DPI&F note

Sub-surface drip irrigation:

System design

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Design considerations

A qualified irrigation designer experienced with sub-surface drip (SDI) installations should design all systems. The design should be developed in close consultation with the grower and their consultant to ensure that it fits in with farm infrastructure, long-term farm plans and management skill of the irrigator.

SDI systems have a high initial investment cost and must be designed, installed and managed appropriately to achieve the longest life expectancy and best possible performance. Cutting corners on any of these will result in poor system performance and reduced system life.

Proper hydraulic design is the first step in installing a successful SDI system. This ensures that the system effectively deals with the constraints imposed by crop and soil characteristics, field size, shape and topography, and water supply.

Irrigation capacity

The SDI system must be capable of meeting the crop water need during peak water demands for your crop and location. This demand (in mm/day) can be estimated from the 3-day peak evapotranspiration rate (with a greater then 90 percent reliability) obtained from daily evaporation data. This value is divided by the SDI irrigation efficiency to give the gross irrigation capacity requirement (see the example calculations).

This demand is combined with available water supply capacity to determine the area that can be irrigated using the formula:

$$\text{Area (ha)} = \frac{\text{Flow rate (L/hour)} \times \text{Pumping hours (hours/day)}}{10000 \times \text{Gross Irrigation Capacity Requirement (mm/day)}}$$

Evapotranspiration in excess of irrigation capacity is met from stored soil water. In soils with low water holding capacity (for example sands) the required irrigation capacity is higher. The irrigation application depth must match the water holding capacity of the soil to avoid deep drainage below the root zone – thus irrigations on sandy soils are generally more frequent with less water applied at each irrigation.

Block or zone size and drip tape spacing

The part of a field that can be watered at the same time is called a block or zone. It is determined by the characteristics of the drip tape selected (emitter discharge rate and spacing, lateral spacing and operating pressure). In the past drip tape spacing has largely been based on commercial experience and the type of crops being grown. For row crops like cotton on medium to heavy clays spacings of 1m (with each row planted above the tape) or 2m spacings (with the tape mid-way between adjacent crop rows) are commonly used. For broadacre crops on similar soil types the spacings have ranged from 1 to 1.5m.

The optimal spacing is determined by soil characteristics and depth of tape placement. Wider spacings reduce the investment cost in the system but may not spread water uniformly enough to supply crop needs. Deep drainage is a risk as irrigators on wider drip spacings attempt to increase the lateral spread of water by

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increasing the duration of the irrigation. On lighter textured soils spacings less than 1m may be necessary. The optimal spacing can be found using the pit method outlined below:

1. A soil pit is excavated in the soil where SDI is to be installed to a depth of the expected effective root zone (usually at least 1m). It should be wide enough to allow at least six drip emitters to be installed around the outside of the pit so that there is minimal interaction between the wetting fronts.
2. Drill a 10mm diameter hole to the proposed depth of installation (usually 300 to 400mm) at 300mm back from the pit face.
3. Insert a piece of spaghetti tube with wire inside it (to prevent blocking of the tube) to the desired depth in the hole and backfill with bentonite. Carefully remove the wire from the spaghetti tube.
4. Attach the other end of the spaghetti tube to a variable speed peristaltic pump. Start the irrigation using an application rate similar to that for the proposed SDI system.
5. The position of the wetting front over time is monitored by visual observation of the wetted soil on the face of the pit. At the completion of the irrigation it is possible to excavate the face of the pit to expose the wetting pattern immediately below the spaghetti tube opening.

This approach can more accurately determine the optimal lateral spacing for your system then relying on past experience in other soil types and districts.

The amount of drip tape needed for a block or zone can be estimated using the formula:

$$\text{Drip tape (m per ha)} = \frac{10{,}000\ \text{m}^2/\text{ha}}{\text{Drip tape spacing (m)}}$$

Soil characteristics, plant spacing and water quality determine the choice of emitter spacings. Wider spaced emitters allow a larger emitter opening that may be better where water quality is less than optimal. Emitter spacing is usually less then lateral spacing – the most commonly used are between 300 and 750mm. The number of emitters per unit area is given by:

$$\text{Emitter number/ha} = \frac{10{,}000\text{m}^2}{\text{Lateral spacing (m) x Emitter spacing (m)}}$$

There is a range of drip tapes available with differing flow rates. The choice of tape will depend on several factors. Low flow rate tapes enable longer tape lengths to be used but increase the risk of emitter clogging.

Manufacturers charts of tape characteristics can be used to determine the flow rate needed and the maximum size of each block or zone. This information specifies the nominal emitter flow rate (L/hour) at different emitter spacings and inlet pressures, together with the maximum lateral length.

The desired flow rate (L/ha/hour) is found from:

$$\text{Flow rate (L/ha/hour)} = \text{Emitter number/ha x Emitter flow rate (L/hour)}$$

The possible block size is found from:

$$\text{Block size (ha)} = \frac{\text{Available Flow rate (L/hour)}}{\text{Flow rate (L/ha/hour)}}$$

The advantage of fewer blocks is in minimising the cost of the system. However, if there is a chance that the available supply could decline (for example with a bore in a declining aquifer) it may be best to reduce individual block size and setup a greater number of blocks to maximise the irrigated area.

Tape installation depth

Tape installation depth is determined by crop, soil type and farming practices. Deep installations reduce possible soil evaporation losses and allow for deeper tillage practices. There may also be less risk of root intrusion into emitters and mice damage. The disadvantages of deep installations include:

- Limit the effectiveness of the system for crop germination;
- Restrict the availability of surface applied nutrients;
- Greater risk of deep drainage losses if not irrigated appropriately.

Most installations have been at 300mm to 400mm depth. Check texture changes in your soil profile. Drip tape should be installed above any restrictive clay layers in the soil to aid lateral soil water redistribution. In soils with a sandy subsoil deep drainage losses increase and poor lateral spread occurs if the soil cracks open below the drip tape. In row crops tape is generally installed parallel to crop rows.

Flushing requirements

Adequate flushing velocities must be allowed for in the design of the system to remove sediment from the laterals and the flushing manifold. A minimum flushing velocity of 0.3 m/sec is needed in the laterals. Without an adequate flushing system design and regular maintenance the SDI system will become clogged, reducing crop yield and system life.

Field size, shape and topography

Within limits SDI systems can be designed for a range of field sizes and shape. The design needs to consider field topography to minimise the likelihood of soil “suckback” into the emitters at system shutdown. Designers should be provided with the following:

- Accurate GPS maps
- Contour maps showing 0.5 m variations in slope
- Field layout and size, access and roads
- Soil properties and changes in soil type

Irrigation application depth

The irrigation application depth and length of application are directly related. The irrigation application depth for each block is given by:

$$\text{Application depth (mm)} = \frac{\text{Flow rate (L/ha/hour) x Hours of irrigation}}{10000}$$

Filtration, flushing and water treatment

The filtration system is the most important component of a SDI system. In selecting the appropriate filter consideration needs to be given to:

- Water quality;
- Emitter size;
- Operational and maintenance requirements for the system.

The water to be used must be analysed before developing the SDI system to determine its chemistry. This will give an indication of the fertilisers to be avoided to prevent chemical clogging of emitters. Acid treatments are used to prevent clogging and clear partially plugged drip tape. Chlorination is used to control biological clogging of emitters by slimes and algae. The need for chlorination is determined by the water source and its composition.

Drip tape hydraulics

Pressure losses from friction occur when water flows through the drip tape. These losses are related to water velocity, tape inside diameter and roughness, and lateral length. The emitter flow rate (Q) is given by:

$$Q = kH^x$$

where

k = emitter co-efficient

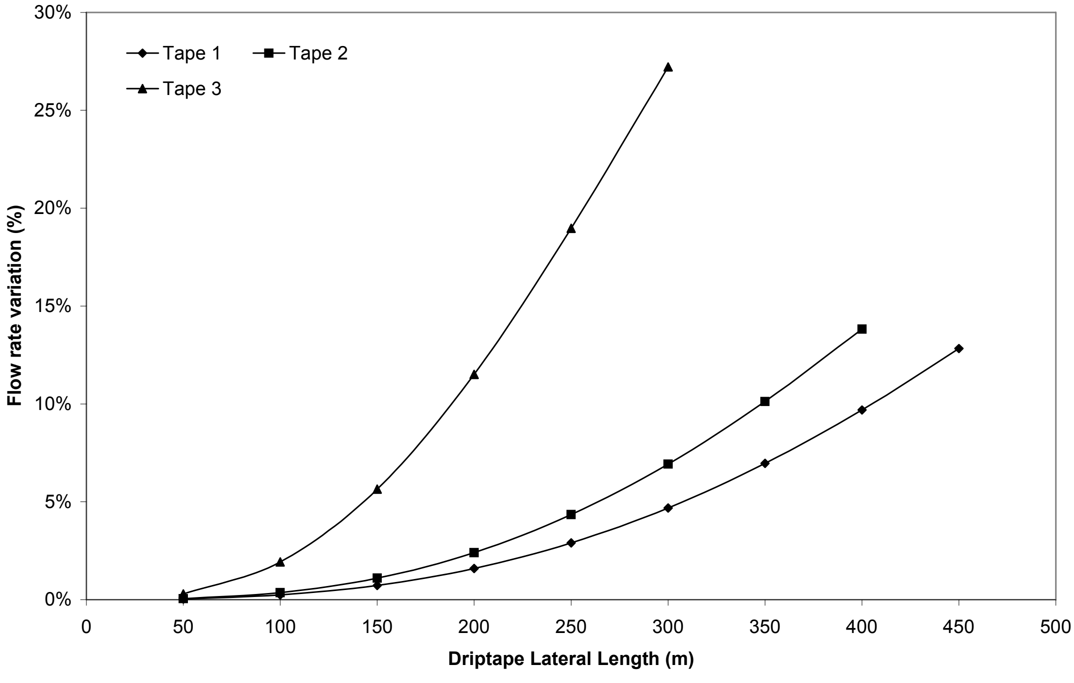
H = pressure at the emitter

x = emitter exponent

The emitter exponent (x) value lies between 0 and 1. An emitter with a value of 0 is fully pressure compensating – the flow rate is independent of the pressure. An emitter with a value of 1 is non-compensating, meaning any percentage change in pressure results in an equal percentage change in flow rate. Most SDI drip tapes have an emitter exponent of around 0.5 - this means that a 20 percent change in pressure along the lateral results in a 10% change in flow rate.

In a properly designed system flow rates should not change more than 10 percent along the lateral. The manufacturer should provide you with the emitter exponent for their product. Figure 1 shows the effect of run length for three types of drip tapes on flow rate variation – the characteristics of these tapes are summarised in Table 1.

Friction losses increase with length of the lateral and the smaller the internal diameter of the tape, which



explains the increasing flow variation with increasing lateral length in Figure 1.

Figure 1 Flow rate variation with increasing lateral length for three types of drip tapes used in SDI installations

Table 1 Characteristics of three tapes shown in Figure 1

	Internal Diameter (mm)	Wall thickness (mm)	Emitter Flow rate (L/hour)	Emitter spacing (mm)	Emitter co-efficient (k)	Emitter Exponent (x)
Tape 1	25	0.38	1.1	500	0.364	0.48
Tape 2	22.2	0.38	1.05	500	0.373	0.45
Tape 3	15.7	0.38	1.1	500	0.364	0.45

Friction losses also increase with increased velocity of water in the drip tape. If high capacity drip tape is chosen to minimise clogging the length of possible run may need to be reduced to maintain good uniformity. The block size may also have to be reduced to match flow rate to water supply. Decreases in run length and block size increases the average cost of installation and operation of the system.

Land slope affects the pressure distribution along the drip tape lateral. Irrigating uphill increases pressure losses along the lateral length. If the downhill slope is too steep the flow rate at the end of the line may be too high.

The coefficient of manufacturing variation (Cv) indicates the variability in manufacturing of the drip tape. A Cv of less than 10 percent is considered good, from 10 to 20 percent, average; and greater than 20 percent, marginal to unacceptable. The Cv for drip tape should be obtainable from the manufacturer – use this to aid product choice.

The two major suppliers of SDI drip tape have freely available software programs you can download to assist you in looking at the hydraulics of your proposed installation. The programs are:

- HydroCalc available from Netafim (www.netafim.com/Downloads)
- Pro Designer available from T-Systems (www.tsystems.com.au/design/prodesign.html)

Case study: SDI design for irrigated lucerne

For a lucerne crop to be grown at Biloela the 3-day peak evapotranspiration rate is 13.2 mm/day. Using an assumed SDI irrigation efficiency of 90% the gross irrigation capacity requirement is 14.7 mm/day (13.2mm/day ÷ 0.9).

The gross irrigation capacity requirement is combined with available water supply capacity (a bore supplying 90,000 L/hour) and the average available pumping hours (18 hours a day) to determine the area that can be irrigated using:

$$\text{Area (ha)} = \frac{\text{Flow rate (L/hour) x Pumping hours (hours/day)}}{\text{10000 x Gross Irrigation Capacity Requirement (mm/day)}}$$

$$= \frac{\text{90,000 L/hour x 18 hours/day}}{\text{10,000 x 14.7 mm/day}}$$

$$= \text{11 ha}$$

Assuming that a drip tape lateral spacing of 1.2m is optimal, then the length of lateral required is:

$$\text{Drip tape (m per ha)} = \frac{10000\ \text{m}^2\text{/ha}}{\text{Drip tape spacing (m)}}$$

$$= \frac{10000\ \text{m}^2\ /\ \text{ha}}{1.2\ \text{m}}$$

$$= \text{8333 m per ha}$$

Assuming with the desired emitter spacing is 0.6m then the number of emitters in each hectare is found from:

$$\text{Emitter number} = \frac{10{,}000\text{m}^2}{\text{Lateral spacing (m) x Emitter spacing (m)}}$$

$$= \frac{10{,}000\text{m}^2}{1.2\text{m x } 0.6\text{m}}$$

= 13889 emitters/ha

Assuming that the selected drip tape has an emitter flow rate of 1.2 L/hour at an inlet pressure of 100 kPa (14 psi) then the required flow rate is:

Flow rate (L/ha) = Number of emitters/ha x Emitter flow rate (L/hour)

= 13889 emitters/ha x 1.2 L/hour

= 16667 L/ha/hour

The block size that can be irrigated is given by:

$$\text{Block size} = \frac{\text{Flow rate (L/hour)}}{\text{Flow rate (L/ha/hour)}}$$

$$= \frac{90{,}000 \text{ L/hour}}{16667 \text{ L/ha/hour}}$$

= 5.4 ha

Thus two blocks 5.4 ha can be irrigated (totalling 10.8 ha, just less then the 11 ha that can be irrigated to meet the gross irrigation capacity requirement of 14.7 mm/day).

If the supply rate were to decline than only one 5.4 ha block could be adequately irrigated. An alternative would be to split the field into 3 x 3.6ha blocks. With a decline in the available supply to 60,000 L/hour irrigating two 3.6 ha blocks (and leaving one unirrigated) is possible. It is better than only irrigating one 5.4 ha block (and leaving the other unirrigated).

Assuming that a 12-hour irrigation suits daily labour requirements then the application depth for each block will be:

$$\text{Application depth (mm)} = \frac{\text{Flow rate (L/ha) x Hours of irrigation}}{10000}$$

$$= \frac{16667 \text{ L/ha/hour x } 12 \text{ hours}}{10000}$$

= 20mm

The investment cost of SDI systems is high. Proper design procedures must be followed to ensure system longevity, performance and minimise operating costs. Shortcuts to minimise investment cost run the risk of increasing operating costs and/or the chance of system failure.

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Further information

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There are an increasing number of commercial irrigators experienced with SDI within Australia across a range of crops. If considering SDI you should discuss this with experienced growers as well as the experienced field staff of the major SDI system suppliers who can put you in contact with experienced SDI irrigators.

Information is also available on the World Wide Web through the Trickle-L Discussion List. This list has over 650 members (irrigators, manufacturers, resellers, researchers, extension personnel) in 35 countries. Details on joining this list can be found at the Microirrigation Forum Web site at www.microirrigationforum.com . This site contains archives of discussions related to drip irrigation (and SDI in particular) that you can readily examine.

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