IrriPlan®

AFFORDABLE IRRIGATION SYSTEMS FOR GOLF;

How to save money and avoid false economies.

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Affordable irrigation for golf:
How to save money and avoid false economies

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Preface

This article seeks to give some advice on how to make irrigation more affordable for golf developers without compromising the integrity and reliability of the system. It also identifies short-cuts and specification reductions that are ***false economies*** and should be avoided.

This article also highlights areas in golf course design that impact on irrigation cost and identifies some small but significant aspects to course design that can reap savings in irrigation cost.

There will always be downsides to a "budget" or "economy" system. Where a client has a restricted budget, our philosophy at Irriplan is not to design a cheap system but to value-engineer the system. There are many installed irrigation systems that are over-specified but under-engineered. Our approach to design, is that all systems should be properly engineered and designed as a whole, so that there are no weak links in the chain. To use a cliché the "*system should be greater than the sum of its parts*".

Reducing cost necessarily requires compromises. Some compromises afford more significant savings than others and some compromises result in false economies. Some compromises will reduce efficiency and performance, others will reduce reliability and longevity. This article attempts to indentify which compromises are acceptable for different circumstances and which compromises can be mitigated or alleviated by other means.

1.0 Design

1.1 Irrigation design

It can be argued that judicious value-engineering requires more thought than simply designing a "state-of-the-art" system. Value-engineering certainly requires more creative innovation and independence of thought to stray from designing the conventional. It also requires objectivity to be able to dispassionately assess which value-engineering compromises are appropriate and acceptable and which ones are not. This is the difference between a mere irrigation ***designer*** and an irrigation ***engineer***.

The key to achieving objectivity in value-engineering is the independence of the design engineer. If the designer is an employee or paid consultant to an irrigation equipment manufacturer, they surely have a conflict of interest in being objective about value-engineering, as they have a vested interest in the sale of some of the components (sprinklers and controls) on behalf of their employers, but not other components such as pipe, fittings, pumping plant and installation costs.

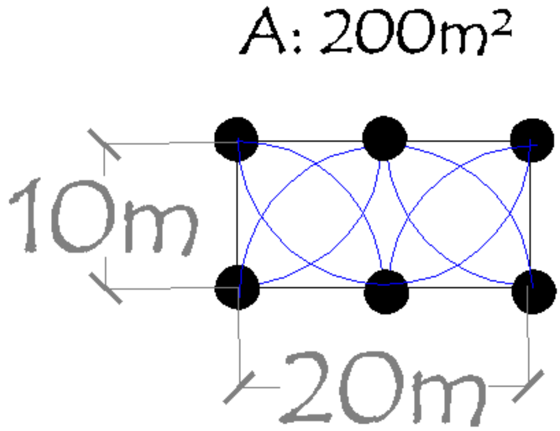
An independent engineer, whose sole income is derived from client fees, has no such conflict of interest and is unencumbered in making decisions that are in the best interests of the client, not the manufacturer, distributor or contractor.

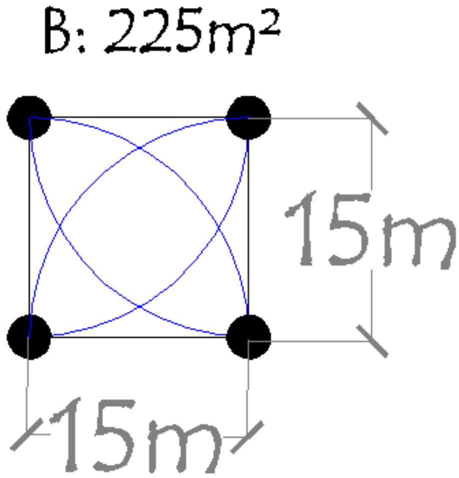
In this respect Irriplan argue that to solicit a "free" design from a manufacturer is always a false economy and it is especially the case with a value-engineering exercise. Of course we would say this… but consider this; how many manufacturer-designed systems do you think there are that have been over-engineered in terms of pipe, pumps and fittings, but under-specified in terms of sprinklers and controls.

1.2 Golf course design

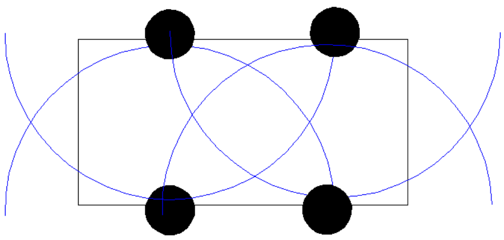
1.2.1 Tees

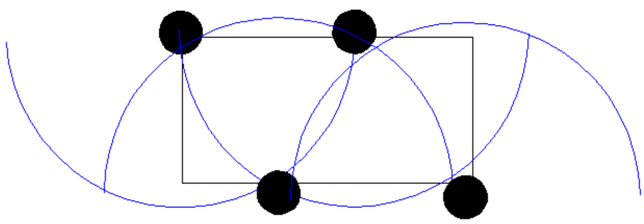
Tees always cost more to irrigate then greens, not least because there are typically 3-5 tees per hole but only one green. However what is often overlooked is that the shape of a tee has a greater influence on the cost of the irrigation than its size; a simple example is a square tee versus a rectangular tee.



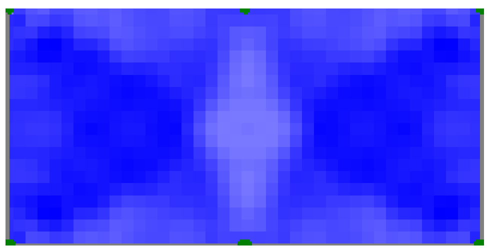


Tee A is smaller than tee B but requires 50% more sprinklers. To irrigate a rectangular tee with merely 4 sprinklers results in either poor uniformity of application or overthrow.

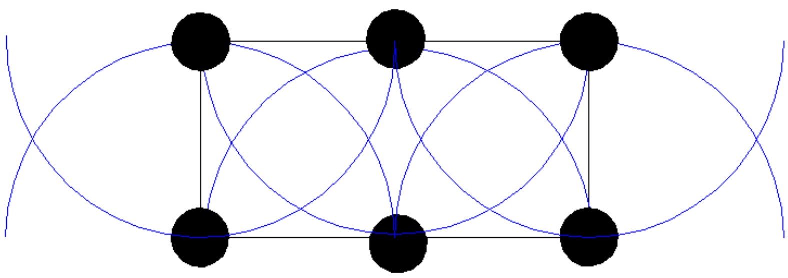




Furthermore the rectangular tee with 6 sprinklers has the problem of un-matched precipitation; there are 4 sprinklers with 90° arcs and two sprinklers with 180° arcs. For the same sprinkler/nozzle, the precipitation rate is twice near the corners of the tee as it is in the middle of the tee, resulting in a dry spot in the middle of tee (see right). The dry spot can be avoided if the 90° and 180° sprinklers are operated by separate valves – which adds yet more cost.



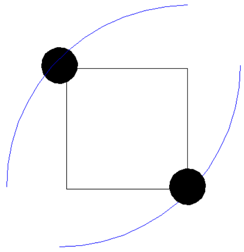
Typically for a rectangular tee the precipitation rates are matched by setting all the arcs to 180°.



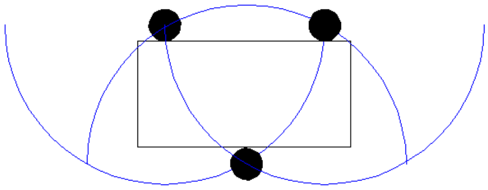
However this results in “wasted” sprinkler coverage to the front and back of the tee; this may or may not be desirable depending on the type of golf course and its environment.

Saving 2 sprinklers per tee (by having square rather than rectangular tees) will not represent a significant cost saving for one particular hole, but when there are several tees per hole and 18 holes, the savings accumulate.

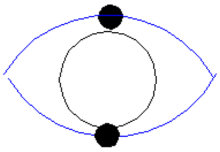
Small, square tees (≤100m²) can be irrigated adequately with merely 2 sprinklers. For a tee of 10m x 10m the diagonal distance from two opposing corners is 14m; so a 14m radius nozzle would be required.

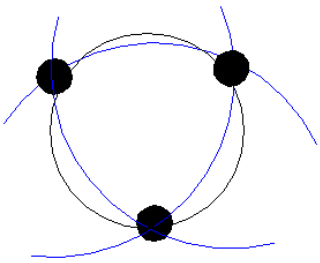


Small rectangles are undesirable as they require 3 sprinklers and result in more wasted water if the arcs are matched at 180°.



Circular tees are actually quite cost-effective to irrigate; small round tees can be irrigated with 2 sprinklers, whilst larger tees will only require 3 sprinklers.





To conclude, the shape of the tee, as designed by the architect, has as big (if not bigger) an impact on the cost of the irrigation system as the size of the tee.

1.2.2 Greens

There is very little opportunity to ever value-engineer the irrigation for the greens; this is because –

- Greens are a priority area with the highest irrigation demand on the course
- Greens normally only require 4-5 sprinklers anyway, so little scope to reduce the no. of heads.

Notwithstanding the above, larger greens are always more difficult to irrigation than smaller ones and as with tees, shape is just as important. Long narrow greens (≤20m wide) are easier to irrigate than very wide greens.

1.2.3 Fairways

Golf course design has significant impact on the cost of fairway irrigation and it is in this area, more than any other, that the course architect and agronomist influence the cost of the irrigation system.

Much debate in recent years about sustainability has highlighted the problem of water use for irrigation. Many design strategies that reduce water consumption will also reduce capital cost of the irrigation system. These design strategies are well-documented and this article will not describe them in detail. Nevertheless, however obvious they are, there is
merit in repeating the two most fundamental factors;

- Wherever possible reduce the area of irrigated turf and use natural vegetation in the style of a desert course.
- Use drought-tolerant grasses. For warm-season grasses in more temperate climates, encourage developers and the wider golfing community to accept and understand winter-dormancy. Make a virtue of it!

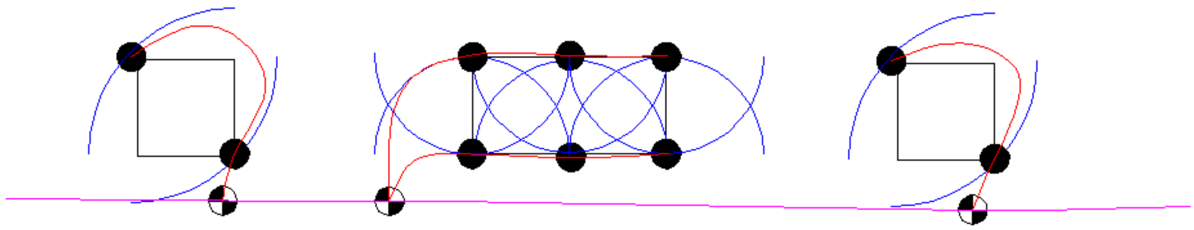
2.0 Irrigation systems

2.1 Tee sprinkler systems

Tee valves

Typically each tee should have its own solenoid valve to facilitate independent operation of each tee (Back, Middle, Front), as is shown below.

Conventional tee sprinkler system



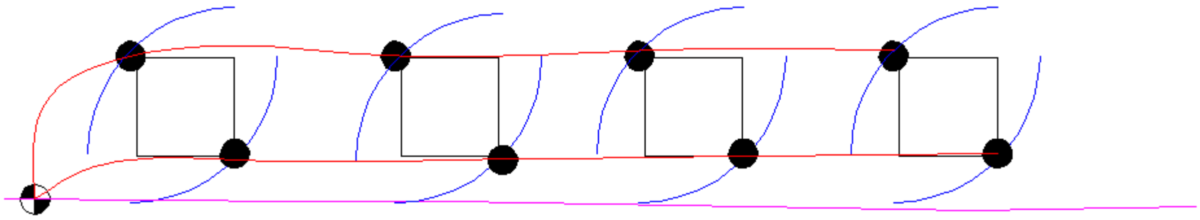
Having independent valves for each tee is necessary

- to be able target water according to demand (e.g. exposed v. shaded tees)
- where the precipitation rates of each tee are different (different sprinkler spacings/arcs)

However where all the tees are constructed with the same root-zone, same grasses, same cut-height and cut-frequency and have the same exposure to sunlight, wind and traffic (and therefore the same irrigation demand), the need to apply different amounts of water to the tees is negated.

Furthermore if all the tees are the same width and the sprinkler system has a uniform precipitation rate for each tee (same sprinkler/nozzle/arc) it would be acceptable to operate all the tees of one golf hole from the same valve. Newer models of sprinklers have a valve-stop mechanism which enables each to sprinkler to be isolated and therefore a means of manual independent control.

Value-engineered tee sprinkler system



The previously illustrated conventional tee system has 3 tees (10mx10m, 20mx10m and 10mx10m), the "value-engineered" system above has four tees (each 10m x 10m) so the total area of teeing surface is identical (400m²). So despite having more tees (4 v. 3), the value engineered system will have a less costly irrigation system because

- Less sprinklers (8 as opposed to 10)
- Less valves and decoders (1 as opposed to 3)
- Less runs of lateral pipe and changes of direction, so quicker to install

From a golf design perspective, the downside to the value-engineered sprinkler system is that it requires a uniform and consistent shape and size of tee. This might not be in keeping with the golf and aesthetic requirements of the project.

2.2 Green sprinkler systems

On conventionally-sized modern ("USGA-type") greens, Irriplan consider it a ***false economy*** to install a block-operated sprinkler system as opposed to a valve-in-head system. You save only modest sums of money, but compromise the performance and efficiency of the system, especially if you are using the greens sprinklers to water the surrounds and have different sprinkler arcs.

Irriplan only consider block-operated sprinkler systems appropriate for small greens (≤400m²), such as on a pitch-and-putt course or as a retro-fit to moderately-sized "push-up" greens.

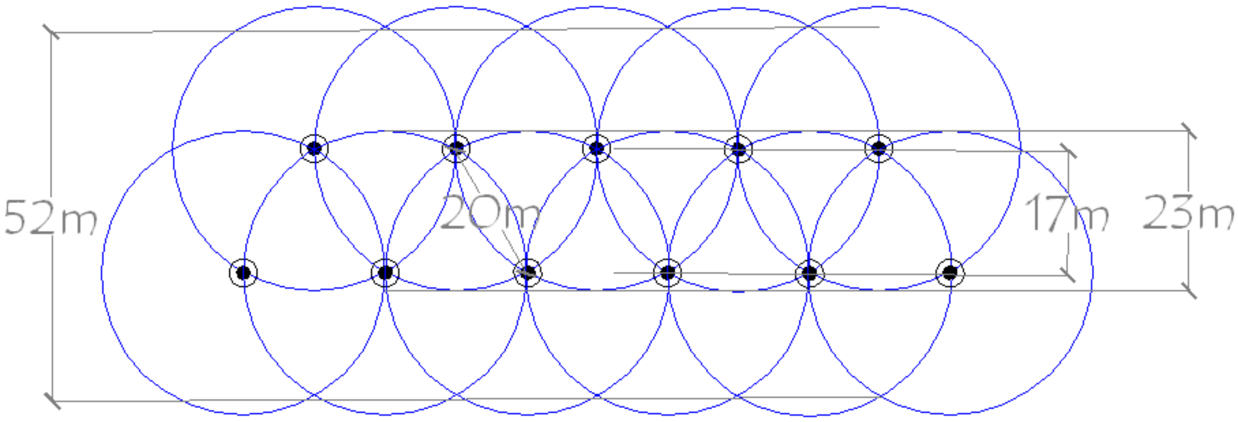
2.3 Fairway sprinkler systems

There are a multitude of options when designing the irrigation of the fairway sprinkler system and obviously there is greater scope for value-engineering in a cool, temperate climate than a hot arid one.

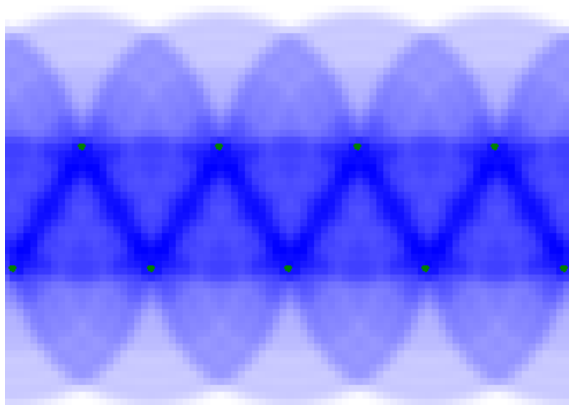
2.3.1 Temperate climate (e.g. Northern Europe)

In temperate climates the most prevalent type of fairway sprinkler system is a twin-row, full-circle, valve-in-head system, typically a triangular configuration at 20m spacing with head-to-head coverage. This gives a maximum width of coverage of 52m, but the "effective" width of uniform coverage is ≤23m, see below.

Twin-row, full-circle, head-to-head, 20m triangular spacing

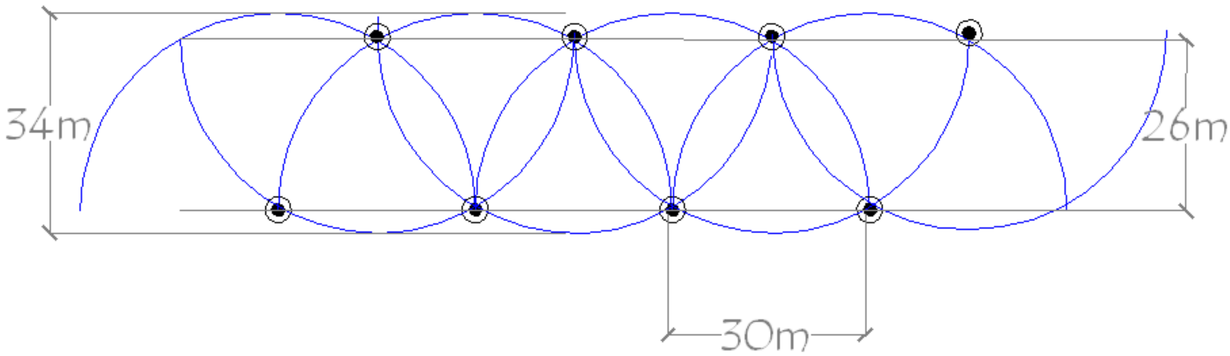


Densogram:
twin-row, full-circle, triangular spacing



As the densogram to the right shows, the result is good uniformity of application to the "corridor" within the rows of sprinklers (≈20m width) and some additional, although not very uniform, coverage to the semi-rough and rough, outside the rows of sprinklers.

There is some scope here to introduce a more cost-effective solution that involves irrigating only the fairway and not the rough. This is only really possible if the fairway width is ≤30m. For such circumstances a twin-row, long-radius, part-circle, system is possible.

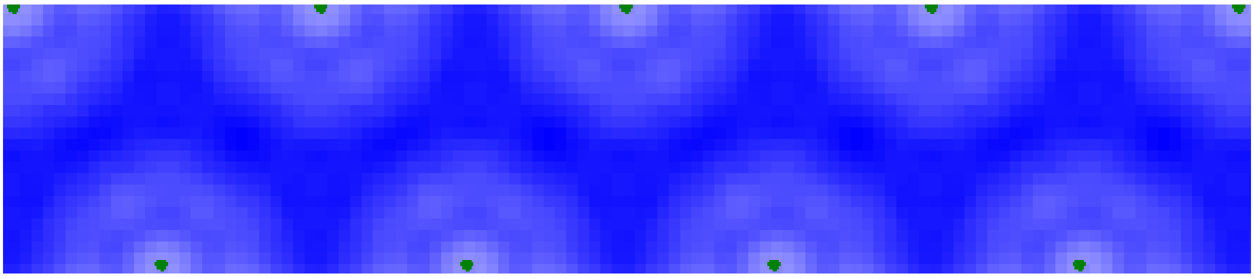


With this type of system the sprinkler spacing can be up to 30m, triangular and head-to-head. Such a system affords a considerable reduction in cost (relative to the 20m full-circle system) due to;

- 33% reduction in number of sprinklers
- 33% reduction in number of decoders
- ≈25% reduction in water consumption

- Smaller mains pipe network and pumping required due to reduced water consumption

Densogram: twin-row, 180° arcs, triangular ≈30m



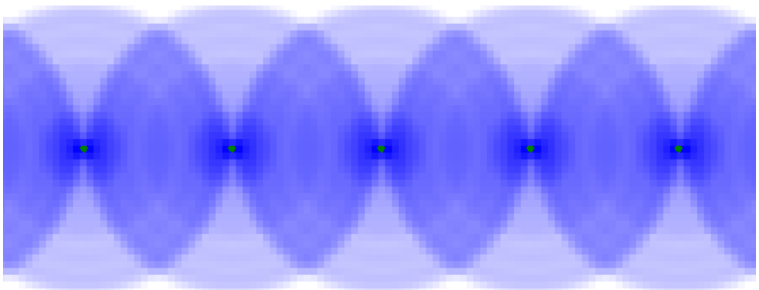
The downside is that the rough does not get irrigated, although it is possible to increase the arcs of the sprinklers up to 220°. Any greater than 220° and there is excessive overthrow.

Single-row systems

Irriplan consider single-row systems as a ***false economy*** and only to be considered for very northerly locations and only as a last resort. Our experience is that *the best thing about a single-row system is that it can be upgraded to a three-row system*. The reason why, is easily illustrated with the densogram below.

Densogram: single-row sprinklers

The light-coloured, V-shaped dry areas perpendicular to the sprinkler positions are known as "scallops". With single-row sprinklers the density and colour of the sward will correlate with the density of water application (as above) and the scallops will manifest themselves in the turf.



Temporary/manual irrigation

In temperate climates for certain types of golf courses it is often considered that fairway irrigation is a luxury rather than a necessity. Certainly this is justified for some types of established golf courses; however for new constructions that seek to grow-in the turf in time for a course opening, irrigation is an insurance policy that ensures establishment of the sward – this is especially the case if seeding in the Spring. In these circumstances developers often consider the option of a conventional automatic system for the greens, tees and approaches but seek a temporary, low-cost solution for the fairways.

There are two main types of manual irrigation suitable for this situation

- Self-travelling sprinklers; a moving sprinkler that reels in a galvanised-steel wire tethered to a stake. The sprinkler is fed by flexible hose connected to the hydrant.
- Hose-reel sprinklers; a rotating drum of polyethylene pipe with a sprinkler on the end is reeled in by water flow through a turbine.

Hose-reels are more expensive, but facilitate the use of bigger sprinklers (so less machines are required and hence less labour) and are easier to move (there are no hoses to drag-around).

However there are obviously downsides to both these manual systems;

- Can cause damage to seed-bed, dragging seed around, especially the hoses for self-travelling sprinklers.
- More traffic on the seed-bed/recently germinated sward
- High labour requirement
- Day-time irrigation results in evaporative water losses
- Night-time irrigation requires careful scheduling of the runs and management of labour
- Poor uniformity of application - but not as bad as an automatic single-row sprinkler system because the sprinklers move continually in a straight-line eliminating the scallops and also you can double-up the runs to apply water like a two-row system.

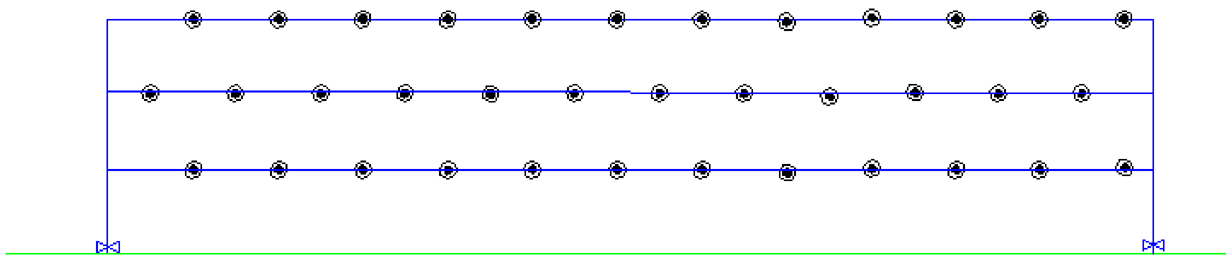
Block-operated sprinklers systems

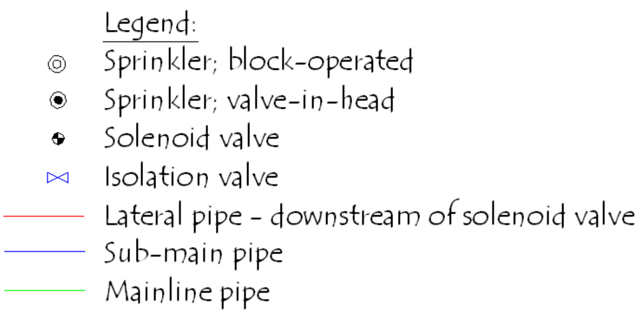
Block-operated systems are also a cost-effective way of irrigating fairways in a temperate climate. This type of system can also be installed in semi-arid climates as described below.

<u>2.3.2 Semi-arid and sub-tropical climates</u>

In semi-arid and sub-tropical climates, where irrigation of the semi-rough/rough is required and a multiple row sprinkler system is necessary, a typical conventional system would comprise three-rows of valve in-head sprinklers, with sub-main pipes looped to each end of the fairway.

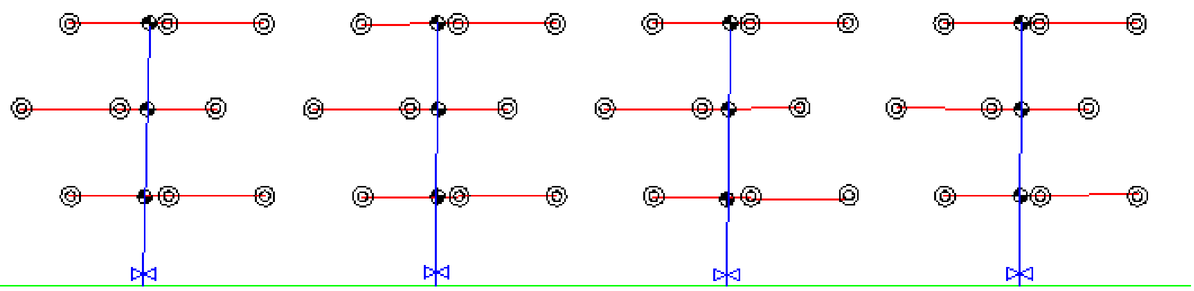
3-row, valve-in-head sprinkler system; typical pipe schematic





An alternative to the above specification is to install a block-operated system. With this kind of system, the sprinklers do not have their own solenoid valve but are operated in groups or “blocks” by a separate solenoid valve. In the example below each there are 3 sprinklers per solenoid valve.

3-row, block-operated system; typical pipe schematic



The block-operated system is cheaper because;

- the sprinklers are less expensive
- there are less valves to operate, so the control system requires less cable and less decoders/satellites.

Block-systems are simpler, require less service and maintenance and are easier to operate. However there are some downsides;

- less precision/flexibility of control as the sprinklers are operated in groups of three and not individually, this results in some loss of efficiency*.
- more time-consuming to install, lots of dead-time as machine is turned around and moved to install the next lateral/sub-main
- careful planning of the design is required to avoid grouping part-circle and full-circle sprinklers on the same valve

*This is the argument propounded by most suppliers of irrigation equipment and there is some justification for this. However there are some counter-arguments and ways to mitigate their effect;

- most valve-in-head systems for fairways are paired at the controller so they don't have individual head control anyway. A reduction in flexibility from 2 sprinklers per control station to 3 sprinklers per control station is therefore not a huge compromise
- most superintendents don't program the irrigation to the level of precision that a valve-in-head systems allows; they generally set the same sprinkler run-time to all sprinklers on the fairway.
- If there is a particular circumstance around a sprinkler that means the turf requires additional water or less water, then this can be accommodated in the block-system by changing the nozzle.
- If there is a dry-spot on a mound, a valve-in-head sprinkler is never going to solve this problem anyway; the only solution is an additional small sprinkler, manual watering and/or the addition of some soil amendment.

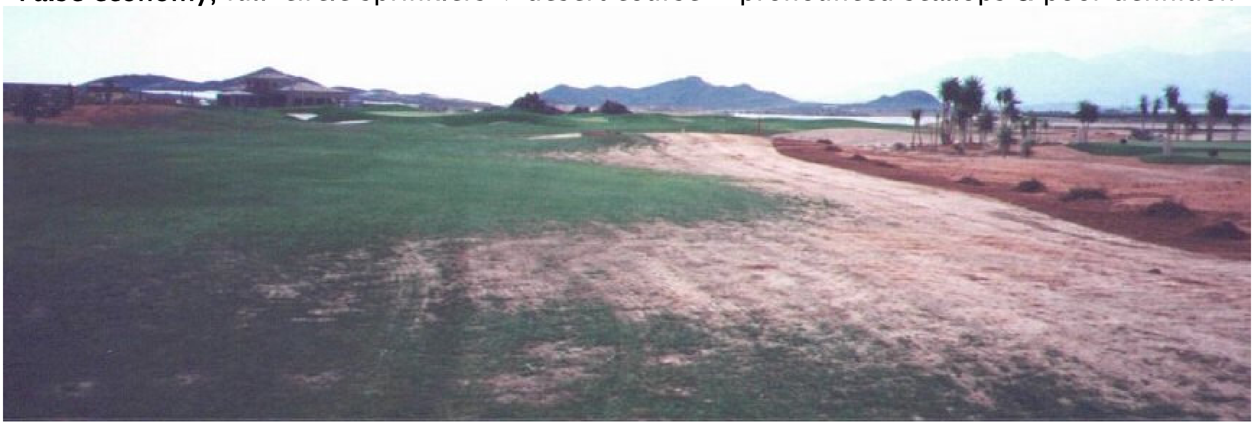
2.3.3 Arid climate

With arid climates value-engineering the sprinkler system at the expenses of efficiency or performance is nearly always a ***false economy***, unless there is a plentiful, reliable and cheap water supply – this is rarely the case.

One could increase the sprinkler spacing from the typical 20m to say 22m, but this would only save very modest amounts and would result in a reduction in application uniformity and hence reduced efficiency.

Desert-style courses in arid climates need multiple-rows of individually-controlled, valve-in-head sprinklers. In particular these courses should have part-circle sprinklers on the defined perimeter of the turf to avoid overthrow and also to accentuate the aesthetic quality of the definition between course and desert. It is a false economy to reduce the number of rows of sprinklers and use only full-circle sprinklers. The result will be wasted water, poor definition of the course and pronounced scallops.

False economy; full-circle sprinklers + desert course = pronounced scallops & poor definition



NB. The above was not an Irriplan project!

2.4 Equipment selection

Some manufacturers market two sprinkler product lines for golf; a "budget" line of sprinklers and a "premium" line of sprinklers. Where this is the case, there are obvious savings to be made with the budget line for only a little compromise in functionality, but on the whole these savings are not very significant.

Much more significant savings can be made by installing sprinkler models from the manufacturers' non-golf, turf sprinklers, known in the industry as "res/com" sprinklers (they are mainly used in residential, commercial and landscape applications).

However these sprinklers are only really appropriate for close sprinkler spacing (≤20m) for small areas such as tees, carries/walkways, greens surrounds and areas of amenity turf such as around the club-house. Indeed a majority of golf courses in Europe have tees with this type of sprinkler installed.

They can and have been used on fairways, but it should be noted that they are very susceptible to damage by aeration operations (verti-draining, hollow-coring) because they are very difficult to see and locate.

2.5 Pipe & fittings

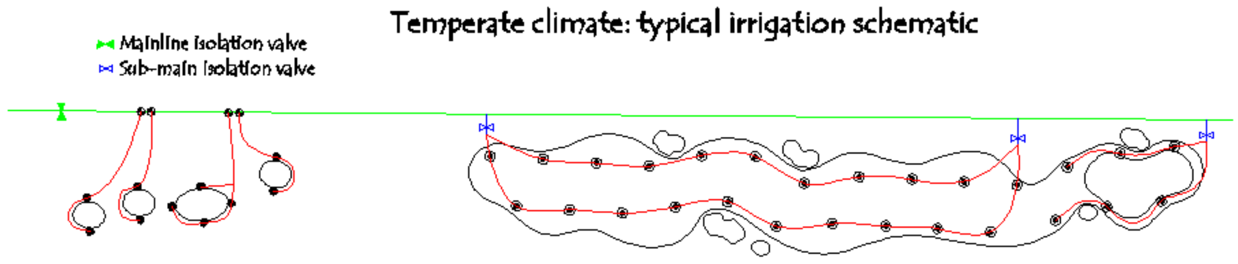
It is an obvious ***false economy*** to use cheap pipe and fittings. Irriplan doesn't advocate any kind of value-engineering for these components which form the fundamental "chassis" of an irrigation system.

A well-jointed, good-quality polyethylene pipe network should have design-life of 50 years. The pipes are the most difficult, disruptive and expensive part of the system to have to replace. This is therefore a long-term investment that merits getting right first time.

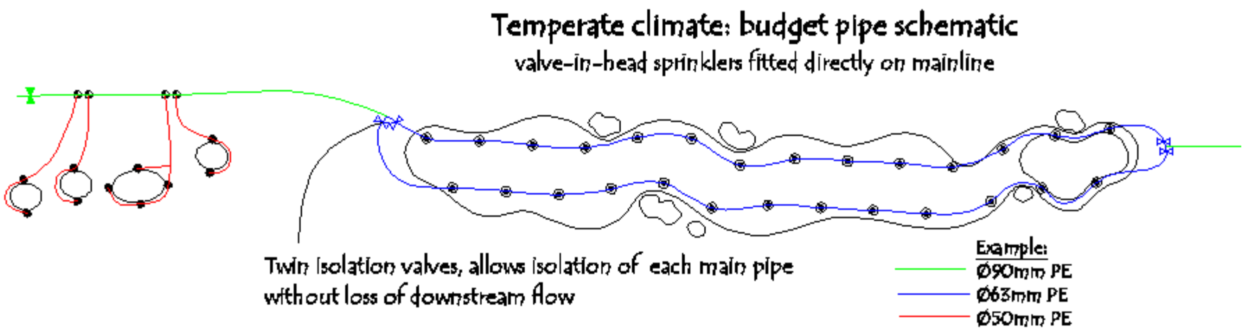
The only way to save money with a pipe network is to ensure that the system hydraulics are optimised and that no pipes are unnecessarily over-sized. To this end Irriplan always model the system hydraulics using computer software to test various different pipe networks to determine the most economical and practical pipe network to achieve a given application.

Fitting sprinklers directly on the mainline

Ordinarily best practice is to fit valve-in-head sprinklers onto a sub-main pipe which is connected to the mainline pipe via an isolation valve. In this way if there is a problem with a sprinkler, the sub-main can be isolated and the sprinkler can be repaired/replaced without loss of downstream flow (see figure below).



By fitting the sprinklers directly on the mainline you can reduce the amount of pipe and cable that has to be installed. However this should be done with caution and safeguards implemented to ensure continuity of downstream flow. The example below shows multiple isolation valves to enable the individual isolation of each main pipe so that in the event of a problem downstream flow can be maintained in the other pipe.



There are downsides to this system-

- although downstream flow can be continued, it is not maintained at the same capacity
- a problem with a fairway sprinkler means that the entire length of pipe has to be isolated, so the greens sprinklers on that pipe are also inoperable
- only really suitable for a twin-row system
- highly not recommend for single-row systems as downstream flow cannot be continued

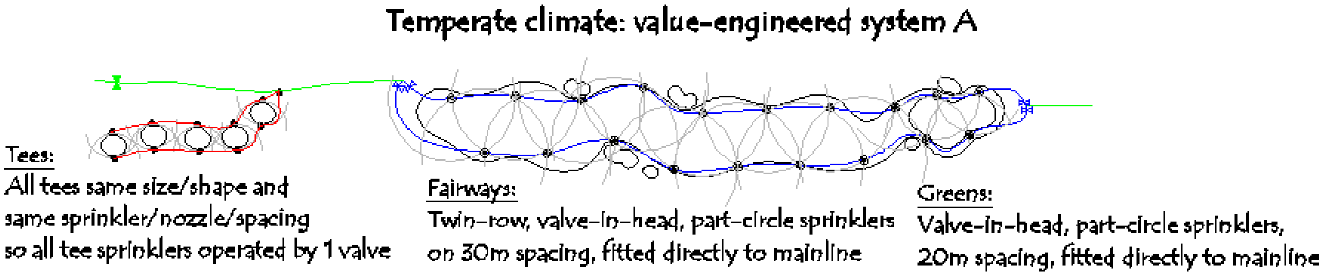
It can be argued that in a temperate climate these compromises are acceptable, because it doesn't take long to repair a sprinkler or replace the valve/rotor, so that pipe should not have to be isolated for any length of time.

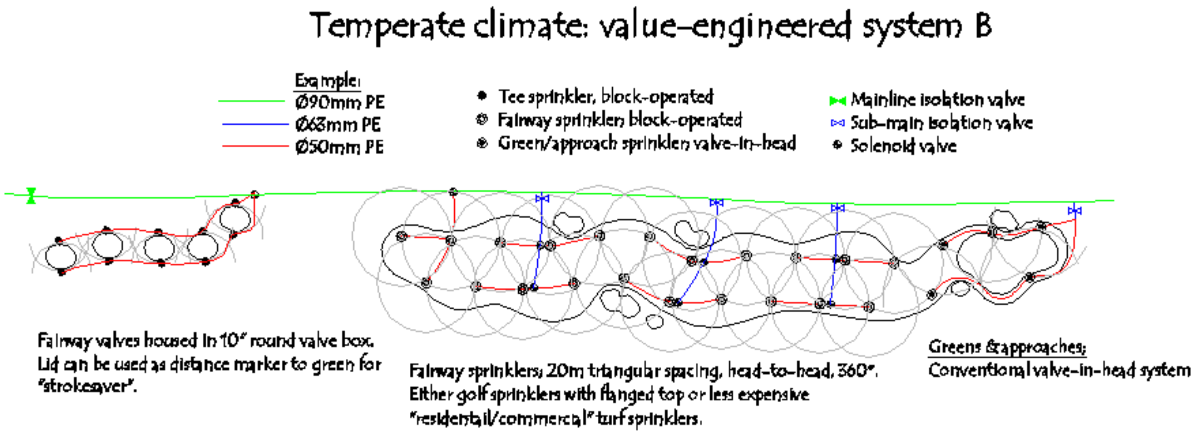
However in an arid climate this system is not recommended for the following reasons

- Multiple-row systems would make the pipe network extremely complex
- Potential to make cost savings are less significant the bigger the system is
- The pipes would have to be quite large to carry the required flow for the system so all pipes would have to be trenched, whereas with a conventional system one would trench the mainlines and plough the sprinkler sub-mains. So again the cost savings are offset by increased installation costs

Summary

As previously described there are a multitude of options available in value-engineering a sprinkler system. To follow are just two examples that combine some of the elements previously described.





Each type of systems has its upsides and downsides; the most appropriate type of system will depend on the circumstances and requirements of the project, the budget, availability of water and the objectives of the developer. Below is a summary comparison of the two examples above;

	A	B
Cost	medium	low
Water use	low	high
Ease of service/maintenance	medium	v. easy
Ease of operation	medium	v. easy

2.6 Pumps

As with the pipe and fittings Irriplan does not advocate any value-engineering of the pumping plant, except for a few minor features that might reduce functionality but not performance or efficiency.

2.7 Control systems

Multi-wire satellite control systems will cost considerably more than a two-wire decoder or a hybrid satellite-decoder system.

The great majority of control systems in Northern Europe are two-wire, decoder systems. As decoder control systems have become more sophisticated, more reliable and less susceptible to lightning, their prevalence has extended south to more arid climates. This trend will probably continue as specifying a decoder control system is an easy way to make considerable cost savings.

There are however some downsides, but these can be mitigated with careful design and planning.

- Lightning; the perception in the market-place is that decoder systems are somehow more susceptible to lightning strikes. This is not strictly true; if the control system is carefully-designed with lightning protection and earthing, decoder systems are no more susceptible to lightning than satellite systems. However no system is 100% immune to lightning damage.
- Field control: satellite control systems are favoured on large installations on new constructions, because the field satellite controllers on the course can be used to test the irrigation and grow-in the course prior to the installation of the PC. Usually the PC is housed in the superintendent's office and this might not be constructed in time to house the irrigation PC. If this is the case then a hybrid decoder/satellite system will afford some cost-savings without loss of the field control. Alternatively it is possible to install a decoder system with a temporary wall-mounted controller in the pump house or a temporary location found for the PC, until the Superintendent's office is built.
- Fail-safe; in the event of the failure of the central PC, the irrigation of a satellite system is still operable automatically from the field satellites. This is also the case with a hybrid system. However with a decoder system, loss of the central PC or interface means loss of automatic operation of the entire system, unless there is a second, back-up PC and interface.

3.0 Water resources

3.1 Groundwater abstraction

Water supply is often one of the most neglected aspects in the early stages of planning a golf project. Undertaking a hydro-geological and water resources feasibility study in the early stages of the process is essential. This should ideally be undertaken by, or in association with, the golf irrigation engineer who should be able to calculate the irrigation water requirements for peak daily consumption, an average year, a drought year and a grow-in year.

If there is sufficient groundwater resources available, then this is very good news as this source of water usually represents the lowest cost to develop.

3.2 Treated Sewage Effluent (TSE)

If there is TSE plant for a local population nearby this will be a valuable source of cheap water. However few golf course are located near municipal water treatment plants.

Often the golf course will be the centre-piece of a larger resort comprising hotels and real-estate with its own water treatment plant. This again will be a valuable source of cheap water. However the amount of water generated from a resort water treatment plant is usually very modest and **much less** then the peak daily demand of a golf course. Rarely does a resort generate enough TSE to irrigate a golf course.

TSE will be produced throughout the year, but the irrigation demand will be very seasonal. Often the peak output of TSE from the resort will NOT coincide with the peak demand. In semi-arid and arid climates, golfers often want to play in the Spring and Autumn so the peak occupancy of the resort (and therefore the peak TSE output) does not coincide with the peak irrigation demand (Summer).

For this reason TSE must be stored during peak output for subsequent use during peak demand. Furthermore TSE will rarely suffice on its own to supply a golf course with irrigation water. It will nearly always have to be supplemented with other supplies, such as harvested rainwater.

3.3 Rainwater harvesting

Where it rains, this is an obvious cheap source of water; or is it? The water is free of course, but there is the capital cost of constructing a reservoir to store the water. The reservoir needs to be budgeted for in the early stages of planning the development and one should not fall-back on the idea that a golf lake can be used a storage reservoir (see para 3.4 below), except in tropical climates where dry seasons are short.

3.4 Reservoirs

Irriplan do <u>not</u> recommend, in the strongest possible terms, the use of golf or amenity lakes as water storage reservoirs. This is because an empty reservoir is ugly and also a potential safety hazard. Do not be fooled by the notion that the lake can be "topped-up". If it is being topped up during the irrigation season, it's a ***balancing*** lake, not a water ***storage*** reservoir.

For the avoidance of doubt, a balancing lake merely reconciles the continual inflow from a water supply with the night-time demand from the irrigation system. Thus with a balancing lake there is only a diurnal, not seasonal, variation in the water level. A water storage reservoir reconciles seasonal supply with seasonal demand and necessarily has to be much, much larger than a balancing lake.

Also do not be fooled into thinking that with a sufficient number of inter-connected lakes around the course, one can store the seasonal demand of the golf course for a semi-arid/arid climate. This will rarely work because in order to reduce drawdown from a lake or lakes you need to design them with a large surface area. The corollary to this that the increased surface area of water will result in considerable evaporative losses* and the shallow nature of lakes results in poor water quality.

* *this was once rebutted by someone who suggested that this could be countered by making the lakes smaller in surface area and deeper. It took me some time to explain that making them deeper does not solve the problem, since even if one pumps water from the bottom of the lake the water draws down from the top, exposing the banks!*

It cannot be stressed enough that if the water supply is a combination of predominantly seasonal sources, there is no other solution but to construct an off-site storage reservoir which is away from view from golfers and the general population of the resort.

It is paramount therefore during the early stages of planning a golf course or golf resort that a proper water resources feasibility study is undertaken to determine the following

- Peak daily and seasonal TSE output from resort
- Potential yield from rainwater harvesting
- Hydro-geological prognosis to assess potential for groundwater abstraction
- Irrigation water requirements – peak daily, monthly, average annual, 1 in 20 year drought
- Monthly water balance
- Required capacity of reservoir
- Preliminary assessment of site to determine potential locations for reservoir

Failure to undertake a feasibility study or even an initial prognosis for a project in semi-arid/arid climate will almost always result in greater costs and master-planning/design revisions later in the project.

4.0 Summary

4.1 Quick tips to value-engineer the irrigation system

- Square or circular tees are cheaper to irrigate than rectangular ones
- Avoid excessively large greens, especially wide ones - long but narrow (≤20m) is OK.
- Consider a twin-row part-circle system for fairways in a temperate climate
- Consider a block-system for fairways in a temperate, semi-arid or sub-tropical climate
- Design the irrigation system in a way that allows the majority of the pipe to be installed by mole-ploughing rather than trenching (assuming ground conditions permit).
- Use a decoder control system or hybrid system with an entry level PC
- In temperate climates consider fitting sprinklers directly onto mainline (not sub-main) but ensure there are numerous isolation valves to avoid loss of downstream flow in the event of a problem. Absolutely do not do this with a single row fairway system.
- Consider use of “res/com” sprinklers for small areas such as tees, greens surrounds and amenity turf.

4.2 False economies to avoid

- It is a false economy not to undertake a water resources feasibility study or initial prognosis for a golf project in any environment, but particularly a semi-arid or arid one.
- Do not use a golf or amenity lake as an irrigation storage reservoir. It’s acceptable as a daily ***balancing*** reservoir but not as seasonal ***storage*** reservoir.
- Do not cut corners with design; hire an engineer who is qualified and verifiably independent.
- Avoid single-row sprinkler systems on fairways; if you really have to save that much money consider a well-designed manual system or make savings elsewhere to afford a twin-row system.
- Avoid block-operated sprinkler systems on greens
- Avoid cheap pipe fittings and avoid cheap cable connections
- Avoid reductions in isolation valves
- Be very careful of value-engineering the irrigation system in an arid climate