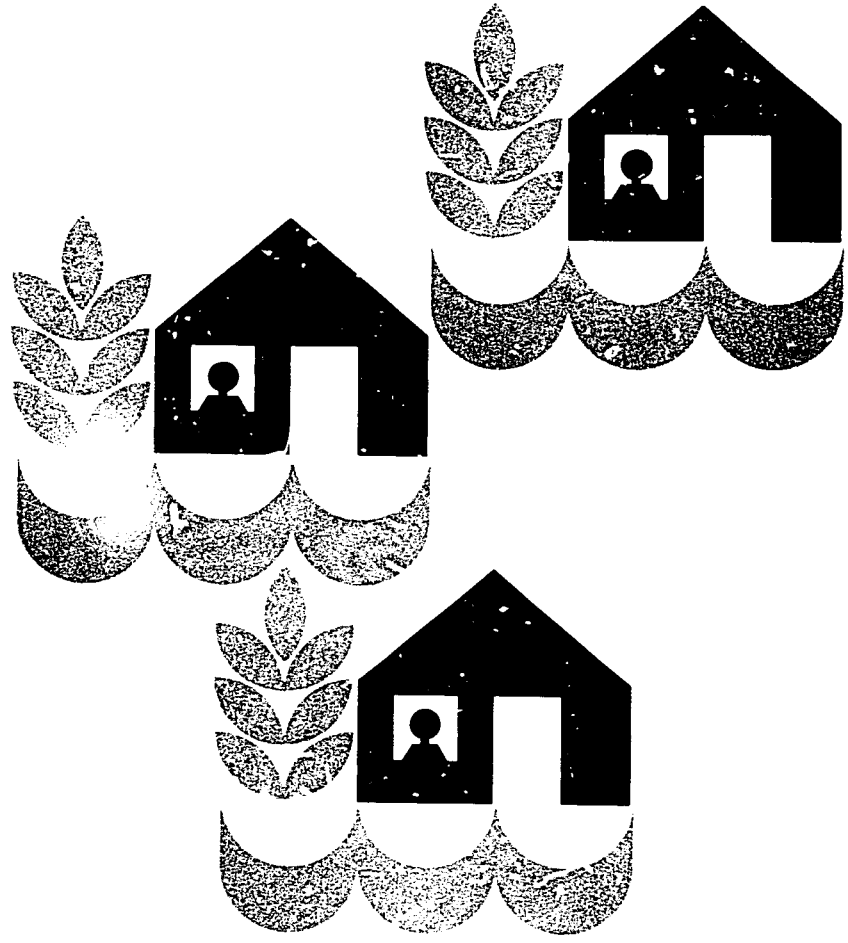
# FARM IRRIGATION STRUCTURES

## Planning Guide No. 4, Water Management Synthesis Project



# *Farm Irrigation Structures*

## *Planning Guide No. 4*

*by*

*A. R. Robinson*

*Water Management Synthesis Project*

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# INTRODUCTION

Well-designed irrigation control structures are essential to successful on-farm water management. Good structures for surface irrigation can result in more efficient water application, water savings, labor reduction, and ultimately, higher crop yields.

Farm irrigation structures, however, are often the most neglected part of the irrigation system. Today, in most countries, irrigation engineering stops at the farm watercourse. Design and construction of small canals and farm watercourses and the control structures for them are usually left to the farmers. Farmers, who have little understanding of the design of such structures, often fail to construct them properly or to use them at all. Poor design and construction and improper operation and maintenance cause structures and systems to fail. The results of this failure — widespread erosion, poor water distribution, and unreliable water supplies — lead the farmer to make fewer investments. All of these factors lower crop yields.

*Farm Irrigation Structures* examines the question of why good irrigation structures are needed and explains what structures are required. Design considerations are examined and construction and installation needs are outlined. The importance of proper system operation and continued maintenance is stressed. Finally, recommendations for improving farm irrigation structures are presented.

This planning guide is intended for those people who are concerned with the development and improvement of farm irrigation systems and agricultural production, including

*senior officials in agricultural and irrigation planning and operating agencies and departments
*development officers
*engineers
*extension agents
*technicians
*leading farmers who may construct and operate the improved systems.

*Lack of farm irrigation structures and poor operational practice have caused this farm watercourse to fail.*

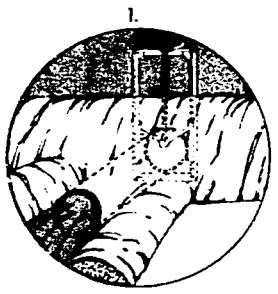
## WHAT ARE FARM IRRIGATION STRUCTURES?

Farm irrigation structures are used for water control from the outlet on a distributary canal to the farmer's field and in field ditches, channels and pipelines throughout the field. They are also used in farm drains for water removal.

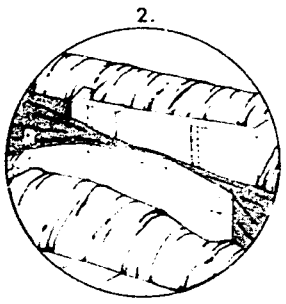
These channels, pipelines and structures are typically for flows of water from 150 liters per second to only a few liters per second. Most attention in engineering design, however, has been with flows greater than 300 liters per second to very large canals. As a matter of policy, most irrigation projects have been designed and operated, until recently, on the assumption that farm irrigation delivery systems are the responsibility of the farmer. Because farm delivery systems are small, they are often assumed to be simple. Even though that is not true, the channels and their control structures must be designed, constructed, operated, and maintained by these farmers without much assistance.

*With good control structures, there is better irrigation with less labor.*

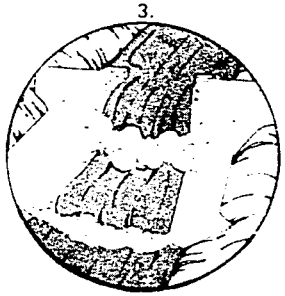
# Typical Farm Structures for Effective Delivery of Water



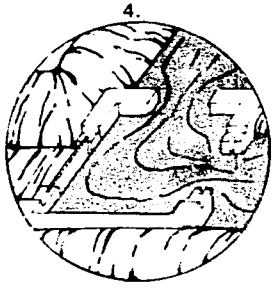

TURNOUT



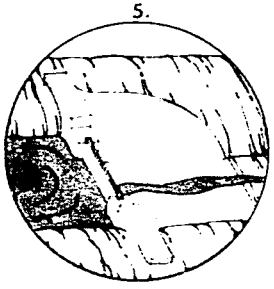

MEASURING FLUME



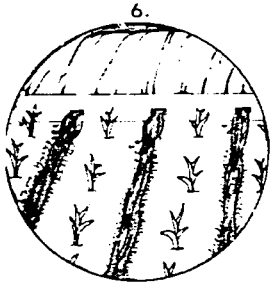

DROP



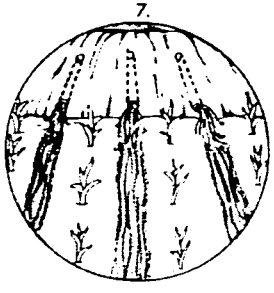

DIVISOR



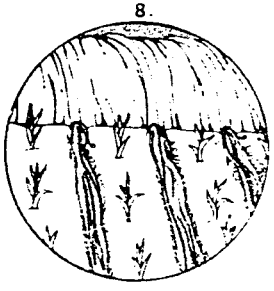

CHECK



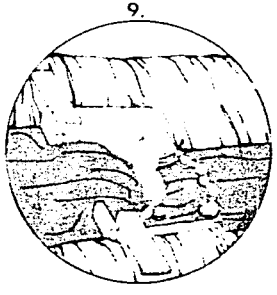

GATED PIPE




SPILES




SIPHONS

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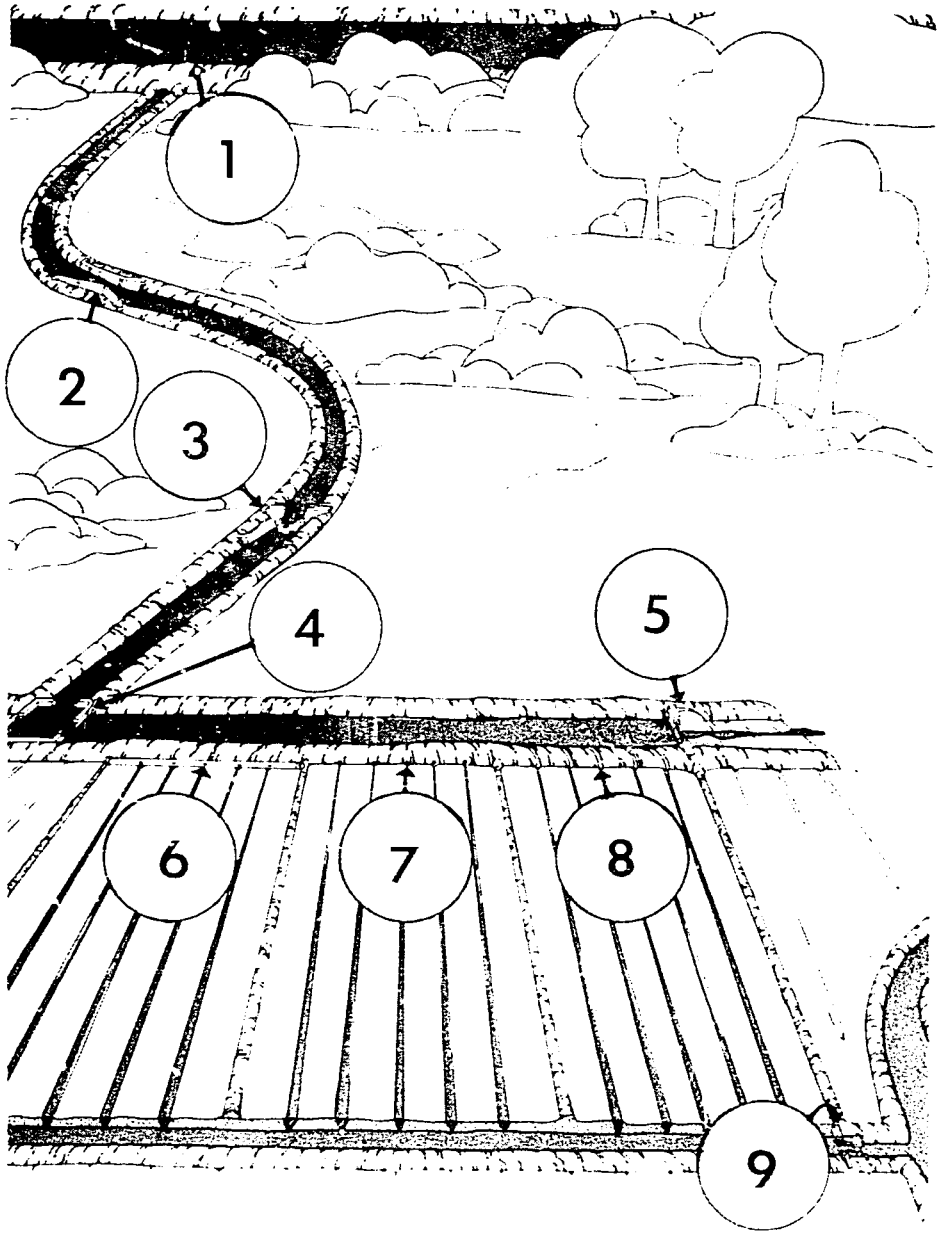


## WHY ARE FARM IRRIGATION STRUCTURES NEEDED?

There is a world-wide need for better farm irrigation structures. Irrigation structures have long been neglected because of lack of understanding about their importance and from lack of concern.

Farm irrigation structures are needed to do these tasks on an irrigation system:

*divide flow of water
(division structures)

*control velocity
(drop structures, stands)

*deliver water without erosion
(check structures, stands, risers with valves)

*measure water
(weirs, flumes, meters)

*deliver correct amounts of water
(turnouts, cuts, siphon tubes, valves, gated pipes)

The need for structures to be used in flow control can be seen, for example, when you look at an irrigation system and see a series of cuts in the ditch bank. Outlets are uncontrolled except through use of mud or soil to shut off the flow. You may also see turnouts of simple pipes without regulating gates. In those cases, the delivery of water depends upon the availability and depth of water in the delivery channel. The flow is not dependent upon soil or crop needs.

Inadequate distribution of water can be corrected through the use of irrigation structures. Structures and devices for water measurement can greatly improve distribution and promote efficient water use.

In lands where slope in the watercourse is a problem, drop structures that control the velocity of the water can regulate the system and reduce erosion.

**Benefits of Irrigation Structures**

*Irrigation structures properly installed, used, and maintained will benefit farmers in many ways including these:*

*Reduces erosion on slopes

*Controls amount of water delivered to fields

*Reduces watercourse deterioration

*Increases equitable water distribution among farmers

*Controls wastage and seepage of water

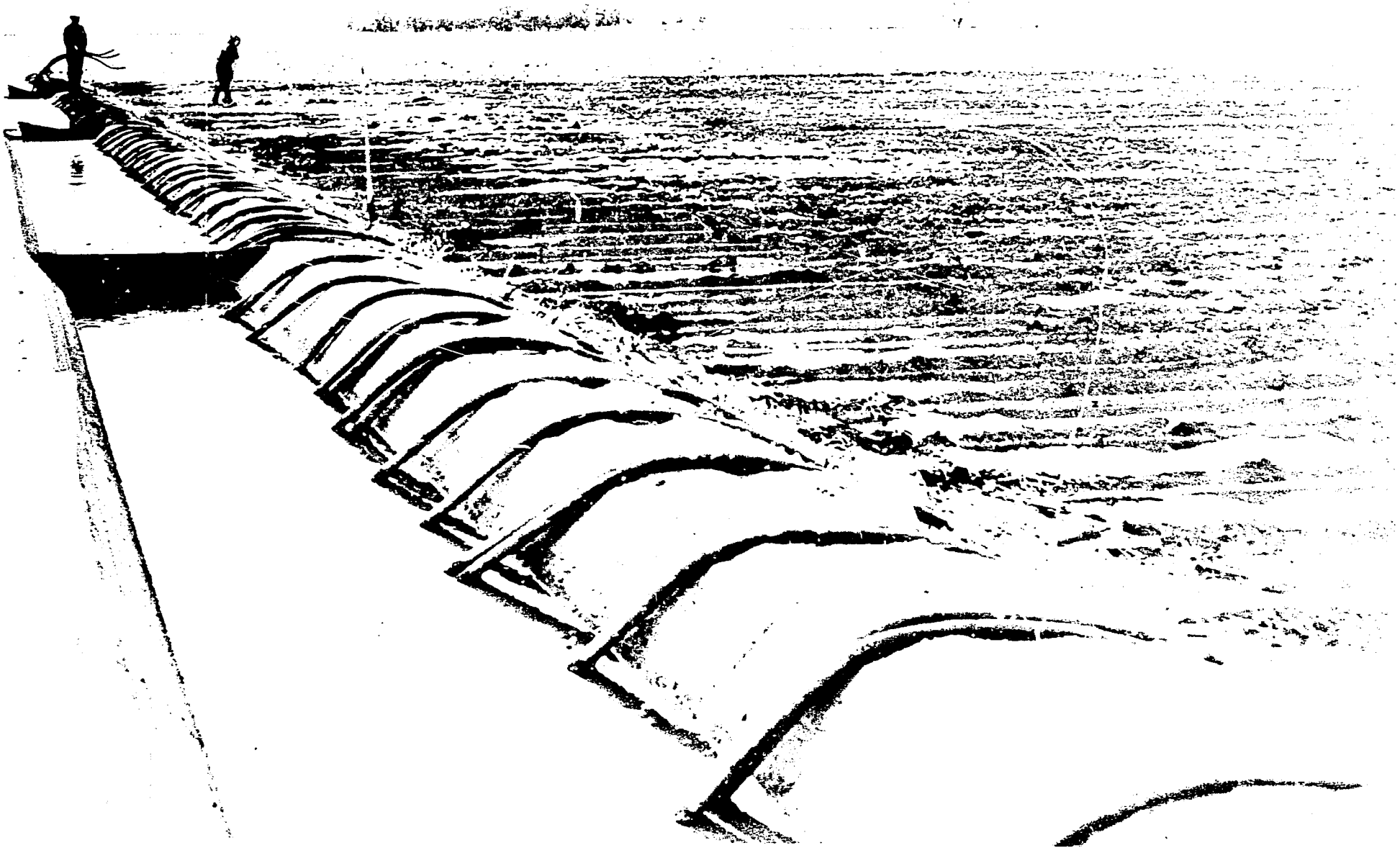
*Reduces chances of waterlogging and salinity

*These benefits contribute to the larger goals of good irrigation management:*

*More water available for crops

*More land can be irrigated properly with a dependable water supply

*Higher yields will result from better water application



*Good water management with lined watercourse using checks and siphon tubes.*

## WHAT STRUCTURES ARE NEEDED?

The small irrigation structures discussed in this planning guide include all canals, structures and devices used to deliver water by gravity to the crop. They include:

- Conveyance systems
  - -earth and lined canals
  - -pipelines (underground, surface)
- Control structures
  - -canal (turnouts, divisors, drops, checks, outlets)
  - -pipeline (inlets, stands, risers, valves, vents)
- Water measuring structures (weirs, flumes)
- Miscellaneous structures (crossings, bridges, siphons)

*Check structures are often needed in a watercourse to control irrigation water effectively.*

*Concrete canals are preferred but may be too expensive to construct.*

## CONVEYANCE SYSTEMS

Unlined earth canals are the most common means of conveying water to the fields. They are preferred by many farmers because they can be built and maintained easily by the farmer. Some disadvantages are:

- they may lose excessive water through seepage and leakage
- they are easily eroded
- burrowing rodents may cause damage
- weed growth may be excessive

Lined canals can correct many of these problems and they have the following advantages:

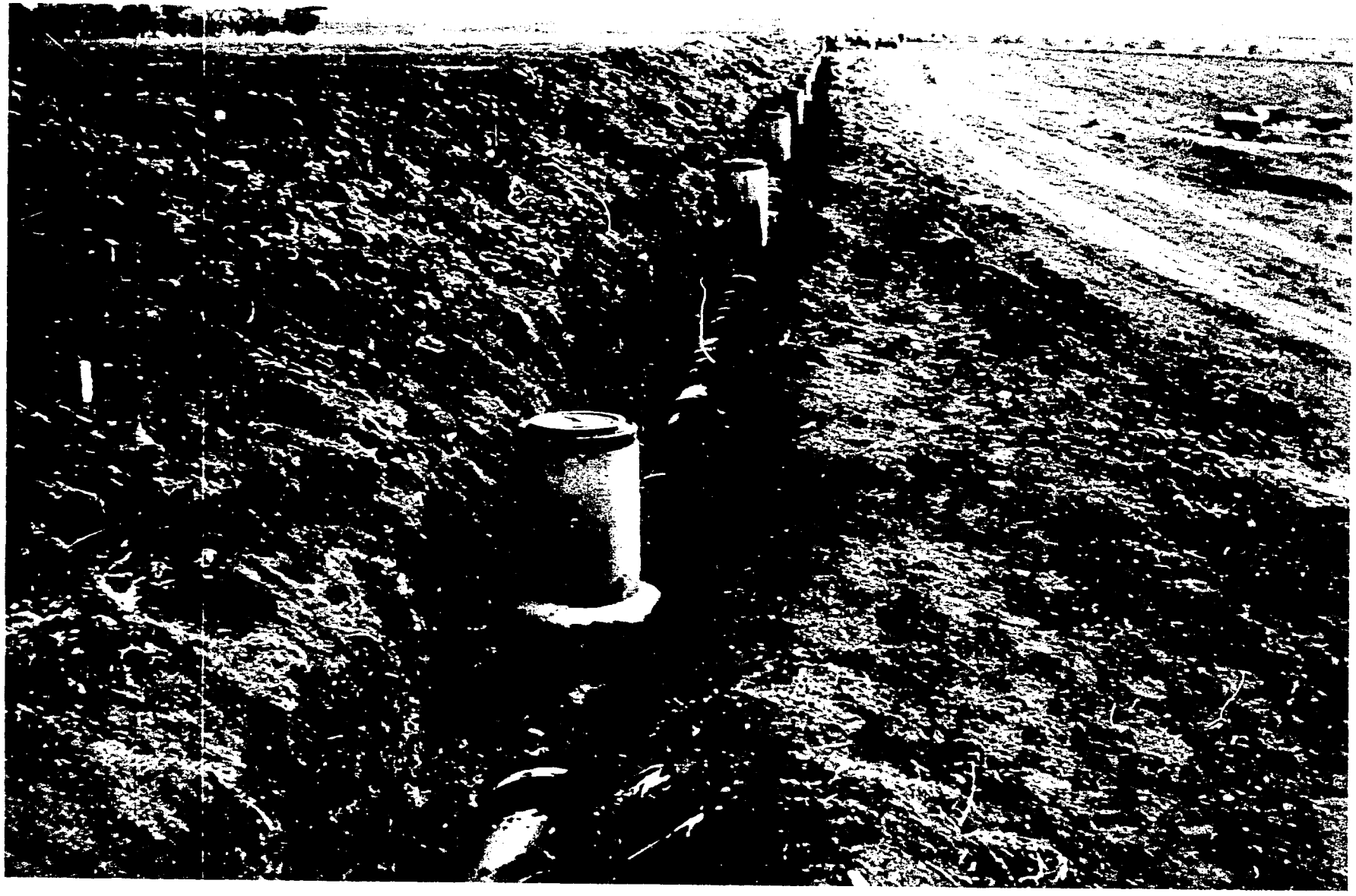
- they reduce losses from seepage and leakage
- they can provide more assured delivery of water
- they can be smaller, occupying less land than earth canals

However, lining is expensive and the cost may be prohibitive. Animals and humans can damage linings and vegetation has to be controlled.

Gravity pipe irrigation systems have many advantages over canal systems. Some advantages are:

- Minimum seepage and evaporation losses
- No loss of land occupied by ditches
- Better weed control
- Good water distribution on uneven topography
- Better control of water
- Reduced maintenance compared to surface systems

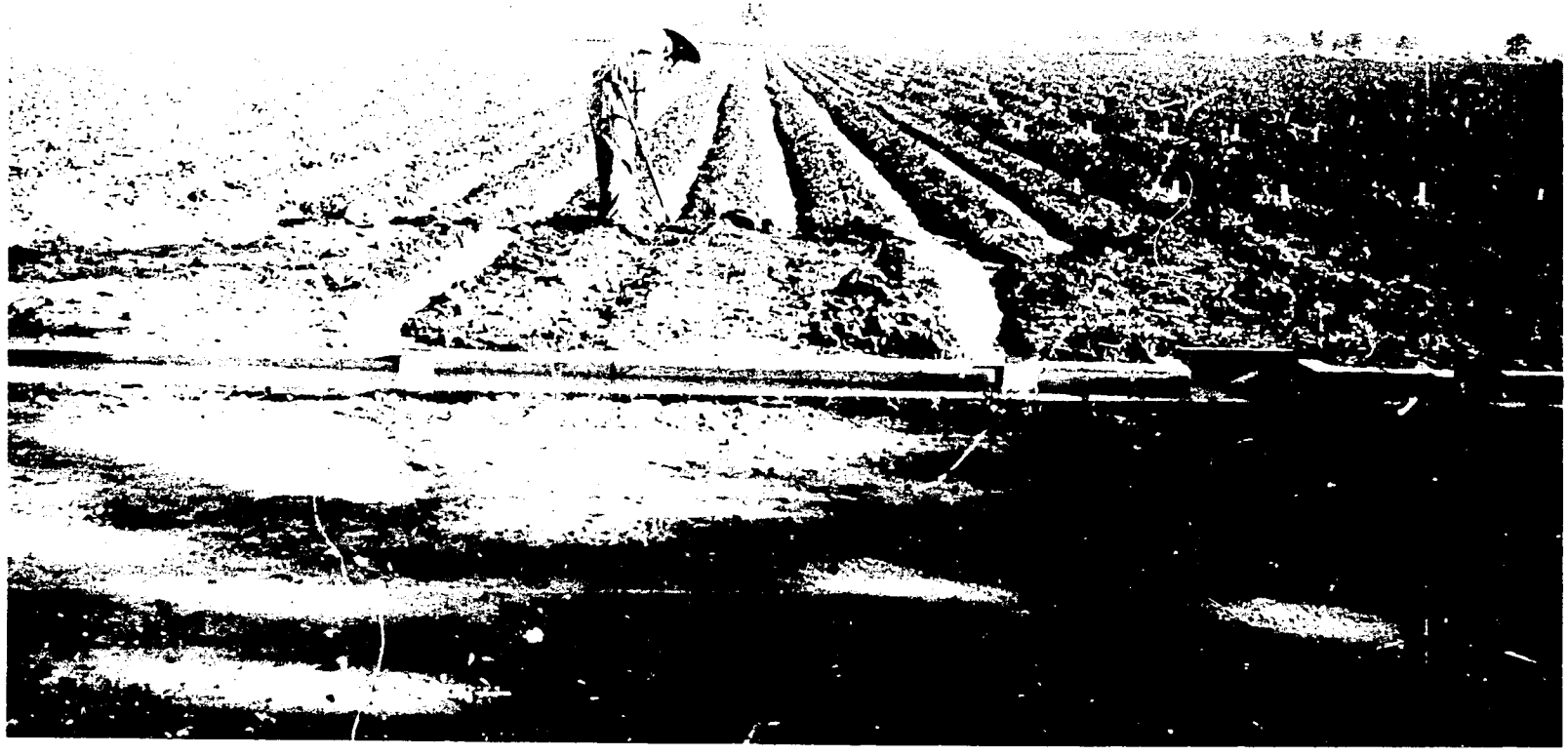
The disadvantages are high initial cost, possible leakage and damage due to vandalism and misuse. Damage may require frequent replacement.



*Underground pipe systems save land and deliver water to fields with reduced water loss. This system is under construction.*

## TURNOUTS

Turnouts or outlets are used in the conveyance system to deliver water from a small channel directly to a field. They usually include a structure with a control gate. A structure is sometimes used upstream and downstream for stability and to control erosion. Other turnout structures utilize gates, siphons and pipes. Turnouts are needed to insure an equitable supply to each field and/or farm.



*Gated outlets along the side of a lined canal.*

## MEASURING DEVICES

Measuring flumes or weirs are needed to accurately measure the irrigation water. Recently developed flumes give accurate measurements with a minimum use of hydraulic head. Pipelines may have meters in the line to measure the flow. Water measurement is necessary if water is to be allocated equitably and according to a plan.

*Measuring flumes are desired for determining the rate of water flow.*

## DIVISOR BOXES

For dividing the flow into two or more channels, divisor boxes are placed in the watercourse. The box may have movable dividers for variable divisions or be rigidly constructed for fixed divisions of flow. Divisors insure equitable distribution of water.

## DROPS

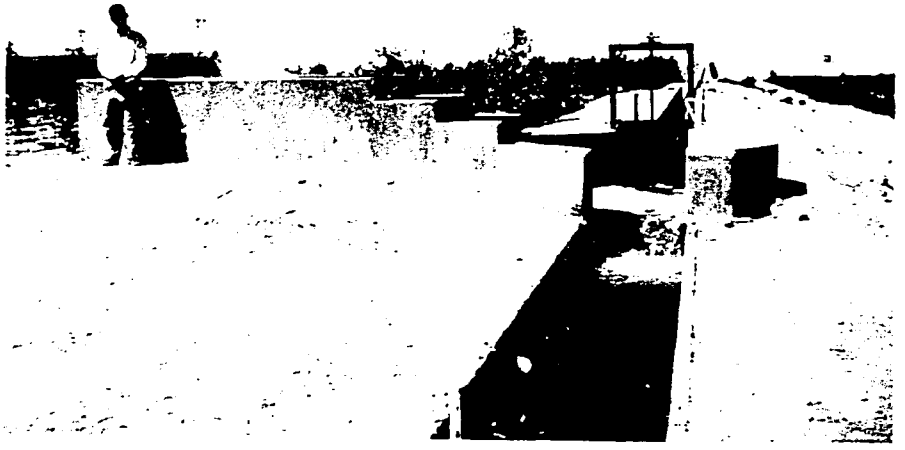
Drops are needed to control the flow velocities and to dissipate the energy in the flowing water in a protected section. The primary purpose is to drop the water level under controlled conditions. Drops are used

1) to control the water velocities upstream from the drop to prevent erosion

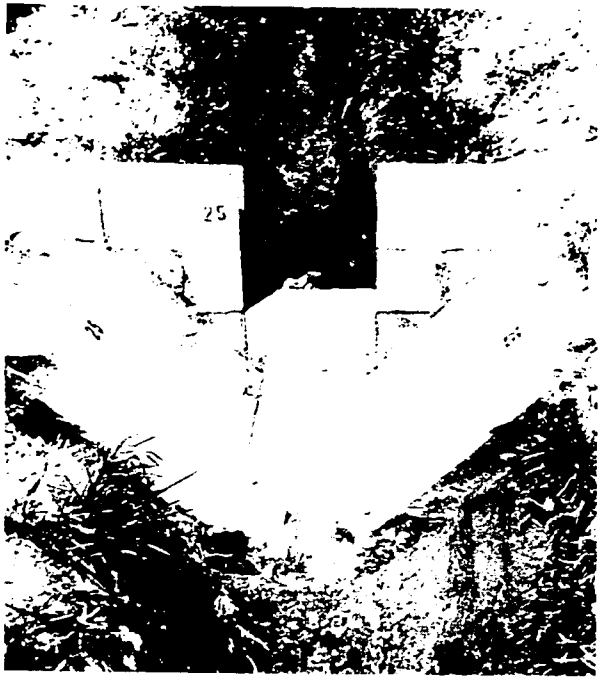
2) to drop the flow to a lower level

3) to dissipate the excess energy

4) to control downstream erosion.



*Divisors are needed so that the irrigation water can be delivered to different areas.*



*Concrete drop structure*

## CHECK STRUCTURES

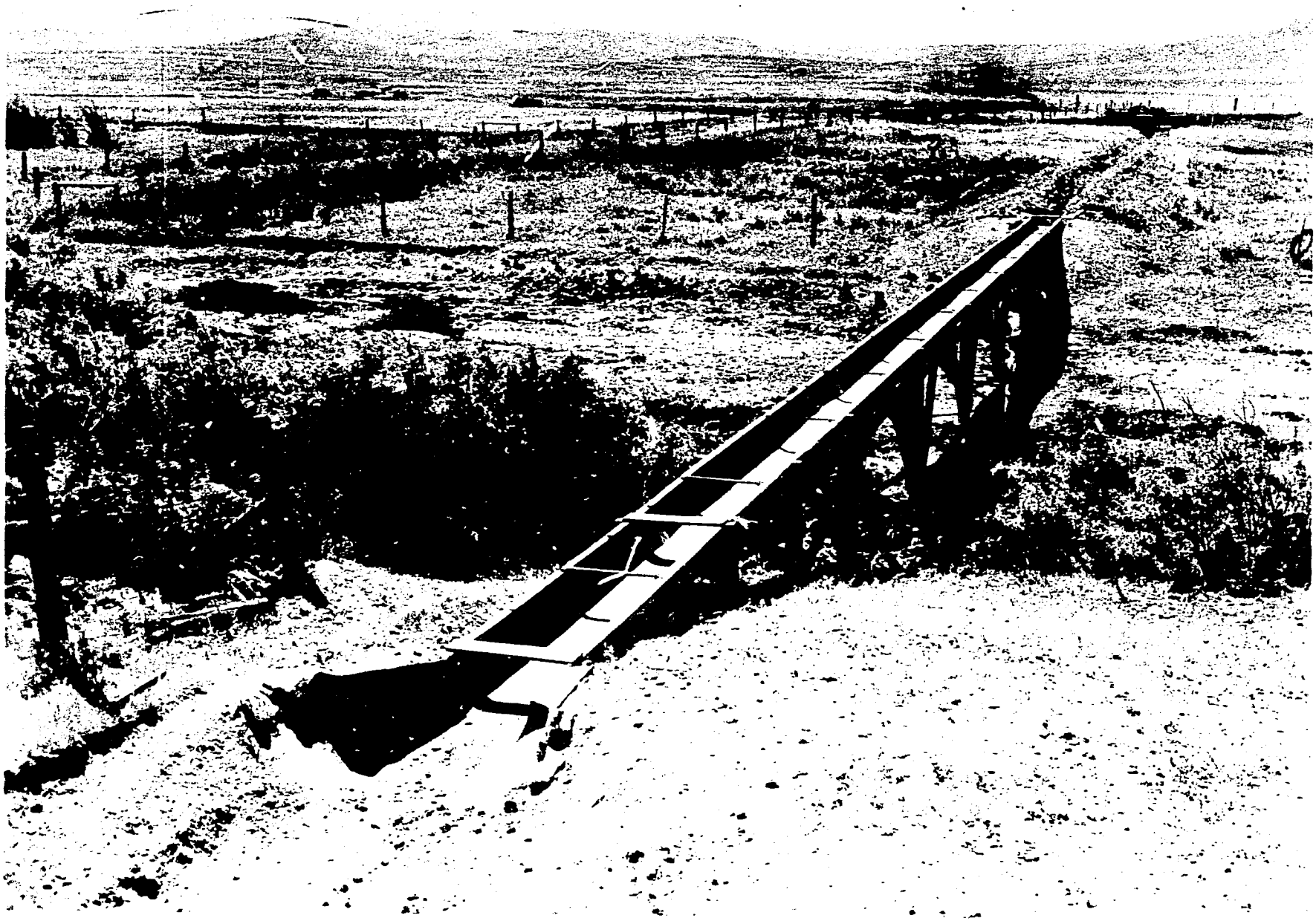
Check structures are often used as drop structures and many times are combined into one structure to control flow in a channel. The primary purpose for check structures is to regulate the level of the water surface upstream from the check. Checks may be permanent or temporary, portable or stationary. They may check the entire flow or allow a portion of it to pass.

*Movable check structures can be used in lined and earth canals.*

## OTHER CHANNEL STRUCTURES

There are other structures used for crossings, underground siphons, culverts and bridges. These structures are used to prevent damage to the channel and to provide a crossing for traffic to use. Trash racks are sometimes used where there is a great amount of weeds and trash, particularly at the entrance to pipelines.

*Culverts provide a bridge over the watercourse, reducing damage by animal and human traffic across the watercourse.*



*Irrigation trestle flume for crossing depressions.*

## PIPE SYSTEMS

Pipe systems have the advantage of saving land since the systems can be partly underground and the pipe can be movable and/or removable. There is better control of water, fewer weed problems and less water loss.

Three types of low-pressure pipe systems are used for gravity irrigation.

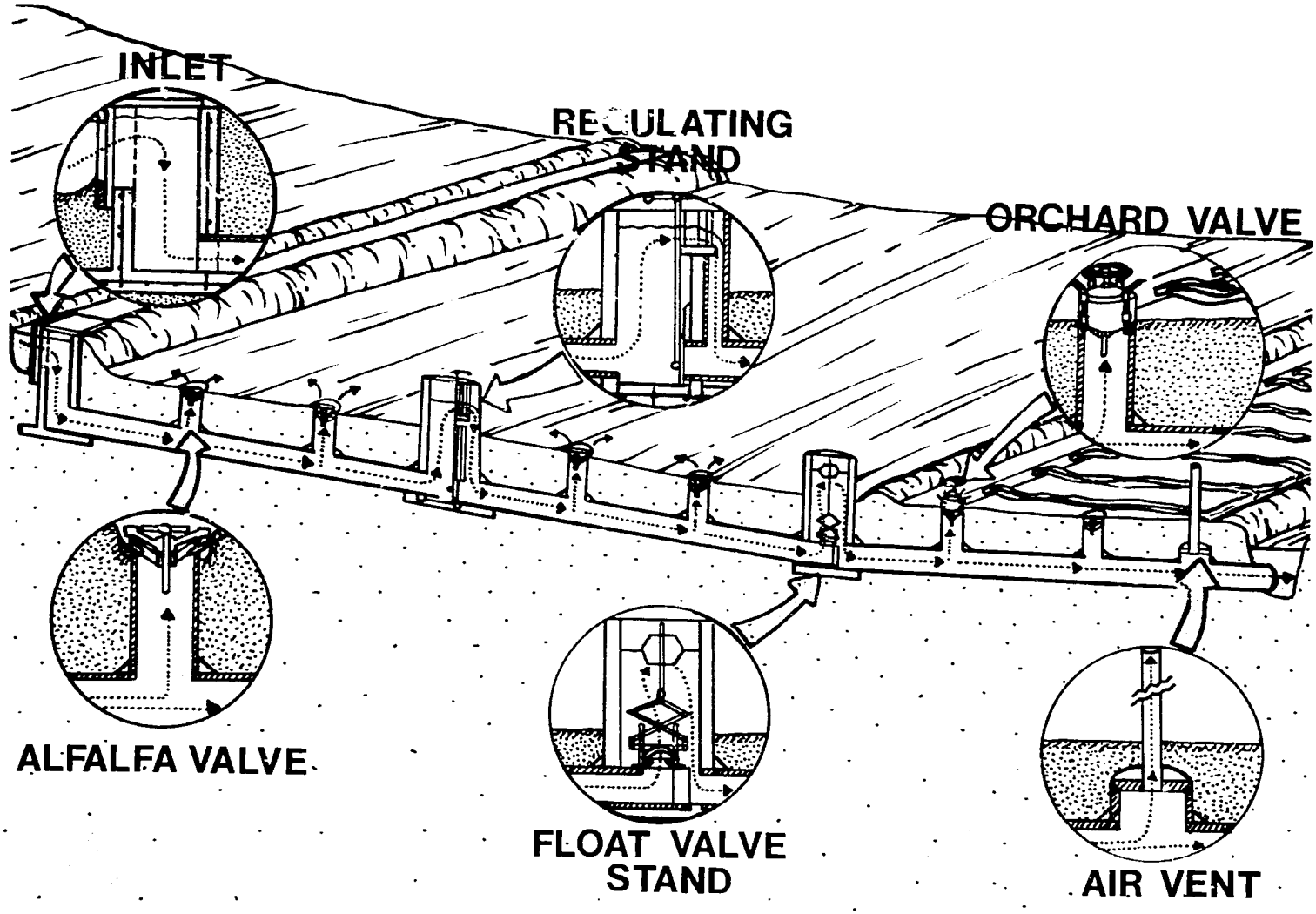
1. *Buried pipe*--Water enters from a canal or pump and is delivered by risers to the surface where it is used directly to irrigate. Structures are required at the inlet, stands and air vents are needed to regulate the pressure, and risers and valves are necessary to deliver water to the fields.

2. *Combination of buried pipe and portable surface pipe attached to risers.* The surface pipe is usually gated so the water is delivered at many points along the pipe.

3. *Portable surface pipe*--receives water from a pump or directly from a canal. Frequent gate openings along the pipe are used to deliver water to rows and furrows.

*Buried pipeline under construction with mortar joints.*

*Gated aluminum surface pipe*




*Schematic diagram of an underground concrete pipeline with appropriate control structures.*

## WHAT ARE DESIGN CONSIDERATIONS?

Small irrigation structures must be adapted for use in particular areas depending on flows, availability of materials, labor, skills, financing, irrigation methods, customs and water delivery schedules. Small, low cost structures that can be built and installed with local labor and materials are required. The structures must be very durable, easy to adjust, relatively leakproof and give good control. Both permanent and portable structures are required.

The important considerations for design include:

1. availability of water requiring division, equitable delivery, and minimizing leakage, spillage and seepage
2. water delivery system to be used; i.e., demand, continuous flow, or rotation
3. type of field irrigation system
4. area topography and available hydraulic head for the system
5. area served by each watercourse and/or pipeline
6. crops to be irrigated
7. amount of time each watercourse is used and number of times each turnout is used
8. the number of turnouts and the amount of regulation for each
9. need for regulating flow depths in the system requiring either permanent or temporary checking or both
10. importance of minimizing head loss in the system
11. need for flow measurement
12. availability of materials and labor

Social and economic considerations are very important for the improved system and include:

1. Availability of skills and cost of labor for construction and irrigating
2. cost of materials
3. marginal cost or value of water
4. availability of capital to finance the improved system
5. organization of the water users or lack thereof
6. crops and cropping systems
7. experience and understanding of the users
8. cooperative nature of the users
9. pride in ownership
10. potential theft problems of the structures and materials for other uses

In some areas there are other design factors that must be considered; such as domestic uses, washing and bathing, and need for animal access.

*A watercourse designed for effective water control would include provision for water measurement.*

## WHAT ARE CONSTRUCTION AND INSTALLATION NEEDS?

The small structures and watercourses require an emphasis on economy and simplicity for construction and installation. They must be durable, reliable, and easy to adjust and operate.

### STRUCTURES

Three types of construction predominate in most areas:

*Brick masonry with cement mortar covering the surface is most common. Poured concrete footings and slabs are generally used to place the brick structures.

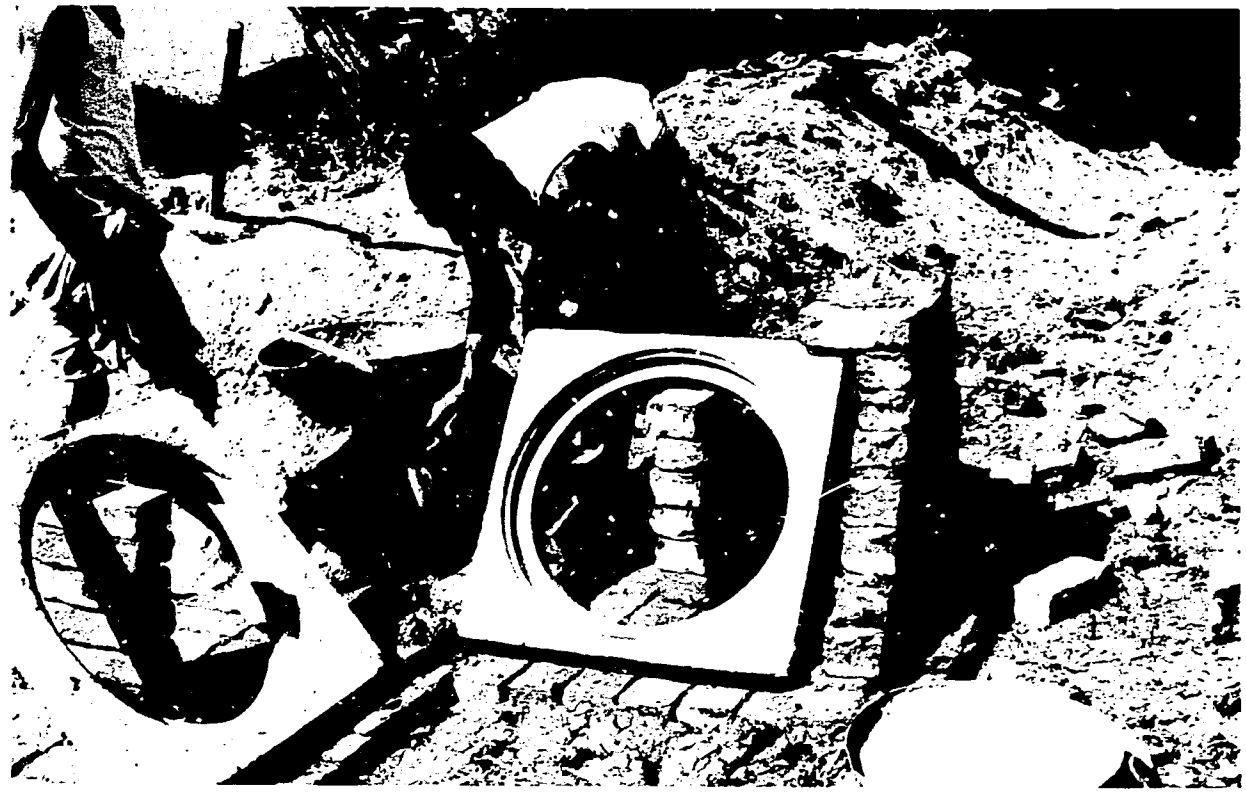
*Concrete blocks, precast sections and entire precast structures are common. The sections may be flat rectangular or part circular, parabolic or trapezoidal shaped, and used to form linings and/or structures.

*Poured-in-place concrete structures and linings are in limited use.

Metal and wood structures are rarely used because of material shortage.

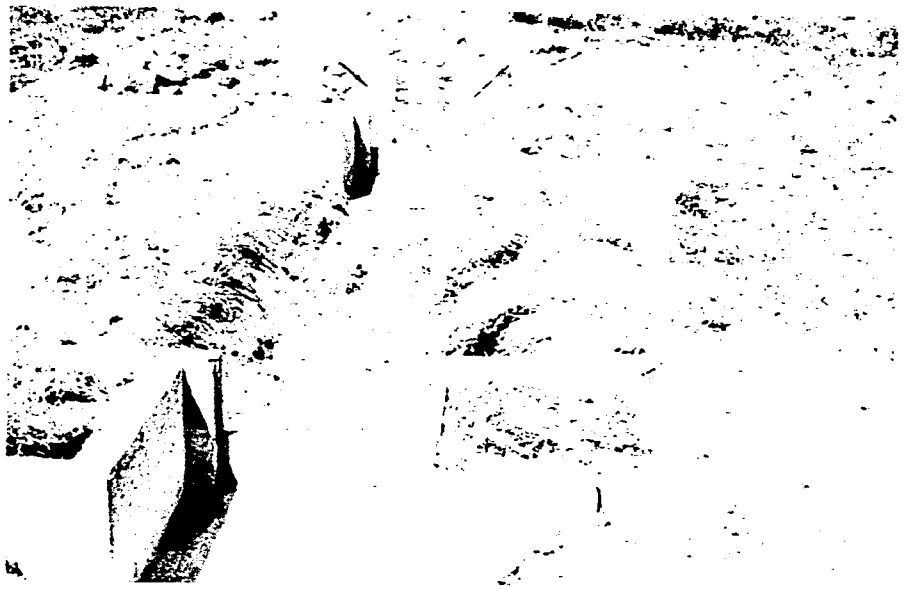
Small irrigation structures usually require a concrete pad, slab or footing placed on compacted soil. Poured-in-place concrete structures require forms, properly braced and tied. Brick structures are placed using the best local practice and the water-side covered with a layer of mortar. After the concrete and/or mortar for the structures has had time for complete curing (usually 5 days), they should be carefully backfilled. Many failures occur because of improper backfilling and poor compaction of the base.



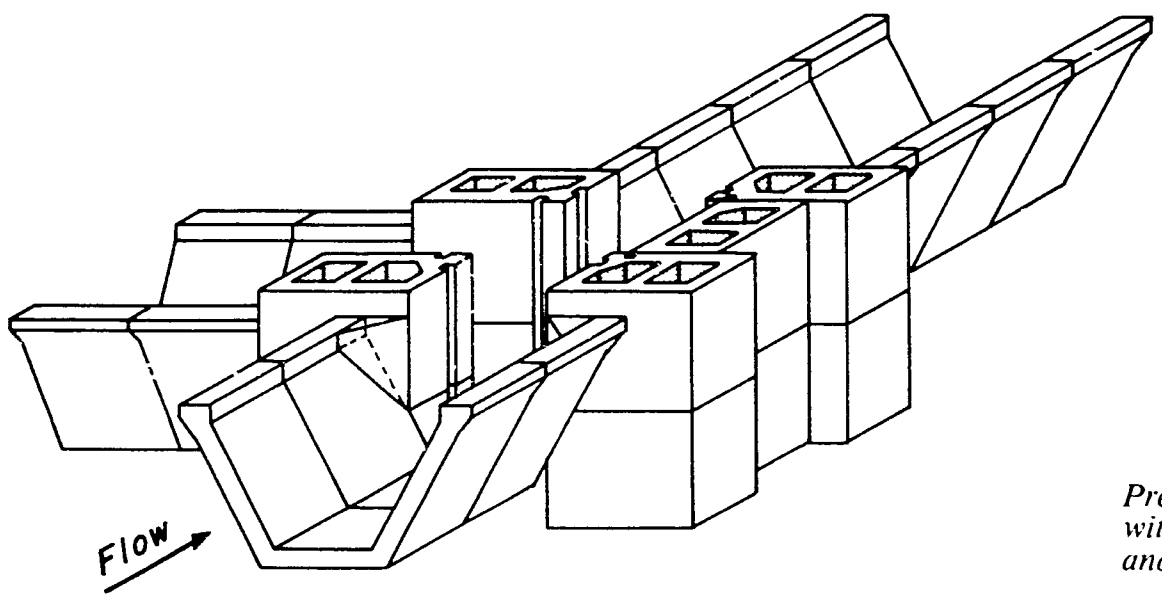


*Brick masonry installation of concrete turnout structures developed in Pakistan.*

*Concrete block drop structure*



*Poured-in-place concrete drop structure*




Isometric View

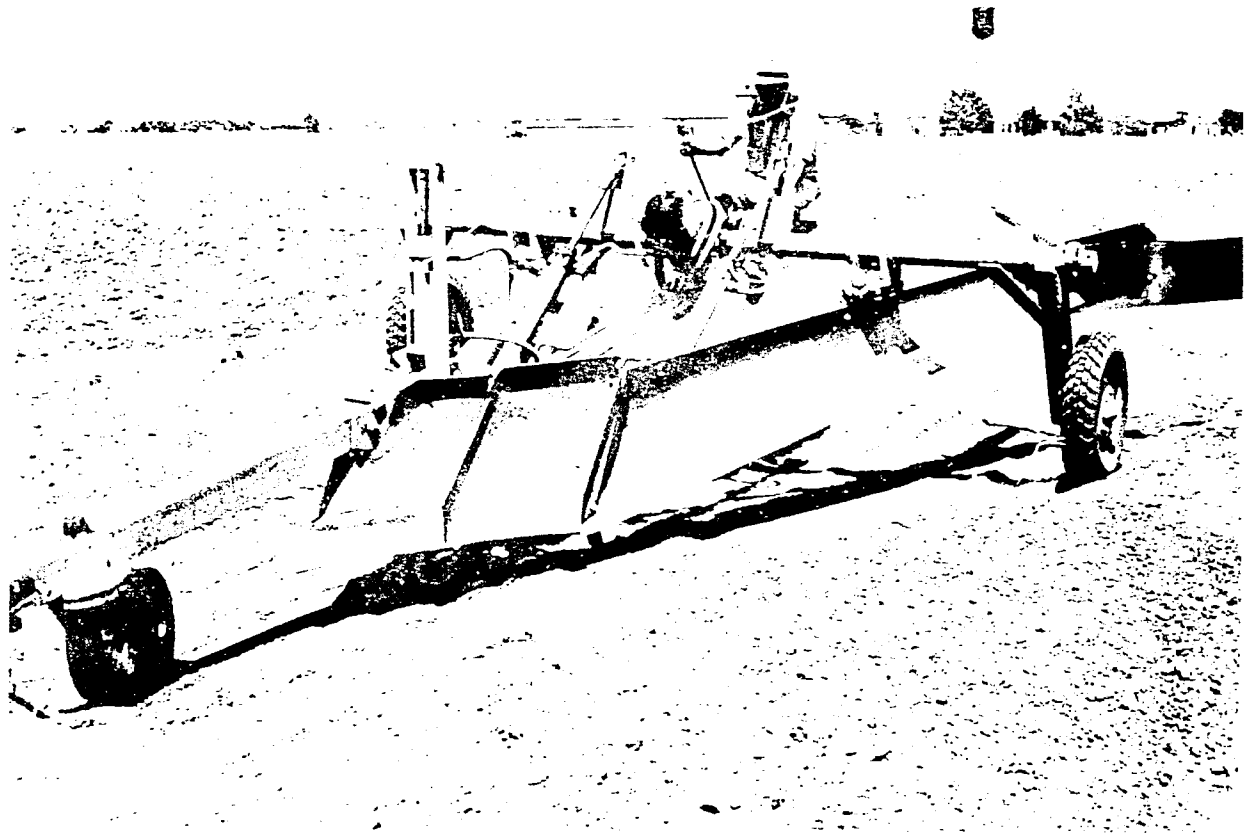
*Prefabricated sections made at the site with portable equipment are assembled and mortared in place.*

## FARM CHANNELS

Small, earth irrigation channels are formed by hand labor, with animal-pulled equipment, or with mechanized plows.

Brick or concrete-block masonry, poured concrete, and precast concrete sections are commonly used in lined canals. Asphalt and plastic lining have been used to a limited extent.

Before placing the lining, the soil should be dampened and compacted. The concrete and mortar mix should follow specifications and should be thoroughly mixed, preferably with a mechanical mixer. Steel reinforcement is generally not needed for small sections, but contraction joints should be provided about 5 meters (15 feet) apart. Brick-lined canals are usually covered with a mortar layer.



*The mechanized plow will form the earth ditch.*

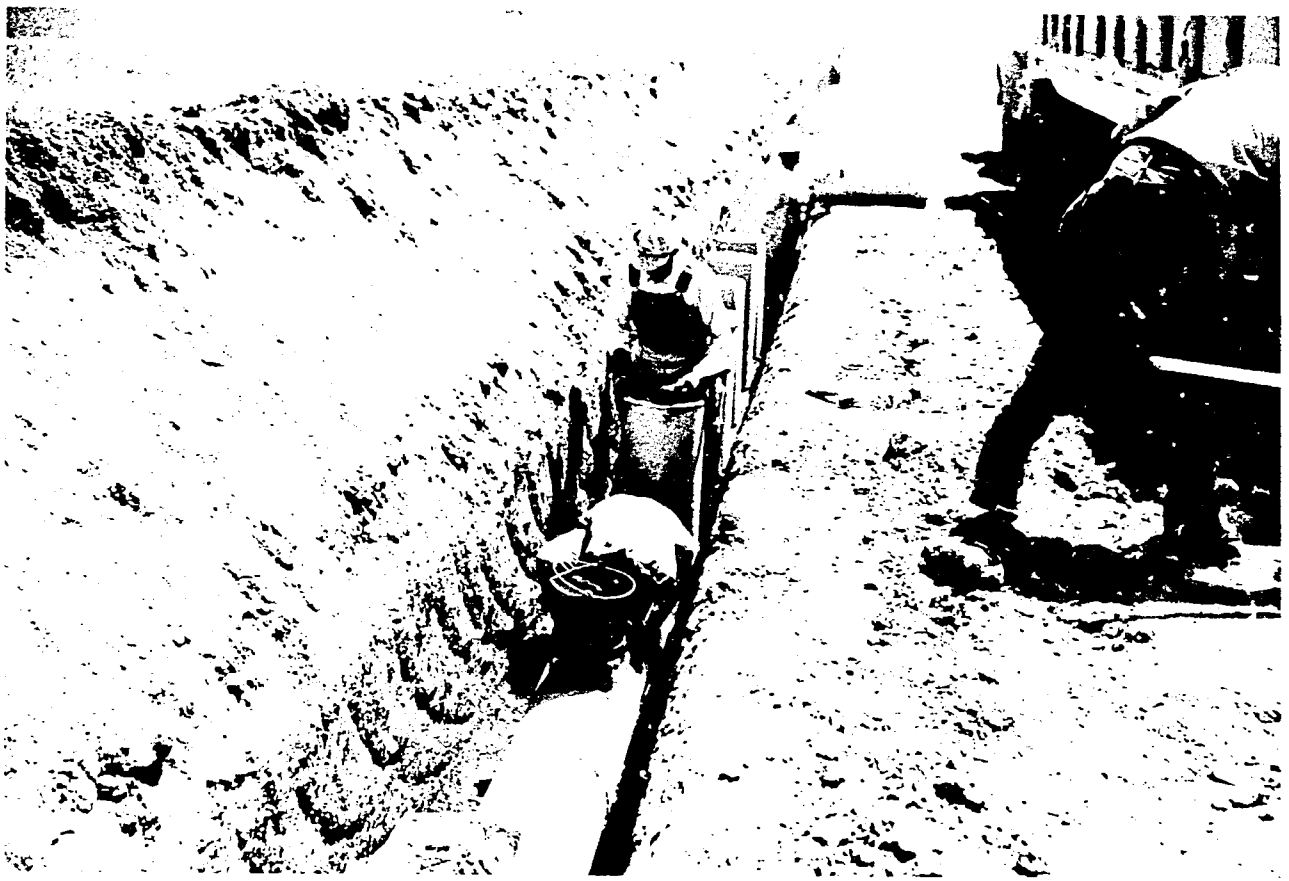
*Concrete lining placed with movable forms.*

## PIPELINES

Construction, installation and testing of low pressure pipe systems should follow specifications similar for those given by the American Society of Agricultural Engineers. The construction of underground pipelines usually requires more specialized equipment and supervision than for surface systems.

Pipe trenches are excavated deep enough that there is ample earth cover over the pipe. The pipe must lay flat on the earth throughout its length. Backfilling is carefully made to insure that the pipe is not crushed. Concrete pipe is commonly used, but plastic, asbestos, cement and fiberglass are also installed.

Structures for pipelines are almost always made from concrete pipe set on a poured concrete pad.



*Concrete pipeline with mortar joints and attached risers for valves.*

*Pipe systems provide better control and less maintenance than open channel systems.*

## WHAT ARE OPERATION AND MAINTENANCE REQUIREMENTS?

The proper operation of an irrigation system depends on an organizational structure that will insure equitable water delivery to the users. For equitable delivery, there must be water measurement, good conveyance systems and positive controls.

A farmer organization is needed to equitably deliver the water based on availability, right, and land holding of each individual. One individual employed or designated by the farmer organization should be responsible for water delivery and also for recommending maintenance needs for the system.

Good maintenance of the irrigation systems and structures is necessary for the delivery of water. Sediment, debris and vegetation must be removed, and cracked or deteriorated features must be repaired. Ditch erosion, bank caving, and weak or low spots in the ditch banks should be corrected. If erosion is occurring, changes in or additions to the ditch structures may be needed. Placing crushed rock or coarse gravel along the bank and bed in areas where erosion is occurring may help reduce erosion.

Maintenance of small on-farm watercourses, pipelines and structures is the responsibility of the farm owner, cultivator, and operator. Many times the cleaning and maintenance of the system is neglected in lieu of more pressing farm tasks. Farm owners should take prime responsibility, or else require regular maintenance of systems as a part of operator-renter contracts. The importance and advantages of good maintenance of systems should be stressed with extension-type programs and publications.



*Concrete lined canal with siphon tubes for irrigating. Checks can be placed in the ditch to irrigate the desired section.*

*Concrete drop structures must be properly designed to operate effectively.*

## USE AND MISUSE OF IRRIGATION STRUCTURES

Irrigation structures, when properly designed, constructed and operated, will save labor and water, improve irrigation applications, and increase crop yields. Several areas where structures must be correctly designed, constructed and operated are the following:

1. Both channel and pipeline structures must have a foundation, such as a concrete slab, that will support the structure without cracking, moving or tilting. Cracking of a concrete or masonry structure will cause failure.

2. Flow overtopping of both channel and pipeline structures is a common problem. Channel structures must be designed so that the flow spills in the channel and does not run over the bank. Pipeline structures must have provisions for spilling within the structure and not over the top.

3. Attention must be given to seepage around the structures which will result in failure. Careful backfilling of the structure is important. Most small structures require cut-off walls, usually on the upstream and downstream ends to prevent seepage. Pipelines on slopes require supporting collars.

4. Leaks at pipe joints and where pipe joins with structures are serious and must be repaired.

5. Turnouts should be controlled with gates that are easily opened and/or closed, do not leak and can be locked in place.

6. Sediment deposition upstream from check structures is a common problem resulting in the need for more ditch cleaning. The sediment can be partially eliminated by lowering the check, resulting in high velocities in the ditch section. The desired velocity is one where there is no scour and no deposition.

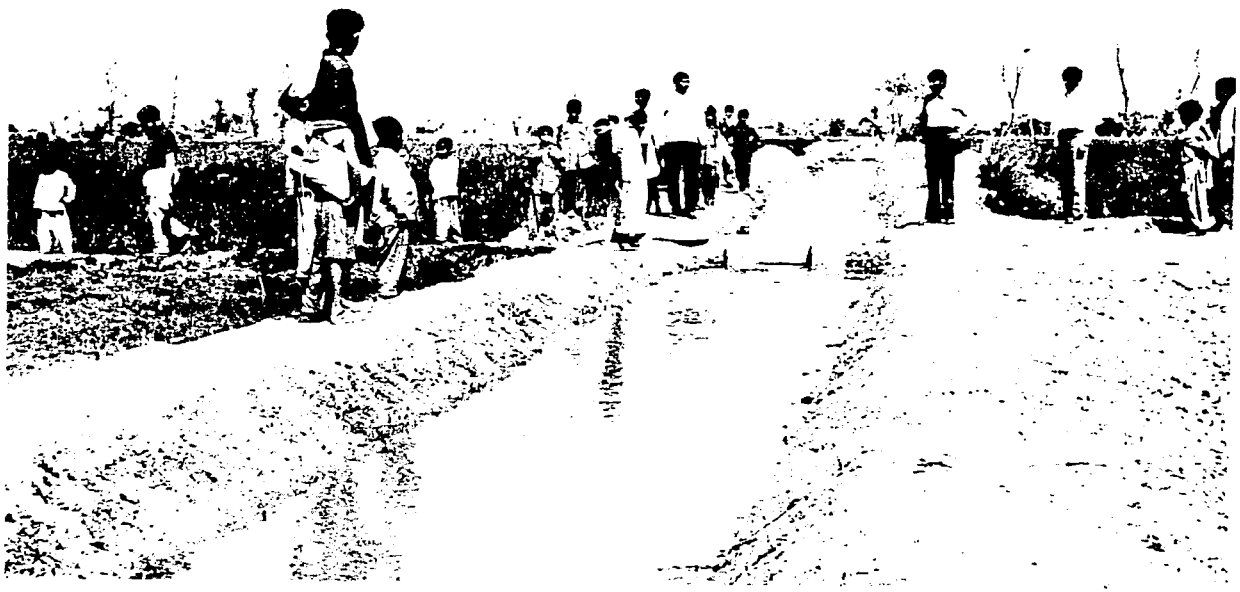
7. Erosion of channels due to poor design and use of structures is also common. A common problem is the design of drop structures with attention only to downstream erosion control. Many times these structures actually aggrevate upstream channel erosion due to improper checking of the water surface at the drop.

## RECOMMENDATIONS

There is a world-wide energy shortage and more emphasis is being placed on gravity irrigation systems that are energy efficient for production of food and fiber. Most of the gravity irrigation systems have been in use for many decades and need to be improved. Some of the results of improvement programs will be:

- more efficient use of water
- better distribution
- water saving
- better crops
- labor saving

Educational programs need to be established to work with the farmers, farmer organizations, and governmental agencies to promote programs for improvement of the farm irrigation systems. Farmer organizations are needed to assist in planning and construction, and to supervise the operation. Governmental agencies should furnish designs of the systems. Avenues are required for funding the needed improvements and construction. Evaluations are needed, after construction, to determine future changes in design, operational procedures and to give guidance for additional programs.



*Irrigated agriculture needs adequate water control through farm irrigation structures to function efficiently.*

# Farm Irrigation Structures Planning Guide

This planning guide was prepared by staff of the Water Management Synthesis Project of the Consortium for International Development, with Colorado State University and Utah State University serving as lead universities. It is also available in Spanish and French.

Prepared in cooperation with the United States Agency for International Development under contract AID-DSAN-C-0058.



September 1982

Prepared by

A. R. Robinson, agricultural engineer
Dan Lattimore, editor
Wayne Clyma, project co-director
Jack Keller, project co-director
Darlene Velder, copy and layout
L. Worth Fitzgerald, AID

For more information about the project or for a copy of the complete Handbook on Farm Irrigation Structures, contact

Water Management Synthesis Project
Engineering Research Center
Colorado State University
Fort Collins, CO 80523 USA
(303) 491-8285

Water Management Synthesis Project
Ag & Irrigation Engineering
Utah State University
Logan, UT 84322 USA
(801) 750-2785