Government of Tripura
Forest Department

TRIPURA SCATFORM PROJECT

2020

Guidelines for Soil and Moisture Conservation

JICA

Government of Tripura
Forest Department

SMC Guideline

Abstract

1. Soil and water form two major components of a forest ecosystem and they directly influence the status, health and nature of the flora and fauna that such ecosystem is likely to support. It is obvious therefore that while managing the forests the forest officials have to deal with these components and make their best efforts for their conservation to sustain the plants and animals.
2. As part of the JICA Project being implemented by the Forest Department, Govt of Tripura, the manual on Soil and moisture conservation has been prepared for induction training of the project personnel and front-line forest staffs. The object of this manual is to present the basic ideas of the science of soil and moisture conservation.
3. Tripura has extremely erosive soil with intensive rainfall. Soil erosion is deemed as one of the most contributing factors of forest degradation and sediment disasters in the streams and rivers. Therefore, intensive countermeasures for the soil and moisture conservation are required in addition to the sustainable forest management activities in the project.
4. To enhance quality of forest and its management in the target catchment areas/beats, the following activities for the soil moisture conservation will be conducted as the Soil and Moisture Conservation Component of the project.
    i) Check dams
    ii) Brushwood Check-dam for Gully plugging
    iii) Bundelling
    iv) Contour Trenching
    v) Filter Strip
5. In the project, three (3) models of check dams will be built in the valleys related to the sustainable forest management activities in the target catchment areas/beats: earthen (two types) and concrete core embankment or reinforced concrete structures. Site condition, main purpose, and stakeholders of activities of respective check dams are summarized in the manual.

6. "Guidelines for Soil and Water Conservation Works, include guidelines for check dams and other soil moisture conservation works, were prepared and applied to the soil moisture conservation works. However, the guidelines include few engineering aspects of the check dams, and it will be easier for officials of TFD to conduct planning, designing, constructing, operating and maintaining the structures thoroughly.

7. The environmental effect of the forest cover can be monitored in order to clarify effects of the soil moisture conservation including afforestation activities. The monitoring results will be used to establish a preliminary forest hydrological model in Tripura.

8. Tentative monitoring plan will be as follows and required cost of the monitoring is included in the items related to the social and environmental consideration of the project:

Reduction of flood discharge

Raising water table in area

Reduction of sediment discharge

9. The soil moisture conservation including afforestation helps reduction of sediment discharge from the catchment. Rainfall observation and Soil Substrate (SS) of the flow will be monitored at just downstream sites of representative check dam by RMU of the representative check dams. In addition to monitoring of SS, Biochemical oxygen demand (BOD) of flow will be monitored in consideration of the effect to fishery.

10. There are many scopes of convergence under this component which will be explored through project life. However, the essential convergence would be with MNREGA scheme to tap some financial resources for supporting labour costs and some small material costs. PMU & DMU together will facilitate/coordinate convergence work for this component form line department.

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Contents

1. General

There are three (3) components of the SMC in the catchment, namely,

- Reforestation including plantation, rehabilitation, and agro-forestry development
- Non-structural measures: Land use regulation, public awareness for forest, livelihood assistance/poverty alleviation, etc.
- Structural measures: divided into two (2) kind of works;
  - Catchment conservation works other than water harvesting structures: Those are implemented to minimize the soil erosion around the structures. In addition those are also implemented to prolong the life span of water harvesting structures (check dams). Representative conservation works are as follows: Gully plugging works, contour trench works, terrace works, contour bunding works, mulching, plantation and filter strip works along the river, river/stream bank protection works (bandalling), etc.
  - Water harvesting structures: check dams (construction of embankment)

Activities of the Tripura SCATFORM Project includes implementation of all of the above measures.

Since the Phase I Project, the structural measures of the SMC adopt integrated intervention, which targets the whole area from the upstream catchments to the downstream command area within the same micro watershed. For this purpose, three (3) models, namely: 1) Model 1 (intervention in upstream parts), 2) Model 2 (intervention in the middle parts of the micro watershed) and 3) Model 3 (intervention in the downstream command areas) were developed to be adapted. Brief of three (3) models are described table below.

Table1.1 : Brief Description of Three Models of Structural Measures

Model Name	Terrain Conditions	Major Installation Structures
A. Model 1 (intervention of the upstream parts)	• Narrow valley • Steep slope (more than 20%) • Small catchment less than 5ha	• Gully plugging • Plantation with staggered contour trenches • Plantation with half-moon terraces • Mulching • Embankment: small earthen check dam (check dam type I)
B. Model 2 (intervention of the middle parts of the micro- watershed)	• Narrow valley • Steep to moderate slope (10-20%) • small catchment less than 10 ha)	Gully plugging Bench terracing Plantation with half-moon terraces Staggered contour trenches Plantation along rivers and stream banks Mulching Embankment: Short embankment (with CC core or clay core, and with submerged or partially submerged spillway)
C. Model 3 (intervention for the downstream command areas)	• Wide valley • Gentle slope (less than 20%) • Small catchment less than 20 ha	Gully plugging Contour bunding Bench terracing Plantation along water body, rivers and stream banks Mulching Embankment: embankment with average width 40m(with CC core or clay core, with submerged or partially submerged spillway, water storage area less than 2 ha)

The structural measures of the SMC of the Project are illustrated as follows :

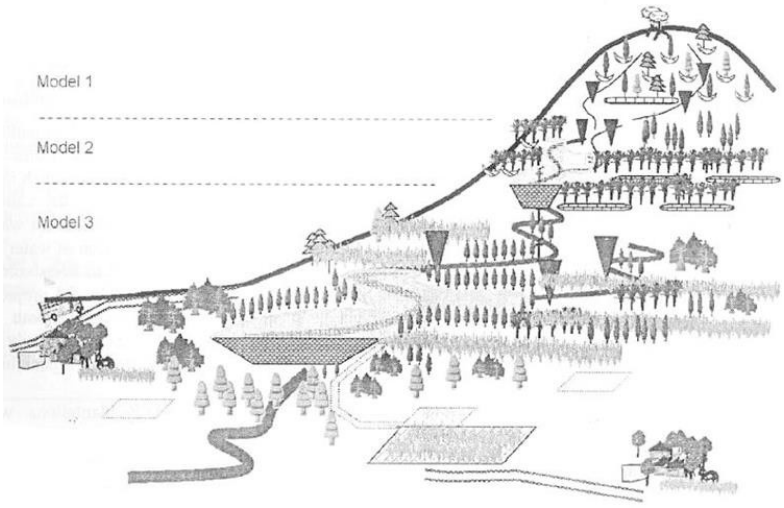


Figure 1.1 Structural Measures of SMC in Tripura

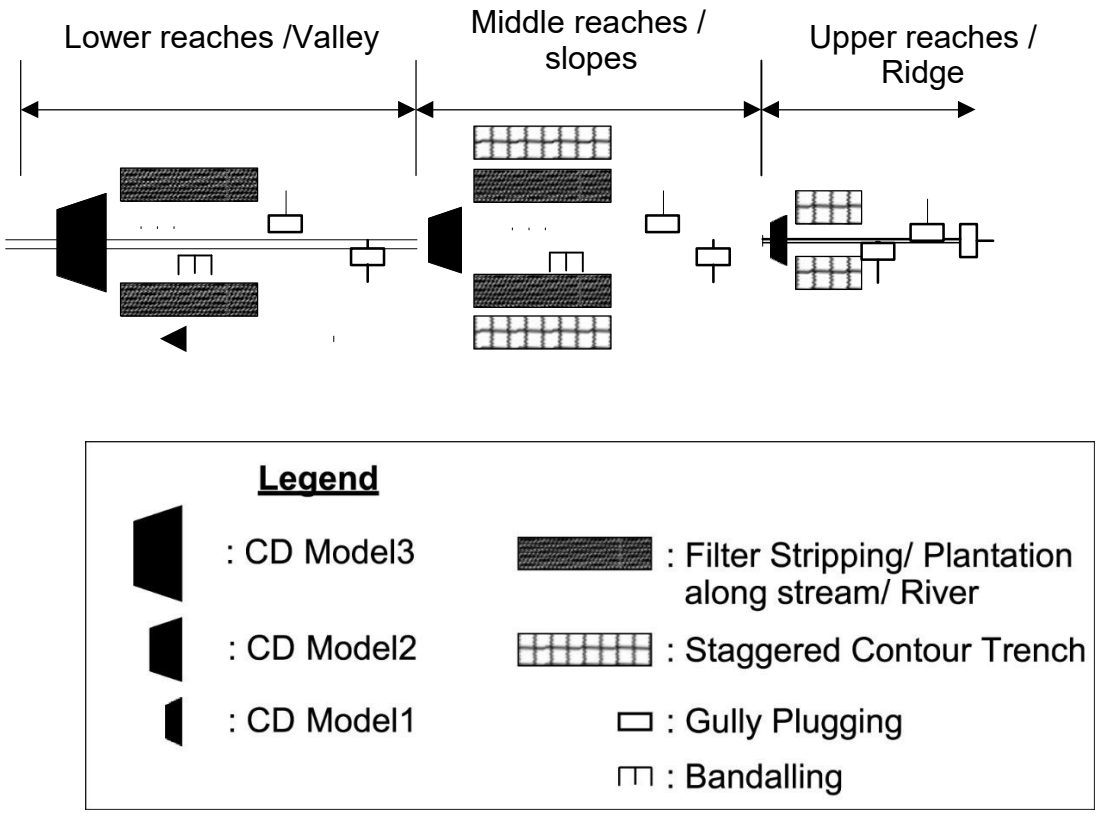


Figure 1.2 Layout of SMC Works along Gully/ Stream/ River in Tripura

In order to implement the Project effectively, the following two (2) operation and effect indicators for the SMC were stipulated during formulation of the Project :

Table1.2 : Operation and Effect Indicators related to Soil and Moisture Conservation

Indicator	Target	Monitoring Method	Responsibility
Ratio of households having accessibility to water in the target villages	100% of household in target villages	Household survey and focus group discussion to JFM families about access to a check dam/tanks or other sources within 500m radius from their dwelling units. This survey will be conducted by RMU with support of Livelihood Coordinator and Community Organizers at the project commencement, the end of 4th and 7th year as well as the End-Term Survey.	SDFO/ DFO/ PMU
The ratio of soil moisture in forest of project target area	10% increase of the proportion of soil moisture at between target areas for the one in control forest in dry season	Monthly measurement of soil moisture at 4 measurement points (2 measurement and 2 control points) in and near the target area within each Beat starting from 1st year by RMU. Recoding in their observation register maintained for the purpose. The format shall be supplied by PMU.	RMU/ PMU (MIS Cell)

During implementation of the structural measure of SWC, the above indicators should be kept in mind. Objectives/functions, planning including the appropriate places of measures, designing, construction, and operation and maintenance of the above structural measures of the SMC are explained hereunder:

2. Gully Plugging Works

2.1 Objective/Function

The gully plugging works are the barriers installed across the gully to reduce the runoff velocity of the gully, to retain the sediment behind them, and to reduce the gully erosion of the micro watershed.
The gully plugging works consist of the barrier and the optional downstream and upstream aprons. The following structures are used as the barriers:

Temporary check dam

a. Pallasiding work by bamboos (for small and narrow gullies)
b. Brushwood check dam (single or double row post)
c. Small earthen check dam Semi-permanent check dam
d. Stone check dam
e. Log check dam

It is difficult to install the semi-permanent check dams as the gully plugging works because of the difficulties to obtain the stone and log materials in Tripura. In addition, small earthen check dam will also not be installed because of small durability of silty soil in Tripura.

The pallasiding works by bamboos are applied to the severely eroded narrow gully in the model 1, 2, and 3, and the brushwood check dams to the severely eroded wider gully in the model 2 and 3.

The brushwood check dam as the representative gully plugging works are shown in the pictures below.

Photograph: Representative Brushwood Check Dam

1. Fig: Representative Brushwood Check Dam in Atharamura Beat

2.2 Implementation of Gully Plugging Works

The gully plugging works will be implemented by RMU and JFMC/EDC. Planning, design, construction, and operation and maintenance (O&M) of the gully plugging works are summarized below:

(1) *Planning*

Potential sites of the brushwood check dam will be selected by the RMU in consultation with JFMC/EDC, in consideration with the following criteria.

- The site should be in the project area.
- The gully should be the active source of sediment production, in which the gully bed is not covered with vegetation and exposed and the bed materials are exposed.
- The gully at the potential brushwood check dam site is straiten as much as possible.
- The curvature of the gully bank at the potential pallasiding work site should be below 90 degre.
- In case of long and severely eroded gully, multiple gully plugging works should be considered.
- Materials of the gully plugging should be available at and around site.
- Priority of shall be given to the potential sites on the severely eroded gully in the upper watershed and in the upstream catchment of the proposed check dam.

For all potential sites, RMU and JFMC/EDC will make a joint inspection to investigate applicable structure type and the sustainability of structure using the above criteria. The final site selection will be done by RMU in consultation with JFMC/EDC, considering the joint inspection results, budget constraint, condition of the gully, and required scale of structure. However, it is difficult to determine the appropriate sites of the gully plugging works because difficulty of access of the sites before plantation works. Therefore, the final selection of site might be made during or after the plantation.

(2) *Design*

After approval of the works by DMU, drawings of the brushwood check dam and pallasiding works by bamboo will be prepared by RMU. Prior to the design of the works, cross section all leveling survey shall be carried out by the RMU. Representative design and technical specification of the gully plugging are as follows:

Single row brushwood check dam: Used as one of a series of the check dams

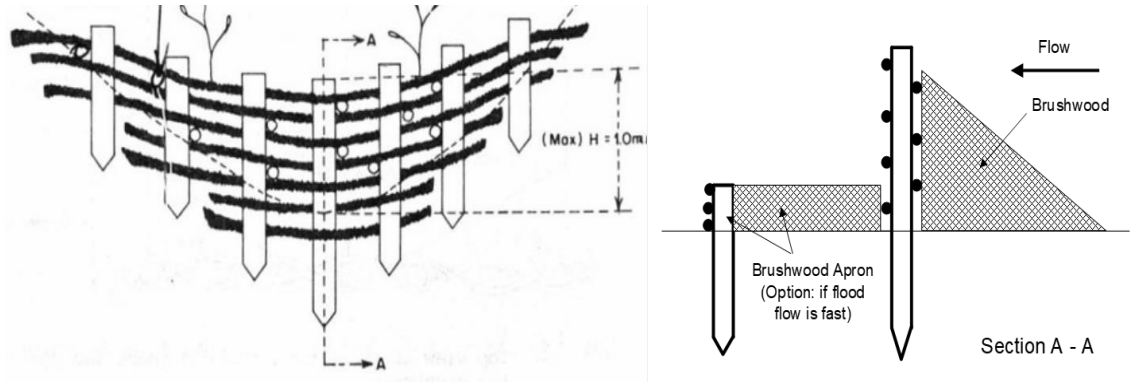


Figure 2.1(1) Design of Measure Works in Gully Plugging (1)

Double rows brushwood check dam

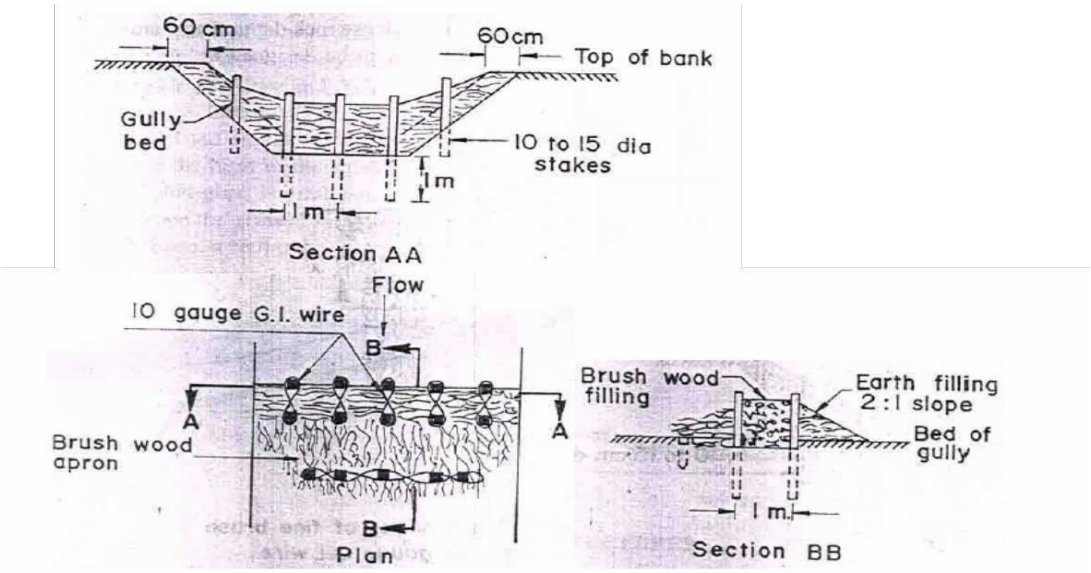


Figure 2.1(2) : Design of Measure Works in Gully Plugging (2)

Table2.1 : Representative technical Specifications of Gully Plugging

Structure	Technical Specifications
Pallasiding work (for Model 1, 2,and 3)	◦ Branching: 3m wide and 1m height ◦ Brushwood: 12m length and 1mwide ◦ Packing: 3m × 1m × 1m The curvature of the gully bank or stream should be below 90 degree. Three (3) sets of bamboo poles should be given. The diameter of bamboo pole should be nearer to 5 cm. Small earth filling or sand bags filling should be there.
Brushwood check dam (for Model 2 and 3)	- Type of wood Awl, Near, Kota, Kari, Ram Della ballahas - Diameter 10cm - Length 12m - Nos. required2nos - Type of bamboo Barrack bamboo - Diameter 75mm to100mm - No required2nos - Length of bamboo 12m Fixation of one layer of champak kampa tarja wall with split bamboo. - Split bamboo (tarja) width75mm - Bamboo button width40mm - Depth 1.5m The depth will be restricted to 1to 2 m. The length will be split bamboo - Split bamboo (taraj) width-75mm - Bamboo button width-40mm - Depth- 1.5 m The depth will be restricted to 1-2 m. The length will be restricted to 12- 24 m. - The galvanized iron (G.I.) wire gauge should be 10 gauge. The diameter of wooden post should be around 10-12 cm

Based on the detailed design, JFMC/EDCs prepare cost estimate and timeline in consultation with RMU. During the cost estimate, the extra G.I. wire shall be included for the repair works. DMU will approve the detailed design and estimate amount sanctioned. MOU of the works will be signed between JFMC/EDCs and RMU.

(3) *Construction*

Construction of the gully plugging works shall be carried out by JFMC/EDC/ with appointed construction supervisor (CS) with the following manners:

1. Appointment of BO as CS by JFMC/EDC under the consent of RMU.
   Construction supervision of the works should be done in compliance with the standard operation procedures of TFD.
2. Cleaning of the site and access road by JFMC/EDC/ with CS
3. Layout of the plan in the site with indelible mark by JFMC/EDC/ with CS
4. Arrangement of equipment, materials and labors by JFMC/EDC/ with CS
5. Construction by JFMC/EDC/ with CS Check measurement by CS/RMU
   Maintain the construction records including the photographs by JFMC/EDC/ with CS
6. Final inspection by RMU

(4) *Operation and Maintenance(O&M)*

After reforestation of the upper watershed by the Project, the active erosion on the gully is considered to be controlled. In the meantime, it is necessary to maintain the functions of the gulley plugging works. As mentioned in the above section 2.1, the pallasiding works by bamboo and the brushwood check dams are the temporary structures. Occasional O&M of structures are required to keep those functional. O&M of the structures shall be done by JFMC/EDCs, by use of the revolving fund under the technical assistance of RMU. The following inspection and repair shall be carried out by JFMC/EDCs and RMU:

- Occasional inspection and repair: after the heavy rainfall by JFMC/EDCs
- Overall inspection: after the monsoon season by JFMC/EDCs and RMU. During the overallinspection, repair/ rehabilitation works during the dry season shall be planned by JFMC/EDCs and RMU. The repair/rehabilitation works by JFMC/EDCs shall be finished before the monsoon season and the inspection to confirm the works shall be carried out by RMU.

(5) *Technical Assistance*

Technical assistance for the preparation of detailed design cost estimate and time line will be provided by DMU, PMU, PMC and resource agencies within the government.

(6) Timeline of the Works

No.	Procedure	Responsibility	Timeline
1	**Planning (site section)**	JFMC//EDC, RMU/DMU/PMU	-
2	**Design**		
2.1	Detailed Design	RMU	7-21 days
2.2	Cost estimate	JFMC/EDC/RMU	

2.3	Approval of design, cost estimate and construction schedule	DMU	7-14 days
2.4	Agreement of design, cost estimate and construction schedule)	JFMC/EDC/RMU	7 days
3.	**Construction**		
3.1	Appointment of Construction Supervisor (CS)	JFMC/EDC/RMU	7 days
3.2	Site Clearing	JFMC/EDC and CS	1-2 days
3.3	Layout of the plan in the site	JFMC/EDC and CS	1-2 days
3.4	Arrangement of materials and equipment	JFMC/EDC and CS	1-14 days
3.5	Arrangement of labor	JFMC/EDC and CS	2-7 days
3.6	Construction	JFMC/EDC and CS	7 days
3.7	Final inspection	RMU	1 days

3. Contour Trench Works

3.1 Objective/Function

The contour trench works are the method of constructing the trenches along the contour lines of the slope with 10 - 30%. Objectives of the trench works are to retain water and sediment on the slope, to increase the water infiltration, to improve local soil moisture, and as the result, to reduce the runoff discharge and sediment to the downstream watershed. There are three (3) types of the contour trenches, that is, continuous trenches, and interrupted (line and staggered) trenches. The continuous contour trenches are essentially used for moisture conservation in low rainfall areas. The staggered trenches are commonly used in Tripura, inconsideration of the rainfall condition (annually1,500-2,500 mm) of Tripura.

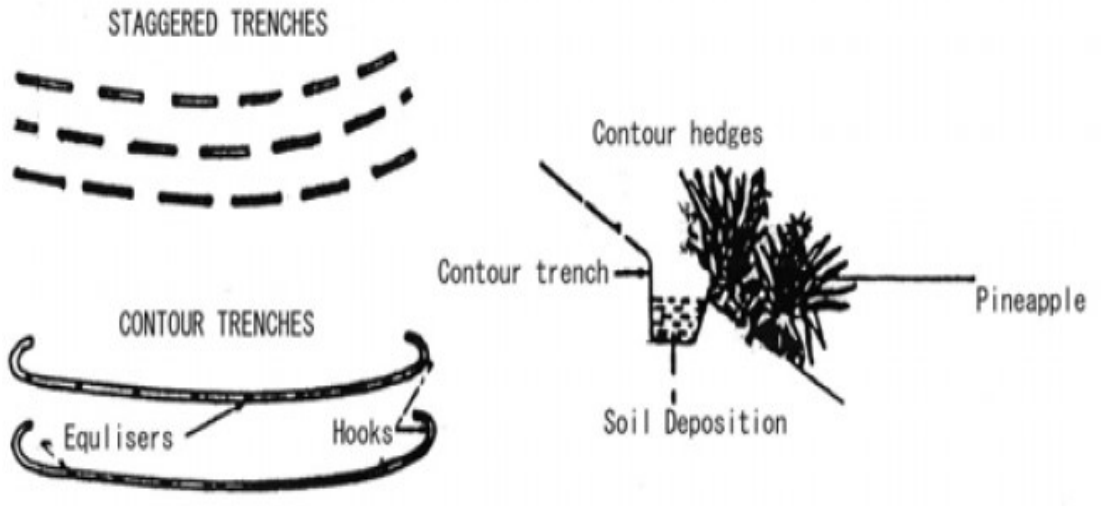
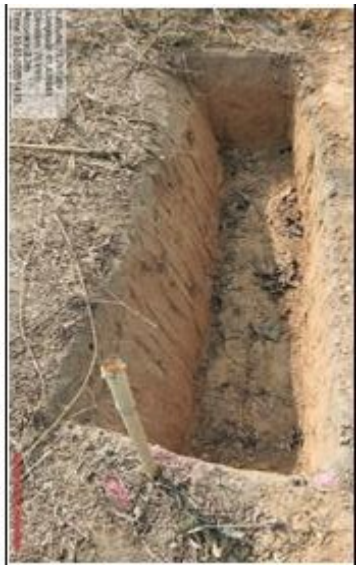


Figure 3.1 Continuous and Staggered Contour Trenches



Photograph Staggered Contour Trench (Source: Field work, 2020 at Belbari Beat)

3.2 Implementation of Staggered Contour Trench Works

The staggered contour trench works will be implemented by RMU and JFMC/EDCs. Planning, design, construction, O&M of the staggered trench works are summarized as follows:

(1) Planning

Potential sites of the trenches will be selected by the RMU in consultation with JFMC/EDC, in consideration of the following criteria.

- The site should be in the project area.
- The site should be the open forest or scrub on the slope with more than 10%, which is the source of sediment yield.
- Priorityshallbegiventothesitelocatedinthejustupstreamcatchmentoftheproposedcheck dam.

For all potential sites, RMU and JFMC/EDC will make a joint inspection to investigate the sustainability of structure using the above criteria. The final site selection will be done by RMU in consultation with JFMC/EDC, in consideration of the joint inspection results, budget constraint, condition of the slope, and scale of installed area of the trenches.

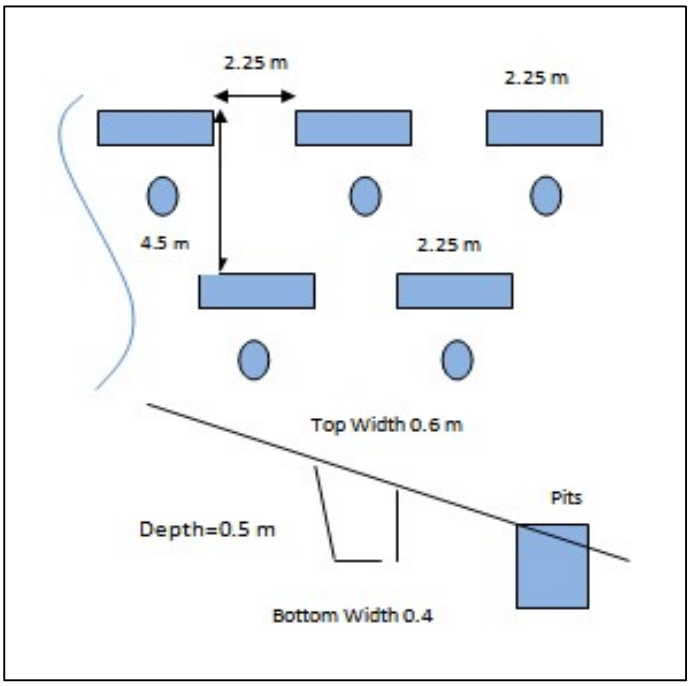
(2) Design

After approval of the works by DMU, the leveling survey of the proposed slope shall be done by RMU. Based on the survey results, outline and drawings of the staggered contour trench works shall be prepared by RMU. The trenches shall be arranged according to the tree species. Required volume of the staggered contour trench works are determined based on (1) the daily rainfall, (2) the runoff coefficient, (3) ratio of the retain capacity of trenches to daily runoff, and (4) the infiltration capacity of soil.

Sample estimation of the required volume and basic layout of the trenches are as follows:

*Sample Estimation (Staggered Trench (10 ha): Pit to Pit 4.5 m * 4.5 m)*

Topics	Formula	Calculation	Solution
Total water received from 10 Ha catchement by Trenches Qt(Cum)	Qt= 10 *Stored (%) * C *R(mm)* A(Ha.)	10 * 0.6*0.4*200 *10 (60% Consider for Harvest)	4800 Cum
Volume of Contour Trench V(Cum) including free board	Length (m) * Av. Width (m) * Depth (m) (TW=60 & BW=40 & depth=0.5)	2.25*0.5 *0.5	0.5625 Cum
No. of Contour Trench Required for 10 Ha	Q /(V *f) trench will fill two times	100000/(4.5*4.5)	4938 No.
Assume two filling So water available for trenches filling	Total water by need to be by trench two times filling	4800/2	2400 Cum
Volume of Trenches work in 10 Ha	Length of SCT X sectional Area	4938 * 0.5625	2778 Cum **(Sufficient to Harvest 2400 Cum Water)** (278 Cum/Ha)
Task Rate /Unit on the base of SOR of Tripura state	Assume for Trench Excavation in soil @ 169.5/Cum has been taken from SOR PWD 2020 item 2.13 and deduct 15% contractor Profit, there for it is 144.075/Cum)	144.075 * 278	40052 per Ha



Survey and Layout

In order to apply the basic layout of the trench, the contour lines of the area are required. There are three (3) methods to survey the contour lines for the area, namely 1)by use of DEM (Digital Elevation Model), 2) by use of the survey instruments, and 3) by use of the minor instruments.

1) Use of DEM

PMU prepare the DEM of the project area. It is considered that the DEM presents the actual elevation of the area, because the candidate area is open area without the effect of trees to DEM.

By use of the DEM, Contour lines every 0.5 or 1.0 m can be drawn. Based on the contour map, the layout of the trenches can be designed. Application of layout of trenches shall be done referring the geographical coordinates.

2) By use of Survey instruments (Total station, Theodolite, or Level)
In case that the contour lines by use of the DEM are inaccurate compared with the field condition of the area or there is no DEM prepared, the leveling survey shall be done. The procedures are as follows:

Leveling survey

a. Setting a temporary Bench Mark(TBM)
b. Setting the survey points with the mesh of 10 – 20 m by use of the pegs(bamboo)
c. Surveying the elevation at the survey points

3) By use of the minor instruments
In case no available DEM and the optical survey instruments, minor instruments assembled locally can be used to the leveling survey. The procedures of survey are same as above. The minor instruments and their use in the field can be referred from the following reference.

- "Chapter - 4. Minor Instruments and their use in Watershed", "Manual on Land and Water Management", The Orissa Tribal Empowerment and Livelihoods Program me. http://otelp.org/downloads/implementation_process/manual/land_water_management_manual.pdf

Based on the detailed design, JFMC/EDCs prepare cost estimate and timeline in consultation with RMU. DMU will approve the detailed design and estimate amount sanctioned. MOU of the works will be signed between JFMC/EDCs and RMU.

(3) *Construction*

Construction of the gully plugging works shall be carried out by JFMC/EDC/ with appointed construction supervisor (CS) with the following manners:

1. Appointment of BO as CS by JFMC/EDC under the consent of RMU.
   Construction supervision of the works should be done in compliance with the standard operation procedures of TFD.
2. Cleaning of the site and access road by JFMC/EDC/ with CS
3. Layout of the plan in the site with indelible mark by JFMC/EDC/ with CS
4. Arrangement of equipment, materials and labors by JFMC/EDC/ with CS
5. Construction by JFMC/EDC/ with CS Check measurement by CS/RMU
   Maintain the construction records including the photographs by JFMC/EDC/ with CS
6. Final inspection by RMU

(4) *Operation and Maintenance (O&M)*

The staggered contour trench works are the earthen structures. Therefore periodical O&M works of the structures are required to keep those functions. After construction of the works, O&M of the structures shall be done by JFMC/EDCs by use of the revolving fund of JFMC/EDCs under the technical assistance of RMU.

After the monsoon season, the overall inspection of structures should be carried out and the repair/rehabilitation work be planned by JFMC/EDCs and RMU. The planned repair/rehabilitation works should be carried out by JFMC/EDCs before the monsoon season and the inspection to confirm the works shall be carried out by RMU.

(5) *Technical Assistance*

Technical assistance for the preparation of detailed design, cost estimate and time line will be provided by DMU, PMU, PMC and resource agencies within the government.

(6) *Timeline of the Works*

No.	Procedure	Responsibility	Timeline
1	**Planning (site section)**	JFMC//EDC, RMU/DMU/PMU	-
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2.3	Approval of design, cost estimate and construction schedule	DMU	7-14 days
2.4	Agreement of design, cost estimate and construction schedule)	JFMC/EDC/RMU	7 days
3.	**Construction**		
3.1	Appointment of Construction Supervisor (CS)	JFMC/EDC/RMU	7 days
3.2	Clearing of stub/jungle	JFMC/EDC and CS	3-14 days
3.3	Layout of the plan in the site	JFMC/EDC and CS	1-2 days
3.4	Arrangement of materials and equipment	JFMC/EDC and CS	1-7 days
3.5	Arrangement of labor	JFMC/EDC and CS	2-7 days
3.6	Construction	JFMC/EDC and CS	7 days
3.7	Final inspection	RMU	1 days

4. Other Catchment Conservation Works

As the other catchment conservation works, terraces (bench terrace, half-moon terrace), contour bunding (earthen, brushwood), mulching, plantation and filter strip along the river, river/stream bank protection (bandalling) are summarized in this chapter. Those measures are not commonly applied in Tripura. However, those measures are easy, effective and affordable SMC measures. Therefore, it is recommendable to apply those measures in the Project experimentally.

4.1 Terracing Work

The terracing method is a method in which the slope is arranged to a series of terraces, instead of the original slope. There are two (2) methods can be applied to Tripura condition, that is, the bench terraces and half-moon terraces.

(1) Bench Terrace

Objectives/ Functions

The bench terraces are a SMC measure used on sloping land with relatively deep soils to retain Bandalling water and control erosion. Those are normally constructed by cutting and filling to produce a series of level steps or benches. This allows water to infiltrate slowly into the soil. This practice is typical for rice-based cropping systems. In Tripura, the bench terraces can be found in the rubber plantation around the ridge of the steep hills.

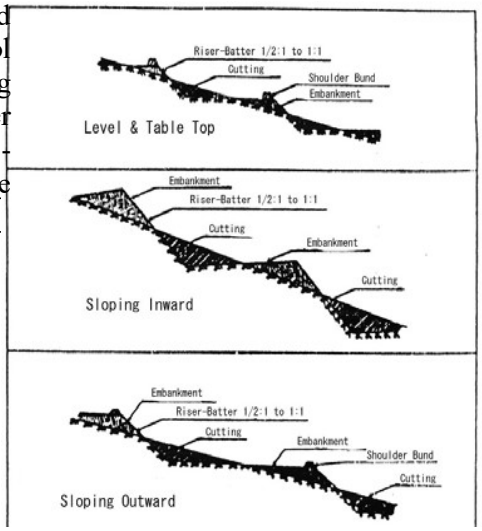


Figure 4.1 : Design of Bench Terraces

Planning and Design

The bench terraces can be constructed on slopes up to 50% (Model 1 and 2). Under field conditions in Tripura, inward sloping terraces would be more effective on account of high rainfall. The potential areas are the sloping land for the agro-forestry with relatively deep soils. The maximum spaces Between terraces are depend on maximum depth of productive soil and the maximum admissible cut for the land slope. The spaces between terraces are determined by the planting distance between trees within the maximum space of the land slope. Further main tree crops are planted in basins, and vegetative cover that is, grass, legumes, etc., is planted / sown in the spaces. The representative technical specifications of the bench terraces are shown in table below:

Table 4.1 : Representative Technical Specifications of Bench Terraces

Structure	Technical Specifications
Bench Terrace (Model 1 & 2)	- Suitable for up to 50 percent slope - Type of terrace: Inward sloping Horizontal interval and vertical interval depends on slope condition. - Slope 30 percent - Depth of cut0.63m - Width of terrace4.2m - Vertical interval1.80m

(1) *Half-moon terraces*

Objectives/ Functions

On moderate slopes (10-20 %) and steeper slopes (>20%), half-moon terraces (60cm diameter and 30cm in depth) are to be established for water harvesting purposes around the ridge of hills. Economic tree species, NTFP species and other species are to be planted in the basins.

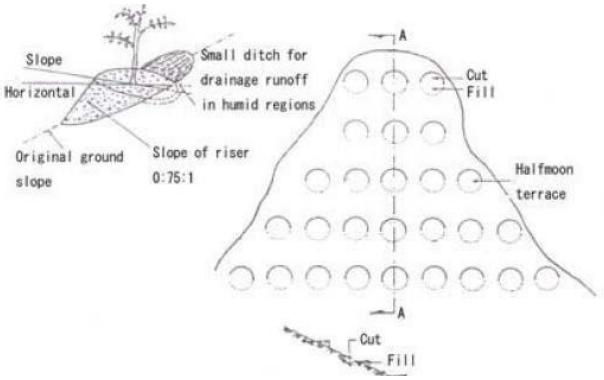


Figure 4.2 : Design of Half-Moon Terraces

Planning and Design

The potential sites of the half-moon terraces are the slope around the ridge of hills, in which the planting is difficult due to steep slope. The representative design and technical specifications are shown in Figure 4.2 and Table 4.2, respectively.

Table 4.2 : Representative Technical Specification of Half-moon Terraces

Structure	Technical Specifications
Half-moon Terraces	- Diameter of terrace0.25m - Half moon area 0.3925 sqm - Volume 0.355 cum. - Half terrace volume0.117

4.2 Contour Bunding

The contour bunding works consist of the earthen contour bunding and the brush wood contour bunding.

(1) Earthen Contour Bunding

Objectives/ Functions

The earthen contour bunding are the simple and low-cost method of constructing the earthen bund/embankment along the contour lines of the slope on gentle slope (< 10%) in order to store the runoff and sediment within the bund area, same as the trenches.

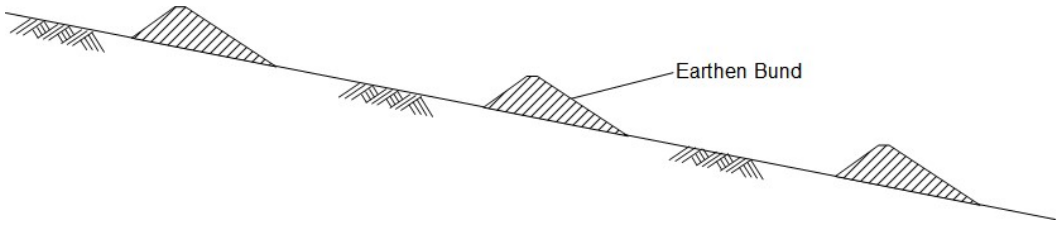


Figure 4.3 : Earthen Contour Band

Planning and Design

In Tripura, there are few possibilities to apply the earthen contour bunding. The potential area of the earthen contour bunding is the agro-forestry area on gentle slope with less than 10% (the model 1). The function bund are same as the trenches, that is, to store the rainwater between the bunds. Therefore, the height of bunds (impound depth of rainfall) and the vertical interval can be estimated with the same manner for the trenches. For the stability of bunds, vegetative measures i.e. grasses and trees are proposed to be plant over the bunds.

(2) Brushwood Contour Bunding

Objectives/ Functions

The brushwood contour bunding works are the method of constructing the brushwood bunds along the contour lines of the slope on moderate slope(10-20%)and steeper slope(>20%)in order to reduce the runoff velocity and to trap the sediment.

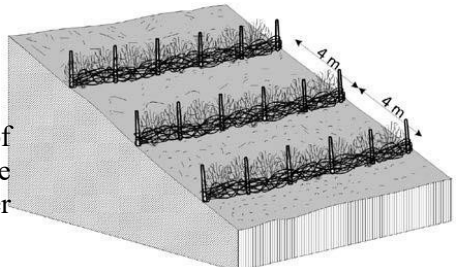


Figure 4.4 : Design of Brush Wood Bund

Planning and Design

The brushwood bunding can be constructed on moderate slopes (10-20 %) and steeper slopes (>20%) by using locally available brushwood supported by wooden stakes. Therefore, potential Slope of the works is limited by the availability of materials. The brushwood bunding is relatively easy to establish and maintain since it does not require external inputs and local unskilled labours can make them using locally available woody materials. It is also both sustainable and eco-friendly since there are no external inputs and no organic matter is burned in the process. The spaces between bunds are determined by the planting distance between trees. Further main tree crops are planted in basins, and vegetative cover that is, grass, legumes, etc., is planted / sown in the spaces. The representative design is shown in Figure4.4.

4.3 Mulching

1. Objectives/Function

Mulching is a SMC practice in which a covering of cut grass, crop residues or other organic materials is spread over the ground between rows of crops or around the trunks of trees. This practice helps to retain soil moisture to intercept the direct impact of raindrops on bare soil to reduces runoff and soil loss, to prevents weed growth, to reduces labor costs of weeding and enhances soil structure.

2. Planning

The application of the mulching depends on locally available materials. If the materials are available, plantation with mulching shall be applied.

4.4 Filter Strip and Plantation along River/Stream

Filter strip and/or river bank plantations shall be established in order to protect or restore riparian areas and ecosystems and mitigate risks of soil erosion at river banks. Both filter strip and river bank Plantation will be conducted basically by Department mode, since the most of the sites for these are expected to be beyond JFMC/ EDC project areas and the beneficiaries are not limited to JFMC/ EDC members. Thus, RMU shall have key responsibility for application of these. However, in case the sites are located in the JFMC/ EDC project areas, they will be conducted by JFMC/ EDC mode. In this case, RMU will take the initiative to apply these and consult with JFMC/ EDC. Then, if JFMC/ EDC agrees the plan of establishment of the plantation shall be incorporated in their micro plan and JFMC/ EDC shall be responsible for creation and maintenance of the plantation under supervision of RMU.

(1) Filter Strip

Objectives/ Functions

The objectives of development of filter strips are to slow runoff from field, trap and filter sediment, organics, nutrients, pesticide and other pollutants before they reach surface water in streams. In addition, it is also expected to reduce soil sheet erosion as well as increase infiltration of rain water. Filter strip is not familiar to the state, thus, this activity will be implemented as trail to accumulate knowledge and experience of development of filter strips.

Methodology

Filter strips shall be developed along narrow streams with gentle slope around15%with 50 feet width strip consisting of plants of different species planted in rows. The design of a filter strip is shown in the figure below. Main components are bamboo, cane, and tree. In the first row towards a stream, 222 bamboos per km shall be planted at spacing 4.5m × 4.5m, 222 cane per km shall be planted at spacing 4.5m × 4.5m in

the second row, and 333 trees per km shall be planted at spacing 3 m x 3 m. After planting bamboo, cane, and trees, maintenance work including weeding is necessary for four years to protect seedlings planted from competition with weeds over light and water.

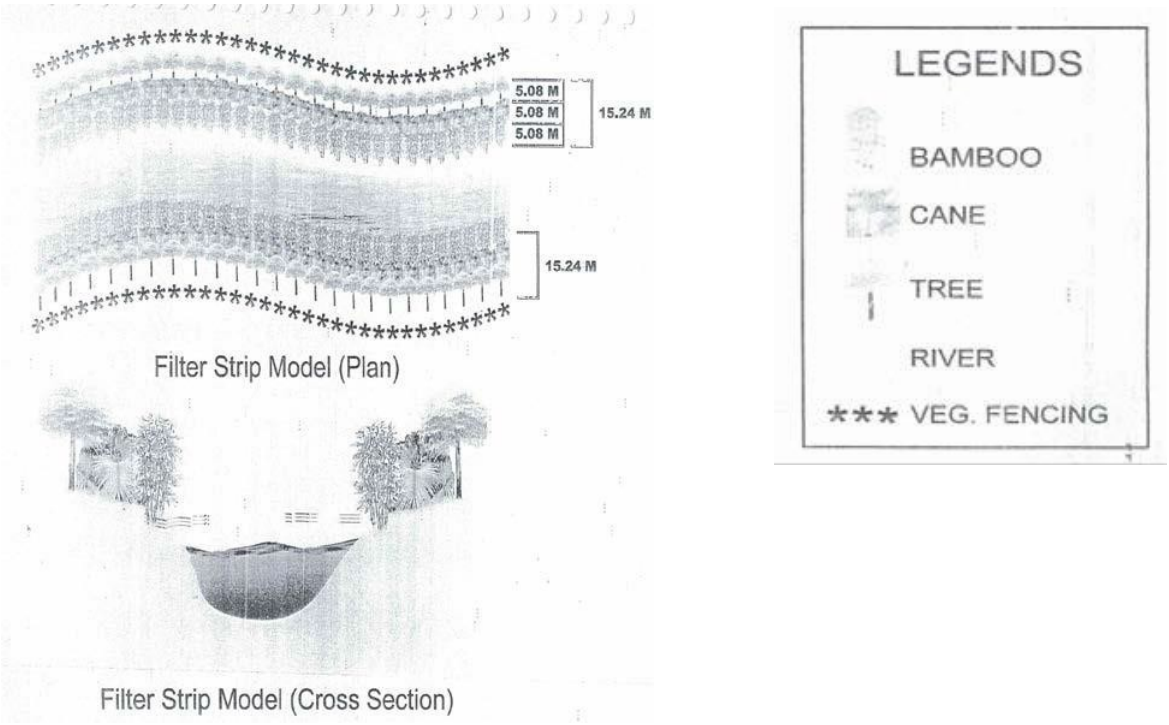


Figure 4.5 : Filter Strip

Implementation Step

<Preparatory Work>
Step1: Select site based on the following criteria: relatively gentle slope around 15 %, area adjacent agricultural lands or lands used for grazing. Site selection will be conducted by Range Officer in consultation with DFO and Beat officers. In case a site is located inside a JFM project area, Range Officer will propose a candidate site to JFMC and the site will be decided with agreement of JFMC. Step 2: Survey the site using GPS instrument and prepare the site including cutting of jungle and disposal of debris etc.
<Creation and Maintenance of 1st year>
Step 1: Digging of pits of 30 cm x 30 cm x 30 cm size up to 222 nos pits each for bamboo and canes with 4.5 m x 4.5 m spacing in a line and 333 nos pits for tree species with 3 m x 3m spacing in a line. The interval between the lines is 5 m.
Step 2: Re-filling of pits after removal of foreign materials, breaking clods and planting stumps/ rhizomes/ seedlings.
Step 3: Closure and fencing with bamboo.
Step 4: Fist weeding including base cleaning at a radius of 0.5 m and cutting weeds in between the lines.
<2nd year Maintenance>
Step1: First weeding including cleaning the base at a radius of 0.5 m and cutting weeds in between the lines.
Step 2: Maintenance fencing if necessary.
Step 3: Second weeding including cleaning the base at a radius of 0.5 m and cutting weeds in between the lines.
<3rd year Maintenance>
Step1: First weeding including cleaning the base at a radius of 0.5 m and cutting weeds in between the lines.
Step 2: Maintenance fencing if necessary.

Step 3: Second weeding including cleaning the base at a radius of 0.5 m and cutting weeds in between the lines.
<4th year Maintenance>
Step1: First weeding including cleaning the base at a radius of 0.5 m and cutting weeds in between the lines.
Step 2: Second weeding including cleaning the base at a radius of 0.5 m and cutting weeds in between the lines.
Step 3: Making fire line 4 m wide and inspection paths 1 m wide and maintenance of them.

Responsibility

In principle, RMU has responsible for site selection, creation and maintenance of this activity under supervision of SDMU/DMU. In case where the activity is conducted in JFMC/ EDC project areas, JFMC/ EDC will be responsible for creation and maintenance of the plantation with support by BO under supervision of RMU. In either cases experience and knowledge obtained through development of filter strips shall be compiled and analyzed by PMU to abstract lessons for future development of filter strips.

(2) River/ Stream Bank Plantation

Objectives/Functions

The objectives of river bank plantation are to reduce soil erosion at river banks, stabilize river banks, check damage of agricultural fields and habitats from flood, serve shelter belt, and provide nutrients for aquatic organisms.

Methodology

Trees shall be planted in liner way along river banks with a single or double row (s) with spacing 3 m x 3 m. After planting, maintenance work including weeding will be carried out for four years to protect seedlings planted in the field from competition with weeds over light and water. Regarding selection of species, soil binding species such as bamboo, cane, tree species such as Dalbergia latifolia and Vitex peduncalaris are recommended. Fruit bearing tree species shall also be planted to enrich river ecosystem.

Implementation Step

<Preparatory Work>
Step1: Select a site based on the following criteria: eroded river bank or vulnerable river bank to erosion, existence of residential areas or agriculture lands along the river or lower catchment of the river, or needs of rehabilitation of vegetation from a view point of biodiversity. Site selection will be conducted by RMU in consultation with DMU and BO.
Step 2: Survey the site using GPS instrument and prepare the site including cutting of jungle and disposal of debris etc.
<Creation and Maintenance of 1st year>
Step 1: Digging of pits of 30 cm x 30 cm x 30 cm size up to 333 nos pits with 3 m x 3m spacing in a line. The interval between the lines is 5 m.
Step 2: Re-filling of pits after removal of foreign materials, breaking of clods and planting of stumps/ rhizome/ seedlings.
Step 3: Closure and fencing with bamboo.
Step 4: First weeding including base cleaning at a radius of 0.5 m and cutting weeds in between the lines.
<2nd year Maintenance>
Step 1: First weeding in the same way as the 1st year. Step 2: Maintenance of fencing if necessary.
Step 3: Second weeding including cleaning the base at a radius of 0.5 m and cutting weeds in between the lines.

<3rd year Maintenance>
Step 1: First weeding in the same way as the 1st year. Step 2: Second weeding in the same way as the 2nd year.
Step 3: Making fire lines 4 m wide and inspection paths 1 m wide and maintenance of them.
<4th year Maintenance>
Step 1: First weeding in the same way as the 1st year. Step 2: Second weeding in the same way as the 2nd year.

Step 3: Making fire lines 4 m wide and inspection paths 1 m wide and maintenance of them.

Responsibility

In principle, RMU will be responsible for site selection, creation and maintenance of river bank plantations. In case, a river bank plantation will be established in JFMC/ EDC project area, JFMC/ EDC has responsible for creation and maintenance of the plantation with support by BO under supervision of RMU.

4.5 Bandalling

(1) Objectives/ Functions

The Bandalling works are a kind of permeable spur-dike works which are widely used in the Indian sub-continent. The objective of bandalling in the Project is to stabilize a river bank where a filter strip or a river bank plantation is established through mitigation of intensity of the water flow. Otherwise the effect of a filter strip or a river bank plantation cannot demonstrate fully because the ground on which the plantations are established probably falls down by erosion in the near future due to erosion at the bottom of the river bank by water flow.

(1) Methodology

Bandalling structures will be constructed with bamboo at a certain angle with water flow direction usually 30 to 40 degrees depending on the flow intensity. Around 2 m length of bamboos will be driven into a river bed by 50 cm. Those bamboos driven into the riverbed will be tighten with the bamboo matt, or, with bamboo crossbars in two steps, upper and lower steps. Construction of bandalling structures is not familiar to Tripura, thus, it will be conducted as trial base. Construction work will be conducted during the dry season when the water level is low.

Pic: Bandalling structure implemented at Burakha Beat (Tripura)

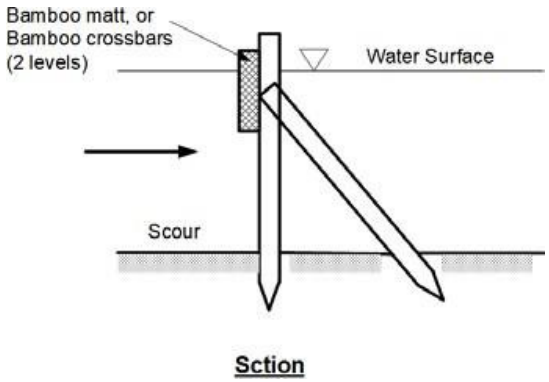


Figure 4.6 : Bandalling Structure Back portion

(2) ***Implementation Steps***

Step1: Identify a site for construction of bandalling structures within the target sites of filter strips and river bank plantations. The site for construction of bandalling structures shall be selected based on the following criteria: erosion of the river bank, depth of a river (less than1m in dry season), height of river bank (less than2.5m). The selection will be made by RMU.

Step 2: Prepare bamboos with 2 m length.
Step 3: Drive the bamboo piles with 30 – 50 cm interval in the riverbed with 30 to 40 degrees towards the water flow. A row of the bamboo piles is supported by the bamboo piles.
Step 4: Tight the bamboos with the bamboo matt or, with bamboo crossbars in two steps, upper and lower steps.

(3) ***Responsibility***

RMU has responsibility for planning and implementation of this activity. As mentioned above, this activity is not familiar to TFD hence DMU, PMU and PMC shall give a proper guidance to RMU.

(4) ***Maintenance and Sustainability (to be revised in order to avoid misunderstanding)***

Basically, the bandalling structures with bamboo do not require maintenance and sustainability from a long-term perspective since the function of the structures is to stabilize the river bank for a while until a filter strip or a river bank plantation is established and roots of trees or bamboo planted firmly bind soil. The flow of the river will change time to time, so that bandalling structures are not expected to demonstrate the function long term. From these points of view, maintenance and sustainability is not required for this activity.

4.6 Timeline of the Works

No.	Procedure	Responsibility	Timeline
1	**Planning (site section)**	JFMC//EDC, RMU/DMU/PMU	-
2	**Design**		
2.1	Detailed Design	RMU	7-14 days
2.2	Cost estimate	JFMC/EDC/RMU	
2.3	Approval of design, cost estimate and construction schedule	DMU	7-14 days
2.4	Agreement of design, cost estimate and construction schedule)	JFMC/EDC/RMU	7 days
3.	**Construction**		
3.1	Appointment of Construction Supervisor (CS)	JFMC/EDC/RMU	7 days
3.2	Clearing of stub/jungle	JFMC/EDC and CS	3-14 days
3.3	Layout of the plan in the site	JFMC/EDC and CS	1-2 days
3.4	Arrangement of materials and equipment	JFMC/EDC and CS	7-30 days
3.5	Arrangement of labor	JFMC/EDC and CS	7-14days
3.6	Construction	JFMC/EDC and CS	7-14 days
3.7	Final inspection	RMU	1 days

4. Water Harvesting Work (Check Dam)

4.1 Objectives/Functions

The water harvesting work is to create a crossing structure in the valley and a upstream impound/reservoir of the structure in order to use the stored water for various human activities, such as, irrigation live-stock, pisciculture, etc. In addition, the function of the water harvesting work is also to regulate the flood discharge and to provide sediment storage and environmental improvement through onsite and offsite effects.
During the Phase I Project, three (3) types of the check dams were adopted as the water harvesting structures in considering of the terrain condition.

In this Project, three (3) models of check dams as the water harvesting structures will also be constructed in the valleys related to the sustainable forest management activities in the target catchment areas/beats: earthen (two models) and concrete core embankment or reinforced concrete structures. Site condition, main purpose, and stakeholders for the activities of respective check dams are summarized in the table below:

Table 5.1 : Check Dams Applied in the Project

Model	Model 1	Model 2	Model 3
Type of Check Dam	Small earthen check dam, Spill way, Planting around the impound (depending on vegetation on site)	Short earthen check dam with clay core, submerged spillway, planting around the impound (depending on vegetation onsite)	Earthen embankment with concrete core or reinforced concrete check dam (average 40 m), submerged spillway, planting around the impound (depending on vegetation on site)

Site condition	Upper part Terrain : narrow valley (just downstream site of gully) Slope : 10-20 % or > 20% Catchment less than 5 ha (less than 223m square)	Middle part Terrain: narrow valley Slope: 10-20% Catchment less than 10 ha (less than 316 m square)	Lower part Terrain: wide valley Slope: gentle, less than 10% Catchment less than 20 ha (less than 447 m square), with water spread area around 2 ha
Main purpose	Water conservation and domestic water use	Water conservation, domestic water use and fishery	Water conservation, domestic water use, fishery and irrigation
Proposed number of dams	3 dams per a JFMC/ EDC in average	2 dams per a JFMC/ EDC in average	0.2 dam per a JFMC/ EDC in average
Stakeholders of activities			
Site selection	RMU in consultation with JFMC/ EDC	RMU in consultation with JFMC/ EDC	RMU in consultation with JFMC/ EDC
Survey/design	survey and design by RMU, cost estimate by JFMC/ EDC under assistance of RMU	survey and design by RMU, cost estimate by JFMC/ EDC under assistance of RMU	RMU under assistance of DMU, PMU, PMC and DPW

Model	Model 1	Model 2	Model 3
Construction	Construction by JFMC/ EDC under supervision of RMU	Construction by JFMC/ EDC under supervision of RMU	Construction by JFMC/ EDC led by RMU
Operation	Operation and monitoring by JFMC/ EDC under assistance of RMU	Operation and monitoring by JFMC/ EDC under assistance of RMU	Operation by JFMC/ EDC under monitoring of RMU
Maintenance	JFMC/ EDC under technical assistance of RMU	JFMC/ EDC under technical assistance of RMU	JFMC/EDC led by RMU under assistance of DMU, PMU, PMC and DPW

Earthen check dams of Model1and 2 which are relatively small scale structures and can be constructed and maintained by local communities (JFMC/ EDCs) are the most cost-effective measures in the long run under Tripura conditions. The concrete core embankment or reinforced concrete check dams of Model 3 which are larger structures and bear water pressure and soil pressure on the valleys and concrete structures require some degree of construction skills and larger investment. Therefore, construction and maintenance of Model 3 shall be done by JFMC/EDC led by RMU, especially for quality control aspect, and also under assistance of DMU, PMU, PMC and DPW.

For implementation of check dams works, it is recommended to refer the following two (2) documents as the technical references:

- Tim Stephens, "Manual on small earth dams – A guide to siting, design and construction, FAO Irrigation and Drainage Paper64", Food and Agriculture Organization of the United Nations, 2010. http://www.fao.org/3/i1531e/i1531e00.htm
- Bureau of Reclamation, United States Department of the Interior, "Design of Small Dams – A Water Resources Technical Publication, Third Edition", United States Department of the Interior, 1987. https://www.usbr.gov/tsc/techreferences/mands/mands-pdfs/SmallDams.pdf

5.2 Implementation of Check Dam Works

Planning, design, construction, and O&M of the check dams works as the water harvesting works) are described below:

(1) *Planning*

Site selection shall be made through the following steps:

Step 1: To screen small catchments (<5ha, <10ha and <20 ha) with points where are the valleys/streams in management area of JFMC/ EDC with air/satellite photographs and GIS by RMU of the Project, and where are the candidate of the potential sites considering the following matters..

- For the model 1 (upper part): downstream of the place where the valley has spread **(Lunga)** or outlet of valley in the micro hill (< 5ha).
- For the model 2 (middle part): down stream of the place where the valley has spread or outlet of valley in small hill (< 10ha)
- Forthemodel3:(down stream part):downstream of the place where the valley has spread or outlet of valley in medium hill (< 25ha)

Step 2: To identify the potential sites from the candidate sites by RMU of the Project, in consultation with representative members of the target JFMC,/ EDC in consideration of the following criteria:

- The water storage area of the check dam should be large as much as possible.
- The length of the check dam (the width of valley) should be short as much as possible.
- The slope of the valley bed at the site should not be steep. Difference of the elevation between upstream and downstream of the site should be within 2 - 2.5m.
- The soil material should be available in and around site.
- The site should be with appropriate accessibility from the villages of JFMC/EDC.
- In consideration of the effect indicator of the Project, the site should be located within 500 m radius from the villages of JFMC/ EDC which have no accessibility to water.
- The site should be appropriate for the other proposed activities of JFMC/EDC.

Step 3: To confirm the potential sites and to finalize proposed check dam sites by the joint inspection of RMU and representative members of the target JFMC/ EDC, in consideration of scale of check dam, efficiency of check dam, willingness of JFMC/ EDC, budget constraint, and the numbers of respective check dams per a JFMC/ EDC and the characteristics in the area of JFMC/ EDC, such as total number of members, number of included villages, activities, management area, etc. However, priority should be given to the potential site of the check dam within 500 m radius from the villages of JFMC/ EDC, which have no accessibility of water, and willingness of JFMC/ EDC.

(2) Design

After approval of the planning by DMU, the detailed design of check dams of model 1 & 2 shall be prepared by RMU. Based on the detailed design, JFMC/EDCs shall prepare cost estimate and timeline in consultation with RMU. DMU will approve the proposed design and amount sanctioned, and minutes of understandings shall be signed between JFMC and RMU.

For the model 3 check dams, RMU shall prepare the detailed design, cost estimate and time line under assistance of DMU, PMU and PMC. DMU shall approve the detailed design and cost estimate.

Prior to the detailed design, the following survey and study shall be conducted by RMU:

- Topographic survey of site: longitudinal sections of the site at 10 m intervals and cross sections with extent covers the proposed embankment, other facilities and expected impound area.
- Study results of the natural condition around the proposed site, such as, 24 hour rainfall records, soil texture, degree of soil degradation, severity of erosion, land capability criteria, infiltration rate, land use, etc.

Representative design the check dams are as follows:

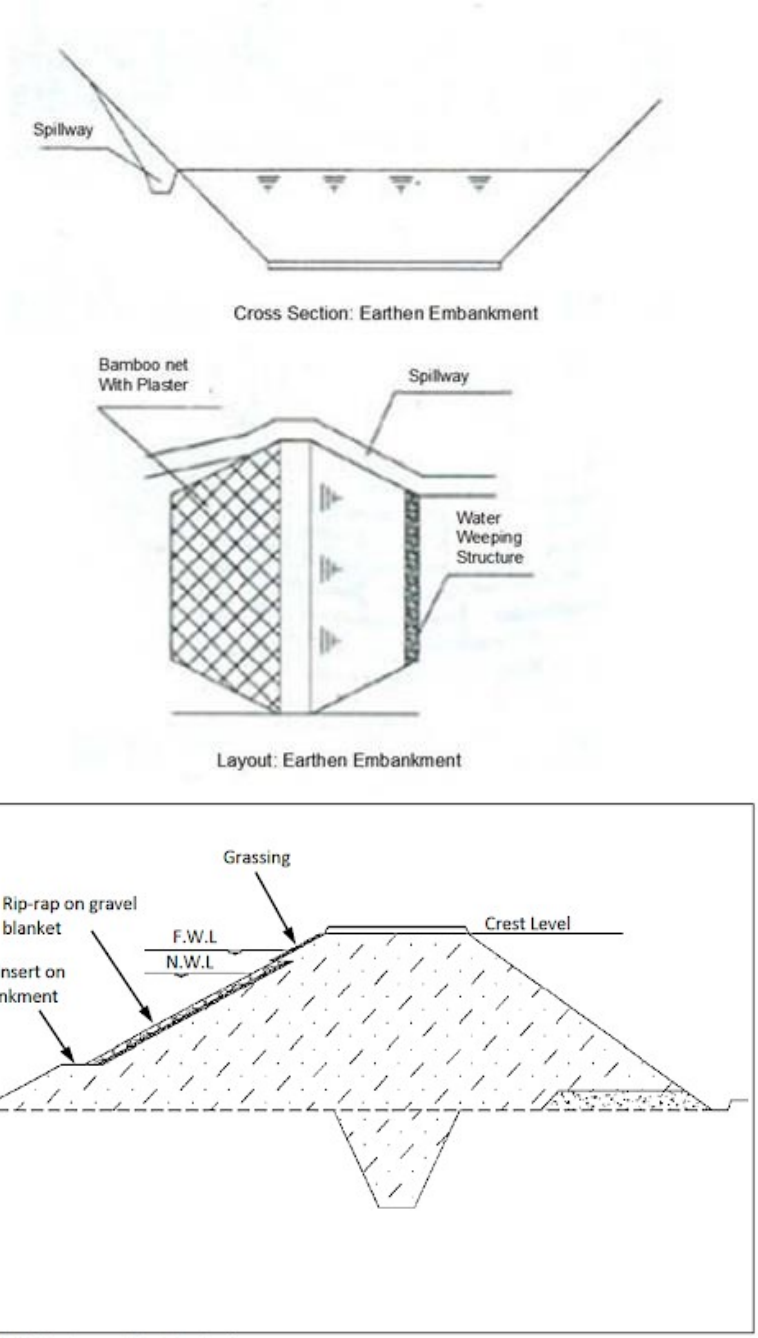


Figure 5.1 Design of Earthen Check Dam

During the detailed design, the following matters shall be kept in mind :

- On wide valleys with gentle slopes (<10%), long earthen embankments will be constructed with relatively large water surfaces (< 2.0 ha). On narrow valleys with moderate slopes (10-20 %), small earthen embankments will be constructed with relatively small water bodies (<0.5 ha). Key trenches should be excavated into impervious foundation structures to prevent embankments from collapsing.
- Impermeable core walls will be introduced to prevent seepage and collapsing of embankments. While concrete-type core walls are sometimes adopted, mud core walls would be considered at sites where suitable soils for impermeable core walls are easily obtained. Types of core wall can be decided from the results of soil surveys at the detailed design stage.
- Spillways are to be lined with brick mortars to prevent erosion from the slopes. In order protect the river/stream bed and banks downstream of the spillway from the spillway discharge the brush wood, sand bags, or mortal gunny bags shall be installed.
- Downstream side slopes of the embankment are to be covered by grass turfing. Up-stream side slope surfaces of the embankment are to be lined with vegetative materials, such as bamboo net with mud/cement plaster, to reduce seepage and prevent scouring by run-off water or wind wave. Coconut leaves / banana leaves may be introduced to the bottom of down-stream side slopes of the embankment as water weeping material.
- Water outlet pipe at the bottom of the check dam shall be included and designed in order to use the impound water for the inhabitant activities.
- In addition, the wooden staircase at the bank (at least one side) of impound area shall be installed from impound surface to the valley bed, considering the water use and avoiding the damage of embankment.
- Around the impound area of the check dam, bamboo plantations and NTFP plantations are to be established to reduce the amount of soil flowing from the slopes into the water and to prevent sedimentation.

(3) Construction

Construction of the check dams of Model 1 and Model 2 shall be conducted by JFMC/ EDC with the appointed CS under the assistance of RMU and Model 3 by JFMC/EDC led by RMU under assistance of DMU, PMU, PMC and DPW.

Firstly, the check dams of Model 2 will be constructed after the plantation works of JFMC/ EDC, in consideration of establishment of fishery by JFMC/ EDC. Secondly, the check dams of Model 1 will be constructed, and finally Model 3.

During the project period, JFMC/ EDCs will be established dividing JFMC/EDCs into 3 groups. Therefore, the construction works of the check dams will also divided into 3 groups.

(4) Operation and Maintenance

The check dams of Model 1 and Model 2 shall be operated and monitored by JFMC/ EDC under assistance of RMU. On the other hand, the check dams of Model 3 will be operated by JFMC/ EDC under assistance of RMU and maintained by JFMC/EDC led by RMU of the Project. The revolving fund of JFMC/ EDC shall be used for the operation and maintenance.

Tripura has extremely erosive soil with intensive rainfall. Due to this condition, the earthen part of the check dams, especially downstream slope of embankment, will deteriorate. Therefore, periodical maintenance works are indispensable to maintain the function of the check dams. Required repair works of the periodical maintenance will be once in every two years with repair of embankment slope and its

vegetation cover, especially downstream slope of the check dam, and removal of sediment in the impound. Design of the maintenance works of all models shall be prepared by RMU. The periodical maintenance works for the check dams of Model 1 and Model 2 shall be conducted by JFMC/EDC under the technical assistance of RMU and those of Model 3 by JFMC/EDC led by RMU of the target catchment/beat. In addition to the periodical maintenance works of the check dams, repair of the vegetation cover of the embankment slope shall be conducted at any time.

(5) Technical Assistance

Technical assistance for the preparation of detailed design, cost estimate and timeline will be provided by DMU, PMU, PMC and resource agencies within the government, especially PWD.

(6) Timeline of the Works

No.	Procedure	Responsibility	Timeline
1	**Planning (site section)**	JFMC//EDC, RMU/DMU/PMU	-
2	**Design**		
2.1	Detailed Design	RMU	7-21 days
2.2	Cost estimate	JFMC/EDC/RMU	
2.3	Approval of design, cost estimate and construction schedule	DMU	7-14 days
2.4	Agreement of design, cost estimate and construction schedule)	JFMC/EDC/RMU	7 days
3.	**Construction**		
3.1	Appointment of Construction Supervisor (CS)	JFMC/EDC/RMU	7 days
3.2	Clearing of stub/jungle	JFMC/EDC and CS	3-14 days
3.3	Layout of the plan in the site	JFMC/EDC and CS	1-2 days
3.4	Arrangement of materials and equipment	JFMC/EDC and CS	7-30 days
3.5	Arrangement of labor	JFMC/EDC and CS	7-14 days
3.6	Construction	JFMC/EDC and CS	20-60 days
3.7	Final inspection	RMU	1 days

ATTACHMENT - 1

Attachment1 : Representative Design of Check Dams

The design drawings shall be compiled in the next revised version through implementation of the Project. For the time being the standard drawings in Annex 4, “Manual on small earth dams”, FAO will be helpful and are attached hereunder;

DRAWING OF EARTHEN CHECI< DI\M

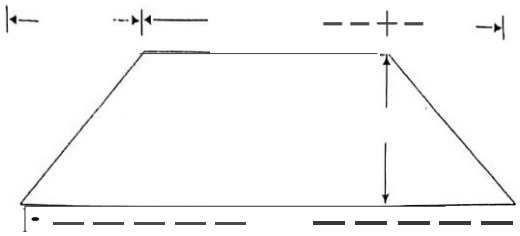


Fig:• 1 Cross·s ct iun of dam

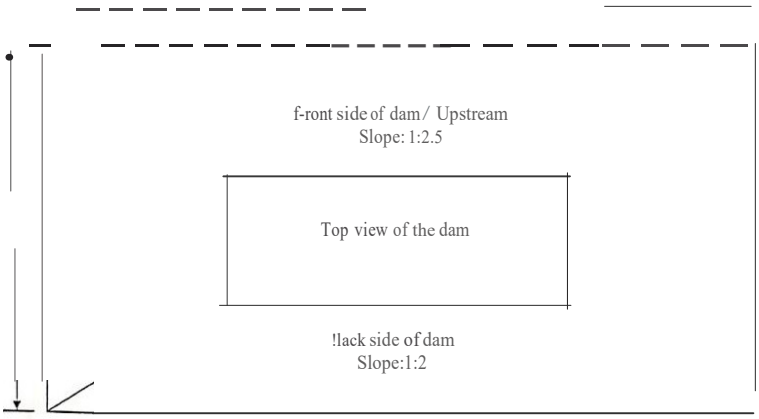


Fig:- 2 Plan of dam and cut-off trench

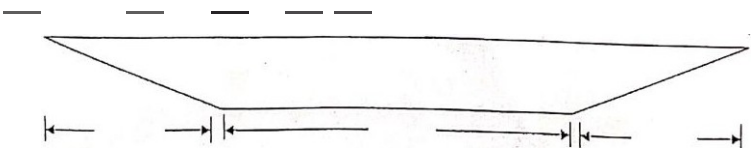
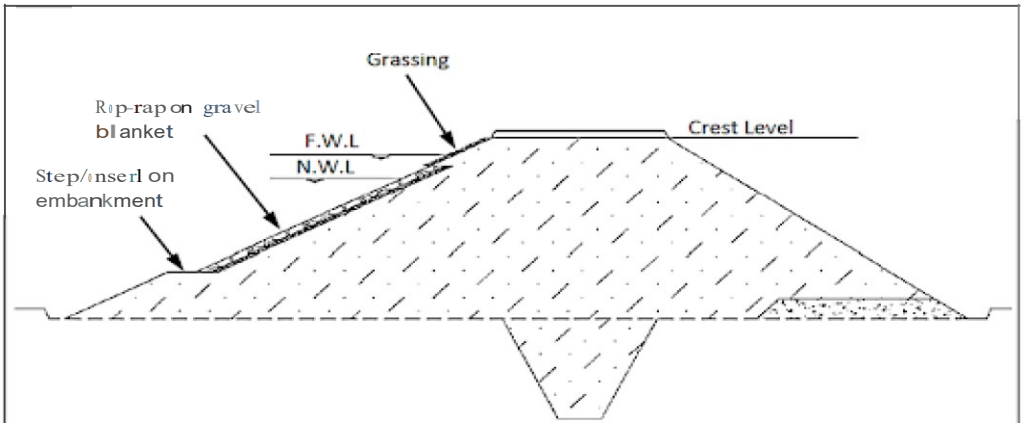
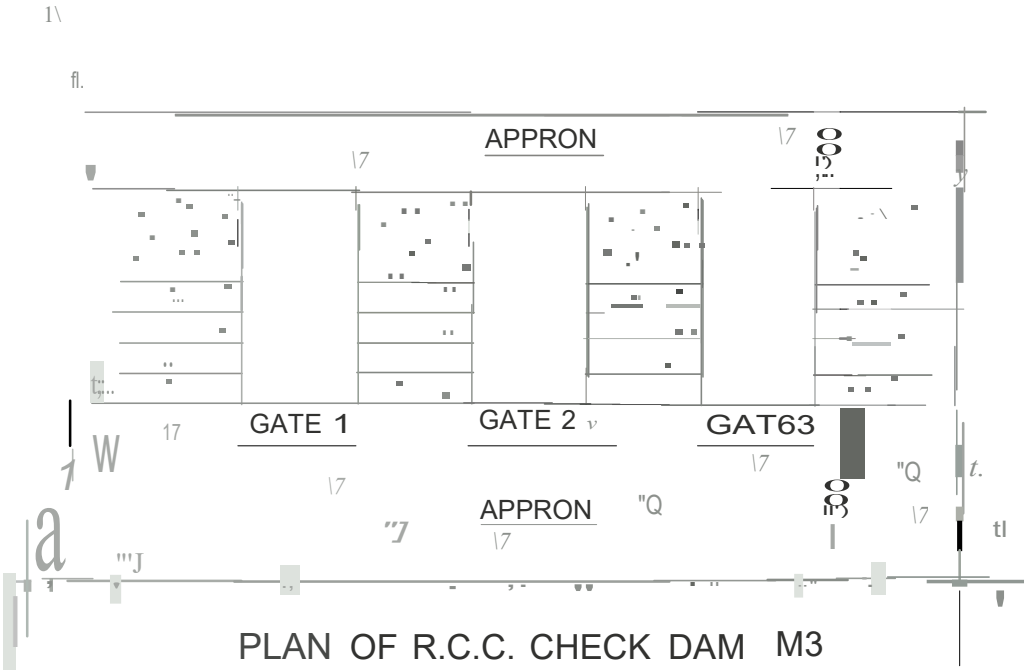


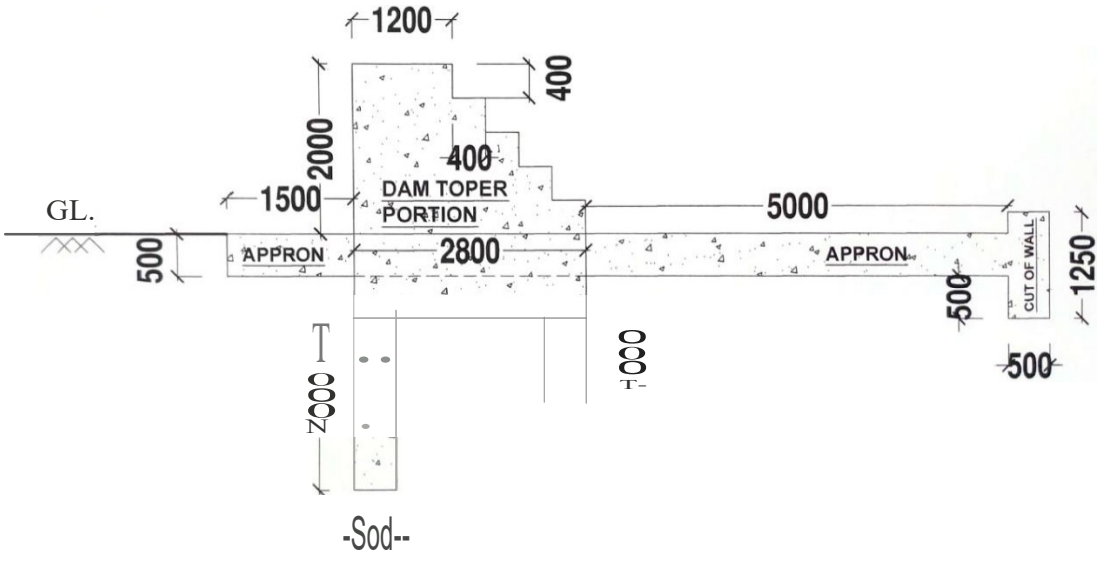
Fig:- 3 Elevation of proposed dam



Modal –11 Check Dam



PLAN OF R.C.C. CHECK DAM M3



SECTION

Modal -III R.C.C Check Dam

1. https://www.google.com/imgres?imgurl=http%3A%2F%2Fecoursesonline.iasri.res.in%2Fpluginfile.php%2F2187%2Fmod_page%2Fcontent%2F1%2Ffig-29.9.jpg&imgrefurl=http%3A%2F%2Fecoursesonline.iasri.res.in%2Fmod%2Fpage%2Fview.php%3Fid%3D1933&tbnid=-clQNTyptBQgQM&vet=10CCUQMyh2ahcKEwi4rrj3_cHpAhUAAAAAHQAAAAAQAg..i&docid=yzhI7o4Huiu2-M&w=626&h=270&q=brushwood%20check%20dam&ved=0CCUQMyh2ahcKEwi4rrj3_cHpAhUAAAAAHQAAAAAQAg
2. https://www.google.com/imgres?imgurl=https%3A%2F%2Fd8zcwdvc14g2e.cloudfront.net%2FcontentAsset%2Fimage%2F9bc05d21-51f4-4d91-8323-5e120a0c1596%2Fimage%2FbyInode%2F1%2Ffilter%2FResize%2CJpeg%2Fjpeg_q%2F70%2Fresize_w%2F1400&imgrefurl=https%3A%2F%2Fnews.trust.org%2Fitem%2F20140814152515-7hnau%2F&tbnid=CyOJ-ve_wp22-M&vet=12ahUKEwjL1LjNiMLpAhXR7TgGHbGaBSkQMygWegQIARA-..i&docid=ZUhC1ujX1kAYCM&w=1400&h=946&q=brushwood%20check%20dam&ved=2ahUKEwjL1LjNiMLpAhXR7TgGHbGaBSkQMygWegQIARA-
3. https://www.google.com/imgres?imgurl=https%3A%2F%2Fwww.researchgate.net%2Fprofile%2FMd_Nayem_Hasan_Munna%2Fpublication%2F332878741%2Ffigure%2Ffig6%2FAS%3A755608970088452%401557162625620%2FBrushwood-check-dams.jpg&imgrefurl=https%3A%2F%2Fwww.researchgate.net%2Ffigure%2FBrushwood-check-dams_fig6_332878741&tbnid=PM9dctkBGl2j4M&vet=12ahUKEwjL1LjNiMLpAhXR7TgGHbGaBSkQMygAegUIARD3AQ..i&docid=UniB9h4ny9MHeM&w=850&h=565&q=brushwood%20check%20dam&ved=2ahUKEwjL1LjNiMLpAhXR7TgGHbGaBSkQMygAegUIARD3AQ
4. Link:- https://www.google.com/url?sa=i&url=https%3A%2F%2Fsswm.info%2Fsswm-solutions-bop-markets%2Fimproving-water-and-sanitation-services-provided-public-institutions-0%2Fcheck-dams-%2526-gully-plugs&psig=AOvVaw02nixs5lpk3gBWsAKOGdih&ust=1590051243132000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCLiuuPf9wekCFQAAAAAdAAAAABAF

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