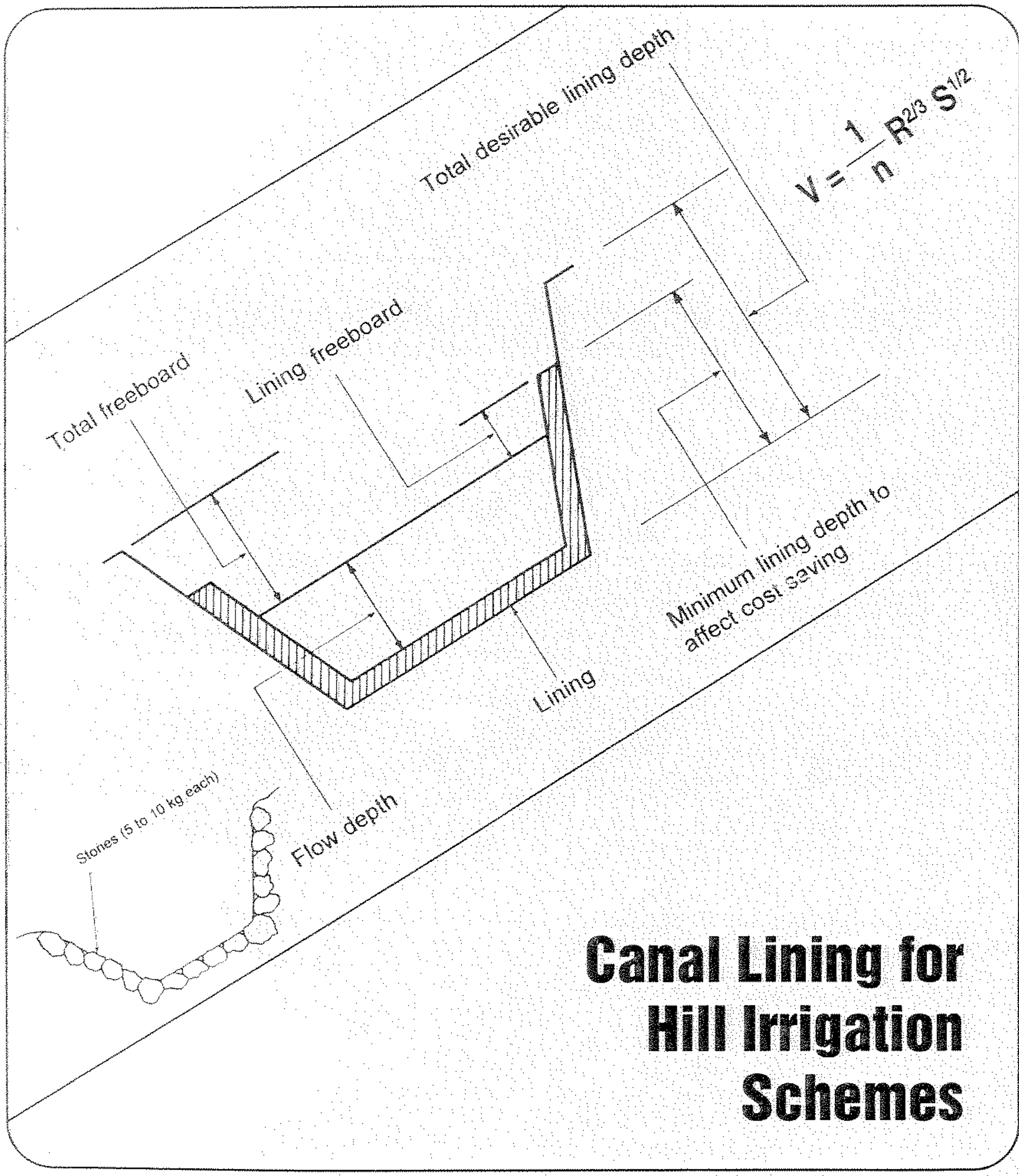
Poverty Alleviation Through Employment Generation in Irrigation Works Programmes

APPROPRIATE DESIGN OF SMALL-SCALE HILL IRRIGATION STRUCTURES



Canal Lining for Hill Irrigation Schemes

NEPAL SPECIAL PUBLIC WORKS PROGRAMME
MANUAL NO. 2

Module No 7

CANAL LINING FOR HILL IRRIGATION SCHEMES

List of Figures

List of Photographs

List of Tables

This module deals mainly with lining canals in stable land zones where the main problems are:

- Seepage of canal water,
- Scour and erosion in the canal, and
- Small earth slumps or rock falls into the canal.

The large diameter precast cement pipe described in this module is also regarded as canal lining. Canals in unstable areas need lining of a special kind to prevent any water leakage which would aggravate existing problems in the area. Appropriate lining for such cases is dealt with in the module for "Problem Area Structures."

Justification for Canal Lining

Earthen canals in hill irrigation schemes need lining for the following reasons:

- to prevent seepage losses,
- to prevent scour and erosion in the canal.

Canal lining is expensive whatever material is used, either local or imported, and there must therefore be clear justification for lining a canal. In other words, the seepage and erosion problems must be significantly severe to justify lining.

How to Deal with Less Severe Problems

If the problem is less severe, is unlikely to become worse in the future, and/or can be tackled by the farmers themselves, then the expense of lining the canal is not justifiable. However, the farmers should be given technical guidance and advice on how to solve the problem on their own.

Making Decisions

The presence and severity of seepage and erosion must be well established before deciding whether to line a canal or not.

Seepage: Establishing the Presence of Seepage

In existing canals it may be possible to visually verify the presence and magnitude of any seepage. When visual verification is not possible, but the presence of a seepage problem is suspected, measurements must be carried out before deciding whether to line the canal or not.

Simple discharge measurements at upstream and downstream points of the stretch of the canal suspected of seepage can help to establish the severity of the problem.

In the case of new construction, seepage areas along the proposed canal alignment can be identified visually but the decision to line these sections must wait until the bench cut and percolation tests are made on the surface of the bench itself.

Severity of the Seepage Problem

When seepage does not threaten the local stability of the canal and does not take away large quantities of canal water which would result in inadequate supplies to the tail end of the canal, lining the canal to reduce seepage is not justifiable.

Such cases of mild seepage can be effectively handled by using local traditional methods such as soaking the canal base and sides with clay slurry, slate lining, etc.

Alternatively, when canal water seepage appears likely to induce local stability problems and when there is a significant loss of canal water affecting deliveries to the tail end of the canal, then canal lining is justifiable.

Erosion: Establishing the Presence of Erosion

Erosion can easily be visually verified.

High flow velocity due to a steep canal bed slope can cause erosion in existing earthen canals.

Erosion will occur when flow velocity exceeds permissible limits.

Permissible limits of canal flow velocity depend on the parent material of the canal:

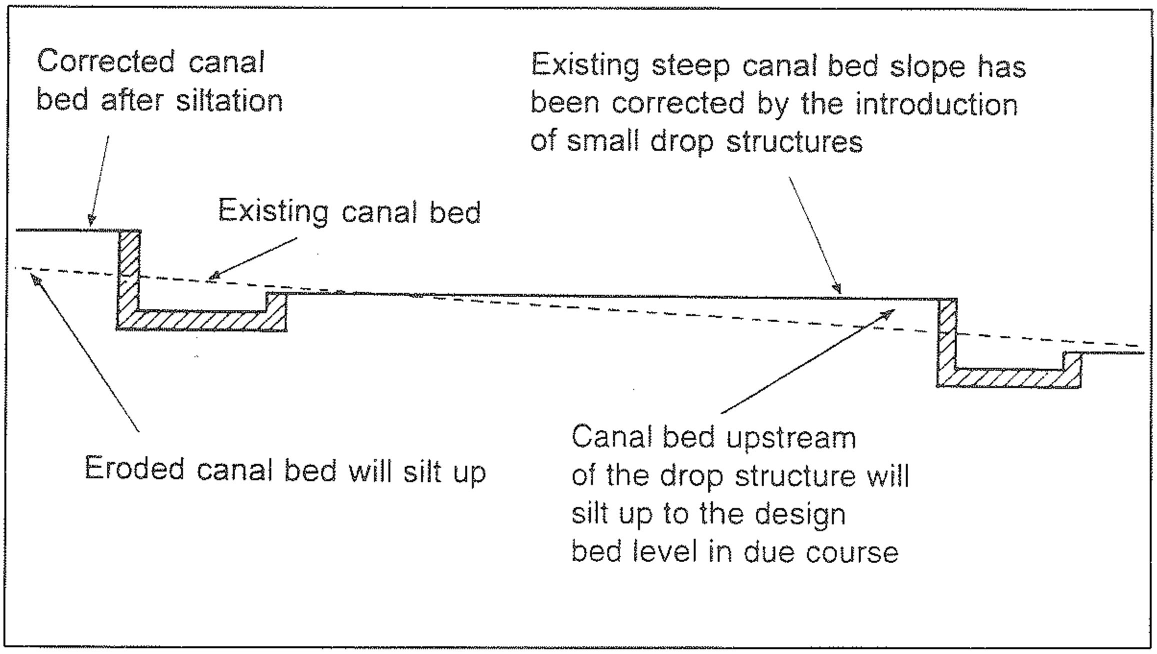
Material	Velocity (mps)
Coarse sand	0.60
Sandy loam	0.85
Loam	0.90
Clay loam	1.20
Gravel	1.20

Slightly higher velocities (in the order of 10%) can be allowed in smaller canals because a small body of water has less erosive power than a large stream.

Erosion can be controlled by reducing the existing canal bed slope or by lining the canal. By introducing a series of small drop structures in the exiting canal alignment, the slope of the canal between the drop structures can be reduced. See Figure 7.1 showing the use of small drop structures to limit the gradient of canal bed slopes to control erosion.

Whichever is the cheaper and more practical of the two methods should be adopted for erosion control.

Figure 7.1
Erosion Control Using a Series of Small Drop Structures



Canal Lining Materials

The table below shows a variety of appropriate materials for the lining of canals to prevent seepage and erosion.

Table 7.1
Materials for Canal Lining

Material	Thickness	Typical Use
Dry-stone	20/25 cm	***Canal bed and bank erosion protection.***
Slate	1/2 cm	***Canal bed and bank erosion protection.***
Clay brick	5 cm	***Canal seepage prevention.*** Canal bed and bank erosion protection.
Soil-cement	3 layers; each layer 2 cm thick	***Canal seepage prevention.*** Canal bed and bank erosion protection.
Ferro-cement	6/8 cm	***Canal seepage prevention.*** Canal bed and bank erosion protection.
Plastic	0.2/2 mm	Canal seepage prevention.
Stone masonry	25/30 cm	***Canal seepage prevention.*** Canal bed and bank erosion protection.
Plain concrete	7.5/10 cm	***Canal seepage prevention.*** Canal bed and bank erosion protection.
Precast cement pipes	45/60/100 cm diameter	***Canal seepage prevention.*** Canal bed and bank erosion protection.

Italics indicate primary use.

Stone Lining

Photograph 7A
A Stone-Paved Canal

Lining with stone, slate or a combination of both is the most appropriate and cost effective solution to erosion problems in small hill canals.

Use of locally available slates and stones, as well as local construction skills, promotes income and employment generation in the village.

Dependency on outside assistance for repairing, renovating or maintaining these canals is also minimised when local materials are used in the construction.

Brick Lining

Photograph 7B
A Brick-Lined Canal with a Trapezoidal Cross-Section

When clay bricks are available in close proximity, clay brick lining can be very cost effective. Both rectangular and trapezoidal canal sections are possible with bricks. When lining trapezoidal canal sections, ordinary clay can be used as a bonding material between bricks. Rectangular canal sections will need a stronger bonding material such as soil-cement or cement mortar. Brick-lined canals are durable and have smooth surfaces offering less resistance to canal flow, allowing the use of smaller canal sections.

Photograph 7C
A Brick-Lined Canal with a Rectangular Cross-Section

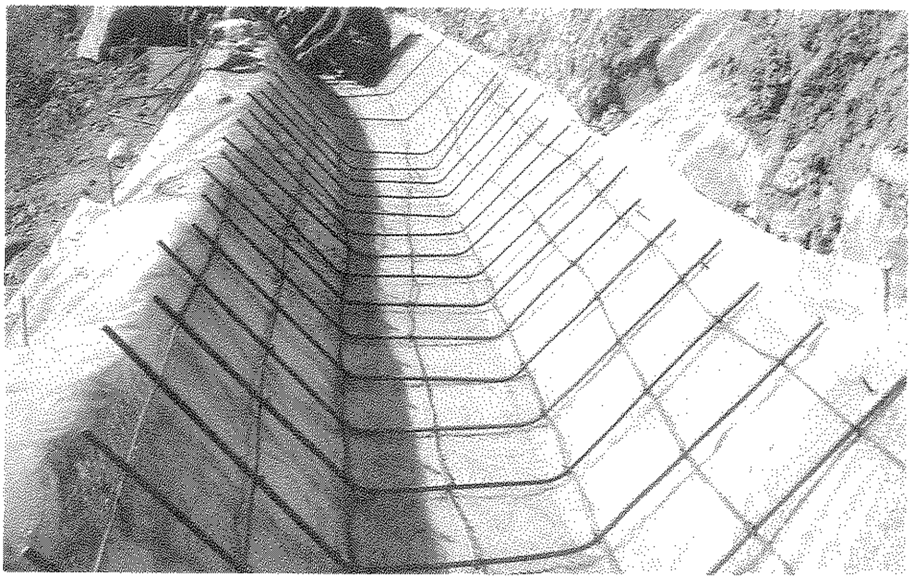
Soil-Cement Lining

Photograph 7D
Village Worker Plastering an Earthen Canal with a Mixture of Soil-Cement

Soil-cement lining is a mixture of red soil (seven parts) and cement (one part). When correctly mixed and applied on the inside of the canal it can prevent seepage.

A 2 to 3 cm total thickness is usually sufficient. For best results, two or more coatings are needed. Each new coat should be applied within three days of the previous coat. Curing hardens the layer of soil-cement. When properly cured, soil-cement can provide a hardwearing, erosion resistant and non-porous canal lining. The technology needed for soil-cement is simple and is readily available in most villages. Soil-cement is not "cattle proof". Cattle must not be allowed to walk over it.

Ferro-Cement Canal Lining



Photograph 7E
Reinforcement and Other Construction Details for Ferro-Cement Canal Lining

Ferro-cement canal lining is a more durable alternative to conventional cement masonry lining.

It is only marginally more expensive than cement masonry lining, even in remote sites.

The construction materials needed for making ferro-cement, such as chicken wire mesh, plastic sheets and nominal steel reinforcement, are easy to transport to remote areas.

Ferro-cement can be cast in-situ (see photograph above) or precast in moulds.

In-situ casting gives the best results because the casting can sit firmly on the excavated and compacted canal shape which helps prevent subsidence.

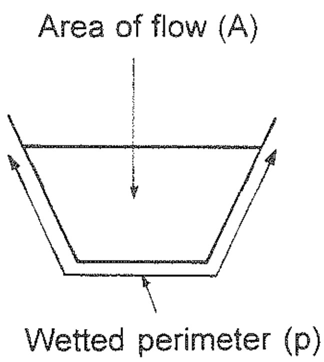
In-situ casting also permits long segments to be cast at one time.

The smooth top surface of ferro-cement casting allows easy cleaning and requires very little maintenance.

Hydraulic Design of Lined Canals

Manning's equation is recommended for sizing of lined canals. The formula must be applied taking into consideration the limiting criteria set out in Table 7.2

Figure 7.2
Manning's Formula



$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

Where V = velocity of flow (m/s)
R = hydraulic radius (m)
S = bed slope of canal
n = Manning's roughness coefficient

The hydraulic radius, R, is computed using the expression;

$$R = \frac{A}{p}$$

Where: A = flow area (sq m)
p = wetted perimeter (m)

Limiting criteria in applying Manning's equation to lined canals are set out in Table 7.2.

Table 7.2
Limiting Criteria for Design of Lined Canals

Recommended Values of Maximum Velocity and Roughness

Lining Type	Maximum Velocity m/s	Roughness coefficient
Dry-stone pitching	1.0	0.025
Slate	1.0	0.020
Soil-cement	1.0	0.025
Brick	1.5	0.017
Stone masonry	2.0	0.020
PCC/ferro-cement	2.5	0.017

Recommended Bed Width : Depth Ratios for Lined Canals

Flow in cumecs	Ratio of Bed Width : Depth
Q > 5.0	1:2
1.0 < Q < 5.0	1:1.5
0.5 < Q < 1.0	1:1.25
0.5 > Q	1:1

Recommended Freeboard (Total Freeboard and Lining Freeboard)

Flow in cumecs	Total Freeboard (cms)	Lining Freeboard (cms)
< 0.5	20	10
0.1 - 0.5	30	15
0.5 - 1.0	40	20
1.0 - 2.0	50	20

Recommended Side Slopes for Lined Canals

Lining type	Side slope V:H
Dry-stone/brick	1:2
Slate	1:1 to vertical
Stone/Brick masonry	1:1.5 to vertical
PCC	1:1.5 to 1:1

For more details on design of lined canals refer to Chapter 3.5 of the PDSP Design Manuals, M8, Part 1.

Hydraulic Design of Covered Canals and Conduits

Covered Canals

Covered canals are generally designed as rectangular sections because rectangular canals are easy to cover. Covered canals must be designed for free flow with a minimum clearance of 10 centimetres between the free water surface and the bottom of the cover slab. Depending on the situation, covered canals may or may not need additional soil cover. If there is a possibility of rock fall damage, minimum soil cover of one metre must be provided.

Covered canals with soil cover are difficult to clean, hence simple manholes must be provided at regular intervals of no more than 3 metres. Long covered canals can easily choke with sediment and other debris. Hydraulic flushing, though recommended in several design manuals, is almost impossible in hill systems because it takes a large body of water moving at high velocity to flush out sediment and debris that has accumulated and hardened inside the canal. Besides, it would be difficult to make certain that all the sediment has been cleared without a visual examination.

Manual cleaning is probably the only method suitable for cleaning covered canals. This requirement must be kept in mind when designing covered canal sections.

Rigid covered canals are not suitable for areas with instability problems.

Manning's formula is used for designing covered canals. For all practical purposes covered canals can be designed as flumes.

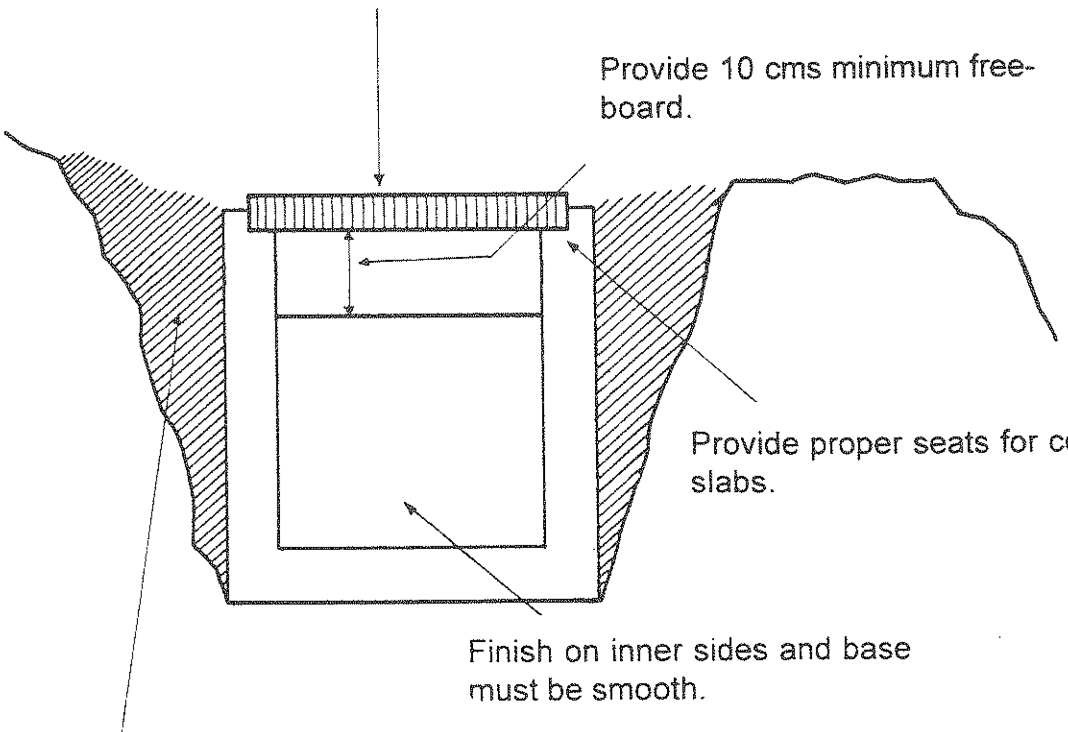
See example T4 in the PDSP Design Manuals, Part D2, Vol. 3 for more details.

Masonry covered canals must be built for maximum durability and strength. Figure 7.3 gives some practical hints for strong and durable construction of masonry covered canals.

Figure 7.3
Some Practical Hints for Making Durable Masonry Covered Canals

Cover slabs must be cast in manageable sizes for easy handling. Cover slab thickness must be controlled to less than 10 cms, by appropriate design and good quality control during construction.

Provide 10 cms minimum free-board.



Provide proper seats for cover slabs.

Finish on inner sides and base must be smooth.

Compacted backfill behind construction works to ensure safety of structure.

- Provide soil cover if there is danger of rock fall damage.
- Use good quality construction materials and good craftsmen to ensure strong canals and cover slabs.

Conduits

Conduits are generally designed as circular sections because circular sections are easy to cast in the hills using moulds.

Conduits must be designed for free flow with a minimum clearance of 0.2 of the diameter between the free water surface and the top of the inner wall.

Depending on the situation, conduits may or may not need additional soil cover.

If there is the possibility of rock fall damage, minimum soil cover of one metre must be provided.

Conduits, because they are sealed end to end, are more difficult to clean than covered canals. Long conduits can choke with sediment and other debris.

Sediment accumulation inside long conduits can be minimised by placing them on steeper bed slopes.

Hydraulic flushing, though recommended in several design manuals, is almost impossible in hill systems because it takes a large body of water moving at high velocity to flush out sediment and debris that has accumulated and hardened inside the conduit. Besides, it would be difficult to make certain that all the sediment has been cleared without a visual examination.

Manual cleaning is probably the only method suitable for cleaning conduits. Conduits will therefore need several manholes.

Lightweight precast cement manholes that easily connect to circular cement pipes may be considered to keep costs down. Rigid conduits are not suitable in areas with instability problems. Roots of large trees can penetrate buried concrete pipes.

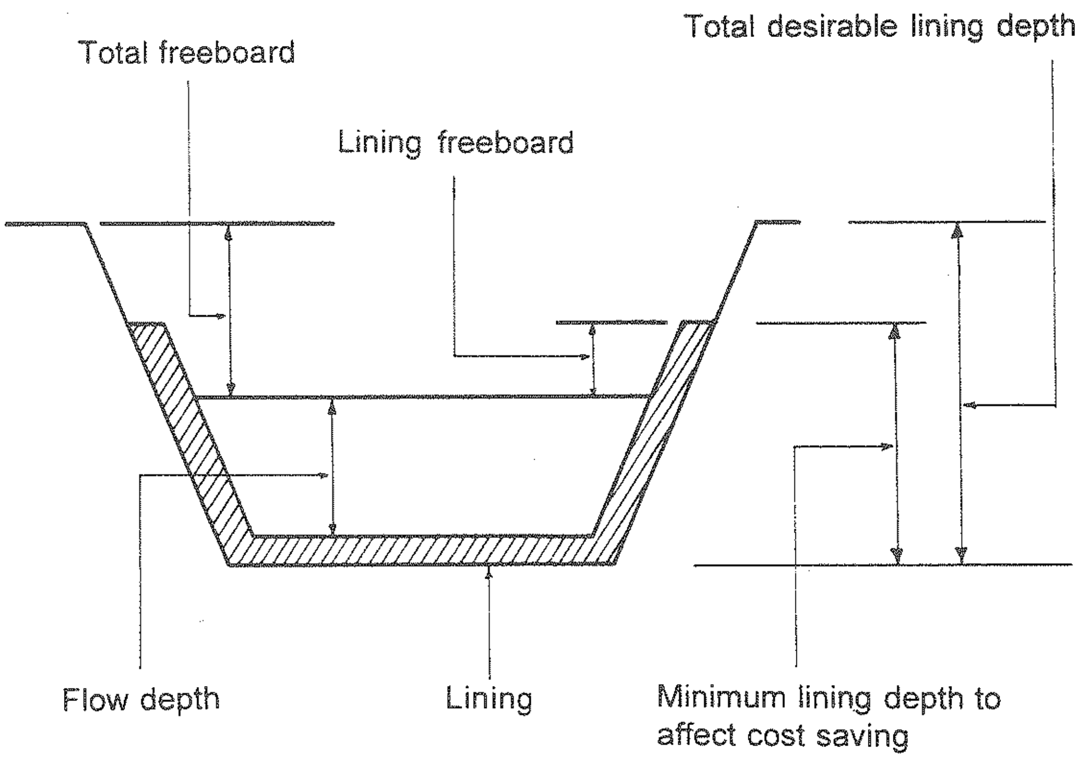
Manning's formula is used for designing conduits which will become only partly full.

Cost Saving Measures

Canal lining is expensive, especially when imported materials, such as cement, are used in the construction.

When long canal lengths need to be lined, and when lined sections are wide and deep, substantial cost savings can be made by lining canals only up to the minimum required depth as shown in Figure 7.4.

Figure 7.4
Measures for Saving Canal Lining Costs



Recommended minimum lining freeboard depends on the flow rate in the canal.

Farmers and Canal Lining

Most hill farmers think that cement canals and cement pipes are a permanent solution to their irrigation problems.

Because of this they are reluctant to agree to the use of other more appropriate materials for canal lining.

Cement is not always the most suitable material for canal lining in hill areas because, if incorrectly used, it can create more problems than it solves.

Cement canal construction requires good quality control, good workmanship and good supervision. Absence of any of these can result in weak canal sections.

Minor damage such as that shown in Photograph 7F can occur very quickly.

Because cement and masonry skills are not readily available in remote villages such damage may remain unrepaired until it develops into a major problem.

The farmers' choice can be influenced by explaining to them the dangers of using non-local materials when adequate local materials and local skills are available in the village to do the same job.

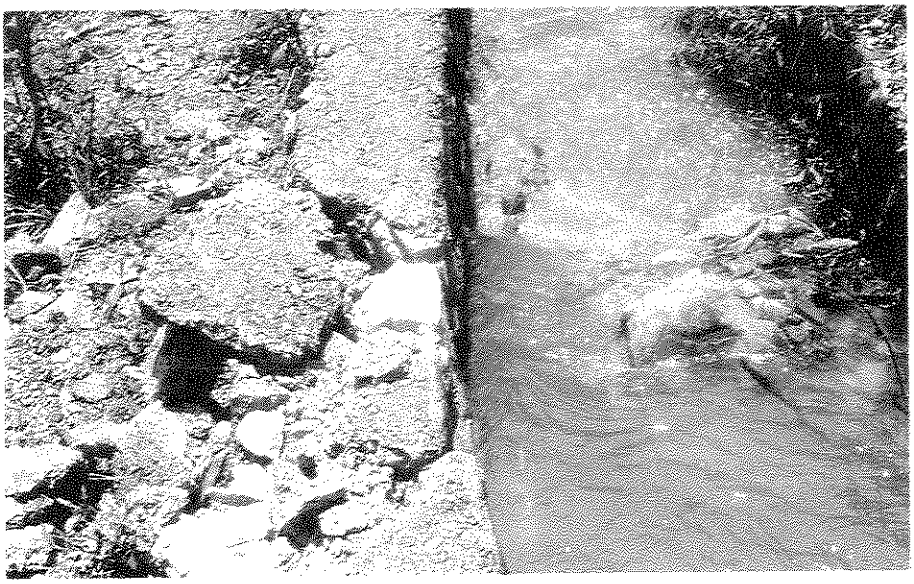
Slate pitching is a very effective way of controlling erosion. Slate-paved canals can also control seepage in steep areas, provided there is sufficient overlap between the slates.

Soil-cement is another material that is very appropriate in the hills. It needs very little cement compared to other cement canals and the skills needed for construction are available in the village.

When local materials and local skills are used, farmers do not have to depend on external assistance to repair their canals.

WARNING

Dangers of Using Non-Local Materials in Preference to More Appropriate Local Materials



Photograph 7F
A Damaged Masonry Canal

This cement masonry lined canal was damaged by a small falling stone because the masonry work was not strong enough to withstand the impact force.

Because cement is not available in the village it is likely that this damage will remain unrepaired for a long time until it eventually develops into a major problem.

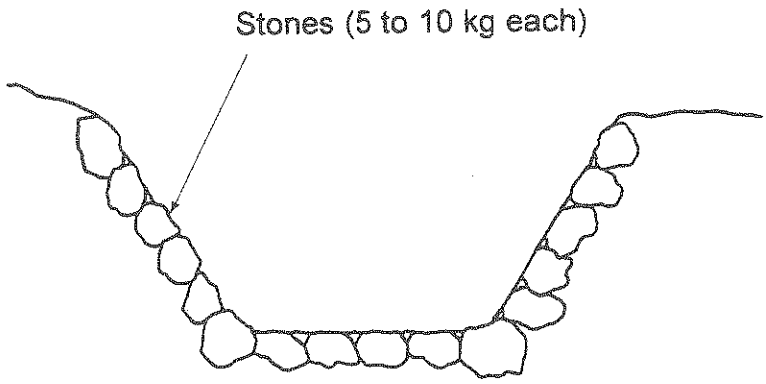
If local materials had been used the farmers could have repaired the damage by themselves.

Advantages and Benefits of Using Local Construction Materials for Canal Lining in Remote Hill Projects

- Local materials are cheaper than imported materials.
- Local materials cost less to transport.
- Both income and employment are generated in the village when local materials such as slates and stones are quarried, dressed and portered by local people.
- The relevant technology for using local materials is often available in the village, leading to further employment generation.
- Dependency on imported materials for future repair and maintenance is eliminated.
- Future repair and maintenance is easy and is within the farmers' control.

Examples of the use of local materials for canal lining are shown in Figure 7.5 and Photographs 7G and 7H.

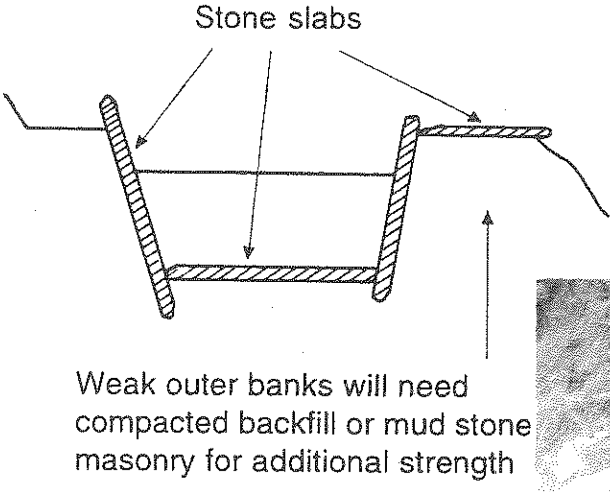
Figure 7.5
The Correct Use of Dry-Stone for Pitching of Canals



Dry-stone pitching prevents erosion caused by high canal flow velocities which are often the result of steep canal bed slopes.
Dry-stone pitching also reduces seepage in stages:

- by moss formation, and;
- eventual filling up of gaps between the stones with silt.

The Use of Slates and Stone Slabs for Erosion Control



Photograph 7G
A Slate-Lined Canal

Slate and stone slabs are effective against erosion. They also provide stability to canal walls, especially when the walls are weakened by the presence of water.

Stone slabs placed on bank tops also provide a hard surface for footpaths.

Clay or Soil-Cement Lining

Photograph 7H
Soil-Cement Lining has Effectively Controlled Seepage in this Canal

Clay or soil-cement lining is effective against seepage.

Several layers of clay or soil-cement lining of different thickness can be applied depending on the severity of the seepage problem.