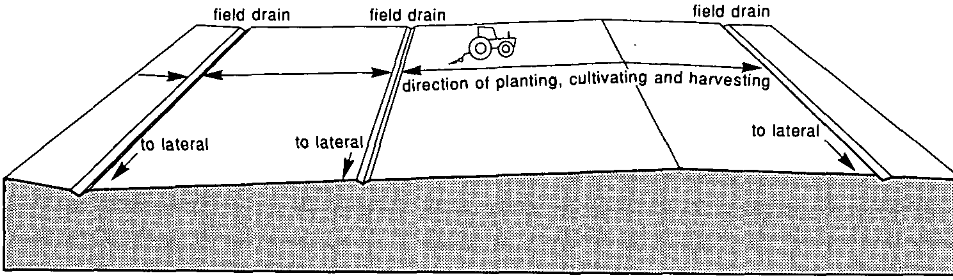

Figure 20.12 The parallel drainage system (after SCS 1971)

most effective method of surface drainage. Figure 20.12 shows a typical lay-out. The system is applicable in flat areas with an irregular micro-topography and where farm operations require regular shaped fields.

The parallel, but not necessarily equidistant, field drains collect the surface runoff and discharge it into the field lateral, through which the water flows towards the main drainage system. The spacing of the field drains depends on the size of lands that can be prepared and harvested economically, on the water tolerance of crops, and on the amount and the cost of land forming (Section 20.2.2).

Where subsurface drainage can be used in conjunction with surface drainage, the field drain spacing needs to be adjusted to the requirements of the subsurface drains. The combined system is referred to as 'Parallel Open Ditch System'. In this case, the ditches function as subsurface drains and are deeper (and steeper) than those of the 'Parallel Field Drainage System'. The ditches cannot be crossed by farm machinery and farming operations are to be done parallel to these ditches. To ensure good surface drainage, 'row drains' should be ploughed from field rows towards the field drain. The system of combined surface and subsurface drains is often applied in peat and muck soils.

20.5 Surface and Subsurface Drainage

20.5.1 Combination of Drainage Systems

The surface drainage measures discussed in the previous sections are aimed at the orderly removal of excess water from the surface. In the absence of these measures, the ponded water and saturated soil will eventually dry up by evapotranspiration and by percolation towards the groundwater. The recharge of the groundwater will induce a rise of the watertable. Consequently, if these lands are to be drained by subsurface drainage, the required capacity will be greater than when a surface drainage system is also available.

Research into this relationship has shown that in some cases benefits can be obtained by combining the two systems. Much depends on the combination of factors like the intensity and duration of rainfall, surface storage, soil physical characteristics (e.g. infiltration rate and hydraulic conductivity), and the groundwater condition (Skaggs 1987).

Schwab et al. (1974) have conducted many years of experiments on the combination of subsurface and surface drainage in heavy soils under different crops. Some of their findings are shown in Figure 20.13.

The yields of all treatments dropped considerably in 1969, which was very dry. In 1970 and 1971, yields in the plots with subsurface drainage (pipe drains) recovered, but the recovery was less in the surface drained plot. This effect was attributed to the progressive deterioration of the soil structure resulting from continuous monocropping and compaction by machinery. The subsurface drainage was apparently able to maintain a good physical soil structure whereas surface drainage was not.

Experiments on surface storage development with time (after land ploughing or harrowing) indicate that the surface condition is not constant throughout a cropping period (see Figure 20.14). As a consequence, the flow of surface runoff for a similar rainfall period at the start or at the end of a cropping season will be different, as will be the subsurface drainage flow.

Skaggs et al. (1982) investigated crop yield as related to surface storage after land grading for surface drainage and the spacing of subsurface drainage. An example of their findings is given in Figure 20.15. It shows that good surface drainage (i.e. low surface storage) leads to higher yields at the same drain spacing, or that wider drain spacings are possible to obtain the same yield.

Intermediate Solutions

Between surface drainage as described above and subsurface drainage by means of pipes, a number of intermediate solutions can be selected to improve the water conditions at the surface and in the rootzone.

For instance, if water conditions in the topsoil are poor because of the occurrence of a hard pan at shallow depth (0.2 – 0.4 m) in otherwise physically good soil, deep ploughing or scarifying can be an appropriate measure.

If the impermeable layer is at greater depth (0.4 – 0.8 m), mole drainage (Chapter 21) can reduce saturation of the top soil by enhancing shallow subsurface flow to the field drains.

For soils with surface layers that are susceptible to crusting (thus hampering

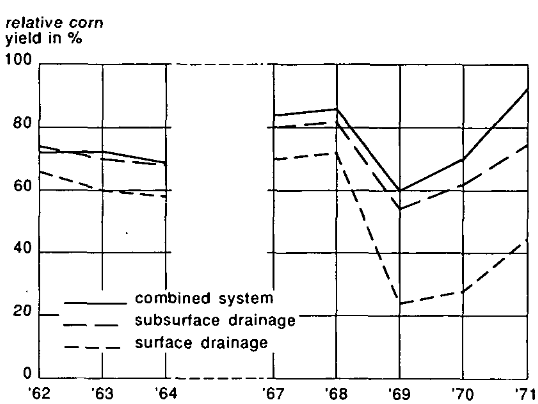

Figure 20.13 Yield development of corn under different drainage systems (after Schwab et al. 1974)

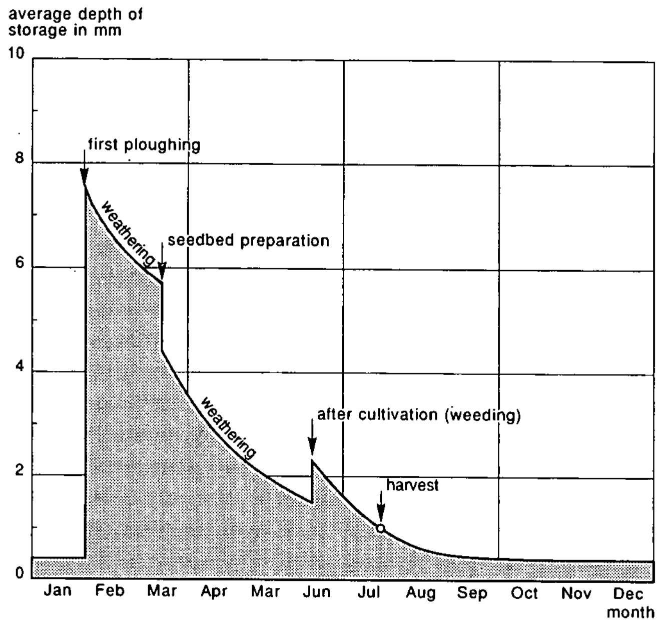

Figure 20.14 Annual variation in surface storage for a clay loam soil on row-crop land bedded for individual crops (after Gayle and Skaggs 1978)

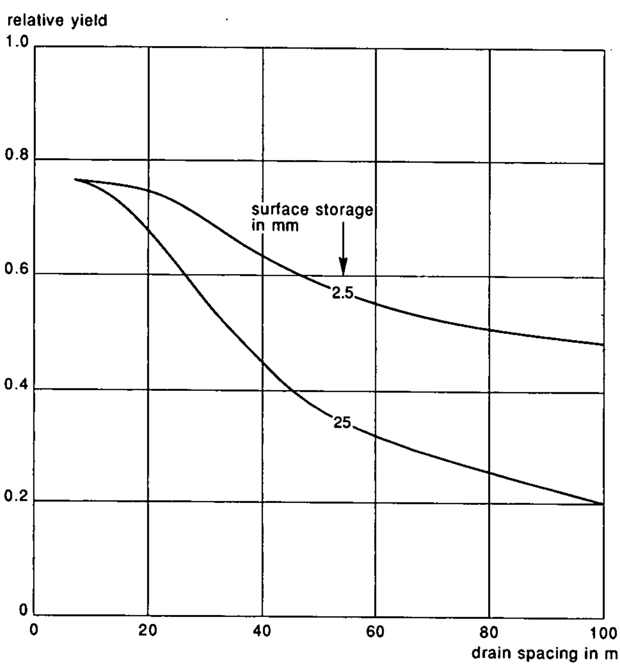

Figure 20.15 Relative yields for different tile drain spacings and quality of surface drainage (after Skaggs et al. 1982)

infiltration), mulching under permanent crops and repeated harrowing in annual crops can help to improve infiltration.

In some countries, trenches made for subsurface drainage are backfilled with gravelly material to enable surface drainage to flow directly into the subsurface drains.

Figure 20.16 shows how different solutions can be combined. Most of them are of a temporary nature and need to be repeated when symptoms of stagnant water reappear at the surface.

20.5.2 Land Forming and Farm Size

As land grading and planing are most effectively done by large machinery, the farm size in which they can be applied is usually also large. Figure 20.17 shows a farm of 230 ha in Australia where surface drainage and irrigation were improved by extensive land levelling. At the same time, the transformation of the fields enabled more rational (mechanized) farming operations.

In developing countries, where farm sizes are usually much smaller, land grading and planing within one farm can hardly be realized. The land units where these operations would be effective are far larger than a single farm.

To obtain good surface drainage by modern land forming, the operations could be done on the scale of blocks consisting of groups of farms. In newly reclaimed areas, the land could be allocated to farmers after land forming has been completed. In existing agricultural areas, however, this often implies a reallocation of lots under a land consolidation program.

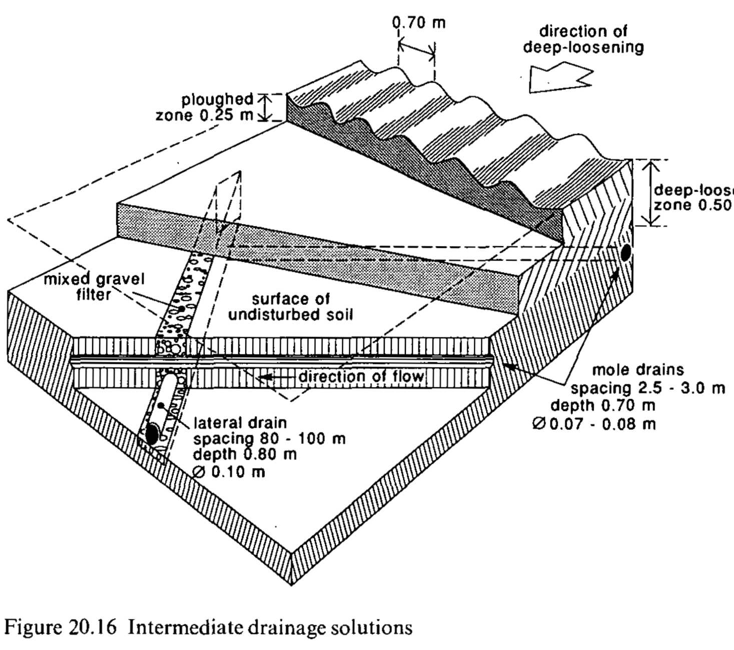

Figure 20.16 Intermediate drainage solutions

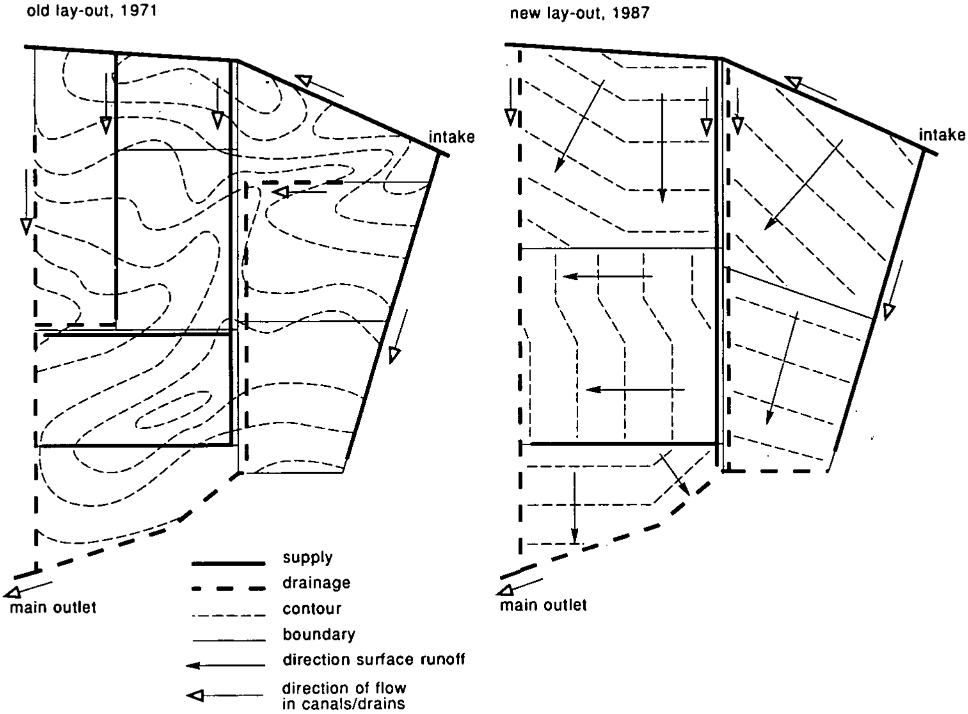

Figure 20.17 Example of land forming to improve surface drainage and irrigation performance and to rationalize farm operations (Australia)

In small-scale situations, the field drains collecting surface runoff from graded land should not belong to individual farmers, but rather to the drainage block, as in small-scale irrigation systems where tertiary canals belong to tertiary units (Figure 20.18).

20.6 Surface Drainage Systems for Sloping Areas

The surface drainage methods applied in sloping areas (slopes > 2%) are closely related to those of erosion control. The methods comprise the creation of suitable conditions to regulate or intercept the overland flow before it becomes hazardous as an erosion force. This usually means some form of terracing.

Drainage and erosion control are not the only reasons why sloping lands are terraced. Sometimes the objective is water conservation. If so, bench-type or step-type terraces are constructed (Figure 20.19). The original slope of the land is altered to form a number of horizontal steps.

Terraces applied for drainage and erosion control are basically of two types:
- The cross-slope drainage system;
- The standard erosion-control terrace.

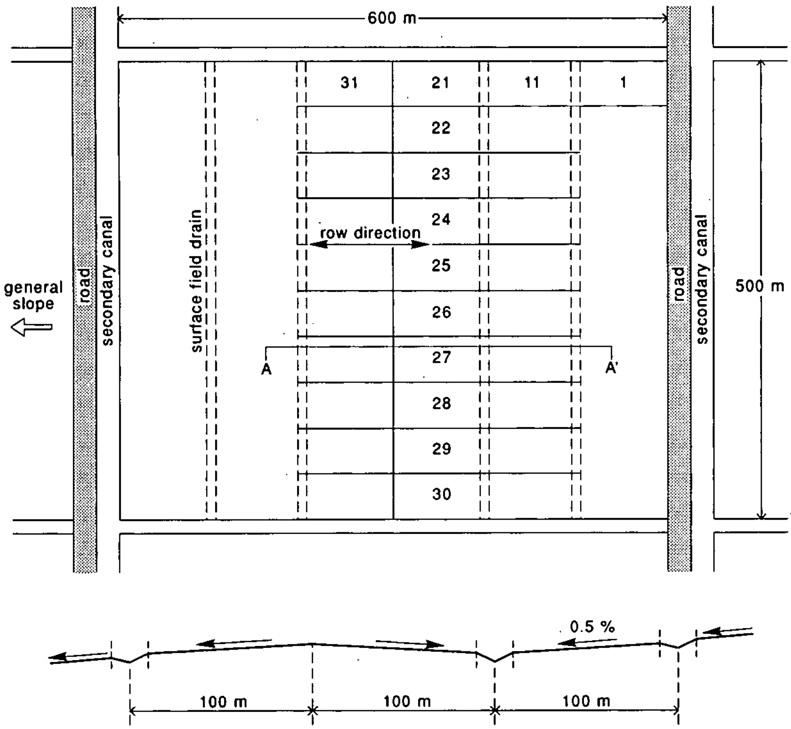

Figure 20.18 Small-scale farming in land-forming block (parallel field drainage block)

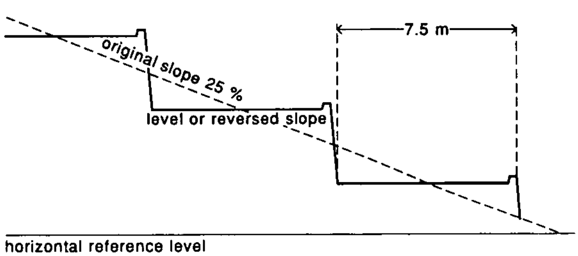

Figure 20.19 Cross-section of a bench terrace system

20.6.1 Cross-Slope Drainage System

The cross-slope drainage system (Figure 20.20) is a channel-type graded terrace, also called a Nichols terrace. It is used on lands with a slope of up to 4%, where flat-land systems would be impracticable in view of erosion hazards. The cross-slope system resembles the parallel field drainage system. It is effective on soils with poor drainage charcteristics and where the overall slopes are rather regular but where many minor depressions occur.

The drains should run approximately parallel to the contours of the land, with a

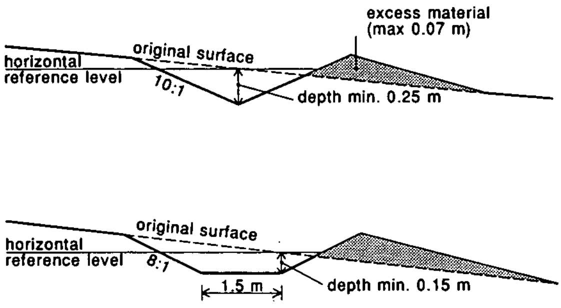

Figure 20.20 Cross-sections of cross-slope drains

uniform or variable grade of between 0.1 and 1% (or a mean of 0.5%), depending on the topography. The use of a variable grade often permits a better alignment of the terrace and a better fit of the terrace to the field. The soil surface between the drains must be smoothed (not graded) and all farming operations should be done parallel to the drains. Spoil from the drains can be used to fill up minor depressions or can be spread out to form a thin layer of not more than 0.07 m on the downslope side of the drains (Figure 20.20).

Cross-slope drains can have either a triangular or a trapezoidal shape, with side slopes ranging from 1:4 to 1:10. Their cross-sectional area can vary from 0.4 to 0.7 m^2. Depths will be between 0.15 and 0.25 m and the top width from 5 to 7 m. The maximum length of a drain is about 350 to 450 m. The distance between the drains depends on the slope, the rainfall intensity, the erodibility of the soil, and on the crops that will be grown, but are usually between 30 to 45 m.

With the cross-slope drainage system, between 80 and 100% of the water contained in the drain is below the original land surface, which reduces the harmful effects of a possible break in the downslope bank.

20.6.2 Standard Erosion-Control Terrace

The standard erosion-control terrace (Figure 20.21) is a ridge-type graded terrace, also called a Magnum terrace, and is used on lands that slope as much as 10%.

The difference between the cross-slope drain and the erosion-control terrace is that with the latter the spoil from the channels is used to build a relatively high ridge on the downslope side. In such channels, only 50% of the water is contained below the

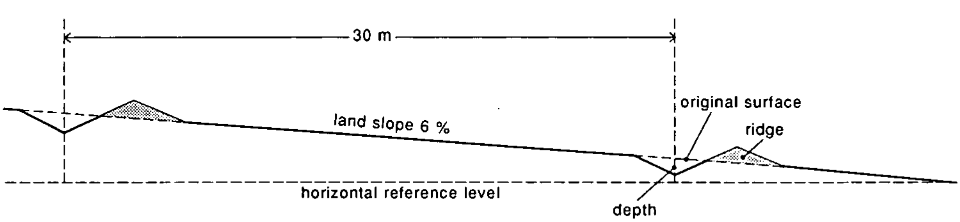

Figure 20.21 Standard erosion-control terrace

original land surface. Greater storages would require greater amounts of earthmoving and would increase the risk of the ridges rupturing.

Like the cross-slope drains, the channels of the erosion-control terraces should run approximately parallel to the contours of the land, with a uniform or variable grade of between 0.1 and 0.6%, depending on the topography. Natural impediments and sharp curves should be avoided.

The distance between the channels is governed by the same factors as the cross-slope drains.

The length of the terraces will usually depend on the location of a suitable disposal ditch. Terraces should not be so short that they impede farming operations, nor so long that the channels would require too great a cut. The maximum length of a terrace channel draining to one side only is about 350 or 450 m.

The flow velocity in the terrace should not exceed 0.6 m/s, although on sandy soils 0.45 m/s is more suitable and 0.3 m/s on pure sands.

20.6.3 Water Disposal in Sloping Areas

In sloping areas, where the field drains run approximately parallel to the contours, the water must be disposed of by a drainage channel which runs downslope. The slope is usually so steep that such channels will have to be lined or fitted with overflow or drop structures to prevent scouring (Chapter 19.7).

In certain circumstances, vegetated waterways can be used. The vegetational cover reduces the flow velocity of the water while at the same time allowing a comparatively high velocity. Permanent, dense, sod-forming grasses are the most suitable. The choice will depend on climate, soil, and available species.

Allowable velocities in erosion-resistant soil covered by dense grass vegetation are 2 m/s for slopes to 5% and 1.75 m/s for slopes of 5 to 10%. In easily erodible soils, the allowable velocities in densely grassed channels are 1.50 m/s with slopes to 5% and 1.25 m/s with slopes of 5 to 10%.

Vegetation other than grasses can be used on slopes of up to 5%. The allowable velocities are then 1 m/s on erosion-resistant soil and 0.50 m/s on easily erodible soil.

In the design of vegetated waterways, the roughness coefficient of the Manning's formula is taken as $n = 0.04$, a value corresponding with that for freshly cut grass. Where the maximum run-off occurs in periods when the vegetation has a higher retarding capacity than freshly cut grass, some 0.10 to 0.15 m should be added to the calculated design depth to ensure that no overtopping occurs. More details on the design of vegetated channels are presented in Chapter 19.5.3.

The waterway can be parabolic, triangular, or trapezoidal. Side slopes should not be steeper than 1:4 to allow the passage of farm machinery. Minimum bottom width is 2.5 m. When the discharge is known and the side slopes and allowable flow velocity have been chosen, the most suitable combination of bottom width, water depth, and grade can be calculated.

Other points to consider are that:
- A vegetated waterway should not be continuously wet; otherwise the vegetation cover will deteriorate. If groundwater is flowing into the waterway, it should be

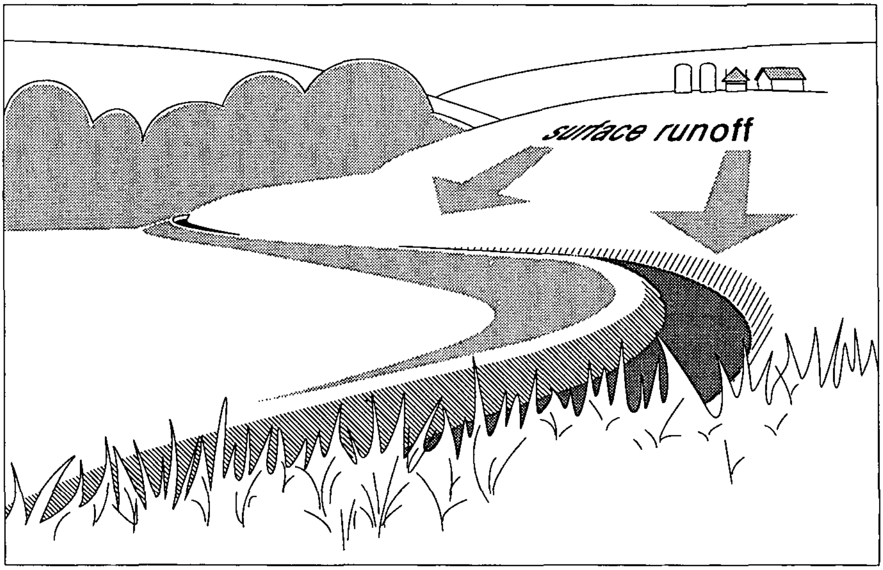

Figure 20.22 The diversion drain

intercepted by a pipe drain. Surface water can be carried off by a small concrete or asphalt trickle channel constructed at the bottom of the waterway;

- The fertility of the soil in the vegetated waterways should be maintained (manuring);
- Seeding mixtures should include quick-growing annuals and hardy perennials; sometimes sodding may be necessary;
- The vegetation should be properly maintained and the waterway should not be passed with farm machinery when it is still wet;
- Special attention should be paid to the terrace outlets; the vegetation cover may be extended over a small distance into the terrace channel;
- Geotextiles can be used to stabilize the soil surface during the establishment of grass seedlings (Schwab et al. 1981).

20.6.4 Diversion or Interceptor Drains

To protect flat areas from flooding by surface runoff from adjacent higher grounds, a diversion or interceptor drain can be constructed at the foot of these uplands (Figure 20.22). For areas not larger than 2 to 2.5 ha at the most, the diversion or interceptor drains can be constructed like terraces; for larger areas they should be constructed as grassed waterways.

To prevent diversion or interceptor drains from silting up, a filter strip can be constructed on the upslope side of the ditch. A depth of 0.45 m for the drain and a cross-sectional area of about 0.70 m^2 are considered minimum values.

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