

POND DESIGN AND CONSTRUCTION

Ponds and pond systems must be properly designed and built if a farmer is to be successful at fish farming. Ponds that are poorly designed or constructed can lead to a number of problems for the farmer, including ponds that don't hold water, ponds that cannot be drained completely (leading to incomplete harvests and poor production on subsequent production cycles), ponds that cannot be filled or drained by gravity, and dykes that fail. On the other hand, well-designed and constructed ponds are easily managed and maintained, leading to less "down time" due to failures and more efficient operation and production.

2.1: POND DESIGN AND LAYOUT

Introduction

Before beginning the construction of a new fishpond, carefully consider the design. A properly designed and constructed pond will be easily managed and will last longer, saving extra work and bringing greater profit. Some specific design considerations to address include:

1. The source of water used to fill the pond
2. How water will be brought to the pond
3. The type of soil available for building the pond
4. The size, shape, and depth of the pond
5. The slope of the pond bottom
6. The height, width, and slope of the dykes
7. The type of drainage system that will be used
8. The layout (arrangement) of ponds used for different sizes of fish

Other questions to consider

- What type of pond do you wish to build?
- What type of fish can be grown here?
 - ♦ Remember if you wish to be a fingerling producer, you will require more small ponds, whereas a food fish producer will require relatively large ponds.

General considerations

- Ponds should be designed based on the type of soil present and the intended culture practices.
- The water source must be able to keep the pond full throughout the culture period.
- Relatively shallow ponds are productive, but the shallow end should be at least 0.5 m deep to avoid invasion by weeds.
- It is always desirable to place screens on pond inlets and outlets to keep out predators, insects, and unwanted fish, and to retain the cultured fish.
- Every pond should be drainable.
- Every pond should have an independent controlled inlet and outlet.
- Excavation of a core trench should be done where soils are less suitable.
- Perimeter and feeder roads are required to provide for movement of machines during construction and at harvest.
- If you plan to drive on the dykes, build them at least 3 metres wide on top, and wider at the base.
- Soil used to build dykes should always be compacted in layers.

Specific design considerations

1. Water sources used for fishponds

Sources of water

- Water sources can be spring water, seepage water, rainwater or run-off, tidewater (marine ponds), water from bore holes (wells), or water pumped or diverted from a river, lake, or reservoir.

Quantity of water needed

- Make a decision on the type of fish to be cultured and the size of ponds, so as to determine the amount of water required.
- Consider the climatic condition of the area, rainfall pattern, and nature of the soil when calculating quantity of water.
- A general rule is that pond water inflow and outflow should equal the pond volume over the period of a month. If inflow is too low, water quality may suffer from oxygen depletion and/or the accumulation of toxicants. However, if the inflow is too high, large amounts of beneficial algae may be flushed from the pond.

- As a rule of thumb, ponds should fill up in less than a week. For small ponds, e.g., ponds smaller than 200 m², 1-inch pipe is recommended. A 400-m² pond needs a 2-inch pipe, while a pond larger than 4000 m² will require a 4-inch pipe (see Table 2.1-1).

Table 2.1-1. Delivery capacities of pipes of different sizes (1 m³ is equivalent to 1000 litres)

Pipe Diameter	m ³ /hr	m ³ /day (24 hrs)
1 inch	1.25	30
2 inches	6	144
4 inches	28	672
6 inches	80	1920
8 inches	136	3264

- To estimate the amount of water available from a specific source, use the simple bucket procedure:
 - a. Measure the capacity of a bucket and measure how long it takes to fill the bucket with water, e.g., a 10-litre bucket filling in 45 seconds. From this, calculate how many litres will be delivered per minute. This is estimated as $(10 \times 60) / 45 = 13.3$ litres/minute.
 - b. Now determine how long it takes to fill a 100-m² pond (e.g., 10 m x 10 m). If the pond had a uniform depth of 1 m, it would hold 100 m³ of water. In actuality the pond does not hold 100 m³ of water, however. For example, if the pond is 50 cm deep at the shallow end and 90 cm deep at the deep end, its average depth is 70 cm or 0.7 m $(50 + 90) / 2 = 70$ cm) and the volume of water required to fill the pond is 70 m³ or 70,000 litres (100 m² x 0.7 m = 70 m³).
 - c. We also know that 1 m³ = 1000 litres. Since we know that our water supply gives us water at a rate of 13.3 litres per minute, we can now calculate how long it will take to fill the pond. This is

calculated as $(70,000 \text{ litres} / 13.3 \text{ litres per minute} = 5263 \text{ minutes}$ or 87.7 hours. This pond will therefore require about three and a half days to fill.

- Remember that with sound management strategies one can successfully culture fish in ponds with inconsistent, undependable, or seasonal water sources.
- Ponds lose water through seepage and evaporation.
 - ♦ The amount of water lost by evaporation depends on factors such as temperature, wind, vegetation, water surface, and humidity. Evaporation ranges from 2 to 7 mm per day. Assume 4 mm per day. So for 100 m² pond, water loss through evaporation would be $= 0.004 \text{ m} / 100 \text{ m}^2 = 0.4 \text{ m}^3$ or 400 litres in a day. So get enough water to replace what is lost by evaporation.
 - ♦ Water lost by seepage depends on soil and construction factors such as the existence of a suitable clay layer under the pond bottom, whether or not good clay cores were placed under the dykes during construction, and the quality of soil used to build the dykes.

Water quality requirements

- The best quality water will be free of silt and clay.
- Good water is also free of insect larvae, predators, unwanted fish species, pesticides and toxins, and excess fertility.
- Water supplied to ponds should be high in dissolved oxygen.

2. Bringing water to the pond

Gravity flow

- Ensure that the level of the drainage canal is below the level of the pond bottom and at least 1.5 m below the level of the inlet canal.
- The level of the inlet canal must allow a slope of 1:1000 to secure a reasonable flow of water; the slope of 1:1000 must work back to agree with the level of the intake.
- Canal slopes generally range from 0.25 to 1%, but for large ponds the slope should be about 0.5%.

Pumping

- Avoid pumping water if there is a cheaper source.
- Use the most economical water source.

Other

- Plan for a drop of 10 cm from inlet pipe to the pond water level to prevent fish from swimming out of pond into the pipe; better yet, use a screen to prevent fish from moving into the pipe.



Figure 2.1-1. Ponds at the Moi University Fish Farm are neatly laid out, with water flowing by gravity from the water reservoir (right) to the ponds (left).

3. Effects of soil types on pond design and construction

Range of soil types

- Topsoil is high in organic material and should not be used to construct pond dykes.
- The composition of mineral soils can range from very sandy to very clayey. These extremes are generally not suitable for fish pond construction. Sandy soils are too porous to hold water, while clay is too compact and adsorptive, depriving the water of essential nutrient elements, particularly phosphorus.
- Soils with 20-35% clay are the best for building ponds.
- Pond bottoms may be classified into three general types:
 - ◆ Inorganic bottoms of gravel, sand, or clay, which are very poor but can be improved by the application of manure or sludge.
 - ◆ Peaty bottoms formed by the accumulation of un-decomposed vegetable debris, which can be corrected by using heavy doses of lime to bring about decomposition.
 - ◆ Mud bottoms, which are the most productive type.

Effects on pond design and construction

- If the site has some soil containing a high percentage of clay (30-35% or more), use this for filling the core trenches beneath the dykes (see Section 2.2 for further information on constructing cores).
- If your soil has a reasonable percentage of clay (20-30%), you can construct the dykes with 2:1 slopes (2 m horizontally for every 1 m vertically).
- If your soil has a low percentage of clay (20% or less), you should increase the dyke slopes to 3:1 to prevent slumping and erosion of the pond banks.

4. Pond size, shape, and depth

Size

- The size of a prospective fish pond should be based on the purpose of the pond.
- If the pond is meant to provide additional food for the family, then it need not be larger than 0.1 ha (1000 m²).
- Larger ponds produce more fish and are usually more efficient producers of fish per unit of land than ponds less than 1000 m².
- A pond of 0.2-0.3 ha (2000-3000 m²) is easily managed by a small farm family. Such ponds can be maintained with a minimum of effort.

Shape

- Rectangular ponds are usually the easiest to build and manage. However, ponds must sometimes be built with irregular shapes to fit the topography and shape of the available space.

Depth

- The best pond depth depends on the fish species, size of fish, and production system to be used.
- The ideal depth for most ponds ranges from 0.75 to 1.2 m.
- For the shallow end, the depth can be from 40 to 70 cm. The absolute minimum is 40 cm; however, 50 to 60 cm is best. Problems that develop in shallow ponds include predation, weeds, and low production.



Figure 2.1-2. A well designed pond allows for a water depth of about 1 metre and has embankments (dykes) with inside slopes of 2 to 1 or greater, depending on soil type.

- The deep end can be from 80 to 120 cm deep, but the best for medium and large ponds is 90 to 110 cm. Areas deeper than 1 m are likely to be less productive: They are cooler than the surface, lower in oxygen, and can become stratified, so most fish will avoid them.
- A small pond of 150 m² (e.g., 15 m x 10 m) with dyke slopes of 2:1 should have a shallow end 50 cm deep and a deep end 75 cm deep.
- The deepest point should be at the outlet.
- The total height of the dykes of such a pond will be 80 cm on the shallow end and 105 cm towards the outlet.
- Remember that sunlight can penetrate up to 1 metre into clear waters, for example in unfertilized ponds. In fertilized fishponds light penetration beyond 60 cm below the water surface is minimal.

5. The slope of the pond bottom

- The pond bottom must have sufficient slope for good drainage. In general, slopes with a drop of 2 cm for every 10 metres along the pond bottom are appropriate.
- If the slope is too gentle, the pond will not be easily drained.
- If the slope is too steep, it may be too shallow at one end or too deep at the other end.

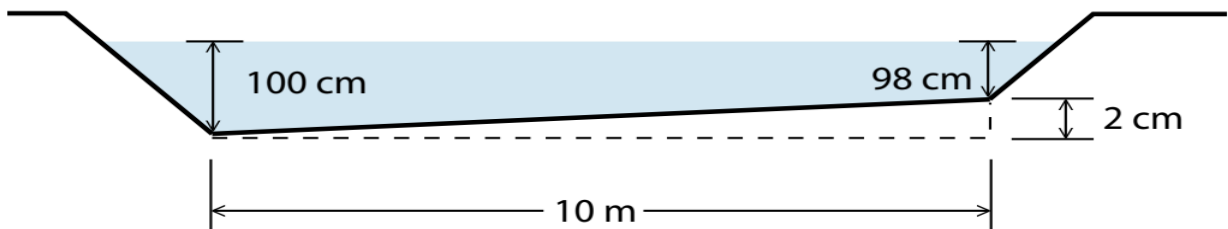


Figure 2.1-3. A well designed pond slopes slightly from the shallow end to the deep end, with a drop of about 2 cm for every 10 metres of length.

6. Design of the dykes—height, width, and slope

Height of dykes

- Dyke height will be set by the depths that you have chosen for the shallow and deep ends of the pond. However, dykes must be built higher than the full water level to guard against overflowing. The additional height of the dyke above the full water level is called “freeboard.”
- Freeboards for ponds less than 1000 m² should range between 20 and 30 cm, but for larger ponds they can be up to 50 cm.

Width

- The width of the dyke at its top should be equal its height but never less than a metre wide.
- The width should be great enough to allow transport of materials, fish, and farm equipment.

Slope

- Slopes that are too steep lead to problems such as erosion and slumping of the dykes.
- Gentle slopes are better due to water pressure, which is highest at the pond bottom; however, slopes that are too gentle encourage the growth of weeds in the pond.
- The slope of the dyke depends on soil type:
 - ♦ The inside slope should be 2:1 to allow water pressure dispersion. The slope should be increased to 2.5:1 if the soil is of lower quality.
 - ♦ The outside slope can be 1:1.
- The width of the base on firm soils should be three to four times the height of the wall. This should be five times the height of the wall on soft soils and with a crest of not less than 1.2 to 1.5 metres.

7. Pond drainage systems

- Pond drains are normally located at the deep end of the pond with the bottom sloping toward them. Most of the ponds used by small-scale farmers do not have drains. In the case of very small ponds, it is of course uneconomical to provide individual drainage facilities.
- Periodic draining and drying of ponds is important because it helps in harvesting fish, eradicating predators, improving the bottom condition of the ponds, and raising production rates.

Standpipes

- The simplest drain is a standpipe protruding from the pond bottom. The lower end of the standpipe is screwed into an elbow which connects to the main drain. The upper end controls the level of water in the pond.
- When the water level is to be raised or lowered, the angle of the standpipe is changed by rotating the elbow.
- The size of the standpipe depends on the size of the pond, the rate at which drainage is desired, and the volume of water coming into the pond for a flow through system.

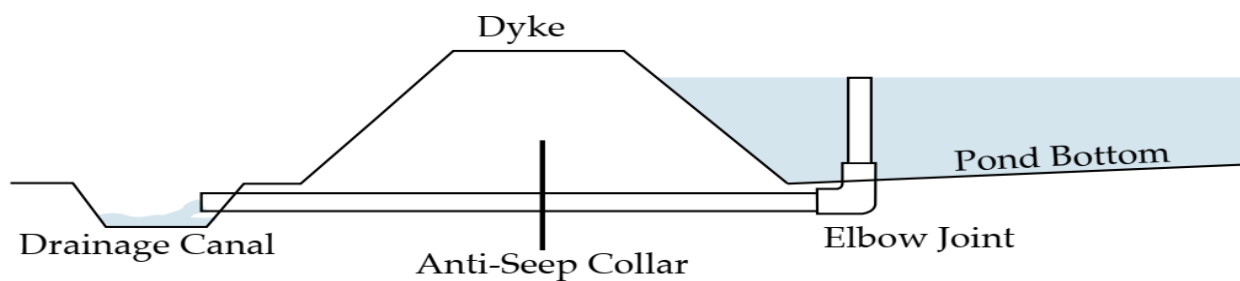


Figure 2.1-4. A cross section of a pond dyke and drainline with standpipe. The maximum water depth is obtained when the standpipe is in a vertical position; the water depth can be lowered by turning the standpipe down towards the pond bottom.

Monks

- The monk is part of the drainage system. It is constructed in front of the dyke (inside the pond) and consists of two parallel lateral walls and a back wall. It can be made of brick or concrete. Boards are placed in slots in the lateral walls to retain water at a desired depth.
- The monk controls the level of water in the pond, prevents escape of fish, and permits progressive draining of the pond during harvesting.
- Monks may prove uneconomical and unnecessary in small ponds. In such ponds it is more economical to dig canals through the dykes to fill, drain, or maintain a consistent water inflow and outflow.

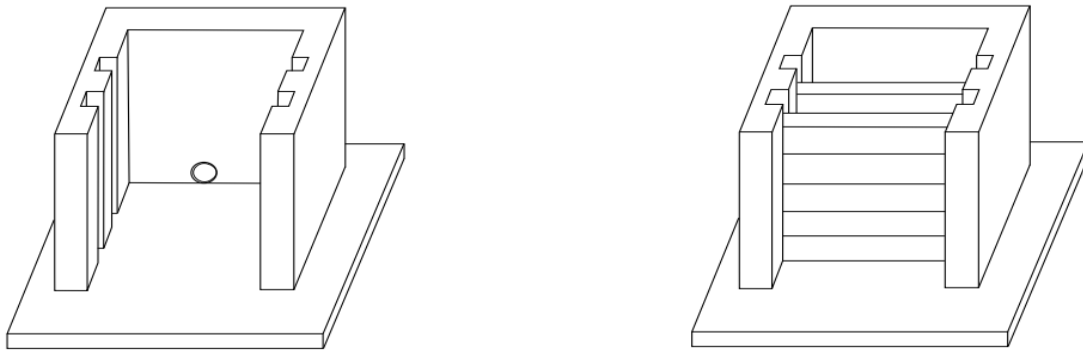


Figure 2.1-5. A figure of a monk. Boards are inserted on edge into the slots to hold water in the pond. A tight seal is obtained by packing clay into the space between the two sets of boards.

8. Layout of ponds

Integrating fish ponds into your general farm layout was discussed in Section 1.2. Within the fish production unit itself, you should lay out and construct your broodfish ponds, spawning ponds, nursery ponds, and growout ponds in sequence and close to each other so that you can move fish from one rearing phase to another easily and quickly. One way of doing this is shown in Figure 2.1-6.

Moving on

With these principles of good pond design in mind, you are ready to move on to the next step—the actual construction of your ponds.

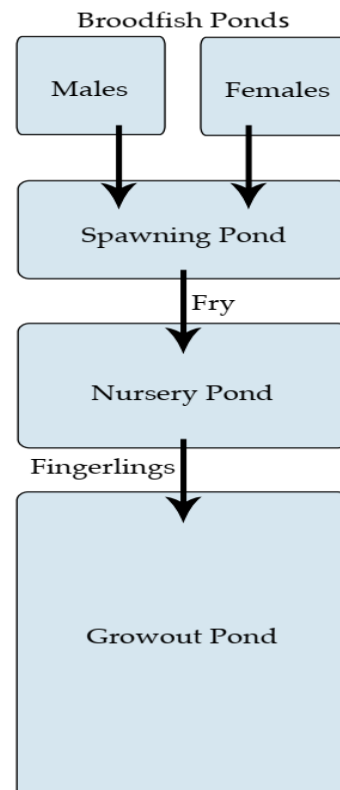


Figure 2.1-6. A logical pond layout provides for easy movement of fish from one rearing phase (pond) to another.

2.2: POND CONSTRUCTION

Introduction

Once you have designed your pond there is a logical sequence of steps that you should follow to build it. These are:

1. Survey the land
2. Clear all vegetation from the site
3. Remove the topsoil from the site
4. Determine pond, drain pipe, and supply canal elevations
5. Peg out the pond, including core trenches, dyke tops, and dyke toes
6. Dig core trenches and pack them with good soil
7. Excavate the pond area
8. Build the dykes
9. Install the drainage system
10. Install the water supply system

Building your pond

1. Surveying the land

- Clear the land to get line of sight.
- Select a reference point for the survey. The standard reference point ("bench mark") is sea level (0 m above sea level). However, in pond construction we use a Temporary Bench Mark (TBM) to help determine elevations and establish slopes. If there is an existing pond use it as the reference point to get the heights of your dykes. If there are no existing ponds, use a fixed point on an inlet or outlet canal as the TBM.
- Start measuring elevations from the supply canal using a level and twine. Determine slope from dyke top to pond bottom for both vertical and horizontal dimensions. This helps in understanding how water will flow from the pond to the drain or back to the river. Raise elevation into canals by blocking with timber or sand bags.
- Survey across water bodies using objects such as bamboo, pipes, etc.

2. Clearing vegetation from the site

- Vegetation should not be included in the soil used to construct the pond dykes, so should be removed from the site prior to beginning to excavate and move soil.

3. Removing topsoil from the site

- Topsoil is not good material to use for dyke construction, so it should be removed prior to excavating the pond.
- Topsoil can be set aside and spread over the dykes after construction is complete, or it can be moved for use elsewhere on your farm, for example in your vegetable garden.

4. Determining pond, drain pipe, and supply canal elevations

- Determine topography (layout) of the land first.



Figure 2.2-1. Vegetation and topsoil should be removed from the area before beginning to build a pond.

- Remember that the elevations of the pond inlet and the outlet to the drain canal determine the elevation at which the pond drain can be placed. Hence the difference in the elevations of the inlet and the outlet determines how deep your pond can be.
- Remember to allow for the freeboard.
- Canal slopes generally range from 0.25% to 1%.
- Cross check your levels to correspond with the TBM so as not to lose dyke height.
- You can also check your pond diagonally, widthwise, and lengthwise.

5. Pegging out the dykes and core trenches

- Decide on the size of the pond and peg the pond area.
- Decide on the dyke slope and width.
- Place pegs at the inner toes, including the four bottom corners. The “toe” is the point where the dyke slope meets the pond bottom. To do this, multiply the desired slope of the dyke by the desired pond depth. For example, at the deep end, the inner toes will be pegged at $80 \text{ cm} \times 2 = 160 \text{ cm}$, while at the shallow end the inner toes will be pegged at $75 \text{ cm} \times 2 = 150 \text{ cm}$.

6. Constructing cores

- If you suspect the dyke or pond bottom soil to be highly permeable, dig a core trench under the dykes around the pond.
- Pack the core trenches with impermeable clay.

7. Excavating the pond area

- Make a decision on pond depth and calculate the dig/fill heights (See Table 2.2-1).
- Begin excavating the pond bottom.



Figure 2.2-2. Pond construction typically involves excavating the inner area and using that soil to build the embankments.



Figure 2.2-3. This area has been pegged out and core trench digging has begun. The core will be packed with soil containing not less than 30% clay before dyke construction begins.

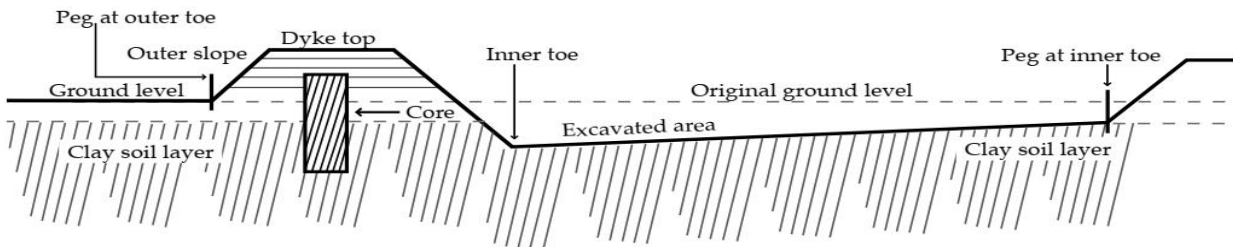


Figure 2.2-4. This cross section shows the relationships of the dyke, inner and outer toes, and the core to the original ground level and clay layer beneath the pond bottom.

- Plan where you take soil from and where you take it to. The fewer times soil is handled, the more efficient and less expensive the project is. Poor organization of soil movement increases labour cost and also results in a poorly shaped pond.
- A two-person stretcher works better in black cotton soil than a wheelbarrow. But one person using a wheelbarrow can move the same amount of soil as two people using a stretcher.
- Black cotton soil (the heavy, black clay soil common in some lowland areas) has a large potential to expand and contract, so large cracks frequently develop in the soil. Do not get this soil too wet during construction — only wet it enough for good compaction.

Table 2.2-1. This table shows the approximate excavation depths that will be needed at different distances from a reference point on land of different slopes.

Slope	1 m	5 m	10 m	100 m
1%	0.01 m	0.05 m	0.1 m	1 m
0.5%	0.005 m	0.025 m	0.05 m	0.5 m
0.25%	0.0025 m	0.0125 m	0.025 m	0.25 m



Figure 2.2-5. A two-person stretcher works very well for moving soil from the excavated area to the embankment area, especially in heavy clay soils.

8. Constructing the dykes (levees)

- The most important component of a pond is its walls (also referred to as the “dykes,” “levees,” or “embankments”).
- Use soil excavated from the pond area to construct the dykes.
- Construct the dykes gradually, in layers about 20 cm thick at a time.
- Compact each layer before the next layer is put down.

9. Installing the drainage system

- Install the drain after the dyke has been raised at least above the original ground level.
- Cut a trench for the drain pipe across the dyke at the selected point in the deep end.
- The top of the drain pipe should be below the deepest part of the pond.
- Lay the pipe at the proper slope through the dyke; slope should be not less than 1%.
- Install at least one “anti-seep collar” along the drain pipe (see Fig. 2.1-4).

- For small ponds, a PVC pipe fitted with a gate valve would be more suitable than a monk with timber boards.
- Place a screen at the outflow to keep out predators and unwanted fish, and to retain the cultured fish.



Figure 2.2-6. Dyke construction is done in layers about 20 cm thick. Each layer is well compacted before the next layer is added.



Figure 2.2-7. A PVC standpipe being installed in a new pond. With the standpipe in the vertical position the full pond will have a water depth of approximately 1 m.



Figure 2.2-8. Although more expensive to construct, monks are sometimes used instead of standpipes. In this example, some of the upper boards have been removed to lower the water level in the pond.

10. Installing the water supply system

- Inlets deliver water to the fish ponds while outlets regulate the water level in the ponds and ensure complete drainage.
- Canals or pipes can be used to bring water to the pond. Types of delivery systems include open canal, channel lines with bricks and/or stones (open channel in black cotton soil can have cracks), PVC pipes, bamboo pipes, tiles, and gate valves.
- The inlet should preferably be directly opposite the outlet. This allows proper mixing of water in the pond and of course heat dispersion.
- Place the inlet at the middle of the dyke on the shallow end, and make it smaller than outlet (overflow).
- Do not let the canal end at the pond because in times of floods there is need to allow water to bypass the pond without causing any flooding.
- Raise diversion canals into the pond slightly higher (e.g., 2 cm) than the feeder canal.
- Allow for water to drop at least 30 cm between the inlet pipe and water level (surface). This area is referred to as the free board (mentioned earlier).
- Give the inlet canal a slope of 0.5% and work out the depth as explained earlier. For example, for every 5 metres you will have a drop of 2.5 cm to maintain a slope of 0.5% calculated as shown:
$$2.5 \text{ cm} / 5 \text{ m} \times 100 = 25 \text{ cm} / 5000 \text{ cm} = 0.5\%$$
- You can also siphon water from a higher pond to a lower one.
- Water brought into the pond should be passed through a screen to keep out insects and other predators.

Estimating pond construction costs

Example 1

One pond of 100 m² requires about 15 people working 8 hours to construct in 8 days. This will cost $15 \times 8 \times \text{Kshs } 127 = 15,240.00$. Alternatively if 8 people are constructing a 100 m² pond they will be required to work for 15-16 days at an average of 8 hours per day. The cost will be $8 \times 16 \times \text{Kshs } 127 = 16,256.00$. Inlet canal, outlet canal, cement, sand, and pipes will cost about Kshs 5,000.00. Total cost of the pond should be Kshs 21,256.00. Consider other incidentals especially due to the prevailing weather. This may have an additional cost of about Kshs 3,750.00. In total, the cost of constructing one 100 m² pond should be Kshs 25,000.00 (US\$ 338.00 at an exchange rate of Kshs 74.00 to a dollar).

Example 2

If 8 people are constructing 300 m² pond they will be required to work for 26.25 days at an average rate of 8 hours per day. The cost will be $8 \times 26.25 \times \text{Kshs } 127 = 26,670.00$. Inlet canal, outlet canal, cement, sand, and pipes will cost an additional Kshs 5,000.00. Total cost of the pond should be Kshs 31,670.00. Now consider other incidentals especially due to the prevailing weather, which may bring in an additional cost of about Kshs 3,750.00. Therefore, the total cost of constructing a 300 m² pond should be Kshs 35,420.00 (US\$ 479.00).

Moving soil

A 100 m² pond whose average depth is 70 cm will have $10 \times 10 \times 0.7 \text{ m} = 70 \text{ m}^3$ of soil to be moved or excavated. This should take 8 people about 8 days if they each dig 1 m³ of soil, move it to the dyke area and compact it. Ideally, the amount of soil to be excavated from the pond area would be about equal to the soil needed to construct the dykes. This can occur if the land has a gentle slope, allowing for the amount of the soil removed from the pond to be just enough to raise the dykes to the required level. Generally, however, the volume of the soil on the dyke (the total dyke surface area for 100 m²) is about 120 m³; this is more than the volume to be excavated from the pond area, so some additional soil will need to be brought in.

Moving on

Now that you have designed and constructed your new pond, you are ready to prepare and stock it for your first crop of fish. The next chapter reviews the major species that are suitable for fish farming in Kenya.