

5.2 Developing a surface irrigation system

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Key points

- what to consider when selecting an irrigation system
- what is involved in upgrading a surface irrigation system
- soil types for storages and canals
- the 'perfect' layout for an irrigation system

This topic is aimed at those wishing to develop a new surface irrigation system or expand or upgrade an existing system. It is designed to help prevent the farmer making the same mistakes that others have made over the last twenty years. It combines experience with commonsense and some detailed technical advice.

The development of a large-scale surface irrigation system can be quite complex and good advice is essential. It is often found that good advice is paid for one way or the other and it is cheaper before construction starts.

Questions for developments

A farmer looking to develop or upgrade any irrigation system needs to be able to answer all of these questions:

- Is the terrain irrigable?
- Are the soils fertile and suitable?
- Is the climate suitable for the crop?
- Is there a reliable, good quality water supply?
- How much area can be developed?
- How much will it cost?
- Will it make money?
- Do I have the required licences in place?

An irrigator must know the answer to all these questions before any construction proceeds.

What is irrigation?

Before looking at development in any detail it is worth reflecting on the basics. Irrigation is the process of artificially providing water to the soil in the crop root zone to enable a crop to prosper and yield well.

The process, then, includes the crop, the soil and the irrigation system.

These three aspects must work well together for a successful outcome. Poor performance from any one of these will lead to a poor result.

Matching irrigation system to soil

Lengthy and meaningful debates can be had on whether surface, sprinkler, or drip is the best form of irrigation. Of particular interest, however, is not which system may be preferred but **which system is best suited to a particular situation and crop.**

The single most important consideration in deciding which irrigation system is best suited to a particular situation is the **soil.**

The soil is the medium which takes in and stores the irrigation water for the crop to use. As stated above, the irrigation system, the soil and the crop must work well together to achieve a good crop yield.

Sandy soils: No matter how much a farmer may like surface irrigation, it is not possible to irrigate a field crop in a very sandy soil with surface irrigation because the water would infiltrate into the top part of the field mainly, and the tail end would get very little water. There are also real difficulties irrigating a crop in a sandy soil with subsurface drip because the water cannot sub up to the seed after planting. A sandy soil is well suited to efficient sprinkler irrigation.

Clays: Clay soils, however, are well suited to surface irrigation because the soil infiltration rates quickly slow to very low, allowing the water at the top of the field to flow over the wet soil and supply the dry soil further down the field.

Loams: A medium loam soil has more options, being basically suitable for all types of irrigation.

Matching the irrigation system type to the soil is a very important consideration which is sometimes overlooked. It is much easier to change an irrigation system than basic soil characteristics. Table 2.5.1 summarises the major considerations when selecting the most suitable type of irrigation.

Table 2.5.1. What type of irrigation suits me?

Irrigation type:	Surface	Mechanical sprinkler	Drip
Capital cost	L	M	H
Operation and maintenance	M	H	M–H
Labour requirements	H	M	L
Management	M–L	M	H
Water use	M–H	L–M	L
Yield potential	H	H	H
Surface drainage needs	H (regular laser levelling required)	M (for stormwater only)	M (for stormwater only)
Soil infiltration needs	M–H (high initial infiltration followed by moderate sealing for best distribution uniformity)	H (high infiltration rate required)	L.
Soils best suited	Heavy soils	Medium to light soils	Medium soils
Soils less suited	Sand (risk of deep drainage)	Heavy clays (infiltration problems)	Heavy (hard to pre-irrigate) Light (hard to sub up)
Lifestyle and personal	Your choice: some like dirt – some like gadgets.		

Note: L = low, M = medium, H = high



Answers for developments

A straightforward and systematic procedure has been developed to ensure that the correct answers are available at the outset and that nothing is missed. The following information must be obtained:

- preliminary inspection and selection of the potential area
- feasibility topographic (levels) survey of the whole potential area
- water quality analysis
- available water volume and reliability
- water supply delivery capacity
- determination of crop water requirements
- assessment of required irrigation water supply capacity
- agricultural soil suitability (samples and test pits – what's under the surface). See SOILpak B9 '[Soil survey for development or re-development](#)'.
- engineering soil properties for canals and embankment construction.

From this information it is possible to complete:

- a whole farm layout,
- a preliminary design and costing, and
- a preliminary economic analysis.

If the preliminary assessment is satisfactory, then it is possible to complete:

- a detailed survey and design,
- a final costing,
- a final economic analysis, and
- construction.

A thorough investigation is essential to ensure that any potential problems are foreseen and overcome before one clod of earth is turned. Development can stop at any of the above stages if serious problems are encountered. Once construction begins, it is very expensive to change, while it is easy and cheap to rub out and shift some lines on drawings. Shift things on paper, not in the field!

Using a consultant

As with all things, there are many who offer advice and are keen to help with irrigation development. There are those who 'know it all', although they have no formal training and little experience. There are those that know only a little but offer the lot. Be very careful. An irrigation consultant has a large impact on the development and it is vital that he/she is qualified and trained in the correct field, and is experienced. Ask if your consultant is qualified and what experience they have. Ask around and find out how they went with other projects.

Who can provide a complete answer to your development questions? A qualified engineer with detailed irrigation experience is a good option, as is a qualified surveyor with additional training in irrigation engineering. The important requirement is that an irrigation consultant must have the necessary training and experience in irrigation engineering to add value to an irrigator's own experience.

Any consultant may choose to use others qualified in specialised areas, such as soil science, but the consultant should know what has to be done and why, and should coordinate the project.

Development layouts

The first and most important part of the design process is to start with the whole farm layout. Worry about the detail such as sizes and so on after the whole farm is fitted together. Try a few alternatives and work with the designer and have your say (or at least review the preliminary layout before the detailed design is started).

A good layout requires:

- uniform runs of reasonable length
- regular field shapes
- a minimum number of control structures and crossings, and
- good access.

In particular, it means attention to detail and design. It should ensure that no unforeseen 'bugs' occur after implementation which reduce the efficiency of the operation.

It is vital that the layout is right before proceeding to the next steps. Any changes to the farm layout will mean changes throughout the whole system. It is quite expensive, for example, to decide later to merge two fields into one larger one, if land levelling has already put a pronounced step between the fields. If unable to afford required changes, a farmer may be stuck with an inbuilt inefficiency.

A good layout does not guarantee success, but at least it makes it possible.

A 'good' layout in fact could probably be defined as one that allows farmers to optimise their operations. This means that all of the elements that make up the system coordinate and function properly. Water is applied at the right time and in the right amount and uniformly, irrigation tailwater and stormwater run-off are removed quickly, cultural operations and access are enhanced, and labour is minimised.

Avoid having the supply and tailwater systems crossing. The best option is to have the supply system on one side of the development and the tailwater system on the other. Position the tailwater drain on the outside of the development to allow for easy overflow or blow-out of large stormwater events.

A staged development

Only a very few farmers can afford not to stage a development. Most tread the fine line of developing only enough to match finances but making this large enough to be an economic unit. As Stage I makes money, Stage II proceeds, and so on.

Any work done in Stage I must be readily adaptable for Stage II, III, and so on. Do not build temporary works for Stage I, rebuild for Stage II, and then build the final works for Stage III. For instance, build full-size canals and structures for Stage I, even though they are too big for the first area developed. If you need two pumps for the complete job, build the full pumping station and only install one pump for Stage I.

Design elements for development

Individual elements of the system must be selected and sized to be cost effective and efficient, and to fit into the overall system. There are many solutions to each design task, and several can be tested 'on paper' before the best is selected. Again, it is always cheaper to try pumps, shift earth and build canals on paper than in the field.

Do not forget to take stormwater and flooding into account when designing your system. In many cases it can be just as important to get the water off your fields during floods as it is to apply it.

Pumping station

The pump station is the workhorse of the irrigation system. Very large volumes of water are handled in an irrigation system, and the operation and energy costs makes it worthwhile optimising the pump and motor selection and the station layout.

Pump performance: When evaluating alternatives, consider operation and maintenance as well as capital cost. The cheapest pump to buy may not be the cheapest overall. Choose a pump which is efficient not just at the normal or most common flow and lift, but also over the full range of duties proposed (that is, normal river as well as low and high river). Allow a margin in the pump duties of up to 20% above the manufacturers' performance figures: the pump performance can be below the predicted performance by this margin because of pump wear and adjustment and a difference between laboratory and field conditions. Check several models and makes to find

one which most closely matches the required duty. No one pump is going to be the best for all jobs.

Which motor?: Determine the input power required to the pump. This power must be made available from the motor continuously. The choice between diesel and electric motors can be made by considering capital, operation and maintenance costs together as a total cost. Other factors such as reliability of electricity supply and ease of operation must also be considered.

If diesel is selected, then the continuous power rating of the motor must be checked. The performance figures published by the engine manufacturers should comply with recognised standards. Unfortunately there are currently at least five recognised standards (ISO 3046, AS 4594, BS 5514, DIN 6270 and SAE J 816). The international (ISO) standard should be used if available.

De-ratings must be applied to this continuous power to allow for non-standard conditions, including altitude, air temperature, humidity and allowance for extras such as fans, alternators, and transmissions. As well as these specified de-ratings, allow a safety factor of 20%.

Final selection of the suitable motor will depend on the operating speed and power flexibility over the duty range. The most efficient motor is the one which operates closest to its point of minimum specific fuel consumption.

In the case of an electric motor, the continuous rating must be adequate to cover the pump duty plus a 15% safety factor.

Further information on pumps is available in WATERpak Chapter 1.8.



Station layout and dimensions: The most common reason for poor pump performance is a lack of adequate submergence of the pump inlet. A lack of sufficient submergence can result in poor performance and damage to the pump. In using an inclined river bank installation, one of the problems is finding a pool of sufficient depth. Depth should always be measured, and not taken from hearsay.

With vertical installations, the pump suction bell has to be located with the correct clearances from the walls and floor of the pumping station to ensure an evenly distributed inflow of water to the pump inlet. Uneven distribution and high velocities can favour the formation of vortices, introducing air into the pump and reducing capacity. The sump dimensions have to be sized to suit the pump capacity: don't use a rule of thumb.

The correct size of rising main or discharge pipe will be the lowest cost alternative when capital costs and operating costs are summed over the life of the pipe, using a suitable discount rate.

Consider head loss through the outlet when choosing between an overflow bubbler type and a flap gate:

- When pumping into a storage, an overflow type outlet may result in significant energy cost increases, unless a low level outlet is also provided.
- Be very careful with flap gates on pipelines as they can cause massive pressure surges in the pipeline from water hammer and can also cause damage to the pumping station structure when slamming shut.

Storages

An on-farm storage or ring tank can be used to harvest supplementary (off-allocation) stream flows and on-farm and overland flow (if appropriate). It also allows the easier management of regulated flows, as irrigation can start or finish before or after regulated flows arrive at the farm.

Storages should also be incorporated in the tailwater return system, allowing re-circulation of irrigation tailwater and capture of first flush stormwater, which may contain nutrients or pesticides.

Sometimes a 'surge reservoir' or 'buffer storage' is constructed to store stormwater run-off by gravity inflow for later pumping to the ring tank storage.

Siting: In planning the storage, consider using natural depressions for additional storage or using natural ridges for banks (where nature has constructed part of the embankment). Incorporating billabongs and gullies, however, is often of little advantage in many cases, as these features often store only a relatively small amount of water and are often subject to licence restrictions and environmental complications.

Sizing: Determining the best size of storage for a particular farm is difficult and should be done by simulating the storage behaviour under the anticipated crop demands, taking into account past stream flows. A computer program is available to do this laborious task.

The optimum depth to store this water is a balance between the cost of the embankment, the value of the land inundated, and the value of the water lost due to evaporation.

- For a given volume of water, a large shallow storage requires less earthworks but inundates a larger area and loses more water from evaporation.
- Increasing storage depth reduces land and evaporation losses, but the larger quantities of earth, longer construction hauls and the more rigorous construction requirements of higher banks rapidly increase costs.

A circular ring tank requires the least earthworks for a given surface area and can be used where suitable. More often a square or rectangular shape as close to square as possible is used to fit in with property and field boundaries.

Reducing evaporation: Evaporation losses can be reduced by constructing internal dividing walls to form cells. One cell is completely emptied at a time. Generally the value of the water saved cannot justify the cost of more than one dividing wall (two cells) with the appropriate connecting pipe work and gates. Celled construction often may suit staged development.

Protecting the bank: Large storages often suffer badly from bank erosion due to wind-generated waves. Rip rap and other hard surface protective measures cannot generally be justified economically.

Although grass has been used for bank protection in the past, this is no longer recommended as it has been found that even grass roots can penetrate many metres into a storage embankment and are thought to contribute to wall failures.

Flat inside batters are essential to allow dissipation of wave energy.

An 8:1 inside batter has been shown to be effective in minimising wave erosion.

Outside batters should not be constructed any steeper than 2:1 to provide stability and reduce rilling erosion from rain. Rilling erosion is also minimised by grading the crest to the inside. Detailed guidelines on storage design, construction, maintenance and management and included in the [Guidelines for Ring Tank Storages](#).

Seepage: To build a costly storage without proper investigation is dangerous. Detailed soils investigation involving (at the least) backhoe pits and possibly electromagnetic (EM) surveys and pits is required to determine soil properties for design and to ensure, as far as possible, that any potential seepage paths can be cut off. It is worth having an engineer on hand to evaluate soils as they are dug from backhoe pits.

Skill and experience are also required to interpret EM surveys.

Supply canal

Where large flows are required and suitable clay soils are available, open canals are efficient and cheap. Before canals are constructed, the soils should be checked by test boring or backhoe pits. (Sealing of canals after construction is difficult and can exceed the initial canal cost.)

The canals should then be hydraulically designed, checking velocity and depth limits for stable flows, assuming uniform flow in most cases. Where possible, the slopes should closely follow the natural ground slopes to reduce excavation and padding, but velocities should

be maintained between 0.15 and 0.5 metres per second to prevent weed problems and bed erosion. A freeboard on the banks above the normal water surface level should be incorporated to allow for bank settlement and flow depth variations due to canal conditions or discharge variations. Freeboards should increase with canal capacity from a minimum of 250 mm up to 500 mm or more.

Canal bends should have a sufficient radius to avoid erosion on the outside of the bends. A common rule is to use a radius of twenty times the water depth, or a minimum of 15 metres.

Head ditches

Head ditches normally have a slope of about 1 in 10,000 to minimise the number of control structures, to maintain uniform water levels above field level (command) and to make the setting of outlets (siphons) easier. Flat ditches have to be carefully maintained to ensure their capacity is not reduced. Steeper ditches require temporary or permanent checks to maintain head at the outlets. If fields are stepped to overcome steep side falls, the head ditch might require stepping at each field boundary. A flatter grade means a larger ditch to carry the same flow.

A low pad is normally constructed to the design grade with laser controlled equipment. The ditch can then be graded or delved to the desired depth, leaving the banks at the required height and on grade. The banks should be sufficiently high to provide a water level 150 to 300 millimetres above the field level, to provide adequate head for siphons or outlets.

The ditches are often designed with some over-capacity to allow for the effects of temporary weed growth and to accommodate flow variations. A flat-bottomed trapezoidal head ditch is more expensive to build than a 'V' ditch but has more capacity and is easier to use. An overflow should be provided at the end to allow non-damaging overtopping in an emergency.

Field design

The principle of surface irrigation revolves around the intake or infiltration rate of the soil. Water is provided to the field so that wetting of the root zone is satisfied by infiltration through the surface. Once the root zone at the top of the field is refilled, the water should advance down the field to continue refilling the root zone without wastage by continued high infiltration at the top. This process requires heavy clay or clay loam soils and reasonable field slopes to complete an irrigation in a reasonable time and to prevent the top end of the field from overtopping.

The appropriate run length can be determined in theory by balancing the advance and recession phase, giving all parts of the field approximately equal irrigation. Until recently, the infiltration characteristics of a field were difficult to measure and the field hydraulics difficult to model. Equipment and computer models are now available to optimise the run length to suit the soil and the farmer's requirements.

Ideally, the run length should be as long as possible, to enhance farming operations and limit the number of head ditches and taildrains and the labour in watering. Although longer runs have been used in the past, run lengths now are generally limited to a maximum of about 800 metres. In furrow irrigation, longer lengths require larger furrow streams, leading to furrows being overtopped and eroded. The possibility of furrow erosion from storm run-off is also a risk with long runs. Shorter run lengths are necessary in soils of higher infiltration capacity.

Other factors also impose limits on run length. In picking cotton, for instance, the capacity of the picker basket can limit the length. In many cases, the layout has to fit between two defined boundaries. The distance between boundaries should be divided by the whole number which gives a run length closest to the ideal. Once the run length has been selected, the furrow stream (number and size of siphons) and irrigation setting times are adjusted to evenly apply the required amount of water into the root zone.

Furrows should be designed to run down the slope, although some crossfall can be tolerated. Excessive crossfalls can result in furrow overtopping, leading to erosion across the furrows. Very little or no crossfalls can be tolerated with bay or border check irrigation. Uniform run lengths are desirable in any field and preferably on the whole farm. Furrows should be parallel to side boundaries, avoiding point rows at headland and taildrains.

Landforming is expensive, and it is not practical to change the natural slope too much. Large cuts can also result in the exposure of infertile

subsoil, with subsequent yield loss for several years. On the other hand, it is difficult to achieve even gradings where slopes are too flat, say 1:2000. If necessary, shorter run lengths can be used to minimise earthworks on very flat country.

Nearly all fields are now graded using laser controlled equipment. Lasers make construction easier and provide very uniform grades which greatly facilitate irrigation and drainage. Computer programs are available to calculate grading schedules. Fields should be broken into sub-areas to minimise earthworks, and different combinations of run length, down slope and cross slope should be tried.

Be wary of designers and contractors who are overnight experts. Just because they have a computer doesn't mean that they can design a system: 'have computer, can design' or 'have laser bucket, can construct' does not make sense. Training and experience will save large sums of money with field design and construction. To start laser grading a field without a design is like driving to Birdsville without a map.

Taildrains

Taildrains are required to remove furrow or bay run-off following irrigation or rainfall. In most areas, drain capacity will be dictated by storm flows. The capacity provided will depend on the time in which drainage must be provided. Most crops require drainage of stormwater within 24 to 48 hours. For high value, waterlogging-sensitive crops such as cotton, more rapid drainage is desirable, but the costs of drains and culverts increase rapidly. The design capacity is therefore a compromise between the time taken to drain the field and drainage costs.

The selection of the design storm is necessary to complete the hydraulic design of the system. The cost of providing facilities to cater for a large event may never be recouped. A one in five year event is usually selected as the design storm for cotton. The drain capacity is then designed to remove this water from the field in, say, 24 hours.

Taildrains should have gentle grades, but preferably steeper than 1:3300, with almost zero capacity at the end. Drain batters should be very flat to allow ready access across the drain when it is dry and provide a turning area for cultivation practices. Generally a 20 horizontal to 1 vertical slope is used on the field side with say 10:1 batter on the road side. Taildrains must be low enough to completely drain the field without causing erosion into the drain from the irrigation furrows or bays. Generally the depth between the drain bed and the field level should not exceed 300 mm to 400 mm.

Tailwater return system

Scarcity of water and environmental factors mean that re-circulation of tailwater is essential in most areas. The high cost of labour also means that careful supervision of irrigation, cutting off of siphons at precisely the correct time, is often not practical. Re-circulation is an economic alternative.

If possible, tailwater should be collected in a buffer storage to overcome the problem of matching tailwater pumps to the variable tailwater flows. When sufficient volume has collected in the buffer, the water can be pumped to a main storage or directly to the supply system for irrigation. Pumping tailwater directly back into the supply system for irrigation can cause problems with adjusting the necessary control structures to cater for the variable tailwater flow.

The tailwater return system also collects stormwater run-off, which in many areas is a welcome addition to the water supply. Even with buffer storage, there is a need to safely dispose or blow-out stormwater from large events. Tailwater pumps cannot keep up to a large storm or may not be working during a storm, due to access problems, for example. An emergency overflow facility is required, allowing excess water to be disposed of safely. A grassed bywash around the buffer storage may be used, or a gap can be provided in the bank of the tailwater return drain where design water level is at natural surface level. A gated weir structure in the tailwater system is sometimes required to release stormwater but exclude floodwater.

Culverts

All surface irrigation systems require culverts for access and flow control. Culverts are expensive, and a good layout will minimise the number required. Concrete culverts have a longer life, but steel pipe is easier to lay and can be cheap if second-hand pipe is available. Modern surface coatings are now increasing the service life of steel structures.

The choice of correct culvert size is a compromise between the capital cost of the extra size versus the capital and operating cost due to extra head produced by using a smaller pipe. The smaller pipe will require a greater head (water level upstream of the culvert will rise), requiring higher canal banks upstream and resulting in higher pumping costs over the life of the project.

Headwalls should be used to:

- contain the road or canal embankment,
- make the culverts more efficient hydraulically (reducing head loss),
- minimise silting in the culvert, and
- aid maintenance.

Headwalls can sometimes be added in the final stages of the development to save initial cost.

Remote sensing

The technology of remote sensing of water levels in channels and storages and remote control of gates and pumps is becoming very useful. It can provide significant advantages during normal irrigation and when controlling stormwater. The possibilities are nearly limitless:

- alarms can be set when water reaches a certain level anywhere on your farm;
- pumps can be started and monitored;
- gates can be opened and closed from the office or anywhere else to reduce the need to drive on slippery and narrow channel banks.

Remote sensing also provides the opportunity to collect accurate information for the assessment of on-farm water use efficiency and system performance. In the near future, accurate on-farm water balance measurements will be routine. With this technology it will be possible to know where each megalitre is on the farm.

Soils for storages and canals

Soils can loosely be classified by particle size as follows:

Class	Particle size
Rock	Large
Gravel	
Coarse sand	
Fine sand	
Silt	
Clay	Very small



Generally, as the particle size of the soil becomes smaller, the soil leaks less water. For water-holding and conveyance structures, only silts and clays are suitable. Sands and gravels in a ring tank storage or supply canal or drain will leak too much water. This leakage will also continue indefinitely unless sealed by membranes or clays.

A clay is made up of particles which are microscopic in size and are held together by molecular forces. Once wet a clay will leak only a very small amount. Very heavy clays have a saturated permeability which is so small it is difficult to measure.

Silts are made up of particle sizes which are very small (cannot be seen with the naked eye) but which are considerably larger than clay particles. Silt does leak a little and will continue to leak even when saturated.

Ideally then, all ring tank storages and earthen canals and drains should be constructed out of clay. Once the floor and walls of a clay ring tank or canal become wet the seepage losses are very small.

Any silts, sands or gravelly areas within the ring tank or canal will leak and must be sealed by lining with a layer of compacted natural clay from nearby or by membranes or imported bentonite or similar.

Experience and training is required to distinguish between a silt and a clay because both look very similar, particularly when dry.

Further information on storage and canal seepage is available in WATERpak Chapter 1.6.

Electromagnetic surveying for storage or channel site selection

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Irrigation infrastructure can experience significant seepage losses if inappropriately located on permeable soils. Detailed soils investigation involving backhoe pits are required as a minimum to determine soil properties for storage design. (See, for example, *SOILpak for cotton growers* C1 'Soil pit digging: where, how and when?')

A better option (one which provides more detail) is an electromagnetic (EM) induction survey. EM surveys of existing or planned irrigation infrastructure and irrigated fields can show variations in soil properties. The site selection of channels and on-farm storages has been improved by the use of EM surveys. These surveys allow the delineation of a field into distinctly different areas, based on apparent electrical conductivity, and allow accurate targeting of soil sampling and measurements. The appropriate location of channels and on-farm storages reduces losses to groundwater systems and increases the water resource available for productive use.

EM surveys generate data in the form of apparent electrical conductivity (EC_a). Apparent electrical conductivity is primarily related to the salt, clay and moisture content of the soil. The EC_a value is a potential indicator of soil permeability. The EC_a data are linked to GPS data at the time of collection: this ties them to a specific location for future reference. The resulting point source data are analysed with the aid of computer-generated mapping to look for trends. Several sites in each test area are then selected for 'ground-truthing' by backhoe pits or test boring and higher level analysis. The aim of ground-truthing is to confirm the range and properties of soil variations identified by the EM survey.

Soil profiles can be highly variable, consisting of layers of fine, medium and coarse textured soils, which resulted from prior stream and aeolian deposition that formed the current landscape. Surface soil features do not necessarily give an accurate indication of the nature and permeability of the underlying soil. Most soil based irrigation structures require 3.5 to 5 m of uniform medium to heavy clays below the deepest cut in order to have acceptable seepage losses.

The EM technology allows for a much more thorough subsurface investigation. It also allows for identification of patterns of soil types.

Further information on EM surveys is included in WATERpak Chapter 2.6.

The perfect layout

Naturally, there is probably no such thing. Obviously the 'perfect' layout for Narrabri, NSW will be different to that for Emerald, Queensland and Hay, NSW.

However, there are a number of desirable qualities a good layout should provide:

- uniform run lengths over the whole farm
- regular rectangular fields
- a minimum number of control and access structures consistent with easy access
- a deep square ring tank to store irrigation tailwater and first flush stormwater and to help manage regulated water
- a supply system on one side of the farm and a tailwater return system on the other side, with drains less than 3 m deep and canals with banks less than 3 m high
- a tailwater return system on the outside of the irrigation area to allow for stormwater blow-out
- a natural depression at the bottom of the tailwater return system which can be used as a buffer storage filled by gravity during large storms; its contents can then be pumped back to the ring tank or fields at leisure
- each field with the same soil type within the field.

What is the optimum run length?

Like everything else with an irrigation system, this depends on the crop and the soil and the natural slopes. The objective of selecting a run length is to provide the longest run that allows even application of irrigation water and that applies the required depth of water in a convenient irrigation

setting time without erosion of the soil during irrigation or storms.

As the run lengths increase the furrow flows need to become larger and the tailwater volumes become larger to achieve even irrigation. Further, with longer run lengths it becomes very difficult to apply small irrigation applications. In summary, shorter is better for irrigation efficiency and uniformity of application but the cost of development and operation increases. The best compromise for cotton grown on grey cracking soils is between 400 and 800 metres.

The optimum grades? This answer is simple: as close to the natural slopes as possible, because changing grades is very expensive and damages the thin productive topsoil layer. Anything from 1:500 (0.2%) to 1:1650 (0.06%) can be managed efficiently by varying furrow flows and irrigation setting times. Grades steeper than 1:500 can suffer erosion from storms if runs are too long, and grades flatter than 1:1650 are difficult to drain and yield loss from waterlogging can be a problem.

Conclusion

It is possible to 'put together' a surface irrigation system with little more than some earthmoving equipment and commonsense. Many farmers are prepared to do this, unaware of the complexities of the system with which they are about to become involved (ask someone who has tried!). The result is very often a system that costs more to construct and is a pain to operate. This may be in the short term, due to higher or unnecessary construction costs and loss of their time, or in the long term, due to higher operating costs.

An irrigation engineer can marry the skills of a civil or agricultural engineer and an agronomist. He or she should ensure that the system is cost effective and that it can be operated efficiently. Design costs generally run to only a few percent of the overall development costs.

Every element of a surface irrigation system can and should be designed to operate correctly. It is a great relief to a farmer to know that what is being built will work properly. A good design repays itself many times over.

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