MINISTRY OF AGRICULTURE
EXTENSION & PROJECT IMPLEMENTATION
DEPARTMENT
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EPID AGENTS HANDBOOK
for
SOIL & WATER CONSERVATION
by
K. GOWANS
Please make the following corrections in EPID Agents Handbook for Soil and Water Conservation.

1. Pg 16 second line; change "(B)" to "(V)"

2. (a) Pg 19 right side, second paragraph, first line add "on next" after "8 to 11".
   (b) forth line from bottom add "second" after "the"

3. Pg 25 first line under "Bench Terraces" change "bottom" to "bottom".

4. Pg 40 Three shapes of drainage channels are shown at the bottom of the page. Write "rectangular" over the one on the left, "Trapazoidal" over the center one and "parabolic" over the right one.

5. Pg 41 near center of fifth line from bottom should be "0.7 meters".

6. Pg 46 top of second column should be "25" not "15".

7. Pg 49 heading should read "small earth Dam Construction"

8. Pg 63 the equation for volume of pond near bottom of the page should be
   \[ \text{Vol} = \frac{3.14}{2} \left( \frac{D}{2} \right)^2 \right] \]
   \[ = \frac{3.14}{2} \left( \frac{R + S}{2} \right)^2 \]
   \[ + \frac{R S}{2} \]
   \[ D = \text{depth}; \ R = \text{radius}; \ S = \text{Horizontal distance of slope} \]

9. Pg 65 below figure change \( R = 30 = 15 \) to \( R = \frac{20}{2} = 15 \)

10. Pg 66 nine lines from bottom change "are" to "for" at end of the line.

11. Pg 74 in third line under preliminary investigations after "season" cross out "about" and add "may not flow during the dry season. Investigating".

12. Pg 79 third lines from bottom should read "\( V = \text{liters per minute of supply} \)"

13. Pg 81 under area change to read to convert "acres" to "hectares" multiply by "1.4047"; to convert "acres" to "sq. feet" multiply by 43,560.
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SOIL EROSION IN ETHIOPIA

Five years ago (1970) W.D. Ware-Austin, Advisor to the Ethiopia Soil and Water Conservation Division, stated that Ethiopia loses one billion tons of soil every year from erosion. This is equivalent to sixty thousand (60,000) hectares one meter deep every year. So in the last five years, Ethiopia has lost three hundred thousand hectares of soil—more than enough soil to feed and clothe sixty thousand families. But Ethiopia is not losing people at the same rate, in fact the population is increasing. Rough calculations show that for every hectare lost there are ten more people to feed each year. With these kind of figures no country can survive. Hunger and starvation have already come to Ethiopia, but an even greater threat looms in the future if something is not done soon. Soil erosion and population explosion are on a collision course. The result could mean mass starvation.

In a recent report prepared under the direction of Dr. Leslie Brown, an authority on agricultural development, it was stated that a noticeable impact must be made on the problem of soil erosion in the next three years, and within ten years soil erosion control should be firmly and universally accepted and complete. This report was particularly concerned with the Wollo and Tigre regions, but areas in Eritrea, Hararghe and Shoa regions also have very serious erosion problems. However, soil erosion can be seen in every region of Ethiopia.

It does not take an expert to see the destruction of land in Ethiopia resulting from soil erosion. It is particularly noticeable when driving from Addis Ababa to Dessie and then
on to Mekele and Asmara. All the forests have been cleared from the mountain slopes; excess grazing has stripped the land bare of brush and grass; all the land is cultivated, even the very steep slopes; and many of the streams are choked with gravel and boulders which have been washed from the hills by excessive runoff. The loss of top soil has lowered crop yields.

Some have said that soil erosion has been going on for a long time in Ethiopia so why get excited about it now? Yes, soil erosion has been going on for a long time; part of the Nile flood basin is made up of soils from Ethiopia. Yet there is good reason to believe that the rate of soil erosion has increased in the last thirty or forty years. It is not hard to find farmers that can remember a spring that no longer flows, or a field that he plowed which is now a gully, or a meadow that no longer produced good grass for his cattle, or a forest that is no longer present to supply him with fuel. When the last spring is gone, the last field has been washed away, the last meadow has been destroyed, and the last tree has been cut down, what is man to do? Will another bag of fertilizer get him by, or a new seed?

The sad part about all this is that it has been said many times in the recent past but nothing has been done. What is required to stop soil erosion?

First: A strong desire to do something about it; not just talk and plan. Shelves are filled with plans still unimplemented.
Second: A realization that soil conservation is nothing more than good soil management which every farmer, livestock man, forester, and road builder should be doing. In other words, there is nothing magic about soil conservation; it is just good land management. Soil conservation should be an every day occurrence, not something special or that requires somebody special to do it.

Third: An educational program that informs everyone what has to be done and how to do it.

Fourth: Technically trained and dedicated people to go out and assist farmers. These technically trained people need not be highly trained. They need only to know how to use simple tools and implement some simple practices.

Fifth: A few simple laws which can be and will be enforced would help but are not necessary. The enforcement of the laws now on the books which prohibit the cutting and burning of forests would help.

This handbook has been written for all of you who want to help solve the problem of soil erosion in Ethiopia. It is not complete but it is the first step to help you to help farmers to improve soil management practices. If you can do this, you will be helping Ethiopia save its soil.
How to Make the Farmers Aware of Soil Erosion

Generally speaking most farmers in Ethiopia are either aware of soil erosion or can be easily convinced that soil erosion is taking their land away: Their problem is not so much being aware that soil erosion is taking place but what can be done about it.

Farmers are not aware that ploughing up and down a slope increases soil erosion. They must be shown how to plough on the contour. If you help them lay out contour strip across the slope they will be able to plough on the contour.

Farmers don't realize that a small gully will soon grow into a big gully. They need help to divert water from the head of the gully, build check dams and plant trees, sissel, bamboo and grass.

Farmers don't realize that all slopes between 25 and 40 percent must have bench terraces if they are cultivated. They need help in building good bench terraces.

Farmers don't realize that slopes above 40% should not be cultivated. They must be convinced that these slopes should not be cultivated but planted to grass, shrubs or trees.

These are some of the improved soil management practices that will help stop erosion. Farmers very often will accept them if they are made aware that these practices will help save their soil. Some farmers will tell you that they are losing the fertilizers they have applied with the soil that is lost by erosion and they are looking for ways to save their soil.
There is a very good film that can be shown to farmers to increase their awareness of soil erosion. It is called "save our soil", and is in Amharic as well as English. If you have a projector available, the film can be borrowed from EPID Headquarters. This film is good to show in a village where a soil conservation program is to start.

Community effort is usually required to develop a co-ordinated soil conservation program in an area. For instance, contour strips in one isolated field may not be very effective especially if water is coming into the field from above, whereas, the contour strips over the entire catchment or sub catchment would be very effective. (A catchment includes all the land which drains into a stream. A catchment is the same as a watershed). A large gully usually passes through more than one farmers field and will required community effort to control the gully.

Field meetings in an area to point out the effects of soil erosion can be helpful to start a soil erosion control program. The area should be first evaluated to determine the problems and what is required to correct the problems. Solutions to the problems should be practical and a commitment should be made with the farmers to put the improved practices into effect.

A small sub catchment can be selected as a demonstration area. Here the fields can be contour stripped, gullies stopped, cutoff drains constructed and trees planted. Additional cropping practices farmers should be helped with are row planting, rotation of crops, strip planting, use of good seed and proper use of fertilizers.
Evaluating Land for Soil Conservation

There are many systems for evaluating land. Often the term "Land Use Capability" is used to evaluate land for proper land use. At the present time no system has been universally used in Ethiopia; in fact very little of the land has been evaluated for best land use.

The information presented here is to guide Extension Agents evaluate land so they can help farmers improved the management of their land. It is not meant to be a system of land use capability. However, as agents became more familiar with the factors involved a system will be evolved which is adapted to Ethiopian conditions and which the Extension Agents can use.

Soil Erosion is a function of

A) Eroding Force
   Water; (rainfall, running water)
   Wind; (intensity)

B) Land Erodability
   Soil; (texture, structure, depth)
   Slope; (percent, length)
   Vegetation; (kind, density)
   Land Management; (crops grown, conservation practices)
   Crop Management; (kind of crop, method planting)

Eroding Force

Rainfall: Usually we can say that there will be more soil erosion in areas of high rainfall than in area of low rainfall but there are so many factors to be considered that this is not generally true.
Other factors of rainfall that must be considered are distribution during the year, the amount of rainfall in a given period of time (intensity) and the length of time the rainfalls. (duration) For instance, rainfall distributed throughout the year would cause less erosion than the same amount of rainfall in a few months of the year, because the intensity would be less when the rainfall is distributed over a longer period of time. A rain storm with a high intensity for a short time will cause much more erosion than a rain storm with a low intensity for a long duration.

In the medium and low rainfall areas of Ethiopia the first rains of the season are often very heavy. This is the time of the year when crops have not started to grow and the soil is bare. A large amount of soil is lost when these heavy rains fall on bare soil.

Raindrops are the major cause in starting soil erosion. They are able to beat bare soil into flowing mud. Only a thin layer of live or dead organic matter on the soil surface is required to absorb the beat of raindrops and protect the soil.

Running Water

Muddy water running over the soil surface soon seals the surface so that water is not able to soak into the soil. Rainfall that does not soak into the soil soon accumulates on the surface and begins to runoff. This running water will carry soil with it and the faster it flows the more soil it will carry.
Runoff water flowing over cultivated soil will cause sheet erosion which carries away the top soil or the most fertile soil. The steeper the slope the faster the water will run and the more soil that will be lost.

Runoff water usually will begin to accumulate and form a small stream. If this stream flows over unprotected soil a gully soon starts. Before long the small gully increases in size and destroys a field.

Wind

Wind can cause very serious soil erosion but it is usually much less than erosion caused by water. In dry areas where the soil does not have plant growth to protect it, winds soon start to move the soils. Sandy soils and soils with a low percent of clay are the most easily eroded by wind.

A surface cover of vegetation is the best protection against wind erosion.

Vegetation will slow the wind over the land surface and hold the soil in place. Trees planted around houses, along field boundaries, and along drainageways will slow the wind over the land; but grass and other low growing plants are just as effective in preventing loss of soil by wind erosion.

LAND ERODABILITY

Land erodability is related to two groups of factors. One group has to do with the physical factors of the land; that is texture, structure, depth, slope and length of slope. The other group has to do with the way the land is managed; that is the vegetation or crops growing on the land and the treatment of the land.
Soil Texture

Soil texture is an expression of the sand, silt and clay in the soil and can be roughly determined in the field by the way soil feels when moist. Sandy soils are gritty, silt soils are smooth and clay soils are sticky. Sands and silts have little binding or cementing power while clay holds the soil together into clods or soil aggregates. One measures of soil erodability is the relation of sand and silt to clay. The higher sand and silt is to clay the more susceptible the soil is to erosion.

Soil Structure

Soil structure refers to the way soil particles are held together. If you look carefully at soil, you will find that some soils are full of many fine holes through which water can move and others are very dense which prevents water from moving in them. Decomposing organic matter in the soil helps to build good soil structure. Soils under grass and other vegetation which have never been cultivated or cultivated for many years will develop a very porous soil structure. Soils which are regularly cultivated should have organic matter added every year either from crop residues or from farm yard manure. In this way the soil structure will allow the rain that falls to penetrate the soil rather than runoff.

Soil Depth

Shallow soils are more susceptible to erosion than deep soils because shallow soils can become saturated causing water to runoff. Also saturated soils on slopes sometimes will slide off of the hills causing small land slides or slip outs.
Slope of the Land

Slope has two variables to consider. One is the steepness or the percent slope (% slope = vertical distance times 100 divided by the horizontal distance) the other is the length of the slope. Each can be evaluated separately but one affects the other, therefore, it is well to consider them together in the field when evaluating the soil erosion potential.

Soil erosion will be greater on steeper slopes for several reasons: water runs faster, it has less time to soak in before running off, and fast running water carries more soil. Erosion is not in proportion to the steepness of the slope but increases more rapidly as the slope becomes greater. As the length of the slope increases the soil erosion will increase, because there is a build up in the amount of runoff which increases soil erosion.

How the Land is Used

Vegetation

Land with a cover of natural vegetation such as grass or forest is well protected against erosion. The dense vegetation breaks the fall of raindrops while the soils are porous allowing most of the rain to be absorbed into the soil. The water that does runoff usually flows in drainage ways well protected by natural vegetation.

When this vegetation is removed and the land is cultivated serious erosion often begins. Rain drops break the soil lose, runoff begins, and before long gullies start to form.
Land Management

Erosion of land can be controlled by the way it is managed. The rainfall, wind, slope and soil must be considered to properly manage land. Land that is not properly managed soon becomes unproductive.

As a general rule, all land over 2% slope must be cultivated on the contour, land with 3 to 8% slope should have broad base or narrow base terraces, land with 8 to 40% slope should have narrow based or bench terraces and land over 40% slope should not be cultivated.

All waterways should have a permanent grass cover or a rock cover and protected from overgrazing. All slopes that cannot be protected with terraces should be planted to grass or trees and not over grazed. Gullies must be stopped with check dams, planted to grass, and trees, and protected from grazing.

Crop Management

Crop management can be very important in preventing soil erosion. The kind of crop, the way the crop is cultivated, when the crop is planted, and how the crop residue is used all have an important influence on soil erosion.

Land planted to row crops such as maize or beans is more easily eroded than land planted to close growing crops such as wheat or teff.

On long moderately steep slopes, strips of row crops and close growing crops across the slope is better than all planted to row crops. Rotation of crops on the land will help crops grow better and protect the land.

Crops should be planted as soon as possible when the rains start so that the crops will become established to protect the soil. Crop residues should be left on the soil to help increase organic matter and protect the soil from the force of raindrops.
Making a Simple Farm Plan

The land must be evaluated before a farm plan is developed. The form on the following page is used for recording the information about the farm.

A map of the farm can be drawn on a separate sheet of paper or on the back of the form. Each field on the farm is labeled on the map and described on the form.

After the land has been evaluated improved soil and crop management practices are recommended for each field. Now you will be able to tell the farmer what kind of improved practices are required and where they should be made. You should go over the land with the farmer and show him what is recommended. You should arrange to provide him with instructions in how to make the necessary improvements.

Example of farm plan:

Fig. 1. Sketch map of farm.
Land Evaluation Sheet

Farmers Name: ___________________________ Ext. Centre: ____________
Village: _________________________________ MPP _____________________
Estimated Rainfall: _______________________

Land Characteristics

<table>
<thead>
<tr>
<th>Field</th>
<th>Hectare</th>
<th>Slope</th>
<th>Texture</th>
<th>Erosion Hazards</th>
<th>Drainage</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>4</td>
<td>5</td>
<td>Clay</td>
<td>Gully</td>
<td>Fair</td>
</tr>
<tr>
<td>B</td>
<td>1.5</td>
<td>12</td>
<td>Clay loam</td>
<td>Mod sheet</td>
<td>Good</td>
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<tr>
<td>C</td>
<td>1.0</td>
<td>30</td>
<td>Rocky Cl.</td>
<td>Sheet</td>
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<tr>
<td>D</td>
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<td>42</td>
<td>Rocky loam</td>
<td>Sever Sheet</td>
<td>V.Good</td>
</tr>
<tr>
<td>E</td>
<td>-</td>
<td>-</td>
<td>&quot;</td>
<td>Gully</td>
<td>-</td>
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</table>

Recommendations

<table>
<thead>
<tr>
<th>Field</th>
<th>Action</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>Grass strips 20 meters apart</td>
</tr>
<tr>
<td>B</td>
<td>Grass strips 8 meters apart</td>
</tr>
<tr>
<td>C</td>
<td>Bench Terraces 3 meters apart with rock face</td>
</tr>
<tr>
<td>D</td>
<td>No cultivation Plant to tree cut grass for fodder</td>
</tr>
<tr>
<td>E</td>
<td>Divert water from Gully; Put in check dams plant sissal, and trees along sides of gully. No cultivation within 3 meters of gully.</td>
</tr>
</tbody>
</table>
LAYING OUT CONTOURS WITH A LINE LEVEL

WHY CONTOUR LINES?
Contour lines across sloping land are guide lines for ploughing on the contour and for constructing terraces. This is the first step in erosion control on cultivated land. These lines can be either on the level or on a slope depending upon the slope of the land and the rainfall in the area.

WHAT IS NEEDED?
Contours across sloping land can be laid out with a simple line level, a string, and two poles or rods. Three people are needed; one on each pole at the end of the string and one in the middle of the string to read the line level. (See fig. 2).

WHAT DOES A LINE LEVEL LOOK LIKE?
The line level is a small metal tube containing a glass with a water bubble. There are hooks on each end of the tube to hang the level from a string. (fig. 3).

Fig. 2. Laying out a contour with a line level.

Fig. 3. Actual size of line level.

Fig. 4. Men A, B and C moving a line on the contour across a slope.
HOW TO USE A LINE LEVEL?

Level contours: Level contours are lines along sloping land on the level or same elevation.

TYING THE STRING TO THE POLES

To lay out a level contour first tie a string at the same distance above the ground on poles A and B as shown in Fig. 2. The string should be 5 meters long where the contours are curving and 10 meters long where the contours are nearly straight.

STEPS IN LAYING OUT A CONTOUR

Start at one end of the field with pole A as shown in Fig. 4. Pole B is moved out into the field until the string is pulled tight. The middle man (C) hangs the line level on the string and directs man (B) to move up or down the slope until the line is level as shown by the bubble in the line level. Man (B) marks the spot where the end of the pole is with a stick, rock, or a little white powdered lime. Man (A) also marks the spot where the end of his pole is; then moves his pole to where the pole of man (B) was. When man (A) moves man (B) moves across the field while man (C) holds the line level. Man (B) again tightens the string and man (C) directs man (B) up or down the slope as before.

This movement is continued, until a line on the contour is marked off across the field. More lines are marked off across the field at appropriate intervals.

Graded Contours

Graded terraces may be desirable in areas with high rainfall. These are terraces with a gentle slope (0.5%) which allows water to run across the slope. However, the water must be put into grass or rock covered waterway to prevent gullies from forming.

LAYING OUT SLOPING CONTOURS

To lay out a contour with a ½% slope tie the string on one pole 2.5 cm higher than on the other pole using a string 5 meters long.

To do this, first tie a string 5 meters long the same distance from the ground on each pole as shown at points A and B in Fig. 2. Then raise the strings 2.5 cm on pole B. Mark this pole with a cloth. Now follow the same procedure for laying out a level contour. The marked pole must always be in the direction toward the lower end of the slope. This means that water will run in the direction of the pole with the flag.
Ridge-Tie Method for Water Conservation

NEED FOR WATER CONSERVATION

In areas of low rainfall, crop yields can be increased by holding water on the land so that it can soak in rather than run off. This applies in many areas of Ethiopia where the rainfall is less than 800 mm.

WHAT IS THE RIDGE-TIE METHOD?

One effective way of holding water on the land is by the ridge and tie method. This method shown in Fig. 7, consists of making furrows and ridges with the local plough across the slope; then blocking the furrows at every 5 meters with soil so water does not run in the furrows. This method has been used in trials by the Institute of Agricultural Research and has increased crop yields in areas of low rainfall.

HOW TO USE THE RIDGE-TIE METHOD

This method of preparing land should be used at the time of planting. In low rainfall areas, all the rain is held on the land and soaks into the soil. Crop yields are increased because more water is available for plant growth.

In Fig. 8 to 11, page two methods of planting seeds are shown. One method is used for small seeded cereals such as wheat, barley and oats. The method is for large seeded crops such as maize, sorghum, and beans.

Fig. 7 What the ridge-tie looks like
PLANTING WHEAT, BARLEY OR OATS

First: Plough the land on the contour leaving ridges and furrows across the field.

Second: Broadcast wheat, barley or oats. If fertilizer is used it should also be broadcasted.

Third: Plough the field again down the ridges. This will cover the seed and leave ridges and furrows.

Fourth: At 5 meter intervals soil is piled up in the furrow with a hoe to block water flowing in the furrow.

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PLANTING MAIZE, SORGHUM AND BEANS

First: Plough the land on the contour leaving ridges and furrows across the field.

Second: Sow seed by dropping the seed in every other furrow. If fertilizer is used, drop the fertilizer only in the furrows with the seed.

Third: Cover the seed by ploughing down the ridge each side of the seed.

Fourth: At 5 meter intervals soil is piled up in the furrow with a hoe to block water flowing in the furrow.
**Termaces for the Small Farmer**

**Fig. 12 Broad Based Terrace**

(a) Terrace made with a one way plough

(b) Terrace made with a two way plough

**Fig. 13 Narrow Based Terrace**

**Fig. 14 Bench Terrace**

**Fig. 15 Modified Bench Terrace for very low Rainfall Areas**

uncultivated

cultivated
Prevents Soil Erosion

Terracing cultivated land will help prevent soil erosion. Water does not run off of terraced land as fast as from non-terraced land, as a result less soil is washed away and more water soaks into the soil. However, poorly constructed and maintained terraces and water ways can result in more soil erosion than land without terraces.

Three Kinds of Terraces

Terraces can be built in several ways. The slope of the land, amount of rainfall, and texture of the soil will determine the kind of terrace best suited to the area. The three most common terraces are the broad based, narrow based and bench terraces. These terraces can either be built on the level or on a grade (gradient). Level terraces are built in low rainfall areas to hold the water on the land. Graded terraces are built in areas of higher rainfall so that water will run across the slope.

Terraces needed in Ethiopia

All of these terraces are used by farmers in Ethiopia. Some are very well constructed, but many could be improved. Even more important though, is that there are many cultivated areas in Ethiopia which should be terraced. It is not easy for the Ethiopian farmer to terrace his land because he does not have the proper equipment to do a good job.

The farmer must either move the soil by hand to build the terraces or he can purchase a mould board plough to move soil. A simple scrapper that can be made locally would help to move soil. These ploughs and scrappers could be purchased cooperatively because they are only needed for a short time by any one farmer.
Lay out Contours First Step

The first step in the construction of any terrace is to lay out contours either on the level or on a gradient across the slope. This can be done with a simple line level. The use of a line level is described under the heading of "Laying out Contours With a Line Level".

Terrace Interval*

The interval of terraces will be determined to a large extent by the slope of the land. Under Ethiopian conditions of the small farmer where oxen drawn equipment is used the terraces will be narrower than in areas where a tractor is used.

The horizontal spacing or the distance between terrace ridges in meters is determined by dividing 100 by the percent slope of the land. (Horizontal Spacing equals vertical spacing times 100 divided by percent slope. For terraces made by farmers with the local plough a vertical interval of one meter is used).

Broad Based Terraces

Broad based terraces (fig. 12) are built on gentle (less than 8%) slopes and are constructed so that all the land can be cultivated.

They are constructed by moving soil to broad ridges at intervals across the slope. Part of the original slope may still remain but a channel is formed so that water is directed across the slope. In order for the water to run across the slope, the terraces must have a grade of about .5%. Care must be taken to run the water from the terraces into a grassed waterway and not into an unprotected ditch. Water that accumulates from the terraces can cause gully erosion if it is not properly taken care of.

* Terrace interval is the horizontal distance between the top of one ridge to the top of the next ridge.
The lower side of the ridge must be protected from erosion with grass or stone. Stolons or roots of creeping grass (Bermuda or Kikuya) planted on the slope will provide the greatest protection. Teff can be seeded on these slopes as a quick growing temporary cover. If stones are used those at the base should be carefully placed in a trench to prevent the wall from collapsing.

Bench Terraces

Bench terraces (fig. 14) have a flat bottom with a ridge to hold water in the terraces. They are built in areas of low rainfall to conserve water and on gently sloping to very steep slopes.

They are built by forming a ridge on the lower side and leveling the soil on the terrace above. The wall on the lower side of the ridge is usually very steep and must be protected from erosion with grass or stones. Soil is taken from the lower side of the ridge to level the terrace and to form the ridge. These terraces on steep slopes must be built by hand. On the more gentle slopes the terrace can be leveled with a scrapper. They should be maintained every year so that water does not break over the top of the ridge.

Bench terraces are similar to narrow based terraces except the bench terraces have a flat bottom and are usually built on a level contour rather than on a gradient. On larger or longer benches ridges should be built across the terrace so the water will be distributed better on the terrace. Terraces are difficult to make perfectly level, therefore, the cross ridges will control the water in the terrace.

Modified Bench Terrace for Very Low Rainfall Areas

In very low rainfall areas (less than 500 mm) the bench terrace may be modified to collect water as well as hold water on the land. These terraces (fig. 15) have been used to increase water on the land which has resulted in increased yields.
These bench terraces are made across a slope with intervals of uncultivated and unterraced land between. Water from the uncultivated land is collected on the bench terrace below. In this way the amount of water on the bench terrace is increased. For example, if the uncultivated area is the same size as the cultivated area and assume that half of the water runs off of the uncultivated area then in an area with 400 mm of rainfall the water collected in the terrace may be 600 mm (400 + 200). This may be enough to produce a profitable crop while the rainfall of 400 mm would not.

**Grassed or stone covered water ways**

Waterways are constructed at intervals across terraced land to collect runoff water and carry it away safely. This excess water may either be run into a natural stream channel or spread over more gently sloping land (see "Design of Cutoff Ditches or waterways" for design of waterways).

Most of the sloping terraces built by the small farmers will not be very long and will not require waterways in the fields to shorten them. Long terraces require waterways at intervals so that large amounts of water does not accumulate and flow on the terraces. Graded terraces should not be longer than 300 meters.

Waterways should be broad with gentle side slopes. A dense grass cover is the most desirable. However, the grass should be planted well in advance of the heavy rain and should be protected from overgrazing. The grass should be allowed to grow 10 cm, or more in height during the rainy season to provide the maximum protection. Newly constructed waterways can be planted with a stoloniferous grass (Bermuda, etc.) and a quick establishing grass such as teff. The teff will protect the waterway the first year while the perennial grass becomes established.

Waterways may also be paved with stone to protect them from erosion. This is particularly true on the more steeper areas. Here a combination of rock check dams and grassed channel bottoms would provide the greatest protection. The side walls of channels on steep slopes should also be protected with rock.

**Remember**

Poorly constructed terraces and poorly constructed waterways can result in more soil erosion then land without terraces.
Preventing and Controlling Gullies

Gullies are symptom of improper land use. They are not the first symptom; first is the loss of fertile top soil by sheet erosion. Gullies are the secondary symptom indicating misuse of land over a long period of time.

When we disturb the natural vegetation by cutting down trees and ploughing under the grass, we expose the land to erosion. As the top soil is washed away water will concentrate more rapidly in natural water ways and form gullies. Less water soaks into the soil for plants to use. While gullies are developing, fertile top soil is picked up and carried off in the runoff.

Misuse of lands is cause of Erosion

One of the most frequent ways of misusing land is cultivating steep slopes. Another way is overgrazing and trampling by livestock which destroy the plant cover and cause gullies. The steeper the slope, the greater the danger of erosion. Steep slopes cleared for cultivation will soon be badly gullied.

Gullies often start in the banks of natural water courses that have been eroded to a greater depth. They extend back into the drainage area and grow deeper as they advance up the slope. Waterfalls are sometimes formed in the sides of these gullies causing branch gullies to form. This branching may continue until a network of gullies cover the entire area.

Preventing Gully Erosion

The first step in preventing the formation of gullies is to plan the cultivated area so as to make the best use of the land.
Often the co-operative action of several farmers will be required. This should include (1) converting to permanent cover, those lands which are too steep or too eroded to cultivate, (2) constructing terraces on the moderately steep slopes, (3) cultivating the gently sloping lands on the contour, and (4) planting the water ways to perennials grasses protected from grazing.

Every effort should be made to prevent gullies from forming. Once a gully starts it is sometimes difficult to stop before considerable soil is lost or an entire field is lost.

Here are some ways to prevent gullies from forming:

1) Use good farming practices to prevent soil erosion
2) Keep water from running down unprotected slopes
3) Protect all waterways with a perennial grass
4) Keep livestock out of grassed waterways and cut the grass for hay.
5) Prevent water from running in cattle trails by spreading water from the trials into adjacent land.

Controlling Gullies

Although severely gullied land may have little immediate value control measures are necessary to protect adjacent land. It is well to determine what is the most economical and suitable protection for each gullied area.

Where practical, runoff water should be diverted from a gully before control measures are started. Terraces or diversion ditches can be used to divert water from the gully. Careful consideration should be given to the disposal of the diverted water. Unless a safe disposal area can be provided no attempt should be made to divert the water. The disposal of concentrated runoff over unprotected areas may cause serious additional gullying.
Any gully, no matter how large and regardless of its condition will eventually be covered with native plants provided it is properly protected. Even though, plants will come in naturally on protected gullied land, recovery will be slow. A surface mulch of dead grass will help to hold seeds and speed the recovery. If the sides of the gully are steep, they should be broken down to provide a place for plants to get started. Check dams will be needed to slow the water in the gully and catch silt. Seeding with a quick starting well adapted grass such as teff will insure a quick recovery in the gully. Finally the gully must be protected from grazing by livestock.

**Plant Shrubs and Trees**

In small or medium sized gullies with small drainage areas it is possible to construct check dams by planting shrubs across the gully. Shrubs placed 20 cm apart in the rows and 50 cm between rows are very effective in slowing water in the gully.

Shrubs and trees planting at the head of the gully will prevent the gully from cutting further up the slope.

**Plant Grass**

If an immediate grass cover is required, it may be necessary to transplant sod. Sod will be required in critical sections at the gully head and at points along the bank and bottoms where protection against waterfall erosion is necessary. Grass covers can usually be established by sodding on areas exposed to runoff that would be impractical to provide a secure cover by seeding. Sod check dams and sod spillways have all functioned successfully.
Build Check Dams

Rock or brush check dams are used in gullies to facilitate the establishment of vegetation or to provide protection at points that cannot be adequately protected in any other way. If the runoff is of sufficient volume to make control by vegetation impractical, check dams must be used.

Check dams are used to collect and hold soil and moisture in the bottom of gullies so that vegetation can be established. They are also used to check erosion at the head of the gully or in the channel of a gully until a protective cover of vegetation can be grown.

Piles of closely compacted rock and brush are all that is necessary across the bottom of the gully if runoff is small. Several low check dams are more desirable than one large dam to slow the water and control erosion in a gully. Low dams are less likely to fail and the overfall of water cuts away less soil in the lower side of the dam. These dams should seldom exceed 50 cm in height. The dams should be constructed far enough into the bottom and sides of the gully to prevent washouts underneath or around the ends of the dams. An apron will generally be necessary to protect the structure from the undermining action of the runoff as it is discharged from the spillway.

Brush check dams (Fig. 16.)

Brush dams are best suited for gullies having small drainage areas and with soil conditions that permit the driving of necessary anchoring stakes. These dams are easy to build where brush is available. It is important that the center of the dam be kept lower than the ends to allow water to flow over the dam itself rather than around the ends.
Rock Check Dams (Fig. 17).

Loose rock dams are desirable where plenty of suitable rock is readily available. They are used in gullies of moderate slope with small or medium sized drainage areas. A well constructed loose rock dam will be more durable than a brush dam; they also have the advantage because of their flexibility and weight to hold it in contact with the bottom of the gully.

Too often erosion controls are installed and then neglected until they become so badly damaged that they are no longer effective. They should be inspected periodically, especially after heavy rains, to determined whether they need minor repairs. This is particularly true of plant cover while it is being established or rock structures when they are first installed.
Fig 16 Brush Check Dam

View of brush check dam looking up stream

Cross section of brush check dam across stream

Down stream

Cross section of the brush check dam through the center
Fig 17  Rock Check Dam

View of rock check dam looking up stream

Cross section of the rock check dam across stream

X  Down stream side

Up stream side

Sod

tamped soil

Cross section of the rock check dam through the center
Tree Planting for Soil Conservation

Trees are successfully used to control soil erosion. They bind the soil with their roots, break the fall of rain drops and cover the soil with dead leaves.

![Diagram showing rain and wood for fire]

They provide fuel for cooking which saves animal manure for fertilizer and provide wood for building houses (fig. 18). Trees properly spaced over the land will slow the wind, preventing wind erosion and decreasing the loss of water from the soil by evaporation.

Afforestation program

A relatively large scale afforestation program has been going on in parts of Tigre Province for several years. Similar programs are starting in Wollo and Hararghe Provinces. But programs of this kind should be started in all provinces of Ethiopia.

All the very steep slopes which are now cultivated should be planted to trees. Trees should be planted around all homes and villages to provide wood for fuel and building purposes. Trees should be planted along stream channels to prevent erosion. (fig. 19).
Preparation of the Planting Site

A well prepared planting site gives the trees a good chance to survive.

The kind of preparation will depend upon the steepness of the land, the soil depth, the amount of rainfall and the density of vegetation.

Shallow Soils in Dry Steep Slopes

Bench terraces (fig. 20) are recommended on steep slopes with shallow soils in low rainfall areas. They hold water on the land and provide deeper soil in which to plant the trees. These soils occur in the eastern and southern provinces of Ethiopia.

Fig. 20. Bench terraces on steep slopes.

Terraces can be made on the contour with the use of a simple line level. A method is described in "Laying out Contour with a line Level" for using a line level.

Shallow Soils on Dry Moderately Steep Slopes

On moderately steep slopes contour trenches can be dug to hold the water. These trenches can be dug about 45 cm deep and 45 cm wide on the contour around the slope (fig. 21).
The trenches should be about 2 meters apart across the slope. They can be extended contours with dams ever 5 meters to keep water from running in the trench or they can be interrupted terraces about 5 meters long with a meter between trenches. The trees are planted on the ridge formed from the soil taken from the trench.

Fig. 21. Contour trenches for tree Planting.

Deep Soils

Very little site preparation is required for planting trees in deep soils. If the trees are planted properly and protected from competition by weeds the first year, the trees will grow very well. An area, about one meter in diameter around the trees, should be kept free of grass and weeds, (fig. 22). This area can be mulched with the dead weeds to protect the soil from erosion and reduces loss of moisture from the soil.

Fig. 22. Keep planting site free of grass & weeds.
Digging the tree Planting Holes

Holes should be dug far enough in advance of planting so that the soil in the hole becomes thoroughly wet by the rains. This is most important in low rainfall areas where all the water that falls must be conserved for plant growth. In high rainfall areas holes can be dug any time after the soil becomes wet.

Tree planting holes should be dug 30 cm deep and 30 cm in diameter. Smaller holes do not allow room to properly place the seedling in the hole and larger holes are not necessary (Fig. 23). It is important that holes are deep enough so that the seedling can be planted at the proper depths without bending the roots.

Fig. 23. Dig the correct size hole.

Planting the Tree

Attention to proper details in planting is the most important for the survival of the trees. The following points must be observed. (Fig. 24.).

1) Roots should never become dry. Carry the seedling in plastic bags from the nursery to the planting site.

2) Roots should never come in contact with dry soil. Be sure the soil is moist when the seedling is planted.
3) Roots should hang down without bunching or curling when placed in the hole.

4) Soil must be firmly packed around the roots. No air pockets should remain around the roots.

5) Seedlings should be planted the same depth as in the nursery.

Fig. 24: Plant the tree properly.

**Protect the Young Trees**

The trees must be protected from competition from weeds and grass the first year. (fig. 25).

Roots of grasses and weeds take moisture from the soil around the young trees which eventually kills the tree.

Fig. 25. Protect the tree the first year from competition.
Cattle, sheep and goats must be kept away from the young trees. These animals will often eat or pull the trees from the soil. Either keep the cattle from a newly planted area for at least two years or protect the individual trees with a fence of rock or brush. (Fig. 26). Trees around the house must be protected with a fence.

![Fig. 26: Protect young trees from livestock.](image)

Selecting the Proper Trees

There are many trees that will grow well in Ethiopia. Some of them are native to Ethiopia and others have been brought here from other countries. Experimental plantings have been made in various parts of Ethiopia to determine the best tree for each area.

The local conditions of an area and the expected use to be made of the tree will determine which tree to plant. Not all trees will do well in all areas and some trees are more desirable for certain uses than others.

Before you select your tree, consult with the local forester from the Ministry of Agriculture. He can help you select the proper tree and will furnish you the seedlings.
Design of Cutoff Drains or Waterway

Cutoff drains may be required above a cultivated field if runoff water is coming into the field from the land above. This is particularly true of fields below steep slopes. Cutoff drains should be constructed above cultivated field before terraces are constructed because the excess water may destroy the terraces.

These drains must be constructed to carry the expected runoff safely to the main drainage system without forming a gully. Several methods have been developed to design a ditch to carry the estimated amount of runoff water.

The method described here is given in "Soil Conservation" by Norman Hudson and is a method used by the U.S. Soil Conservation Service but modified for African Conditions. The characteristic and size of the catchment are required to find the depth and width of the ditch.

The shape of three channels are given in figure 27 along with equations for area hydraulic radius and top width of these channels. Hydraulic radius is used to measure the effect of the channel surface to reduce the flow of water. It is defined as the cross section divided by the wall perimeter.

Fig. 27. Shape of drainage channels.

<table>
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<th>Area</th>
<th>bd</th>
<th>bd + zd²</th>
<th>2/3 zd</th>
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<tr>
<td>Hydralic Radius</td>
<td>( \frac{bd}{b + 2d} )</td>
<td>( \frac{bd + zd²}{b + 2d \sqrt{1 + z²}} )</td>
<td>( \frac{2d}{3} )</td>
</tr>
<tr>
<td>Top width</td>
<td>b</td>
<td>( t = b + 2dz )</td>
<td>( z = \frac{2a}{2d} )</td>
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</table>
The use of the tables and figures to determine the size of a drainage ditch can best be explained by working out examples.

Example A.

Design a drainage channel to be dug in clay with a uniform cross section and medium thin grass cover. This channel will collect water above a cultivated field. The area above the field is nearly square and has 8 hectares; relief is hilly with an average slope of 25%; infiltration is slow into a clay soil; vegetal cover is poor; and there is low surface storage. The steps to follow to determine the depth, width, and grade of the ditch are listed in table 1.

From table 2 values for the catchment characteristic, hill relief has 15, slow infiltration has 15; poor vegetal cover has 15; and low surface water storage has 15; giving a value (c) for the characteristic of the catchment of 60.

Enter table 3 (runoff from a square catchment) with 8 hectares and 60 characteristics to obtain a runoff 1.75 meters per sec. Allowable velocity from table 6 in the clay with medium grass cover is 1.8 meter per sec.

Calculate the area of channel from $A = \frac{Q}{V}$ where $Q$ (runoff from catchment) is 1.75 cu.m/sec, the velocity is 1.8 meters per sec.

A trapezoidal ditch will be used where the slope ratio $Z$ is 1, depth is 70cm. By using the equation for area in fig.27, the bottom (b) is found to be 0.1 meter and the top width is 2.1 meter; and hydraulic radius is 0.36. From table 7 the roughness is 0.03. Using fig.27 with roughness of 0.03 hydraulic radius of 0.36 and a velocity of 1.8 the gradient of the ditch is found to be 0.6 cm per meter.
Table 1.

1. Relief (table 1) Hilly 15
2. Soil " Slow 15
3. Veg. " Poor 15
4. Surface storage Low 15
5. Characteristics

6. Hectares 8
7. Q. (Cu.m/Sec.)(table 2,3,4) (Square)1.75

\[ Q = V A \]

9. Allowable Velocity (Table 5) 1.8
10. Area \( A = \frac{Q}{V} \)

For a trapazodal Pitch (fig. 27)

11. Ratio (z) 1
12. Depth (meters) (d) 0.7
13. Bottom (meters) (h) 0.7
14. Top width (meters) (t) 2.1
15. Hydraulic radius (R) 0.36
16. Roughness (table 6) (n) .03
17. Max grade cm/meter (fig. 28) .6
<table>
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<th>(100)</th>
<th>(75)</th>
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<td></td>
<td>Extream High</td>
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<tr>
<td></td>
<td>Steep greater Hilly</td>
<td>10-30% slope</td>
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</table>
| Vegetal cover          | Very poor to | Poor to fair  | Fair to good  | Good to excel-
|                        | bare cover;  | cover; culti-
|                        | nearly so     | vated crop   | of in good     | cover; 90%     |
|                        | land          |               | land          | in good grass  |
|                        | 20            | 15            | 10            | 5              |
| Surface storage        | Negligable    | Low; well     | Normal, many  | High; many     |
|                        | few depressions defined | surface depression, | drainage not | well defined   |
|                        | steep drainage |              |               |                |
|                        | ageways       | 20            | 15            | 10             | 5              |
Table 3. Runoff from a square catchment.

Ha = area of catchment in hectares;
C = Catchment characteristics

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Table 4. Runoff from a broad and short catchement

Ha = area of catchment in hecatres;
C = catchment characteristics

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Table 5. Runoff from a long and narrow catchment

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Figure 28 Nomographic solution of Manning's formula

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Characteristics and Restrictions

The small earth filled dams described here are built by people from small Ethiopian villages or settlements with picks, shovels, and soil carriers. They are designed primarily to provide water for cattle as well as for domestic use. In some places a small cooperative nursery could be irrigated to start certain plants to be set out at the beginning of the rainy season.

These dams can be built by 200 to 300 people in less than a month. In other words if a small village or group of people wanted to increase their water supply they could do it by donating their labour for a relatively short time.

Earth filled dams are safe and will last indefinitely if certain precautions are taken. To be sure these dams are constructed properly; first: no dam under 5 meters high should be constructed without the advice of a Soil and Water Conservation Agent; Second: no dam over 5 meters high should be constructed without the advice of a Soil and Water Conservation Agent and Supervisor; third: no dam over 8 meters high should be constructed by the method described here. No dam should be built within 2 km. upstream of a main road, or village. If these precautions are followed, small earth filled dams can be successful. Soil erosion control measures must be taken in the catchment area behind the dam to prevent the dam from silting up.

Finding the Site

The need for water will of course determine where a dam or other water storage facility is to be built. Nevertheless, certain areas have better characteristics than others for small earth dams. The best dam sites can often be found in low rounded hills with relatively short drainage ways. Any place where a large amount of water can be stored with the least
amount of soil in the earth fill is an ideal site. A natural streambed is ideal where the gradient is nearly level and where it widens out behind some natural restriction. Often a good site can be found just below the junction of two small streams.

Available Soil for fill

Sufficient soil must be available at the site for constructing the earth fill. The amount of soil required can be estimated as follows:

\[
\text{Total Volume of Fill} = \text{Volume of Center core} + \text{Volume of side slopes}
\]

\[
\begin{align*}
\text{Vol. of core} &= \frac{1}{2} CH \quad (L=S) \\
\text{Vol. of sides slopes} &= \frac{1}{2} H^2R \quad (L+S)
\end{align*}
\]

\[
\text{Total Volume of fill} = \frac{H}{2} (L + S) \times (C + H \times R)
\]

H = Height of dam  \quad S = Stream width  
L = Length of dam crest  \quad R = Ratio of bottom length of one side to height of dam.
C = Width of crest or top

All measurements in meters and volume in cubic meters.

Example:

- Dam length = 30 meters  \quad Stream width = 4 meters
- Height of dam = 6 meters  \quad Slope ratio = 3:1
- Width of crest = 4 meters

Total Vol. of fill = \( \frac{H}{2} (L + S) \times (C + H \times R) \)

Total Vol. of fill = \( \frac{6}{2} (30 + 4) \times (4 + 6 \times 3) = 2244 \text{ Cu.meters.} \)

Man days to Construct the Dam

The number of Man days required to construct the dam can be calculated by using the volume of soil required to build the dam.
In the example 2,244 cubic meters of soil are required to construct this particular dam. On the average each man will move between $\frac{3}{8}$ and $\frac{1}{2}$ cubic meters of soil per day. In areas where soil must be carried a long distance use $\frac{1}{2}$ cubic meter. Let us assume in the example that the soil is easy to obtain than 2,244 cubic meters x 2 (takes 2 days to move 1 cubic meter) equals 4,488 man days to construct this dam.

Let us say that we pay each man 6 kilograms of grain per day. This means that 26,928 kilograms or about 270 qt. of grain will be required.

**Soil for Core of Dam**

The center core of the dam must be as impervious as possible to water, therefore, it must be compacted. Not all soil material will be impervious when compacted. Loams, sandy loams, and sandy clay loams are the best texture to use for the core. These textures are the easiest to compact to form an impervious core. Clays are not desirable because they crack when dry and water will seep through the cracks when the reservoir is filled; nor are sands desirable because they cannot be compacted to form an impervious core. No rock, gravel, or organic matter should be included in the core because these materials interfere with soil compaction.

Rocky, sandy and clay soil can be used in the fill each side of the core. If a choice can be made between materials, clay soils can be placed on the upper side or wet side of the core and sandy or rocky soil can be placed on the dry side of the core.

**Location and Design of Emergency Spillway**

An emergency spillway must be provided for all dams. It is seldom possible to build a dam large enough to hold the entire runoff from a catchment. Once the reservoir is filled, the excess water must be allowed to pass around the dam and back into the original stream channel without going over the top of the dam. Usually a dam will be destroyed if water goes over the top because a channel is very quickly cut through the earth fill.
A spillway must be protected from erosion and built large enough to carry the runoff from the catchment. A spillway cut into rock will provide the most protection against erosion. A natural grass spillway will provide the most protection for a spillway cut into soil. Also a wide spillway will provide greater protection against erosion than a narrow spillway.

When possible spillways cut around both ends of the dam will provide greater protection to the dam. These spillways can be placed at the same level or at different levels depending on the conditions.

The width and depth of the spillway will be determined by the characteristic of the catchment. The amount of runoff from the catchment will be determined by the size of the catchment, the amount of water falling in the area, kind of land use, soil texture, and slope of the land. One method for determining the width of a spillway with a given freeboard (freeboard is the distance between the top of the dam and the bottom of the spillway) is as follows:

Width of spillway = Flood discharge factor \( F \) \( \times \) Rainfall factor \( r \) \( \times \) Topographic factor \( T \)

These factors can be determined for a catchment from the following tables.

\[ \text{Flood discharge Factor} = F \]

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**Rainfall Intensity Factor** = \( R \)

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<tr>
<td>1.5 km</td>
<td>.71</td>
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<tr>
<td>2.0 km</td>
<td>.63</td>
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<tr>
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<td>.55</td>
</tr>
<tr>
<td>3.0 km</td>
<td>.45</td>
</tr>
<tr>
<td>4.0 km</td>
<td>.40</td>
</tr>
<tr>
<td>5.0 km</td>
<td>.34</td>
</tr>
<tr>
<td>6.0 km</td>
<td>.30</td>
</tr>
</tbody>
</table>

**Topographical Factor** = \( T = (a) + (b) + (c) \)

<table>
<thead>
<tr>
<th>Surface Cover ( (a) )</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>i) Tick brush</td>
<td>.05</td>
</tr>
<tr>
<td>ii) Thick grass</td>
<td>.1</td>
</tr>
<tr>
<td>iii) Medium grass or shrub</td>
<td>.15</td>
</tr>
<tr>
<td>iv) Cultivated land</td>
<td>.2</td>
</tr>
<tr>
<td>v) Bare or eroded</td>
<td>.25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Soil Type ( (b) )</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Well drained (Sandy loams)</td>
<td>.10</td>
</tr>
<tr>
<td>2) Moderately permeable (loam)</td>
<td>.20</td>
</tr>
<tr>
<td>3) Slowly permeable (clay loam)</td>
<td>.25</td>
</tr>
<tr>
<td>4) Very slowly permeable (clay)</td>
<td>.40</td>
</tr>
<tr>
<td>5) Shallow soils impeded drainage</td>
<td>.3</td>
</tr>
<tr>
<td>6) Impervious soil or water-logged</td>
<td>.5</td>
</tr>
</tbody>
</table>
**Slope (c)**

1) Flat to gently sloping 0-5%  .05
2) Moderately sloping 5-10%  .10
3) Moderate steep 10-20%  .15
4) Steep 20-40%  .20
5) Very steep greater than 40%  .25

**Example A**

A catchment of 2 km. long has an area of approximately 200 ha. with a rainfall of 800 mm. The soil is moderately permeable (loam) on a moderately steep slope with a medium cover of grass and shrub. What is the minimum width of the spillway if the freeboard is to be 2 meters (distance between the top of the dam to the bottom of the spillway)?

Flood discharge factor (f) for 200 hectare area with a 2 meter freeboard spillway is 40.

Rain Intensity factor (R) for a 2 km. long catchment in a 800 mm. rainfall zone is 66.

Topography factor (t) is a sum of surface cover of medium grass and shrub which is 0.15, a moderately permeable soil which is 0.20, and a moderately steep slope which is 0.15 making a total of 0.50

\[ \text{Spillway width} = F \times R \times T \]
\[ = 40 \times 0.66 \times 0.5 \]
\[ = 13.6 \text{ meters} \]

**Example B**

A catchment 1.5 km long contains 150 hectarea with an estimated rainfall of 600 mm. About 10% of the area has well drained soils on steep slopes with shrub cover, the balance of the area has moderately sloping slowly permeable soils which are cultivated. The dam will have a freeboard of 1.5 meters (from the top of the dam to the bottom of
the spillway). What is the minimum width required for the spillway?

Flood discharge factor \( (F) = 30 \)

Rainfall factor \( (R) = .73 \)

Topography factor \( (T) = (.15 \times 1 + .2) \times .1 + .9 \times (2 + .25 + .05) \)

\[ = .5 \]

Width spillway

\[ = 30.5 \times .73 \times .5 \]

\[ = 11 \text{ meters} \]

**Design of Dam**

The design of all small earth dams described here will be essentially the same. They will have a compacted core built on an impervious foundation. A trench will be dug into the foundation the length of the dam to 'Key' in the core. Fill material each side of the core will have a slope of 3:1; crest or top width of the core will be a function of the height of the dam.

A cross section of a typical earth filled dam is shown in figure 29.

---

Fig. 29 Cross Section of a Typical earth filled dam.
Foundation

A foundation should be prepared under the center core to prevent seepage under the dam. All loose soil, rock, sand and organic matter should be removed to an impervious layer. This impervious layer may be soil, or rock. Some foundation soils may require additional compaction and bonding with the core to prevent water seeping through them.

Rock should be chipped to form a rough surface for bonding the core. Open seams in the rock should be filled with soil and compacted to prevent seepage into the rock.

When the foundation is completed, it should appear as a trench across the bottom and up the sides of the dam the same width as the crest of the dam.

Core

The core should be carefully constructed because this portion of the dam will determine the success or failure of a dam built with hand labour. Carefully selected soil material properly compacted will produce a good core.

After the foundation has been prepared the core can be started. A bond is made between the foundation and the core by compacting the filled soil into the foundation. Rock foundations should be roughened by chipping and soil foundations should be loosened with a pick to make a good bond. One crew of workers should be assigned to build the core and careful attention should be given to see that the proper soil is used throughout. At most sites an area should be set aside where soil for the core can be taken.

Every 10 to 15 cm, of soil should be compacted before the next layer is brought in. After the soil is spread over the area water should be added to form a firm ball when squeezed. Compaction, where bonding is required along the foundation, should be done by tamping with a log. The log can be about 10 cm, in diameter and 2 meters long. Additional layers can be compacted by trampling. A number of workers can tramp each layer in place.
Laying out the Dam

The centre line and top of the dam is first pegged (lines A in fig. 30). These points will be the reference points for the dam and should be securely marked.

The crest or top width of the dam can then be pegged. Crest width will depend on the height of the dam. Dams less than 5 meters high must have a width of at least 3 meters. Dams between 5 and 8 meter high must have a width of at least 4 meter.

Lines should then be pegged along the stream channel walls and across the stream channel to be used for preparing the foundation. These lines should correspond to the crest width (lines B in fig. 30).

A distance 3 times the dam height is then marked in the channel above and below the crest lines in the channel. Parallel lines with the crest lines are then pegged in the channel (lines C in fig. 30). These lines make the outside edge of the fill. Later on when construction starts stringes can be stretched between points B + C to guide the edge of the fill up the channel walls.

The spillway is then pegged as shown by lines D and E in fig.30. Freeboard or depth of spillway is determined from tables in the section on spillway design.

Fig. 30 Birdseye view of dam site with lines pegged for construction of the dam.
The dimensions of the core can be maintained by using strings to guide the workers. These should be sited in occasionally to keep the core in line. Building up of the core should stay ahead of the fill material on each side.

**Previous fill**

The kind of material used in this pervious fill will vary considerably. Where possible the **clay** material should be placed on the upper or wet side of the core and the sandy materials on the lower or dry side. The clay soil will slump less than sands when wet, and the sandy soil will drain better.

Rocks and gravels can be included but no organic matter (grass or three roots and limbs).

The larger rocks should be set aside for covering the dam. The entire dam should be covered if possible. Where insufficient rock is available only the upper portion of the wet side of the dam should be covered with rock. This will prevent waves from cutting into the dam.

Before the pervious fill is started all grass and other organic matter should be removed from the area. The soil should then be loosened to a depth of about 10 cm, to help bond the fill with the underlying soil.

**Clearing the Reservoir**

All trees and shrubs should be removed from reservoir area to be covered with water. If left those materials will decompose and polluted the water.

Where possible most of the soil to be used in the pervious fill as well as the core should be taken from the reservoir area. In this way a larger water storage area can be developed.
Siphon Outlets

A siphon outlet is a convenient method for taking water from the reservoir. This siphon can be installed after the dam is built and does not interfere with the construction of the dam. Also the siphon can be started again if the water stops flowing. It is also possible to remove the siphon for cleaning if it becomes plugged.

The diagram of a siphon is shown in fig. 31. The essential parts of the siphon are the 5 cm. diameter pipe, priming arrangement, no return value, and outlet value. The siphon can be assembled on site.

Water use below dam is shown in figure 32. A concrete water trough for cattle with float value is set in place so that it cannot be moved. A domestic water outlet with a spring loaded value is near by but fenced with gate to keep the cattle out.
Fig 32 Arrangement of water valve for domestic use and cattle watering
POND CONSTRUCTION

Ponds are used in many areas of Ethiopia to store surface water for use during the dry season. Water from these ponds is often used by both humans and livestock because the next water source is generally several kilometers away. This water source is not the most desirable but if no other water is available, it is most essential.

**Siting:**
The location of the pond should be as near as possible to where the water is needed. Three other conditions to consider when locating a pond are water to fill the pond, pollution of water and depth of soil.

Water to fill the pond may be diverted from a stream or may be collected from an area above the pond. The approximate area required to collect water for the pond can be calculated as follows:

1. From Table 2 pg 43 determine catchment characteristics
2. From table 3, 4 or 5 determine the runoff factor using catchment characteristics and 10 hectares.
3. Hectars behind pond = cubic meters storage \(\times 10^{2}\) runoff factor \(\times 10^{3}\) millimeters rainfall

Ponds should be dug above villages or cattle feeding areas so that dirt from these areas is not collected in the pond. Polluted water should not be collected in the pond.

A hole should be dug to the depth of the pond where the pond will be dug. In some areas a hard rock or a very sandy soil may underly the site. Exploring the underlying layers before the pond is started will help locate the proper site.

**Shape**
The shape of pond is not important but most hand dug ponds are circular. It is easier to carry soil from all sides of a circular pond. Rectangular shaped ponds are easier to build with a tractor. However, for the present most ponds in
Water Loss

Loss of water from seepage through the bottom of the pond and from the water surface by evaporation can be considerable. Seepage losses will vary considerable but ponds with a clay seal are expected to lose less than 0.03 cm/hr. In a 6 months period at this rate a loss of 1.3 meters of water will occur.

Evaporation is influenced by air temperature, wind, length of days, and humidity. Considerable variation can be expected from place to place and during the year. A rough estimate of evaporation from a lake can be obtained from Fig. 33. This combined with the loss from seepage should be added to the expected water use to determine the volume of water required.

![Fig. 33. Evaporation from lakes in Ethiopia.](image)

Rough estimates of seepage and evaporation losses from lakes are given in Table 8. These depth figures can be used to calculate the volume loss.

<table>
<thead>
<tr>
<th>Elevation (Meters)</th>
<th>Loss from seepage &amp; Evaporation (m)</th>
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</thead>
<tbody>
<tr>
<td>500 - 1000</td>
<td>4.0 - 3.7</td>
</tr>
<tr>
<td>1000 - 1500</td>
<td>3.7 - 3.2</td>
</tr>
<tr>
<td>1500 - 2000</td>
<td>3.2 - 2.9</td>
</tr>
<tr>
<td>2000 - 2500</td>
<td>2.9 - 2.5</td>
</tr>
<tr>
<td>above 2500</td>
<td>less than 2.5</td>
</tr>
</tbody>
</table>
Example

Find volume of water for use from a pond at 1500 meters elevation, 30 meters in diameter, 6 meters deep with a side slope of 1:2.

\[
V_{o l.} = 3.14 \left(6 - 3.2\right) \left(\frac{(15 - 12)^2 + 15^2}{2}\right) = 1029 \text{ Cu. m.}
\]
or 1029,000 liters

Seepage

Seepage losses from a pond can be reduced by compacting the soil or sealing the bottom with clay. Most soil except very coarse sandy or gravelly soils can be sealed by compacting. The depth of soil compaction will vary with the depth of the soil below the water surface. Soil should be compacted 5 cm deep for every meter below the water surface. For example, a pond 6 meter deep will be compacted as follow:

Soil in the first meter below the surface should be compacted 5 cm deep; soil in the second meter 10 cm; in the 3 meter 15 m; in the 4 meter 20 cm; in the 5 meter; 25 cm; and the bottom or 6 meter the soil should be compacted to a depth of 30 cm.

If the soil is very sandy or gravelly, a clay soil blanket can be spread over this very permeable layer. The thickness
of the clay soil layer should be 10 cm thick for every meter below the water surface. Moisten this layer and tamp into place. Salt (sodium chooride) applied at a rate of 1 kilogram per one square meter will decrease the permeably of soil. The salt should be worked into the surface layer of the soil. Salt will rot seal sand but will seal the clay layer.

**Evaporation**

Evaporation losses can be reduced by increasing the depth of the pond. In other words, if a greater volume of water is required a deeper pond is better than a wider pond.

Another way to reduce evaporation is to cover the pond. A thatched roof similar to a tukle would reduce evaporation as much as 50% or more.

**Digging the Pond**

Ponds are often 20 to 40 meters in diameter, 3 to 6 meters deep with side slopes of 1:1. After marking out the pond, soil is removed and placed in a mound around the pond. Soil should be placed at least 3 meters from the edge of the pond. An opening is left in the circular mound around the pond are filling and taking water from the pond. Stone steps into the pond should be placed along the side where water enters so as to protect the walls from erosion and to be used by people taking water from the pond. Livestock should not be allowed to enter the pond but water should be carried out to a trough for their use. If livestock are allowed to enter the pond, the walls will soon be broken down, the pond filled with soil, and the water polluted.
Surface Water Storing Project

Preliminary Investigation

Date of Investigation ____________________________
Investigation made by ____________________________
Investigation recommended by ______________________
Region: __________________ Woreda: _______________
Awraja: ______________ Village: __________ Or villages ________

Is area part of an EPID MPP? yes, No

Present water source for human needs: Spring, pond, river
Does it last through dry season? yes, no
How far is water from nearest village? _______km
How far is water from farthest village? _______km
Is water clean? Yes, No
How many people use water from this source? _______
Is water restricted to certain people? Yes, No
Do animals and humans use some water source? Yes, No

Present water source for animal needs: spring, pond, river,

Does it last through dry season? Yes, No
How far do cattle go for water? _______km
How long does it take one way? _______hr.
How many cattle _______ sheep _______ use this water?
Is water source restricted to certain villages? Yes, No
Have people died from lack of water in last year? Yes, No
Have cattle, sheep, goats, or donkeys died from lack of water in last year? Yes, No
Are the people interested in working to build storage for water? Yes, No
Are they willing to volunteer their time for one month to build storage for water? Yes, No
How many people would be willing to work without pay to build storage for water? _______
Do people in area need food? Yes, No
How many people would work to build storage for water if they were paid $0.75 a day? _________________

Soils in area:
Textures: Clay, clay loam, loam, sandy loam
Color: brown, reddish brown, black
Depth: less than 0.5 meter; .5 to 1 meter; more one meter
Course fragments: gravelly, rocky
Amount of erosion: slight, moderate, severe

Are gullies present? Yes, No
What percent of land is cultivated _______________________
What percent of land has grass cover _______________________
What percent of land has brush cover _______________________
Is land flat, gently sloping, steep, rolling; mountainous?

Crops grown___________________________________________
Major problems with crops ________________________________

Possible surface water storage to be developed: dam or pond

If dam is to be built fill in the following:
Approximate height of dam __________________
Approximate length of dam ___________________
Is soil available for building dam? Yes, No
Soil texture to be used; clay, loam, sandy loam
Approximate water shed (catchment) behind dam _______ hectare
Approximate area to be flooded by reservoir behind dam _______ hectares

Is land to be flooded community owner? Yes, No
Is there likely to be a problem with land ownership if dam is built? Yes, No
Explain if yes, _________________________________________
Can spillway for dam be cut in rock?  Yes,  No

Average rain fall in area if known ________________mm

How many people would benefit from the dam or pond____

How many livestock will use the water cattle, sheep, goat, donkey etc. ____________

How large an area will this population cover _______km²

Could the dam be large enough to be used for irrigation

Yes,  No

If yes, Approximate area of land to be irrigated _____ ha.

If pond is to be built fill in the following:

Can land for pond be donated?  Yes,  No

Is there a problem to obtain land for pond?  Yes,  No

If yes explain __________________________________________

_____________________________________________________

How will the pond be filled? ____________________________

_____________________________________________________

Can a stream be diverted to fill the pond?  Yes,  No

How many people will volunteer to work without pay to dig the pond?______________________________

How many people will use the water _______________________

" " livestock will use the water _______________________

How many people will work to dig the pond if paid $0.75 per day______________________________
Surface Water Storage Project
Post Construction Questionnaire
(Dam, Pond, Stream Diversion)

Please attach any relevant information to this form

Date _____________________ Prepared by ________________________

Construction Supervised by ______________________________________

Location:
Province ____________ Warada ____________ Village ______
Direction and distance from village ____________________________

Climate, Relief, Land use
Rainfall _______________________ mm
Relief: Flat, gently sloping, hilly, mountainous
Soil texture in area ____________ Soil Color ____________
Crops grown: _____________________________________________
Approximate Percent of land cultivated ____________ %
" " " " in grass ____________ %
" " " " in shrubs, trees, rock ____________ %

Population using water from project
Number of villages _________________________________
Number of families _________________________________
Number of people _________________________________
Number of Cattle, oxen, horses, donkeys: ______________
Number of sheep and goats: _________________________
Furtherest people came to new water source ______________
Furtherest people came to old water source ______________
Is the new water source clean for people? [□] Yes [□] No

How can the new water source be improved for human use? ____

Is the new water source adequate for the area? [□] Yes [□] No

If not, explain what should be done ______________________________________________________________________

Fill in the Following for Dam

Height of dam __________________m length of dam ______________m

Width of crest __________________m width of spillway ______________m

Depth of spillway below top of dam __________________________m

Width of bottom of soil fill _____________________________m

Was bottom of core on impervious material? [□] Yes [□] No

Texture of soil used in fill __________________________________

Was dam covered with rock? [□] Yes [□] No

Was dam planted to grass? [□] Yes [□] No kind of grass __

Slope of soil fill on upper side (water side) of dam __________

Slope of soil fill on lower side of dam _________________

Volume of soil in fill ____________________________m$^3$

Date started ________________ Date finished ______________

Number of working days to complete dam _________________

Average number of people working on dam in one shift _______

Was one or two shifts used? ____________________________

Man days required to complete dam ________________

If grain paid: Kind of grain paid _______________

Amount of grain paid per man per day _______________

If paid in cash amount per man per day $ ______

Total amount of grain or cash paid to build dam __________
Area of reservoir $m^2$
Average depth of water in reservoir when filled $m$
Approximate volume of water in reservoir $m^3$
Cost of cubic meter of water \(\frac{\text{Cost to complete pond}}{\text{Cubic meters of water}}\)
Approximate No of months without recharge months

Fill in the following for pond

Diameter of pond $m$ depth of pond $m$
Approximate value of soil removed $m^3$
Texture of soil removed
Date started Date finished
Number of working days to complete pond
Average number of people working on pond in one shift
Was one or two shifts used? 
Man days required to complete dam
If grain was paid kind of grain paid 
Amount of grain paid per man day If cash paid: 
Amount of cash paid per man day 
Total amount of grain or cash paid to complete pond
How will pond be filled? 
Volume of water in pond when filled
Cost of a cubic meter of water \(\frac{\text{cost to complete pond}}{\text{cubic meter of water}}\)
Fill in the following for a stream diversion:

(Use same form if a pond and a stream diversion were constructed at a site)

Length of ditch ____________________
Depath of ditch ____________________ width of ditch _____________
Cubic meters of soil removed _________________________
Kind, size, and shape of diversion from stream _______________

Date started _____________ Date finished _____________
Number of working days to complete diversion ditch ___________
Average number of people working on ditch in one shift _____
was one or two shifts used? __________________________
Man days required to complete dam __________________
If grain was paid: kind of grain paid _____________
amount of grain paid per man day ____________________
If cash paid:
Amount of cash paid per man day __________________________
Total amount of grain or cash paid to complete ditch __________
The objective of spring development is to increase the flow, improve the useability and protect the water from contamination.

Preliminary Investigation

A spring should be investigated during the dry season to determine the reliability. Springs that flow during the rainy season about other springs in the area may be helpful. A spring that does not flow the year around may not be worth developing.

Cleaning Spring Area

The area immediately around the spring opening must be cleaned of soil, vegetation and loose rock. Usually this cleaning will increase the flow of springs. Seeps or permanently wet areas may develop a flowing spring when the soil is removed.

Collection of flow

After the spring area is cleaned the kind of collection box for the water can be determined. Some spring openings are from a small fracture in the rock. In other areas water may be seeping from a large water bearing zone.

Water from a fracture in the rock may be collected directly into a collector box. This box may be a rock and concrete structure built around the spring opening. A pipe should take the water from the box to a water trough. See fig. 34 for details.

Water seeping from a large water bearing zone must be collected into a collector box. Collector lines must be dug along the seepage zones so that water can be collected into a centred box (fig 35). Perforated pipe, rock lined channels or gravel
fill can be placed in the collector lines to keep the channels open. The lower side and bottom of the channels should be packed or filled with clay to form a seal so that water does not seep away from the channel. The area above the collector lines should be fenced to keep livestock out. A pipe should take water from the collector box to a water trough.

**Water Trough and Water Jug fill**

The pipe from the collector box should deliver water into a trough for livestock. Provision should be made for filling domestic water jugs before the water goes into the trough. Details of one plan is shown in fig. 36.
Figure 34  Spring Development from Small Water-Bearing Zone

Concrete Spring Box with Lid

Concrete water Trough with Wall

Channel into rock fracture

Spring Development from a rock fracture

Concrete Spring Box with Lid

Tamped Soil or Clay

Concrete Water Trough with Wall

Gravel Fill

Spring Development in a small steep Area
Figure 35  Spring Development from Large Water-Bearing Zone with Collector Pipes

Tamped Clay
Perforated Pipe
Gravel Fill

Perforated Collector Pipes

Top View of Spring with collector pipes

Concrete Water Trough

Concrete Spring Box

Pipe

Side view of spring with collector pipes
Fig. 36  Cattle Watering Trough Construction

Trough with wall  Side View

Trough with pipe from spring under trough  Side View

Top View of Cattle Watering Trough
Hydraulic Rams

A hydraulic ram is a pump operated by water power. It uses the power of falling water to pump water to an elevation above the source of water.

Operation:

Water is conducted through a drive pipe to the ram (fig. 37). The water enters the ram under pressure and escapes through the outside value until a certain velocity is reached at this velocity pressure causes the outside value to close forcing a small flow into the air chamber. As soon as the pressure equalizes, the check value closes and the outside value opens until the velocity increases again, repeating the process. Pulsations occur from 25 to 100 times a minute, resulting in a nearly continuous discharge through the delivery pipe. Water must be drained away from the ram because it will not operate under water.

Design:

The volume of water that a ram will pump depends on the fall between the source of supply and the ram, the height the water is to be raised from the ram to the outlet, and the quantity of water available.

The following data are needed to design a hydraulic ram installation:

1. fall in meters from supply to ram
2. Height in meters the water is to be raised vertical distance between ram and point of delivery.
3. Supply of water available at ram in liters per minute.
4. Volume of water output required in liters per hour.

The following formula gives the number of liters that will be delivered per hour to a given point by the ram.

\[ D = \frac{V \times E \times 60}{F} \]

- \( D \) = liters per hour delivered
- \( V \) = liters per hour of supply
- \( E \) = height water is to be raised in meters
- \( F \) = fall in meter

Figure 12-14 Diagrammatic sketch of ram

Figure 37. Typical ram installation
## Conversion Tables

### Length

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<th>To</th>
<th>Multiply by</th>
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### Kind (Ethiopia)

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### Area

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<th>Area</th>
<th>Multiply by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Square Meter</td>
<td>10,000</td>
</tr>
<tr>
<td>&quot;</td>
<td>1,000,000</td>
</tr>
<tr>
<td>Square Kilometer</td>
<td>100</td>
</tr>
<tr>
<td>&quot;</td>
<td>2.5</td>
</tr>
<tr>
<td>&quot;</td>
<td>247</td>
</tr>
<tr>
<td>Hectare</td>
<td>10,000(100x100m)</td>
</tr>
<tr>
<td>&quot;</td>
<td>2.47</td>
</tr>
<tr>
<td>Gasha</td>
<td>40</td>
</tr>
<tr>
<td>Acres</td>
<td>43,560</td>
</tr>
<tr>
<td>&quot;</td>
<td>Sq. feet</td>
</tr>
</tbody>
</table>

### Weight

<table>
<thead>
<tr>
<th>Weight</th>
<th>Multiply by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gram</td>
<td>0.001</td>
</tr>
<tr>
<td>&quot;</td>
<td>0.0353</td>
</tr>
<tr>
<td>Kilogram</td>
<td>1,000</td>
</tr>
<tr>
<td>&quot;</td>
<td>35.27</td>
</tr>
<tr>
<td>&quot;</td>
<td>2.205</td>
</tr>
</tbody>
</table>

### Some Traditional Ethiopian Units

<table>
<thead>
<tr>
<th>Traditional Units</th>
<th>Multiply by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferasala</td>
<td>17</td>
</tr>
<tr>
<td>Kuna</td>
<td>5</td>
</tr>
<tr>
<td>Dawulla</td>
<td>100</td>
</tr>
</tbody>
</table>
### Weight

<table>
<thead>
<tr>
<th>To convert</th>
<th>To</th>
<th>Multiply by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ounce (oz)</td>
<td>Gram</td>
<td>28.35</td>
</tr>
<tr>
<td></td>
<td>Pound</td>
<td>0.0625</td>
</tr>
<tr>
<td>Pound</td>
<td>Gram</td>
<td>453.6</td>
</tr>
<tr>
<td></td>
<td>Kilogram</td>
<td>0.454</td>
</tr>
<tr>
<td></td>
<td>Ounce (oz)</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Kilogram</td>
<td>100</td>
</tr>
<tr>
<td>Quintal</td>
<td>Ton (metric)</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Pound</td>
<td>220.5</td>
</tr>
<tr>
<td>Ton (Metric)</td>
<td>Kilogram</td>
<td>1,000</td>
</tr>
<tr>
<td></td>
<td>Quintals</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Pounds</td>
<td>2,204.6</td>
</tr>
<tr>
<td>Ton (Short)</td>
<td>Pound</td>
<td>2,000</td>
</tr>
<tr>
<td></td>
<td>Kilograms</td>
<td>907.2</td>
</tr>
<tr>
<td></td>
<td>Tons (Long)</td>
<td>0.89</td>
</tr>
<tr>
<td>Cubic foot water</td>
<td>Pounds</td>
<td>62.43</td>
</tr>
<tr>
<td>Gallon of water</td>
<td>Pounds</td>
<td>8.345</td>
</tr>
<tr>
<td>Liter of water</td>
<td>Kilograms</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Grams</td>
<td>1,000</td>
</tr>
</tbody>
</table>

### Volume

| Cubic Centimeter     | Liters | 0.001  |
|                      | Cubic inches | 0.061  |
|                      | Cubic centimeter | 1,000  |
|                      | Cubic meters   | 0.001  |
|                      | Gallons (U.S.) | 0.264  |
| Hectare centimeter   | Liters | 100,000 |
|                      | Gallons (U.S.) | 26,496 |
|                      | Acre inch     | 1.026  |
|                      | Cubic centimeter | 28.326 |
|                      | Cubic meters   | 0.028  |
|                      | Liters | 28.32   |
|                      | Gallons (U.S.) | 7.48   |
|                      | Gallons (Imp.) | 3.785  |
|                      | Cubic feet    | 0.833  |
|                      | Pints         | 0.134  |
|                      | Quarts        | 8      |
| Gallons (U.S.)       | Gallons (U.S.) | 27,120 |
|                      | Hectare Centimeter | 0.975  |

### Volume of Tank

#### Square Tank

Volume (Liters) = Length (m) x Width (m) x height (m) x 1000

#### Round Tank

Volume (lts.) = Diameter (m) x Diameter (m) x height (m) x 785
Weight Volume Characteristic of Certain Material

<table>
<thead>
<tr>
<th>Material</th>
<th>Kg/Cubic meter</th>
<th>Cubic Meter/ton metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>1510</td>
<td>0.66</td>
</tr>
<tr>
<td>Concrete</td>
<td>2410</td>
<td>0.44</td>
</tr>
<tr>
<td>Gravel</td>
<td>1925</td>
<td>0.52</td>
</tr>
<tr>
<td>Lime</td>
<td>850</td>
<td>1.18</td>
</tr>
<tr>
<td>Sand</td>
<td>1605</td>
<td>0.62</td>
</tr>
<tr>
<td>Soil</td>
<td>1605</td>
<td>0.62</td>
</tr>
<tr>
<td>Water</td>
<td>1000</td>
<td>1.00</td>
</tr>
<tr>
<td>Wood (Tidh)</td>
<td>384</td>
<td>2.61</td>
</tr>
<tr>
<td>Wood (Zigba)</td>
<td>640</td>
<td>1.61</td>
</tr>
</tbody>
</table>

Area of a Plain

- Triangle
  \[ Area = \frac{bh}{2} \]
- Rectangle
  \[ Area = bh \]
- Parallelogram
  \[ Area = bh \]
- Trapezoid
  \[ Area = \frac{(a + b)}{2} \cdot h \]
- Circle
  \[ Area = \pi r^2 \]
  \[ \pi = 3.14 \]
- Irregular Plain
  \[ Area = d\left(\frac{w_1+w_2}{2}\right) + w_2 + w_3 + w_4 \]

\[ a = \text{top} \]
\[ b = \text{base} \]
\[ d = \text{distance between strips} \]
\[ H = \text{height} \]
\[ r = \text{radius or \( \frac{1}{2} \) diameter} \]
\[ w = \text{width of strip} \]
**Concrete Mixes and Materials**

**Approximate amount of material for 10 square meters of concrete**

<table>
<thead>
<tr>
<th>Thickness of Concrete (cm)</th>
<th>Concrete (Cu.M.)</th>
<th>Sacks of Cement</th>
<th>Sand (Cu.M.)</th>
<th>Gravel (Cu.M.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 cm</td>
<td>1.0</td>
<td>8</td>
<td>0.5</td>
<td>0.7</td>
</tr>
<tr>
<td>15 cm</td>
<td>1.5</td>
<td>12</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>20 cm</td>
<td>2.0</td>
<td>16</td>
<td>1.5</td>
<td>1.4</td>
</tr>
<tr>
<td>25 cm</td>
<td>2.5</td>
<td>20</td>
<td>2.0</td>
<td>1.75</td>
</tr>
</tbody>
</table>

**Water Tight Concrete**

- **Cement** -- 1 part by volume
- **Sand** -- 2 " " "
- **Gravel** -- 3 " " "
- **Hydrated lime** 13 liters per 50 kg cement

**Recommended Proportions of Water to Cement for Different Kind of Work**

<table>
<thead>
<tr>
<th>Liter of Water to add to each sack of cement if sand is</th>
<th>Suggested mixture for a batch</th>
<th>Material per Cu. Meter of Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Very Wet</strong></td>
<td><strong>Wet</strong></td>
<td><strong>Damp</strong></td>
</tr>
<tr>
<td>Subjected to very conditions (dairy floors, etc.)</td>
<td>16</td>
<td>18</td>
</tr>
<tr>
<td>Subjected to moderate conditions (water apert floors, alks, storage tanks, etc.)</td>
<td>19</td>
<td>22</td>
</tr>
<tr>
<td>Subjected to light water foundations, falls, mass concrete etc.)</td>
<td>21</td>
<td>24</td>
</tr>
</tbody>
</table>

* maximum size of aggregate 20 mm
+ " " " " 40 mm
White wash that sticks

1. Slowly add boiling water to 8 liters of lime stirring constantly.

2. Add 2 liters of salt to lime paste and stir thoroughly. Add water to bring to proper thickness for brushing.

3. Just before using add one hand full of cement and a teaspoon of ultramarine bluing to each bucketful of white wash. Cement makes white wash adhere strongly to any surface and bluing gives the white wash-cement mixture a snow-white appearance.

Amount of Paint Required for Wood Surface

Divide the number of square meters of surface by 5. This gives the number of liters of paint required for 2 coats of paint.

FROM: "Handbooks of weight and measure, Conversion tables and other data often needed in Agriculture"

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