SITE IMPROVEMENT CATALOGUE
# Introduction

# Health and Safety

# Drainage

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# Access

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# Slope Stabilization

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Objective:

This catalogue has been produced to assist site improvement actors in the following ways:
1. To avoid injuries or casualties on site
2. To follow good construction practice and avoid common errors
3. To make informed decisions as to what interventions are appropriate and cost effective
4. To ensure consistency with other SI actors across all camps

The guidance contained in this catalogue is applicable in all camps in Cox Bazaar district, including Teknaf camps.

Important Note:

The sketches/designs in this catalogue are for guidance purposes only; they are not a substitute for engineering design. All site improvement works should be designed and overseen by a qualified engineer.

Site Improvement or Site Development?

**Site Improvement**: Small scale, low tech works implemented using casual labour, typically consisting of secondary and tertiary pedestrian access and drainage and low-risk slope stabilization.

**Site Development**: Technically complicated, large scale or high risk works, often involving machinery, such as vehicle roads or concrete retaining walls. Site Development works are generally implemented directly by IOM or SMEP or by UNHCR, WFP or LGED through contractors (not NGO partners). All Site Development works require full engineering design, to be submitted to the relevant Site Management Area Coordinator (i.e. IOM or UNHCR) for approval.

This catalogue is provided for Site Improvement works only. Agencies planning to implement Site Development works should coordinate with IOM/UNHCR (as appropriate), who can provide technical assistance.
Supervision, Risk Assessments and Safety Inductions:

- All works should be supervised by a technically qualified construction worker.
- Each site to be overseen by a trusted foreman who knows the safety procedure and has received basic First Aid training and has access to a First Aid kit.
- At high risk sites (e.g. where there are machines, deep or fast flowing water, deep excavations or large soil retention activities), conduct a Risk Assessment and allocate a dedicated Safety Warden to monitor the site safety and ensure no public access.
- Provide a safety induction tailored to the activity for all labourers, especially when working alongside machines. Explain how to use new tools & machines such as a generator or drilling tool.

Protective Equipment:

- All workers should wear hi-visibility vests.
- Use appropriate Personal Protective Equipment suitable for the construction activity (i.e. gloves, goggles) or weather conditions.
- As far as possible, encourage all labourers to wear closed shoes (not sandals); Rain boots should be worn while working in wet areas.
- Use a mask, gloves and boots for clearing drains.

Supervision, Risk Assessments and Safety Inductions:

- Avoid overcrowding sites. Only hire as many labourers as required for the task, and provide sufficient space for them to work.
- Maintain tidy sites: Scattered materials and tools lying around present trip hazards.
- Prevent the public and (and especially children) from entering the construction area using tape and/or warning signs as appropriate.
- Discuss access and safety issues with the local community prior to starting work.
- Never leave deep excavations uncovered overnight.
- Provide shade and drinking water for labourers.
- Maintain clear separation of activities and access areas when working alongside machines.
- In the case of soil instability, a qualified technical person should verify the site safety. Sides of excavations where volunteers / workers are exposed to danger from moving ground should be made safe by sloping, shoring or other effective means.
- Deep water:
  - Fence off from public.
  - Provide rescue rope.
  - Safety Induction.
<table>
<thead>
<tr>
<th>High Risk Tools / Materials</th>
<th>Risks</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Excavation</strong></td>
<td>Spade, shovel, hoe, pick, etc.</td>
<td>Cuts &amp; impact injuries</td>
</tr>
<tr>
<td><strong>Deep Excavations</strong></td>
<td>Latrine pits &amp; similar</td>
<td>Falling &amp; drowning</td>
</tr>
<tr>
<td><strong>Portering</strong></td>
<td>Bag, Bucket, Wheelbarrow</td>
<td>Back injuries</td>
</tr>
<tr>
<td><strong>Unloading</strong></td>
<td>Heavy materials</td>
<td>Impact injuries from falling materials</td>
</tr>
<tr>
<td><strong>Sandbag Works</strong></td>
<td>None</td>
<td>Back injuries</td>
</tr>
<tr>
<td><strong>Bamboo Works</strong></td>
<td>Machete, saw, drill</td>
<td>Cuts</td>
</tr>
<tr>
<td><strong>Unstable structures</strong></td>
<td>Falling bamboo</td>
<td></td>
</tr>
<tr>
<td><strong>Brick Works</strong></td>
<td>None</td>
<td>Dropping bricks on feet</td>
</tr>
<tr>
<td><strong>Concrete Works</strong></td>
<td>Wet concrete</td>
<td>Alkali burns</td>
</tr>
<tr>
<td><strong>Reinforcement Works</strong></td>
<td>Tie wire &amp; sharp edges</td>
<td>Cuts &amp; scratches</td>
</tr>
<tr>
<td><strong>All Public Works</strong></td>
<td>None</td>
<td>Risks to public</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>High Risk Tools / Materials</th>
<th>Risks</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Working at Heights</strong></td>
<td>Ladders</td>
<td>Falling</td>
</tr>
<tr>
<td><strong>Grinding Works</strong></td>
<td>Hand grinder</td>
<td>Cuts</td>
</tr>
<tr>
<td><strong>Working on Slopes</strong></td>
<td>Loose fill</td>
<td>Tripping/ Falling&lt;br&gt;Ankle sprains&lt;br&gt;Landslides</td>
</tr>
<tr>
<td><strong>Working in High Temperatures</strong></td>
<td>None</td>
<td>Sun stroke &amp; dehydration</td>
</tr>
<tr>
<td><strong>Working Alongside Machines</strong></td>
<td>Excavators, bulldozers, etc.</td>
<td>Running over feet, crushing against walls, etc.</td>
</tr>
<tr>
<td><strong>Working Close to Water</strong></td>
<td>Unseen hazards</td>
<td>Slips and falls</td>
</tr>
<tr>
<td><strong>Clearing Drains</strong></td>
<td>Dirty water</td>
<td>Slips&lt;br&gt;Cuts from hidden objects</td>
</tr>
<tr>
<td><strong>Waste Management</strong></td>
<td>None</td>
<td>Cuts</td>
</tr>
</tbody>
</table>

*refer to Protection Sector guidance on portering
Guiding principles for stormwater management in the camps:

1. **Slow down the flow of water and promote infiltration in the less densely populated upstream half of the catchment area** to reduce flooding in congested downstream areas
   - Only use impermeable canal lining (brick, concrete, tarpaulin, etc.) where necessary, such as for high velocity flows or down steep slopes
   - Maintain a gentle slope in all drains by following contour lines as far as possible
   - Use check dams or steps on steep drains
   - Use silt traps to promote infiltration and prevent downstream drains & culverts from blocking.
   - Store water upstream using retention basins or ponds
   - Allow unpopulated valley floors to flood, in order to reduce peak flows downstream

2. **Prevent surface erosion** to prevent silt washing off exposed slopes and blocking drains downstream
   - Plant grasses on exposed slopes to protect the surface
   - Use jute or geotextile roll to protect exposed soil if there is no time for grass to grow before monsoon
   - Use catch/ridgeline drains connected to discharge drains to prevent water flowing over the hill face

3. **Use robust brick & concrete drainage in densely populated areas on steep slopes.**
   - Brick/concrete drains are easy to clean and provide maximum capacity in congested areas
   - Robust drains prevent scouring and erosion
   - Brick/concrete drains are prone to brittle failure and are difficult to repair

4. **Promote durable solutions**
   - Use soft/flexible infrastructure (not brick and concrete, which cannot accommodate ground movement) where possible, e.g. in open valleys
   - Plant vegetation along embankments to protect from erosion and prevent collapse

5. **Ensure networked drainage**
   - The drainage network must be considered as a whole, with connected drains from source to outlet
   - Drainage capacity should increase as you move downstream
Note: Kutapalong-Balukhali Expansion camps shown for illustration purposes only. Detailed flood risk maps for all camps (including Teknaf) are available from ISCG Natural Hazards Task Force.
FLOODING RISK MAP

**Camps 4, 4Ext, 17, 18, 20 & 20Ext:**
- **Low risk**
- Low population density
- Shelters on hills (not in flood plains)

Catchment area for major rivers:
- Reduce flow speed and promote infiltration & retention
- Use unlined drains & natural materials
- Follow natural river curves
- Use silt traps where possible, esp. at natural bottlenecks

**Camps 1-8:**
- **Medium risk**
- High population density
- Few shelters in flood plains
- Use natural materials in open valleys
- Use brick & concrete drains in congested areas

**Mudhuchara River (Camps 6, 7 & 8):**
- **HIGH RISK**
- Medium population density
- High flood level
- Fast flowing water

**Camps 9 & 10:**
- **HIGH RISK**
- High discomfort level
- High population density
- High water level & shelters in flood plains
- Slow moving water

**Camps 10 & 11 River:**
- **VERY HIGH RISK**
- High population density
- Low lying shelters & high flood level
- Fast flowing water

**Camps 11, 12 & 19:**
- **Medium risk**
- High population density
- Few shelters in flood plains

- Use natural materials in open valleys
- Use brick & concrete drains in congested areas
DRAINAGE: KEY PRINCIPLES

1. RETENTION
Slow down & retain water in the sparsely populated upstream half of the camp to reduce peak flows in the rivers downstream
Use natural drains (unlined / jute bag / bamboo) to allow infiltration
Follow natural river curves
Retain water using retention basins, ponds or silt traps
Allow community gardens to flood

2. SURFACE EROSION & SILTATION
Prevent surface erosion - Silt washing off exposed slopes creates blockages downstream
Protect slopes with terracing, jute roll &/or planting
Use catch/ridgeline drains
Silt traps
Build small silt traps along drains in open valleys

3. BRICK & CONCRETE DRAINS IN SHELTER AREAS, NATURAL DRAINS IN OPEN VALLEYS
Robust, easy to clean brick drains in high density shelter areas prevent erosion & reduce blockages
Natural drains in open valleys promote infiltration and slow down flow

4. BRICK & CC DRAINS IN LOW LYING CONGESTED AREAS
Remove water quickly to minimize duration of flooding
Easy to clean brick drains maximize capacity in congested areas
Clean drain & choke points frequently

5. OVERFLOW INTO PADDY FIELDS
Paddy fields can store excess water from rivers which prevent water from backing up into the camps
Allow drains to overflow into paddy fields

N.B. CiC & UNO to negotiate with land owners

Note: Kutapalong-Balukhali Expansion camps shown for illustration purposes only. Detailed flood risk maps for all camps (including Teknaf) are available from ISCG Natural Hazards Task Force
1. RETENTION

Camps 17, 18 & 20 (green) = approx. 30% of total catchment area (yellow)

Unpopulated valleys can be used as retention basins

Install slow-draining dams every 50-100 m

Slow drains with natural materials

Water floods community gardens during heavy rain
Max water height limited by height of weir

Drain behind shelter

Peak water level

Valley drain
2. SURFACE EROSION & DESILTING

Planted terraces slow down surface water & prevents erosion
Drains along ridgeline & terraces link to cascade drain

Slow-draining barriers across valley floor to slow down water & prevent silt from clogging downstream drains:

Geotextile wrapped around loose rubble (use brick in Bangladesh)

Jute fabric prevents surface erosion while pants are still growing

Straw bale silt fence
3. SECONDARY DRAINAGE:
Fast flowing brick & CC drains in low-lying congested areas to take water quickly out of the camp

4. PADDY FIELDS:
Excess water can safely be stored in paddy fields to prevent flooding in shelter areas
Allow water to overflow into the paddy fields by breaking down the river banks at the start of the monsoon

5. DOWNSTREAM RIVERS:
Dredge river downstream of camp and clear culverts below main road

3, 4 & 5. CONGESTED AREAS, PADDY FIELDS & DOWNSTREAM RIVERS
DRAINAGE: GUIDING PRINCIPLES

1. Slow water down
- Flooding downstream is caused by quick run-off upstream
- Maintain a gentle slope in all drains and avoid drains running straight down slopes if possible. Run drainage along contours to make sure that drainage has manageable gradients.
- Use check dams or steps on steep drains
- Store water upstream using using ponds or silt traps
- Promote infiltration

2. Prevent erosion
- Silt washes off exposed slopes and blocks drains downstream
- Plant grasses on exposed slopes to protect surface
- Use jute fabric to protect loose soils if there is no time for grass to grow before monsoon season
- Use catch/ridgeline drains to prevent water flowing down the hill face

3. Durable does not necessarily mean brick/concrete
- Grass planted drains or swales are durable, cheap, slow water down, and allow infiltration (reducing flow volume)
- Brick/concrete drains speed up water flow which can increase flooding downstream
- Brick/concrete drains in flat areas create stagnant water in the dry season
- Brick/concrete drains cannot accommodate ground movements or settlement

4. Dry season drainage & grey water
- Promote infiltration to avoid stagnant water
- Separate grey water (from bathing & laundry areas) from main drains
- Use infiltration drains for bathing & laundry spaces
- Plant in drains and along edges to clean water

5. Always consider the full network
- Do not design drainage components in isolation
- The solution may lie upstream
- Ensure your intervention does not cause problems downstream
1. Drainage levels

- Level 3 (tertiary): drains the household plots; connects to level 2
- Level 2 (secondary): drains water down the hill; connects the household drainage (L3) to the valley drainage (L1)
- Level 1 (primary): drains the water out of the secondary valleys; connects to primary valley drainage or river

2. Drainage positioning

- Level 3: around plot with main drain along the hill side; plan for 1% slope to maintain flow but minimize velocity; water from roofs should fall directly into the drainage, not onto the slope
- Level 2: follows topography as much as possible: along contours in open areas, or down ravines or alongside stairs in built-up areas; collects all level 3 drains on the way down; water needs to be slowed down (e.g. use steps or check dams); no borders above ground on the sides of the drains
- Level 1: follows the lowest line of the valley floor; collects all level 2 drains on the way out of the valley
DRAINAGE: CAPACITY ESTIMATION

1. Some typical figures (to be adapted to local context)
   - Rain intensity: 0.5 mm/min for short time intervals (up to 3 hours)
   - Surface area for level 3: 150 - 300 square meters (5-10 plots)
   - Surface area for level 2: few thousand square meters
   - Surface area for level 1: several acres (1-3 ha)

2. Minimum guiding values for drainage capacity (to be adapted to local context)
   - Level 3: 5-10 L/s; drain section of 1’ x 1’
   - Level 2: 40-80 L/s; drain section of 1.5’ x 1.5’
   - Level 1: 300-600 L/s; drain section of 4’ x 3’

3. Consider exceedances – what happens if the capacity is exceeded?
   - High impact/risk (e.g. culvert with housing upstream) – oversize component with a safety factor
   - Low impact (e.g. valley drain surrounded by community gardens) – no need to oversize

Source: ARUP Surface Water Management guide
1. Identify the topography and contours and flow paths (refer to p.17). Modelling software can produce this automatically from contour information, but it should be verified by a site walkover. Flow paths (direction of flow downhill) should be directed at 90° degrees from contours.
2. Identify existing natural and man-made drainage components and the catchments (black dashed line) and the sub catchments (orange dashed line).
3. Identify existing natural and man-made drainage components and the catchments.
4. Identify the drainage network (if all the water cannot be prevented or used at the source).
5. Identify hierarchy of the drains:
   - Tertiary (grey) – neighbourhood level
   - Secondary (black) – running past the site in to which the tertiary site drains discharge
   - Primary drain (blue) – a large drainage canal, stream or river in to which a secondary drain discharges.
DRAINAGE: SCENARIOS & OPTIONS

1. Household & Pathway
   a. Infiltration Drain
   b. Bamboo & Basha Bera
   c. Brick / Brick & CC

2. Catch / Ridgeline Drains
   a. Overview
   b. Precast Concrete

3. Cascade / Discharge Drains
   a. General
   b. Key Detail: Discharge Point

4. Stairways
   a. Brick / Brick & CC

5. Slow &/or Store
   a. Retention Basins
   b. Silt Traps

6. Secondary
   a. Congested: Brick & CC
   b. Open: Bamboo & Basha Bera
   c. Open: Jute Bag
   d. Perforated Precast Panels

7. Primary
<table>
<thead>
<tr>
<th>Category</th>
<th>Type / Material</th>
<th>Depth (ft)</th>
<th>Width (ft)</th>
<th>Materials BD T/m</th>
<th>Labour BD T/m</th>
<th>Porter cost</th>
<th>Total BD T/m</th>
<th>Durability</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household, Pathways &amp; Catch Drain</td>
<td>Bamboo &amp; basha bera</td>
<td>2</td>
<td>2</td>
<td>1100</td>
<td>300</td>
<td>Low</td>
<td>1400</td>
<td>Poor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5” Brick wall + 3” CC base</td>
<td>2</td>
<td>2</td>
<td>1200</td>
<td>1000</td>
<td>High</td>
<td>2200</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>Discharge</td>
<td>Jute bag with sand-cement</td>
<td>1.5</td>
<td>1.5</td>
<td>2200</td>
<td>200</td>
<td>High</td>
<td>2400</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Geotextile bag w. earth filling</td>
<td>1.5</td>
<td>1.5</td>
<td>1300</td>
<td>200</td>
<td>Low</td>
<td>1500</td>
<td>Good</td>
<td>Recommended</td>
</tr>
<tr>
<td></td>
<td>Brick &amp; CC</td>
<td>1.5</td>
<td>1.5</td>
<td>1000</td>
<td>1000</td>
<td>High</td>
<td>2000</td>
<td>Moderate</td>
<td>Recommended</td>
</tr>
<tr>
<td></td>
<td>Precast concrete</td>
<td>1.5</td>
<td>1.5</td>
<td>2000</td>
<td>1200</td>
<td>High</td>
<td>3200</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>Secondary</td>
<td>Bamboo</td>
<td>3</td>
<td>-</td>
<td>2300</td>
<td>400</td>
<td>Low</td>
<td>2700</td>
<td>Poor</td>
<td>Plant along edge and through walls</td>
</tr>
<tr>
<td></td>
<td>Jute bag &amp; earth filling</td>
<td>3</td>
<td>-</td>
<td>1300</td>
<td>400</td>
<td>Low</td>
<td>1700</td>
<td>Poor</td>
<td>Plant along banks</td>
</tr>
<tr>
<td></td>
<td>Jute bag with sand-cement</td>
<td>3</td>
<td>-</td>
<td>3900</td>
<td>500</td>
<td>High</td>
<td>4400</td>
<td>Moderate</td>
<td>Use geotextile instead</td>
</tr>
<tr>
<td></td>
<td>Geotextile bag &amp; earth filling</td>
<td>3</td>
<td>-</td>
<td>2000</td>
<td>400</td>
<td>Low</td>
<td>2400</td>
<td>Good</td>
<td>Plant along banks</td>
</tr>
<tr>
<td></td>
<td>10” Brick wall + 3” CC base</td>
<td>3</td>
<td>3</td>
<td>3000</td>
<td>1300</td>
<td>High</td>
<td>4300</td>
<td>Good</td>
<td>Use up to 5’ wide</td>
</tr>
<tr>
<td></td>
<td>10” Brick wall + 3” CC base</td>
<td>3</td>
<td>6</td>
<td>3800</td>
<td>1800</td>
<td>High</td>
<td>5000</td>
<td>Not economic over 5’ wide</td>
<td></td>
</tr>
<tr>
<td>Silt trap</td>
<td>Jute bag &amp; earth filling</td>
<td>3</td>
<td>20’x20’</td>
<td>16,000</td>
<td>4000</td>
<td>Low</td>
<td>20,000</td>
<td>Plant along banks</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10” x 4’ Brick wall w. earth base</td>
<td>3</td>
<td>20’x20’</td>
<td>40,000</td>
<td>5000</td>
<td>High</td>
<td>45,000</td>
<td>Not cost effective</td>
<td></td>
</tr>
</tbody>
</table>
1. HOUSEHOLD & PATHWAY

a) Infiltration Drain for Bathing Facilities

Grill over entrance to prevent drain blocking
Quick draining, granular backfill
Wrap pipe in geotextile to prevent silt from entering drain
Plastic pipe, perforated so that water can enter

<table>
<thead>
<tr>
<th>Description</th>
<th>Perforated plastic pipe in channel surrounded by coarse aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key detail</td>
<td>Wrap pipe in geotextile to prevent silting upCut/drill small holes in pipe to allow water to soak in and out</td>
</tr>
<tr>
<td>Scope of Use</td>
<td>Connect to bathing units to prevent grey water entering main drainsBest in sandy soils. Increase size of trench / soak pit in silty soils</td>
</tr>
<tr>
<td>Advantages</td>
<td>Durable, invisible Efficient use of space Good for processing grey water from water points and bathing units</td>
</tr>
<tr>
<td>Disadvantages</td>
<td>High cost Difficult/technical construction Not suitable in clay or non-absorptive soils</td>
</tr>
</tbody>
</table>

Option: Use soak pit instead (similar to a latrine pit but with porous walls and base)
b) Bamboo & basha bera drain

Borak bamboo cross-beams at 3-5’ spacing prevent walls from collapsing

Line drain walls with basha bera mats behind borak bamboo stakes

Borak bamboo stakes embedded 1.5’ into the ground. Slope walls out for H > 1’

Compacted earth base allows filtration

Option: Add cement screed or tarpaulin to improve water flow (but prevents infiltration ⇒ stagnant water in dry season)

<table>
<thead>
<tr>
<th>Description</th>
<th>Bamboo and tarpaulin household-level drain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key detail</td>
<td>Compacted earth base</td>
</tr>
<tr>
<td></td>
<td>Side walls are permeable</td>
</tr>
<tr>
<td></td>
<td>Include check dams in steep areas</td>
</tr>
<tr>
<td>Scope of Use</td>
<td>Alongside minor pathways and ridgelines</td>
</tr>
<tr>
<td>Advantages</td>
<td>Simple to build &amp; repair</td>
</tr>
<tr>
<td></td>
<td>Efficient use of space with pathway above</td>
</tr>
<tr>
<td>Disadvantages</td>
<td>Needs to be replaced frequently</td>
</tr>
<tr>
<td></td>
<td>Difficult to clean</td>
</tr>
</tbody>
</table>

Option: Borak bamboo walkway above drain (N.B. use borak in cross direction) Efficient use of space but increased cost
c) Masonry, small capacity

**Option 1: Concrete base**
- Jute/geo bag filled with brick chips behind weep hole
- 3-4” min concrete base
- Compacted sub-base
- Brick wall is lower than surrounding ground
- Max. 2’ for single layer brick wall

**Option 2: Brick base**
- Single leaf brick wall
- 1” cement screed
- Brick base
- Compacted sub-base

<table>
<thead>
<tr>
<th>Description</th>
<th>Small brick &amp; cc drain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key detail</td>
<td>Install weep holes if wall is above 2’</td>
</tr>
<tr>
<td></td>
<td>Drain edge is lower than surrounding ground (so water can flow in)</td>
</tr>
<tr>
<td>Scope of Use</td>
<td>Small drains alongside tertiary roads/pathways/stairways in congested areas</td>
</tr>
<tr>
<td>Advantages</td>
<td>Durable</td>
</tr>
<tr>
<td></td>
<td>Simple to build &amp; repair</td>
</tr>
<tr>
<td></td>
<td>Good in congested areas</td>
</tr>
<tr>
<td>Disadvantages</td>
<td>High cost</td>
</tr>
<tr>
<td></td>
<td>No infiltration &amp; high flow velocity</td>
</tr>
<tr>
<td></td>
<td>• Increased risk of flooding downstream</td>
</tr>
<tr>
<td></td>
<td>• Use baffles to slow water on steep drains</td>
</tr>
</tbody>
</table>

Small drain alongside brick road. Note that water can flow off pathway into drain.
2. CATCH DRAIN / RIDGELINE DRAIN

a) Overview

A catch drain along edge of hilltop to prevent water running down hill-face. Connect to cascade drain at low point.

Plant along ridgeline and protect exposed soil with planting & jute roll or terracing – see Stabilization.

- **Description**: Drain along ridgeline to prevent water running over ridge and down hill-face.
- **Key detail**: Connect to discharge drains at low-points (look for natural ravines)
  - Plant along ridgeline
  - Drain can be any material (e.g. jute bag, bamboo, brick, etc.)
- **Scope of Use**: Along the edge of hilltops or terraces to prevent water flowing down hill-face
  - Connect to discharge drain

Drone image showing catch drain (red) around hilltop shelters, connected to cascade drains (dark blue) at intervals.

- **Natural materials allow infiltration and slow down water, but require annual repair**
- **Brick**: durable and easy to clean but can increase erosion downstream. Use steps to reduce water speed
b) Precast concrete V-drain

<table>
<thead>
<tr>
<th>Description</th>
<th>V-drain with precast reinforced concrete pavers mortared together</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key detail</td>
<td>Drain edge is lower than surrounding ground (so water can flow in)</td>
</tr>
<tr>
<td></td>
<td>Chip edges of panels to create rough surface for mortar to bond to</td>
</tr>
<tr>
<td>Scope of Use</td>
<td>Alongside roads and pathways</td>
</tr>
<tr>
<td></td>
<td>As catch drains alongside ridgelines or terraces, connected to discharge drains</td>
</tr>
<tr>
<td>Advantages</td>
<td>Durable</td>
</tr>
<tr>
<td></td>
<td>Simple to build &amp; repair</td>
</tr>
<tr>
<td></td>
<td>Panels can be moved to a new location if necessary (e.g. site is re-planned)</td>
</tr>
<tr>
<td>Disadvantages</td>
<td>No infiltration &amp; high flow velocity</td>
</tr>
<tr>
<td></td>
<td>• Increased risk of flooding downstream</td>
</tr>
</tbody>
</table>

Precast concrete paver
Available from
SMEP.information@gmail.com

Recommended paver size: 3” x 1’ x 2’
(to limit carrying weight)

Plant along edge

V-drain alongside pathway
3. CASCADE / DISCHARGE DRAINS

a) General

- Top of drain to be lower than surrounding ground to allow water to run into drain

Jute/Geotextile bag

Option 1: Add seeds to filling
Option 2: 5-10% cement

Jute bag base with jute bag walls (Option: 5-10% cement for durability)

Rough, uneven surface of jute/geotextile bags reduces water velocity > reduced erosion

**Table: Cascade/Discharge Drains**

<table>
<thead>
<tr>
<th>Description</th>
<th>Key detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drain top to be lower than surrounding ground to let water flow in</td>
<td>Add check dams or steps to reduce velocity / dissipate energy</td>
</tr>
<tr>
<td></td>
<td>Plant vegetation between bags to slow down flow and improve durability</td>
</tr>
<tr>
<td>Scope of Use</td>
<td>Connecting drains along terraces/ridgeline to valley drains</td>
</tr>
<tr>
<td></td>
<td>Replacing natural ravines/gullies</td>
</tr>
<tr>
<td>Material Options</td>
<td>Jute bag &amp; sand/cement: moderate durability, easy to repair</td>
</tr>
<tr>
<td></td>
<td>Geotextile bag: Durable, easy to repair</td>
</tr>
<tr>
<td></td>
<td>Brick: Moderate durability, difficult to repair</td>
</tr>
<tr>
<td></td>
<td>Precast concrete: Durable, difficult to repair</td>
</tr>
</tbody>
</table>

Precast concrete panels from SMEP
Option: brick check dam to slow water

Brick and CC
b) Key Detail: Discharge Point

- Step in drain to dissipate energy
- Valley drain
- Reinforce base of valley drain below discharge point
- Double layer of jute/geotextile bag with sand-cement filling at base of discharge point
- Compacted earth
- Drain wall: Jute/geotextile bag with earth filling
- Drain base:
  - a) Jute bag with sand-cement filling – durable but prevents infiltration
  - b) Geotextile bag with earth filling – durable and allows plants to grow
- Widen drain at discharge point to dissipate energy
4. STAIRWAYS

a) Brick / Brick & CC

- Water allowed to flow off steps into drain
- Weep holes every 3’ for retaining walls > 2’ high
- Masonry wall <2’: single brick >2’: double brick
- 3” CC base
- Compacted sub-base

**Description**
Brick or Brick & CC drainage/retaining wall along stairways

**Key detail**
Check dam or steps to reduce flow velocity

**Scope of Use**
Alongside stairways

**Advantages**
Durable and easy to clean

**Disadvantages**
More expensive & slower to build than jute bag with sand-cement mix alternative

- Weep holes in retaining wall
- Steps in drain to slow down water
- Backfill missing soil behind retaining wall
5. SLOW AND/OR STORE

a) Retention Basins - Large dry basins in upstream valleys

Description
Flooding unpopulated upstream valleys reduces risk of flooding downstream in congested areas

Key detail
Encourage water to overflow banks into community garden areas by creating small dams. Flood level is controlled by the height of the dam. Multiple small dams along length of valley reduces risk of bursting. Relocate shelters, latrines and facilities in flood plain

Scope of Use
Upstream valleys in underpopulated camps

Cost
Low cost, but depends on dam material

Advantages
Very cost effective. Reduces flooding in congested areas downstream and prevents downstream drains being blocked. Trapped silt can be reused post-monsoon

Disadvantages
Requires possible relocation of low-lying shelters, latrines or facilities

Valley drain
Max water height limited by height of damn

Deliberately flood community gardens using slow-draining dams at 50-100 m intervals

Retention basins reduce flooding downstream
b) Silt trap

Description:
Man-made basin where water slows down and deposits silt

Key detail:
Allow water to drain slowly through the front wall to prevent stagnant water
Porous wall options:
Geotextile bags with broken brick filling; geotextile roll stretched across borak bamboo stakes; perforated brick wall, etc.

Scope of Use:
In front of culverts
Anyplace where there is unused land along the drain

Advantages:
Prevents culverts from being blocked with silt
Silt can be used as fill material
Traps waste

Disadvantages:
Requires space
6. SECONDARY DRAINAGE

a) Congested areas: Brick & CC, Medium-Large Capacity

- Check dams to reduce flow speed
- Water can flow into drain
- Weep hole on both sides of drain

<table>
<thead>
<tr>
<th>Description</th>
<th>Medium to large size brick and CC drain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key detail</td>
<td>3-4” concrete base. Concrete quality &amp; thickness is key</td>
</tr>
<tr>
<td></td>
<td>Weep holes at 3’-6’ centres if wall is above 2’</td>
</tr>
<tr>
<td></td>
<td>Brick wall sits on CC base. Extend CC base past brick walls</td>
</tr>
<tr>
<td></td>
<td>to ensure good strength below wall (edge region is weakest)</td>
</tr>
<tr>
<td></td>
<td>Sub-base is well compacted</td>
</tr>
<tr>
<td></td>
<td>Surrounding path/road is higher than drain edge</td>
</tr>
<tr>
<td></td>
<td>Install silt traps along drainage where possible</td>
</tr>
<tr>
<td>Scope of Use</td>
<td>Secondary drainage in congested areas</td>
</tr>
<tr>
<td>Advantages</td>
<td>Durable and easy to clean</td>
</tr>
<tr>
<td></td>
<td>Cost effective up to 4-5’ wide</td>
</tr>
<tr>
<td>Disadvantages</td>
<td>Difficult to repair</td>
</tr>
<tr>
<td></td>
<td>Cannot accommodate ground movement » brittle failure</td>
</tr>
</tbody>
</table>

+ Easy to clean

Need to raise road & shelter level to match top of drain

- Drain walls double as retaining walls to path and shelter

Maximize capacity in congested spaces
**b) Bamboo & Basha Bera**

- Jute bag along ridge
  - Plant along ridge or through basha bera to increase durability
- Slope walls outwards
- Back-fill behind basha bera and compact
- Borak piles + multi cross bars, with basha bera layer behind
- Unlined base allows infiltration
- Tie back to buried stake to prevent collapse

---

**c) Jute Bags**

- Plant between/through jute bags for long-term strength
- Unlined base allows infiltration

---

### Description

Large size open channel drainage in less congested areas

### Key detail

- Minimise spacing of borak & tie backs to buried stakes
- Slope walls outwards to prevent collapse
- Plant along edges to ensure long term durability (need to protect plants from foot traffic)

### Scope of Use

Large capacity drains in valleys

### Advantages

- Low cost, flexible (no brittle failure)
- Allows infiltration

### Disadvantages

- Basha bera needs to be replaced frequently
  - Use jute or geotextile instead

---
d) Hollow/perforated precast concrete panels (LGED detail)

<table>
<thead>
<tr>
<th>Description</th>
<th>Hollow/perforated precast concrete panels laid over an open ditch</th>
</tr>
</thead>
</table>
| Key detail  | Geotextile layer prevents sand from eroding below panels  
Water can infiltrate through perforated panels into the ground (and vice versa, preventing collapse through hydrostatic pressure) |
| Scope of Use| Open valleys with fast flowing water, where erosion is a risk |
| Advantages  | Durable  
Can be easily and safely dredged  
Allows infiltration. Plants can grow through holes in concrete panels |
| Disadvantages| Expensive |
ACCESS: STRATEGY

Goal: All shelters are accessible from the road via ‘all-weather’ pathways

CONTENTS:

1. Stairways
   a) Bamboo & Jute/Geo Bag
   b) Brick
   c) Precast Concrete O-Ring
   d) Raised Brick Stairway

2. Pathways
   a) Raised Sand
   b) Jute Bags
   c) Brick (BFS & HBB)
   d) Brick (Congested Areas)
   e) Raised Pathway (Open Valleys)
The access strategy for the first half of 2019 is a balance between improving the durability of the main access routes and ensuring that all areas of the camp remain accessible during the 2019 monsoon season.

**Durable highways**
- Herringbone brick paving on vehicle access routes
- Brick flat soling pathways and masonry stairways along pedestrian highways and paths to key facilities

**All-weather access during 2019 monsoon season**
- Cement-stabilized jute bag pathways and bamboo / jute bag reinforced stairways connecting all areas of the camp connecting to the nearest brick pathway
- Bamboo bridges across waterways

**Pre-monsoon targets:**
The targets for 2019 should be that all households are:
- Within 300 m of an all-weather* emergency vehicle access route**
- Within 150 m of a paved or quick-draining sand pedestrian access route
- Accessible from the nearest paved pathway via all-weather access routes***

---

*All-weather*: Does not flood and is stable underfoot during rains

**Minimum standard**: Stepless brick pathways over 10’ wide

***Minimum standard**: Cement-stabilized jute bag pathway/staircase
<table>
<thead>
<tr>
<th>Category</th>
<th>Type / Material</th>
<th>Width (ft)</th>
<th>Materials BDT / m</th>
<th>Labour BDT / m</th>
<th>Total BDT / m</th>
<th>Durability</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stairway Tread = 12” Riser = 7” Width = 4’</td>
<td>Jute bag w. 10% cement</td>
<td>4</td>
<td>1000</td>
<td>300</td>
<td>1300</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Geo bag w. 5% cement</td>
<td>4</td>
<td>1100</td>
<td>300</td>
<td>1400</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bamboo Riser w. Geobag &amp; 5% cement tread</td>
<td>4</td>
<td>1900</td>
<td>400</td>
<td>2300</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 Brick riser brick tread</td>
<td>4</td>
<td>1600</td>
<td>900</td>
<td>2500</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 Brick riser w. 3” CC tread</td>
<td>4</td>
<td>1600</td>
<td>1000</td>
<td>2600</td>
<td></td>
<td>2 brick risers: add 800 BDT/m</td>
</tr>
<tr>
<td></td>
<td>1 Brick riser w. 3” precast tread</td>
<td>4</td>
<td>2100</td>
<td>1200</td>
<td>3300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pathway</td>
<td>Jute bag w. sand-cement</td>
<td>6</td>
<td>1000</td>
<td>200</td>
<td>1200</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Geo bag w. 5% cement</td>
<td>6</td>
<td>1100</td>
<td>200</td>
<td>1300</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Brick flat soling</td>
<td>6</td>
<td>1550</td>
<td>350</td>
<td>1900</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Herringbone (single layer)</td>
<td>6</td>
<td>2050</td>
<td>450</td>
<td>2500</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Herringbone (two layer)</td>
<td>6</td>
<td>3300</td>
<td>700</td>
<td>4000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1. STAIRWAYS

a) Bamboo & Jute/Geotextile Bag

Tread:
Jute bag with 10:1 Sand-Cement mix
Geotextile bag with 15:1 Sand-Cement mix

Riser:
Option 1: Borak bamboo riser held in place using half borak stakes
Option 2: Steel staple (made from 8mm reinforcement bar) embedded 1’ into ground

Preparation:
Cut steps into ground and compact well

Key detail
Cut stairs into slope and compact before laying bags
Add 5-10% cement to increase durability
Use geotextile to increase durability

Durability
Jute: 6-12 months (longer with higher cement content)
Geotextile: 1+ years

Advantages
Quick to build
Geotextile with sand-cement could last a long time

Disadvantages
Jute bag is not durable. Surface is not flat. Trip hazard as materials wear out.
Bamboo pegs present trip hazard
Steel staples may be stolen
b) Brick

Riser (both options):
Minimum: 1 brick thick, laid flat, mortared
Recommended: Two-brick thick riser, laid in alternating courses
Lay foundation course at same level of lower tread, with top course of brick riser parallel to pathway

Option: Precast concrete tread (available from SMEP)
Durable and quick to install, but increased cost. Can reduce riser to one brick thick as precast paver protects top of riser

| Key detail       | Brick riser to be two bricks thick and laid in alternating courses  
|                  | Brick riser starts minimum 1 course below level of lower step     |
|Durability        | Highly trafficked pathways                                        |
|Advantages        | Durable, stable under foot                                       |
|Disadvantages     | Slow to build                                                     |
c) Precast Concrete O-Ring

Cut steps into ground and compact well

Compacted infill: Top: 5" sand-cement mix
Bottom: Soil

Min. overlap between upper & lower ring = 12"

Key detail

<table>
<thead>
<tr>
<th>Key detail</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precast latrine rings with compacted infill</td>
<td></td>
</tr>
<tr>
<td>Sand-cement top layer to create good walking surface</td>
<td></td>
</tr>
<tr>
<td>Minimum 1’ overlap between each ring</td>
<td></td>
</tr>
</tbody>
</table>

Scope of use

Narrow stairways in hard to reach locations

Advantages

Quick to install
Durable

Disadvantages

Hard to transport O-Rings to site
Narrow

Credit: DRC. Note side drain and handrail
d) Raised Brick Stairway

**Side wall:**
Two-brick thick wall, laid in alternating courses
Weep holes at 3’ spacing to allow water to drain (if top surface of steps is porous)

**Drain wall:**
H < 2’: One brick thick wall
H > 2’: Two-brick wall, laid in alternating courses
Weep holes at 3’ spacing to allow water into drain & prevent collapse of wall
Max height of retained soil = 4’
Top of wall is lower than retained soil

**Drain base:**
3” Cast concrete or masonry, laid over compacted soil

<table>
<thead>
<tr>
<th>Key detail</th>
<th>Brick side wall required in congested areas when stairway is raised 0.5 m+ above surrounding level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durability</td>
<td>Good</td>
</tr>
</tbody>
</table>
| Advantages         | Sidewall prevents edge of stairway from collapsing
                       Brick sidewall necessary to prevent erosion cutting under stairs |
| Disadvantages      | Slow to construct                                                                                 |
2. PATHWAYS - PEDESTRIAN

a) Raised Sand Pathway

- **Key detail**
  - Sand pathway raised above surrounding ground to ensure water drains off path
  - Sandy / quick draining soil required

- **Side wall – Option 1:**
  - ½ Borak stakes with basha bera walls

- **Filling:**
  - Quick draining compacted sand filling

<table>
<thead>
<tr>
<th>Key detail</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durability</td>
<td>Very poor</td>
</tr>
<tr>
<td>Advantages</td>
<td>Very cost effective. Quick to install</td>
</tr>
<tr>
<td>Disadvantages</td>
<td>Edge walls are easily damaged.</td>
</tr>
</tbody>
</table>

Plant along sides to prevent people walking on side walls.

Side wall – Option 1:
½ Borak stakes with basha bera walls
b) Cement Stabilized Jute Bag Pathway

Filling:
10:1 sand-cement
N.B. Needs good quality sand, not earth

Key detail
Jute bag pathway with sand-cement filling
Do not over-fill bags
Use good quality sand, not earth

Durability
6 -12 months

Advantages
Cost effective and quick to install
• Quickest method to achieve all-weather access to all parts of the camp

Disadvantages
Needs replacing annually
Undulating surface » trip hazard
c) Brick Pathways

- **Edge bricks:**
  - Embed min. 5” into ground
  - Lay face-to-face and mortar to increase strength

- **Top layer:**
  - Lay bricks on narrow edge in herringbone (zig-zag) pattern

- **Bottom layer:**
  - Lay bricks on wide edge in regular (parallel) bond

**Table:**

<table>
<thead>
<tr>
<th>Name</th>
<th>Brick Flat Soling (BFS)</th>
<th>Herringbone Brick (HBB)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Key detail</strong></td>
<td>Ground is well compacted before laying bricks</td>
<td>Herringbone brick over BFS sub-layer</td>
</tr>
<tr>
<td></td>
<td>Bricks laid flat in herringbone pattern</td>
<td>Compacted sand sub-base if possible</td>
</tr>
<tr>
<td></td>
<td>Vertical edging bricks to restrain brick surface</td>
<td>Vertical edging bricks to restrain brick surface</td>
</tr>
<tr>
<td></td>
<td>Provide sand-cement jute bag to protect edging bricks</td>
<td>Provide sand-cement jute bag to protect edging bricks</td>
</tr>
<tr>
<td><strong>Scope of use</strong></td>
<td>Pedestrian</td>
<td>Heavy vehicular</td>
</tr>
</tbody>
</table>
d) Brick Tertiary Road with Major and Minor Side Drains

- Plant turf over bare soil
- Brick flat soling or herringbone brick
- Water can run off road into drain
- Weep holes
- Brick retaining wall
  - 2 bricks thick: light traffic (e.g. TomToms), $H < 4'$
  - 3 bricks thick: medium traffic (e.g. 4x4s), $H > 4'$
- Weep holes
- Primary drain with masonry wall & 3” thick concrete base
- Jute/geotextile embankment reinforced with planting is an option if space allows

**Table:**

<table>
<thead>
<tr>
<th>Key detail</th>
<th>Detail</th>
</tr>
</thead>
</table>
| Wall thickness depends on wall height and weight of traffic: | 2 bricks thick: light traffic (e.g. TomToms), $H < 4'$  
3 bricks thick: medium traffic (e.g. 4x4s), $H > 4'$  
Weep holes in retaining wall to reduce water pressure |

| Durability | Good |
| Advantages | Good in congested areas  
Durable |
| Disadvantages | Expensive  
Slow to build |
e) Raised Pathways with Jute Bag or Bamboo Retaining Wall

**Retaining wall:**
- Geotextile bag with earth infill > allows planting
- Jute bag walls with 1:10 sand-cement fill (no planting) – include PVC weep holes

**Sand-cement jute bag protects edge of pathway**

**Borak stakes tied back to buried stakes to prevent collapse of wall**

**Vetiver plants along edge:**
- Add small fence to protect from foot traffic
- Vetiver roots strengthen earth banks

**Bamboo & basha bera retaining wall:**
- Borak stakes at 3’-5’ centres
- Muli ‘cross beams’ behind borak stakes
- Recommended: Borak capping beam connecting stakes (not shown)

**Key detail**

<table>
<thead>
<tr>
<th>Key detail</th>
<th>Max. slope of retaining wall = 2:1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a) Geo bag with earth infill (no cement). Add seeds or plant to improve durability</td>
</tr>
<tr>
<td></td>
<td>b) Jute bag with 10:1 sand-cement to improve durability (N.B. clean sand, not earth). Add weep holes (PVC pipes) if using cement</td>
</tr>
<tr>
<td></td>
<td>c) Bamboo &amp; basha bera: Tie back to buried stakes to prevent collapse</td>
</tr>
<tr>
<td></td>
<td>Minimise spacing of borak stakes</td>
</tr>
</tbody>
</table>

**Durability**
- Jute bags: Moderate
- Geotextile and planting: Good

**Advantages**
- Cost effective. Quick to install.

**Disadvantages**
- Less easy to maintain. Requires more space than brick retaining wall
1. Small Retaining Wall  
2. Mass Retaining Wall  
3. Terracing  
4. Planting on Slopes  
5. Slope Protection

N.B. All retaining structures should be designed by an engineer.

<table>
<thead>
<tr>
<th>Category</th>
<th>Type / Material</th>
<th>Height (ft)</th>
<th>Materials BDT / m</th>
<th>Labour BDT / m</th>
<th>Total BDT / m</th>
<th>Durability</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1m retaining wall</td>
<td>Jute bag w. earth</td>
<td>4</td>
<td>8,000</td>
<td>1,000</td>
<td>9,000</td>
<td>Poor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Geo bag w. earth</td>
<td>4</td>
<td>10,000</td>
<td>1,000</td>
<td>11,000</td>
<td>Good if planted</td>
<td></td>
</tr>
<tr>
<td>10” Brick wall</td>
<td></td>
<td>4</td>
<td>14,500</td>
<td>2,500</td>
<td>17,000</td>
<td>Good</td>
<td>0.5m deep foundation</td>
</tr>
</tbody>
</table>
1. SMALL RETAINING WALL

N.B. Indicative dimensions only! All retaining structures should be designed by an engineer.

<table>
<thead>
<tr>
<th>Key detail</th>
<th>Max. height: 4’ above ground level (5’ of retained soil) If H of retained soil &gt; 5’: use mass retaining wall Adequate foundation depth required to prevent sliding Well compacted sub-base Weep holes to prevent hydrostatic pressure with brick chips wrapped in jute/geo bag behind to allow water to drain Expansion joints every 30’-40’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durability</td>
<td>To retain loose soils e.g. alongside pathways in congested areas Alternative: consider using geotextile bags if there is sufficient space</td>
</tr>
<tr>
<td>Advantages</td>
<td>Durable</td>
</tr>
<tr>
<td>Disadvantages</td>
<td>Expensive</td>
</tr>
</tbody>
</table>

Retained soil higher than top of wall to avoid water soaking into ground behind wall

Option 1: Back fill full height & length of wall with brick chip
Option 2: Brick chips wrapped in jute/geo bag behind weep holes

Min. 18”

Sand-cement jute bags to protect kerb

Pathway

Perforated pipe connecting to outlet, wrapped in geotextile and surrounded by brick chip

N.B. Indicative dimensions only! All retaining structures should be designed by an engineer.

Advantages
To retain loose soils e.g. alongside pathways in congested areas
Alternative: consider using geotextile bags if there is sufficient space

Disadvantages
Expensive

Collapsed retaining wall due to missing weep holes
2. BRICK MASS RETAINING WALL

N.B. Indicative dimensions only! All retaining structures should be designed by an engineer.

Wall thickness depends on many factors including the height of retained soil, soil properties and loading conditions.

Option 1 (preferred): Backfill with quick-draining brick chips
Option 2 (shown): Brick chips wrapped in geotextile bag behind weep holes

Perforated pipe connecting to outlet, wrapped in geotextile and surrounded by brick chips

Key detail
- Design for max. 8’ height of retained soil
- H (soil) > 8’: Consider other designs of retaining structures
- All retaining structures should be designed by an engineer.
- Adequate foundation depth to prevent sliding
- Well compacted sub-base with reinforced concrete base slab
- If soft spots are found during excavation, remove the poor soil and replace with granular material or better fill soil, and then covered with geotextile to prepare the subbase
- Weep holes to prevent hydrostatic pressure with jute/geo bags with brick chips infilled behind weep holes to allow water to drain
- Expansion joints every 30’-40’

Application
- To retain steep slopes in congested areas (e.g. alongside roads)

Advantages
- Durable

Disadvantages
- Expensive
3. TERRACING

- **Key detail**
  - Combine with drains along each terrace, connected to discharge drains
  - Maintain slope on terrace to prevent water ponding & infiltration
  - Plant deep rooted vegetation (e.g. vetiver) at start of monsoon season
  - Bamboo stakes embedded in firm ground, not loose fill
  - Provide drains along each terrace, connected to discharge drains at low points
  - Maintain slope on terrace to prevent surface water from soaking into ground
  - Plant terrace at start of monsoon season to provide long-term strength (bamboo will rot after 6 months)

- **Application**
  - Exposed hillsides in areas without shelters

- **Advantages**
  - Low cost
  - Durable if combined with planting

- **Disadvantages**
  - Bamboo will rot after 6 months
4. PLANTING ON SLOPES

Plant mixture of deep rooted plants (e.g. tree saplings or vetiver) and surface cover (e.g. buffalo grass)

Plant vetiver in rows (1’ between plants along the row, 2’-3’ between rows) to create swales / small terraces that channel water sideways along slope. Plant 2-3 slips in each spot.

Option: Open-weave jute roll folded at top and nailed into the ground using bamboo/steel staples

Compact loose soil to avoid surface erosion

Line of jute bags at base to trap any silt run-off and to secure jute roll

**Key detail**

Plant mixture of deep-rooted and surface plants to ensure durability – follow FAO guidelines
Combine with catch drain along ridgeline and across slopes
Use planting to create swales (natural drains) along slope and connect to discharge drain at the gully location
Compact loose soil. Use jute roll to protect soil surface. Use of open weave jute roll preferred as the tight weave prevents surface grass from growing

**Application**

Exposed hillsides in areas without shelters

**Advantages**

Cost effective and durable

**Disadvantages**

Doesn’t provide structural support until after the vegetation takes root (~1 year)
5. SLOPE PROTECTION

Options:
- Earth filled geo bags – can be planted > long-term strength
- Sand-cement filled jute/geo bags > stronger in short term. Requires weep holes

PVC pipes act as weep holes

Wall thickness:
- < 4’ Single bag
- < 8’ Double bag at base
- < 12’ Three bags at base
Lay bags in alternating courses

16mm reinforcement bar
hammered through bags and into ground increase shear strength

Bamboo fence for safety and to protect plants

Plant quick growing, long-rooted grasses (e.g. vetiver) along ridgeline to provide long-term strength.

Avoid vertical walls if possible

<table>
<thead>
<tr>
<th>Key detail</th>
<th>Provide weep holes (PVC pipes) if using sand-cement. Use construction sand (not earth) for sand-cement mix. Water each layer during construction (if using cement). Fence along ridgeline for protection.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>To strengthen embankments</td>
</tr>
<tr>
<td>Advantages</td>
<td>Quick and easy to build. Durable if combined with planting. Protects surface from erosion.</td>
</tr>
<tr>
<td>Disadvantages</td>
<td>Retaining capacity is limited compared to brick or concrete.</td>
</tr>
</tbody>
</table>