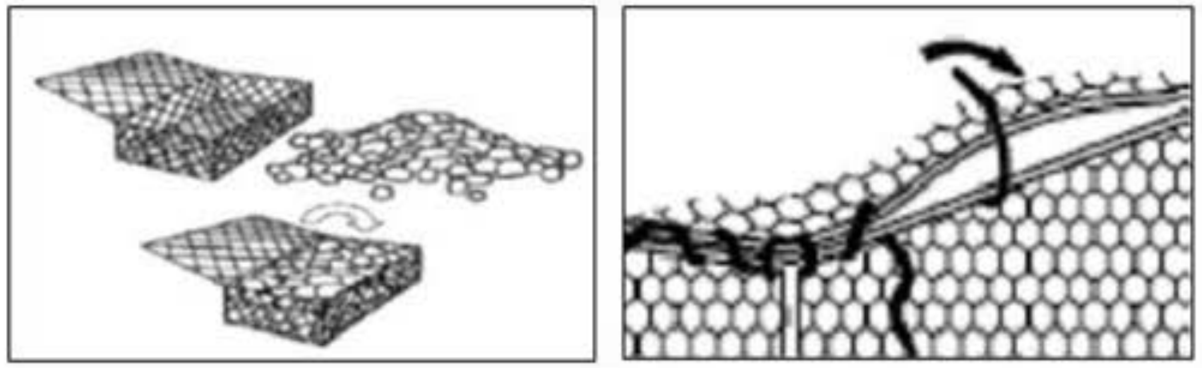
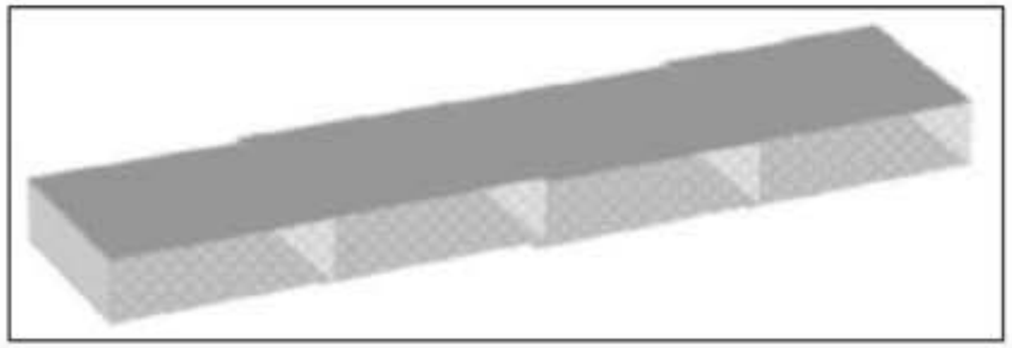
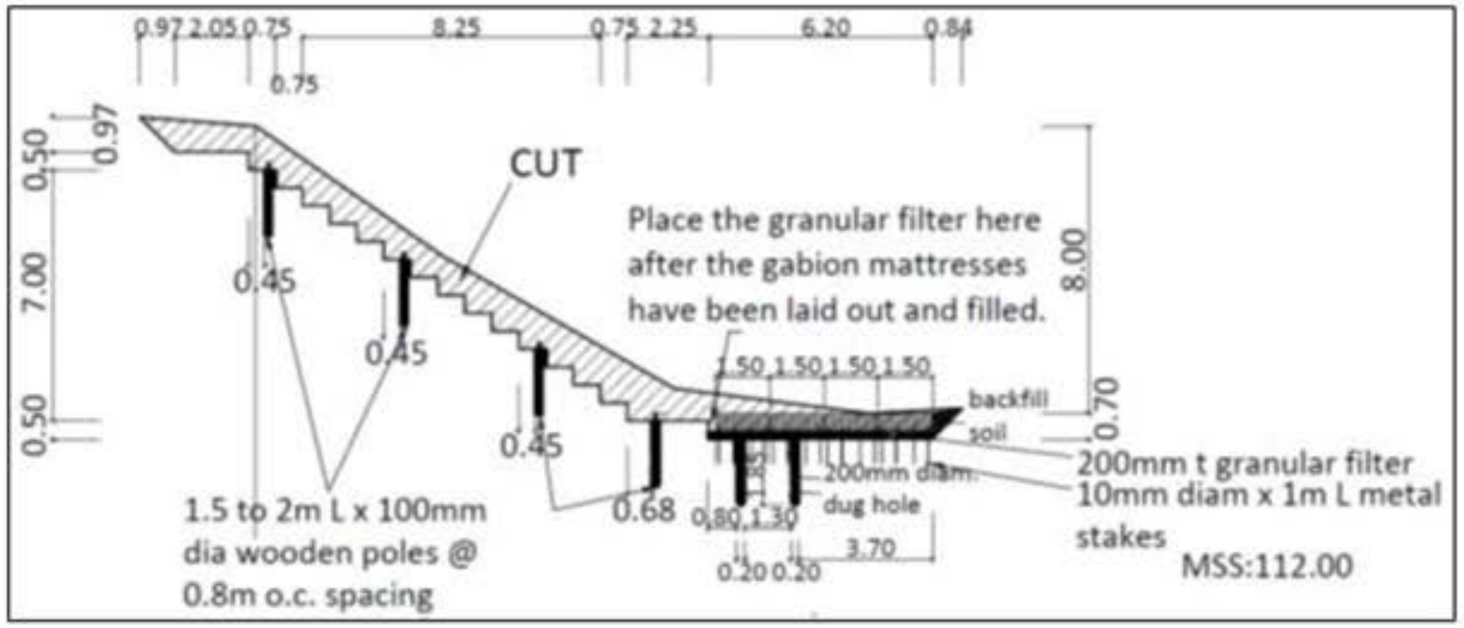


Fig. C.3.4: Layout of a completed gabion mattress (isomorphic view)



4. The gabion mattresses are filled with rock manually in such a manner that the stones are fitted firmly and a stable, compact mass is attained. The contractor must see to it that the stones are placed properly at all times during the construction and the baskets must not bulge or move out of position. Once the mattress baskets are filled, the lid is placed on top and laced properly on the four sides. This process is shown in Fig. C.3.3. The layout of a completed gabion mattress is shown in Fig. C.3.4. Fig. C.3.5 shows the whole site layout with the work completed up to this point.

Fig. C.3.5: The first stages of construction completed: the posts have been inserted to reinforce the foundations; and the mattress at the bottom has been installed



GABION CASCADES (3)

C3

Construction Procedure (continued)

5. The filter layer at the back slope is then placed and the slope backfilled up to the level of the top of the first gabion.

6. The baskets for the next layer of gabions are then placed on top of the first, offset backwards into the slope by 750 mm (or as determined by the design). The baskets are laced securely to the baskets below, along all connecting edges.

7. The baskets are then filled with rocks up to 1/2 height and stiffeners are placed at the two opposite longer edges of each basket to support the sides and prevent bulging. Filling of the baskets is completed and the lid laced down on top.

8. The same procedure is continued, following steps 5 and 6 until the top of the cascade is reached. Fig. C.3.6 shows the layout of the site at this point.

9. At both sides of the gabion cascade, a 300 mm thick and 300 mm high rock mortar sidewall shall then be constructed. See Fig. C.3.7.

Fig. C.3.6: Further stages of construction completed: the gabions have been installed all the way up the cascade

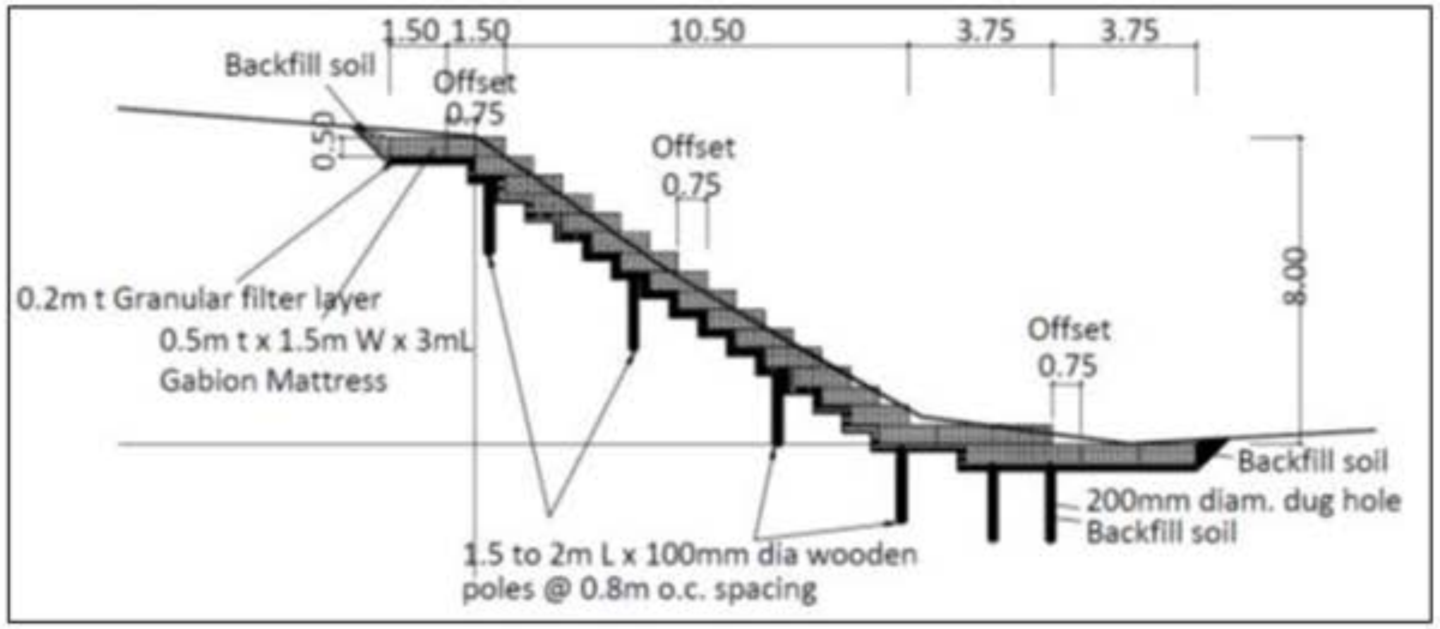
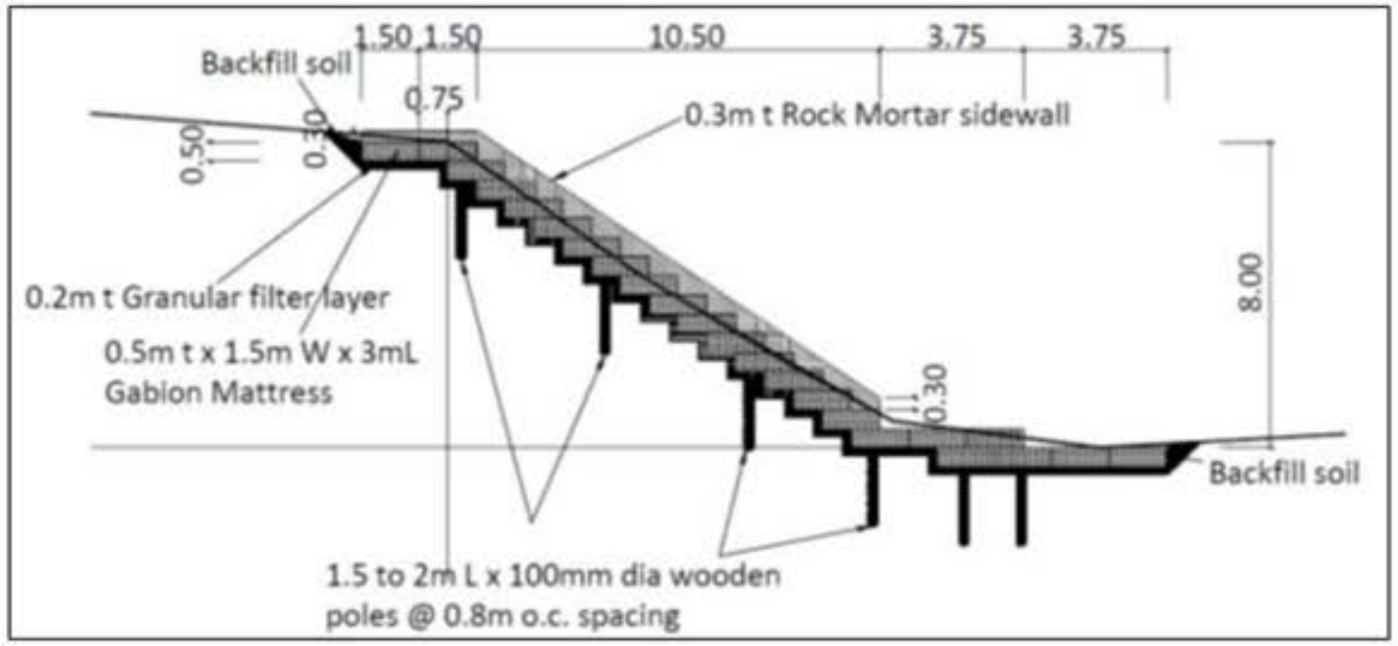


Fig. C.3.7: The final stages of construction completed: the sidewall has been completed along the sides of the cascade




Constructing gabion cascade on cut slope at SP31 in Son La Province


Constructing gabion cascade on cut slope at SP31 in Son La Province


Gabion cascade on cut slope at SP31 in Son La Province


Gabion cascade on fill slope at SP35 in Thai Nguyen Province

8 DETAILED RESULTS FROM THE DEMONSTRATION SITES

This section gives a series of tables that record the main results from the project's five demonstration sites in three provinces of northern Viet Nam. These show the species used (Table 4), the methods used (Table 5), the collated cost rates compared between the five sites (Table 6), and the detailed works and rates for four of the demonstration sites (Tables 7 to 10).

Table 4: List of plants used in bioengineering and mixed techniques

Plant	Scientific name	Bac Kan (Riverbank)	Thai Nguyen (Cut slope)	Thai Nguyen (Embankment)	Son La (Riverbank)	Son La (Cut slope)
Vetiver grass	*Vetiveria zizanioides*	√	√	√	√	√
Willow-leaved water croton	*Homonoia riparia*	√			√	
Weeping fig	*Ficus benjamina*	√				
Tiger grass	*Thysanolaena latifolia*		√			
Golden dewdrop	*Duranta erecta*		√	√		
Blanket grass	*Axonopus compressus*		√	√		√
Indian willow	*Salix tetrasperma*			√	√	
Randia tomentosa	*Randia tomentosa*		√			√

Table 5: Demonstrated bioengineering and engineering techniques

Ref.	Option	Bac Kan (Riverbank)	Thai Nguyen (Cut slope)	Thai Nguyen (Fill slope)	Son La (Riverbank)	Son La (Cut slope)
A.1	Large grass planting	√	√	√	√	√
A.2	Short cover grass planting			√		√
A.3	Grass seed + mulch + mesh		√			
A.4	Brush layers	√	√	√	√	
A.5	Palisades		√			√
A.6	Live fences	√		√	√	
A.7	Fascines	√		√		
A.8	Live poles and truncheons	√			√	√
A.9	Live check dams		√			
B.1	Vegetated rip rap	√				
B.2	Vegetated gabions				√	
B.3	Concrete frame + large grass		√			
C.1	Concrete frame + stone infill		√			
C.2	Stone-lined drains		√	√		√
C.3	Gabion cascades		√	√		√
C.4	Gabion mattresses				√	

Table 6: Collated results for labour inputs at four demonstration sites (labour unit: man-days)

Ref.	Item	Unit	SP4, Bac Kan			SP32, Son La			SP35, Thai Nguyen			SP31, Son La			Average labour requirement
			Riverbank			Riverbank			Roadside slope			Roadside slope			
			Quantity	Total labour	Labour / unit	Quantity	Total labour	Labour / unit	Quantity	Total labour	Labour / unit	Quantity	Total labour	Labour / unit	
	Improvement/repair of access road (about 1000 m)	Lump sum	1	105	105.00	1	270	270.00							187.50
	Temporary tents & storage (5% of other construction costs: 1 + 3a + 4 to 15)	Lump sum	1	70	70.00	1	103	103.00							86.50
	Site clearance including disposal	m^2	757	45	0.06	557	7	0.01				1	16	16.00	5.36
	Compensation for trees (official rate 1,950,000, doubled for contingency)	Lump sum	1	8	8.00	1	3	3.00							5.50
	Earthworks (Cut) for slope formation of medium soil including disposal locally or up to 1 km away	m^3	386	80	0.21	980	305	0.31							0.26
	Earthworks (Cut Slope) for slope formation / trimming	m^3 of cut							258.25	150	0.58	950.43	150	0.16	0.37
	Earthworks (Fill) for slope formation including compaction to K85	m^3	37	20	0.54	105	52	0.50							0.52
	Earthworks (Fill Slope) for slope formation / trimming	m^3 of fill							100.02	35	0.35	10.97	45	4.10	2.23
	Earthworks for slope surface preparation (trimming and making ready for planting and/or rock works)	m^2	757	20	0.03	855	10	0.01							0.02
	Disposal of debris and surplus materials locally or within 1 km including any fees	m^3	20	35	1.75	20	2	0.10	20	5	0.25	15	10	0.67	0.69
	Transportation of materials from road to site	m^3				631.5	825	1.31							1.31
A.1	Construction of Vetiver Grass Lines	m^2 of planted area as designed	80	9	0.11	29	7	0.24	298.71	90	0.30	281.78	75	0.27	0.23
A.2	Construction/planting of Short Grass	m^2 of planted area							615.58	110	0.18	144.39	30	0.21	0.19
A.3	Construction of wide-mesh Jute Net with grass seeding	m^2 of constructed area							324.31	200	0.62				0.62
A.4	Construction of Brush Layers	Linear m of terrace	170	15	0.09	50	13	0.26	207.41	60	0.29				0.21
A.5	Construction of Live Palisades	Linear m of planted row							75	60	0.80	189.32	60	0.32	0.56
A.6	Construction of Live Fences	Linear m of row	54	4	0.07	60	12	0.20	221.5	90	0.41				0.23
A.7	Construction of Fascines	Linear m of row	50	4	0.08				107.96	60	0.56				0.32
A.8a	Construction of Live Poles	Linear m of row	76	6	0.08	22	3	0.14							0.11

Ref.	Item	Unit	SP4, Bac Kan			SP32, Son La			SP35, Thai Nguyen			SP31, Son La			Average labour requirement
			Riverbank			Riverbank			Roadside slope			Roadside slope			
			Quantity	Total labour	Labour / unit	Quantity	Total labour	Labour / unit	Quantity	Total labour	Labour / unit	Quantity	Total labour	Labour / unit	
A.8b	Construction of Truncheon Cuttings	Linear m of row										79.33	30	0.38	0.38
A.9	Construction of Live Check Dam	Piece (1 constructed dam)							1	2	2.00				2.00
B.1a	Construction of Vegetated Riprap Type 1 (K0 – K5)	Linear m as designed	47	120	2.55										2.55
B.1b	Construction of Vegetated Riprap Type 2 (K8 – K10)	Linear m as designed	32	80	2.50										2.50
B.1c	Construction of Vegetated Riprap (C7 – C10)	Linear m as designed				31.5	87	2.76							2.76
B.2	Construction of Vegetated Gabions (C5-C7 & C12-C13)	Linear m as designed				13.5	16	1.19							1.19
B.3	Construction of mortared masonry frame with grass planting	m^2 of constructed area							201	300	1.49				1.49
C.1	Construction of mortared masonry frame with dry stone revetment	m^2 of revetment							1,104.87	1,800	1.63				1.63
C.2a	Construction of dry stone pitching for drainage channel at base of fill slope (including earthworks for trimming)	linear m of channel							58.53	25	0.43				0.43
C.2b	Construction of mortared masonry-lined channel on cut slope (includes earthworks for trimming)	linear m of channel							106.69	100	0.94				0.94
C.2c	Construction of mortared masonry drains at roadside and 1st level (including earthworks for channel trimming)	linear m of channel										160.13	150	0.94	0.94
C.3a	Construction of gabion cascade	m^3 of gabion cascade							23.29	100	4.29	25.6	36	1.41	2.85
C.3b	Construction of Gabion (1st layer, C2-C7 & C10-C13)	Linear m as designed				80	172	2.15							2.15
C.3c	Construction of mortared rock side wall for gabion cascade	m^3 of stone side wall							16.2	50	3.09	2.19	45	20.55	11.82
C.3d	Construction of additional steps to existing cascade	m^3 of masonry							5	20	4.00				4.00
C.4	Construction of Gabion Mattress (C2-C7 & C10-C13)	Linear m as designed				80	343	4.29							4.29
	Construction of Toe Riprap (K0, K6, K7)	Linear m as designed	25	52	2.08										2.08
	Construction of concrete slope revetment at slope toe (including earthworks for slope trimming)	m^2 of revetment										79.78	130	1.63	1.63

Table 7: Summary of detailed labour inputs at riverbank protection demonstration site SP4, Bac Kan Province

Item No.	Item	Unit	Quantity	Total labour (man-days)
Conventional Civil Works Items				
1	Improvement/repair of access road (about 1000 m)	Lump sum	1	105
2	Temporary tents & storage (5% of other construction costs: 1 + 3a + 4 to 15)	Lump sum	1	70
3a	Site clearance including disposal	m^2	757	45
3b	Compensation for trees (official rate 1,950,000, doubled for contingency)	Lump sum	1	8
4	Earthworks (Cut) for slope formation of medium soil including disposal locally or up to 1 km away	m^3	386	80
5	Earthworks (Fill) for slope formation including compaction to K85	m^3	37	20
6	Earthworks for slope surface preparation (trimming and making rady for planting and/or rock works)	m^2	757	20
7	Disposal of debris and surplus materials locally or within 1 km including any fees	m^3	20	35
Physical Measures				
8	Construction of Toe Riprap (K0, K6, K7)	Linear m as designed	25	52
Bioengineering Measures				
9	Construction of Brush Layers	Linear m of terrace	170	15
10	Construction of Live Poles	Linear m of row	76	6
11	Construction of Live Fences	Linear m of row	54	4
12	Construction of Fascines	Linear m of row	50	4
13	Construction of Vetiver Grass Lines	m^2 of planted area as designed	80	9
14	Construction of Vegetated Riprap Type 1 (K0 – K5)	Linear m as designed	47	120
15	Construction of Vegetated Riprap Type 2 (K8 – K10)	Linear m as designed	32	80

Table 8: Summary of detailed labour inputs at riverbank protection demonstration site SP32, Son La Province

Item No.	Item	Unit	Quantity	Total labour (man-days)
Conventional Civil Works Items				
1	Improvement/repair of access road (about 1000 m)	Lump sum	1	270
2	Temporary tents & storage (5% of other construction costs: 1 + 3a + 4 to 16)	Lump sum	1	103
3a	Site clearance including disposal	m^2	557	7
3b	Compensation for trees (official rate 5,020,400, doubled for contingency) & disturbance to land	Lump sum	1	3
4	Earthworks (Cut) for slope formation of medium soil including disposal locally or up to 1 km away	m^3	980	305
5	Earthworks (Fill) for slope formation including compaction to K85	m^3	105	52
6	Earthworks for slope surface preparation (trimming and making ready for planting and/or rock works)	m^2	855	10
7	Disposal of debris and surplus materials locally or within 1 km including any fees	m^3	20	2
8	Transportation of materials from road to site	m^3	631.5	825
Physical Measures				
9	Construction of Gabion Mattress (C2-C7 & C10-C13)	Linear m as designed	80	343
10	Construction of Gabion (1st layer, C2-C7 & C10-C13)	Linear m as designed	80	172
Bioengineering Measures				
11	Construction of Brush Layers	Linear m of terrace	50	13
12	Construction of Live Poles	Linear m of row	22	3
13	Construction of Live Fences	Linear m of row	60	12
14	Construction of Vetiver Grass Lines	m^2 of planted area as designed	29	7
15	Construction of Vegetated Riprap (C7 – C10)	Linear m as designed	31.5	87
16	Construction of Vegetated Gabions (C5-C7 & C12-C13)	Linear m as designed	13.5	16

Table 9: Summary of detailed labour inputs at roadside slope protection demonstration site SP35, Thai Nguyen Province

Item No.	Item	Unit	Quantity	Total labour (man-days)
Conventional Civil Works Items				
1	Earthworks (Cut Slope) for slope formation / trimming	m^3 of cut	258.25	150
2	Earthworks (Fill Slope) for slope formation / trimming	m^3 of fill	100.02	35
3	Construction of additional steps to existing cascade	m^3 of masonry	5.00	20
4	Construction of mortared masonry frame with dry stone revetment	m^2 of revetment	1,104.87	1,800
5	Construction of dry stone pitching for drainage channel at base of fill slope (including earthworks for trimming)	linear m of channel	58.53	25
6	Construction of mortared masonry-lined channel on cut slope (includes earthworks for trimming)	linear m of channel	106.69	100
7	Construction of gabion cascade	m^3 of gabion cascade	23.29	100
8	Construction of mortared rock side wall for gabion cascade	m^3 of stone side wall	16.20	50
9	Clearance of debris and surplus material from site	m^3 of waste	20.00	5
Bioengineering Measures				
10	Construction of Brush Layers	linear m of planted terrace	207.41	60
11	Construction of Live Palisades	linear m of planted row	75.00	60
12	Construction of Live Fences	linear m of planted row	221.50	90
13	Construction of Live Fascines	linear m of planted row	107.96	60
14	Construction/planting of Vetiver Grass Lines	m^2 of planted area as designed	298.71	90
15	Construction/planting of Short Grass	m^2 of planted area	615.58	110
16	Construction of mortared masonry frame with grass planting	m^2 of constructed area	201.00	300
17	Construction of wide-mesh Jute Net with grass seeding	m^2 of constructed area	324.31	200
18	Construction of Live Check Dam	Piece (1 constructed dam)	1	2

Table 10: Summary of detailed labour inputs at roadside slope protection demonstration site SP31, Son La Province

Item No.	Item	Unit	Quantity	Total labour (man-days)
Conventional Civil Works Items				
1	Site clearance	Lump sum	1	16
2	Earthworks (Cut Slope) for slope formation / trimming	m^3 of cut	950.43	150
3	Earthworks (Fill Slope) for slope formation / trimming	m^3 of fill	10.97	45
4	Construction of mortared masonry drains at roadside and 1st level (including earthworks for channel trimming)	linear m of channel	160.13	150
5	Construction of concrete slope revetment at slope toe (including earthworks for slope trimming)	m^2 of revetment	79.78	130
6	Construction of gabion cascade (including supplying bundles of live cuttings)	m^3 of gabion cascade	25.60	36
7	Construction of mortared rock side wall for gabion cascade	m^3 of stone side wall	2.19	45
8	Clearance of debris and surplus material from site	m^3 of waste	15.00	10
Bioengineering Measures				
9	Construction/planting of Live Palisades	linear m of planted row	189.32	60
10	Construction/planting of Truncheon Cuttings	linear m of planted row	79.33	30
11	Construction/planting of Vetiver Grass Lines	m^2 of planted area as designed	281.78	75
12	Construction/planting of local Short Grass	m^2 of planted area	144.39	30

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