MINISTRY OF AGRICULTURE AND COOPERATIVES
THE GOVERNMENT OF THE REPUBLIC OF ZAMBIA

THE STUDY ON THE CAPACITY BUILDING AND DEVELOPMENT FOR SMALLHOLDER IRRIGATION SCHEME IN NORTHERN AND LUAPULA PROVINCES

TECHNICAL MANUALS

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JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
SANYU CONSULTANTS INC., JAPAN

Foreword

This Technical Manual is a part of Smallholder Irrigation Development Package produced under the Study on the Capacity Building and Development for Smallholder Irrigation Scheme in Northern and Luapula Provinces. The Study is carried out from March 2009 to July 2011 in partnership with all those concerned officers of the Ministry of Agriculture and Cooperatives. The Study produces following dissemination materials for smallholder irrigation development, which altogether consist of the Package.

1) Technical Manual (Part I: Comprehensive Guideline, Part II: Process Description Manuals)
2) Posters (6 sheets of A-3 size, utilized as picture stories as well)
3) Leaflets (2 kinds of total 6 pages each, English)
4) News Letters (featuring site development including brief manual-like explanation, total 69 volumes of A-4 both sides printing issued)

Ideas incorporated in this Manual are fully based on the experiences of the Study, which includes the implementation of pilot project to examine the best technologies appropriate in the context of the Study Area. The Study, throughout the pilot project, conducted various trials on diversion weirs depending on each site condition, canal alignment with a very simple tool that is sprit line level, on-farm irrigation methods, irrigated agriculture, etc. and also low-input agriculture components, e.g. compost manure, promoted with the smallholder irrigation.

This Manual is structured in two parts that are “Part I: Comprehensive Guideline” – presenting various issues for smallholder irrigation development such as rationale of the smallholder irrigation development, irrigation by type depending on the site condition, irrigation facilities, irrigated agriculture, etc, and “Part II: Process Description Manuals” – elaborating various irrigation facilities step by step with illustrations that can be constructed by the farmer themselves with technical assistances from the government officers, e.g. provincial and district TSB officers and BEOs/CEOs. The Part II also incorporates irrigated agriculture practices centering on low-input agriculture. Although ideas in this manual should not be over generalized, they are expected to be tools of practical application to further extend similar smallholder irrigation development to wherever there is potential.

Readers of this Manual are to be the government irrigation technical officers and also agriculture extension officers or development practitioners for smallholder irrigation on the ground. We expect the readers to utilize this Manual in respect of each condition, but also to try out the disciplines asserted throughout the text in practice. Being still humble enough for over generalization, experiences in the pilot project are illustrated as much as possible corresponding to the general description of the ideas to indicate how the ideas are to be realized. However we also believe that the actual experience is the living source of the text to be conveyed from its origin to various contexts.

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PART I COMPREHENSIVE GUIDELINE

CHAPTER 1 DEVELOPMENT OBJECTIVES AND STRATEGY

1.1 Rationale

Annual rainfall of the Republic of Zambia (Zambia) reaches over 1,000 mm in some regions. Nevertheless, 90 % of annual rainfall concentrates in rainy season from December to April. Further, unstable rainfall pattern causes unstable agricultural productivity, resulting in serious food shortages in certain times.

Smallholder farmers have thus been damaged by natural vagaries such as heavy rainfall and also drought. Only rain-fed agriculture, which has long been the core of Zambian agriculture, can hardly span their life from a season to the next season. Before next harvesting season comes, farmers may just end up with very little food left over, which implies even no seed left for the next season.

Although irrigation potential in the country is estimated to be around 360,000 ha[1], only a little fraction of the vast potential has been taped so far. Therefore, improvement of smallholder farmers' productivity through introduction of irrigated agriculture is believed to be an urgent task for food security, poverty reduction, and economic development. There is therefore a pressing need of establishing a guideline with elaborated manuals to facilitate the development of the smallholder irrigation schemes.

As it may be noticed from past experiences, the development of smallholder irrigation facilities needs to be low-cost and easy to manage, taking into account the farmers' financial and managerial capacity. Cost of the construction materials such as reinforcing steel and cement are also comparatively expensive in the landlocked country, Zambia. Therefore, in developing smallholder irrigation schemes, farmers (groups) should be able to play the greatest role. With this in mind, following guideline with manuals are presented:

1.2 Definition of Smallholder Irrigation

National Irrigation Plan (NIP) was established in July 2005 to promote a use of irrigation to accelerate sustainable agriculture development. Major target groups for this intervention include smallholder farmers who are the target of this manual. However, the NIP does not specify what kind of irrigation schemes should fall under the category of smallholder irrigation, but only mentions the schemes for the smallholder farmers. Therefore, in this Manual, following are applied to specify what the smallholder irrigation is; namely,

Smallholder irrigation schemes are those that;

1) should be operated and maintained exclusively by the beneficiary smallholder farmers, and may require government/donors' assistances in case of upgrading of existing facilities, e.g. from simple (temporary) scheme to permanent scheme, or in the event of major rehabilitation of permanent schemes;
2) should be constructed with farmers' participation to the maximum extent; whereby simple structures, e.g. temporary diversion weirs made out of locally available materials, can be constructed by themselves with government's technical assistances, and even permanent structures made of foreign materials (e.g. cement, iron bars), upon being provided by the government, donors, etc., should be tried by themselves given the technical assistances from the government; and
3) should have preferably less than 50 ha of irrigation command area, where full scale of Environmental Impact Assessment (EIA) is not required according to the Environment Protection and Pollution Control (Environmental Impact Assessment) Regulations, 1997. Then, smallholder irrigation schemes less than 50 ha of command area may further be divided into 2 categories such as those less than 5 ha as mini-scale and the others more over 5 ha as small scale. Irrigation schemes with over 50 ha can, of course, be categorized in smallholder irrigation if it is fully operated and maintained by smallholder farmers. However it may be better to further segregate it within the category of smallholder.

1.3 Limitation of this Manual

This Manual deals with gravity irrigation system only. Gravity irrigation is the

[1] Source: Agricultural Statistics Bulletin 1995/96 (MACO, 1997), Smallholder Irrigation and Water Use Programme, FAO, 2004, Irrigation Policy and Strategy, September 2004

cheapest and most maintainable irrigation hence most sustainable. The Manual may undertake a storage type irrigation system with reservoir, but the scale shall not go beyond what the farmers can construct by themselves. It means large-scale dams whereby heavy equipment is required in the construction are not undertaken.

As per structure of smallholder irrigation schemes, this Manual undertakes 2 systems, 1) simple schemes and 2) permanent schemes. Simple schemes are those ones constructed by locally available materials, e.g., wooden logs, wooden poles, bamboos, grasses, twigs, clay soils, cobbles and stones, etc. There are already this simple irrigation schemes in Northern and Luapula provinces, which have been constructed by farmer themselves. This Manual provides some form of improved simple diversion schemes.

Permanent scheme, on the other hand, can be a concrete wall type diversion system and/or wet-masonry diversion system. These 2 systems are undertaken in this Manual by providing design criteria, elaborated process of how to construct such diversion structures, etc. Also provided is a design manual of spillway whereby even simple diversion weir can survive over seasons by discharging a flood safely.

This Manual recommends an upgrading from simple (temporally) scheme to permanent scheme. Smallholder farmers can start irrigation with a simple diversion scheme, e.g., temporary diversion weir, made of locally available materials. With some experiences, they can smoothly move onto the next step that is more stable form of irrigation with permanent structure.

In other words, we may say that farmers should start irrigation with whatever means they can devise in their locality, and when they think they can graduate from that form of primitive irrigation, it is the time to move onto the advanced form of irrigation with permanent structure. This upgrade approach will definitely ensure scheme sustainability.

1.4 Objectives of Smallholder Irrigation Development (SHID)

The objectives relevant to the smallholder irrigation development are categorized into three; namely,

SHID Overall Goal: Poverty among rural population is alleviated through promoting broad agriculture development based on increased agriculture production and productivity.

SHID Purpose: Livelihood for smallholder farmers is improved through promoting irrigated agriculture with an emphasis on dry season cultivation that fulfills the foot shortage between the seasons as well as that can enable cash crop production.

SHID Outputs: 1) Institutional capacity such as facilitation and technical knowledge and skills relative to smallholder irrigation development is built among government officers,

2) Farmer organizations responsible for constructing, operating and maintaining smallholder irrigation schemes are established with facilitation from the extension officers concerned,

3) Simple schemes are established out of locally available materials by farmers with the government technical assistance, and permanent structures are also constructed by the farmers given technical as well as foreign material assistances by the government/donors, and

4) Dry season irrigation and supplemental irrigation during lean rainy season are established in the smallholder irrigation sites with appropriate agriculture extension services from the extension officers.

1.5 Implementation in Technical and Administrative Lines

Implementation arrangement follows the existing government organizational setting up consisting of HQs TSB, Provincial TSB, District TSB and Block/Camp extension area. Responsibility at different levels of the technical line can be summarized as:

Central level (HQs): Irrigation trainings for TSB officers at province and district, monitoring and evaluation of smallholder irrigation development at national level, banking of appropriate irrigation technologies/experiences and these dissemination, and facilitating the exchange of the technologies among provinces,

Province level: Technical advices to the district TSB officers concerning smallholder irrigation development, monitoring and evaluation at provincial level, facilitating the exchange of irrigation experiences among districts,

District level: Technical advices to the block and camp extension officers concerning smallholder irrigation development, procurement of such foreign materials as cement and steel bars for permanent structures, designing and direct supervision for the construction of permanent structures, monitoring and evaluation at district level, and facilitating block-to-block-visit for the extension officers, and

Block/Camp level: Identification of potential areas for smallholder irrigation schemes, facilitation of the farmers including identification of the potential beneficiaries, arrangement of farmer-to-farmer visit in the block/camp, organizing them into irrigation group/club, facilitation of the construction work, follow-up of operation and maintenance, etc.

As stated above, there is a different role at the district TSB level according to what structures are to be constructed. To construct simple schemes, block/camp extension officers should be at the frontline with the farmers benefited while the district TSB officers can stand as a technical advisor to the block and camp extension officers.

In case of permanent structure schemes, however, the district TSB should be in the frontline in terms of both designing and construction since such structures need certain knowledge of hydraulic and structural engineering and in cases designing of flood based on return period probability. Designing of permanent structures should be tried by district TSB officers with this Manual as reference and the design should be checked and endorsed by provincial TSB.

CHAPTER 2 PARTICIPATORY PLANNING

This Manual advocates that participatory development does not necessary mean only farmers' participation but rather defined as participation by all the actors involved in the smallholder irrigation development such as farmers, village headperson, frontline extension officers, TSB officers, and other officers in the related fields, local authority, NGOs, etc.

2.1 Workshops at Different Cadre

Participatory workshop can be held at any levels of national, provincial, district and also block/camp areas. National and provincial level workshop can identify the stakeholders and general problems surrounding smallholder irrigation sector. Workshop at district level can learn the problems for a specific regional agricultural situation from the officers' point of view. Workshop at block/camp level can identify the structure of the problems specific to their villages from the farmers' point of view.

As national level and provincial level workshops need particular logistics, these workshops may be conducted once a year only or otherwise held by taking an advantage of a meeting for other purposes at that level. The workshop should incorporate the evaluation of the past year's performance and also the planning of the following year's action programme with the relevant target.

Workshop at district level including block/camp officers can be held by taking an advantage of their annual meeting. In most of the districts in Zambia in nowadays context, annual meeting inviting all the block and camp extension officers is held only once a year. This is due mainly to financial constraint for the logistics. During this workshop, the officers should exercise evaluation of the past year's performance, and also discuss and agree the following year's action programme with the target.

2.2 Entry Workshop at Village Level

Entry workshop at village level is staged into three: 1) problem analysis &

prioritization, 2) selection of the project design option, and 3) action plan formulation. Problem analysis will identify the problems in the villages and the prioritization will identify necessary components in addition to the irrigation development. The problem analysis & prioritization workshop is held in such manner of:

1) Choose a wider Core Problem so that almost all the problems which the villagers are facing can be covered by Problem Analysis (note that “Life is not easy or Villagers are in hunger” may fulfill the purpose under present conditions),
2) A block/camp officer, one of the village leaders or a young farmer can write down the problems on a big khaki paper during the workshop for the participants, and
3) Prioritize the problems by using Scoring; one of RRA tools, or by simple hand-raising by the village participants (an example is shown in the following tree-structure diagram).

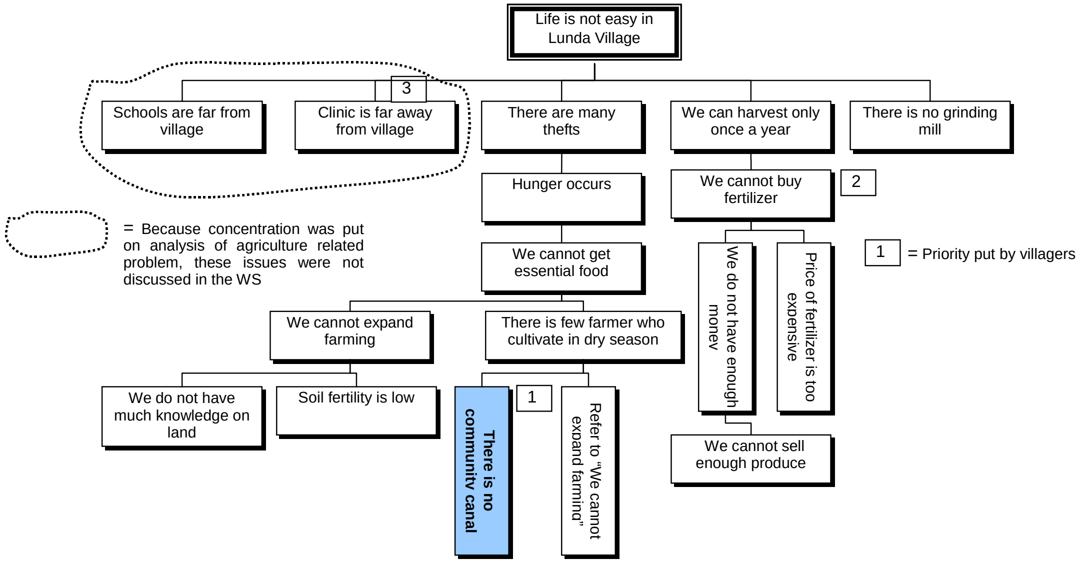


Figure 2.1 Problems Analysis Carrie out at a Village in Kasama District, June 2009

Right after the problem analysis session, the concerned block/camp extension officer together with the district TSB officer prepare some options/alternatives of the project design for the smallholder irrigation scheme. Options include, for example, a diversion weir made of sand bags, locally available materials (temporary weir), wet-masonry, etc., taking into account farmers’ self-effort to the largest extent while minimum level of outside physical assistances.

Now it will be the decision for the farmers to choose, but the facilitation should be given in such a way of selecting labor-intensive and less-cost option. If they choose labor-intensive option, they do not need to pay money. Even if they want permanent structure, they can be convinced to start with simple structure and then they can upgrade to permanent structure sometime after they have practiced irrigation with the simple one.

After basic project design is decided, an action plan is formulated at the village. The purpose of formulating the action plan is to clarify and to let all the villagers concerned understand the project design, responsibilities, obligation and conditions (see the table below for an example). Several components such as seed multiplication, seed bank, exchange-visits, introduction of green manure, compost manure making, land conservation, establishment of fishponds, etc. need to be incorporated.

Table 2.1 An Example of Action Plan to Construct Irrigation Scheme

Activities	Indicators	By When	Responsible persons	Actors	Supporters	Risks
1. Collection of clay soils	30 wheel borrows of soil are delivered to the site	by end June 2010	Chairman of the Irrigation Club	All the members	CEO in charge	Availability of clay soils
5. Construction of weir	10m length and 1.5 height weir is constructed	by end August 2010	do	do	District TSB/BEO	No other business

In allocating the responsibility between the villagers and outsiders, the issue in mind is that the smallholder irrigation scheme is of a self-help type project. Therefore, the owner of the scheme is obviously the farmers from the beginning. It should be rather government participation to the farmer’s project than farmer's participation to the government project.

In sum, farmers are expected to do whatever they can do with maximum efforts, while the government does the rest, especially technical parts. For example, all the labors and locally available material are automatically from the farmers and the government provides technical assistances for designing, construction, operation and maintenance. And, in case of upgrading to permanent structures, foreign materials are to be provided by the government/donors but again voluntary labors by the farmer themselves.

In case that BEO/CEO in charge is not familiar to the above Problem Analysis tool (and runs shortage of khaki paper), the officer in charge may show picture stories prepared under this Study (there are 4 volumes of picture stories showing 4 types of simple diversion weirs). In case that the target farmers get interested in such simple structures, then simply start discussing the action plan with the target farmers.

CHAPTER 3 DESIGNING OF THE IRRIGATION SCHEMES

Developing smallholder irrigation exclusively depends on the natural resource that is water. Needs for irrigation from the farmers therefore do not always meet the commencement of smallholder irrigation project. Potential in terms of stream flow as well as topographic condition, whether gravity diversion is feasible or not within the farmer's self-effort, should be examined as the first step.

3.1 Irrigation Type

Topography in Northern and Luapula provinces, and Zambia by and large, can be basically divided into four types; namely, 1) mountainous area, 2) transition area from mountain to upstream *dambo* area, 3) upstream of *dambo* areas and 4) middle – down stream of *dambo* area. Mountainous areas and transition areas are physically not suitable for building large-scale irrigation schemes due mainly to its hilly and undulating topography.

On the other hand, however, those areas can provide a lot of potentials for small-scale gravity irrigation system from the viewpoint of easy water abstraction. In contrast to them, upstream and mid stream *dambo* areas, where large wetlands extend alongside the river/stream, can be developed for medium to in some cases large-scale irrigation schemes.

Figure 3.1 illustrates typical irrigation systems developed along river/stream in Zambia. They are categorized in eight irrigation types, Type A – Type H, as described below. Of them, this Manual undertakes Type A – Type D systems:

1) **Mountain Stream Diversion:** This is located at the most upstream of rivers where the river slope is steep. Irrigation system is normally at small-scale as water flow is small. Key factors to make a plan of this type of irrigation system are water abstraction to be easy by gravity, farmlands to be situated near water source, and mountain/hill slope to be at least somewhat gentle so that farmlands can be developed with irrigation.

2) **Stream Diversion at Transition Area between Mountain and Upstream *Dambo*:** This type of irrigation system is located at transition area between mountain torrent area and upstream of *dambos*. The slope of river/stream is still somewhat steep. This irrigation system can be relatively at middle size because the amount of water flowing in the river/stream is richer than the diversion point of type (A) above. The conditions for the establishment of this irrigation system are almost same as the type (A). This means that the water abstracted from river/stream can be conveyed to the farmland by gravity.

3) **Stream Diversion located at Upstream of *Dambos*:** This is situated at an upstream area of *dambos* where surrounding areas are of still hilly topography. Pumping devices like motorized/engine pump, treadle pump may be utilized to supplement water in the furrow and/or to irrigate upper lands which cannot be covered by gravity from the furrow. Bucket irrigation with dug-well water is also applied in this area.

4) **Stream Diversion located at Mid-down Stream of *Dambos*:** Similarly to the type (C) above, river/stream diversion sites are found at river course within *dambo* area. A diversion weir is to be located inside *dambo* area, say mid to downstream areas of *dambos*, thus weir length becomes longer to

cross the *dambo*. In order to gain larger area to irrigate, the furrow (canal) tends to have longer distance. The irrigable area is set in between the stream and the furrow. Due to the gentleness of the stream, the furrow cannot run away from the stream, thereby making it difficult to develop wider irrigable area within a limited distance from the diversion point.

5) **Dam for Impounding:** This type is usually built at upstream to mid stream of rivers providing relatively large-scale dams to impound river/stream water, and a gravity furrow system for water delivery. Irrigable areas will become large-scale involving large number of beneficiaries. The points to make this scale of irrigation schemes sustainable are operation and maintenance of irrigation facilities, water distribution management, and set-up and management of well functional water users association.

6) **Surface Engine / Motorized / Treadle Pump based Irrigation including Bucket:** In order to irrigate hillside from mid to downstream *dambo* areas except places which can be covered by gravity irrigation, lifting of water from rivers/stream cannot be avoided and either engine/motorized pump or treadle pump are considered as water lifting device. Treadle pumps may also be used at very small-scale.

7) ***Dimba* Farming at Dambo Area:** Traditional *dimba* farming is practiced at *dambo* areas at both middle and downstream of *dambos*. Unless it is covered by any of the gravity diversion irrigation systems, cropping is done with a help of bucket irrigation or under residual moisture.

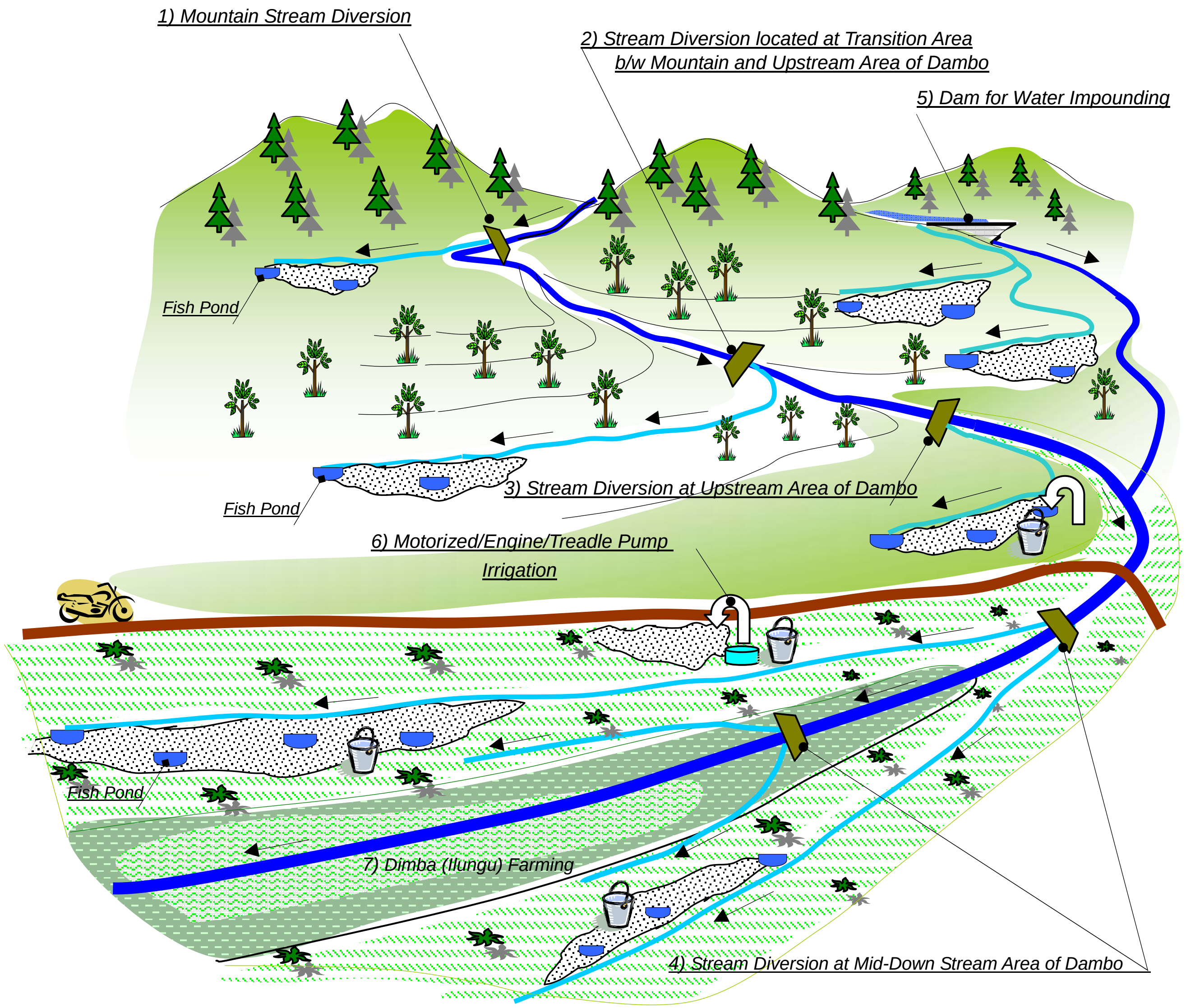


Figure 3.1 Irrigation System in Zambia (Type A – Type D are undertaken in this Manual)

8) **Sprinkler Irrigation Scheme:** This irrigation system occupies a quite small number of existing irrigation schemes in Northern and Luapula provinces. This type usually involves motorized pumps for water abstraction and pressure pipes for water delivery. Location of pumping sites must be carefully studied where water is tapped from streams/rivers taking into account the magnitude of floods.

3.2 Stream Flow

Stream flow is almost entirely corresponding to rainfall. Upon the onset of rainfall, stream flow starts increasing, and then as rainy season comes to the end the flow starts retarding. Throughout the dry season, almost all the streams continue reducing the flow and in some cases dry up. Discharge record is not available for those relatively small streams this Manual targets. Given this situation, following can be given as an idea of how the stream potential is assessed;

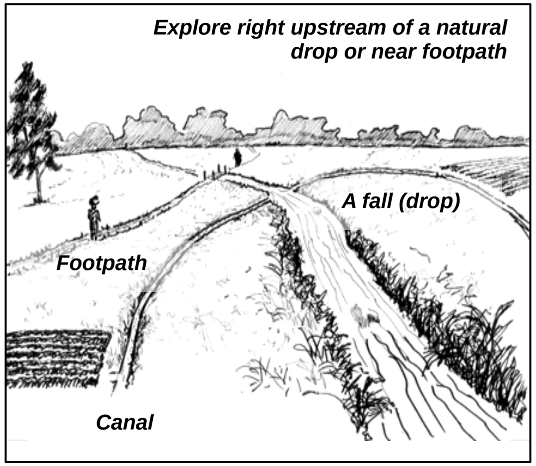
1) Visit the potential diversion site and observe the flow with the concerned farmers and ask them "if this stream dries up on the course of dry season or continues flowing until the next rainy season". If the answer is "dries up", abandon the site and move next potential site. If the stream is perennial; Ask the farmers "how much flow will decrease towards the end of dry season". They may answer "the flow reduces to less than half or less than one-third as compared to the flow at the beginning of the dry season".

2) Try to measure the stream flow. There are two methods as elaborated in PART II "Process Description Manuals, 11. Discharge Measurement". They are 1) float measurement and 2) V-notch or rectangular notch measurement. Notch measurement usually gives accurate results, while float measurement is convenient if the stream is considerably big.

It is noted that the flow measured at the beginning of dry season does not directly entail the possible irrigable area as the flow reduces towards the end of dry season. Therefore stream flow measured at this stage should be taken as reference only. Critical issue is how much water decreases towards the end of dry season. Though farmers may inform the reduction to about half or about one third, there is a tendency to always underestimate the retarding ratio, which inevitably causes abandoning of part of the irrigation service area.

With this in mind, it is recommended that at least at first year the development should not be ambitious or rather start with relatively small area. It is suggested that in any case no more than half of the potential area shall be developed even if the flow looks very constant, and in case that certain flow retarding is expected, the development at the first year should be limited to less than one-fifth to even one-tenth of the potential area.

3.3 Diversion Site



Gravity irrigation system starts with diversion weir. Potential diversion sites being blessed with perennial flow, the depth should not be very deep; preferably limited to 2m according to experiences. Good sites can very often be found at villagers' footpath which crosses a perennial stream and also at just upstream of natural drops (small fall).

Footpaths usually traverse streams at a shallower place, forming a topographic condition of easily diverting and getting water onto the farms nearby downstream. Just upstream of natural drops (small fall) could easily lead the water into canal by gravity thanks to the elevation difference.

3.4 Development in a Stream

There may be a series of potential sites located nearby along a stream. Sometime after farmers have started irrigation development at a specific site, upstream farmers in the same stream may start developing irrigation by seeing their peer's achievement. This may cause water deficit for the downstream site, creating water dispute among the concerned.

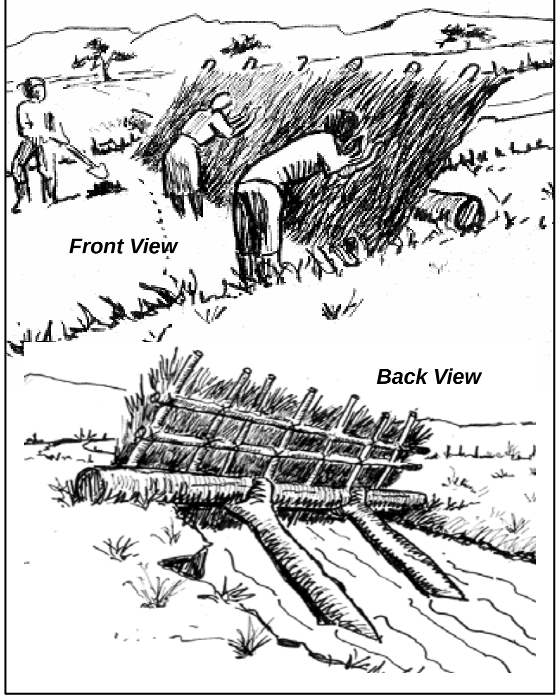
Stream diversion as its nature always favors upstream sites thereby downstream farmers often result in at the mercy of the upstream farmers. This situation takes place very often where stream flow is not enough to cover all the sites concerned. Even if the downstream farmers who started irrigation earlier express their water right, they may end up in vain, and then finally water dispute takes place.

Village headperson being involved, they may agree rotational allocation of the water between the sites. This arrangement will work to resolve the water dispute to some extent. However, water flow itself is limited in most of the smallholder irrigation potential sites. An arrangement therefore should be taken into account in case that there are several potential sites located nearby along a stream. The development in this case should always be tried from the upper most reach and then proceed to downstream according to the water availability.

3.5 Construction of Simple Diversion Structures

First step is to believe that diversion weirs can be constructed by using locally available materials such as wooden log, bamboo, grasses, soils, etc., and can raise the water level across even over a 20 meter width stream and as high as 1.5 meter depth. Following are tips of what simple diversion weirs can fit to what kind of streams (for detail, refer to the Part II Process Description Manuals).

Diversion Weir in a Narrow Stream

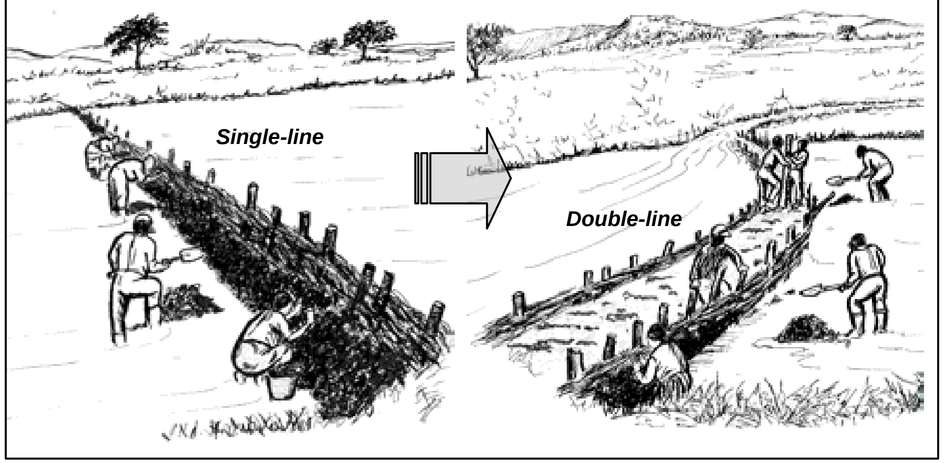


In case of narrow stream, constructing diversion weir is very easy: 1) put a horizontal member (wooden log) astride the both banks preferably supported by a wooden prop from the behind, 2) place vertical members, on the horizontal member, of bamboo, twig, and reed inclined to downstream, 3) put grasses on the vertical members and then clay soil thereon.

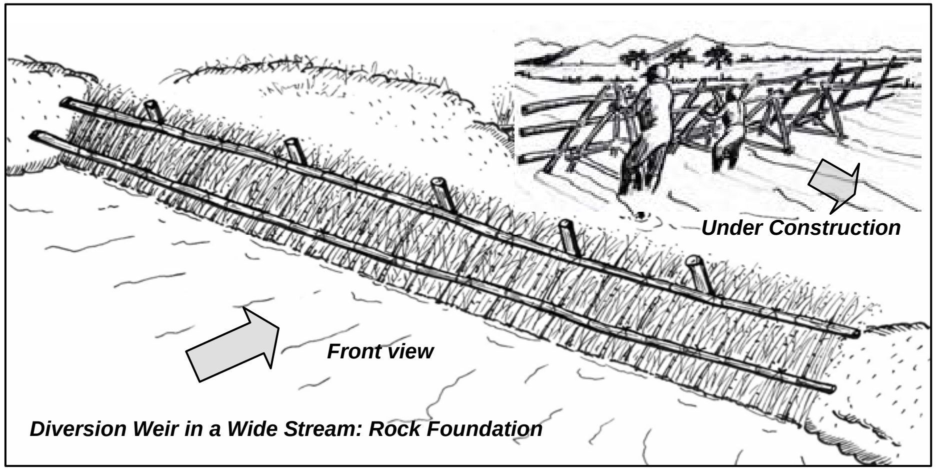
In case of wide stream, there are mainly two ways of constructing a diversion weir depending on the foundation condition: i.e. soil or rock.

At soil foundation, 1) drive wooden logs into the foundation across the stream preferably 30 – 50 cm interval, 2) put grasses alternately through the logs like weaving the logs, and then 3) patch clay soils upstream on the woven wall. This single-line weir is very simple and can fit in *dambo* areas. If leakage needs to be minimized, 4) make another line of the wooden-log woven with grasses about 70 cm to 150 cm downstream from the first line, 5) put clay soil in between the two lines and compact the soil by footing/treadling. This double-line weir can also work as footpath for villagers.

Diversion Weir in a Wide Stream: Soil Foundation



At rock foundation, 1) first prepare trigonal prop stand structures which support the weir body from behind across the stream, 2) put horizontal members of twig or bamboo in front of the props preferably every 30 – 50 cm interval in vertical, 3) put vertical members of twig, bamboo and reed on the horizontal members, 4) put grasses and then clay soils thereon.



3.6 Construction of Permanent Diversion Structures

This Manual presents total 3 types of permanent diversion structures; namely, 1) wet-masonry wall type weir supported by buttresses, 2) concrete wall type weir supported by buttresses, and 3) wet-masonry gravity type weir. To minimize the cement volume, the first 2 structures are designed by having buttress, prop type supports. With the buttress, the body itself can stand as vertical wall-like one thereby reducing cement volume. Following are the standard recommendation of the types in accordance with the height:

Table 3.1 Recommended Type of Permanent Weir with Relevant Height

Height (Max.)	Type to be Selected	Remarks
H =< 1.5 m	Wet-masonry wall type	
1.5 < H =< 2.0 m	Wet-masonry/Concrete wall type	According to the site condition either type be applied.
2.0 < H =< 3.0 m	Concrete wall type	No more than 3.0m height shall be tried.
2.0 < H =< 5.0 m	Wet-masonry gravity type	1) No more than 5 m height shall be tried under direct force account construction. 2) Between 2 – 3 m of height, either type be applied according to the site condition, e.g. in case that there are lots of cobbles, this type can be applied.

Note: the height (H) in the table shall not include the height of basement. Source: JICA Study Team

As the height of the wall becomes taller, wall-type weir would have difficulty of standing against water pressure. Also sliding along the contact between the foundation and the weir body might take place. In such case, more stable structure should be introduced, e.g. gravity type wet-masonry weir.

Permanent structure can hardly be constructed in deep *dambo* areas. In *dambo* areas, there is always a thick organic sedimentation accumulated, most of which are not consolidated yet. The foundation would therefore start sinking by the weight of the structure as exampled in the photo. The example shows as much as about 20cm settlement, opening a way for leakage in the beneath of the weir.

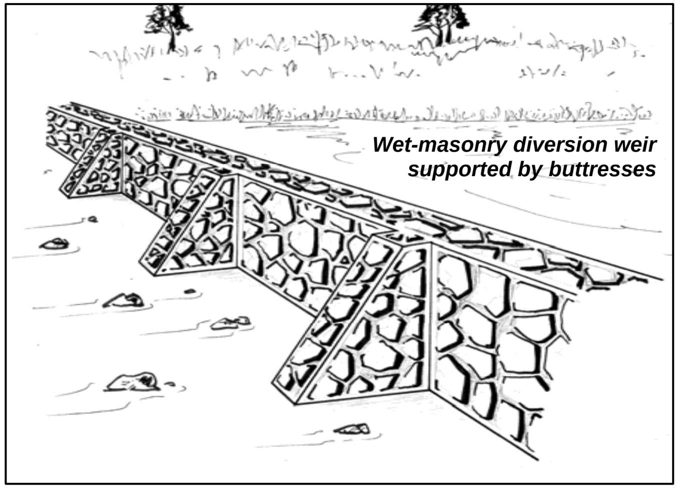
Blocks of the weir body slided down at contraction joints due to settlement of the foundation.

In fact, as the contraction joint between the concrete blocks slided down, much leakage underneath the weir body did not take place. Otherwise leakage underneath the weir body could have stopped the weir from functioning. Therefore, this Manual recommends NOT to construct permanent structure in deep *dambo* areas.

3.6.1 Wet-masonry Wall Type Weir

Wet masonry weir is made of stones/ rocks with cement mortar. Wet-masonry weir is not much familiar in Zambia but it can apply to upland streams where stable foundation, e.g. rock foundation, can be found. Cement mortar is applied in this structure, but farmers may try clay-mortar as the first step constructing simple weir. Thereafter, they may move to the cement mortar wet-masonry weir, which is permanent.

In applying this permanent weir, meandering of the stream should be well observed. Under any possibility for the stream to meander, no this kind of permanent weir should be constructed. From this point of view as well, farmers can try simple weir made out of stones/rocks with clay-mortar where possible. Sometime after they have observed the diversion situation, they may move to the permanent one. No more than 2 m height shall be tried for this type of masonry wall type structure, and preferably the height shall be limited less than 1.5m (excluding the thickness of foundation basement).



3.6.2 Concrete Wall Type Weir

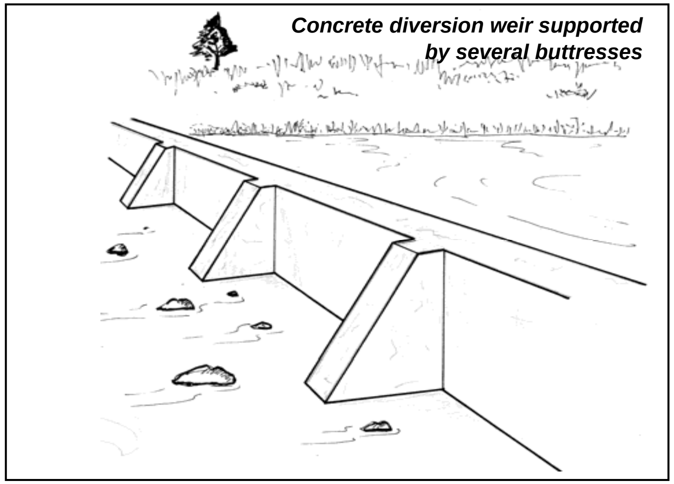
Concrete made weir functions almost the same way as those of cement-mortar masonry weir. This, however, is much higher in construction cost and needs skilled labor or at least qualified technical assistance in mixing, placing and curing concrete. Placing concrete requires formwork, which also needs skilled carpenters. Therefore this Manual recommends this type of weir only in sites where wet-masonry weir can hardly be constructed.

If a diversion weir requires more than 1.5m - 2m height, it is considered that wet-masonry type weir becomes difficult to stand against water pressure unless otherwise well supported by continuous buttress from the behind (in this case, the cross section of the weir becomes gravity self-standing type weir against water pressure). With this situation, following are recommended:

Weir height;

Less than 1.5 – 2.0 m:	Wet-masonry weir supported by several buttresses,
More than 1.5 – 2.0 m:	Concrete wall weir supported by several buttresses (however the height not more than 3.0m in any case)

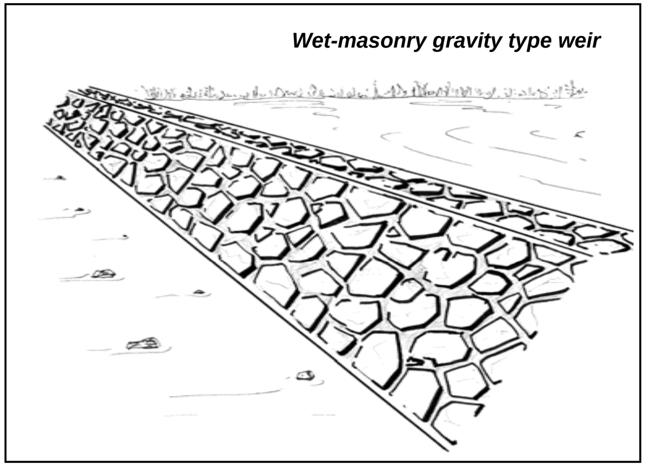
In case that the height is between 1.5 m and 2.0 m, the type can be selected according to the site condition; namely, where there are lots of stones and cobbles available and also where there is a solid foundation, wet-masonry weir may be selected otherwise concrete weir should be selected. It is also remarked that without irrigation/civil engineer at site, no weir more than 1.5 m above the ground level should be constructed due to high risk of accident.



3.6.3 Wet-masonry Gravity Type Weir

In case height of wall becomes more than 3.0 m, there could be a difficulty for wall type weir to stand water pressure even if the body is constructed with concrete. Even if the wall itself can put up with the pressure, the foundation may not be able to stand to seal the water because contact line between the wall base and the foundation is not long due to the nature of the wall type structure. Therefore, this Manual does not recommend to construct wall type weir in case of the height being more than 3.0m, and in such case gravity type weir should be introduced instead.

Since gravity type weir requires mass volume of stuff in the body, wet-masonry structure should firstly be considered. Wet-masonry structure can be cheaper than that of concrete made ones. Likewise, if there are lots of stones at the site, this gravity type wet-masonry weir can be tried instead of concrete wall type even in case that the wall height is less than 3.0 m.



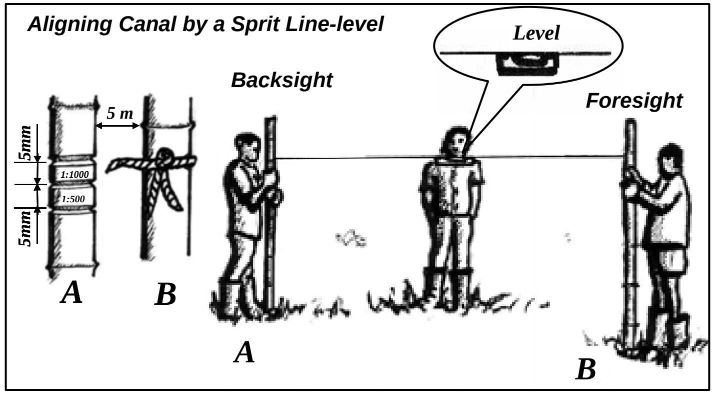
Since the construction modality proposed under smallholder irrigation is of direct force account, no civil contractor is to be engaged in the construction. It means all the construction works are to be undertaken by hired skilled labors supervised by district TSB/provincial TSB and unskilled labors who are the beneficiary farmers. In this arrangement of construction, there could be a high risk of accidents in putting up a diversion structure more than 5m height even if it is a gravity type wall. Therefore, this Manual recommends that no diversion structure whose height is more than 5m should be tried.

3.7 Design of Canal

Canal (called furrow in Zambia) conveys the diverted water from the intake point to the farming land. Difficulty associated with main canal is how to put suitable alignment according to the topographic condition without using sophisticated survey equipment. Construction, on the other hand, is not so difficult since most of the work required could be managed with simple agriculture tools such as hoe, shovel and in cases pick.

3.7.1 Aligning of Canal

The simplest way of aligning canal is to follow the water flow by gravity; namely, 1) dig the canal from the diversion point for example a 10 meter distance, 2) let the water flow in the dug canal, 3) deepen the canal and/or shift the canal alignment toward lower side (stream side) if the water does not run well, and 4) repeat the process until the end point.



Better way of canal alignment is to use sprit line level. Interval of the two poles should preferably be 5 – 15 meter depending upon the topographic condition, and one side of the tied points should be 0.5 – 1 cm higher than the other in case of 5 meter interval and it should be increased to 1.5 – 3 cm if the interval of the 2 poles is set at 15 m. Pole with higher tied point should always be placed foreside, not like conventional alternate placing. 0.5 cm difference in 5 meter gives 1:1,000 gradient suitable for gentle topography like *dambo* area, and 1 cm gives 1:500 gradient adaptable for sloped topography (for detail explanation, refer to Part II Process Description Manuals 10. Canal Alignment with Sprit Line Level).

In some areas, topography is too gentle to align canal with sprit line level. An example is that the foreside of the line-leveling cannot find out any point 0.5 – 1.0 cm lower than the backside in a straight way of interval 5 m. Faced with this situation, line-leveling usually starts staggering the way. In such cases, simple coping measure is to set the interval at 15 meter instead of 5 meter whereby the height gap of the 2 tied points is set at 1.5 – 3 cm as above-mentioned. Should it not be able to work still, then conventional survey by using dumpy level is required. Ideal longitudinal gradient in this case should be 1:1,000.

3.7.2 Design of Canal

Canal is categorized into two; either non-lining or lined. Lining can be made of brick or masonry (concrete lining is sometimes seen but the cost beyond farmers' affordability excludes this option from the Manual).

Earth canal is most commonly used in existing schemes. With simple tools such as hoe, hand shovel, and wheelbarrow, construction is very easy and cheap.

Taking the concept of self-help development into account, this type of canal seems to be the most suitable for smallholder farmers. However, since this is non-lining, water conveyance loss is high due to seepage/leakage and much maintenance works such as grass cutting, de-silting, reshaping of cross section and so on are needed in every season.

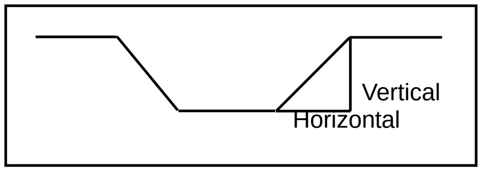
Lining can be done with stone, brick or masonry. These canals reduce the canal conveyance loss and also minimize maintenance works as compared to earthen canal. In particular, reducing the canal conveyance loss becomes very important when diversion water is not enough to cover all the prospective service area. Lining can also prevent the canal from being eroded, which in turn minimizes the maintenance work and makes canal life longer.

Investment for lining, on the other hand, is higher than earth canal except for stone lining. Farmers in rural area make bricks by themselves. Therefore, brick lining is cheaper than masonry, and damaged parts or bricks can easily be replaced by the farmers. Masonry lining is more durable than brick, but requires cement, which may go beyond the farmers' affordability. Masonry with clay mortar can also be tired in this regard.

For earthen canals, standard trapezoidal shape is commonly used but in some cases side slope results in vertical due mainly to the easiness of hoe excavation. The side slope to be required depends on the stability of the soil and often can become vertical if the soil is hard enough and very cohesive. Recommendable side slopes for different soils are given in Table 3.2.

Table 3.2 Recommendable Side Slope of Canal

Type of Soils	Vertical : Horizontal
Clay	2 : 1 - 1: 0(vertical)
All other soils	1: 0(vertical) - 1 : 1
Sand	1 : 1 - 0.5: 1



The design velocity of canals must be determined within the limits of two factors; namely, 1) the minimum allowable velocity that causes neither accumulation of sediment of soils nor growth of waterweeds, and 2) the maximum allowable velocity that does not produce erosion of canal materials by the flow.

The minimum allowable velocity can be in a range of 0.45 – 0.90 m/sec. Within this range of mean velocity, soil sediments are not accumulated in a canal where the particle size of suspended sediment is not larger than silt. Waterweeds hindering the flow capacity of the canal will not grow when the mean velocity is more than 0.7 m/sec.

On the other hand, maximum allowable velocity is presented in Table 3.3 depending on the canal material. Within the allowable velocity, erosion of canal material will not take place.

Table 3.3 Maximum Allowable Velocity

Canal Material	Allowable Velocity, (m/s)
Sandy soil	0.4 - 0.6
Sand-loam	0.5 - 0.7
Clay-loam	0.6 - 0.9
Clay	0.9 - 1.5
Rock	1.0 - 2.0
Thin concrete	1.5 - 2.5
Wet masonry	2.50

Source: Canal, Design Manual, MAFF, Japan, 1987

Steep longitudinal slope creates erosion due to its high flow velocity though it can reduce the canal section. On the other hand, too gentle longitudinal slope causes heavy silting in the canal and also enlarges canal section to accommodate the required flow. Taking into account the two factors, Table 3.4 shows the recommended canal longitudinal slope. In sum, this Manual recommends 1:1,000 longitudinal slope in relatively flat lands e.g. *dambo* areas and 1:500 longitudinal slope in a relatively sloped topography.

Table 3.4 Maximum Minimum Slope of Canal

Design Flow, liter/s	Minimum	Maximum
5	1:2000	1:100
10	1:2000	1:100
15	1:2000	1:100
30	1:2000	1:200
50	1:2000	1:300
100	1:2000	1:400

Source: Canal, Design Manual, MAFF, Japan, 1987

CHAPTER 4 CONSTRUCTION ARRANGEMENT

4.1 Construction in General

The irrigation facilities range from primitive but cheap one to modern but costly one. In this Manual, primitive one is of simple diversion schemes while modern ones are either wet-masonry structure or concrete structure. All the materials for simple schemes should be provided by farmers themselves while foreign materials required for permanent structures can be provided by the government, donors, or other stakeholders e.g. NGO, religious organizations, etc.

As for construction, considering the financial affordability of the farmers, the principle for the construction should center on intensive labor manual work by the farmers themselves. Construction, therefore, will not employ any heavy equipment nor engage local contractor in principle. In this regard, even the construction of permanent structures do not employ civil contractor in principle and therefore should be carried out under direct force account by the government. Under this system, district TSB procures necessary foreign materials such as cement, iron bars, and timbers for formwork and farmers undertake the work under the technical supervision of the TSBs.

As a matter of fact, construction of permanent structures may need to engage skilled labors such as masonry and carpentry. In this case, BEOs/CEOs and the farmers should learn the technique at the beginning stage of the construction so that the employment can be minimized. BEOs/CEOs are also expected to furnish the technique they have acquired to other areas. The payment to the skilled labors is undertaken by the concerned district TSB under the direct force account system.

4.2 Work Scheduling

Construction work should be commenced as early as possible after rainy season has finished. Working hour is recommended from early morning to noon, such as 7:00 to around 12:00 or 13:00, in general though it is on the farmers' decision. According to field interviews, farmers usually do heavy work only in the morning because they can avoid hot weather of the afternoon and in cases meager meal makes them difficult to work over noon.

Though it is ideal to start constructing irrigation facilities right after rainy season has finished; preferably in April, there may be some villagers still busy for harvesting sometime until May. Therefore, construction work carried out in early time such as April & May could be arranged to be only one or two times a week or otherwise by rotating the participants.

Then, construction work after June can engage almost all the relevant members by rotational turn throughout weekdays since harvesting could be finished till then. As an example, construction work by rotation may be programmed as shown below:

Table 4.1 An Example of Work Rotation

Number of beneficiaries	Participants per day	Parties organized	Working days/ week	Working Rotation
< 30 households	10	2	6	Party-A: Mon., Wed. and Fri. Party-B: Tue. , Thur. and Sat.
> 30 households	20	2	6	Party-A: Mon., Wed. and Fri. Party-B: Tue. , Thur. and Sat.

On the course of the construction, BEOs/CEOs should facilitate farmer leaders to record the progress how much work has been done with how many labors. Sometime after the work has progressed, requirement-per-unit-work can be calculated based on the record. The estimated requirement-per-unit-work will help the participants to know; 1) how long the construction work takes to complete, 2) necessary modification of schedule inclusive of reinforcement of labors, and 3) also when to arrange necessary material as the work progresses.

4.3 Tool Arrangement

As heavy tools/equipments will not be employed, the construction should proceed with simple tools that are already familiar to the farmers. The tools to be used for the construction are: panga, hoe, shovel, spade, trowel, picks, saw, hammer, spirit level, wheel-barrow, buckets, etc. Some tools that the farmers do not have, in most cases pick, big hammer, shovel, spade and wheel barrow, may be arranged by concerned provincial and district TSBs and rented out to the farmers upon request.

CHAPTER 5 ORGANIZING FARMER IRRIGATION CLUB

5.1 Organizing Process

The process of implementing a smallholder irrigation project starts with participatory kick-off workshop (entry meeting). Upon confirmation of the farmers' commitment, a planning workshop shall be held with the BEO/CEO in charge. Through the workshops, preliminary plan of the diversion structure will be discussed and preliminary canal alignment will also be done on the site.

Then, the participants will formulate the action plan of activities for the implementation. Also, they shall select the responsible person for each activity. The responsible persons could be potential leaders who will be the candidate of the committee members of their organization. Therefore, they do not have to finalize the committee members at this stage.

As to building an organization, the official registration or officers' setting-up is often made in advance to starting the activities; or start the activities right after the selection of the potential leaders in the initial process of the establishment of irrigation club. This Manual proposes the latter approach (see Figure 5.1), whereby middle to latter half of the whole process of building the organization will proceed parallel to the implementation of the project.

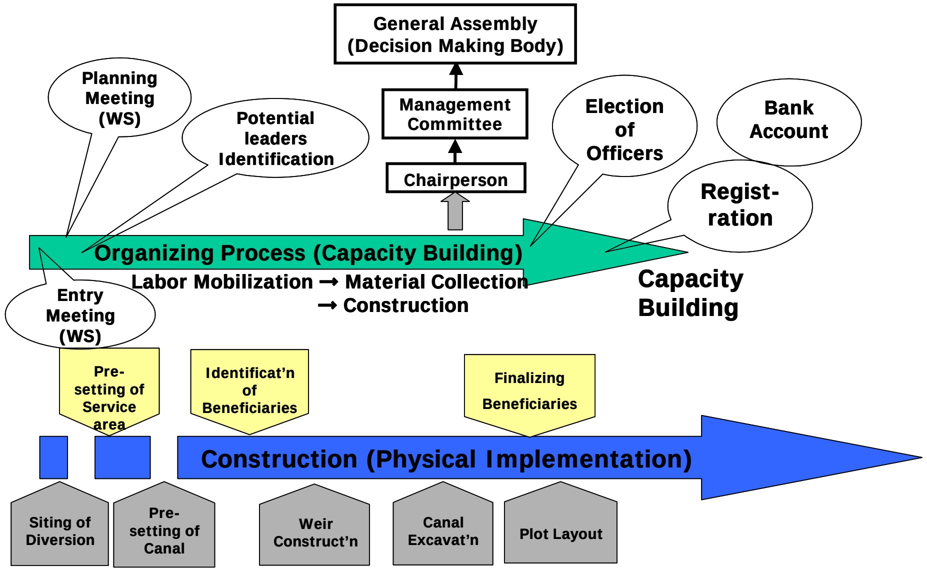


Figure 5.1 Organizing Process & Project Implementation

In this latter case, the potential leaders are given roles of mobilizing the fellow villagers for labor work, arranging the local materials and collecting the sharing amount if cash contribution is required with strong leadership. As for the potential leader, so to speak, it is as if taking examinations for becoming a leader in real sense through on-the-job-training.

On concerning the important matter, such as cash contribution, it should be discussed and decided in the villagers' meeting and not in the workshops mentioned above that may have a possibility of calling only a limited number of participants. If there is an existing organization, utilize its general assembly meeting and not just committee members' meeting since there is a great possibility that the chairperson will behave beyond his/her authority for the decision-making.

It is noted that the chairperson has also only one vote in terms of decision-making as same as other members. This is a point where chairperson often mixes up his/her role and authority. The decision-making by the consensus in the villagers' meeting or in the general assembly of the irrigation club shall be the process, for which the outsider should intervene properly.

At the time of completion of their works, the activities could be said as being well done. In a sense, it could be said that the potential leaders pass the hardest process of implementing the project. In this stage, most of the villagers will already recognize who is appropriate for the chairperson, and other members of the committee such as vice-chairperson, secretary, treasurer, etc.

So, here comes a time to carry out the election, and decide the committee members, ratify the by-laws by all the members and in the end they may register the organization officially with its by-law. In the case of handling certain amount of cash, the registered organization shall open a joint bank account under the names of the chairperson, vice-chairperson and treasurer.

5.2 Organization Internal Set-up

Role and authority on planning, decision-making and implementation should be clearly defined in a proper organization. For example, when a farmer organization thinks about the following dry season crop, they go through a process of planning of water use and allocation, decision-making of the plan, and execution of the approved plan. Authority for these three aspects must be independent.

If we consider the case of irrigation club, planning will be done by a group like agriculture development group or water management group formed by volunteers or elected persons within the club and decision on whether to execute the plan will be made by the general assembly. General assembly is composed of all the membership.

Under the general assembly, management committee is formed consisting of the chairperson, vice chairperson, secretary, treasurer, and auditor (being a part of the committee or as independent in case they deal with much cash). The management committee will be in charge of the execution or day-to-day management according to the decision made by the general assembly (see Figure 5.2). In case the irrigation scheme is very small, the management committee can be in charge of planning: that may be most of the cases in smallholder irrigation schemes.

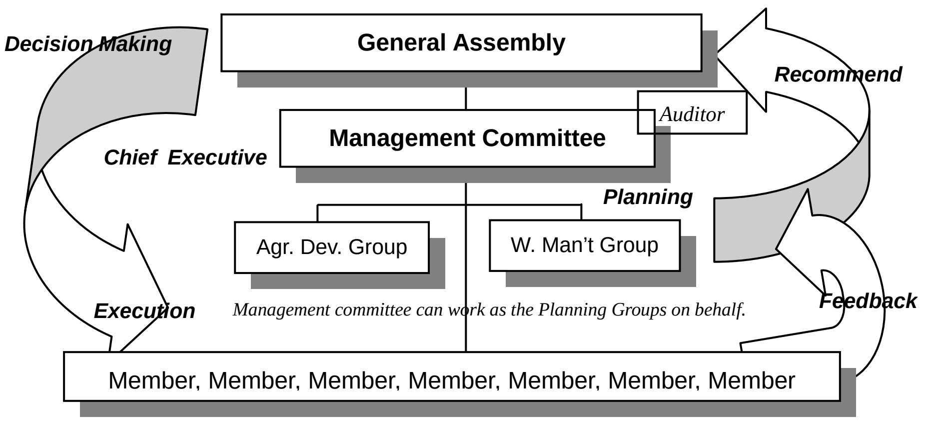


Figure 5.2 Internal Organization Setting-up of Irrigation Club

Difficulty concerned with irrigation club is that management committee members come out from the members of the general assembly. For private companies, shareholders and managers are different personnel, but as per irrigation club, the members of the management committee including the chairperson are selected among the members of the general assembly.

Although the chairperson is the chief executive officer, he/she has only one vote in decision-making in the general assembly. Sometimes the authority and duty of the chairperson are mixed up. To prevent the authorities from being abused and promote transparency of the organization, such idea of decentralized organizational setting-up should be extended to all the membership.

The quality of leadership, more than any other single factor, determines the success or failure of an organization. The remarkable success of some of the farmer's organizations can be attributed largely to the leaders and the kind of leadership that they have exercised. Leadership is a process of influencing individual or group of individuals to achieve a collective response to resolve a particular problem or any given situation.

Collective style of leadership is a kind of leadership wherein the leading group organ, the management committee, stands as the united center of leadership; hence, all important issues are collectively tackled, decided upon and implemented. The united effort and integrated action of the members to perform their respective tasks promote initiative and reliance of every member in carrying out decisions by the collective.

Basically, Collective Leadership is the application of the principle of democratic centralism by the club's leadership. In essence this is the interplay of democracy and centralism or of freedom and discipline.

WHAT IS DEMOCRACY: Democracy is a system of exercising authority over farmer organization wherein the general membership holds the ruling. In case of the irrigation club the ruling power or authority is the general assembly composed of all the membership. All important issues must be ruled by this general assembly.

WHAT IS CENTRALISM: Centralism is the principle or system of centralizing power or authority. In the irrigation club, centralization is lodged in the *management committee. Thus, the implementation of the irrigation club's policies, guidelines, the O&M responsibilities or all activities of the irrigation club for that matter is being centralized by the members of the committee.*

Democratic-Centralism is the principle wherein utility of democracy and centralism or of freedom and discipline is the basis or guide of the leaders as well as the members of the club in the discharge of their functions and in the accomplishments of the assigned tasks. The system of democratic centralism is a distinct feature of irrigation club in its operation.

Simply saying, any decisions must be decided democratically by the general assembly but once the decision is made the decision must be implemented in a centralized way under the supervision of the management committee. This mechanism ensures the irrigation club complete or total orientation with the fellow farmers' participation of regulation making process and in carrying out O&M tasks. Four rules that ensure organizational unity based on the principle of democratic-centralism are:

1) The individual is subordinate to the irrigation club. This means that the interest of the individual is under the interest of the irrigation club. Everyone must follow the club's constitution and by-laws, guidelines and rules of the club and all decisions and agreements made without personal reservations,
2) The minority is subordinate to the irrigation club. This means that the decision made on behalf of the whole club is based from the majority of the members. If ever there are other positionings of the minority these should be subordinated with the majority's collective decision,
3) The lower organ is subordinate to the higher organ. This means that the decision and rules set by the higher organs which represent the broader scope of the club must be followed by the lower level. For example if the general assembly, which is the highest organ, promulgates a regulation, even the management committee is bound to abide by the regulation.
4) The whole irrigation club is subordinate to the general membership. This means that all decisions coming from the general membership, as the lead organ, must be followed by all members of the irrigation club, of course inclusive of management committee members.

CHAPTER 6 OPERATION AND MAINTENANCE

6.1 Rotational Irrigation

As per water distribution, there are two different methods at the main canal level; namely, 1) proportional distribution to secondary groups, and 2) rotational distribution among the secondary groups[2]. The former, proportional distribution, entails continuous flow in the main canal and accordingly continuous inflow into secondary groups. The latter, rotational distribution, distributes irrigation water into a secondary group on basis of on-off.

For the proportional distribution, the canal flow in the main canal is diverted continuously and proportionally to the different secondary groups. Amount of the irrigation water shared to each secondary is decided on the size of irrigated area. The water sharing is done according to the opening width of a turnout structure or by adjusting the opening of the turnout. Then, a farmer belonging to a secondary group can share the irrigation water on a rotational basis; namely, farmers in the secondary group carry out irrigation one by one based on the irrigation schedule.

As per rotational distribution among secondary groups, all the canal flow into the scheme is alternately diverted to a secondary canal, or a group of secondaries, of the service area. Rotational distribution is thus done at the secondary canal level. Thereafter, field level rotational irrigation is once again carried out among the farmers in the secondary canal. This rotational system entails equal water distribution among the secondary groups, but the size of the main canal should be the same as the intake portion all the way down to the turn-out point of the last secondary.

Which water distribution should be applied depends on the size of the irrigation scheme and also what type of turnout at the secondary canal level is used.

[2] It is remarked that secondary group means in most of cases on-farm group so that secondary canal means on-farm feeder canal.

Generally, as the irrigation system becomes bigger, proportional distribution is applied mainly because the system does not require main canal size being same to the end and also turnout at the secondary intake is constructed in such a way of controlling the flow into the secondary canal.

On the other hand, smaller irrigation system may prefer rotational distribution as it ensures fair water distribution among the secondary groups. Since smallholder irrigation schemes mostly fall in small-scale category, this Manual recommends the rotational distribution at the secondary level.

6.2 Irrigation Schedule

To properly operate an irrigation scheme, irrigation schedule should be prepared. Irrigation schedule shows an irrigation interval, the date and time, when the farmers should irrigate. The irrigation interval should not exceed a permissible maximum irrigation interval that is determined based on moisture holding capacity of the soil.

Though the maximum irrigation interval depends on the soil characteristics and also crop type, it can be said that the interval should not be over 8 days in most cases. In fact, it may extend up to 2 weeks interval under cool weather while it may limit to only 5 days under very hot and dry weather. In general, this Manual recommends that every secondary group should receive irrigation water at least once out of every 8 days, or crops may start wilting.

All the secondary canals may be grouped into 8, 6, 4, or 2 in such a way that each group should have almost equal service area. The rotational distribution is therefore carried out from one secondary group to the other. Then, on-farm level rotation is further planned amongst the farmers in a secondary group. Following should be considered in planning the field level rotational irrigation from the viewpoint of workability:

> Example:
> - One-day irrigation hour: 12 hours
> - Water application duration per farmer in a group:
>   2 hrs. (1/6 of 12), 3 hrs. (1/4 of 12)
>   4 hrs. (1/3 of 12), 6 hrs. (1/2 of 12)

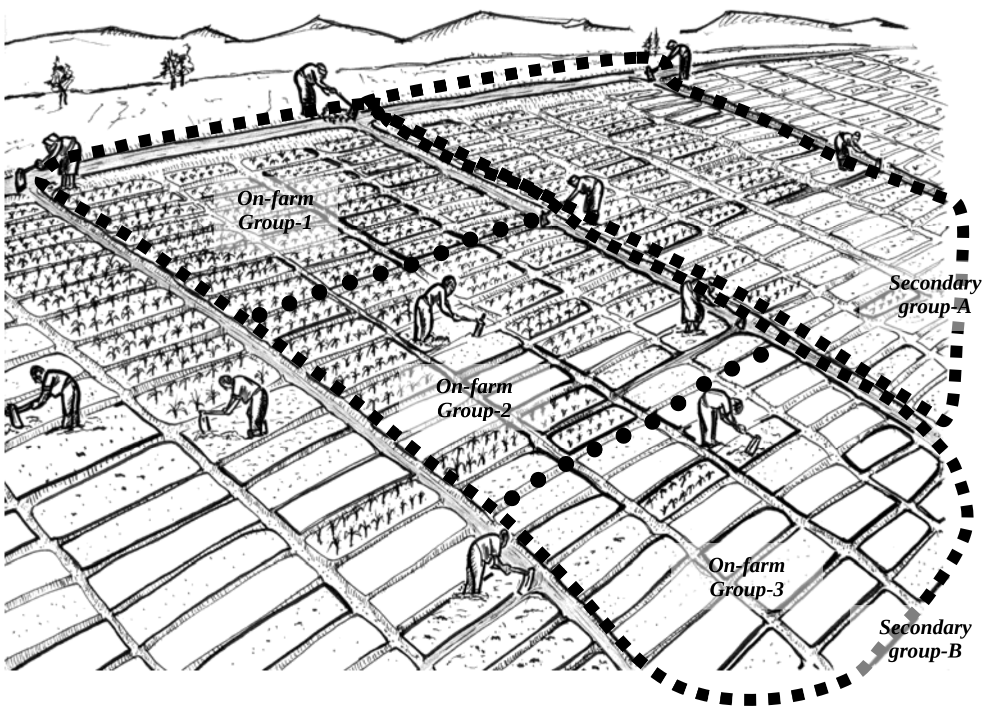
1) The minimum duration per irrigation per farmer is in the order of 2 to 3 hours,
2) The maximum duration per irrigation per farmer is in the order of 10 to 12 hours, and
3) The water application duration per farmer in a group should be a part of the one-day irrigation hour, e.g., 1/1, 1/2, 1/3, or 1/4 of the hour.

Table 6.1 An Example of Irrigation Schedule

Condition: Total number of secondary canals = 8, Nr. of farmer per secondary = 4

At main canal	Maximum irrigation duration per group		At a secondary level		Irrigation hour/ group	Selection
Nr. of 2nd groups	days	hours	Nr. of on-farm groups	Farmers/ on-farm group		
8	1	12	4	1	3	○
			2	2	6	○
			1	4	12	○
4	2	24	4	1	6	○
			2	2	12	○
			1	4	24	
2	4	48	4	1	12	○
			2	2	24	
			1	4	48	

Note: irrigation is planed at least once not more than 8 days.



An example of irrigation schedule is given in Table 6.1, on condition that there are 8 secondaries, each of which has 4 farmer members in average and irrigation is done only during daytime, 12 hours a day.

It is noted that the irrigation schedule may not be fixed as the irrigation interval may change depending on the stage of crop development. For instance, at the initial stage the interval will be shorter while at maturity stage the interval can be longer as the roots have fully developed. This means that the timetable will be reviewed as the season progresses.

6.3 Estimation of Scheme Irrigation Water Requirement

Net crop water requirement is normally defined as the depth or amount of water meeting the water loss through evapo-transpiration so that the crop can grow optimally. In the absence of experimental data, seasonal crop water requirement values for ordinary crops may be as follows, taking into account of overall irrigation efficiency of 0.5 (ratio of what is provided bb the irrigation scheme over what is consumed by crop).

Table 6.2 Net and Gross Crop Water Requirement

Crop	Seasonal Water Requirement		Growth Period	Net Crop Water Requirement		Gross Crop Water Requirement	
	mm depth or litter/m^2	m^3/ha	Days	m^3/ha/ days	liter/s/ha	m^3/ha/days	liter/s/ha
Beans	180 – 300	1,800 – 3,000	120	15 – 25	0.2 – 0.3	30 – 50	0.4 – 0.6
Onion	300 – 400	4,000 – 5,000	90	44 – 56	0.5 – 0.7	88 – 112	1.0 – 1.4
Maize	320 – 450	3,200 – 4,500	120	27 – 38	0.3 – 0.5	54 – 76	0.6 – 1.0
Potatoes	340 – 520	3,400 – 5,200	120	28 – 43	0.3 – 0.5	56 – 86	0.6 – 1.0
Cabbage	350 – 500	3,500 – 5,000	90	39 – 56	0.5 – 0.7	78 – 112	1.0 – 1.4
Tomatoes	390 – 550	3,900 – 5,500	90	43 – 61	0.5 – 0.7	86 – 122	1.0 – 1.4
As a thumb of rule (in case of 24 hours irrigation):							**1.2**
As a thumb of rule (in case of 12 hours irrigation):							**2.4**

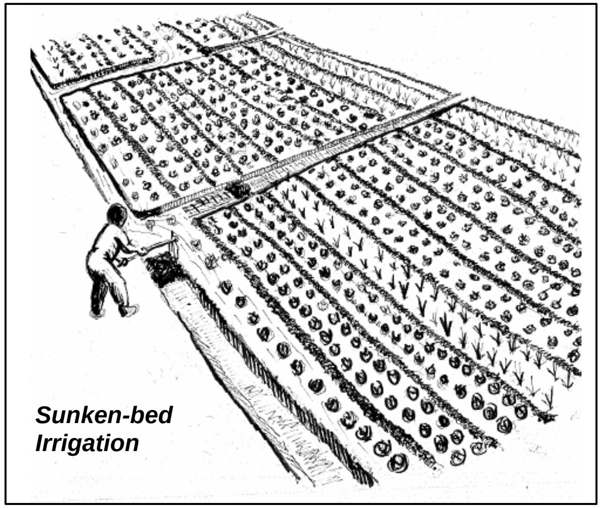
With the above gross crop water requirement, it can be known how much diversion water is required to irrigate the prospective areas or visa versa; namely, based on the available flow in the stream how much acreage can be irrigated will also be known. Roughly, an amount of 2.4 liter/s/ha of gross cop water requirement can be applied as design water requirement for daytime irrigation while the 1.2 liter/s/ha may be used if farmers try day and night time irrigation.

In other way, it can be roughly said that a crop area of 1 hectare needs about 1.2 liter per second of gross irrigation water under 24 hours continuous application. This means a flow of 10 liter per second could serve 10 hectares at maximum (mathematically, it is 8.3 ha). However, as most farmers do daytime irrigation only, possible irrigable area could be less than half of that. Therefore, possible service area could be said to be equal acreage to the water amount in liter per second; say 10 acreages on 10 liter/s, 30 acreages on 30 liter/s, etc (1 acreage equals to 0.4 hector).

6.4 On-farm Irrigation

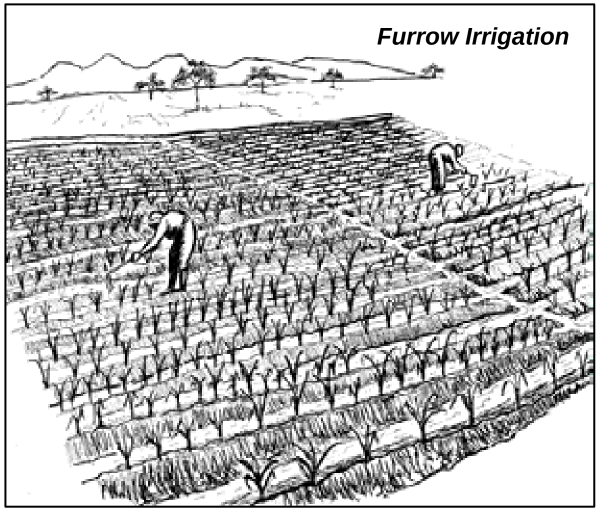
Smallholder irrigation almost exclusively adopts surface irrigation methods for on-farm. Surface irrigation system conveys water to the farmland by an overland gravity flow. This method is categorized into: 1) sunken-bed, 2) furrow and 3) border strip irrigations. Of them, border strip hardly applies to small lands, therefore the on-farm irrigation should adopt the first two methods: sunken-bed irrigation or furrow irrigation.

Sunken-bed irrigation is the most common type of surface irrigation. This method is suited for any kinds of crops such as row crops, orchard, wheat, alfalfa, rice, etc., as long as water logging does not last for very long (water logging should not be more than 48 hours). As per the efficiency of on-farm



Sunken-bed Irrigation

irrigation application, sunken-bed irrigation could achieve as high as 80% when it is properly leveled and well managed.



Furrow irrigation system looks like commonly used ridged rain-fed agriculture since it consists of furrows and ridges. The furrow irrigation is best suited to row crops such as maize, beans, onions, tomatoes, potatoes, etc. The water is led to the furrow that should be on a uniform longitudinal slope, and capillarity lifts the water into the ridges. This irrigation sometimes gives a risk of localized salinization in the ridges if the soil contains salt. As per on-farm application efficiency, furrow irrigation could reach 70%, about 10 % less than the sunken-bed irrigation.

From the viewpoint of efficient water use, sunken-bed irrigation is recommended as this irrigation method could avail of the water for crops about 10% more than furrow irrigation. However, sloped topographic condition requires heavy land leveling work and often terracing to convert the slope into a series of cascaded beds. If a topographic condition is associated with 4% slope (1/25) or more, the width of a terrace cannot go beyond about 2 m. This means that almost every bed would result in accompanying terracing which entails too much laborious work.

Therefore, on sloped lands, say more than 4% slope, furrow irrigation may be much preferred by the farmers and in deed adaptable. The spacing of the furrow can follow the rainy season's ridging spacing; preferably 60 – 80cm. Ridge height, equally to furrow depth, should be around 20 – 25 cm in order for capillary to lift the water toward ridge. Standard height of ridge adapted during rainy season is usually 30 cm, and this height is so high that capillary may not be able to wet the soil around the seed.

Furrow length can be 3 m in the shortest case and be extended to as long as 10 meters depending on the consistency of the gradient and the length of the plot owned by the farmer. Limiting factor of furrow length may be the length of the plot since the service area is usually divided into pieces, say 0.05 – 0.1 ha each as an example, and cultivated by many farmer members.

Another factor of determining the length of furrow is water volume available. If the water volume is very critical, say less than 2 liter/s, furrow length should not be long; preferably to be 3 – 5 m or even less, otherwise it takes too long time to fill up the furrow and results in great water loss.

In case of flat lands such as *dambo* areas and lower parts of hilly areas, sunken-bed irrigation can be best suited. Smallest size of sunken bed could be 0.9 m x 2 m, and can be enlarged depending on the soil, leveling and the size of the plot owned by the farmer. Water volume available may limit the size of bed; namely, if water volume is very critical, say less than 2 liter/s, the size should be small such as 0.9 x 2 m taking into account the time required to fill up the basin.

Though sunken-bed irrigation is very suitable for flat land, *dambo* area is often associated with water logging problem especially near the stream. In this case, furrow irrigation can be applied instead of sunken-bed and drainage may also be required. *Dambo* areas may adopt sunken-bed irrigation in its higher elevation where water logging does not take place, which is close to the main canal, and furrow irrigation in the vicinity of stream.

6.5 Maintenance

Maintenance should be done by the farmers' organization with technical advices from the BEOs/CEOs concerned. Maintenance work is required for the main facility; that is diversion weir, and canal including its ancillary facilities. The work can be categorized into two: 1) regular maintenance and 2) routine maintenance.

Regular maintenance includes; 1) re-shaping of the canal slope, 2) removal of silt or sediments inside the canal, and 3) removal of debris and other obstructions, and this is usually carried out just before the irrigation season starts. Routine maintenance should be done as required or at least once a month throughout irrigation season. It includes cutting of grasses at canals, particularly its inner sections, de-silting and removal of debris in the canal.

6.5.1 Weir Maintenance

As per temporally weirs such as brush dams, no routine maintenance work is usually required during the season except minor repairs. However, replacement/renovation should be done every year sometime before they start the season's irrigation. It is advised that after they have finished the season's irrigation, the weir should be dismantled and such precious material as big logs, sacks, pegs, etc. should be kept. These materials can be again used for the next season.

For the permanent weirs, no routine maintenance work is required. However, physical observation shall be made once in every 2 – 3 days to check whether the weir is functioning as designed or not. Especially, crack on the weir, deformation of the weir, and settlement of a part of weir shall always be paid attention. If the cracks are small, so-called hair crack, they are not harmful. However, should noticeable settlement, and thereby cracks on the concrete be found, those cracks should be filled with cement mortar.

6.5.2 Canal Maintenance

Stream water usually contains certain amount of suspended particulars, causing sedimentation in the canal. Eroded soil loss from field also gets into canal, resulting in the sedimentation in the canal. Maintenance work for canal should be done at least once before the irrigation season starts. Maintenance works required for the canal are; cleaning, weeding, de-silting, re-shaping, and also minor repairs as described below:

1) Bushes and trees on the canal embankments should be removed. They may obstruct the water flow and their roots will open the banks and develop leakages.
2) Grasses, sediments and debris in the canal should be removed. While cleaning the canal, care must be so taken that the original shape of the cross-sections is kept. For this, a wooden frame with exact dimensions of the designed cross-section can be of great help.
3) Crossing sections by people and animals (livestock) along the canal should be strengthened by hard compaction or lined with stones, bricks or wet-masonry.
4) Holes/cracks in the canal should be filled with sticky clay soil, and eroded sections should be rebuilt to the original shape.

CHAPTER 7 APPROPRIATE FARMING UNDER IRRIGATION

If your client farmers are basically satisfied with their food crops from rain fed agriculture, it is a good time to consider trying irrigated cash crop production in the dry season. Diversified cropping systems offer them an opportunity to stabilize their farming system as a whole and to enhance the quality of their livelihood. In this part of technical manual provides you with two major strategies applicable to the agricultural and agro-ecological conditions of the Study area: Market-Oriented Agriculture Development and Soil Management.

7.1 Market-Oriented Agriculture Development

Irrigated agriculture in the dry season is a good business opportunity for smallholder farmers. By tapping water resource from small streams or rivers, they can produce high-value crops and sell surplus to the potential market in and out of the village. Expand your image of market from small stand in the village to a bigger market in the district, city market in the provincial capital, or even a mega market in urban cities like Lusaka and Copperbelt; potential market is present just in front of the farmers. In fact, a lot number of fellow farmers are selling their produces to those markets, gaining considerable amount of Kwacha. What farmers have to do is to produce what the market needs and ship it at the right time, not to produce what they can produce.

7.1.1 Profitability of Major Crops

If farmers' self-sufficiency level of staple crops is at a certain level, consider producing cash-crops. For example, results from an agricultural marketing survey suggest that tomato, onion, cabbage, green maize, rape Irish potato and beans are potential crops for market-oriented agriculture. Here is examples of how much net income can expected from a unit of land for a couple of major crops: onion, cabbage, Irish potato, tomato, and groundnuts. As shown in the table, around ZMK 1.5 million of net income can be expected from a lima (1/4 ha) of groundnuts; it is a minimum amongst the five listed crops. It accounts for about ZMK 380,750, if cultivating in quarter lima (1/16 ha). The biggest net income can be anticipated from onion production. It reaches as much as ZMK 3.6 million per lima and ZMK 891,500 per quarter lima.

Of course, resulted profit may vary according to the quality of produces, market price, distance from market, negotiation power with buyers, timing of production, supply in the market, etc. In any case, it remains as a well-established concept that irrigated agriculture in dry season is a good business opportunity. As an average of 10 major crops, a net profit of approximately ZMK 1.9 millions can be anticipated from one lima and thus ZMK 485,500 from quarter lima based on 439 samples in the area.

Table 7.1 Profitability of Major Crops, as of Dry Season 2009 (ZMK/lima)

Crop	Production Cost	Gross Income	Net Income (ZMK)		
			1.0 lima	0.5 lima	0.25 lima
Onion	1,200,000	4,766,000	3,566,000	1,783,000	891,500
Cabbage	2,347,000	5,644,000	3,297,000	1,648,500	824,250
Irish Potato	1,022,000	3,690,000	2,668,000	1,334,000	667,000
Tomato	1,303,000	3,134,000	1,831,000	915,500	457,750
Groundnuts	155,000	1,678,000	1,523,000	761,500	380,750
Average*	929,000	2,871,000	1,942,000	971,000	485,500

Source: Harvest Survey (2010) Note: Average is for 10 major crops.

The size of manageable land to be irrigated may vary depending on the potential of irrigation water, size of land to be allocated[1], availability of funding for agricultural inputs, labor force to be allocated, means of transportation for marketing. You should not be too optimistic but does not have to be too pessimistic. To be sure, here is a guiding principle based on the actual achievement from the pilot project.

In the pilot project carried out in the 2010 dry season, an average size of newly opened land area for irrigated agriculture was approximately 0.16 lima/ member. For the improved sites, newly added area was 0.22 lima/ member. From this result, one scenario can be drawn: for the first year of the new construction, approximately 1/4 lima can be newly irrigated and, for the second year, another 1/4 lima can be added, resulting in 1/2 lima of land per member. As a result of

[1] As irrigation scheme is somehow a communal entity that requires collective activities of the farmers, it is often the case and is recommended that irrigable land is equally allocated among the members regardless how big his/her original farmland is in the range of irrigable land.

two years of construction work, each member farmer can cultivate approximately 0.5 lima of newly irrigated land. From 0.5 lima/household, ZMK 761,5000/household can be generated from groundnuts as a least profitable crop and ZMK 1,783,000/household from onion as the most promising crop.

7.1.2 Impact of Irrigated Agriculture to Smallholder Farmers

One may ask how significant they are for the smallholder farmers in the Study area. To answer this question, result of the baseline survey provides basic picture of the smallholder farmers; an average income per household in the sampled 12 villages in six districts was ZMK 5.8 million, raging from ZMK 2.9 million to ZMK 16.3 million. Taking ZMK 1,9 million/lima as an expected net income of vegetable production, the net benefit from 0.5 lima can be ZMK 971,000/ household. It shares 17 % of their ordinal income of ZMK 5.8 million.

Furthermore, for those who are under the poverty line (ZMK 8,191,150 per household estimated based on the baseline survey), a required amount to reach the poverty line is estimated ZMK 1,507,000 per household. As an expected income from irrigated agriculture from 0.5 lima is ZMK 971,000/household, the smallholder irrigation scheme may have an equal meaning to help those farmers get a half way closer to the poverty line.

7.1.3 Economic Impact of Irrigated Agriculture in the Area

If you are an extension officer or anyone who is in charge of agricultural development in the area, it should be something of your great interest to see how beneficial the smallholder irrigation schemes are. Otherwise, you would not like to promote it. In reality, smallholder irrigation schemes are quite feasible and persuasive given the low investment cost for the construction. Here is an anticipated economic impact from the standard size of irrigation scheme, based fully on the result from the pilot project.

As an outlook, a total benefit per site derived from the irrigated agriculture during the dry season can be roughly simulated. Assuming the total irrigated area based on the result of pilot project in the 2010 dry season, the total irrigated area per site is expected as large as 3.96 lima for improvement and 2.92 lima for new development. Accordingly, an estimated net profit per site reaches ZMK 7.7 million for improvement site and ZMK 5.7 million for new development with an average net income at ZMK 1,942,000 per lima.

Table 7.2 Simulated Profit per Site (ZMK)

Type	No. of Farmers	Area Newly Irrigated		Expected Profit
		ha	lima	
Improvement	18	0.99	3.96	7,690,000
New Development	19	0.73	2.92	5,670,000

Source: Result of the Pilot Project.
Note: Average net income is an average of 10 crops at ZMK 1,942,000/ lima.

As irrigable area continues expanding for a couple of years, more economic benefit can be expected as time pasts, given appropriate extension services fully provided to the farmers in the potential area. Most outstanding fact is that no additional funding for materials is virtually required other than recurrent cost for extension activities. That is, this much economic impact can bring about at the marginal cost zero. It should be noted, however, that preferable potential sites will be usually first developed than the others; the number of sites to be developed may decrease as time pasts.

7.2 Soil Management

Northern and Luapula provinces are widely covered by acidic soil called “acrisols.” A soil sampling test carried out by JICA Study team revealed that an average acidity of 10 soil samples in Kasama district was pH 4.2, ranging from pH 3.9 to pH 4.7. Other factors important to plant growth were not desirable as well. For example, Cation Exchange Capacity (CEC), a measurement for nutrient retention capacity of the soil, was low: averaging 4.3 $cmol(+)\cdot kg^{-1}$ as compared to the value of more than 20 recommended in Japan. Because of low fertility of soil in the Study area, even applying enough amount of water at right time, the plants may not be able to perform their full potential. Other notable elements of the soil include fusible boron; an average 0.09 is far less than the standard (0.5-1.0). Low value in fusible boron often causes damage on the top of leaves making the color blackish.

Moreover, it is not just a matter of fertility but is also associated with the physical characteristics of soil sphere. Even if farmers apply a plenty of premium chemical fertilizer, it could be a waste of money unless soil maintain good structure to hold the chemical substances; nutritious elements can easily leach out without retention effect from organic materials. To maintain and improve soil condition, several countermeasures can be applied: application of organic fertilizer, intercropping of legumes, and crop rotation.

7.2.1 Application of Organic Fertilizer

There are two different dimensions in the effect of organic fertilizer: improve soil fertility including physical characteristics of it, and minimize the cost of fertilizer. In addition to helping improve soil fertility, applying enough amount of organic fertilizer improve physical characteristic of the soil, whereby effect of chemical fertilizer becomes more efficient and durable. Also, improved soil sphere help the growth of plants' roots. Thus, it is highly recommended to produce organic fertilizer by farmers' own effort.

There are two major making methods of compost: one that facilitates anaerobic microorganisms and the other that makes the use of aerobic microorganisms for the decomposition process of organic matters. Conventional method, seen as a form of mounded compost, is a type of former type. A traditional farming practice of *Fundikila* is also considered as a sub-type of this method. The conventional method takes much more time than the latter: about three months to finish as compared to two to three weeks in latter one.

Considering the whole range of cropping calendar in the area, it is far recommendable to incorporate the latter one, or "new method," because compost will be ready in a short period of time that is before the commencement of the dry season irrigated agriculture. For instance, if farmers start producing compost right after the end of rainy season, there is not much time to wait for a three-month period of time. Therefore, the new method is best applicable to the dry season agriculture.

There is a unique method of compost called *BOKASHI* developed in Japan. *BOKASHI* compost fully utilizes the ability of aerobic microorganisms by which decomposition process can be much faster than conventional method. To maintain appropriate population of aerobic microorganisms, the method becomes to be relatively labor-intensive; you have to keep the temperature of the organic materials below the threshold for the bacteria to be alive. Materials need to be overturned every once a few days for two to three weeks. To be more practical, two sessions of technical manual address how to make *BOKASHI* compost and how to make accelerator to decomposition process of it.

Application of organic fertilizer can enhance soil fertility and even improve soil structure by which effects of chemical fertilizer can be further increased through improved retention capacity of the soil. More specifically, by applying organic fertilizer, soil structure becomes more complex, having different size of individual soil particles. Under such condition, root penetration and thus access to soil moisture and nutrients is improved, while infiltration and retention capacity of water and nutrients themselves become high, resulting in a greater growth of crops. Therefore, even after applying organic fertilizer, or "because" it is applied, use of appropriate amount of chemical fertilizer is still recommended as they create synergy effect for the cropping system.

7.2.2 Intercropping of Legume

Legume helps improve soil fertility as it fixes nitrogen in the atmosphere to ammonia. In fact, this process, biological nitrogen fixation, is facilitated by bacteria within nodules in the root system of the plants. Therefore, just by planting legume crops in the plot, soil fertility can be improved. To make use of it, intercropping of legume with other crops is recommended. For example, beans or groundnuts should be planted with other crops like maize.

Mixed cropping of green maize and climbing beans (circled)

Intercropping of climbing beans and maize was tried in the pilot project in the 2009 dry season and it was found that climbing beans is a good source of fresh vegetable. You can pick bean leaves while standing—it is much easier to harvest than dwarf varieties. Another lesson from the pilot project suggests that planting timing of climbing beans should be long after maize is planted. Otherwise, they compete with each other and beans physically obstacle the growth of maize.

To make it easier, relay cropping is recommendable. Plant the climbing bean before the harvest of maize and the beans climb the standing residues of maize even after maize is harvested. It can avoid unnecessary competition between beans and maize. Although dwarf varieties are also a good alternative, introduction of climbing beans has a couple of advantageous effects over dwarf varieties. First, climbing beans generally demonstrate much higher productivity per unit of land than dwarf varieties. Second, climbing beans is much more tolerant to diseases associated with moisture on the ground.

There are other recommendable combinations of intercropping: tomato-cassava, onion-cabbage, and eggplant-marigold for example. In an intercropping of tomato and cassava, tomato can benefit from the perennial support of cassava stem, while cassava can enjoy irrigation water originally applied to tomato. Combination of onion and cabbage can reduce the damage of cabbage from a variety of warms as onion repels those warms. Combination of eggplant and marigold is well known. Eggplant is easily affected by nematode through continued planting in the same land. But marigold deters it; in fact, marigold is given a lot of credit as pest deterrent and applicable to other crops too.

In any case, introduction of legume is highly recommended because legumes improve nutritious balance of the farmers' diet. However, do not combine legume with onion—it has some antagonistic effect. Even though estimated calories consumed per person are seen sufficient, there still are a lot of children having unnecessarily pot belly, implying chronic malnutrition. Adding beans to their daily diet can increase their protein intake and help improve their health status especially for those who are in growing phase.

7.2.3 Crop Rotation

Continued production of single type of crop causes disadvantageous effect in its production. For example, pathogenic microbes, viruses or even nematode stimulate their population under a continued favorable environment. In addition, continued production of a particular crop consumes particular nutritious elements in the soil—in other word, necessary soil fertility depletes. To cope with those problems, it is strongly recommended to rotate the farmland from one crop to others.

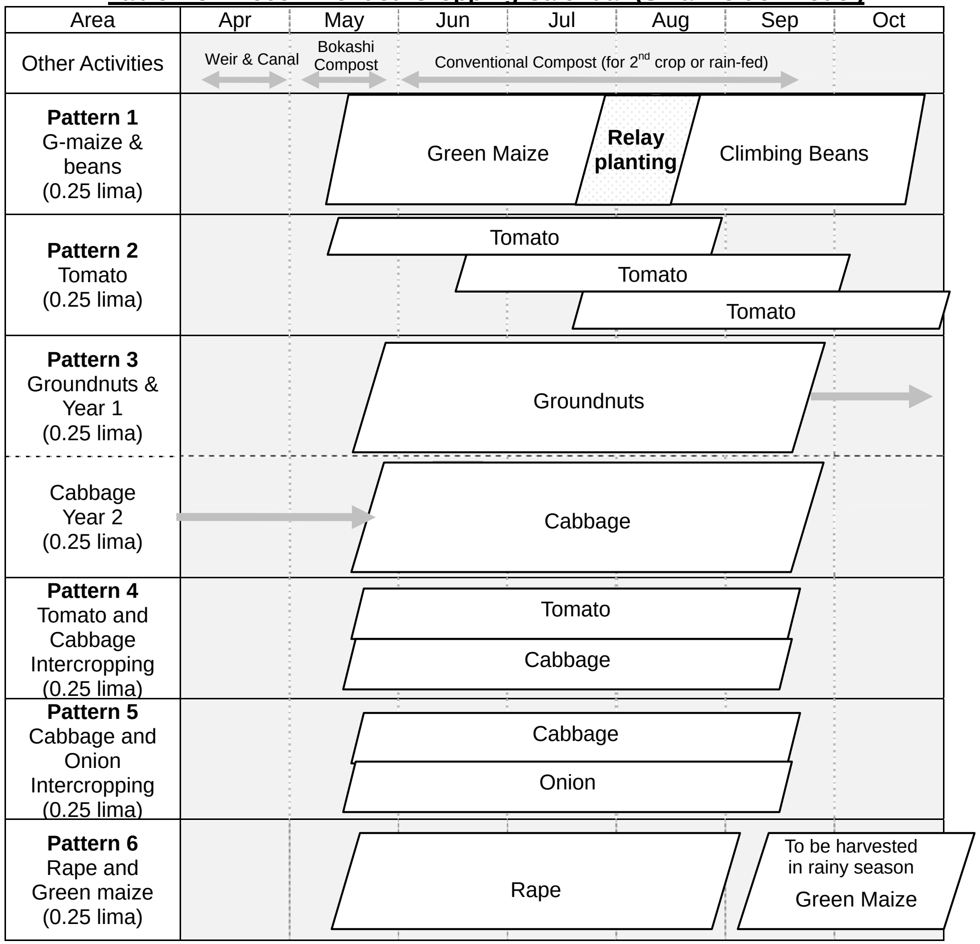
When considering the rotation pattern, it is good to start with legumes especially for those who cannot buy enough amount of fertilizer. For instance, beans or groundnuts should be planted without so much investment for fertilizer. Then, for the second year, vegetables, such as tomato, can be introduced. Planting legume makes difference in the second year production. In fact, the one who ever tried crop rotation from groundnuts to maize claimed he was able to enjoy higher productivity than others.

Note that rotation between the crops in the same family is not as effective as ones in distant relations. For instance, tomato, eggplant, and Irish potato are in the same family and thus rotation among them is not so recommended. Same is true for cabbage, Chinese cabbage and rape. To make it simple, combination of common vegetables with legume crops like beans, soybean and groundnuts is good to remember.

7.3 Recommended Cropping Calendar

There is no solid cropping calendar exclusively recommendable over the others. Here recommended is, therefore, a sample model to be planted under irrigated agriculture for smallholder farmers. It is assumed that 0.25 limas of farmland is a standard size for irrigated agriculture. Accordingly, the dry season agriculture starts with the preparation of irrigation in and around April when the dry season usually begins. It may take a few days just to repair the weir originally constructed in previous season, or take a few weeks to reconstruct the weir and rehabilitate/clean the whole length of canal; in this model, a one-month period is shared for that activity in April.

Table 7.3 Recommended Cropping Calendar (Smallholder Model)



After irrigation system becomes to be an ideal setting, next step is to prepare Bokashi compost. By using water from the irrigation mixed with other materials necessary for the compost, Bokashi compost can be prepared in a two-to-three week period. Therefore, mid or late May is an expected time for the actual planting of dry season crops. The benefit of planting in an early stage of the season is to spare workforce for maize harvesting after the preparation of the dry season crops.

Table 7.3 provides 6 patterns of cropping calendars. First is a relay cropping of green maize and climbing beans. Green maize is planted in May and, before its harvest, climbing beans are planted underneath the maize plants so that beans can climb the maize plant. They enjoy the stands of the maize plant even after the harvest of maize cobs. Note that if the climbing beans are planted too early, it may disturb maize's growth.

Next pattern is to plant crops in a different timing little by little. By this method, the labor force for planting can be dispersed. Then, risk of damage by the change in natural condition can be averted. Also, produce can be harvested and marketed little by little for a longer period of time, avoiding unnecessary loss of harvest. It also can hedge the risk of price change, if at all.

The third one is a model of rotation cropping. If it is difficult to purchase fertilizer, incorporation of legume in the system is highly recommended. For example, cultivate groundnuts for the first year and cabbage in the following year; it helps improve soil fertility to some extent. However, it should be noted that even with the legume crop, use of chemical fertilizer is due recommended.

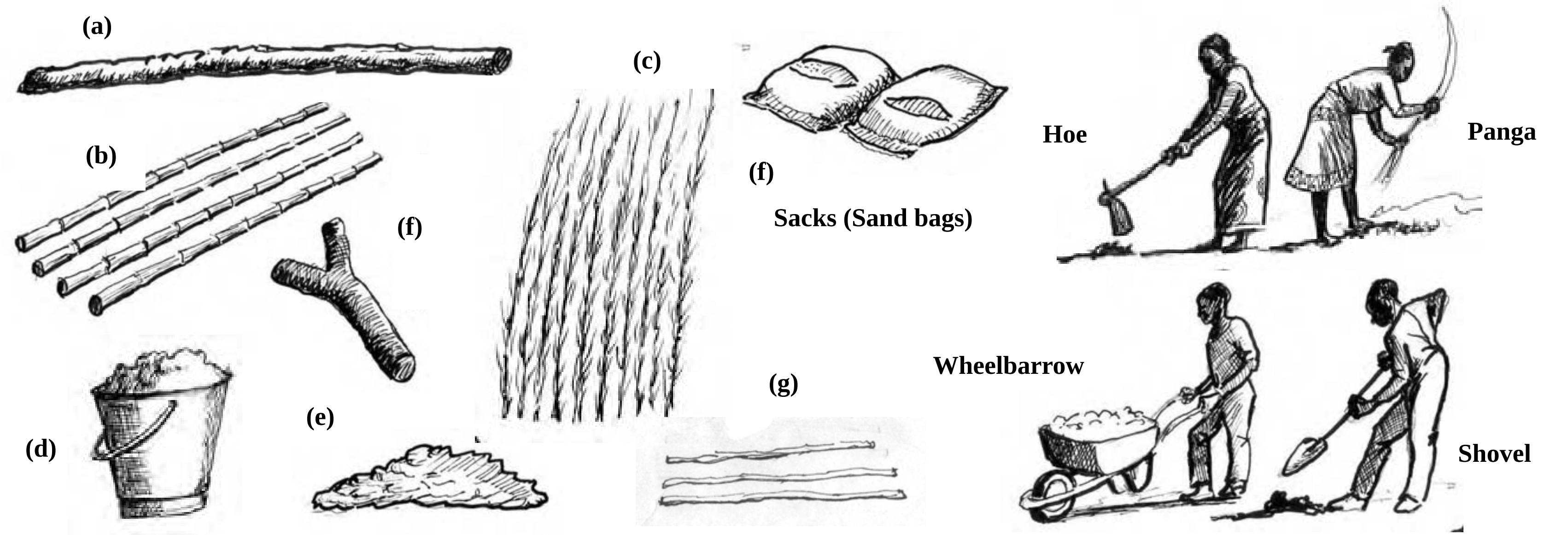
Pattern 4 & 5 are intercropping. By planting tomato with cabbage, for example, occurrence of pest to cabbage can be reduced; same is true for onion and cabbage combination. Lastly, double cropping is also recommendable especially for advanced farmers who can well take care of the soil and crops. Although the harvest of second cropping sometimes goes into the rainy season and careful management is required, higher price can be conceived.

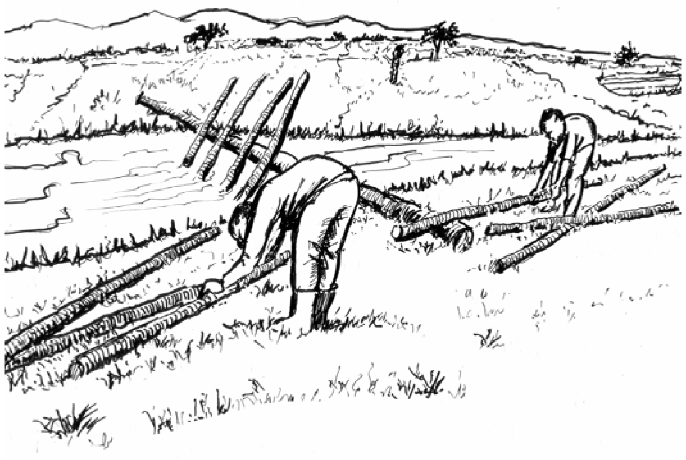
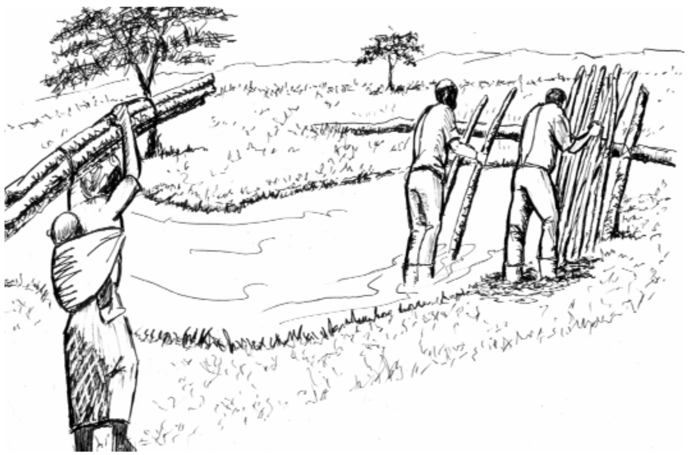
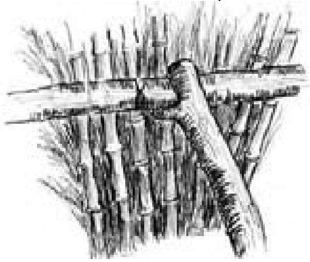
With a soil with lower pH or high acidity, maize is best fitted. Other crops relatively suited are chili pepper, soybeans, rice, wheat, sorghum. Least tolerant group includes cabbage, tomato, and spinach; good soil management is necessary. Crops prone to low fusible boron include eggplant, tomato, and sunflower, while grass plants are relatively adoptable. Thus, maize, sorghum and finger millet are relatively suited in that condition.

The take home message is that if cultivating vegetable crops, any measurement has to be taken to cope with poor soil condition. Now, get started and enjoy irrigated agriculture in the dry season!

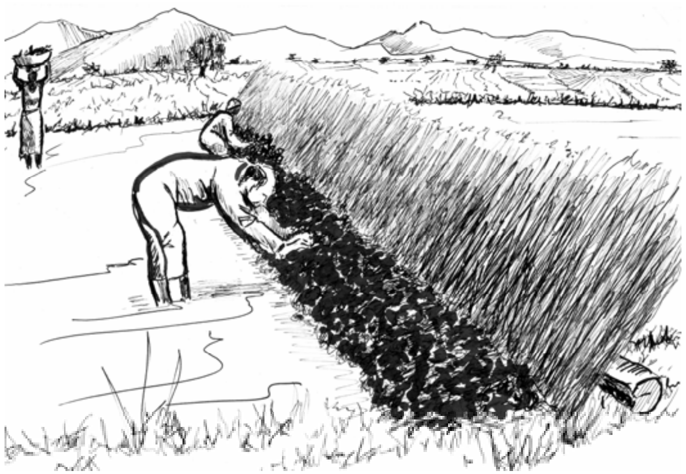
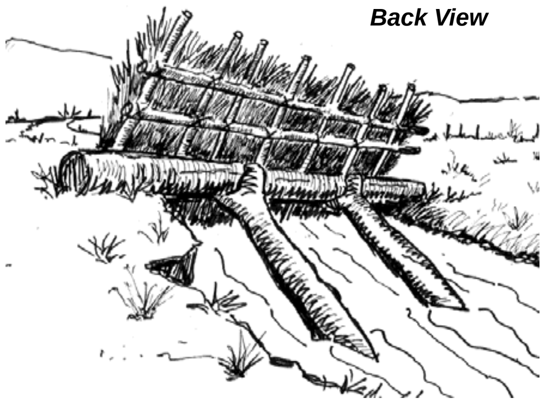
PART II PROCESS DESCRIPTION MANUALS

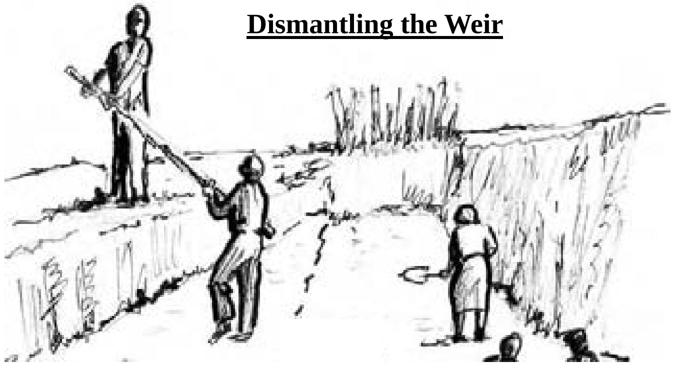
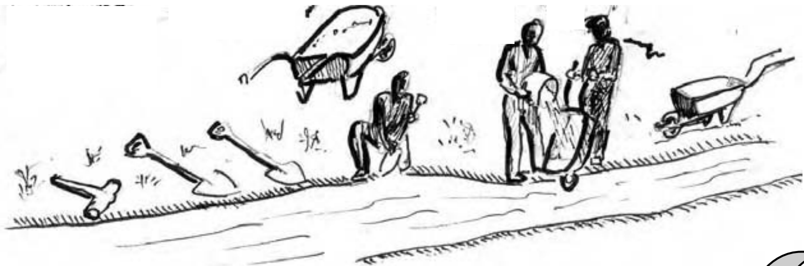
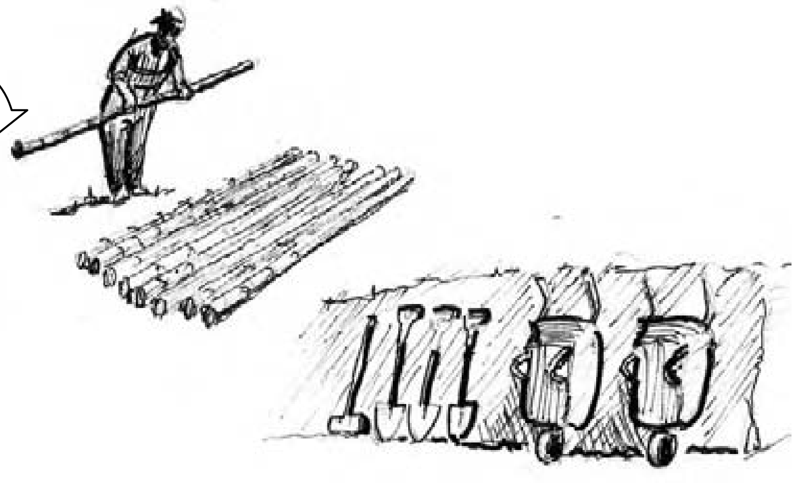
1. Construction of A Simple Weir: Inclined Wall Type (best suited at narrower streams)

Step	Materials to be collected
0	**Collect all the following materials (refer to the illustration below)**; (a) A log: to be put horizontally on the stream bank across the diversion point (Quantity: 1 nos., Refer to Step-1) (b) Bamboo/Twigs: to stand in front of the horizontal log (Quantity: 8 – 10 nos. per 1 meter width of the dam, Refer to Step-2) (c) Grasses (Elephant grass): to be put in front of vertical members (Quantity: depend on the size of the dam, Refer to Step-3) (d) Clay soil: to patch on the grasses. And, if necessary, the clay soil is put in the streambed to replace the sand foundation (Quantity: depend on the size of the dam, Refer to Step-5) (e) Ordinary soil: to patch on the clay soil patched on the grass (Quantity: depend on the size of the dam, Refer to Step-6) (f) Log: to support the brush dam (Quantity: depend on the size of the dam) (g) Creeper: to fix the bamboo/twigs to the horizontal log (Refer to Step-2) **Implements;** Hoe, Shovel, Panga knife, Wheelbarrow, Watering can, Sacks (Quantity of these implements depends on the number of participants for construction of the Dam).
	

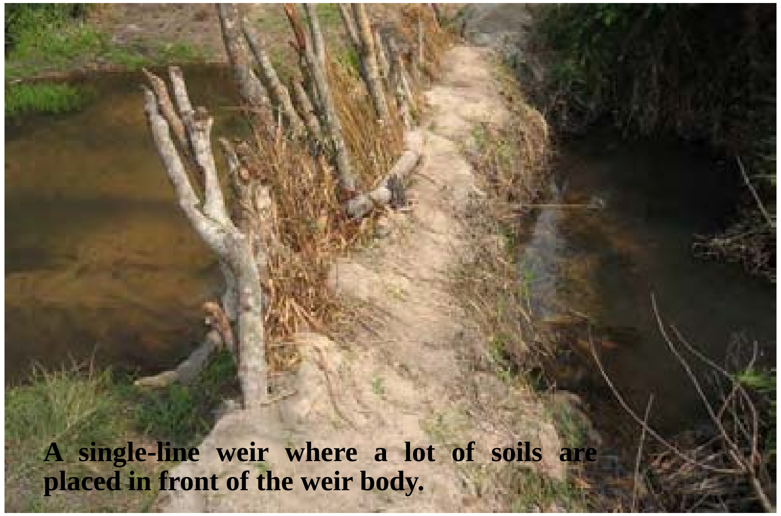
Step	Process	Description	Remarks
1		**<u>Put A Log Horizontally;</u>** Put a horizontal supporting log at the diversion point across the stream. It is advisable that the horizontal log is put on a place where there are tree stump/rock for support of the log. If there are no objects for support, put something such as stone to keep the log from moving by water pressure and weight of the brush dam itself. Length of the log is selected depending on the site condition such as width of the stream.	In case of such site where the material of stream bed is composed of thick sand layer, there is a need to replace the sand layer with imported clay soil. To make replacement work easy, a cofferdam may be constructed using sandbags. If the sacks are not available at the site, banking (soil filling) can be applied.
2		**<u>Stand the Vertical Members;</u>** The vertical members composed of bamboo/twigs are put in front of the horizontal supporting log as seen in the illustration.	To put grasses and soil easily, the vertical members such as bamboo/twigs should be put as close as possible together. These vertical members are placed into the foundation, which in cases has been replaced by clay soil, and again connected to horizontal support log at the top, using materials such as runner (see below). 

Step	Process	Description	Remarks
3		**<u>Placing the Grasses;</u>** Grasses are placed or fixed in front of the vertical members.	To prevent swelling out of grasses, the grasses are bound by horizontal members such as bamboo and tied together with the vertical members as shown in the illustration. 
4		**<u>Pile the Grasses</u>**; Grasses are piled horizontally on vertical standing grasses. See the illustration at the left.	To make the structure less porous to water, the horizontal layers of grass are placed in front of vertical layers of grasses in a criss-crossing way. This pattern helps in making the weir very much water tight. To prevent swelling out of grasses, the grasses may be bound by a vertical member (bamboo) once again.

Step	Process	Description	Remarks
5		**<u>Patch the Clay Soil;</u>** The clay soil is patched on the grasses as shown on the illustration in the left hand. Furthermore, to significantly prevent water leakage, the layer of clay soil constructed may be covered by soil existing around the brush dam.	To prevent water leakage, clay soil is patched tightly on the grasses. The clay soil is put not only on grasses as a part of dam but also on the stream banks in contact with the weir to minimize water leakage passing through banks.
6	 ***Front View***	**<u>Completion of Construction;</u>** The weir is then completed. See the illustrations in the left hand and below. 	**<u>Note; Maintaining the Weir</u>** During operation of the irrigated farming, the diversion weir should be maintained carefully. For instance, if a hole is found at the weir, immediately stop it by sealing with clay soil. This process will restore the weir its former good shape, as the hole will be a source of weakness whereby the structure can fail.

Step	Process	Description
7	**Dismantling the Weir**  **Washing the Tools**  **Transporting Materials and Tools to the village** 	**Note; Dismantling the Weir and Set Aside the Main Materials** These types of weirs are constructed as temporary facility for the intake of stream water for irrigation farming in dry season. Therefore, the weir should be dismantled before the start of the rainy season because such kind of structures are constructed across the river/stream and as such, the diversion weir becomes an obstruction for safety flow of floods. Main materials such as logs, bamboos and twigs are then set aside at a suitable place in the village. If properly stored, these materials will be reused for few years to come. **Setting aside the Materials & Tools** 

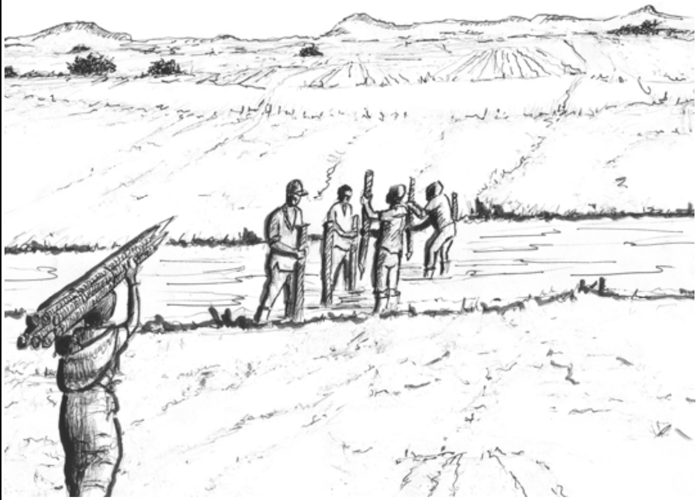
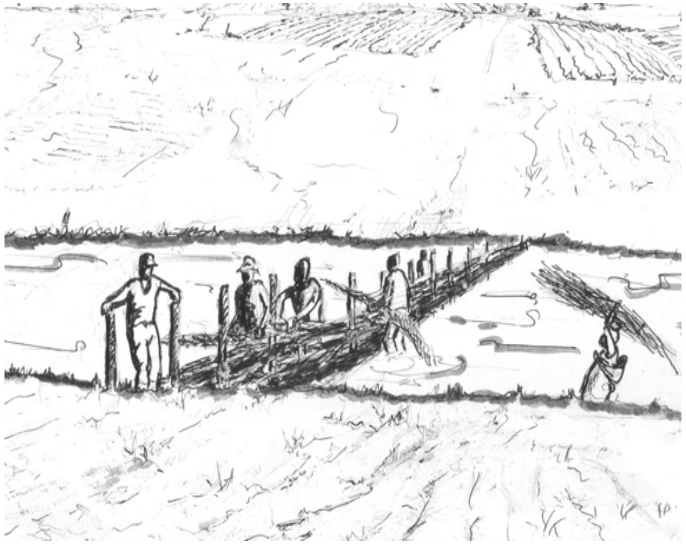
Examples of Inclined Weir (Kawambwa District, Luapula Provicne)

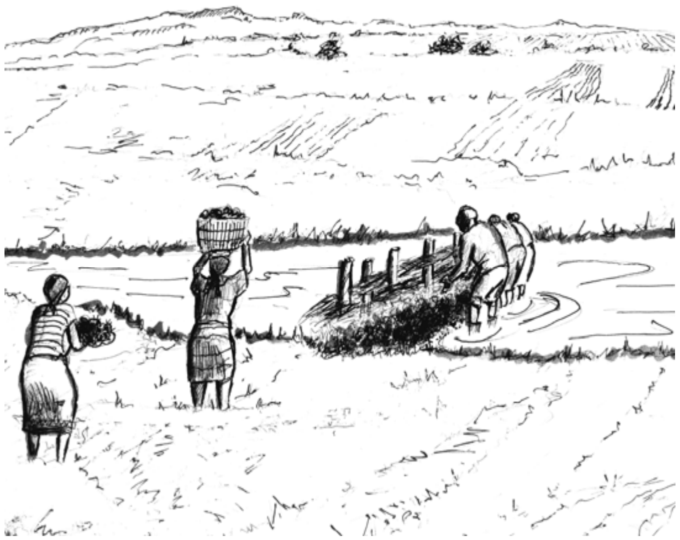
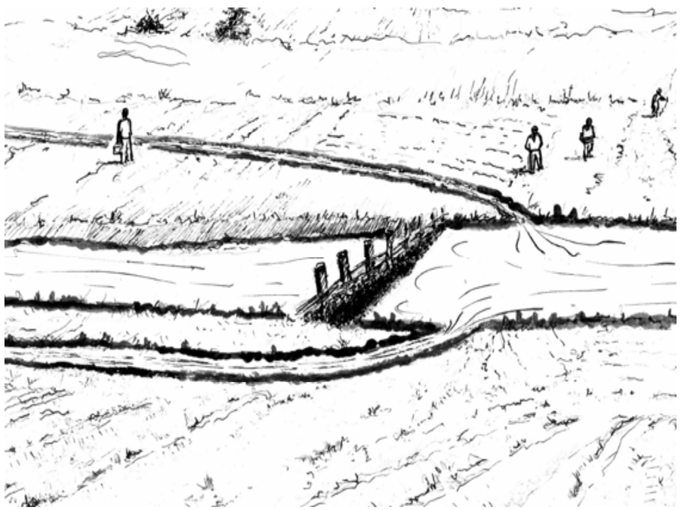


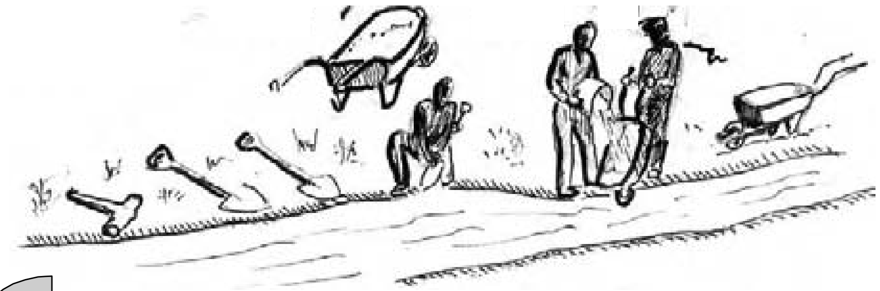
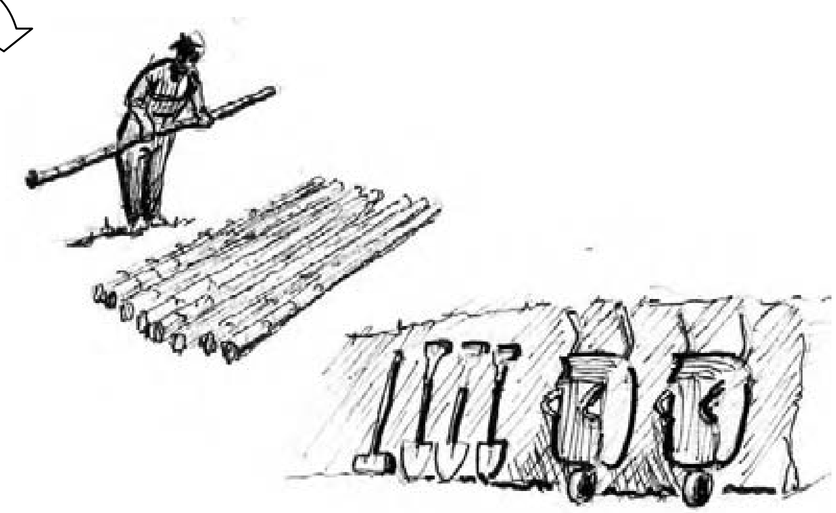
A single-line weir where a lot of soils are placed in front of the weir body.

Back view of a single-line weir, supported by wooden logs.

2. Construction of A Simple Weir: Single-line Wall Type (best suited at wider streams whose foundations are not rock)

Step	Process	Description	Remarks
1		**<u>Position the Wooden Poles;</u>** Position the wooden poles at the diversion point across the stream with an interval of 20 – 30 cm. In short, there should be 3 to 5 numbers of wooden poles per one meter. The poles are driven into the ground at a depth of more than 0.3m, below soft foundation if any. Length of the pole depends on the site condition, more especially in relation to the design tapping water level.	In case of a certain site in Kasama District, width of the stream at diversion point was about 6m. About 20 wooden poles were piled with 0.2 - 0.3m of interval. Good straight poles with a sizable diameter should be the ones to be used in this step. The hammering of the poles into 0.3 m below the bed level should be done in order to overpass sand foundation if any, which would be prone to scouring effect if placed above 0.3m.
2		**<u>Weave the Grasses through the Poles;</u>** To tap the stream flow, grasses (elephant grass etc.) are woven horizontally through the poles. See the illustration in the left hand. 	A good chunk of grasses is taken, and then is twisted and finally it is woven between the poles. The bundled woven grasses are treaded layer by layer as they are put criss-crossing on upright logs. This kind of compaction is required in order to achieve water tight situation. When the bundle has reached the end, the next bundle should not start at the very end of the last bundle, but rather, it should start at midway in order to minimize gaps.

Step	Process	Description	Remarks
3		**<u>Put the clay soil on the Grass Fence;</u>** Put the clay soil on the grass fence. To prevent water leakage from the grass fence and boiling due to sand bed material of the stream, clay soils are put on the grass fence and the bottom of the stream up to certain level. 	It may not be effective to use sandbags as a measure of preventing leakage by boiling/piping on the bottom of the stream. Rather using clay and ordinary soil to seal the gaps in the grass fence and the bottom of stream is effective because the gaps would be clogged with particles of clay and soil. After putting the clay soil on the grass fence and the bottom of stream, soils (stream bed material where appropriate) are thrown to the grass fence.
4		**<u>Completion of Construction;</u>** The weir is completed after following all the steps above.	During operation of the irrigated farming, the diversion weir should be maintained carefully. For instance, if a hole at the weir is found, it should be immediately sealed with clay/ordinary soil. This process will restore the weir its former good shape.

Step	Process	Description
5	**Dismantling the Weir** **Washing the Tools**  **Transporting Materials & Tools to the village** 	**Note; Dismantling the Weir and Set Aside the Main Materials** These types of weirs are constructed as temporary facility for the intake of stream water for irrigation farming in dry season. Therefore, the weir should be dismantled before the start of the rainy season because such kind of structures are constructed across the river/stream and as such, the diversion weir becomes an obstruction for safety flow of floods. Main materials such as logs, bamboos and twigs are then set aside at a suitable place in the village. If properly stored, these materials will be reused for few years to come. **Setting aside the Materials & Tools** 

Examples of Single-line Weir (Mbala District (left), Mporokoso District (right), Northern Provicne)


Common type of single-line weir.


An Improved single-line: There are 2 lines of poles in which there are grasses sand-witched.


There are 2 lines of poles in which there are grasses sand-witched.