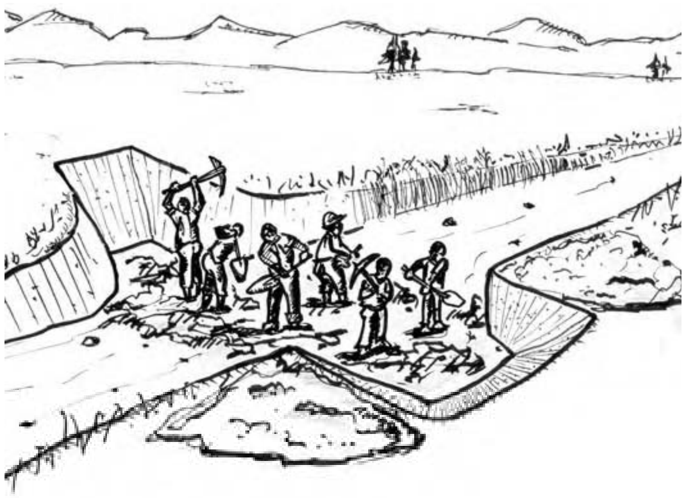
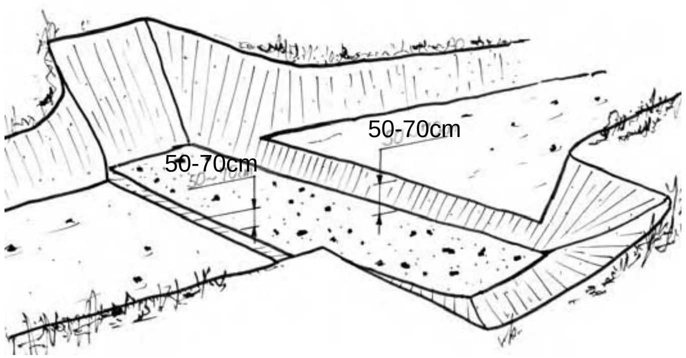
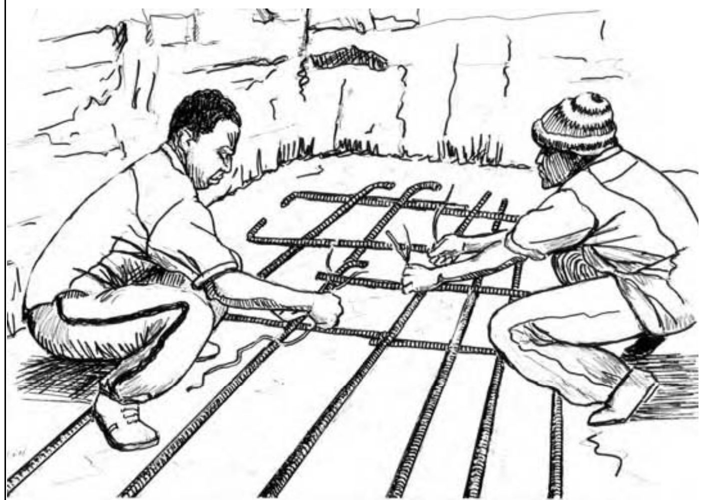
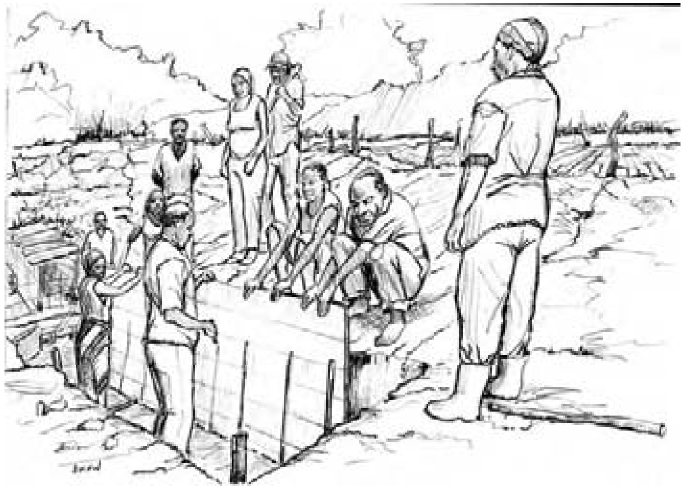
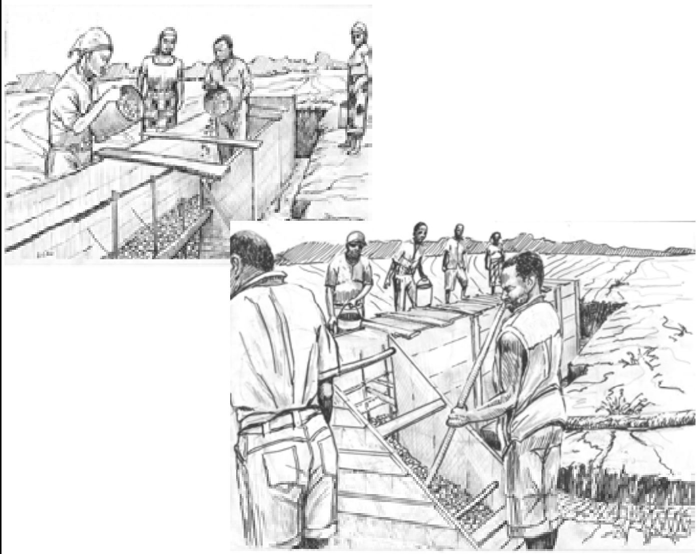
6. Construction of Permanent Weir: Concrete Wall Type (preparation process is same as the steps in 5. Wet Masonry Wall Type)

Step	Process	Description	Remarks
5		**Excavation of River foundation:** While keeping construction site dry, excavate the river/stream bed of the construction site until all the organic materials deposited therein have been removed and to the depth where hard foundation is found. Abutment should also be excavated at least 2 m to the horizontal direction into river bank on both sides.	Materials and tools to be prepared should refer to the steps in 5. Wet Masonry Type. Also, dewatering (or diverting the stream water to downstream) should refer to the relevant steps in 5. Wet Masonry Type.
6		**Further Excavation:** Foundation of the diversion weir to be constructed should further be excavated 50 cm to 70 cm in depth unless otherwise there is already rock foundation.	If soft soil or unsuitable soil is exposed, additional excavation should be carried out. **Attention:** To prevent landslide, shape of the wall at abutment should be in slope, if the depth of excavation is expected to be deeper than 1.5m.

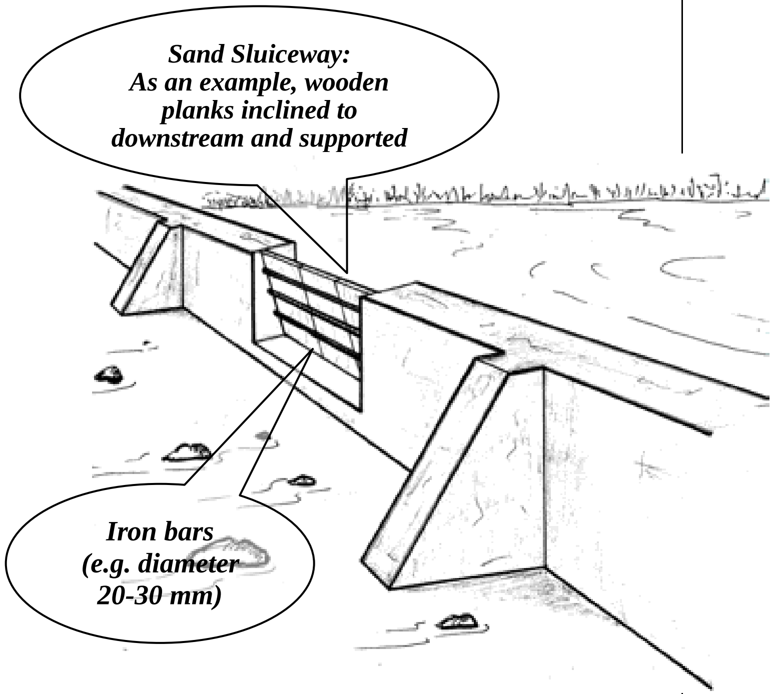
Step	Process	Description	Remarks
7		**<u>Chipping Rocky Foundation:</u>** If there is rock on the bottom of river bed, chipping should be done to make concrete to firmly contact with the foundation.	To chip the rocks, you may use hammer, and chisel if you have. Otherwise chip the rock foundation by hammer.
8		**<Weir Construction>** **<u>1) Assembling Reinforcement bars (for base concrete)</u>** Assemble the reinforcement bars as shown in the left illustration including the base concrete portion (reinforcement bars should start from the base concrete). It is recommended to assemble the bars at intervals of 25-30cm. (usually 30cm). As for the size of reinforcement bar, Y12 (12mm) and Y16 (16mm) of diameter are usually used for weir construction. Y means deformed bar.	Make sure that the persons who deal with the reinforcement bars should wear gloves for safe.

Step	Process	Description	Remarks
9		**<u>2) Assembling Reinforcement bars (for weir wall)</u>** Assemble the reinforcement bars as shown in the left illustration including the base concrete portion (reinforcement bars should start from the base concrete). It is recommended to assemble the bars at intervals of 25-30cm. (usually 30cm). As for the size of reinforcement bar, Y12 (12mm) and Y16 (16mm) of diameter are usually used for weir construction. Y means deformed bar.	Y12 and Y16 are used for horizontal and vertical members respectively. Make sure that the persons who deal with the reinforcement bars should wear gloves for safe.
10	  	**<u>3) Measuring Materials for Concrete Mixing:</u>** In order to get proper concrete for weir construction, standard mixing proportion of cement to sand and crushed stone is: 1 : 2 : 4 in terms of volume, which is equivalent to 1 bag of cement (50kg), 2 bags of sands and 4 bags of crushed stones. To measure the materials for making concrete, the batch box is useful. The volume of the box is 37 little which is equivalent to the amount to one pocket of cement. The size of the box is 0.6m * 0.3m * 0.21m.	Prepare drums of water for concrete mixing at the site on the day of construction. The water should be clean. If the sand is dry, pour 1 jerrican (20 liter) of water and mix it in advance. Then, additional water should be sprayed and mixed to keep proper consistency. Stones should be crushed in advance with a diameter of 15-20 mm. The mixing should be carried out on an exposed rock foundation or floor like thin concrete base, otherwise soil could be mixed up, making the concrete quality poor.

Step	Process	Description	Remarks
11	 Note: Concrete shall be mixed on a rock foundation, on a steel plate or otherwise at first construct a floor like thin flat concrete base and start mixing concrete thereon	**<u>4) Concrete Mixing:</u>** Prepare drums of water for concrete mixing at the site on the day of construction. The water should be clean. If the sand is dry, pour 1 jerrican (20 liter) of water and mix it in advance. Then, additional water should be sprayed and mixed to keep proper consistency. Stones should be crushed in advance with a diameter of 15-20 mm.	The mixing should be carried out on an exposed rock foundation or floor like thin concrete base, otherwise soil could be mixed up, making the concrete quality poor.
12		**<u>5) Placing the base concrete</u>** The base concrete with horizontally placed wire mesh and reinforcement bars vertically arranged is placed on the bottom of construction space (excavated area). The thickness of the base concrete is expected to be the same as further excavated depth as shown in the illustration of Step No.6, say 50 – 70 cm. Wait until concrete dries up while giving it proper curing.	

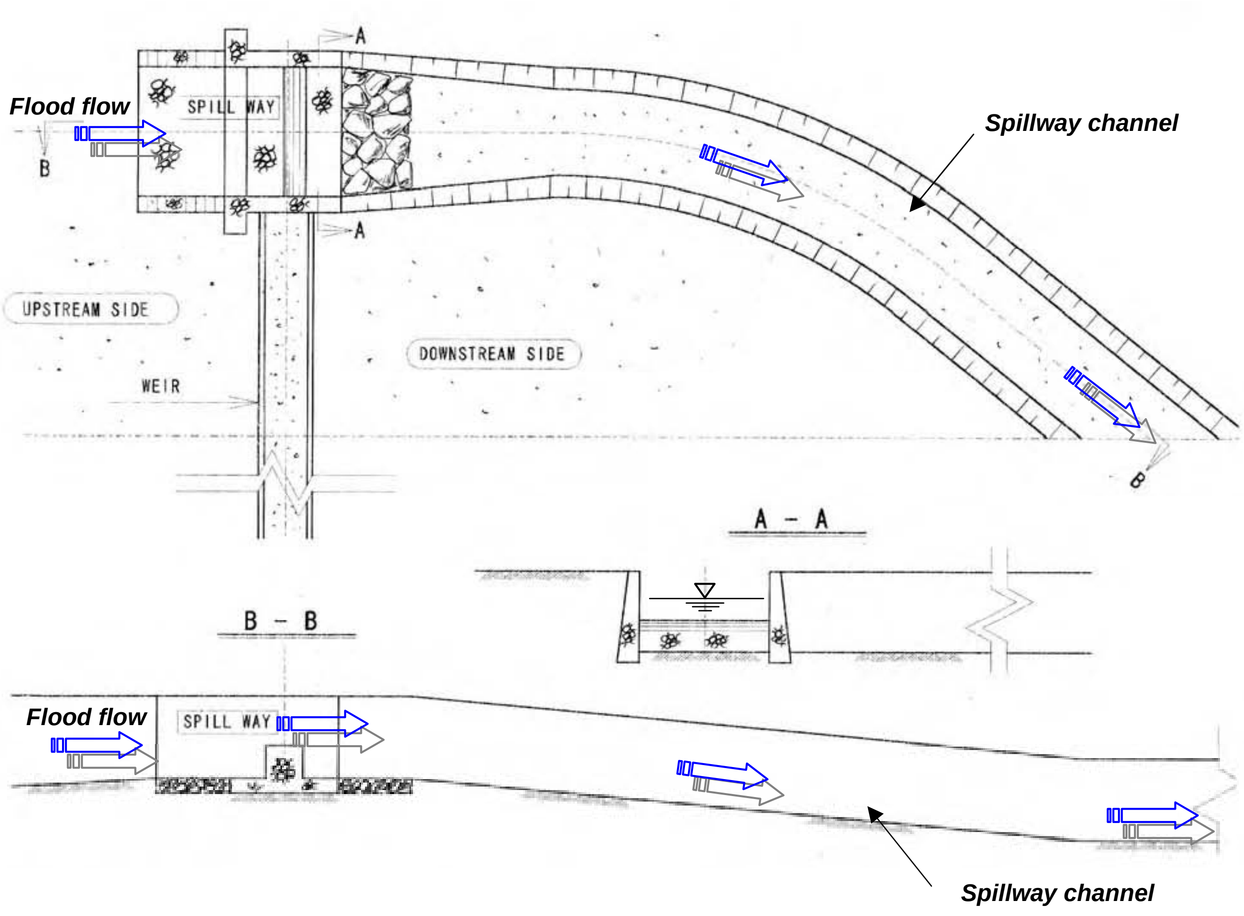
Step	Process	Description	Remarks
13		**<u>6) Assembling Framework (Shuttering)</u>** Assemble framework (Shuttering) to place the concrete while covering reinforcement bars assembled. The inside of frame works should be coated with a bit of oil; it helps smooth removal of the framework after concrete is ready.	Make sure that the persons who deal with the reinforcement bars should wear gloves for safe.
14		**<u>7) Placing Concrete to Weir Wall</u>** Pour concrete into the framework layer by layer. 30cm thickness is recommended to place for each layer. Interstices and gaps inside of the framework should be filled thoroughly with concrete by poking the concrete with sticks and/or stamping the concrete by foot. Simple sand sluiceway can be installed by opening a part of the body, say 50-100 cm width and the depth being 2/3 of the wall height (for detail, refer to 5. Wet Masonry Type).	Concrete should be gently placed in order not to disturb reinforcement bars assembled properly. Voids in the weir body should be filled with concrete entirely to stop water leakage and strengthen the weir body. After completion of placing concrete, the top of weir should be covered with wet grasses or wet straw mats for good curing purpose. This type of weir is recommended for the weir having more than 2.0 m of weir height.

Step	Process	Description	Remarks
15			

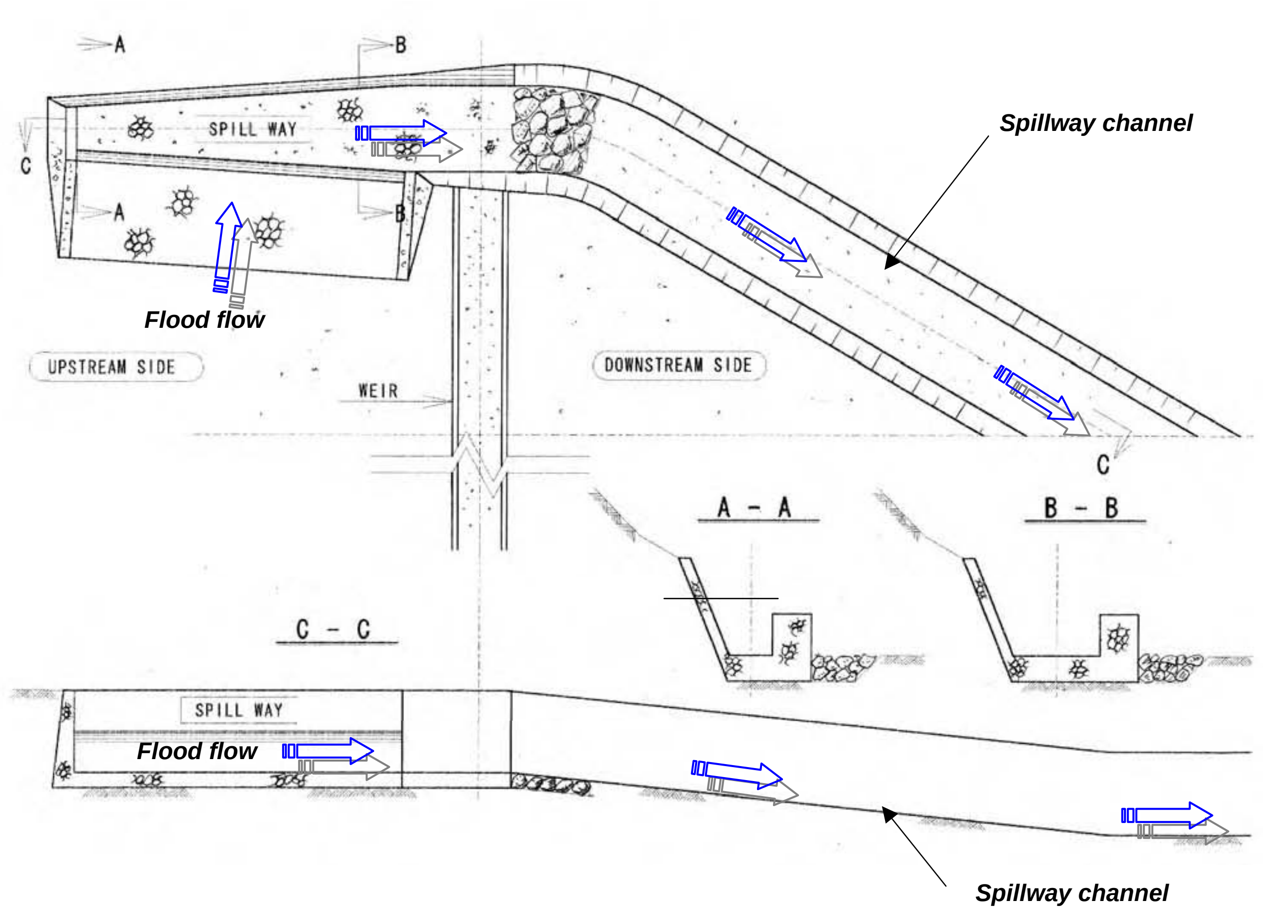


Concrete wall weir supported several buttresses

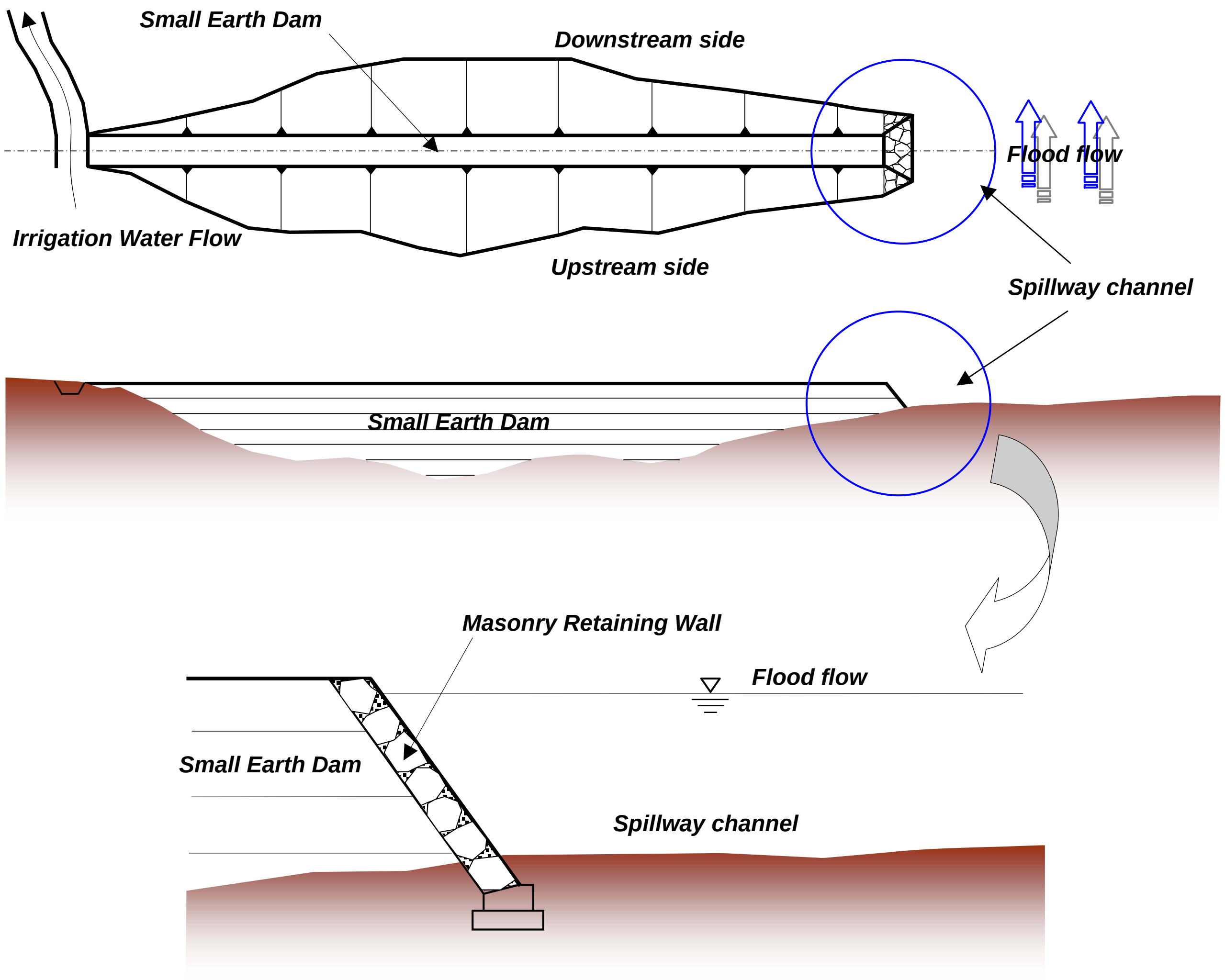
7. Construction of A Spillway: Shoot Type

Step	Process	Description
1		Structure of spillway should be designed to ensure the safe release of the maximum flow equivalent to the design flood discharge. It must be carefully determined so as not to cause any adverse effects on the weir body, foundation and reservoir. Although spillway is usually equipped with an energy dissipation pond, such structure is not necessary because, in this case, the slope of spillway channel is not so steep. Due to its solidness and durability, concrete or stone masonry with mortar is preferable as the material of spillway. In general, shoot-type spillway, illustrated on the left, is suitable to flat area where the slope of riverbank is gentle and thus there is enough space to construct the spillway.

8. Construction of A Spillway: Side-Inflow Type

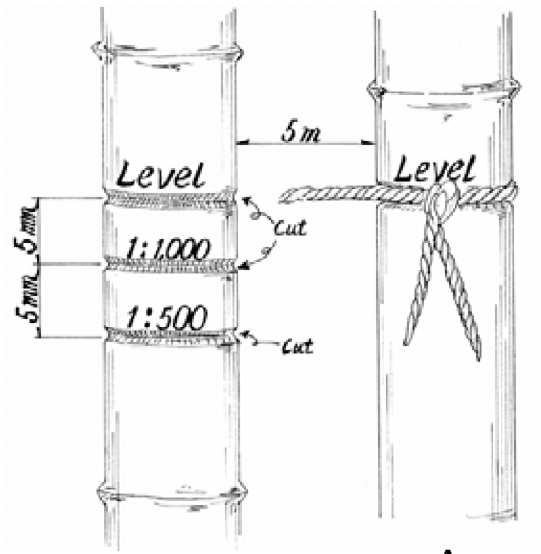
Step	Process	Description
1		Structure of spillway should be designed to ensure the safe release of the maximum flow equivalent to the design flood discharge. It must be carefully determined so as not to cause any adverse effects on the weir body, foundation and reservoir. Although spillway is usually equipped with an energy dissipation pond, such structure is not necessary because, in this case, the slope of spillway channel is not so steep. Due to its solidness and durability, concrete or stone masonry with mortar is preferable as the material of spillway. In general, side-inflow-type spillway, illustrated on the left, is suitable to mountainous area, where the topography of the site is seep and thus there is not much space for the construction of wider type of spillway.

9. Construction of A Spillway: Natural Type

Step	Process	Description
1		Structure of spillway should be designed to ensure the safe release of the maximum flow equivalent to the design flood discharge. It must be carefully determined so as not to cause any adverse effects on the weir body, foundation and reservoir. Although spillway is usually equipped with an energy dissipation pond, such structure is not necessary because, in this case, the slope of spillway channel is not so steep. Due to its solidness and durability, concrete or stone masonry with mortar is preferable as the material of spillway. In general, natural-type spillway, illustrated on the left, is suitable to the area where is enough space to make the flood flow safely without any particular facilities but only masonry retaining wall to protect the embankment of earth dam. This type of spillway intends to practically apply the ground to channel bed of the spillway.

10. Canal Alignment with Sprit Line-level (Section 1; Assemble Line-level)

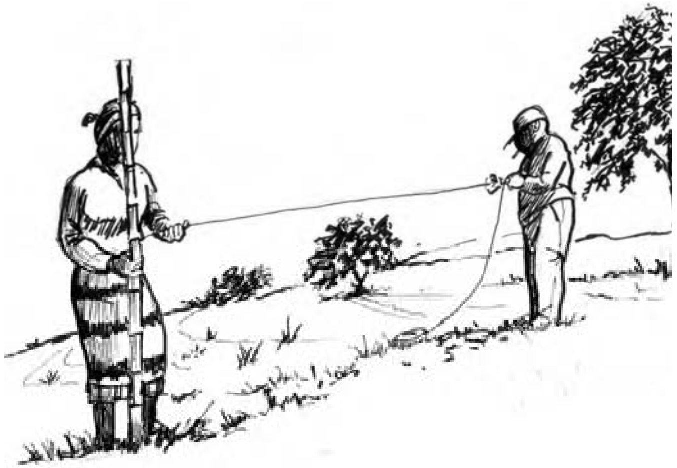
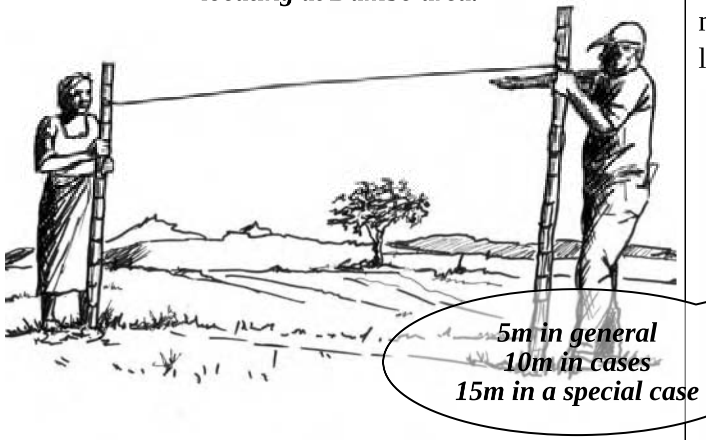
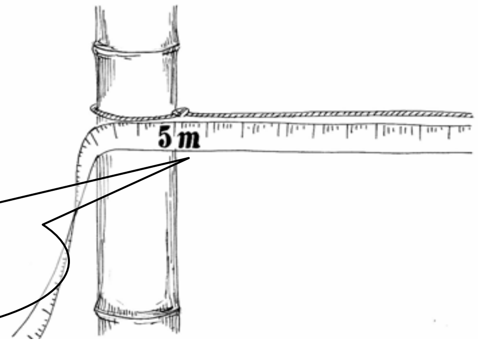
Step	Process	Description	Remarks
1		**Adjust the Poles;** Two (2) poles should be prepared and are cut in the same length. 	Local materials such as bamboo/wooden poles are applicable. The lengths of poles should be adjusted to the height of pole holders. Usually, the poles are about 1.7m to 1.8m in height. The poles should have a sizable diameter so that they are easy to hold. Bigger poles with bigger diameters would be difficult to handle.
2		**Make Groove on the poles (to know gradient on field);** To tie and fix a string, make circular groove around the poles at the same height of both poles—around 1.0-1.3 m from the bottom.	The position of the groove should be set in accordance to the height of the reader of the spirit level. Usually, the height of the groove is from 1.0m to 1.3m from the bottom of the poles. When measuring the level point on field, the grooves should be marked with same height of both poles. However, when measuring a particular slope, grooves should be set at different heights. The table on the next page shows an example of positioning the groove on each pole according to a required slope (same as canal longitudinal gradient).

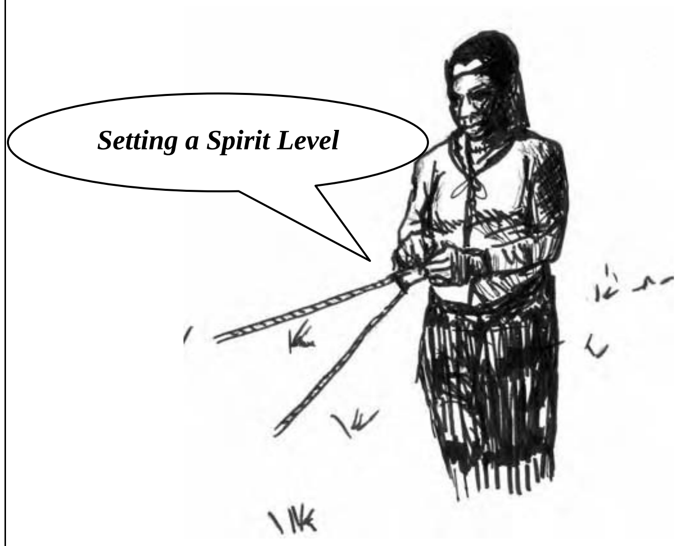
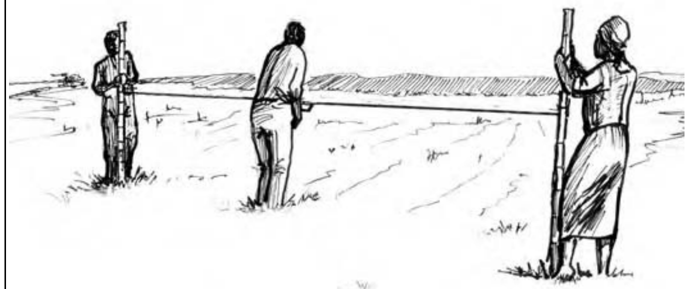
Step	Process	Description	Remarks
3	 B A	**<u>Put Grooves at Different Heights on One of the Poles:</u>** Take one of the poles and make grooves on the pole as shown in the left illustration. The position of the groove is 5mm lower than the first one (top one), and another 5 mm from the first one. The pole at the right side has a groove fixed at, for example, 1.3m from the bottom of the pole as an example (see the groove on the Pole A). On the other hand, the pole standing at the left hand side has 3 grooves (see the grooves on the Pole B). These grooves indicate the level line, 5mm lower than the level line and 10mm lower than the level line.	In conventional way of using a sprit line level, the 2 grooves should be put on the same height in order to know the same elevation points at the 2 poles. However, to align a canal with a designed gradient, we need to make a difference of the elevation in between the grooves of the 2 poles. As an example, 5 mm difference over a distance of 5m gives 1/1,000 (5mm/ 5,000mm) gradient, and 10 mm difference over the same 5m distance gives 1/500 (10mm/5,000mm) gradient. If the 2 poles are placed over a distance of 10m, 10mm difference gives 1/1,000 (10mm/ 10,000mm) gradient and 20mm difference gives 1/500 (20mm/ 10,000 mm) gradient.

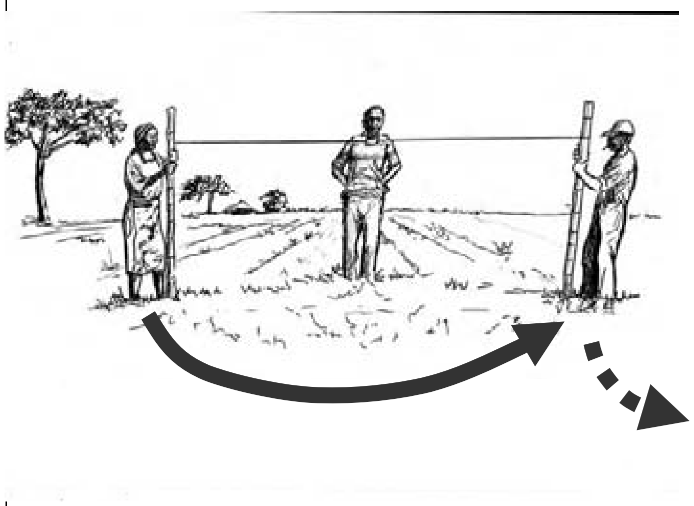
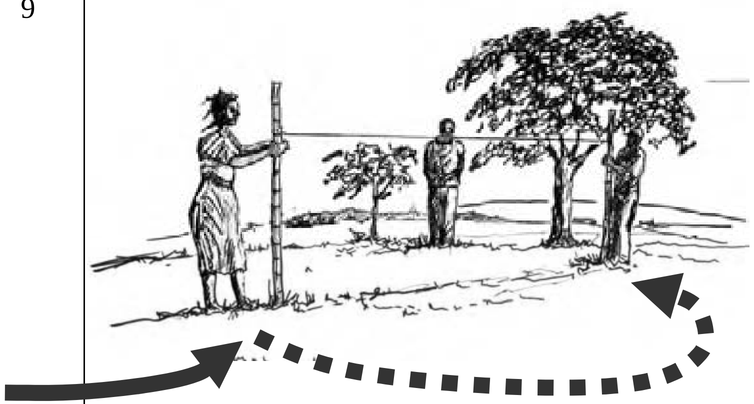
Design gradient of canal	Elevation difference of 2 grooves	Distance between the 2 poles	The position of grooves from the bottom	
			Stick-(A)	Stick-(B)
1/1,000	5.0 mm	5 m	1.3 m	1.295 m
1/500	10.0 mm	5 m	1.3 m	1.290 m
1/1,000	10.0 mm	10 m	1.3 m	1.290 m
1/500	20.0 mm	10 m	1.3 m	1.280 m

The table shown on the left gives an example for the position of the grooves (tying position of the string for the 2 poles) to set the designed slope of canal on the site.

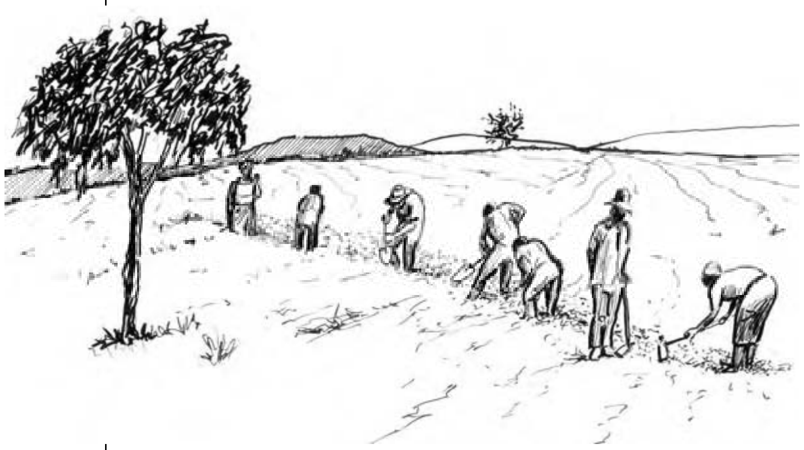
On a gentle topography like *Dambo* areas, 1/1,000 is recommended while on a sloped topography, 1/500 slope is recommended.

Step	Process	Description	Remarks
4		**<u>Fix the String;</u>** Tie the string on a grove marked on the above steps. 	
5	***The distance should be 5m in general, but may be extended to 10m in the site locating at Dambo area.*** 	**<u>Testing the line-level;</u>** The length of the string, same as the distance of the 2 poles, should be 5m in most cases but in some cases it can be as long as 10m. 	The length of string depends on the site condition. Usually, 5m length of string is ideal as it is easy to handle. However, if the topography is too gentle and difficult to find an appropriate point within the 5m distance, extend the string up to 10m. Elevation difference of 10-20 mm could be found within the 10m distance. In case you cannot still find out appropriate point within the 10m distance, you might extend the distance of the 2 poles up to 15m as a special case. In this case, 15mm elevation gap can give 1/1,000 gradient (15/15,000) and 30mm elevation gap can give 1/500 gradient (30/15,000).

Step	Process	Description	Remarks
6		**<u>Set a Spirit Level (completion of assembling the line-level):</u>** After the required span between the poles is set, set the spirit level on the string. 	The position where the spirit level is fixed should be the center of the string, e.g. 2.5m point with 5m of string, 5.0m point with 10m of string.
7		**<u>Starting the Canal Alignment with Sprit Line Level:</u>** Line-level can be used to know a sloping point for the design longitudinal slope of the canal. To survey that, at least three persons are needed: two for pole holders and one to read the level.	A slope of 1/500 on a sloped (inclined) land is recommended while 1/1,000 slope may be applied on a flat land e.g. *dambo* areas. One may think 1/1,000 slope is too gentle for water to flow. However, this slope is quite enough to let the water flow in the canal by gravity. As most topography in Zambia is very gentle, steep canal slope with more than 1/500 is not recommend. On the other hand, gentler gradient than 1/1,000 is not recommended either since spirit line level may not accompany such accuracy.

Step	Process	Description	Remarks
8		**<u>Surveying Sloping Point on the Field;</u>** The pole holders should stand at an interval of 5 meters or 10 meters according to the length of the string put over the poles. At this time, the pole holder whose string is tied at a lower position than that of the other pole should stand at a higher position e.g. at the starting point of the canal (He/she stands on the left side in the illustration). The other pole holder (the person on the right) will move to the point where the bubble in the spirit level comes to the center. The level reader checks whether the bubble in the spirit level is at the center or not.	The tied point on the right pole is, as an example, higher by 5 mm than the tied point on the left pole in the illustration. With this situation, when the bubble in the sprit level comes to the center, it automatically means that the ground at the right pole is 5 mm lower than that of left pole. If the distance of the 2 poles is 5m, it gives 1/1,000 gradient (5mm/ 5,000 mm) to the ground over the 2 points).
9	 This placing may be called off-set leveling since the evaluation gap between the grooves is off-set by the elevation difference of the ground where 2 poles are placed.	**<u>Do progressing Placing of the Poles:</u>** After a sloping point is set, the pole holder who stands at higher point (left person in the illustration) should move the point to where the other one was (right person in the illustration). The points where the pole holders stand act as bench marks where the pegs are now driven. After this, repeat the same procedure until the required distance of canal is achieved. Upon completion of the line-leveling over the designed distance of the canal, re-align some pegs to get a smoother canal alignment (avoid zigzag alignment).	This method is completely different from conventional pole placing. Conventional placing requires us to place the 2 poles alternately in order to identify a counter level, while this canal alignment necessitates us to place the 2 poles progressively. By placing the 2 poles progressively, designed elevation difference, corresponding to the canal longitudinal slope, over the 2 points is secured since the tying points of the string on the 2 poles are different in elevation.

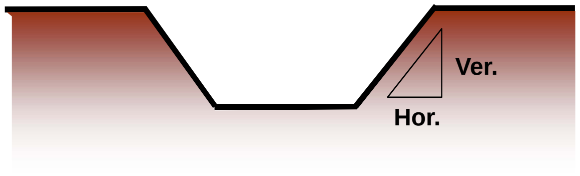
11. Canal Design and Construction

Step	Process	Description	Remarks
1		**Excavation of Canal** Canal should be excavated to the required shape and depth. Dig a canal by removing soft and unnecessary materials in the soil. If necessary, replace with suitable materials and compact it firmly.	
2		For keeping the cross-sectional shape of the canal uniformly, a template can be used. The template is made out of locally available material like twigs collected on the site (see an example of the left illustration).	

<table>
<tr><th>Step</th><th>Process</th><th>Description</th><th>Remarks</th></tr>
<tr><td>3</td><td>

<u>Recommended Side Slopes for Different Types of Soils</u>

<table>
<tr><th>Type of Soils</th><th>Recommendable Side Slope
(Ver.) : (Hor.)</th></tr>
<tr><td>Clay</td><td>2 : 1</td></tr>
<tr><td>All other soils</td><td>2 : 1</td></tr>
<tr><td>Sand</td><td>1 : 1</td></tr>
</table>



</td><td>For any canals, standard trapezoidal shape is commonly used. Required slope depends on the stability of the soil. Recommendable side slopes for different soils are given in table on the left.</td><td>Generally, rectangular cross section requires less excavation. Considering stability of the canal wall, it is recommended to adopt trapezoid cross section as exampled in the left illustration. However, rectangular cross section may be adopted in case the depth is less than 0.6 m and the soil is of clay since such canal wall can stand vertical.</td></tr>
<tr><td>4</td><td>

<u>Maximum Allowable Velocity</u>

<table>
<tr><th>Type of Canal Material</th><th>Maximum Allowable Velocity, (m/s)</th></tr>
<tr><td>Sandy soil</td><td>0.4 - 0.6</td></tr>
<tr><td>Sand-loam</td><td>0.5 - 0.7</td></tr>
<tr><td>Clay-loam</td><td>0.6 - 0.9</td></tr>
<tr><td>Clay</td><td>0.9 - 1.5</td></tr>
<tr><td>Rock</td><td>1.0 - 2.0</td></tr>
</table>

</td><td>The design velocity of canals must be determined within the limits of two factors: 1) the minimum velocity should be more than that level preventing accumulation of sediment and growth of waterweeds, and 2) the maximum velocity should be less than that level causing erosion of canal materials by the flow. Refer to the left table for maximum allowable velocities of different types of canals. These maximum allowable velocity can easily be achieved in most of the canals where canal gradient is within the recommended ones.</td><td>A recommended minimum velocity can be 0.45 - 0.90 m/s. Within or more than this range of velocity, soil sediments are not accumulated in a canal where the particle size of suspended matters is not larger than that of silt. It means if the flow velocity is kept more than the range, the flow itself can carry the suspended particles, thereby no sedimentation is accumulated in the canal. Most waterweeds will hardly grow when the mean velocity is more than 0.7 m/sec. However, there is difficulty in achieving this minimum velocity in most of the canals, hence this velocity is a reference.</td></tr>
</table>

Step	Process	Remarks

Step 5

Discharge (lit./s)	Bed Width (m)	Canal Slope 1/i	Side Slope Ver.		Side Slope Hor.	Water Depth (m)	Vmax (m/s)	Freeboard (m)	Canal Height (m)	Remark
5	0.25	2,000	0	:	1	0.238	0.084	0.112	0.350	
5	0.25	1,000	0	:	1	0.180	0.111	0.109	0.289	Reccommendable
5	0.25	500	0	:	1	0.138	0.145	0.107	0.245	Reccommendable
5	0.25	400	0	:	1	0.127	0.158	0.107	0.234	
5	0.25	300	0	:	1	0.114	0.176	0.106	0.220	
5	0.25	200	0	:	1	0.098	0.204	0.106	0.204	
5	0.25	100	0	:	1	0.077	0.261	0.106	0.183	

Discharge (lit./s)	Bed Width (m)	Canal Slope 1/i	Side Slope Ver.		Side Slope Hor.	Water Depth (m)	Vmax (m/s)	Freeboard (m)	Canal Height (m)	Remark
5	0.25	2,000	2	:	1	0.167	0.089	0.109	0.276	
5	0.25	1,000	2	:	1	0.136	0.116	0.107	0.243	Reccommendable
5	0.25	500	2	:	1	0.110	0.148	0.106	0.216	Reccommendable
5	0.25	400	2	:	1	0.102	0.160	0.106	0.208	
5	0.25	300	2	:	1	0.094	0.178	0.106	0.200	
5	0.25	200	2	:	1	0.083	0.206	0.105	0.188	
5	0.25	100	2	:	1	0.067	0.262	0.105	0.172	

Remarks:

Recommended Canal Dimension for Various Discharges

In the tables, recommended canal dimensions are presented for different design discharge levels, including bottom width, water depth and total depth (= water depth + freeboard).

Discharge: 5 liter/sec
Where: roughness coefficient is 0.05

Step 6

Discharge (lit./s)	Bed Width (m)	Canal Slope 1/i	Side Slope Ver.		Side Slope Hor.	Water Depth (m)	Vmax (m/s)	Freeboard (m)	Canal Height (m)	Remark
10	0.35	2,000	0	:	1	0.283	0.101	0.114	0.397	
10	0.35	1,000	0	:	1	0.215	0.133	0.111	0.326	Reccommendable
10	0.35	500	0	:	1	0.165	0.173	0.109	0.274	Reccommendable
10	0.35	400	0	:	1	0.152	0.188	0.109	0.261	
10	0.35	300	0	:	1	0.137	0.209	0.108	0.245	
10	0.35	200	0	:	1	0.118	0.242	0.107	0.225	
10	0.35	100	0	:	1	0.092	0.309	0.107	0.199	

Discharge (lit./s)	Bed Width (m)	Canal Slope 1/i	Side Slope Ver.		Side Slope Hor.	Water Depth (m)	Vmax (m/s)	Freeboard (m)	Canal Height (m)	Remark
10	0.30	2,000	2	:	1	0.228	0.106	0.112	0.340	
10	0.30	1,000	2	:	1	0.185	0.138	0.110	0.295	Reccommendable
10	0.30	500	2	:	1	0.150	0.178	0.108	0.258	Reccommendable
10	0.30	400	2	:	1	0.140	0.193	0.108	0.248	
10	0.30	300	2	:	1	0.129	0.213	0.108	0.237	
10	0.30	200	2	:	1	0.113	0.247	0.107	0.220	
10	0.30	100	2	:	1	0.092	0.316	0.107	0.199	

Remarks:

Discharge: 10 liter/sec
Where: roughness coefficient is 0.05

Note: as one may see velocity is low e.g. 13 – 18 cm /s only depending on the canal dimension. With this velocity, sedimentation will take place in the canal to an extent, and therefore beneficiary farmers are required to carry out desiltation at least every time before they start the year's irrigation.

Step	Process	Remarks
7	(see tables below)	Discharge: 15 liter/sec Where: roughness coefficient is 0.05

Discharge (lit./s)	Bed Width (m)	Canal Slope 1/i	Side Slope Ver.	:	Hor.	Water Depth (m)	Vmax (m/s)	Freeboard (m)	Canal Height (m)	Remark
15	0.40	2,000	0	:	1	0.335	0.112	0.117	0.452	
15	0.40	1,000	0	:	1	0.255	0.147	0.113	0.368	Reccommendable
15	0.40	500	0	:	1	0.196	0.191	0.111	0.307	Reccommendable
15	0.40	400	0	:	1	0.180	0.208	0.110	0.290	
15	0.40	300	0	:	1	0.162	0.231	0.109	0.271	
15	0.40	200	0	:	1	0.140	0.268	0.109	0.249	
15	0.40	100	0	:	1	0.110	0.343	0.109	0.219	

Discharge (lit./s)	Bed Width (m)	Canal Slope 1/i	Side Slope Ver.	:	Hor.	Water Depth (m)	Vmax (m/s)	Freeboard (m)	Canal Height (m)	Remark
15	0.35	2,000	2	:	1	0.264	0.118	0.114	0.378	
15	0.35	1,000	2	:	1	0.214	0.152	0.111	0.325	Reccommendable
15	0.35	500	2	:	1	0.174	0.197	0.110	0.284	Reccommendable
15	0.35	400	2	:	1	0.163	0.213	0.109	0.272	
15	0.35	300	2	:	1	0.149	0.237	0.109	0.258	
15	0.35	200	2	:	1	0.132	0.274	0.109	0.241	
15	0.35	100	2	:	1	0.106	0.350	0.108	0.214	

Step	Process	Remarks
8	(see tables below)	Discharge: 20 liter/sec Where: roughness coefficient is 0.05

Discharge (lit./s)	Bed Width (m)	Canal Slope 1/i	Side Slope Ver.	:	Hor.	Water Depth (m)	Vmax (m/s)	Freeboard (m)	Canal Height (m)	Remark
20	0.45	2,000	0	:	1	0.367	0.120	0.119	0.486	
20	0.45	1,000	0	:	1	0.281	0.158	0.115	0.396	Reccommendable
20	0.45	500	0	:	1	0.216	0.206	0.112	0.328	Reccommendable
20	0.45	400	0	:	1	0.199	0.223	0.111	0.310	
20	0.45	300	0	:	1	0.179	0.248	0.111	0.290	
20	0.45	200	0	:	1	0.155	0.288	0.110	0.265	
20	0.45	100	0	:	1	0.121	0.367	0.109	0.230	

Discharge (lit./s)	Bed Width (m)	Canal Slope 1/i	Side Slope Ver.	:	Hor.	Water Depth (m)	Vmax (m/s)	Freeboard (m)	Canal Height (m)	Remark
20	0.40	2,000	2	:	1	0.291	0.126	0.115	0.406	
20	0.40	1,000	2	:	1	0.236	0.164	0.112	0.348	Reccommendable
20	0.40	500	2	:	1	0.191	0.211	0.111	0.302	Reccommendable
20	0.40	400	2	:	1	0.179	0.229	0.110	0.289	
20	0.40	300	2	:	1	0.164	0.253	0.110	0.274	
20	0.40	200	2	:	1	0.145	0.293	0.109	0.254	
20	0.40	100	2	:	1	0.117	0.373	0.109	0.226	

Step	Process	Remarks
9		Discharge: 30 liter/sec Where: roughness coefficient is 0.05

Discharge	Bed Width	Canal Slope	Side Slope			Water Depth	Vmax	Freeboard	Canal Height	Remark
(lit./s)	(m)	1/i	Ver.		Hor.	(m)	(m/s)	(m)	(m)	
30	0.50	2,000	0	:	1	0.451	0.132	0.123	0.574	
30	0.50	1,000	0	:	1	0.343	0.174	0.118	0.461	Reccommendable
30	0.50	500	0	:	1	0.263	0.227	0.114	0.377	Reccommendable
30	0.50	400	0	:	1	0.242	0.247	0.114	0.356	
30	0.50	300	0	:	1	0.218	0.275	0.113	0.331	
30	0.50	200	0	:	1	0.188	0.319	0.112	0.300	
30	0.50	100	0	:	1	0.147	0.409	0.112	0.259	

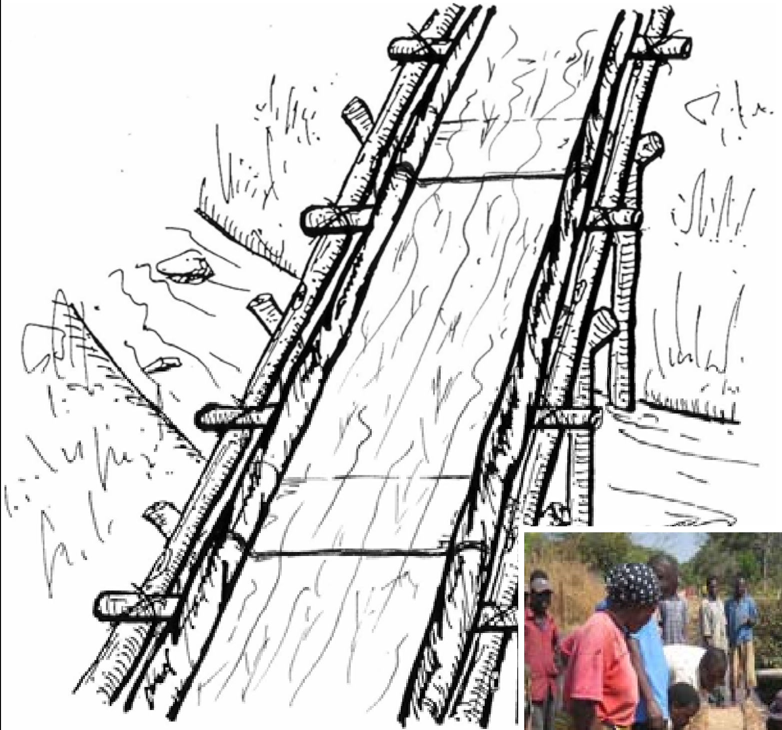
Discharge	Bed Width	Canal Slope	Side Slope			Water Depth	Vmax	Freeboard	Canal Height	Remark
(lit./s)	(m)	1/i	Ver.		Hor.	(m)	(m/s)	(m)	(m)	
30	0.45	2,000	2	:	1	0.344	0.140	0.118	0.462	
30	0.45	1,000	2	:	1	0.280	0.182	0.115	0.395	Reccommendable
30	0.45	500	2	:	1	0.227	0.234	0.113	0.340	Reccommendable
30	0.45	400	2	:	1	0.212	0.254	0.112	0.324	
30	0.45	300	2	:	1	0.194	0.282	0.112	0.306	
30	0.45	200	2	:	1	0.172	0.326	0.111	0.283	
30	0.45	100	2	:	1	0.139	0.416	0.111	0.250	

Step	Process	Remarks
10		Discharge: 50 liter/sec Where: roughness coefficient is 0.05

Discharge	Bed Width	Canal Slope	Side Slope			Water Depth	Vmax	Freeboard	Canal Height	Remark
(lit./s)	(m)	1/i	Ver.		Hor.	(m)	(m/s)	(m)	(m)	
50	0.60	2,000	0	:	1	0.556	0.150	0.128	0.684	
50	0.60	1,000	0	:	1	0.421	0.198	0.122	0.543	Reccommendable
50	0.60	500	0	:	1	0.322	0.258	0.118	0.440	Reccommendable
50	0.60	400	0	:	1	0.297	0.281	0.117	0.414	
50	0.60	300	0	:	1	0.266	0.313	0.116	0.382	
50	0.60	200	0	:	1	0.230	0.363	0.115	0.345	
50	0.60	100	0	:	1	0.179	0.465	0.114	0.293	

Discharge	Bed Width	Canal Slope	Side Slope			Water Depth	Vmax	Freeboard	Canal Height	Remark
(lit./s)	(m)	1/i	Ver.		Hor.	(m)	(m/s)	(m)	(m)	
50	0.50	2,000	2	:	1	0.438	0.159	0.123	0.561	
50	0.50	1,000	2	:	1	0.356	0.206	0.119	0.475	Reccommendable
50	0.50	500	2	:	1	0.290	0.267	0.116	0.406	Reccommendable
50	0.50	400	2	:	1	0.271	0.289	0.116	0.387	
50	0.50	300	2	:	1	0.249	0.322	0.115	0.364	
50	0.50	200	2	:	1	0.220	0.373	0.115	0.335	
50	0.50	100	2	:	1	0.178	0.478	0.115	0.293	

Canal Ancillaries

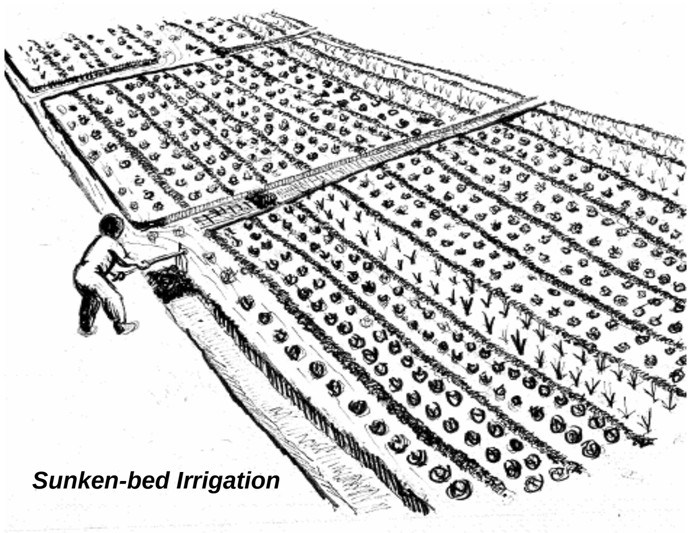
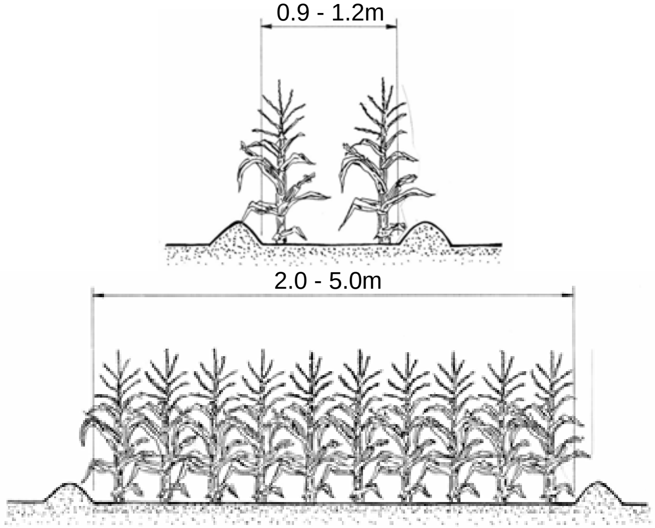


A Canal Bridge crossing a gully:
On the frame assembled with wooden poles and supported by twigs from the ground, long tall grasses are placed on and a bunch of grasses about 20 cm in diameter is placed on the both edges, and thereon plastic sheet is placed.

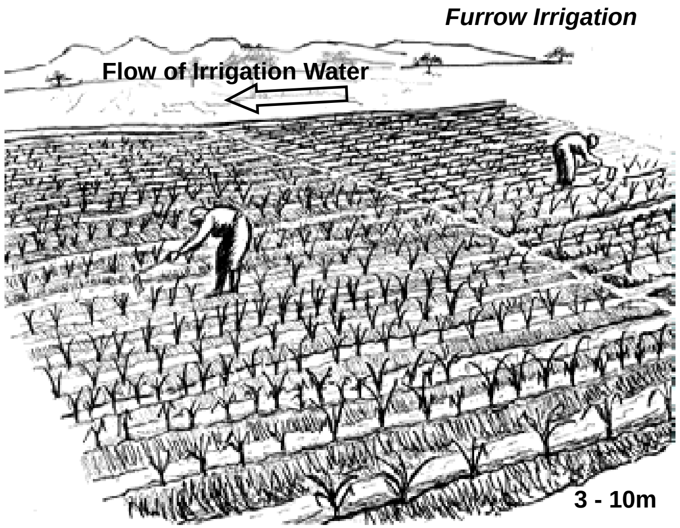
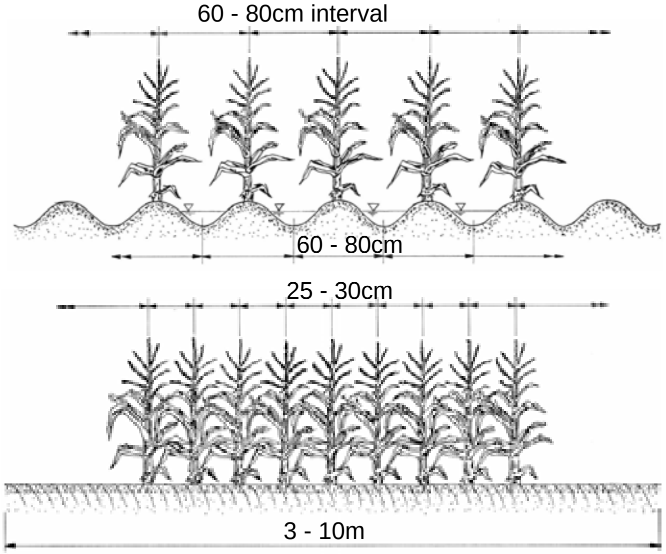
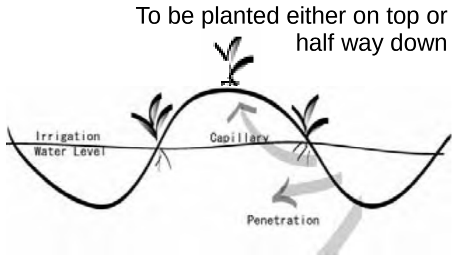
On-farm ditch covered with stone pitching:
Where farm land is located on a sloped area, stone pitching can be applied on the ditch in order to prevent the soil from being eroded.

If stone is not available in and around the site, even banana sheath can be used as a temporal material for ditch lining in order to prevent soils from being eroded.

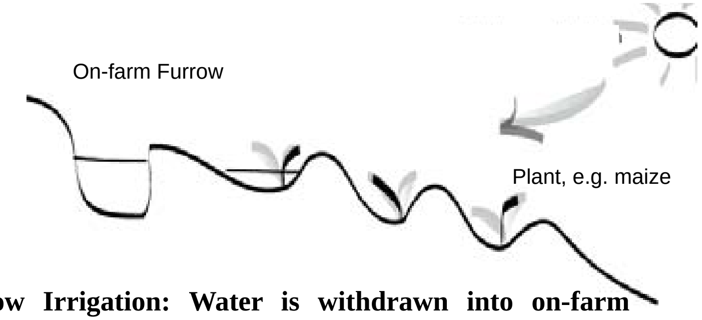
12. On-farm Irrigation Method (Section 1; Sunken-bed Irrigation)

Step	Process	Description	Remarks
1	 Sunken-bed Irrigation	**<u>Making the Sunken Bed;</u>** This sunken-bed on-farm irrigation system is applied to a very flat area, and not to steep topography. To do this on-farm irrigation method, make a sunken bed, which is a leveled area in the field, surrounded by earth bands. The leveled area is flooded during the on-farm irrigation. Sunken-bed irrigation is suitable for many crops.	In sunken beds, the crops grow on the flat surface, which are surrounded by small earth embankment and are kept wet for a long time when the bed is irrigated. The advantages are; 1) the amount of water can be given with a minimum amount of labor if beds are well leveled, 2) water losses can be kept low by minimum run-off, and 3) beds last for a long time once they are constructed.
2		<u>Refer to the Illustrations</u> Sunken-bed irrigation needs a good water supply to fill the basin quickly. This in turn requires accurate land leveling with a good earth embankment surrounding the bed. Also it is required that the intake at the bed should be clogged when the water reaches around 3/4 of the length of the bed, after which water is to reach up to the end by gravity in the bed.	The width and length of the sunken bed is normally 0.9 - 1.2m and 2.0 - 5.0m respectively but depends on the type of crops and soil. If the soil is sandy, it is recommended to shorten the length, say to 3 m or even to 2 m length.

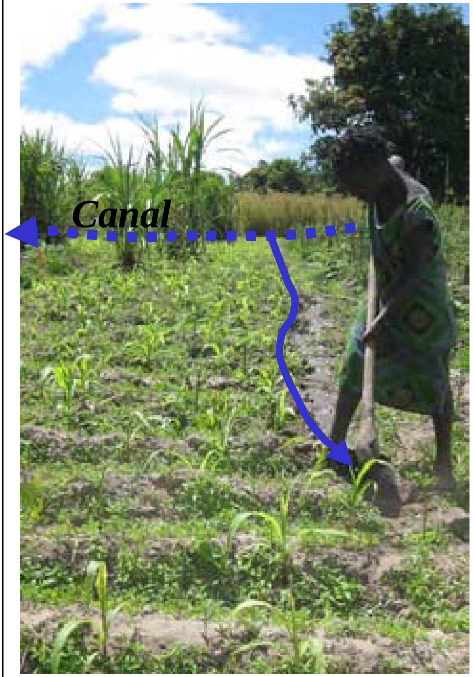
On-farm Irrigation Method (Section 2; Furrow Irrigation)

Step	Process	Description	Remarks
1		<u>**Making the ridges and furrows;**</u> This furrow on-farm irrigation system is applied to a relatively steep topography, and not to very flat area. To practice this on-farm irrigation, make ridges and furrows, just same as the one for rain-fed agriculture. Note that the interval of ridges, same as that of furrows, should not be too wide, say not over 100 cm in any case. Intervals of over 100 cm can be seen in rain-fed agriculture, however with these wide intervals, irrigation water can hardly wet the crops planted on the ridges.	Under furrow irrigation, water is taken to the plant through long and narrow on-farm channels (on-farm furrows) formed in the soil at regular intervals, between the crop rows (ridges). The length of the furrow is normally 3 - 10 m but depends on the type of soil and the land slope. If the topography is very uniform, the length of furrows/ridges can be extended up to 10m or otherwise better to limit within 5m in most cases.
2		<u>Refer to the Illustrations</u> Water is gradually absorbed into the bottom and sides of the long on-farm channel (on-farm furrow) wetting the soil. Crops are usually grown on top of or half way down the ridges between furrows. 	It is important to use the right shape of furrow, furrow spacing and length. Good water management is of course very much important for the method to work well. The interval of ridge is usually 60 – 80 cm, equivalent to the one applied under rain-fed agriculture or somewhat narrower than that. Ridge height, equally to furrow depth, should be around 20 – 25 cm in order for capillary to lift the water toward ridge. Cops are planted at intervals of 25 –30 cm on top of or half way down the ridges, which is also equivalent to the practice of rain-fed agriculture.

Examples of On-farm Irrigation Method (Furrow rrigation and Sunken-bed Irrigation)

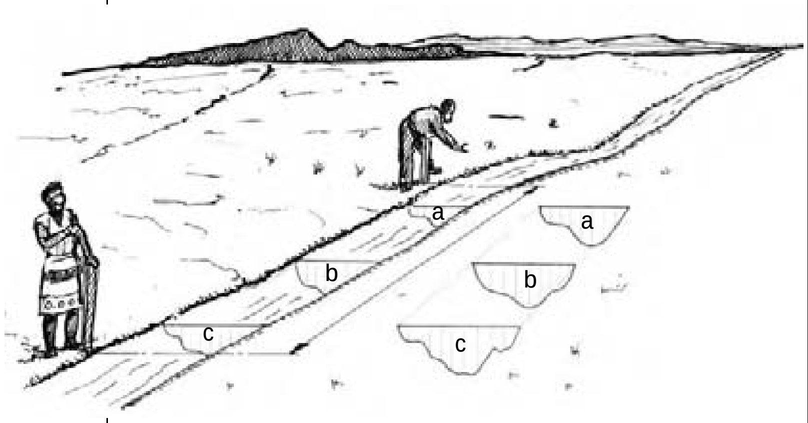
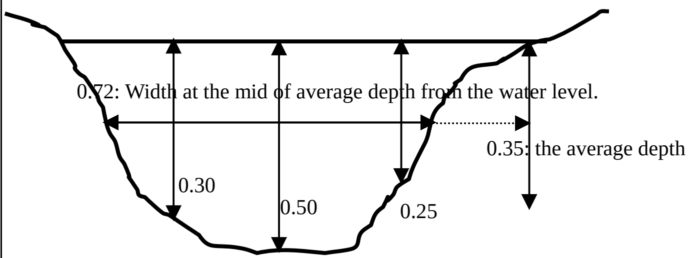


Furrow Irrigation: Water is withdrawn into on-farm furrow, and then wets the soils by capillary.



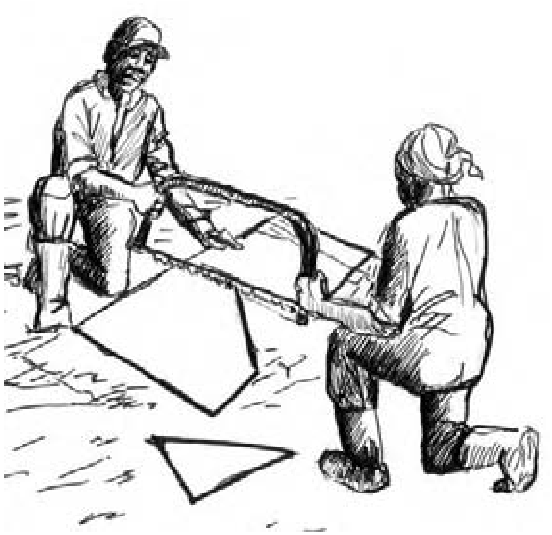
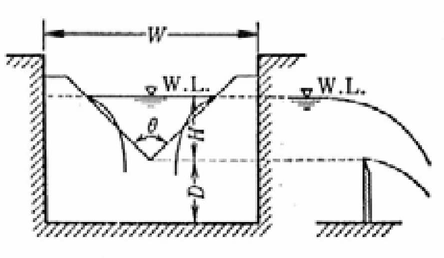
Sunken-bed irrigation: Sunken-bed is a leveled area surrounded by earthen band. Water is led to this bed and wets whole the bed area for the plants.

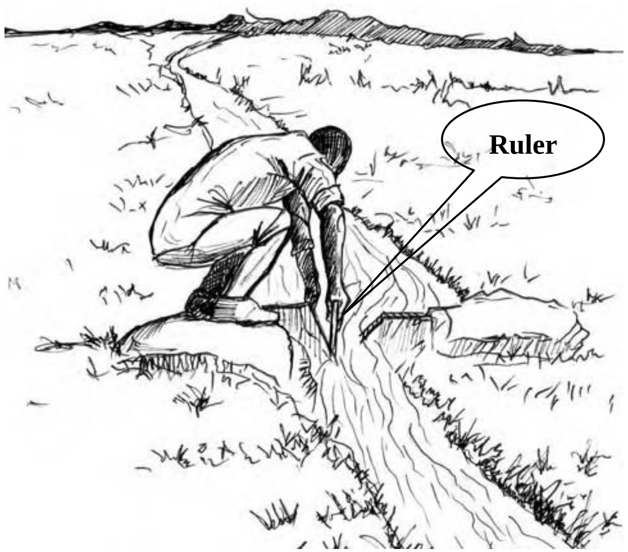
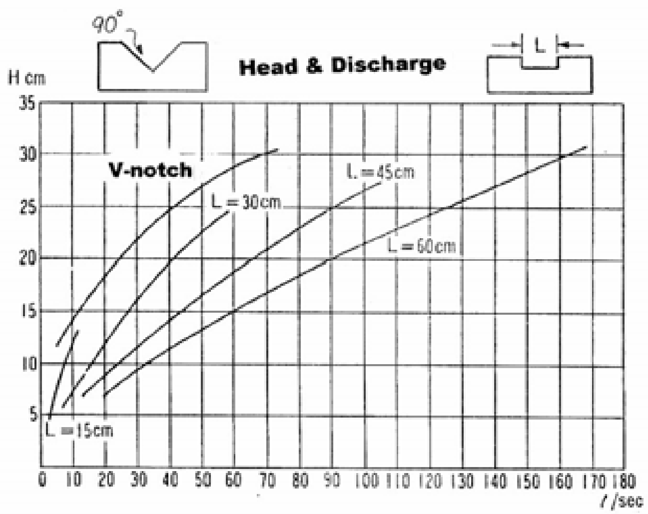
13. Discharge measurement (Section 1; Float Method)

<table>
<tr><th>Step</th><th>Process</th><th>Description</th><th>Remarks</th></tr>
<tr>
<td>1</td>
<td>
</td>
<td><u>Measurement of the Water Area;</u>
The float method is available to know a rough estimate of the stream flow. The amount of flow (Q) can be estimated by measuring the size of the stream (A=water area) and the speed (V=velocity) of the water (Q=A*V).</td>
<td>The water area of the stream (width multiplied by depth) has to be measured. It is better to select a clean and straight section on the stream, at least 5 – 10m long. Measure the depth at one cross-section for at least 3 points (e.g. at 1/4, 1/2, and 3/4 of total width as in the bottom illustration) and calculate the average depth. Then, multiply the average depth into average width of the section, which is the width at the mid point of the average depth from the water level. After the water area for each cross-section is calculated, the representative water area (A) is estimated by averaging all the cross-sectional areas.</td>
</tr>
<tr>
<td>2</td>
<td>How to estimate a cross sectional area:


<table>
<tr><th colspan="2">Depth (m)</th><th>Width, m</th><th>Area, m³</th></tr>
<tr><td>Depth 1 (1/4)</td><td>0.30</td><td rowspan="4">0.72</td><td rowspan="4">0.252 m³
(0.35x0.72)</td></tr>
<tr><td>Depth 2 (1/2)</td><td>0.50</td></tr>
<tr><td>Depth 3 (3.4)</td><td>0.25</td></tr>
<tr><td>Average</td><td>0.35</td></tr>
</table></td>
<td><u>Measurement of the velocity;</u>
A float (e.g. a piece of dry wood) is thrown into the water to measure the velocity. Measure the time (in second) taken by the float to move between the upstream cross-section point (section-a) to the downstream one (section-c). Repeat this measurement at least three times, and calculate the average velocity. Velocity is calculated as follows:
Velocity=Length (m) of the 2 points (e.g. section-a to section-c in the illustration) / time (in second)</td>
<td>The measured velocity at the surface is larger than the velocity along the bottom and sides. Therefore, the measured velocity at the surface needs to be corrected as follows:
-When the water depth<30cm,
Velocity=average velocity times 0.70
-When the water depth>30cm,
Velocity=average velocity times 0.85
Finally, multiply the average water area by the corrected average velocity. This is the amount of flow (Q=A*V) in cum per second. When multiplied by 1,000, it is now the flow in litter per second.</td>
</tr>
</table>

Discharge Measurement (Section 2; V-notch Method)

Step	Process	Description	Remarks
1		**<u>Making a V-notch;</u>** Generally, the v-notch is made of wooden board at an angle of 90 degrees. 	If the amount of stream flow is small such as up to 100 lit/sec, v-notch is available to measure the discharge. The application of v-notch is as following (refer to the figure show in the left): ・ 0.5m<=W<=1.2m ・ 0.1m<=D<=0.75m ・ 0.07m<=H<=0.26m ・ H<=W/3
2		**<u>Set the V-notch in the Stream;</u>** The v-notch is set up at suitable site near the place where it is planned to construct the diversion weir.	The v-notch must stand perpendicularly to the stream flow. To stabilize the v-notch, sand bags can be used.

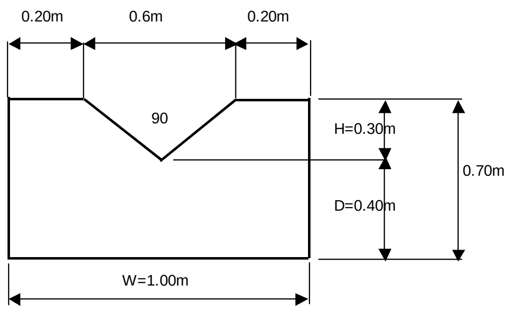
Step	Process	Description	Remarks
3		**<u>Measure the Depth of Nappe;</u>** After setting of the v-notch, the stream flow starts overflowing through the v-notch. The v-notch will be left as it is. When the nappe has become stable, the depth of the nappe has to be measured. The depth here means the distance between the deepest point of the V-notch and the water level right above the deepest point.	To measure the depth of the nappe, a ruler should be prepared. The ruler should be placed perpendicular to the flow exactly, or error in the measurement will take place.
4		**<u>Read the Graph or use Tables;</u>** The amount of stream flow can be known by the graph shown on the left column, or refer to the tables on the following table.	After measurement of the depth of nappe, the depth is checked against the graph to know the volume of flow. The graph shows the relationship between the depth of nappe and discharge. Or otherwise refer to the table on the following page. <u>An exercise in case of V-notch;</u> The depth of nappe: 25cm The amount of flow: 40 lit/sec

Step	Table of Discharge against Ovewflow Depth

4

In case of V-notch:

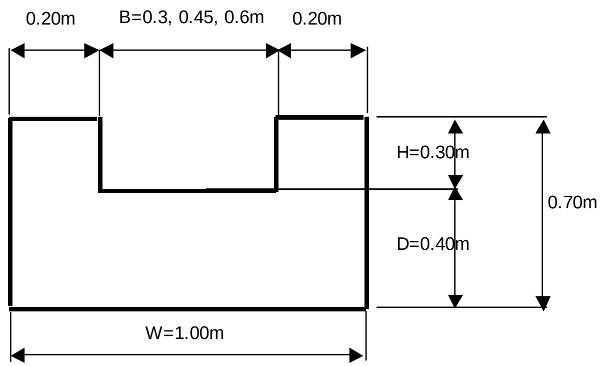
Over flow depth on V-notch	Discharge	
h (m)	Q (m^3/min)	Q (lit/sec)
0.07	0.11	1.83
0.10	0.26	4.41
0.12	0.42	6.92
0.14	0.61	10.14
0.16	0.85	14.14
0.18	1.14	18.96
0.20	1.48	24.67
0.22	1.88	31.31
0.24	2.34	38.95
0.26	2.86	47.63



4

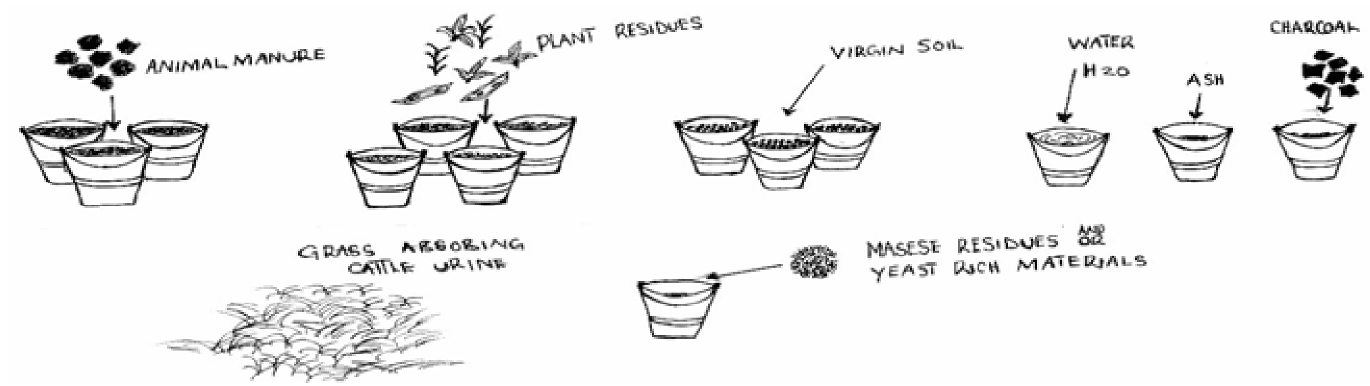
In case of rectangular notch:

Over flow depth on R-notch h (m)	Discharge		
	B=30cm	B=45cm	B=60cm
	Q (lit/sec)	Q (lit/sec)	Q (lit/sec)
0.10	16.59	25.17	34.00
0.12	21.88	32.93	44.54
0.14	27.72	41.36	56.02
0.16	34.08	50.43	68.37
0.18	40.96	60.09	81.56
0.20	48.35	70.32	95.54
0.22	56.23	81.11	110.29
0.24	64.62	92.43	125.80
0.26	73.51	104.27	142.03
0.28	82.90	116.62	158.98

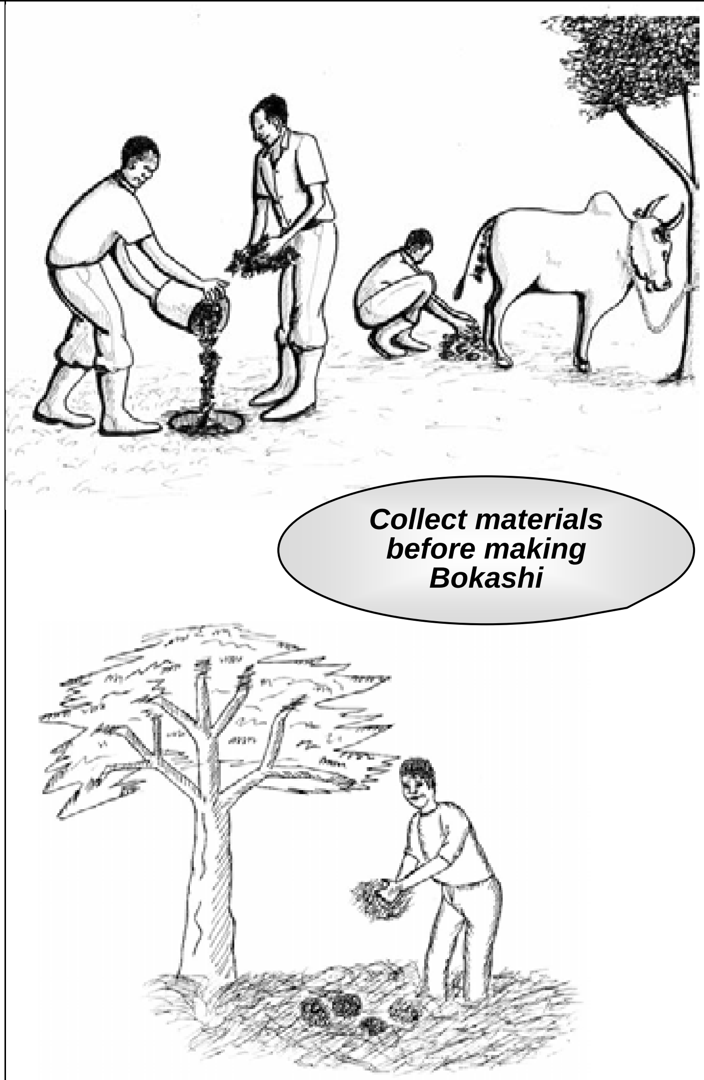


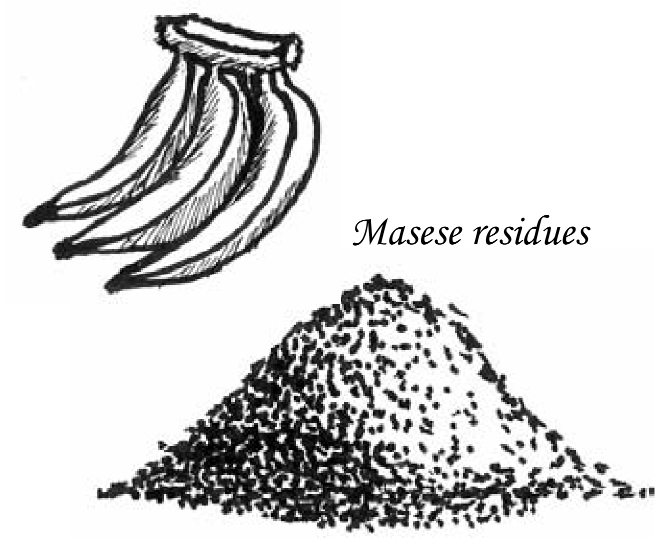
14. Bokashi, A Quick Making Compost Manure

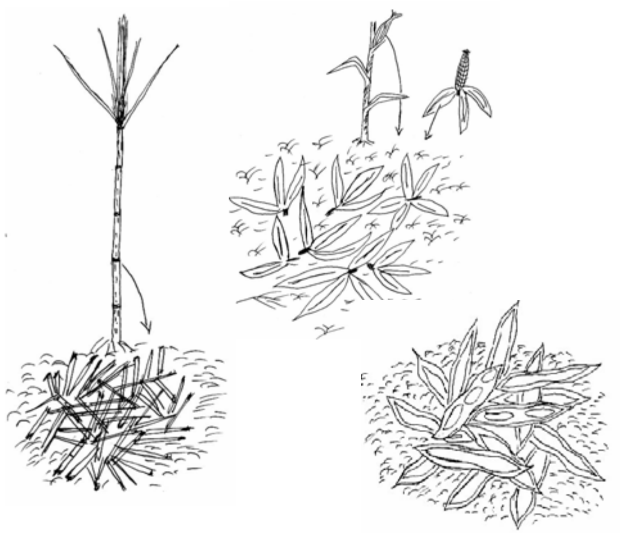
<table>
<tr><th>Step</th><th colspan="2">Materials to be collected</th></tr>
<tr><td rowspan="2">0</td><td>Collect all the following materials for one heap of Bokashi compost:
(a) Materials absolutely necessary
・ Animal manure: 3 bucket
・ Plant residue: 4 buckets
・ Virgin Soil: 3 buckets
・ Water: As required (Necessary to activate microorganism’s activities to decompose organic materials)
(b) Materials preferably added
(Yeast rich Materials: One or some of followings)
・ Chibuku/ Masese residue: a half bucket
・ One portion of Bokashi previously made: 1 bucket
・ Dry yeast for making bread: a half of teaspoon mixed with 500 ml of water (if possible add a spoon of sugar).
・ Banana peal, rotten fruits or other fruit residues: a half - 1 bucket soaked in water.</td><td>(c) Materials added if you have
・ Ash: A half bucket,
It is mainly for pH control of Bokashi.
Ash provides K and the other minerals. However, don’t burn plant residues for it, because if you burn the plant residues, you lose N and C from it, which are important nutrients for making compost.

・ Charcoal: A half bucket,
Break down into small pieces to be mixed with the other materials. It is a kind of microbes’ house, which means that it can provide spaces (microspores of charcoal) to increase effective microbes’ population.
Implements:
Hoe, Shovel, Panga knife, bucket</td></tr>
<tr><td colspan="2">

Recommended proportion of materials can be modified depending on availability of each material. However, the portion of soil should not be more than 30 % of all materials. If the compost contains too much soil, it becomes heavy while nutrient contained in the compost is less.</td></tr>
</table>

Step	Process	Description	Remarks
1		**<u>Collect animal manure;</u>** Tie livestock during night and put plant residues and grass under the animals. In the morning, collect dung and plant residues which have absorbed animal urine, and put them in a pit. To reduce evaporation, pour water in the pit and cover the pit with plastic sheets, banana leaves, etc.	Animal manure including urine, dung, and droppings are rich in nitrogen. However, it can be easily lost through evaporation when they are dried up. Chicken droppings contain more nitrogen that does not easily evaporate, compared to dung of cattle and other livestock. They also contain a lot of phosphate. Although urine contains a lot of nitrogen (ammonia) than dung, it is very difficult to collect. In this method, we can collect high quality animal manure so that we can make high quality compost from less amount of animal manure.

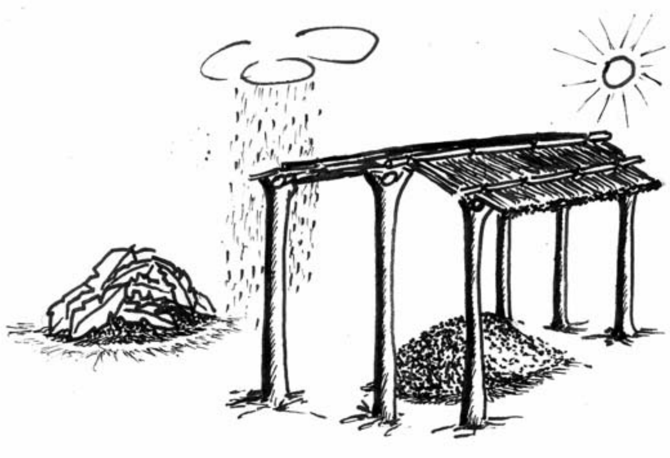
Step	Process	Description	Remarks
2		**<u>Collect virgin soil:</u>** Collect soil from virgin land that is never utilized for planting but has a good plant-ground cover (e.g. *dambo* or forest soils) or from orchard (e.g. under banana trees). Virgin soil contains a lot of active microorganisms that facilitate decomposition of the materials.	Soil contains microorganisms, which facilitate the decomposition. Also, it fixes nitrogen in the materials, reducing the nitrogen loss. Thus, soil should contain a certain amount of clay which quickly fixes nitrogen firmly. Farmland soil is not recommended because it is always exposed to sunshine. UV from the sunshine kills microorganism, and the soil becomes too dry for their activities. Do not put too much soil. This makes it very heavy to carry and the concentration of nutrient becomes low.
3		**<u>Collect Yeast rich materials:</u>** Collect *Chibuku*/ *Masese* residues, which contain a lot of yeast. If you cannot find those residues, use sweet fruit residues or a part of Bokashi previously made or sweet fruit residues. Those materials also contain a lot of yeast. Soak up sweet fruit residues in water for 2-3days to multiply the yeast. Generally, yeast is found on surface of fruits.	During the decomposition process, yeast takes nitrogen from the materials, and uses it for their body growth. The nitrogen in the body of yeast is mainly in a form of amino acid, which is water-soluble; plants can take it easily. As a result, the effect of compost appears relatively rapidly. On the other hand, nitrogen easily leaches out or evaporates than conventional compost. Yeast's body also contains rich vitamins which accelerate plant growth. Yeast works as nitrogen storage. Yeast releases nitrogen rapidly, while clay releases it slowly.

Step	Process	Description	Remarks
4	**The Day First**  	<u>**Prepare plant residues:**</u> Cut the plant residues into small pieces in order to make it easier to mix with other materials and to facilitate decomposition. Cobs of maize, pod of beans, maize bran, sugarcane residues, and other plant bodies are suited. Plant residues contain C, N, K and thus are good nutrients for plants, and energy source for microorganism. In addition, they are decomposed into manure form which contributes to holding appropriate moisture, keeping chemical fertilizer's effect longer. Plant residues are also effective to improve aeration in the heap, preventing a heap from compaction by its own weight. Choose the materials and mix them considering the both points.	Carbon in plant residues contributes to improve physical characteristics of soil. <u>Legume residues</u> are recommendable because they are rich in nitrogen. However, the legume leaves are easy to decompose so that the nitrogen is easily lost. To mitigate the nitrogen loss, fresh materials should be used. It should be noted that the leaves are not good for aeration of the heaps. <u>Maize bran</u> is recommendable, because it is another good energy source for microorganism and is useful to increase yeast population. <u>Sugarcane residues</u> are also good because they contain a lot of sugar. Sugar is a very good source of energy and is easily taken by microorganisms; microbe's activities are accelerated. <u>Leeds residue</u> is not recommended as it does not easily decompose. However, in terms of aeration, it has good effect. Other materials improving the aeration are maize cob, ground nut pods, and rice chaffs.

Step	Process	Description	Remarks
5		**<u>Mix materials:</u>** Mix the small portion of each material together.	If there are a lot of materials, don't mix the materials at once because it is difficult to mix them thoroughly. Take just a small portion of each material, mix them thoroughly, and put them into a good place.
6		**<u>Pour water on the mixed material:</u>** Pour water in order to keep appropriate moisture content. Be sure of not making it too wet or too dry. Ensure to add and mix water equally to whole materials so that all the materials become moist.	You can know you have good moisture content by holding a small portion of mixed materials firmly in your palm. Then, after releasing the hand pressure, a ball shape should be kept on your hand but it breaks easily when you shake.

Step	Process	Description	Remarks
7		**<u>Piling the mixed material with suitable moisture:</u>** After adding appropriate moisture, pile it on the ground, and then repeat again the mixing procedure as above-mentioned. Continue the procedure of mixing small portion of materials until you complete mixing all the materials.	Don't compact the materials as this reduce free air circulation, which is essential for decomposition. Under appropriate moisture content, aerobic microorganisms can get enough water and air for their activities. As decomposition speed of aerobic microorganisms is faster than anaerobic one, use of aerobic activities are maximized in Bokashi making. On the contrary, in conventional method, a lot of water is usually added and materials are firmly compacted, creating a good environment for anaerobic microorganisms. Anaerobic microbes decompose organic materials in slower pace.
8		**<u>Cover the finished pile:</u>** Cover finished pile with banana leaves or plastic sheets. It helps maintain proper moisture and prevent UV of sunshine from killing microbes. While moisture in conventional pit compost does not come down so easily, water will easily evaporate in Bokashi method unless it is covered by such materials.	

Step	Process	Description	Remarks
9		**<u>Keep appropriate temperature</u>:** After 1-2 days, the temperature of the materials rises up to more than 60 degree Celsius. This high temperature kills microorganism in the materials. Thus, often check temperature of the heap to refrain temperature from reaching this deadly high level. The process of checking is simple: 1) stick a panga into the heap, 2) count until ten, 3) pull out the panga, and then 4) touch it to feel the temperature. If it is too hot, break down the heap to release the temperature stuck inside the heap. When the temperature decreases to normal, say 30-45 degree, make heap and cover it again. As you check the temperature, also check the moisture; if it is dry, add water. Check the temperature and moisture once or twice a day during first week. And repeat this process to keep microorganisms alive. The materials are sometimes compacted by self-weight. If you find it, break down the pile, and remake the heap. To reduce compaction and improve aeration, add enough plant residues.	Different from Bokashi method, in conventional methods, materials are kept untouched and temperature becomes very high so that most microorganisms once die. After the temperature has decreased to a favorable level, micro-organisms increase their population and start decomposing again. Due to this process, conventional methods require much more longer time, say at least 3 months to as long as half a year in cases. Note that though it takes shorter period of time to make Bokashi, avoiding high temperature cannot kill disease, viruses, bacteria, or insect pests that might be in the materials. Therefore if there is a prevalent epidemic in the area or when you need to use affected plants, conventional methods are rather recommended than Bokashi method.

Step	Process	Description	Remarks
10		**Now ready to use:** After 2-3 weeks, the compost, Bokashi, is ready to use. Spread all the materials and dry it under shade in order to stop the decomposition. Stop the decomposition when you find the color of materials turned dark. Bokashi method takes 2-3 weeks, while conventional methods take 2-3 months. It is because of quality materials and good conditions for effective microorganism activities (not too dry, not too hot, and sufficient air circulation).	If you find the color of all the materials has changed into dark, decomposition should be stopped immediately. Because if the decomposition process continues, nitrogen in Bokashi changes into other forms. Some part of it changes into a form that can easily evaporate, while some changes into water insoluble form; difficult for plants to absorb.
11		**Keeping the Bokashi:** Avoid sunshine and keep it dry under shed.	Bokashi should be kept in dry condition. If it becomes wet, decomposition will start again and some nitrogen in Bokashi sometimes evaporates and changes into slow acting form. Bokashi contains a lot of useful microorganisms. Therefore, UV from sunshine should be avoided in order not to kill microorganisms.

<table>
<tr><th>Step</th><th>Process</th><th>Description</th><th>Remarks</th></tr>
<tr><td>12</td><td></td><td><u>Apply Bokashi;</u>
Bokashi is used both as basal- and additional- fertilizers.
If you apply Bokashi as additional-fertilizer, a handful of Bokashi is generally applied to each plant. Top-dressing method is not appropriate because microorganisms will be exposed to sunshine. When apply, dig a hole, earthen up with Bokashi, and cover it with soil.</td><td>Apply Bokashi compost in a way to avoid sunshine.</td></tr>
<tr><td>13</td><td><u>Amount of Application per Lima (Standard):</u>
(a) Standardized amount of chemical fertilizer for maize cultivation in Zone III in Zambia
・ D-compound (10:20:10-5s): 50 kg/lima
・ Urea (N=46%) : 50 kg/lima
(b) Amount of each nutrient applied
・ N : 50 kg by 10%+50 kg*46%=28 kg/lima
・ P : 50 kg by 20%=10 kg/lima
・ K : 50 kg by 10%=5 kg/lima
(c) If you want to add same amount of nutrients in terms of N, add the following amount of Bokashi.
・ 28 kg/2.05%(*)=1,366 kg/lima
(d) If the weight of one heap of compost is 20kg, you need:
・ 1,366 kg/ 20kg/heap = 68 heaps/lima</td><td>(e) Amount of other nutrients added
・ P : 1,366 kg by 0.04 %(*) = 0.546 kg
・ K : 1,366 kg by 0.43 (*)% = 5.87 kg
(f) If you want to add same amount of nutrients of chemical fertilizer, you should additionally apply,
・ P : 10kg - 0.546 kg = 9.45 kg/lima
・ K : 5 kg - 5.87 kg = N/A

If you would like to make P-rich compost, chicken droppings are recommendable to add in the materials. Even if this much of application is difficult, application of organic fertilizer help improve physical characteristics of the soil –Add as much as you can.</td><td>(*): Nutrient contents of Bokashi Compost and Compost
<table><tr><th>Type</th><th>Data source</th><th>% N</th><th>% P</th><th>% K</th></tr><tr><td>Bokashi (Cattle dung)</td><td>Study Team</td><td>2.05</td><td>0.04</td><td>0.43</td></tr><tr><td>Compost (Cattle dung)</td><td>Japanese Average</td><td>1.6-2.1</td><td>1.5-3.5</td><td>2.0-4.0</td></tr></table>
In Japan, the amount of Compost application recommended is 5 ton/ha (Cattle Dung)</td></tr>
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