

Technical Brief No.42: Small-scale irrigation design

Small-scale irrigation can be defined as irrigation, usually on small plots, in which small farmers have the controlling influence, using a level of technology which they can operate and maintain effectively. Small-scale irrigation is, therefore, farmer-managed: farmers must be involved in the design process and, in particular, with decisions about boundaries, the layout of the canals, and the position of outlets and bridges. Although some small-scale irrigation systems serve an individual farm household, most serve a group of farmers, typically comprising between 5 and 50 households.

Small-scale irrigation covers a range of technologies to control water from floods, stream-flow, or pumping:

Stream diversion (gravity supply)

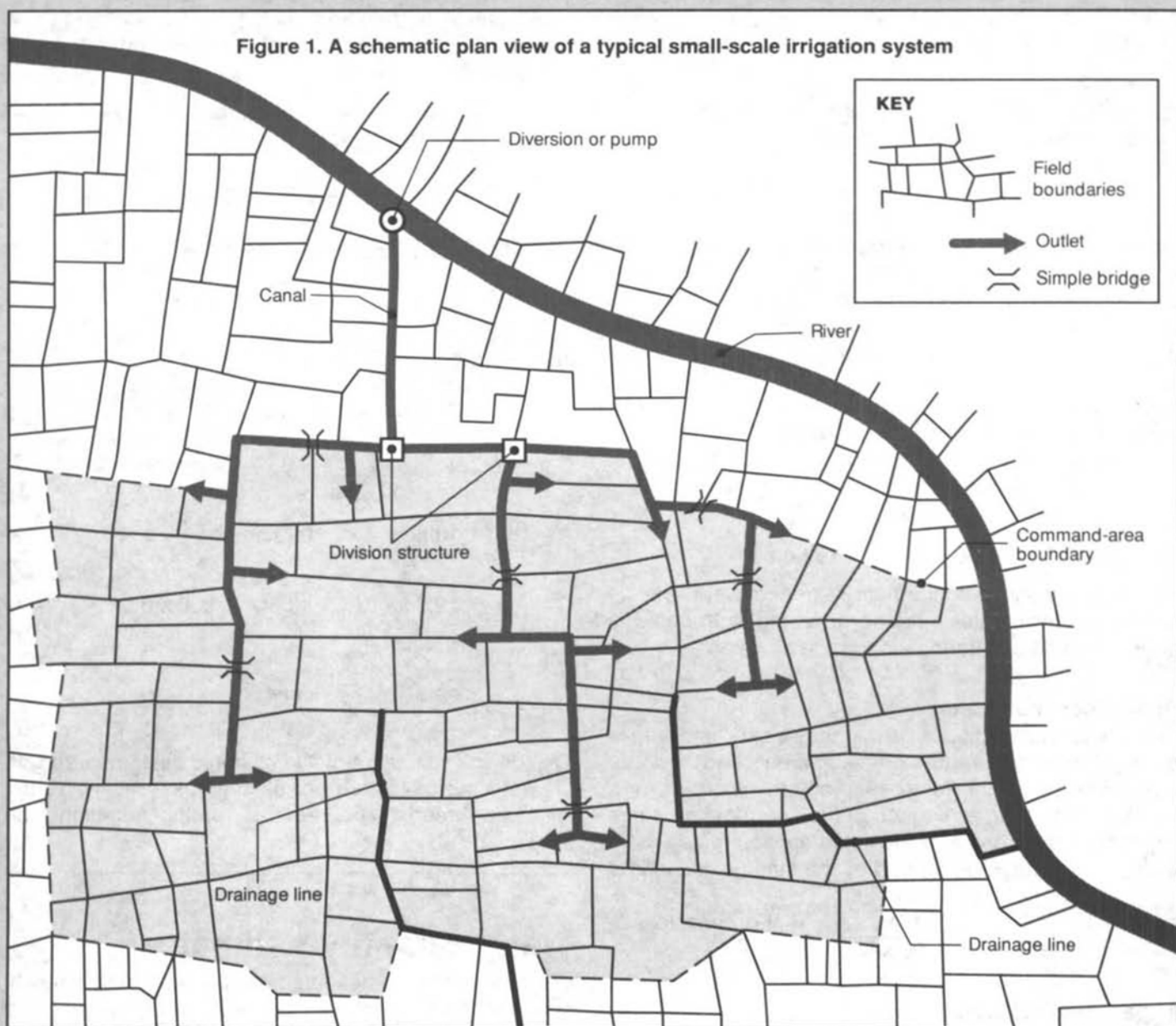
- Permanent stream diversion and canal supply.
- Storm spate diversion.
- Small reservoirs.

Flood cropping

- Rising flood cropping (planted before the flood rises).
- Flood/tide defence cropping (with bunds).

Lift irrigation (pump supply)

- From open water.
- From groundwater.



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Water requirements and irrigable area

Crops require a large amount of water for irrigation, and it is important to calculate water requirements accurately, both to design the supply canal and the pump (if any), and to check that enough water is available from the source.

The amount of water required by a crop depends on the local environment, the climate, the crop and its stage of growth, and the degree to which the crop may be stressed. This requirement may be expressed as a uniform depth of water over the area in millimetres per day (mm/d).

Irrigation requirements

Reference evapotranspiration (ET_o) is the water use of grass (in mm/d) under standard conditions. Local estimates may be available from meteorological offices. Typical values are shown in Table 1. For most crops, the reference evapotranspiration at mid-season can be taken as a reasonable estimate of the peak water requirement.

It is reasonable to assume that 70 per cent of average rainfall is available to the crop; the net irrigation requirement (I_n mm/d) can be estimated as:

$$I_n = ET_o - (0.70 \times P)$$

where P (mm/d) is the average rainfall. If a personal computer is available, then the reference evapotranspiration and net irrigation requirements can be estimated conveniently and accurately using the FAO CROPWAT program and the CLIMWAT database.

Additional water has to be supplied to take account of field-application losses which, with surface irrigation, are typically about 40 per cent, giving an application efficiency of 0.60. The field irrigation requirement (I_f) can be estimated as:

$$I_f = \frac{I_n}{0.60} = \frac{ET_o - (0.70 \times P)}{0.60}$$

The field irrigation requirement represents the rate (in mm/d) at which water must be delivered to the field to prevent the crop suffering a shortage of water.

Design command area

The required canal discharge depends on the field area to be irrigated (known as the 'command area'), and the water losses from the canal. For a design command area A (m^2), the design discharge required Q (l/s) for irrigation hours (H) every day, is given by the field-irrigation requirement multiplied by the area, divided by the time (in seconds):

$$Q = \frac{I_f \times A}{H \times 60 \times 60} \quad \text{plus canal losses}$$

Irrigation-canal losses

Water is lost from canals by seepage through the bed and banks of the canal, leakage through holes, cracks and

poor structures, and overflowing low sections of bank. The canal losses depend on the type of canal, materials, standard of construction and other factors, but are typically about 3 to 8 litres per second (l/s) per 100 metres for an unlined earthen canal carrying 20 to 60 l/s. Losses often account for a large proportion of water requirements in small-scale irrigation, and may be estimated by 'ponding' water in a trial length of canal, and then measuring the drop-of-water level. When the water-surface width in the canal is W metres, a drop of S millimetres per hour corresponds to an average canal loss of:

$$\frac{W \times S}{60 \times 60} \quad \text{l/s per metre length}$$

Example: What design discharge is required for a canal to irrigate an area of 10 hectares in the semi-arid subtropics, when the mean daily temperature is 30°C, and the mean rainfall is 0.2 mm/d during the peak period (mid-season)? The canal is 800m long and is to operate for 12 hours per day.

Losses from a similar canal are measured as 48mm per hour with a water-surface width of 1.5m.

$$ET_o = 7.5 \text{ mm/d; (see Table 1)}$$

Hence the net irrigation requirement is:

$$7.5 - (0.7 \times 0.2) = 7.36 \text{ mm/d;}$$

and the field irrigation requirement is:

$$7.36/0.60 = 12.3 \text{ mm/d}$$

$$\text{Canal losses} = \frac{48 \times 1.5}{60 \times 60} = 0.02 \text{ l/s per metre length}$$

$$A = 10 \text{ ha} = 10 \times 10000 \text{ m}^2$$

$$Q = \frac{12.3 \times (10 \times 10000)}{12 \times 60 \times 60} + 800 \times 0.02$$

$$= 28 + 16 = 44 \text{ l/s}$$

This design discharge of 44 l/s should be compared with the water available from the source. If less is available, the area may need to be reduced, or the irrigation time increased.

Water-quantity estimates

Discharge may be measured using a float, a stopwatch, and tape (for a river), or a weir with a stick gauge (for a small stream or borehole). Technical Brief No. 27 gives details of these methods.

Canal design

Water may be conveyed from the source to the field by unlined or lined canal; pipeline; or a combination of the two. The unlined canal is the most common method in use.

A typical cross-section of an unlined earthen canal for small-scale irrigation is shown in Figure 2. To minimize losses, the canal banks should be built from clayey soil and constructed in layers, with each layer compacted using heavy rammers.

The required size of the canal can be decided using Manning's formula:

$$Q = \frac{A \times R^{0.67} \times s^{0.5}}{n}$$

- Q = discharge (m³/s. Note: 1 m³/s = 1000 l/s)
- A = wetted area (m²)
- R = hydraulic radius (m)
(= wetted area/wetted perimeter)
- s = slope (fraction)
- n = Manning's roughness coefficient
(commonly taken as 0.03 for small irrigation canals)

A design chart, such as Figure 3, can be used.

For example, for a trapezoidal canal in clay soil with side slopes of 1 to 1.5, a design discharge of 44 l/s, and a slope of 0.001 (or 1 m/km), use a bed-width (B) of 0.5 m, and a depth (D) of 0.25 m.

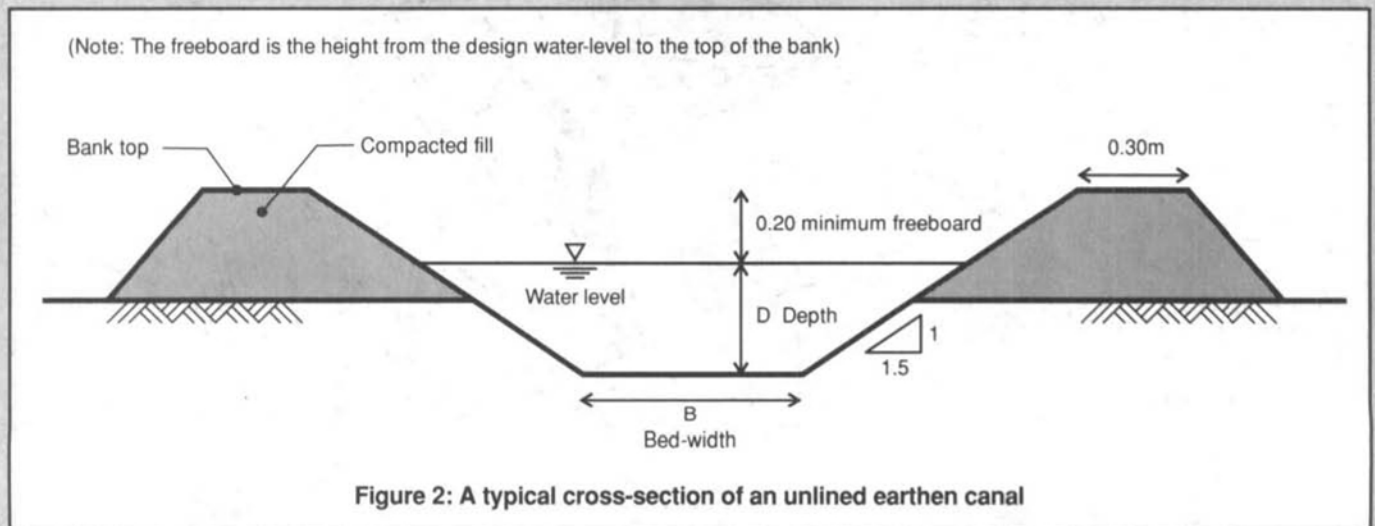
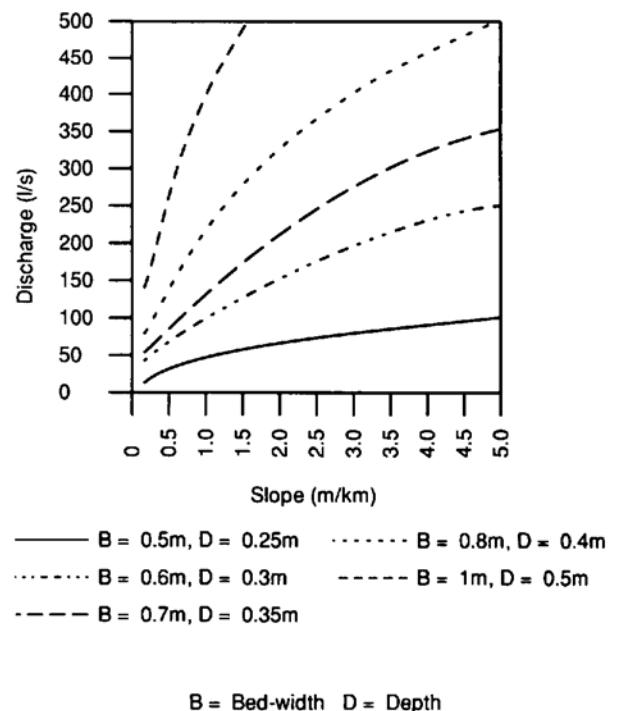


Table 1. Evapotranspiration (ET_o) in mm per day for different agro-climatic conditions (FAO, 1977)

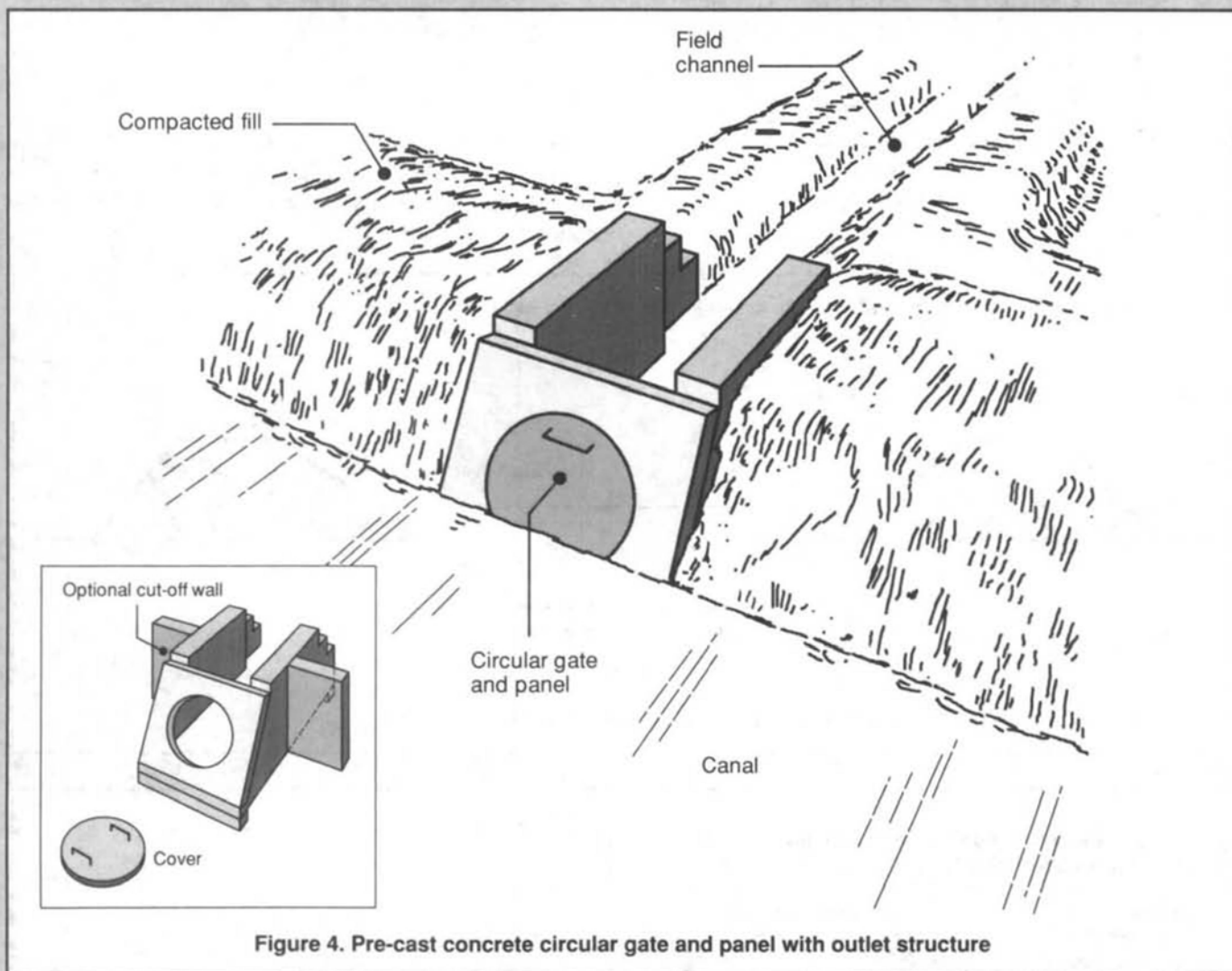
Regions	ET _o in mm per day		
	<10°C	20°C	>30°C
<i>Mean daily temperature</i>			
Tropics			
Humid	3-4	4-5	5-6
Sub-humid	3-5	5-6	7-8
Semi-arid	4-5	6-7	8-9
Arid	4-5	7-8	9-10
Sub-tropics			
<i>Summer</i>			
Humid	3-4	4-5	5-6
Sub-humid	3-5	5-6	6-7
Semi-arid	4-5	6-7	7-8
Arid	4-5	7-8	10-11
<i>Winter</i>			
Humid - sub-humid	2-3	4-5	5-6
Semi-arid	3-4	5-6	7-8
Arid	3-4	6-7	10-11
Temperate			
Humid - sub-humid	2-3	3-4	5-7
Semi-arid - arid	3-4	5-6	8-9



Distribution outlets

Outlets or division structures are used to distribute the water among a group of farmers. If the flow is less than 30 l/s, one farmer can probably use it efficiently for surface irrigation through one outlet, but larger flows need to be divided fairly between several outlets. In either case, it is important that outlets can be closed when not in use, and that water cannot

leak out. The outlet shown in Figure 4 uses a pre-cast concrete circular gate which has proved to be effective in various countries, lasting longer than either a wood or metal gate. Simple bridges made from planks of wood or a concrete slab are also needed (see Figure 1), so that people and animals can cross the canal without damaging it.



Further information

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Smout, I.K., *Technical Brief No. 27: Discharge measurements and estimates*, Waterlines, Vol. 9, No.3, IT Publications, London, 1991.

Stern, P., *Small-Scale Irrigation*, IT Publications, London, 1979.

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