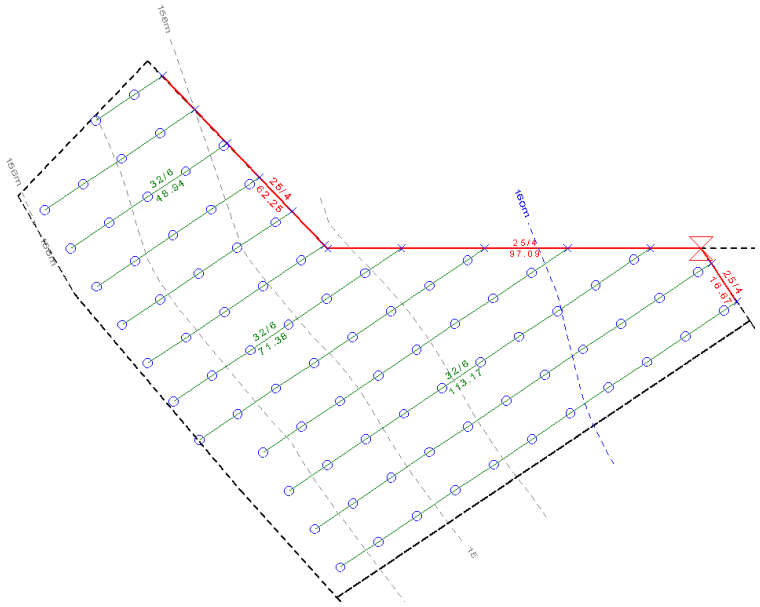
IrriMaker – Step by step

Part 4 – Pipe Sizing – The IrriMaker Approach



In my previous article I showed you how to fill a block with the basic elements (valve, laterals, manifold) needed to perform an infield design. Today we will go over some of the principals that IrriMaker apply when performing pipe sizing calculations applicable to the in-field situation or block design.

When sizing pipes, IrriMaker uses a very similar method than the poly-plot method. This method is well known by many who come from the "design-by-hand" era. If the basics of hydraulics are adhered, it is quite easy to predict the results that IrriMaker will return.

IrriMaker is a tool or calculator that is used by the user to perform his work. The software is only limited by the user's ability and understanding of irrigation design principals. In other words, IrriMaker is not the designer, ***YOU*** *are and if you give the software random parameters, you will receive random answers!*

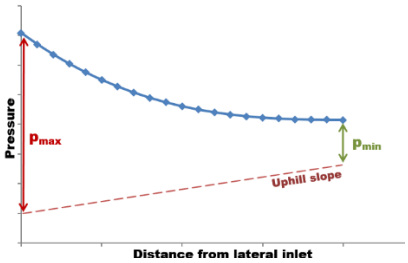
To make it a little bit easier I would like to remind you of some basic concepts that need to be thought of while sizing pipes:

1) The goal of a good irrigation system is to achieve pressure which equate to flow uniformity by designing a system that ensure that each emitter in the system receive the same (or as near as possible) pressure to achieve a uniformly targeted flow rate.

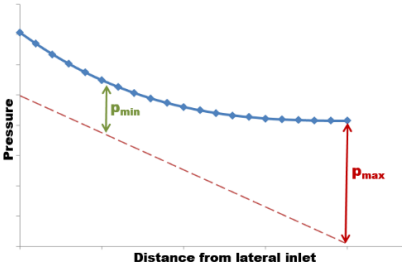
2) The amount of pressure loss in a lateral line is determined by:
    a. friction losses due to pipe diameters and it's associated roughness coefficient (C)
    b. friction losses caused by internal emitters obstructing flow (kd)
    c. pipe slope (topography)
    d. flow losses (emitters drawing flow out of the pipe)

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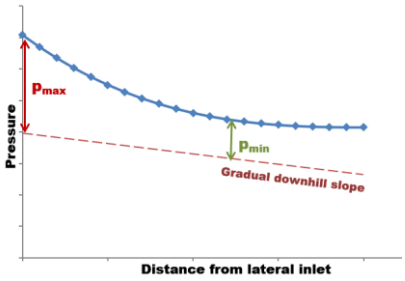
3) When a lateral line is placed up-slope, emitter flow rate decreases rapidly. This is due to gravity playing its part (also called static pressure loss).



4) Similarly, a lateral placed down-slope will gain pressure which will cause the emitter flow rate to increase if the emitters are not pressure compensating.

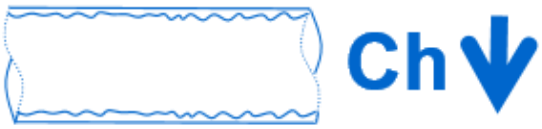


5) Where the topography allow it, placing the lateral line down-slope can produce the most uniform flow discharge rate since losses (negative) and static pressure (positive) cancel each other out to some degree.



6) Increased flow rate or using thinner pipes increase losses, resulting in decreased pressures downstream.

7) In contrast, increasing inside diameter decreases the effect of friction losses, increases volume which in turn provide greater downstream pressure. Increasing diameters will also lower velocity.

8) 



Higher friction factors (Ch) = less friction (internal pipe smoothness)

9) For reference it is needed to mention that IrriMaker generally uses the Hazen-Williams equation

$$Hf = L \cdot \left[\frac{3.59 \cdot Q}{Ch \cdot d^{2.63}} \right]^{1.852}$$

Hf	= friction
L	= pipe length
Q	= flow rate
Ch	= Friction coefficient
d	= internal diameter of pipe

to calculate friction loss unless the user specifically indicate that the Darcy-Weisbach equation

$$Hf = \frac{f \cdot L \cdot v^2}{2 \cdot g \cdot d}$$

f	= friction factor (f = 64 / Re)
v	= average velocity of flow
g	= gravitational acceleration

should rather be used, usually for pipe diameters smaller than a specified diameter.

These are just some of the basics we need to keep in the back of our minds while designing pipe networks.

Pipe sizing with IrriMaker – the IrriMaker approach

First of all, when sizing pipes, the user is required to provide three sizing parameters:

1. No. of Pipe Sizes
2. Maximum Velocity
3. Pressure variation/envelope

1) The number of pipe sizes

The absolute maximum number of pipe diameters that may be used when sizing a single pipe is defined. IrriMaker will endeavor to size all pipes individually with the specified number of pipes (or less if possible) while conforming to the pressure envelope and velocity parameters as specified below. If the number of indicated pipe sizes are not sufficient, the envelope for that specific pipe will be widened and the attained envelope will be reported to give the designer feedback where possible problems exist.

Warning: This is an important parameter, the lower the value the greater the impact.

Recommendation: Use a high value to start to allow IrriMaker more options, IrriMaker will not necessarily use all the sizes you specify, but will have more options to use during its iterations.

2) The allowable maximum flow velocity

The absolute maximum velocity parameter is defined by the designer. IrriMaker will up-size pipes in such a way that the water velocity stays below the defined velocity. Remember that the value entered is the absolute maximum velocity allowed and not the actual velocity as a constant/target as is often perceived by first time users. Velocity is influenced by the amount of water that will need to flow through the available pipe diameters. IrriMaker will never attempt to achieve the maximum velocity but rather use it as a "next size" boundary.

Warning: Higher velocity values will allow IrriMaker to design systems which uses thinner pipes, but when you consider the system "health/durability", the higher velocity may shorten the lifespan of the complete system. Another effect of higher velocity is the increase in friction losses which makes it a challenge to keep a block design within the required pressure variance/envelope. On the other hand, some systems like drip irrigation require minimum velocities to be adhered so that the laterals may be flushed – Consider all external factors, not just the design!

Recommendation: Use the SABI design norms as referenced on www.sabi.co.za as a starting point.

3) The required pressure variation/envelope

The pressure variation can be expressed as a percentage or meter value of the required or design pressure. The design pressure referred to in this instance is the required emitter pressure as defined during the fill laterals stage when the initial pipe and emitter type was selected and placed into the block – refer to Part 3 in the previous article.

Warning: Higher values will cause lower emitter uniformity in non-regulated emitters.

Recommendation: If you apply SABI design principals and you determine a total allowable block pressure variation, part of that variation must be used in the laterals and the other part must be used when sizing the manifold. For example, if you have a 20% total block variation, you can typically size the laterals with a 15% variation and the manifold with 5% thus

achieving a total variation of 20%. The % value referred to here is expressed as a % of the design pressure required at the emitter.

I will explain the effect of each parameter above and how they relate to each other as follows:

For one pipe size:

Assume the following variables:

- ✓ Pressure Variation: 10%
- ✓ Max Velocity: 2m/s
- ✓ Max No. of Pipes: 1

1) If only one pipe size may be used, IrriMaker will select the pipe diameter that can accommodate the full flow that need to pass through it the best. It might be that the pipe database have more than one pipe size available but only the most suitable pipe is selected and the rest of the pipes are ignored.

2) The fact that we only allow the program to use one pipe size might mean that by adhering to the 2m/s velocity the attainable pressure variation is not 10% due to a possible bigger pipe size required to keep the velocity below the maximum. In this instance the velocity have second priority after the selected 1 pipe parameter causing the pressure envelope to increase if the pipe for example run downhill and the emitters do not draw flow from the pipe fast enough. To a degree, the pressure variation parameter is used in the initial selection of the single pipe diameter, but during the iteration process may actually be compromised due to the combined effect of the 1 pipe and maximum velocity parameters.

3) To summarize I would like to recommend that you be careful when setting the number of pipe parameter to 1 and setting the maximum velocity too low.

For two pipe sizes:

Assume the following variables:

- ✓ Pressure Variation: 10%
- ✓ Max Velocity: 2m/s
- ✓ Max No. of Pipes: 2

Now, let's assume the same scenario, but increasing the number of pipe diameters for each lateral to two, the approach is a little different.

IrriMaker will scan all the pipe sizes available in the selected pipe group in the database and choose the smallest diameter to start. Then starting at the end node (the point on the lateral with zero flow past the node), assuming the end node pressure is equal to the design pressure, the flow will be accumulated as you move past each emitter in the direction of the manifold. For each segment between emitters, the slope and friction losses are calculated and the pressure at each emitter is determined. The starting pressure is subtracted each time the pressure at a emitter is determined and if the pressure difference is more than the required 10% pressure variation or the velocity is more than the maximum 2m/s, the total length of pipe attained within the limits are recorded. The next pipe diameter is then selected and the process is repeated. This process is repeated for all available pipe sizes in the selected pipe group in the database resulting in 20 possible answers relating to how far each pipe size can theoretically go. The smallest pipe size that can go the furthest within the pressure envelope and velocity maximum is then selected as the first pipe size.

If a specific pipe diameter can be used the full length from start to end within the 10% envelope and the velocity of the last segment closest to the manifold is less than 2m/s, IrriMaker will not consider multiple pipe sizes even if the user defined multiple pipe sizes as a parameter.

In other words, the pipe is only sized where the velocity is too high. The next diameter in the pipe group is then added to the lateral to be used the remainder of the way leading to the manifold.

If the velocity in the second pipe is also too high before the manifold is reached, the first pipe size will be thrown out and replaced by the next size up and the process is repeated until the best two sizes are found. If no solution is possible, the program will report that a certain lateral could not be sized unless the envelope is widened.

More than two pipes:

Assume the following variables:

- ✓ Pressure Variation: 10%
- ✓ Max Velocity: 2m/s
- ✓ Max No. of Pipes: 3+

With more than two pipe sizes specified, the calculation is more complex because the options also multiplies. Pipes may be combined in many ways and each option result in a varying answer.

Whilst still adhering to the 10% pressure envelope and the 2m/s velocity limit, IrriMaker will again start at the endpoint and determine the pipe size that go the furthest (let's call this pipe A), then the second pipe (pipe B) is added. The combined distance of pipe AB is then recorded.

IrriMaker will then shorten pipe A somewhat and test to see if this new combination results in a longer AB. If no advance in AB is possible a third pipe (pipe C) is added. If this combination reaches the manifold the process is complete.

If ABC is too short and the user only allowed for 3 sizes, then alternatives are tried. For example, pipe B can be shortened so that pipe C reaches the manifold, if not, A can be shortened so that more of B and C can reach the manifold. If this does not give the desired result, the whole process is restarted with pipe A one diameter larger. If none of the combinations of three pipes are successful to reach the manifold (still within the 10% envelope and 2m/s speed limit), the pressure variation will be widened with 1% and the process repeated.

In other words, everything is repeated with an 11% pressure variation. If this is the case, the laterals where the envelope is widened will be reported. The message will typically look like this:

"Envelope widened on line with node # 12 Sized to 14"

This simply mean that a lateral pipe that contain a node with identifier number "12" (usually this node will be the end node of that particular lateral), could not be sized within the set parameters and that the thinnest possible pipe combination was selected, but that the 10% pressure variation for that pipe could not be achieved and that the iteration stopped when the envelope was widened to 14%. This could possibly mean that the pressure variation attainable on that specific lateral is >=14%.

Manifold Sizing:

In manifold sizing the same principals are used. The difference is that where emitters are used to calculate the flow in laterals, with manifolds, laterals are used to define the flow demand. Each lateral has a flow requirement based on the number of emitters in each lateral.

There are lots of other checks and balances that are performed by IrriMaker as well which are not mentioned here. For instance IrriMaker is continually aware of the topography and knows if a pipe is flowing uphill or downhill. Each pipe is viewed with this in mind and sized accordingly, the result a systematic approach and the results are tested in practice on a daily basis as accurate (some say too accurate) and satisfying many designers the world over!

The explanation above should satisfy most and it is with this information we can now proceed to the actual steps of sizing our first sprinkler block.