Water for the World

Designing Intakes for Rivers and Streams

Technical Note No. RWS. 1.D.3

The installation of intakes makes water from rivers and streams more accessible. Water can easily be pumped from an intake to a community distribution system. Long walks to carry water are no longer necessary. The installation of an intake should lead to increased consumption of water which should, in turn, mean improved health for the community.

Intakes must be designed correctly if they are to function properly. A well-designed intake should provide good quality water in abundant quantities. An intake should be inexpensive to install and operate and require as little skilled supervision as possible for its construction and maintenance. This technical note describes the design of three types of intakes: infiltration intakes, gravity flow intakes, and direct pumping intakes. It should be used with "Choosing Where to Place Intakes," RWS.1.P.4, which discusses site selection for and placement of intakes.

The design process should result in the following three items which should be given to the construction supervisor:

1. A map showing the location of the proposed intake. Figure 1 is a sample location map for an infiltration gallery.

2. A list of all labor, materials and tools needed as shown in Tables 1, 2, and 3. This will help make sure that adequate quantities of materials are available so construction delays can be prevented.

3. Detail drawings of the intake to be constructed with all dimensions similar to the one shown for a winged-wall collector in Figure 8.

Useful Definitions

ABUTMENT - A structure supporting a bridge or walkway.

CASING - Lining for wells made either with concrete rings, bricks, or pipe to strengthen the walls of the well and prevent contaminants from entering.

GALLERIES - Long narrow trenches or ditches through which water passes.

INFILTRATION - The process of water passing from the surface through the soil and into groundwater reservoirs.

PRECAST - A concrete structure formed and cast somewhere other than its intended place of use and moved into place when ready.

REINFORCED CONCRETE - Concrete containing reinforcing bars or wire mesh to give it extra strength.

VITRIFIED CLAY PIPE - Clay that is baked and glazed in a very high heat.

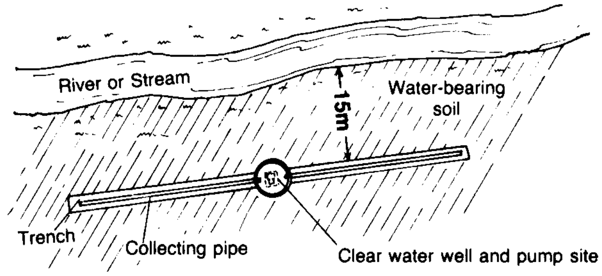

Figure 1. Location Map for Infiltration System

Table 1. Sample Materials List for Infiltration Systems

Item	Description	Quantity	Estimated Cost
Labor	Foreman Laborers	____ ____	____ ____
Supplies	Plastic (PVC) pipe, 50mm, or clay tile or concrete pipe, 10mm Hand or mechanical pump Sand and gravel (for filter beds) String Wooden stakes Sludge pump (if necessary)	____ ____ ____ ____ ____ ____	____ ____ ____ ____ ____ ____
Tools	Shovels, picks, digging sticks (for digging well) Small hand drill Hammer Nails Measuring tape Carpenter's level Measuring rod Bucket	____ ____ ____ ____ ____ ____ ____ ____	____ ____ ____ ____ ____ ____ ____ ____

(NOTE: For additional materials needed, see "Constructing Dug Wells," RWS.2.C.1)

Table 2. Sample Materials List for Gravity Flow System

Item	Description	Quantity	Estimated Cost
Labor	Foreman Laborers	____ ____	____ ____
Supplies	Portland cement Clean sand and gravel, if available, or locally available sand and gravel Water (enough to make a stiff mixture) Reinforcing rod, 8mm Lumber (for forms) Nails Rope and pulley Tripod Tie wire or clamp Wire mesh screen, 10mm Pipe, plastic or galvanized	____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____	____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
Tools	Shovels, picks, digging sticks Measuring tape Wire cutters Hacksaw Hammer Bucket	____ ____ ____ ____ ____ ____	____ ____ ____ ____ ____ ____

Table 3. Sample Materials List for Permanent Direct Pumping System

Item	Description	Quantity	Estimated Cost
Labor	Foreman	____	____
	Laborers	____	____
Supplies	Bricks - seconds can be used for half bricks	____	____
	Portland cement	____	____
	Clean sand and gravel, if available, or locally available sand and gravel	____	____
	Water (enough to make a stiff mixture)	____	____
	Lumber (2.5cm x 15cm; 5cm x 150cm; 10cm x 10cm)	____	____
	Tripod	____	____
	Rope and pulley	____	____
	Barbed wire	____	____
	Log	____	____
	Mechanical pump	____	____
	Pipe and elbow joint (couplings)	____	____
	Wire mesh screen, 10mm	____	____
	Tie wire	____	____
	Clamp	____	____
	Nails	____	____
	Pipe glue	____	____
Tools	Shovels, picks, digging sticks	____	____

Design of Infiltration Intakes

One type of intake is designed so that water from a stream or river passes through the ground and into storage. These are called infiltration intakes because the water collected is filtered as it passes through the ground. The water is generally free from contamination and needs no treatment. The two infiltration intake designs discussed in this section are a well dug in a river bank, and infiltration galleries.

Figure 2 shows a well dug in a river bank of sand and gravel. The well's distance from the stream depends on the type of soil in the stream bank. If the ground contains semi-porous material such as clay, the well can be located only a few meters from the bank. Filtration takes place rapidly in clay so the well can be located closer to the stream. Since water flow is slow in clay, a close location ensures adequate recharge. In more porous soils, such as coarse sand and gravel, the well should be located further than 15m from the bank. An average distance in semi-coarse soils made up of some clay and silt is 15m.

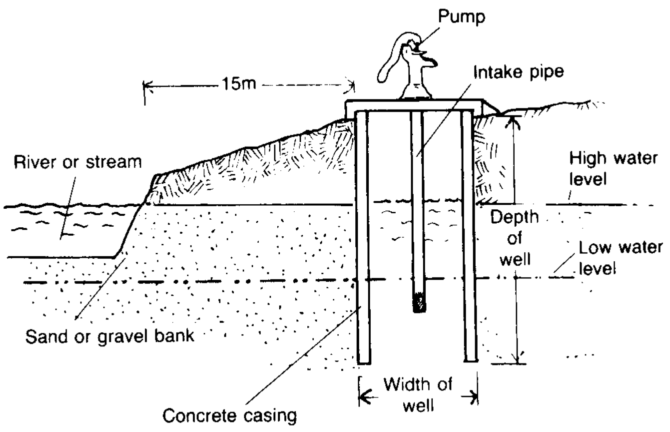

Figure 2. Riverside Well Intake

Water is pumped from the well to the users. During pumping the water enters the well and the groundwater table is lowered. When the groundwater table falls below river level, river water enters the aquifer. As pumping continues, this water flows through the ground, is filtered, and eventually enters the well.

The well should be dug at least 0.5m deeper than the floor of the stream bed and should be lined with concrete rings or bricks and mortar. A hand pump or power pump is installed to pump water from the well to the users. This design is good for small systems with fewer than 150 users. Design information for the well and different types of casing is in "Designing Dug Wells," RWS.2.D.1.

If the infiltration method is to be used to supply water to a larger population, infiltration galleries should be constructed. Infiltration galleries collect water from an area parallel to a river bank through collection pipes. These pipes move the water into a clear water well where it is held for pumping to a distribution system. Figures 3, 4 and 5 show examples of infiltration galleries. The primary design components are: (a) an excavated trench, (b) collecting pipes, (c) a filter bed, and (d) a clear water well.

Excavated Trenches. The infiltration gallery can be located on the stream bank as shown in Figure 3. Trenches should be parallel to the stream or river in water-bearing soil. The trenches' distance from the stream depends on the makeup of the soil. If the soil is a mixture of sand and gravel that is not very coarse, the infiltration galleries can be placed 15m from the stream. Follow the same rules in placing trenches as for riverside wells. The trench should be dug during the dry season when the water table is lowest to ensure that adequate quantities of water are tapped for year-round flow. A depth of 1m below the lowest water table level is sufficient. The trench must slope so that water runs into the storage well. A one percent slope is sufficient for the design (one percent slope = one centimeter per meter). Because trenches are dug below the water level, they must be bailed to keep them free of water during construction. The trenches can be bailed by hand using buckets, or a pump can be used to keep them dry.

Digging trenches in sandy soil is dangerous because the trenches will cave in as digging continues. Never dig trenches so that the edges are higher than a worker's head. If trenches must be dug deeply into the ground, slope the sides to prevent

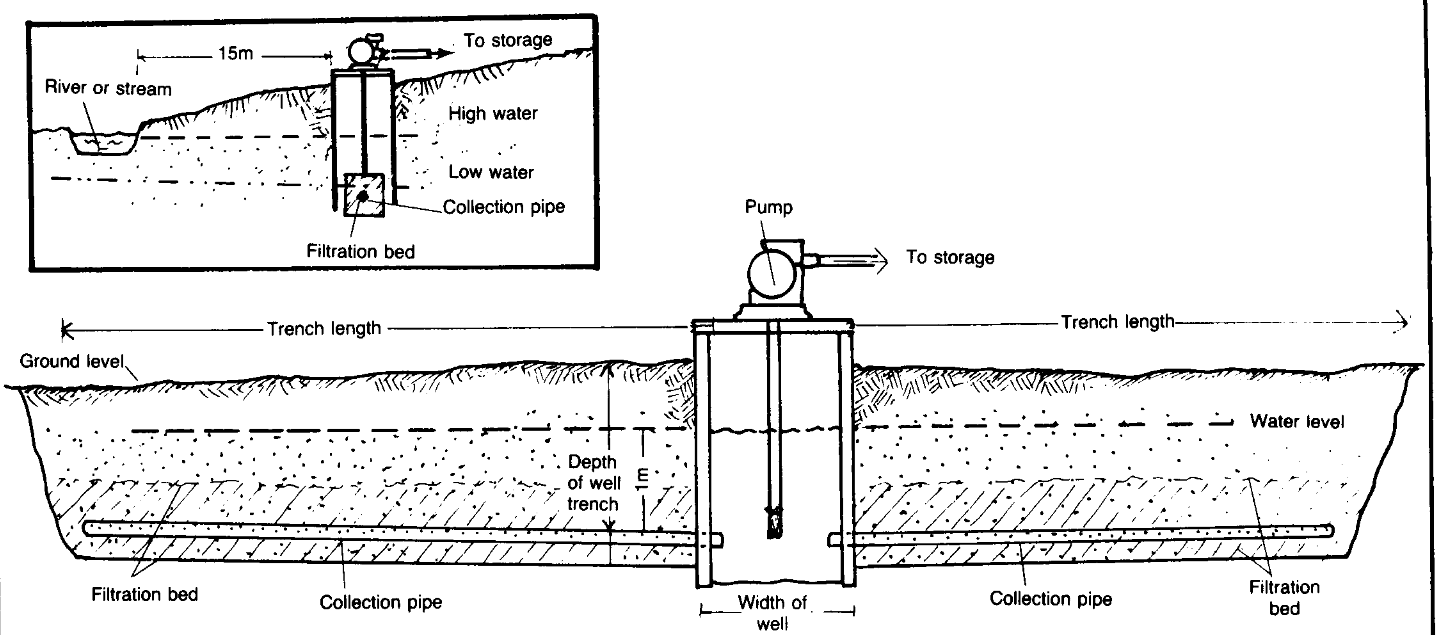

Figure 3. Riverside Infiltration Intake

cave-ins. In very sandy soils, it may be impossible to install trenches in the bank and an alternative should be chosen.

Figure 4 shows an infiltration gallery placed in the bed of a river. The stream is diverted so that a trench can be dug directly in the middle of the stream. The depth of the trench should be between 0.3 and 0.5m. It should be lined with gravel as described in the section on filter beds. Connect one end of the filter pipe to a pipe that runs into a clear water well located on the bank. Lay the pipe so that the slope is approximately one percent, permitting the water to flow easily into the clear well.

A clean-out pipe should be attached to the opposite end of the filter pipe. The clean-out pipe is simply a length of pipe attached to the perforated pipe which leads to the bank opposite the clear well. An elbow is attached to the length of pipe so that a vertical piece of pipe can be connected to it. The vertical section extends above ground level for easy access and is capped so that no debris can enter it. The clean-out system is used to flush out sediment if the collection pipe clogs.

Figure 5 shows another useful design for an infiltration gallery. Collecting pipes are driven from a well located in the bank into the bed of a stream below water level. In some soils, the pipes can be driven by hand using a hammer and drive pipe. In most cases, the pipes need to be driven with a pneumatic hammer braced against the wall of the well. The section of wall that supports the hammer should receive extra reinforcement to prevent it from breaking apart.

One useful technique is to drive large diameter steel pipe into the stream bed and then slide smaller diameter perforated plastic pipe into it, removing the steel pipe as the plastic pipe is put into place. This type of infiltration gallery is useful when sandy soil prevents the installation of trenches in the bank or when stream beds are difficult to excavate.

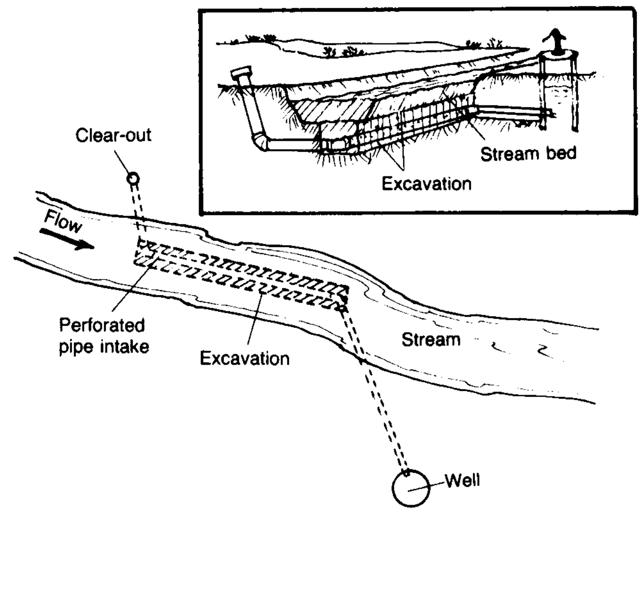

Figure 4. Infiltration System Below Stream Bed

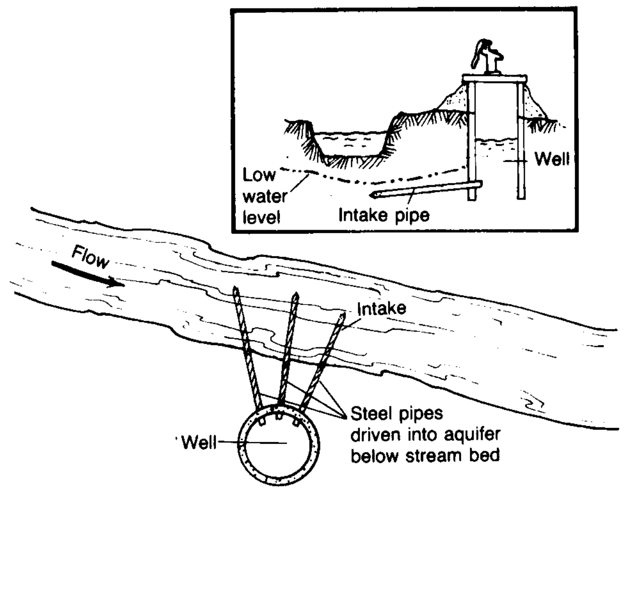

Figure 5. Multiple Pipe Infiltration System

<u>Collecting Pipes</u>. First, decide on the type of pipe. Rigid or flexible plastic, concrete, or vitrified clay pipe can be used. The choice depends on availability and cost. Next, choose the appropriate pipe diameter. This depends on the type of pipe chosen, its length, cost, and availability. If clay or tile pipe is used, 100mm diameter is the smallest available and should be used. If you are using plastic pipe, the diameter can range

between 50mm and 100mm as long as flow is sufficient to meet community needs. If concrete is poured to make concrete pipes, the diameter of the form should be 200mm. Concrete pipe can be made with large gravel and a fluid sand and cement mix. The result is pipe with porous walls through which water flows easily. Careful curing is required. Large diameter pipe allows more water to flow into a system but it is more expensive and the community may not be able to afford it.

Decide on the appropriate size for the inlet holes. If concrete or clay pipe is used, no inlet holes are needed since water enters through openings at the pipe joints. The pipe joints should be at 1m intervals. Plastic pipe needs inlet holes or slots. Inlet holes 10mm in diameter or slots 25mm long can be made with a drill, nail, or small saw. Flexible polyethylene plastic pipe can be purchased with slots already made. Details of inlet hole sizes and the basic design are shown in Figure 6a.

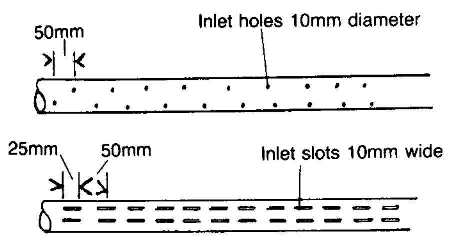

Figure 6a. Collection Pipe for Filtration System

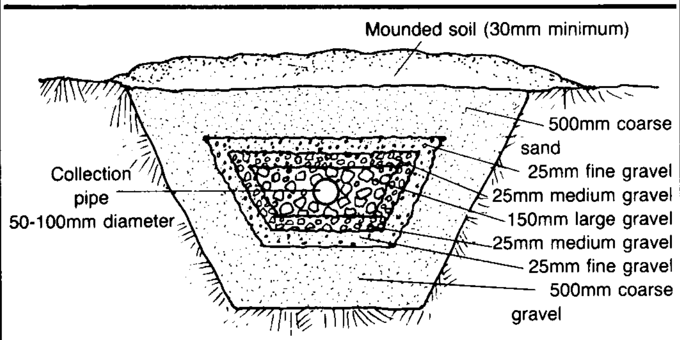

Figure 6b. Filtration Bed

Finally, choose the appropriate pipe length. This will depend on the amount of water needed and the type of soil in the water-bearing zone. Use a longer pipe in fine sand in order to collect greater quantities of water. To determine pipe length, the water flow must be observed. If flow is insufficient, either a larger diameter pipe must be installed or the trenches and collecting pipes must be lengthened to collect more water.

<u>Filter Bed</u>. A filter bed of stone, graded sand and gravel or other suitable filtering material should be built. The filtering material should be placed around the collecting pipe and built out to a width of 0.30-0.40m. Both the surrounding layers and side layers need to be graded to work effectively. Other layers of smaller filter material are added as shown in Figure 6b.

<u>Clear Water Well</u>. Use the design information for a riverside well given at the beginning of this technical note in designing the clear water well. This well serves the same purpose as the riverside well but collects water over a much larger area. Water is pumped from the well into the distribution system. If the infiltration gallery is well constructed, water may need only chlorination before it can be consumed. In some cases, more treatment will be necessary. Water in the clear well should be tested to determine its quality.

For all infiltration systems, water must be pumped to the users. In areas that are spread out or require a lot of water, smaller infiltration wells can be pumped by hand pumps for use at the source. Generally, when infiltration galleries are installed, water is pumped to the users through a distribution system. A pump, using a source of power, pumps water from the storage well to the main storage tank. See "Methods of Delivering Water," RWS.4.M.

Design of Gravity Flow Intakes

In mountainous or hilly regions, water from streams and rivers can be collected through intakes placed directly in streams. In higher elevations, a gravity flow system can be installed to deliver water if there is enough head for the water to reach the users. For an explanation of head and head loss in a system see "Designing a System of Gravity Flow," RWS.4.D.1.

If the intake is located above any inhabited area, the water may not require treatment. People and animals are the major sources of fecal contamination. If neither is present at the place where the water is collected, or upstream from the collection point, fecal contamination is unlikely.

Figure 7 shows a typical intake structure for a gravity flow system. The intake is located on a straight stretch of the river near a convex turn. The best location for the intake is where the bank and floor of the stream are stable.

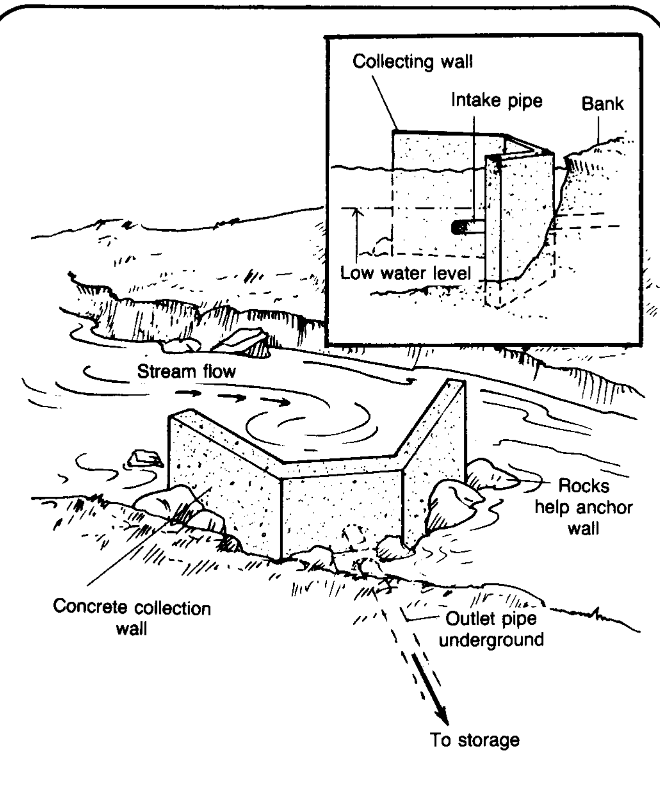

Figure 7. Gravity Flow Intake

The intake is made up of a screened intake pipe, and a reinforced concrete structure with winged-walls. To design this structure, first determine river flow, pipe diameter, pipe material, water level, and size of structure.

Determine the river flow using the methods described in "Selecting a Source of Surface Water," RWS.1.P.3. This measurement will indicate whether there is sufficient flow to meet community needs. Most streams that flow year round will provide ample water.

Determine the diameter of the pipe to be used in the system by using Table 4. Locate an approximate rate of flow for the river in the left hand column. Then look in either column 2 or column 3 to find the correct pipe diameter. For most rural areas, the velocity of water in the system ranges between 1.2-1.8m per second. For example, in a system where the river flow rate is 1 liter per second and the velocity is 1.2m per second, the correct size pipes would be 300mm. Check if the flow is sufficient by comparing the daily water needs (40 liters per day per person times number of people) and the daily flow. The daily flow must be equal to or larger than the daily water requirement.

Table 4. Determining Pipe Diameter

Q = Flow Liters/sec.	V (Velocity) = 1m/sec. - 1.5m/sec.	V (Velocity) = 1.5m/sec. - 2m/sec.
	Pipe Diameter (cm)	Pipe Diameter (cm)
0.63	25cm	25cm
0.83	30cm	30cm
1.0	30cm	30cm
1.3	40cm	30cm
1.6	50cm	40cm
2.0	50cm	50cm
2.3	50cm	50cm
2.6	60cm	50cm
3.0	60cm	50cm

Decide whether to use plastic or galvanized pipe depending on what is available. If the river is fast-flowing, or if flooding is likely to occur, galvanized steel pipe is preferable because of its strength. If the water is piped a long distance downhill to a community storage tank, flexible plastic pipe (polyethylene) is better. It is cheaper and easier to use because of its light weight and flexibility. The best method may be to place steel pipe in the structure for strength and then attach flexible plastic pipe to it for the distribution system.

Determine the level of the water at its lowest point during the year. The intake pipe must be placed in the upper third of the river when the river is at its lowest level. At this point, a water supply is provided all year and sediment from the river bottom will not enter the pipe.

The end of the intake pipe should be screened to prevent the entrance of leaves, stones, sticks, or other large material that could clog the pipe. Usually, 10mm mesh screen is a good size for the intake.

Determine the best size for the reinforced concrete structure. Size will depend on local conditions. The winged-walls must reach far enough into the stream to divert the water toward the intake into a pool which is always deep enough to submerge the intake pipe. The top of the structure stands above the riverbank so that the intake pipe is well supported in the walls and on the bank. The wall should be at least 0.15m-0.20m thick. The basic dimensions for the structure are shown in Figure 8.

Decide how to anchor the collection box and intake pipe. The box should be precast and lowered into a part of the stream where there are large rocks to support it. Digging into the stream bed 0.15m-0.20m will secure the bottom. One wall should be placed firmly against the stream bank and the unsupported side should be braced with large rocks as shown in Figure 7. The intake pipe should be anchored to the bank by digging a trench in the bank

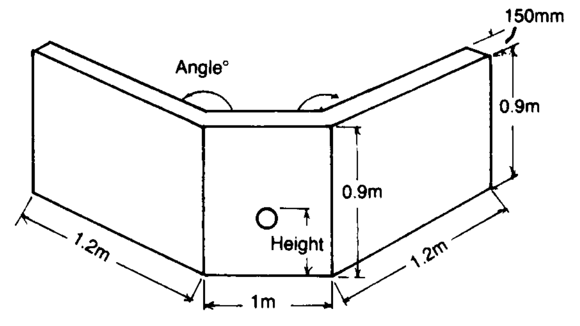

Figure 8. Design of Infiltration Wing-Wall Collector

and burying the pipe about 150-200mm in the ground. Both the intake pipe and collection box must be secure enough to avoid destruction caused by fast-flowing water, flooding, or moving rocks or logs.

Erosion of the bank opposite the winged-wall structure may occur as the stream flow is affected by the extension of the wall into the middle of the stream. To prevent the bank's erosion, reinforce it with rip-rap. The rip-rap should be placed on the bank where the force of water against the bank is greatest.

Construction of a winged-wall collection box requires skilled labor. This method should only be undertaken with the help of an engineer.

Design of Permanent Intakes for Direct Pumping

Water can be pumped straight from a stream or river to treatment and storage using direct pumping. There are many types of temporary intakes but permanent structures are better. Design of a permanent structure is shown in Figure 9. The intake consists of (a) a screened intake with a check valve, (b) a protective concrete ring with perforations, (c) a catwalk, and (d) a power pump. This type of intake should be used only in rivers that have a year-round depth of over 0.50m.

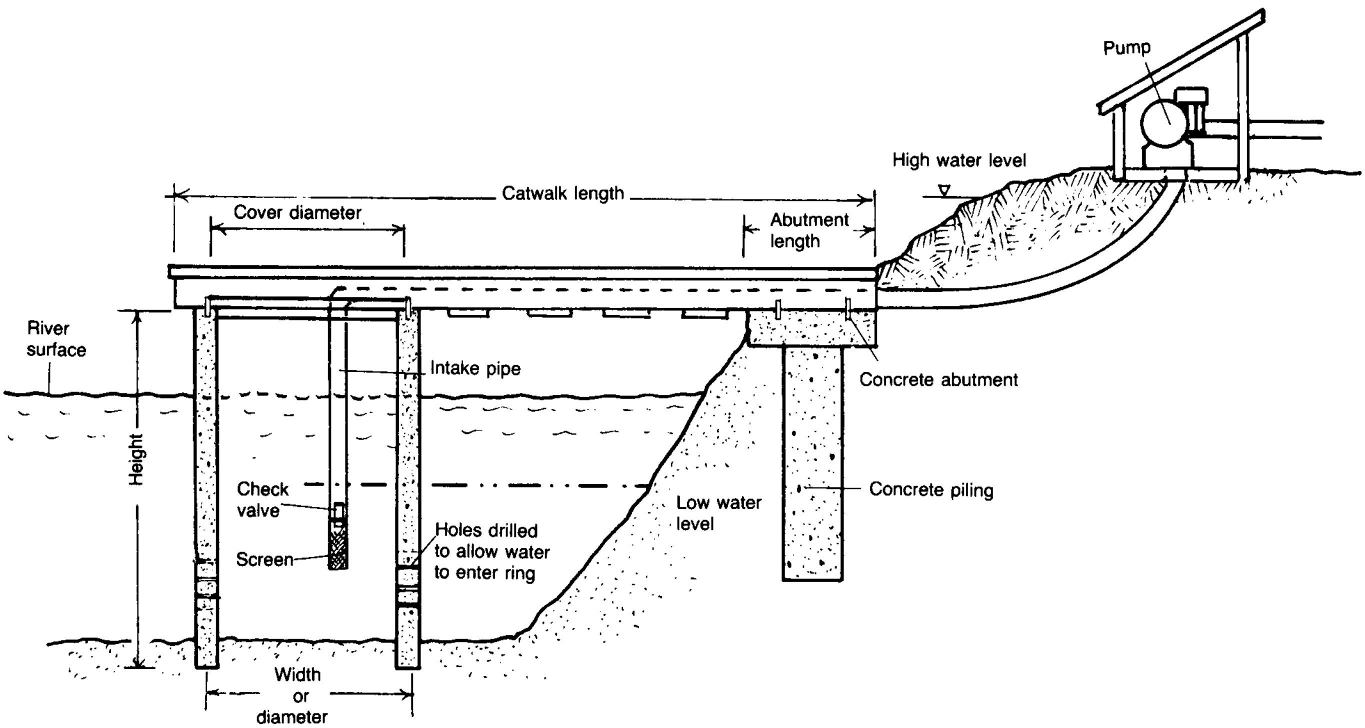

Figure 9. Direct Intake

Intake Pipe. A 50mm pipe with a 10mm wire mesh screen should be used for the intake pipe. The intake pipe is located in the concrete ring (pump well) and stands 300m above the stream bed in order to prevent large particles and sediment from entering the system. The pipe can be either plastic or galvanized steel. The choice depends upon what is available. Flexible plastic is much cheaper and needs no joints or couplings, but steel pipe may prove to be best because of its strength.

Determine the length of the pipe by measuring the distance from the pump to the end of the catwalk. Add to this the distance from the top of the catwalk to 0.30m above the bottom of the stream.

Concrete Rings. Determine the dimensions of the reinforced concrete ring. It should have a height of 1m and a diameter of 1.5m. The ring is precast and lowered into the stream. The ring should enter the stream bed 0.3-0.5m for adequate support. Weight may be a problem so a smaller ring may be designed. The ring should be large enough to protect the intake from water moving at high velocities and from large floating debris. Several small, 50-70mm diameter holes can be drilled in the ring to ensure an adequate water flow to the intake. A wooden cover fits over the ring to protect the intake pipe. When casting the ring, bolts should be placed in the cement so that the catwalks can be bolted to the ring. If the ring is bought, drill holes into the cement and place the bolts in the appropriate places, securing them with mortar. Because casting a ring is difficult, it is best to purchase one that is already made or build one using bricks and mortar as described in "Designing Structures for Springs," RWS.1.D.1. The intake should be located near the deepest part of the river or in a place where the water level is above 0.5m during the entire year. However, care should be shown to locate the intake fairly close to the shore. The design of the catwalk is more difficult the greater the distance from the shore to the intake.

Catwalk. Design a catwalk to connect the stream bank to the concrete ring and to support the intake pipe from the bank to the ring. The catwalk can be made of wood for easier construction. A concrete catwalk should only be designed by skilled engineers. Two timbers 0.10m by 0.10m should be used to connect the concrete ring to the shore. They are laid parallel, 1m apart and bolted to the concrete ring by attaching them to the bolts in the ring. The other end of each timber is attached to the abutment on the shore. Planks, 0.25m by 0.15m, are then nailed to the top to form a walkway as shown in Figure 10. Wooden pipe supports 1.5m apart are bolted to the bottom of the catwalk structure. A 0.5m by 0.15m plank is sufficient for the supports. A small strip of metal or rubber should be fastened to the support and around the pipe to keep it in place.

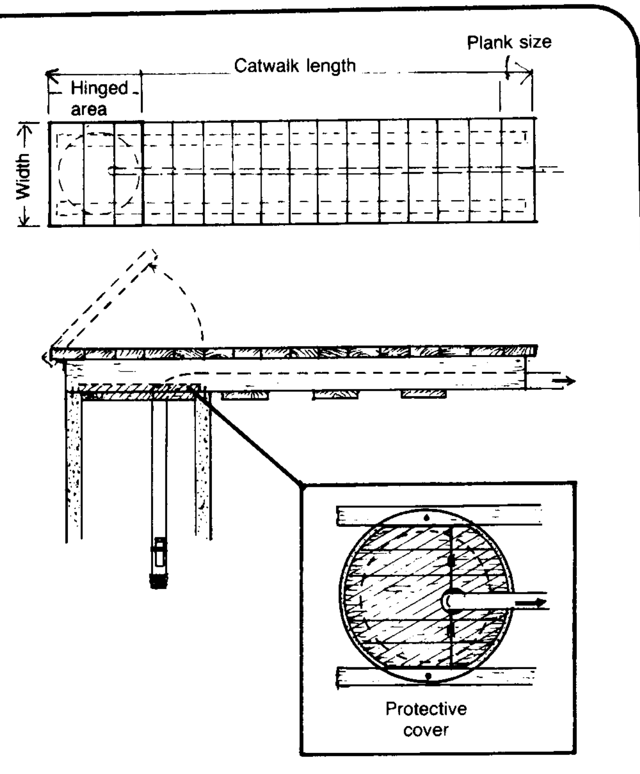

Figure 10. Catwalk and Cover Design

On the shore, build a concrete abutment 1.5m x 1m x 0.15m and level to the top of the concrete ring. This will support the catwalk. To build the abutment, dig out a level area to the desired size. The abutment should be attached to a piling to give the catwalk the needed support. The piling should be half the length and width of the abutment and should extend into the ground 0.5-1.0m. The hole is completely filled with concrete. The abutment and piling should be constructed as a single unit.

Install a pump and connect it to the intake pipe. Put the pump on level ground if possible, about 2m from the shore. To determine the type of pump needed, see "Determining Pumping Requirements," RWS.4.D.2, and "Installing Mechanical Pumps," RWS.4.C.2.

This type of intake structure is very difficult to build and trained technicians are needed. Materials which may be hard to obtain are required and these will raise the cost of the project. This design is only economically practical if many people are served by it.

For design, follow the steps described in Worksheet A. The volume of concrete needed can be determined by finding the volume of the concrete rings using the formula in Worksheet B.

If the concrete ring is too complicated to build a simpler design shown in Figure 11 can be attempted. A concrete base is built with a pipe inserted into it. An elbow is attached to the end and a vertical length of screened steel pipe is connected to it. The pipe in the concrete can be attached to flexible pipe for easy accessibility for maintenance. In deeper streams, a float can be attached to the intake to provide easy location.

Worksheet A. Determining the Amount of Concrete to be Used in Construction of Winged-Walled Intake Structure

1. Total volume = volume of side 1 + volume side 2 + volume side 3

   Volume side 1 = length 1.2 m x width 0.90 m x thickness 0.15 m = 0.162 m^3

   Volume side 2 = length 1 m x width 0.90 m x thickness 0.15 m = 0.135 m^3

   Volume side 3 = length 1.2 m x width 0.90 m x thickness 0.15 m = 0.162 m^3

   Total volume = 0.162 m^3 + 0.162 m^3 + 0.135 m^3 = 0.457 m^3

2. Total volume x 1.5 = volume of dry mix 0.457 cm^3 x 1.5 = 0.685 m^3

3. Cement mixture = 3 parts gravel, 2 parts sand, 1 part cement (50% gravel, 33% sand, 16.7% cement)

   Volume of gravel = 0.50 x total volume = 0.50 x 0.685 = 0.34 m^3

   Volume of sand = 0.33 x total volume = 0.33 x 0.685 = 0.22 m^3

   Volume of cement = 0.167 x total volume = 0.167 x 0.685 = 0.11 m^3

4. Volume of cement = 0.11 ÷ .033 m^3/bag = 3.5 bags of cement

5. Volume of water = 28 liters/bag of cement = 28 liters x 3.3 bags = 98 liters

6. Determine the number of lengths of reinforcing rod by using the following formulas:

   Divide the length of one side and the width of one side by 150mm, the distance between each bar.

   Length in mm ÷ 150mm = number of bars
   1200 mm ÷ 150m = 8 bars
   Width in mm ÷ 150m = number of bars
   900 mm ÷ 150m = 6 bars

   For the entire wall, 14 bars are needed and should be placed as shown in Figure 12.

   Do these calculations for each wall to determine the amount of rebar needed.

Worksheet B. Volume of a Concrete Ring

In the example given, the diameter of the ring is 1.5m and the thickness 0.10m.

a) Area = diameter^2

$$A = \frac{3.11}{4} \times 1.5^2$$

$$A = .785 \times 2.25$$

$$A = 1.76m^2$$

b) Volume = area x thickness. Use this volume in calculating concrete needed for the tube.

$$V = 1.76m^2 \times 0.10m$$

$$V = 0.176cm^3$$

All proportions of mixtures for gravel, sand and cement will be the same as in Worksheet A.

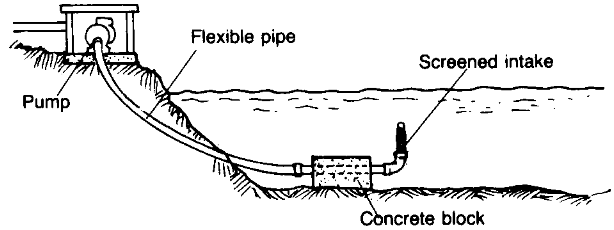

Figure 11. Simple Permanent Intake