TECHNICAL ASPECTS AND COST ESTIMATING PROCEDURES OF SURFACE AND SUBSURFACE DRIP IRRIGATION SYSTEMS

Volume 3 of 3

A MANUAL FOR IRRIGATION FARMERS

by

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This report forms part of a series of three reports. The reports are:
Technical Aspects and Cost Estimating Procedures of Surface and Subsurface Drip Irrigation Systems Volume 1: Main Report **(WRC Report No. TT 524/12)**
Technical Aspects and Cost Estimating Procedures of Surface and Subsurface Drip Irrigation Systems Volume 2: A Manual for irrigation designers **(WRC Report No. TT 525/12)**
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Dr A J Sanewe : Water Research Commission
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List of Acronyms and Abbreviations

ARC-IAE	Agricultural Research Council's Institute for Agricultural Engineering
Agrilasa	The Agri-Laboratory Association of Southern Africa
CV	Coefficient of variation
DI	Dirt index
DU	Distribution Uniformity
EU	Emission uniformity
HG	hydraulic gradient
IR	Irrigation Rate
IRRICOST	A computer program to estimate both the annual fixed and variable irrigation costs
KBase	Knowledge Base System
OHS	Open Hydroponic System
Ppm	Parts per million
PE	Polyethylene
PVC	Polyvinylchloride
SDI	Subsurface drip irrigation
SABI	South African Irrigation Institute
SANAS	South African National Accreditation System
SAPWAT	South African Plant Water Requirements
TDS	Total dissolved solids
WRC	Water Research Commission
WHC	Water holding capacity

1 INTRODUCTION

This manual is the product of a technology transfer project (Project No K5/1806/4) funded by the Water Research Commission (WRC), undertaken by the Agricultural Research Council's Institute for Agricultural Engineering (ARC-IAE), and entitled "Technology Transfer of the technical aspects and the cost estimating procedures of surface and subsurface drip irrigation systems". The information compiled herein is a combination of WRC funded research output, data obtained from irrigation companies that are active in the South African market, and international literature on the topic of drip irrigation and filtration.

The following WRC reports were analysed and information extracted:

1. Du Plessis, FJ; Van Averbeke, W; Van der Stoep, I. 2002. *Micro-Irrigation for smallholders, guidelines for funders, planners, designers and support staff in South Africa.* Report No TT 164/01. Water Research Commission, Pretoria, RSA.
2. Koegelenberg, FH. 2003. "Micro irrigation systems" in: *Irrigation Design Manual.* Revised edition. ARC-IAE, Pretoria. RSA.
3. Koegelenberg, FH; Reinders, FB; Van Niekerk, AS; Van Niekerk, R; Uys, WJ. 2002. *Performance of Surface Drip Irrigation Systems Under Field Conditions*. Report No. 1036/1/02. Water Research Commission, Pretoria, RSA.
4. Marais, A. 2001. *Subsurface Drip Irrigation Systems*. Paper No. 8736. Netafim, White River, RSA.
5. Oosthuizen, LK; Botha, PW; Grovè, B; Meiring, JA; Monkhei, MM; Pretorius, IG. 2005. *Cost estimating procedures for micro-, drip- and furrow irrigation systems as well as economic analysis of the relevant irrigation systems for large- and small scale farmers in the Onderberg/Nkomazi region*. Report 974/1/05. Water Research Commission, Pretoria, RSA.
6. Reinders, FB; Smal, HS; Van Niekerk, AS; Bunton, S; Mdaka, B. 2005. *Sub-Surface Drip Irrigation: Factors Affecting the Efficiency and Maintenance*. Report No. 1189/1/05. Water Research Commission, Pretoria, RSA.
7. Van Niekerk, AS; Koegelenberg, FH; Reinders, FB; Ascough, GW. 2006. *Guidelines for the Selection and Use of Various Micro-Irrigation Filters with Regards to Filtering and Backwashing Efficiency*. Report No. 1356/1/06. Water Research Commission, Pretoria, RSA.

The purpose of the manual is to provide a comprehensive information document for irrigation farmers operating in South Africa and other SADC countries. It should be read and used in conjunction with the KBase, (a database developed as part of the WRC project by NB Systems) which contains technical information on drippers and filters, and the IRRICOST spreadsheet model, a cost estimating tool that was adapted specifically for the purposes of the WRC project by the University of the Free State.

1.1 Defining drip irrigation

The term *drip irrigation* refers to pressurised irrigation systems that irrigate a part of the soil surface area of a field in a controlled manner, as distinct from other systems that are designed to apply water to the entire soil surface. The definition limits the choice of equipment to either surface or subsurface drip irrigation. These two types of systems are found in a variety of on-farm applications, and range from ultra-low flow rates to high flow rates, able to supply water to very small proportions of the surface or subsurface area.

1.2 Origins of drip irrigation

The first experimental system of this type was established in 1959 in Israel by Simcha Blass and his son Yeshayahu in the late 1950s. Blass developed and patented the first practical surface drip irrigation emitter. Unlike earlier systems, which released water through tiny holes but which were blocked easily by tiny particles, water was released through larger and longer passageways, using friction to slow the water flow rate inside a plastic emitter.

1.3 Terminology

A drip irrigation system is understood to include a water pump, filtration and fertigation equipment, and in-field water distribution equipment. A schematic representation of a drip irrigation system is presented in Figure 1.

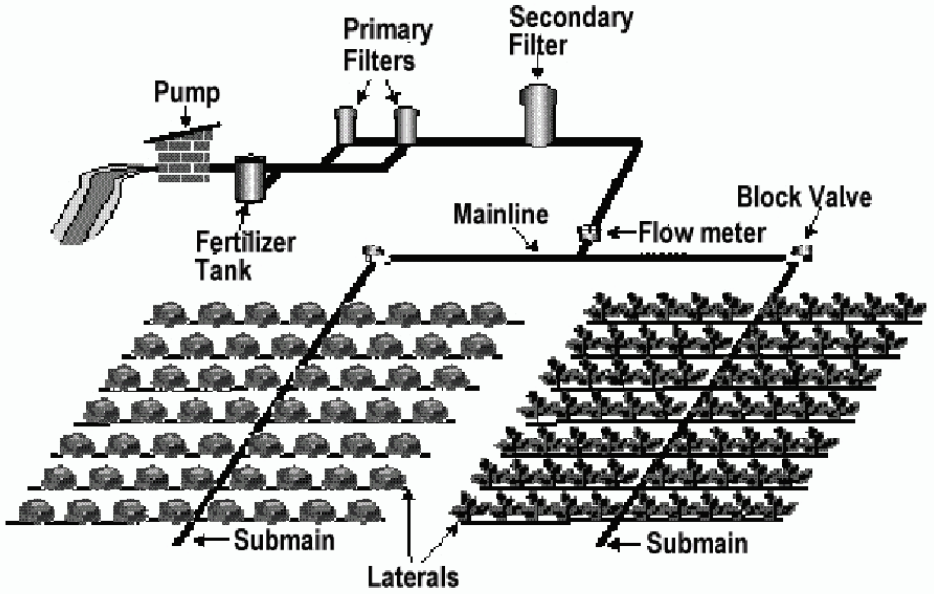

Figure 1: Schematic diagram of a typical drip irrigation system

1.4 Scope of the manual

The manual covers the technical aspects and cost estimating procedures of designing surface and subsurface drip irrigation systems.

This manual includes recommendations and guidelines regarding the suitability and management of soil and water for drip irrigation, and the selection, costing, design, operation and maintenance of drip irrigation and filtration equipment. It is aimed specifically at drip irrigation in field and permanent crop applications, and does not apply to greenhouses or specialised fertigation units.

1.5 Organisation of content

Figure 2 shows the structure of the manual. The content is presented under the three broad headings of technical aspects, guidelines, and procedures.

The technical aspects of drippers and filters are covered in Chapters 2 and 3, which provide background information on different types of equipment, and the factors to be taken into consideration when selecting system components.

Chapter 4 provides details on the methods and calculations used to estimate the cost of drip irrigation systems.

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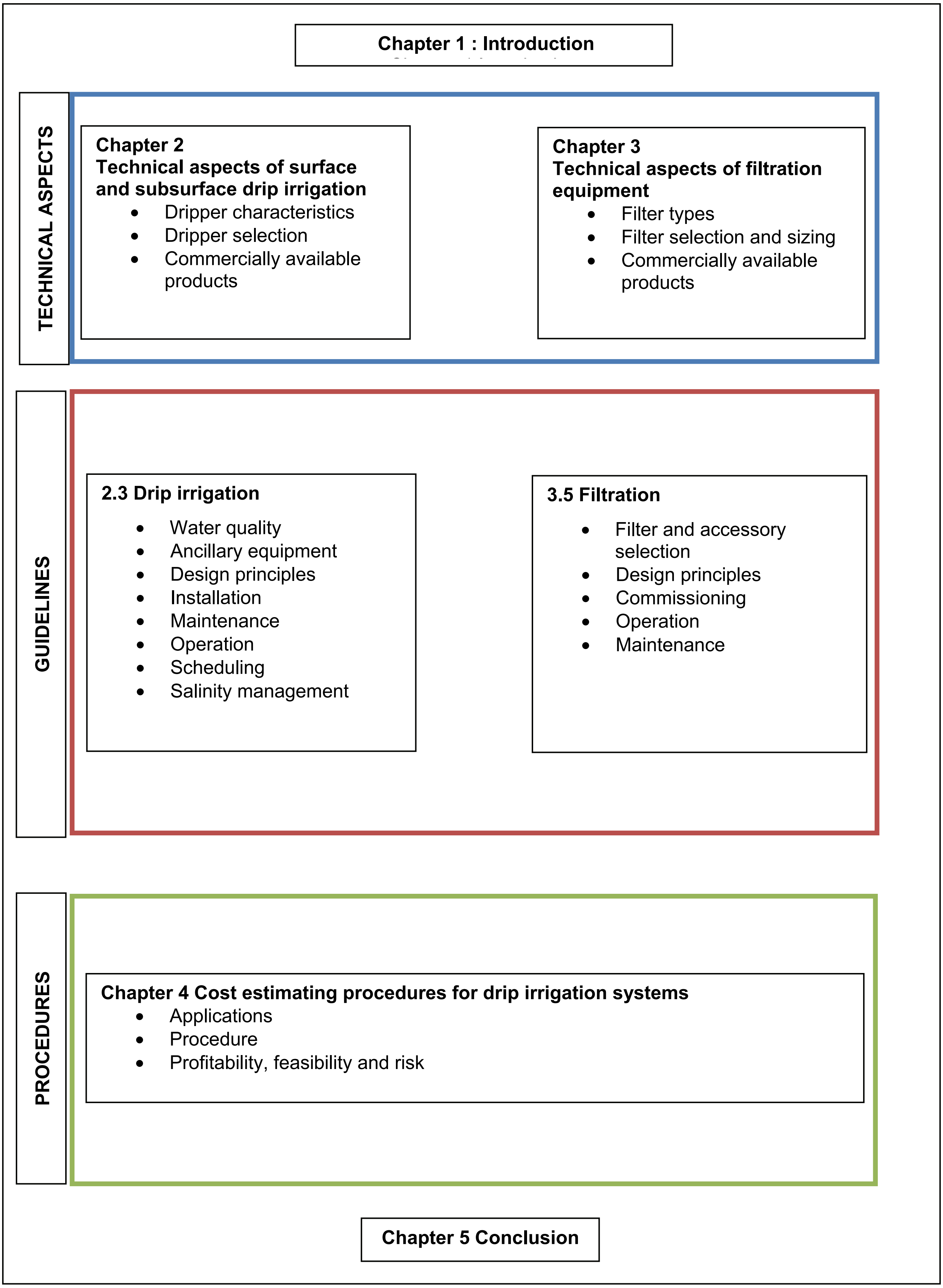

Figure 2: Structure of the manual

2 TECHNICAL ASPECTS OF SURFACE- AND SUBSURFACE DRIP IRRIGATION SYSTEMS

Drip irrigation is considered to be one of the most efficient types of irrigation. However, it is of the utmost importance to correctly plan, design, select, install and maintain all the system components to ensure successful long-term operation.

As shown in Figure 1, the water is pumped via filters and valves through the manifold to the laterals. The mechanisms which let water out from the laterals into the atmosphere are known as drip emitters, drippers, or emitters. Drip emitters are found in a large variety of characteristics and shapes, covering the whole spectrum from small button-shaped drip emitters to inline long flow-path drippers. Some characteristics of drip systems are highlighted in Table 1.

Table 1: Some directives with regard to characteristics of drip systems

Characteristic	Description
Application	Row crops (both permanent and annual crops), also underground on pastures, sugar, cotton, for instance
Method of water application	Point application by means of drip action, lateral distribution by soil
Potential system efficiency	95% +
Mounting of emitter in relation to lateral	On wall inside lateral, or in-line as integral part of tubing, or directly/ indirectly on outer wall of tubing
Emitter interval	Externally mounted: At random intervals. All other: At fixed intervals varying between 0,3 m and 1,25 m
Emitter discharge	0,5 to 25ℓ/h
Operating pressure	5 to 35 m (also pressure compensating)

2.1 Drip emitter characteristics

There is a wide variety of drip emitters commercially available. Distinctions between types can be made on the basis of operating principle (pressure sensitive or pressure compensating), positioning relative to the lateral (internal, external, etc.), and construction (flow path length, etc.).

Regardless of the type of emitter selected for use, it is always important to select good quality, tested components when designing and installing drip irrigation. The use of cheap but inferior materials and novel components which have yet to prove their worth should be avoided. The company membership directory of the South African Irrigation Institute (SABI) provides a useful reference for established and recognised suppliers of irrigation equipment in South Africa.

2.1.1 Dripper types

The purpose of the drip emitter is to apply water at a specific flow rate (determined during the planning process and called the *design emitter discharge*, q_e) over a specific area of soil in the field. Emitter discharge is determined by the pressure of the water at the emitter; the design discharge is delivered at a specific pressure called the *design operating pressure*. At pressures higher than the design operating pressure, the emitter will discharge more than the design discharge, and at pressures lower than the design operating pressure, the emitter will discharge less than the design discharge. The discharge-pressure relationship is characterised by the equation:

$$q_e = K \times p^x \qquad \text{(Equation 2.1)}$$

where

K = discharge coefficient, include qe and units
p = operating pressure
x = discharge exponent

This relationship is presented graphically in Figure 3:

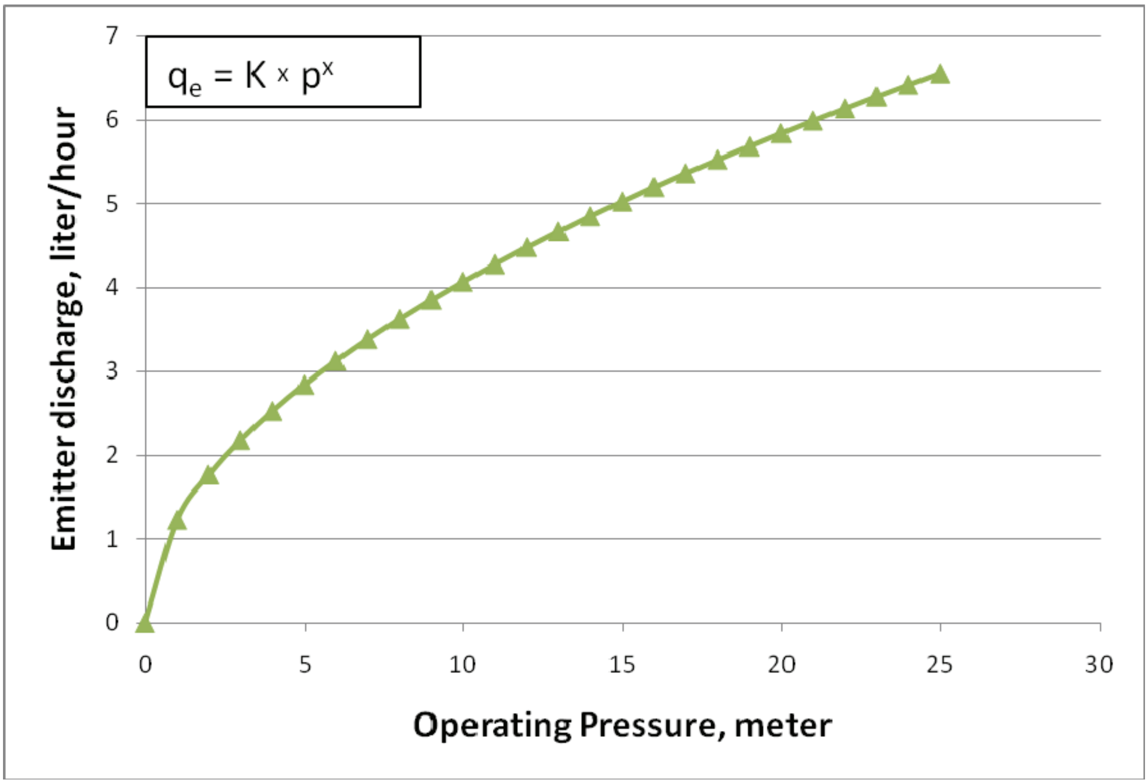

Figure 3: Emitter discharge/ operating pressure relationship of pressure sensitive emitters

2.1.1.1 Pressure sensitive emitters

Pressure sensitive emitters (also known as conventional emitters) operate according to the relationship expressed in Figure 3. The discharge of pressure sensitive emitters is a function of the operating pressure inside the lateral. It is therefore essential to ensure that system pressure inside the sidelines and laterals is kept within the required tolerances during the designing process, in order to maintain uniformity of emitter discharge within the specified ranges.

Advantages of pressure sensitive emitters:

- Relatively low cost compared to pressure compensating drippers
- Simple composition enhances uniform discharge between emitters (low coefficient of variation (CV) values)
- Fewer and uncomplicated components decrease vulnerability to mechanical damage

Disadvantages of pressure sensitive emitters:

- Lateral length and therefore discharge is influenced by topography directly influencing the operating pressure
- Larger pipe diameters are normally used along flatter gradients to limit friction losses
- It is often necessary to maintain downhill flow directions in both laterals and sidelines: costs will escalate in case a more extensive supply system is required
- Relatively complicated design processes, (normally requiring the use of advanced equations, graphic aids, and even computer programmes) are inevitable, and complicate the design process

2.1.1.2 Pressure compensated emitters

In a **pressure compensated** emitter, the regulating mechanism affects the discharge/pressure relationship, with discharge remaining constant over a specified pressure range (as seen in Figure 4). Usually, the only limitation is that a minimum required pressure should be maintained to perform the compensating function. Pressure compensated emitters are available for all types of pressurised systems but are more expensive than non-compensating emitters.

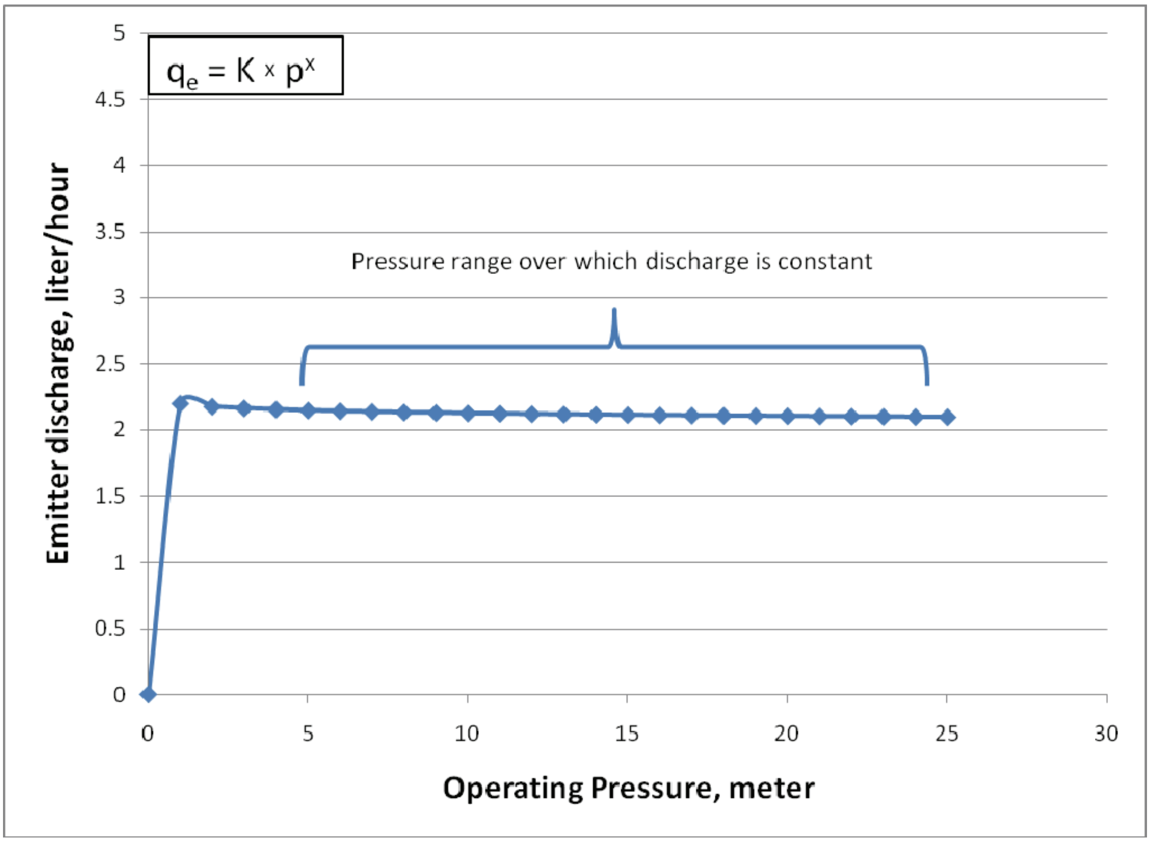

Figure 4: Emitter discharge/pressure relationship of pressure compensated emitters

Advantages of pressure compensating emitters:

- Longer laterals of the same diameter pipe can be used, because emitter discharge remains constant and is not influenced by pressure variations due to friction or topography.

- Similarly, smaller diameter pipes can generally be used in sidelines and laterals, and in some cases even in the distribution network.
- In most cases it is advantageous to maintain a flow direction opposite to that of the soil gradient in the sidelines and emitter lines, thus eliminating supply lines by supplying water to the sideline at the point closest to the source.
- The CV of the emitters constitutes the total discharge variation of a system. Low CV values of well-designed and well-manufactured emitters therefore ensure even distribution of water and plant nutrients, often safely within the normal allowable tolerances.
- Advanced design techniques such as complicated equations and graphic aids, or even computer programmes, are not required for the designing process: Sensible application of basic pipe hydraulics is all that is required for this purpose.

Disadvantages usually associated with pressure compensating emitters:

- Complicated composition involves more components, resulting in increased vulnerability
- The composition of the emitter components makes it difficult to maintain low CV values
- Higher emitter costs

2.1.2 Mounting

Drippers can be mounted onto dripper lines in various ways, as shown in Figure 5. It can be:

- Inline
- Internal
- Integral and
- External

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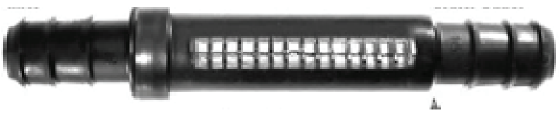
<tr><td></td><td></td></tr>
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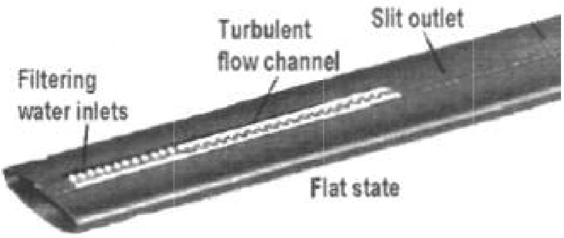
<tr><td>
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<tr><th colspan="2">External</th></tr>
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Figure 5: Ways of mounting drippers to the dripper line

*2.1.2.1 **In-line** with dripper line*

In this case, the dripper is cylindrical with a barbed adaptor at each end. They are fitted to the dripper line (after the pipe has been manufactured) so that the hollow cylindrical core forms part of the dripper line. The pipe is usually cut into pre-determined lengths and the ends of the pipe are mechanically pressed over the barbed ends of the dripper. One limitation is that only specially fabricated dripper pipes can be used. These pipes are available only in specified diameters which fit tightly over the ends of the barbed ends of the dripper.

*2.1.2.2 **Internal** to the dripper line*

The dripper is fixed to the inner wall of the unique dripper pipe by thermal fusing (also known as bond on), during the manufacturing process. Standard polyethylene (PE) pipes are therefore out of the question in this case. Two kinds of drippers are mainly used:

- **Cylindrical drippers**, inserted into the pipe where the wall of the pipe forms the casing of the dripper.
- **Elongated drippers**, (so small that they cause little friction) fixed to the inner wall of the pipe during the pipe manufacturing process.

*2.1.2.3 **Integral** with the wall of the dripper line*

In this case the unique thin-walled dripper line is manufactured so that the dripper components (pressure sensitive or pressure compensating) are formed inside the pipe wall by thermal extrusion.

*2.1.2.4 **External** mounting on the wall of the pipe*

These drippers are fitted with a barbed connection which is pressed either into a pre-punched hole in the dripper line, or into the end of the extension tubing. The diameter of the pipe is irrelevant when using this approach, and standard, low density PE pipes with small diameters can be used. Dripper spacing can be random, according to requirements. The only limitation on the size of the emitter is the manufacturing cost. A measure of robustness is required because of vulnerability to factors such as the movement of people and implements, especially in rare cases where the dripper is linked to the dripper line by means of extension tubing.

2.1.3 Composition and components

There are too many types and compositions of drippers to consider individually: drippers vary to such an extent that it is even difficult to identify common components: Representative examples of drippers that are commonly found in everyday use are illustrated in Figure 5. An initial distinction can however be made between the short and long flow path types.

Short flow path type drippers usually are physically small and discharge is regulated by means of a built-in mechanism.

Long flow path type. All the drippers shown in Figure 5 are of the long flow path type, except the small button type which is mounted to the outside of the pipe. Long flow path type drippers mainly use friction and turbulence in the flow path to decrease the lateral pressure until the design discharge is reached. The cross section area of the flow path is usually about 1 mm². Depending on the design approach, the flow path can vary considerably in length, up to 1 m and more. Although flow velocities are relatively low, the flow is regarded as turbulent because of the continuous changes in direction experienced along the labyrinth. Common components include the following, among others:

2.1.3.1 The inlet

The water flows into the emitter from the lateral via a barbed coupling of the type mounted on the outside of the lateral. All the other types have openings between the outside of the body and the pressure reducing mechanism, which often is part of the body. This opening generally has some kind of grid or screen to prevent dirt from entering the mechanism and blocking the flow path.

2.1.3.2 The body

The emitter body houses the pressure reducing mechanism (except in the integral type, where the core is situated inside the wall).

2.1.3.3 The casing

The casing encloses the body or the active pressure reducing mechanism, and is available in various shapes:

- It can be a shell which fits onto the core, e.g. the larger button type outside the dripper line
- The body and casing can form a homogeneous unit, e.g. the small button type
- It can be a cylindrical casing which encloses the core, e.g. the in-line type
- The dripper line itself can form the casing, e.g. drippers mounted inside, as well as the type formed inside the wall of the dripper line

2.1.3.4 Outlets

All drippers have one or more outlets exposed to the atmosphere. The discharge holes of internal drippers are punched into the wall of the dripper line during the manufacturing process.

2.1.4 Pressure compensating mechanisms

These mechanisms are optionally available as components to most tried and tested pressure compensating emitters, except for the in-line type drippers.

In pressure compensating dripper types, the pressure reducing characteristics of the labyrinth are usually combined with a free-moving diaphragm, of which the active part is situated over and on the downstream side of the labyrinth. This diaphragm is manufactured of a high quality synthetic elastic material which is chemically stable in respect of all known chemicals. The water inside the lateral exercises the necessary pressure which causes the diaphragm to distort, thereby reducing the flow opening and keeping the discharge constant. A flushing action usually takes place during the stage that the dripper line is filled with water and before enough pressure is built up to activate the diaphragm.

Typical examples pressure compensating drippers are illustrated in Figure 6.

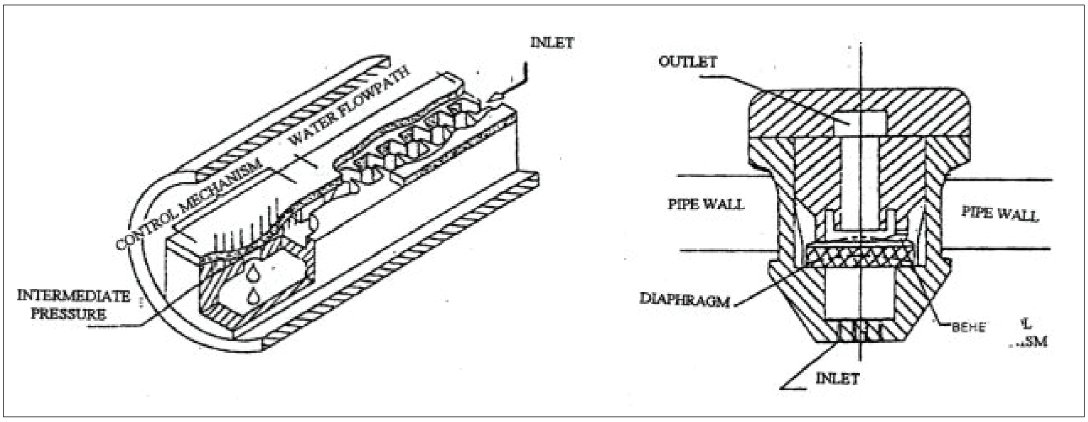


Figure 6: A diagram of typical pressure compensating drippers

2.2 Selection of a dripper type

The choice between one emitter and another, or even between the concepts of pressure sensitive and pressure compensating emitters is often subjective, or made according to preconceived guidelines, or even based on historical or circumstantial reasons. Choices can be made more scientifically, according to the following guidelines:

2.2.1 Drip application

- Drip irrigation has a high system efficiency.
- Most drippers are mounted inside the laterals, and under some conditions whole systems can be suspended above ground level.
- Drip systems have limitations because they feature point application. The lateral water spreading capacity of the soil can therefore be a determining factor in the decision-making process.

The shape and size of the wetted profile in the soil are therefore very important for obvious reasons. It should be able to store at least enough water in an area accessible to the feeding roots (or an acceptable part thereof) of the crop. The method of placing irrigation water on top of the soil, as well as the distribution of water in the soil (especially lateral distribution), should correlate well with the nature, shape and extent of the root system, and any limitations affecting these. These aspects are particularly important in cases where no clear-cut decision about drip irrigation can be made.

Since crop characteristics are usually common knowledge, and limitations from a soil science point of view would have become evident during the soil survey, the only remaining unknown factor is the ability of the soil to distribute irrigation water laterally. Three basic, interactive factors are responsible for this very important characteristic. They are -

- the clay percentage in the soil; and/or
- the percentage fine fraction in the sand; and/or
- the presence of organic material in the soil.

The distribution of the water in the soil occurs along the hydraulic gradient between the wet and the dry soil: laterally by means of capillary action, and vertically due to gravitation. With point application, this wetting and distribution pattern more or less takes the shape of an onion, as shown in Figure 7.

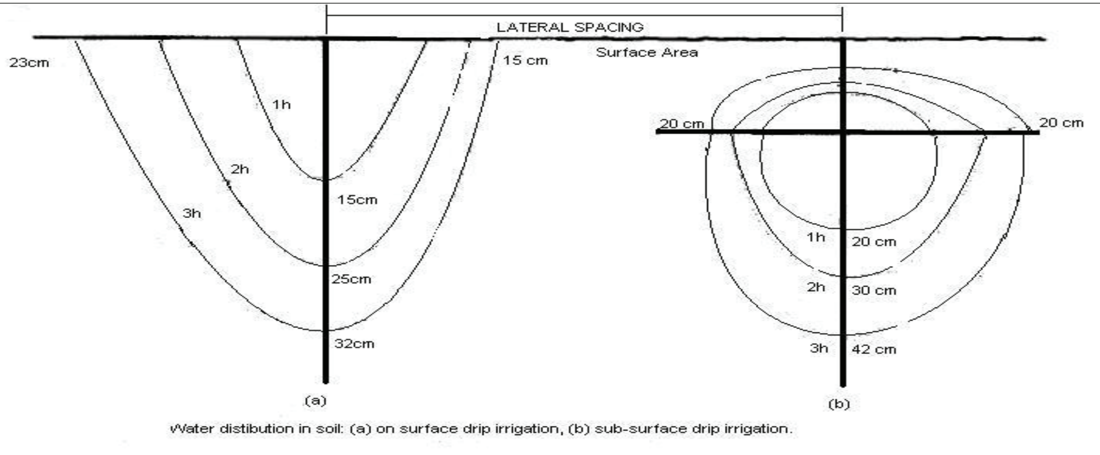


Figure 7: Typical water distribution patterns in soil; (a) surface and (b) subsurface application

Although these factors are individually quantifiable, their combined effect on the lateral water distribution capacity of the soil cannot be calculated theoretically. Further, it is generally assumed that soil with a high clay content gives better horizontal distribution that soils with a high sand fraction (Figure 8).

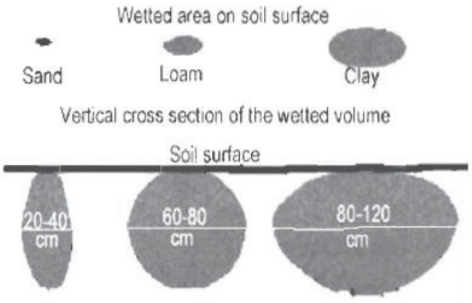


Figure 8: Typical assumed water distribution patterns under drip irrigation depending on soil type

These characteristics can be reliably established through experimental observation and calculation, according to the following guidelines:

- Lay-out dripper lines (preferably 20 m to 30 m long), on the soil that is to be irrigated, with different inter-dripper spacings.
- Connect the lines to a water source which will provide a continuous and stable supply.
- Switch on the system at the required operating pressure, and irrigate for about 12 hours on heavier clay soils, and for about six hours on lighter sandy soils.
- Allow the water to penetrate the soil for a further 24 and 12 hours respectively, without any interference, in order to allow the wet zone to reach its maximum dimensions.
- Dig longitudinal and cross profile furrows, and make the necessary observations and measurements to establish whether the proposed system will satisfy all requirements according to established norms.

Due to the lower emitter discharge of drippers, the standing time is usually longer and the farmer's operating system should be able to accommodate the choice.

Cost aspects play a key role in decision making, and require a careful and objective approach:

- **Crop type:** A drip system on citrus, equipped with double dripper lines, can be more expensive than a micro system. Conversely, a drip system on a vineyard can be cheaper than a micro system.
- **Emitter type:** Pressure compensating emitters are generally more expensive than pressure sensitive emitters, but cost savings on the distribution system may completely reverse the picture.
- **Filtration:** The role of filtration cannot be ignored. Cleaner or dirtier water can overturn the cost implications completely in favour of a different type of system.
- **Operating pressure:** Operating pressure also plays an important role from the operational cost point of view, and should be considered in the total cost structure.

2.2.2 Pressure sensitive or pressure compensating

Besides the cost aspects, specific technical aspects may necessitate the use of pressure compensating emitters under certain conditions:

- The use of pressure sensitive emitters on very steep inclines may require an impractical number of branch lines to maintain specified discharge limits. Pressure compensating emitters may possibly provide the only practical solution.
- Long emitter lines (especially dripper lines with limited diameters), with little or no topographical slope, may have excessive friction losses, and will therefore also not conform to the specified limited discharge tolerances. Additional distribution and/or branch lines, or pressure compensating emitters, are the only alternatives.
- Uneven terrain, where topographic features are the only cause for unacceptable emitter discharge deviations, will naturally require pressure compensating emitters.
- Even systems which can easily and economically make use of pressure sensitive emitters may have sections which will unavoidably endure excess pressure. Pressure compensating emitters will effectively and economically solve this problem.

2.2.3 Different drip system concepts

In general there are two drip system concepts in use: The conventional concept, and the open hydroponic system (OHS) approach. These approaches differ vastly, with the latter not yet having been implemented on either a large scale or over the long term in South Africa.

2.2.3.1 Conventional concept

All systems that make use of the strip wetting principle, both pressure sensitive and pressure compensating modes, fall under the "conventional" category. Although laterals are traditionally placed above ground, in some cases it is more beneficial to place them underground.

The aim of the general conventional approach is to create a continuous wet zone in the soil, within which sufficient feeding roots of row crops will develop and function satisfactorily. It is therefore important to make maximum use of the lateral water distribution capacity of the soil by means of adequate emitter overlapping.

Emitter spacing should therefore be selected sensibly and practically, as shown later in Section 5.6. A pre-assembled dripper line is normally manufactured according to standard manufacturing processes with a wide range of dripper spacing options, ranging from about 0,3 to 1,25 m. This allows the designer to satisfy the minimum system requirements indicated by the results of the experimental tests carried out to determine the potential lateral water distribution capacity of the specific soil.

When underground application of this concept is considered, some features, guidelines and limitations should be considered. Circumstances under which the underground application can be implemented beneficially include:

- Where regular burning occurs, e.g. sugar cane fields
- If the crop and soil combination requires short cycle irrigation
- Where harvesting practices can be simplified, e.g. mechanical harvesting of tomatoes or cotton
- To prevent pathogens from reaching the soil surface, e.g. using sewage

Crops which are typically successfully irrigated with this method include strawberries, sugar cane, chillies, broccoli, lettuce, onions, tomatoes, cotton and water-melon.

The equipment necessary for applying chemicals for plant nutrition, insect control and preventing dripper blockages should be installed at a suitable place in the system.

Root penetration is a potentially serious problem. Plants such as lettuce, asparagus and sweet potato may be more likely to create problems with root penetration, as can shallow (5 to 7 cm) positioning of dripper lines. Special preventive practices may be required:

- Decreasing the pH of the water regularly can be beneficial, but the soil should be monitored periodically to prevent toxicity in the root zone.
- Drippers that close automatically under low pressure conditions are more resistant to root penetration.

- Shock dosages of chlorine can be applied after harvesting for a period just long enough to fill all the dripper lines.
- Scheduling should be effected to ensure that plants never experience any water stress.
- Application of Trefluralin combinations at relatively regular four to six months intervals prevents root penetration.

Potential soil penetration of the drippers due to vacuum conditions is a common problem, especially when the system is switched off. The design should therefore make provision for the following preventative measures:

- Anti-vacuum valves should be installed downstream of all shut-off valves
- Likewise, anti-vacuum valves should be installed at all high points

The installation depth (usually between 0,1 m to 0,3 m) depends on the plant root system and the lateral water distribution capacity of the soil. Water distribution can be improved by implementing the following practices:

- Use drippers with a low discharge (<2 ℓ/h).
- Use plant nutrients containing calcium and nitrates instead of sodium and ammonia to improve water distribution.
- Apply pulse irrigation.

In the USA it has been found that the discharge of pressure sensitive drippers decreases with 10% to 20%. Sufficient provision should be made for this in the design of system capacity.

2.2.3.2 The Open Hydroponic System approach

This concept, which is radically different from conventional drip irrigation practices, was developed in the 1990s in Spain for the irrigation of citrus orchards. The basic approach was derived from the philosophy that ideal conditions for the absorption of water and plant nutrients on a daily cycle need to be provided to a volume of as little as 120 ℓ to the feeding roots of the tree. This means that the full crop water requirement is applied during the active transpiration period every day. Remarkable success has been achieved thus far, especially regarding marketable quality. The concept has been implemented in a number of countries. Research is currently under way locally, and it is therefore appropriate to take note of design factors which are unique to this concept:

- Trees are planted with initially only one emitter each. As demand increases with growth, the original emitter is either replaced with a larger one, or a second one is added. Dripper positions relative to the tree are also adjusted during the early developmental stages. This means that the hydraulic design, especially for soils with steep slopes, cannot be finalised from the outset with pressure sensitive emitters because of tolerance limitations. Pressure compensating drippers are therefore strongly recommended.
- Due to the above-mentioned conditions, it is also basically impossible to make use of a system with emitters that are integral with the laterals, and the use of on-line mounted drippers is also almost unavoidable.

- If the use of in-line or internally mounted drippers is considered at all, the absolutely plant-bound spacing should be taken into account. The manufacturing specifications should make thorough provision for this, especially regarding the thermal characteristics of the specific dripper line material. The installation of this type of system can be very complicated as far as layout is concerned, where one or two emitters have to be provided (and maybe moved) and maintained for each tree.
- Although the cost of the emitter itself is relatively high in systems with on-line drippers compared to other types, it is partially compensated by the use of standard PE pipes instead of special dripper lines.
- This approach also requires the daily provision of plant nutrients with the water. Installing suitable equipment at both the control centre and individual blocks is therefore a prerequisite.
- Automation of the operating and management system will be virtually unavoidable.

2.3 Guidelines

The following guidelines are applicable to both surface and subsurface drip irrigation systems.

2.3.1 Water analysis and sampling

A properly designed drip irrigation system must include provisions to prevent emitter clogging. These provisions should include a water quality analysis to identify the severity of the anticipated clogging problem, a filtration system, and/or aeration/settling ponds. The design must be complemented with a proper operational manual which includes maintenance schedules.

A water quality analysis assists with identifying potential clogging problems due to water quality and preventative measures can then be recommended and applied.

The objective of sampling is to collect a portion of material small enough in volume to be transported conveniently and handled in the laboratory while still accurately representing the material being sampled.

For design purposes, and to draw up a preventative maintenance schedule, sampling must be done at the source. For an existing system, sampling can be done behind the filter to include the impact of fertigation on the water quality.

Samples must meet the requirements of the sampling program and be handled in such a way that they do not deteriorate or become contaminated before they reach the laboratory. Before collecting samples from distribution systems, lines should be flushed sufficiently to ensure that the sample is representative of the supply. Dissolved oxygen or carbon dioxide, pH, or temperature may produce secondary changes in iron, manganese, alkalinity, or hardness. Samples should be taken in a wide mouthed bottle with an opening diameter of at least 35 mm and a capacity as specified in Table 3.

Before filling, the sample bottle should be rinsed two or three times with the water being collected. Depending on the analysis to be performed, the container should be filled completely (most organics analysis) or have space left for aeration, mixing, etc. (microbiological analysis). A record of every sample collected should be made and every bottle identified, preferably by attaching an appropriately inscribed tag or label.

Do not use the same samples for chemical, bacteriological, and microscope examinations, because the prescribed methods of collecting differ. Changes that take place in a sample are either chemical or biological. Certain cations are subject to loss by adsorption on, or ion exchange with the walls of glass containers. These include aluminum, cadmium, chromium, copper, iron, lead, manganese, silver, and zinc; which are best collected in a separate clean bottle and acidified with nitric acid to a pH below 2,0 to minimise precipitation and adsorption on container walls.

Duplicate samples should be taken, and only one set of samples submitted for analysis, keeping the other set as a backup. Records of the sample data, data submitted to the laboratory, and date of analysis should be kept: This could be important in evaluating the impact of delays. All samples should be submitted for a fixed set of analyses, ensuring that analysis for all determinants is done for all samples.

An accredited (SANAS or Agrilasa) laboratory that specialises in water analysis should be used. Details of the method used, accuracy, precision, detection limits, calibration range, number and placement of calibration points and dilutions made, if any, per determinant should be obtained from the laboratory. “Blind” artificial, as well as “blind” duplicate samples should be submitted together with the samples to evaluate the laboratory’s claims of accuracy and precision. Constant volumes should be added and a blank analysis done of the reagent, where reagents were added to the sample, e.g. acidifying the sample for iron and manganese content determination. The anion and cation sums, when expressed as mille equivalents per litre, must balance, because all potable water is electrically neutral. Analyses should only be accepted if the ion balances were of a suitable standard. The test is based on the percentage difference defined as follows:

$$\%\ \text{Difference} = 100\ \frac{\sum \text{cations} - \sum \text{anions}}{\sum \text{cations} + \sum \text{anions}} \quad (5.6)$$

Samples should be re-analysed if ion balances were not satisfactory. The criteria for acceptance are shown in Table 2.

Table 2: Criteria for the acceptance for ion balances

Anion sum (meq/ℓ)	Acceptable difference
0-3,0	**±0,2 MEQ/ℓ**
3,0-10,0	±2%
10,0-800	±2-5%

Temperature, pH, and dissolved gasses are determined in the field. With changes in the pH-alkalinity-carbon dioxide balance, calcium carbonate may precipitate and cause a decrease in the values for calcium and for total hardness. Iron and manganese are readily soluble in their lower oxidation states, but relatively insoluble in their higher oxidation states. Therefore, these cations may precipitate out or they may dissolve from sediment, depending upon the redox potential of the sample. Sulphide, sulphite, ferrous iron, iodide, and cyanide may be lost through oxidation. Changes caused by growth of micro-organisms are highly retarded by storing the sample in the dark and at a low temperature. Immediate analysis is ideal. Storage at a low temperature (4°C) is perhaps the best way to preserve most samples until the next day. Formaldehyde affects many analyses, and should not be used.

The water quality analysis procedures should strive to meet the recommendations described in

Table 3 When the interval between sample collection and analysis is long enough to provide changes in either the concentration or the physical state of the constituent to be measured, the prescribed preservation/handling practices should be followed.

Table 3: Summary of special sampling or handling requirements

Determination	**Container**	**Minimum sample size (mℓ)**	**Preservation**	**Maximum storage recommended**
Alkalinity	P, G	200	Refrigerate	24 hours
Electrical conductivity	P, G	500	Refrigerate	28 days
Hardness	P, G	100	Add HNO_3 to pH<2.	6 months
Metals, general	P (A), G (A)	–	For dissolved metals, filter immediately, add HNO_3 to pH<2	6 months
Nitrogen Ammonia	P, G	500	Analyse as soon as possible or add H_2SO_4 to pH <2, refrigerate.	7 days
Nitrate	P, G	100	Analyse as soon as possible or refrigerate or freeze at 20°C.	48 hours
Nitrate + nitrite	P, G	200	Add H_2SO_4 to pH <2, refrigerate.	None
Nitrite	P, G	100	Analyse as soon as possible or refrigerate or freeze at 20°C.	None
pH	P, G	–	Analyse immediately.	2 hours
Sulphate	P, G	–	Refrigerate	28 days
Sulphide	P, G	100	Refrigerate; add drops 2*N* zinc acetate/100 mℓ.	28 days
Suspended solids	P, G	1 000	Refrigerate	7 days

Refrigerate = storage at 4°C in the dark.

P = plastic (polyethylene equivalent); G = glass; G (A) or P (A) = rinsed with 1+1 HNO_3

It is important to note that the proposed preservation practices for metals and especially iron must be followed explicitly. Water must be filtered before sampling with Wahtmann 40 filter paper. If the water is not filtered and clay particles occur in the water sample, the acid can cause iron to be released in clay particles and give a higher iron reading. Except for the above, the total dissolved solids (TDS) can be measured or determined with the aid of the following equation, whilst Table 4 provides conversions to determine the suitability of water for irrigation:

$$\text{TDS (ppm)} = 0{,}6\,(\text{alkalinity}) + Na + K + Ca + Mg + Cl + SO_4 + SiO_3 + NO_3 + F \quad (5.7)$$

Table 4: Terms, units and useful conversions for understanding water quality analysis reports

1 dS/m = 100 mS/m = 100 mmhos/m = 1 mmhos/cm = 1 000 µmhos/cm
1 mg/ℓ = 1 ppm
equivalent weight = atomic weight / number if charges of particular ion
meq/ℓ = mg/ℓ / equivalent weight
mmol/ℓ = meq/ℓ / number of charges of particular ion
Sum of cations/anions: (meq/ℓ) = EC (dS/m) × 10

2.3.2 Water evaluation scale for dripper clogging hazard

A simple table must be compiled which can be interpreted by farmers. The water sample used to determine the clogging hazard of the water should also be taken in a relatively simple manner. The current directives, e.g. for iron, are considered too conservative, but no clear directives can be concluded from the project.

Many different directives appear in literature, which can be confusing. It was decided to combine all the relevant information and present it in an easily interpreted table. Table 5 presents the emitter-clogging hazards of different elements.

Table 5: Water evaluation scale for drip irrigation clogging hazard

Constituent	**Problem severity**	
	Low	**High**
Physical		
Suspended solids (mg/ℓ)	<50	>100
Chemical		
pH	<7,0	>8,0
Total dissolved solids (mg/ℓ)	<500	>2 000
Bicarbonate (mg/ℓ)	<100	>200
Manganese (mg/ℓ)	<0,1	>1,5
Iron (mg/ℓ)	<0,2	>1,5
Calcium (mg/ℓ)	<10	>50
Biological		
Bacterial population (per mℓ)	<10 000	>50 000

A minimum figure indicates very little or no clogging hazard. If the value in Table 5 is between the minimum and maximum, the possible clogging problem can be prevented by following the normal acceptable maintenance practices as recommended in Table 6, or the relevant water treatment methods as described in paragraph 2.3.3. An expert should be approached to identify the problem if the values are above the maximum figure.

Clogging problems, which may possibly occur with the minimum figures, can be prevented by following the maintenance practices as proposed in Section 5.5 below.

2.3.3 Water treatment

Farmers require simple recipes for water treatment. Solutions selected to prevent possible clogging problems are shown in Table 6. However, when manufacturers make specific recommendations for their dripper lines, these should be followed.

Table 6: Solutions for specific clogging problems

Problem	Solution
Carbonate deposit (whitish colour) HCO_3>100 mg/ℓ pH >7,5	• Continuous acid application – Maintain pH of 5 to 7. • Shock acid application at end of irrigation cycle. Maintain pH of 4 for 30 to 60 minutes.
Iron deposits (reddish colour) Iron concentration >0,2 mg/ℓ	• Aeration to oxidise iron (especially suited to high iron concentration of 10 mg/ℓ of more). • Acid application to promote iron deposits – Injection rate of 1 mg/ℓ chlorine per 0,7 mg/ℓ iron. – Application before filter so that deposits are retained. • Lower pH to ≤4 by daily acid applications for 30 to 60 minutes to dissolve iron deposits.
Manganese deposit (black colour) Manganese concentration >0,1 mg/ℓ	• Application of 1 mg/ℓ chlorine per 1,3 mg/ℓ manganese, before filter.
Iron bacteria (reddish slime) Iron concentration >0,1 mg/ℓ	Application of 1 mg/ℓ chlorine (free chlorine available) continuously or 10 to 20 mg/ℓ for up to 60 minutes as required.
Sulphur bacteria (white cotton-like slime) Sulphide concentration >0,1 mg/ℓ	• Continuous application of chlorine at 1 mg/ℓ per 4 to 8 mg/ℓ sulphur hydroxide. • Application of chlorine as required until 1 mg/ℓ free chlorine is available for 30 to 60 minutes.
Algae, slime	Application of chlorine at a continuous rate of 0,5 to 1 mg/ℓ or 20 mg/ℓ for 20 minutes at the end of each irrigation cycle.
Iron sulphide (black, sandy material) Iron and sulphide concentration >0,1 mg/ℓ	• Dissolve iron by continuous acid application to reduce pH to between 5 and 7.

2.3.4 Selection of equipment

Selecting dependable and proven irrigation equipment is important to ensure effective water utilisation. Using reliable quality products with a proven track record will help ensure low maintenance and a cost effective system. For example, the displays of direct drive flow meters tend to clog with algae, unlike indirect magnetic driven type water flow meters.

2.3.4.1 Pump intake

The capacity of the pump(s) should be sufficient to supply flow and pressure according to system requirements. An additional 10% flow rate should be added to the calculated system capacity to cater for lateral and manifold flushing.

In cases where surface water is utilised, suction pipes must be attached to a float to ensure that better quality water for irrigation is withdrawn near the water surface, as shown in Figure 9. The minimum water depth above a suction pipe should be adhered to in the design and during installation.

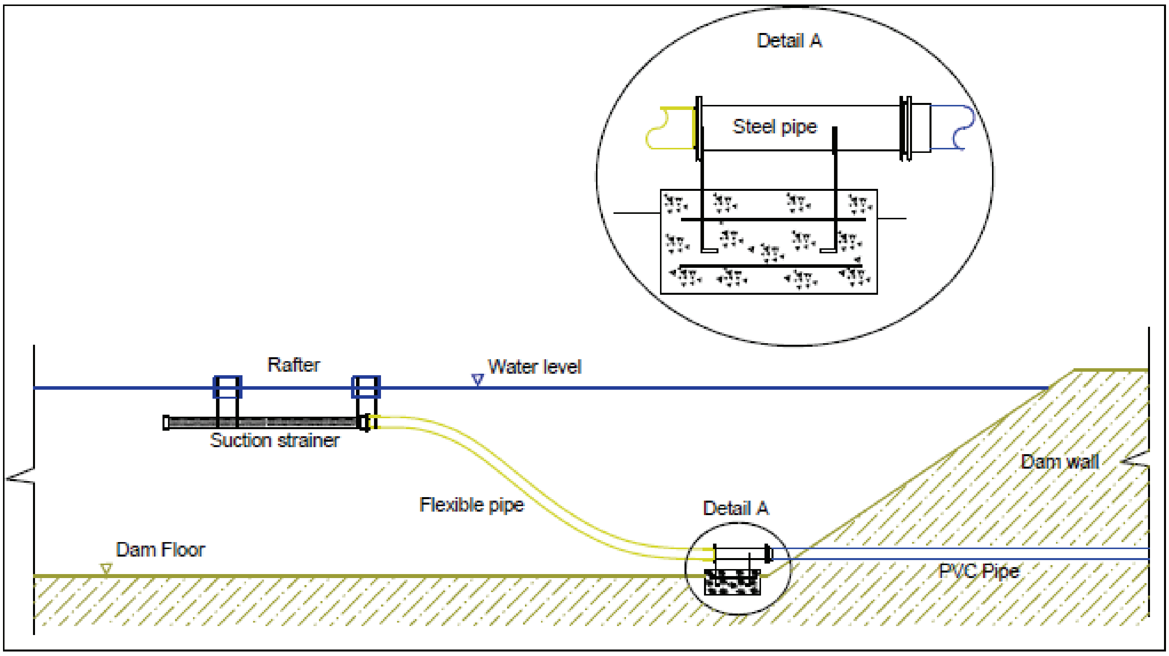


Figure 9: Mounting the suction pipe on a float (Netafim, 2008)

In the case of a storage dam, the suction pipe inlet should also ideally be located away from the point where fresh or flushed water enters the dam, and also oriented correctly relative to the dominant wind direction, as shown in Figure 10.

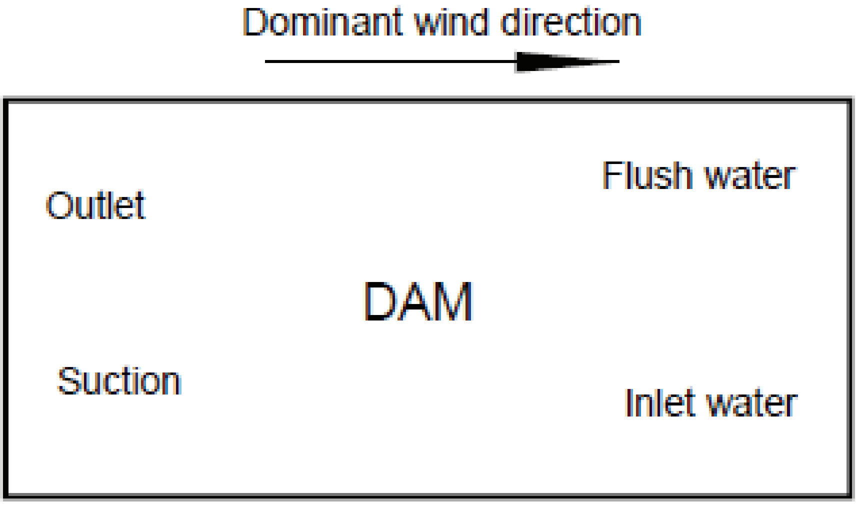


Figure 10: Ideal orientation of inlets and outlets in a storage dam (Netafim, 2008)

Pump intakes should be equipped with strainers to prevent large debris from entering the pump. Also, surface water intakes should be located below the water surface to avoid debris intake and vortex formation, and above the bottom to avoid sediment intake. Figure 11 shows the minimum water depth above a suction pipe to avoid cavitation due to possible vortex formation.

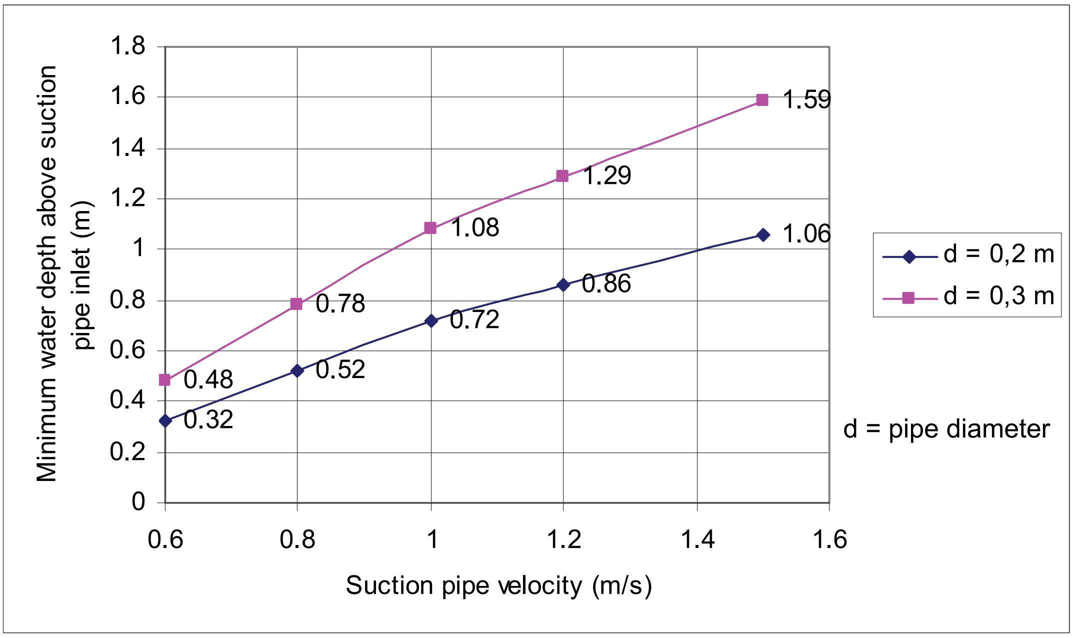


Figure 11: Minimum water depth above suction pipe inlet (T-Tape, 1998)

2.3.4.2 Filters

The type of filter will be determined by the water quality. Sand filters are recommended in most cases, as clogging is one of the main factors leading to system failure. The prescribed filtering guidelines of dripper manufacturers must be adhered to at all times. Filtration is addressed in section 5.9 of this chapter.

2.3.4.3 Air valves

Due to the fact that the sub-surface emitters are covered with soil, vacuums created in the laterals can promote the entry of soil particles into the orifices. It is therefore recommended that a vacuum breaker or air inlet valve be installed at each irrigation block. If a situation exists where the slope of the lateral is not constant, and a high point is created, an additional vacuum breaker should be installed at the highest point on the lateral.

In fields where water is pumped uphill in a lateral, a vacuum breaker should be installed at the highest point. If a flushing manifold is installed, the vacuum breaker should be installed at the highest point of the block. The topography of the main line will determine if an additional vacuum breaker is necessary. For more information, please refer to Chapter 6 of the Irrigation Design Manual (Burger et al., 2003).

2.3.4.4 Flow meters

It is recommended that a flow meter be installed in every drip system. It can provide valuable information on whether the system is operating correctly by comparing the measured flow rate into the system with the design flow rate, providing early warning of possible dripper clogging or leaks. It is also a useful scheduling tool through which the amounts water applied can be verified if meter readings are collected regularly, and is required to operate fertiliser injection systems. Installing the meter behind the filter in the system will protect it from possible breakdowns due to physical impurities in the water.

2.3.4.5 Pressure control valves

Reliable pressure control valves can be installed to ensure that the drip irrigation system always irrigates at the design pressure, especially if undulating topography is present on the site. For more information please refer to Chapter 9 of the Irrigation Design Manual (Burger et al., 2003).

2.3.4.6 Emitters

Thick walled pressure compensating emitter types are more expensive than thin walled regular emitter types, and can also operate over a greater pressure range. In the case of subsurface drip irrigation (SDI), thick walled pressure compensating emitter types appear to be the most efficient type due to their intrinsic resistance to root intrusion, clogging and flow regulating capabilities. Thick walled emitter laterals, compared to thin walled laterals are also less prone to compression, deformation and blockage, when installed in SDI applications. These lateral couplings are also less complicated and more effective, compared to thin walled emitter types.

2.3.4.7 Start connectors

Laterals can be connected to manifolds in various ways, often depending upon the material of the pipes used. Care should be taken to include friction loss through the start connector in the hydraulic calculations as these values vary for the different types of connectors used. Whatever type is used, it is important to ensure the joints do not leak. In the case of subsurface manifolds, a blank piece of pipe (pipe without emitters) is usually fitted between the manifold and the soil surface, where the dripper lateral is then connected.

2.3.4.8 Flushing laterals

Small particles of both organic (e.g. algae) and inorganic (e.g. clay or silt) materials pass through filters and into drip irrigation systems. These particles settle and accumulate in pipelines and emitters, eventually clogging the emitters. To minimise sediment build-up, regular flushing of drip irrigation laterals is required. In the case of surface drip irrigation, each lateral can be flushed individually by opening the lateral end and letting the water from the lateral flow until it is clean. It is also possible to connect a number of laterals together with a flushing manifold fitted with a valve, a practice mostly followed with SDI systems. The laterals can then be flushed together by opening the flush valves (see Figure 12), a system that can also be automated.

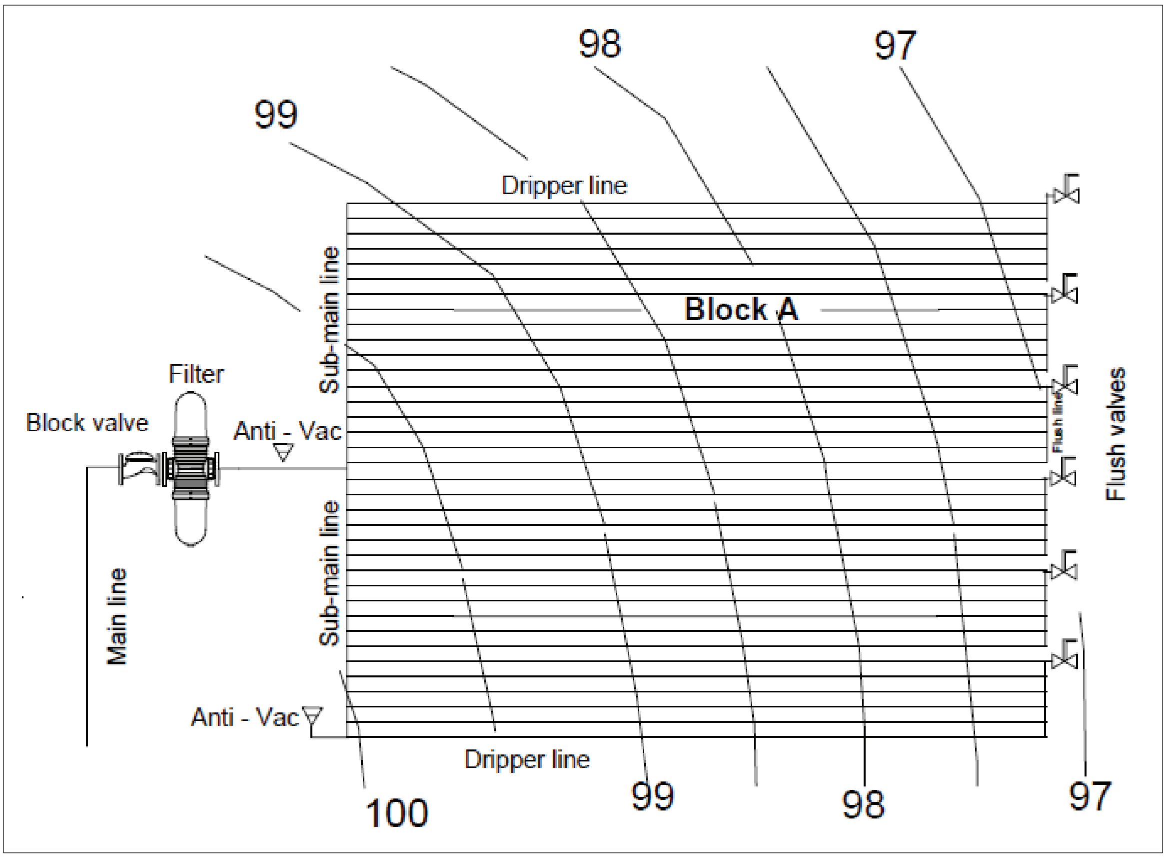


Figure 12: Example of a system with flushing manifolds (Netafim, 2008)

Detailed information on the design of flushing manifolds can be found in the “Manual for Lucerne under subsurface drip irrigation” (Netafim, 2008).

2.4 Design principles

2.4.1 Water source

It is important in the system design process that the farmer/producer/irrigator, crop and soil scientists should take the information regarding the water, nutritive and scheduling requirements of the crop into consideration and make recommendations accordingly. This will enable the designer to design an optimal irrigation system for a specific set of circumstances. The evaluation of the availability and suitability of the water forms an important part of the design for irrigation purposes and the identification of possible clogging hazards for the drip system. The operational rules of the available water sources should be investigated to determine water availability.

2.4.2 Number of operating hours per week

A design approach should be taken that maximises the number of hours during which the system is operated, as this will minimise the required flow rates in the pipes and lead to a more economical system to purchase and operate. As drip irrigation systems can be automated, the suggested maximum number of irrigation hours per week is 144 hours, but this should be discussed with the irrigator to make provision for ESKOM tariff plans, labour availability, breakdowns and other management requirements.

2.4.3 Emission uniformity

Minimum recommended EU is needed to determine the available pressure loss for the lateral and manifold design. All manufacturers of emitters are responsible for providing the necessary information to designers for the determination of the design pressure loss. Recommended EU values are shown in Table 7. The South African Irrigation Institute recommends that an EU value of greater than 90% should be reached.

Table 7: Recommended EU values for different emitter and topography combinations

Emitter type	Number of emitters per plant	Topography/Slope	EU (%)
Point source	≥3	≤2%	90-95
Point source	<3	≤2%	85-90
Point source	≥3	Rolling terrain or incline >2%	85-90
Point source	<3	Rolling terrain or incline >2%	80-90
Line source	Any	≤2%	80-90
Line source	Any	Rolling terrain or incline >2%	70-85

2.4.4 Filters

- **Filtration degree:** If a sand filter is used, there must be a 200 µm control mesh or ring filter downstream of the sand filter to prevent dirt or filter sand from clogging the emitters if the sand filter should fail.
- **Maximum allowable flow-rate through a clean sand filter:** Flow rate <50 m³/h per m² of filter area, with a maximum pressure loss over a clean sand filter of <10 kPa.
- **Maximum allowable pressure loss over the sand filter, with a secondary ring- or mesh filter:** Total pressure loss over the clean filter bank (including sand and ring filter) ≤40 kPa. Maximum allowable pressure differential over filter bank before back-flushing ≤60 kPa.

As a result of the many problems that have been observed regarding the backwashing of sand filters, the following operational rules are recommended:

- At least 50% of the maximum filtration rate (50 m³/h per m² sand surface) is necessary to backwash filters effectively. The maximum backwash rate may not be more than 1,2 times the filtering rate.
- A minimum inlet pressure of 6 m (60 kPa) is required during backwashing.
- The backwashing time of sand filters can be anything from 90-180 seconds. When the flushing action is started, the raw water on the sand bed is flushed first and may appear to be clean. Immediately afterwards, the dirt trapped in the sand bed is flushed out. Backwashing time must be long enough to remove all impurities from the filter.
- The use of compressed air to break up clods in the sand and assist with the backwashing action is recommended if problems are experienced with tunnelling in the sand.

- Filters must be backwashed on a pressure difference basis to maintain the filtration efficiency of filters. The evaluation and setting of sand filter flushing times (approximately three minutes, but until flushing water is clean) must be done regularly.

More details on filtration are provided in section 5.9.

2.4.5 Flushing velocity of laterals

To minimise sediment build-up, regular flushing of sub-surface drip irrigation pipelines and laterals is required. Valves should be installed for flushing of mainlines and manifolds, as well as blocks. Flushing should be done as needed, based on water quality and the amount of material found in pipelines or at lateral outlets. If considerable sediment build-up occurs, laterals should be equipped with automatic flush valves that flush at the start of each irrigation cycle.

A minimum flushing velocity of 0,4 m/s at the end of the furthest lateral is required and this should form part of the design process. The flushing time should be sufficient to purge all foreign materials from the laterals and pipelines. The time should be equal to the replacement of at least the blocks' water volume.

2.4.6 Design report

The design report is an important control mechanism or tool to monitor all the aspects in the design process and help the designer and farmer to guarantee a complete design. An example of this is presented in Table 8.

Table 8: Design report: Drip irrigation system

1. GENERAL INFORMATION

Client's name: . . . . Farm name. . . . .

Contact address: . . . .

E-mail . . . . Tel . . . . .Cell . . . .

Block number:	**Unit**	**Value**
2. CLIMATE		
Month	state	
Weather station	state	
Reference evapotranspiration	mm/month	
3. CROP		
Type	state	
Area	ha	
Planting distance	m	
Row spacing	m	
Natural root depth	m	
4. SOIL		
Effective soil depth	m	
Water holding capacity $(WHC)_{100}^{*}$	mm/m	
Readily available water	mm	
5. EMITTER		
Make/model	state	
Type	State	
Discharge rate	l/h	
Operating pressure	kPa	
Application efficiency	%	
Emitter spacing	m	
Lateral spacing	m	
Wetted diameter	m	
Gross application rate	mm/h	
Delivery rate of block	m^3/h	
6. SCHEDULING	state	
Crop coefficient	Des.	
Evapotranspiration	mm/month	
Net irrigation requirement	mm/month	
Gross irrigation requirement	mm/month	
Theoretical cycle length	days	
Theoretical standing time	hours	
Practical cycle length	days	

Practical standing time	hours	
Working days per week	days	
Irrigation hours per day	hours	
Gross application per practical cycle	mm	
7. HYDRAULICS		
Allowable pressure variation in the block	m	
Required pressure at the block inlet	m	
Maximum flow velocity in mainline	m/s	
Minimum flow velocity in lateral	m/s	
8. PUMP		
Type, model	state	
Impellor size	mm	
Pump operating pressure at duty point	m	
Pump delivery rate at duty point	m³/h	
Efficiency at duty point	%	
Shut-off pressure	m	
Power requirements at duty point	kW	
Power rating of electrical motor	kW	
Motor speed	r.p.m	
9. FILTER		
Type, model, size	state	
Amount	number	
Filter fineness	micron	
Pressure drop over filter		
Clean	m	
Dirty	m	
10. DESIGNER		
Name	state	
Company	state	
Contact details	state	

2.5 Installation of subsurface systems

The installation of SDI laterals should preferably take place in homogenous soils, or at least in fields where the laterals can be installed at a constant depth and constant sub-surface slope. This is to eliminate the problem of specific laterals being installed with high and low points along their length. Installing laterals with varying longitudinal profiles (e.g. undulating topography) can lead to air-locks and thereby the formation of vacuums and the suction of soil particles into the emitter apertures.

The preparation of the field to at least 300 mm deeper than the planned depth of the laterals will help to guarantee constant depth of installation. A tractor mounted ripper with a top mounted reel for the dripper line rolls is the basic implement for installing dripper laterals. A curved steel tube is mounted at the back of the ripper shaft, with a horizontal section just above the lowest point of the ripper shaft. The dripper line is fed through this tube and the dripper line should be held manually in its position at the field edge when the installation process starts. A system of depth-adjusting wheels on the implement can provide a constant depth of installation.

The testing of the system after installation is important to detect and fix any leaks and thereby prevent the possible entry of soil, etc. It is important that laterals should be flushed thoroughly before the first irrigation commences.

2.6 Operation and maintenance

The maintenance of a drip system is of paramount importance for the effective operation. Regular maintenance of the filters system, vacuum valves, the prompt fixing of leaks, the prevention of damage to equipment, the scheduled application of root growth inhibitors and lateral cleaning chemicals are important maintenance aspects, especially in the case of SDI systems.

It is important to inspect the irrigation block after each irrigation cycle to identify possible clogging problems (dry patches or under-performing plants) at an early stage. If leaks occur, they must be repaired as soon as possible.

2.6.1 Filter operation

The filters should be operated according to the indicated guidelines in Section 3.4. A filter maintenance schedule is listed in Table 19.

2.6.2 Lateral flushing

The regular flushing of the laterals plays an important role in the maintenance of the systems. A flush velocity of at least 0.4 m/s is a necessity in the design of the system, especially in cases where water of a quality outside the indicated norms is used.

Visual evaluation of the presence of any solids or organic matter in the water at the lateral outlets can assist the farmer in establishing the required cycle for lateral flushing. The presence of any foreign matter requires an increased flushing cycle and the rectifying of the cause(s). A lateral flushing cycle of at least one flush per two irrigation cycles or per 14 days is recommended, depending on the quality of the water at the inlets and outlets of the laterals.

The recommended flushing velocity for drip laterals must be greater than 0.4 m/s. It is necessary to determine the velocity by calculating the theoretical flow rate for a required minimum flushing velocity of 0.4 m/s at the lateral outlet. This is done by multiplying the velocity by the cross-sectional area of the dripper lateral. This flow rate is then used to calculate the time needed to fill a one litre container at the lateral end.

If this value is exceeded in field conditions, it means that the flow velocity in that lateral exceeds the minimum required velocity. The graph in Figure 13 can be used to establish the time in seconds needed to fill a one litre container for a specific internal dripper lateral diameter. Care should be taken that the pump is able to supply an additional 10% flow above the system’s required flow, for the flushing of the laterals and manifolds.

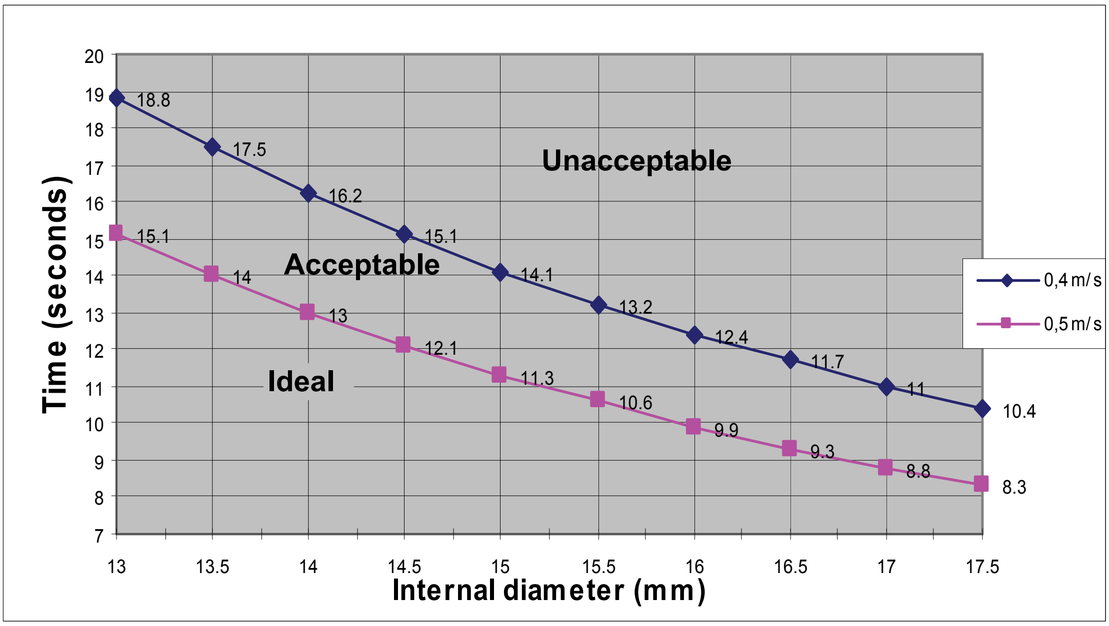


Figure 13: Time to fill a one litre container for a specific diameter lateral

2.6.3 Use of chemicals: acids, chlorines and fertilisers

Chemicals can be used for the elimination of biological and chemical build-up. Irrigation water quality varies from site to site, and as a result each site may require a different type of water treatment in order to prevent emitter clogging. Prevention is by far better than cure as far as clogged emitters are concerned: reclaiming clogged emitters by using chemical treatment is neither practical nor economical due to the high concentration of chemicals required.

A major problem is that the injected chemicals end up flowing through the clogged emitters and the clogged emitters are not cleaned. A solution to this problem is to provide higher pressures with chemical treatment, thereby forcing the chemicals into the blocked emitters.

Details on the application of acid and chlorine can be obtained from the manufacturers of drip irrigation equipment. A good example is the “Maintenance Manual” published by Netafim (2008).

2.6.4 Use of root growth inhibitors

The use of root growth inhibitors is important and necessary for the effective functioning of dripper line emitters that is installed under the surface. Growth inhibitors are usually used with sub surface drip irrigation and root growth inhibitors in the SDI system should be used according to the recommendations from the suppliers of the relevant chemicals. This is to establish the registration (legal approval) of the specific product for use on the specific crop for SDI applications.

Recommendations are that *Treflan*, or an equivalent, should be applied at least twice per year with the first application soon or not more than three weeks after the first irrigation application. *Treflan* should only be allowed to accumulate in the area directly around the emitters if applied through the system and not impregnated in the emitters. Any accumulation of water on the soil surface during or directly after *Treflan* application could damage the crops. *Treflan* should not be applied into wet soil profiles, or just after rain. The procedure for the application of *Treflan* is as follows.

- Start the irrigation system.
- 20 minutes after working pressure is reached, investigate and observe any puddles or water accumulation starting on the soil surface. The formation of puddles on the surface can indicate that the soil is not suitable for *Treflan* application.
- Investigate the whole irrigated area for leaks and rectify/repair.
- Recalculate the number of emitters in the irrigation blocks and the volume of *Treflan* to be applied. An application rate of 0,125 mℓ/emitter is recommended.
- Check the couplings and inlet filter of the chemical injector pump and repair necessary.
- Calibrate the injector pump for at least a 10 minute cycle to establish the delivery rate.
- Ensure that only the sub-surface system is supplied by the pump system during the Treflan application.
- The distribution time for the *Treflan* application is determined by the delivery rate and spacing of the emitters, as well as the lateral length. The distance from the injection point to the furthest emitter determines the distribution time.
- After the application, allow 24 hours before normal irrigation commences.

Treflan application is not recommended in the following cases:

- Sandy soils with less than 8% clay.
- With seedlings, just after transplanting.
- Too wet soils.
- With laterals which were installed at too shallow a depth.
- When the use of *Treflan* is prohibited by law.

The commencement of *Treflan* applications for various crops varies: suggested times are detailed in Table 9.

Table 9: Suggested *Treflan* treatment commencement for various crops

Crop	Treatment commencement
Perennials	Three weeks after irrigation commencement.
Orchards	Six weeks after planting. Assure sufficient weed control to prevent root intrusion from the weeds. From second year, application to start four weeks after irrigation season's commencement.
Seasonal crops and vegetables	Approximately five weeks after the commencement of the normal irrigation and after the germination and establishment phase has passed.
Perennial cash and vegetable crops, asparagus, lucern	First year: four weeks after planting or six weeks after sowing. Second year: four weeks after the start of "normal" irrigation".
Grass and lawns	Four weeks after planting and 2-3 weeks after lawn establishment.

The number of *Treflan* treatments required is a function of crop type, climate and soil type. Table 10 indicates the number of treatments needed per year.

Table 10: Suggested number of *Treflan* treatments

Crop	Effective irrigation period*	Number of treatments	
		Medium and heavy soils (50-80% sand fraction)	Light soils (>80% sand fraction)
All crops	< 2 months	1	1
	< 4 months	1	2
	< 8 months	2	3
	During year	3	4

*The effective irrigation period is the period during which the crops are continuously irrigated. For example, cotton planted during October and the first irrigation application starts during the first week of December, last irrigation at the end of February. In this example, the "effective irrigation period" will be three months.

2.6.5 General

The operating pressure of the system must be higher or equal to the design pressure at all times to prevent precipitation of suspended solids. Low operating pressures also influence the effectiveness of the flushing of the laterals.

Before the irrigation is stopped at the end of a season, the following procedures should be followed:

- Flush the lines.
- Treat the lines with chlorine or acid or appropriate chemicals, depending on the water quality and blockage problems experienced.
- Ensure that no foreign matter can enter the distribution system.

All maintenance precautions are equally important and dependent on the clogging hazard present in the water sample. It is the duty of the suppliers to give the farmers a complete maintenance schedule via the designers of the systems and to explain the procedures to them. The success of a sub-surface drip system is also dependent on the operation and maintenance of the system. The maintenance schedule as shown in Table 11 is proposed for manually cleaned filters. For automatically cleaned filters, the manufacturers' recommendations must be followed.

Table 11: System monitoring and maintenance programme for drip irrigation

Activity	Interval			
	Weekly	Monthly	6-monthly	Yearly
Detect and fix leakages	×			
Monitor pressure difference across filter	×			
Adjust filter back-flush cycle		×		
Monitor pressure at lateral outlets		×		
Monitor system flow (main flow meter)	×			
Monitor air and pressure control valves				×
Water sampling at lateral ends, evaluate changes in quality		×		×
Moisture sensor readings (e.g. neutron probe)	×			
Backwash filters (as needed)	×	×		
Flush laterals and adjust pressure reducing valves		×		
Treatment with Treflan or root growth inhibitor (see Table 10)			×	
Monitor hydraulic and electrical connections	×			
Replace sand of sand filters				×
Chlorine treatment (depending on water quality and application method)				×
Check hydraulic valves and filters to inspect moving parts				×
Clean filter thoroughly		×		

2.7 Management of soil water levels

Soil water can influence the susceptibility of emitters to root intrusion. With the plant roots' function to seek water and nutrients, their tendency is to grow toward the sources of it. In situations where stressed soil water conditions exist, it is "natural" for the plants' roots to attempt intrusion of the emitter apertures. The exact influence of soil water levels on emitter clogging by roots needs specific research, but the management of soil water levels, in terms of accurate scheduling, can possibly help prevent the clogging of the emitters by plant roots.

2.8 Salinity management

Frequent and small water applications with drip irrigation lead to shallow and compact root systems, which increases crop sensitivity to heat spells and stress. Large plants with shallow root systems are also prone to uprooting by strong winds. On the other hand, due to improved aeration and nutrition in the drip irrigated soil volume, the density of roots is usually significantly higher than the roots of crops growing under overhead types of irrigation such as sprinkler systems (Sne, 2006).

The active root system and most root hairs of drip-irrigated orchard trees converge in the wetted soil volume, with the highest density of the active roots in the aerated upper soil layers, provided there is no accumulation of salts. At the margins of the wetted volume, where salt accumulates, active roots are sparse (Figure 14).

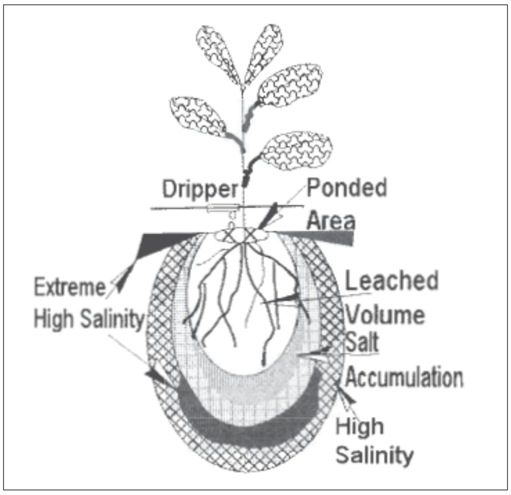


Figure 14: Salt distribution in the wetted soil volume (Sne, 2006)

In low rainfall areas, salt accumulation may damage the soil and the crop. Dissolved salts accumulate at the perimeter of the wetted zone, particularly at the soil surface where the water content of the soil is relatively low. Salts typically build up on the soil surface along the margins of the wetted circles, as well as at a depth below the soil surface and root zone to which irrigation water typically leaches (Figure 14).

As long as adequate irrigation water is applied regularly to replenish the water abstracted by the roots within the wetted soil volume, the soil water content stays high enough in this region to keep the salt concentration low in the soil around the roots. If inadequate water should be applied, the roots would try to grow beyond the area of normal wetting and will then encounter the saline soil volume, which will hinder their further development and negatively influence the plants. If there is a high salt build up with low rainfall patterns, it must be considered to apply water artificially with an overhead irrigation system.

Salt accumulated on the soil surface and in the uppermost soil layer requires preventative management measures with the first rain after the dry season. Irrigation should be applied as long as the rain lasts in order to prevent the salt from leaching into the active root zone (Figure 15).

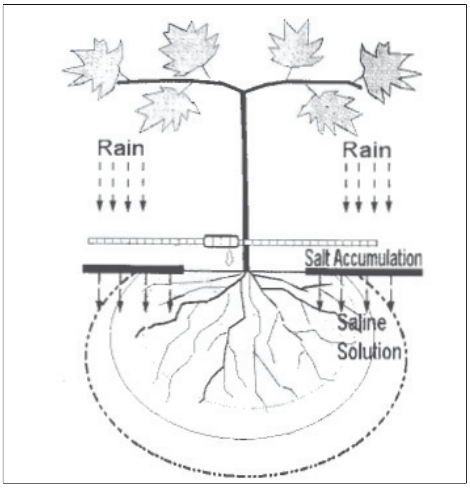


Figure 15: Leaching of salt into the active root zone by rain (Sne, 2006)

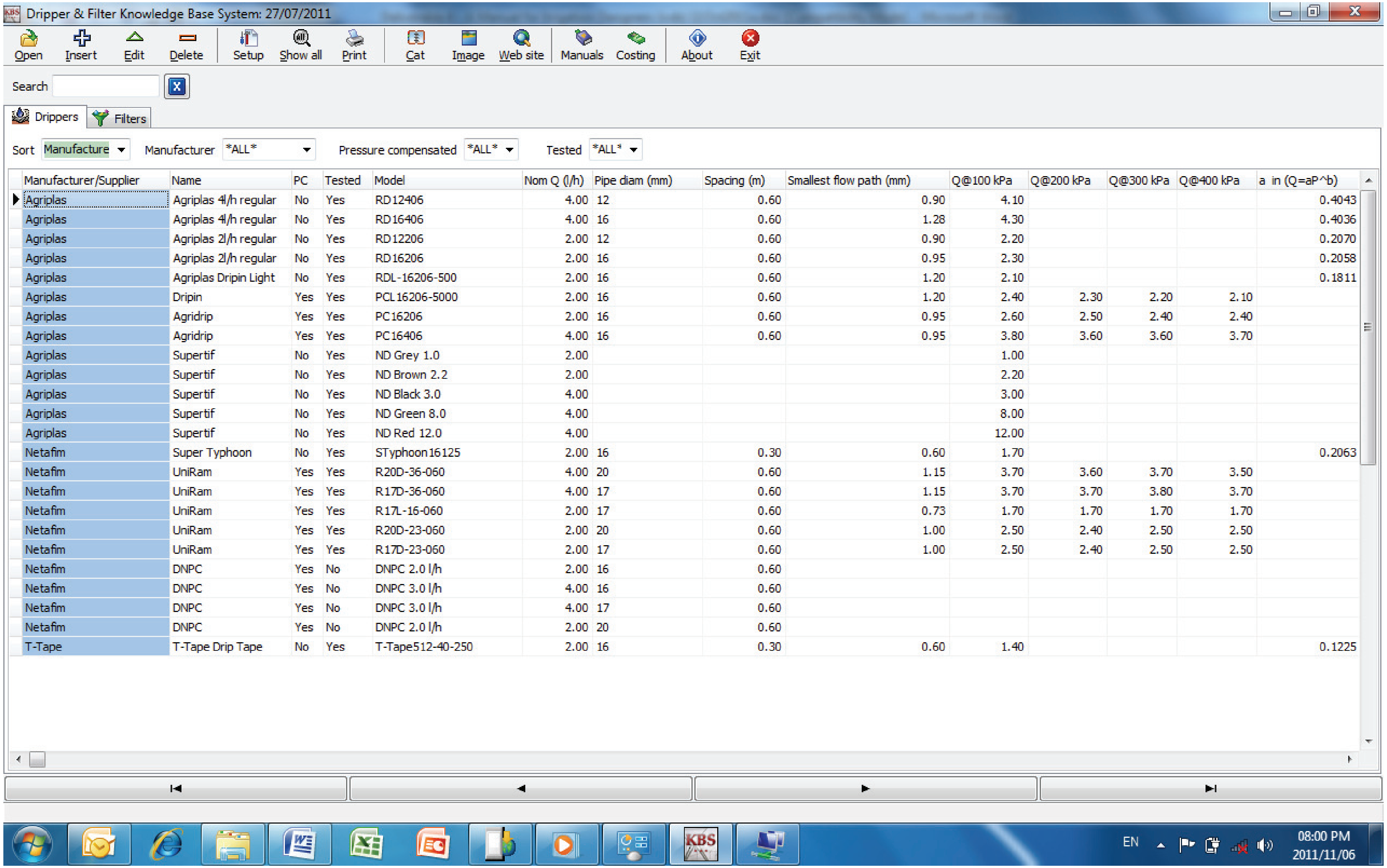
The nutrients applied with the irrigation water follow the same distribution pattern as the salts, but also depend on the interaction between the nutritional elements and the soil. Potassium ions are absorbed on the surface area of clay minerals, and their movement with irrigation water in fine and medium textured soils is limited. Most applied potassium remains in the upper soil layer.

In alkaline and neutral soils, phosphorous precipitates from the soil solution with calcium and magnesium as insoluble salts. In acidic soils, it precipitates with iron and aluminum, and remains in the upper soil layer. Application of phosphorous in deeper soil layers by subsurface drip irrigation therefore increases its availability to the root system.

2.9 Commercially available equipment

A huge variety of drippers are available on the South African market. Data on drippers from the most prominent suppliers have been captured in a Knowledge Base System (KBase) as part of the WRC project and is shown in Figure 16 and is included as a CD in the back cover of Volume 1, the Main Report. Further, the individual suppliers can also be contacted for information and specifications.

Only drippers from reputable irrigation companies where good quality control and testing are in place must be used.



Sort: Manufacture; Manufacturer: *ALL*; Pressure compensated: *ALL*; Tested: *ALL*

Manufacturer/Supplier	Name	PC	Tested	Model	Nom Q (l/h)	Pipe diam (mm)	Spacing (m)	Smallest flow path (mm)	Q@100 kPa	Q@200 kPa	Q@300 kPa	Q@400 kPa	a in (Q=aP^b)
Agriplas	Agriplas 4l/h regular	No	Yes	RD12406	4.00	12	0.60	0.90	4.10				0.4043
Agriplas	Agriplas 4l/h regular	No	Yes	RD16406	4.00	16	0.60	1.28	4.30				0.4036
Agriplas	Agriplas 2l/h regular	No	Yes	RD12206	2.00	12	0.60	0.90	2.20				0.2070
Agriplas	Agriplas 2l/h regular	No	Yes	RD16206	2.00	16	0.60	0.95	2.30				0.2058
Agriplas	Agriplas Dripin Light	No	Yes	RDL-16206-500	2.00	16	0.60	1.20	2.10				0.1811
Agriplas	Dripin	Yes	Yes	PCL16206-5000	2.00	16	0.60	1.20	2.40	2.30	2.20	2.10	
Agriplas	Agridrip	Yes	Yes	PC16206	2.00	16	0.60	0.95	2.60	2.50	2.40	2.40	
Agriplas	Agridrip	Yes	Yes	PC16406	4.00	16	0.60	0.95	3.80	3.60	3.60	3.70	
Agriplas	Supertif	No	Yes	ND Grey 1.0	2.00				1.00				
Agriplas	Supertif	No	Yes	ND Brown 2.2	2.00				2.20				
Agriplas	Supertif	No	Yes	ND Black 3.0	4.00				3.00				
Agriplas	Supertif	No	Yes	ND Green 8.0	4.00				8.00				
Agriplas	Supertif	No	Yes	ND Red 12.0	4.00				12.00				
Netafim	Super Typhoon	No	Yes	STyphoon16125	2.00	16	0.30	0.60	1.70				0.2063
Netafim	UniRam	Yes	Yes	R20D-36-060	4.00	20	0.60	1.15	3.70	3.60	3.70	3.50	
Netafim	UniRam	Yes	Yes	R17D-36-060	4.00	17	0.60	1.15	3.70	3.70	3.80	3.70	
Netafim	UniRam	Yes	Yes	R17L-16-060	2.00	17	0.60	0.73	1.70	1.70	1.70	1.70	
Netafim	UniRam	Yes	Yes	R20D-23-060	2.00	20	0.60	1.00	2.50	2.40	2.50	2.50	
Netafim	UniRam	Yes	Yes	R17D-23-060	2.00	17	0.60	1.00	2.50	2.40	2.50	2.50	
Netafim	DNPC	Yes	No	DNPC 2.0 l/h	2.00	16	0.60						
Netafim	DNPC	Yes	No	DNPC 3.0 l/h	4.00	16	0.60						
Netafim	DNPC	Yes	No	DNPC 3.0 l/h	4.00	17	0.60						
Netafim	DNPC	Yes	No	DNPC 2.0 l/h	2.00	20	0.60						
T-Tape	T-Tape Drip Tape	No	Yes	T-Tape512-40-250	2.00	16	0.30	0.60	1.40				0.1225

Figure 16: List of the drippers and selected data captured in the KBase

3 TECHNICAL ASPECTS OF FILTRATION EQUIPMENT

3.1 Background

The filter is the heart of any drip system. In general, water filters are designed to remove specific types of contaminants for industrial, irrigation or municipal purposes. Filtration and/or treatment of irrigation water for application through drip systems is essential to prevent harmful physical, chemical or organic substances from blocking the emitters.

It is necessary to have a thorough understanding of water quality aspects and a comprehensive knowledge of the variety of drippers for design purposes, because the type of filter to be used and the level of filtration required are closely related to the type of the irrigation system and the effect of impurities in the water on the drippers. Appropriate maintenance schedules, and the correct selection and management of the filtration system, is therefore of particular importance for optimum performance of the irrigation system:

3.2 Filter types

The need to filter irrigation water originated with the development of the micro-irrigation concept in Israel. Initially, mesh filters were used, but the need to filter very dirty water led to the development of more efficient filters which could also handle much higher flow rates. Mesh, disc and sand filters are currently used in South Africa.

3.2.1 Mesh filters

Mesh filters consist of a permeable membrane which is usually located inside a supporting, cylindrical core. The mesh is usually manufactured of stainless steel or a nylon compound. The filtering qualities are determined by the size of the mesh openings, the total mesh area, and the facility for cleaning the mesh during regular maintenance operations. Two typical constructions are illustrated in Figure 17. Mesh filters are suitable for filtering good quality water in which sand and silt occurs. Algae can however block the openings of a mesh filter.

Standard filter ratings						
Micron	300	250	200	130	100	80
mm	0,3	0,25	0,2	0,13	0,1	0,08
Mesh	50	60	75	120	155	200

Figure 17: Mesh filters and fineness ratings (Photo: Arkal)

3.2.2 Disc filters

Disc filters offer a three-dimensional filter action, and therefore have a much higher capacity compared to mesh filters of the same basic dimensions. The filter consists of a number of grooved circular plastic discs which are tightly stacked cylindrically. Water flows from the outside of the cylinder through the discs to the inside. All foreign matter larger than the permeable openings of the specific grooves is retained by the discs.

Dirt is removed from the discs by flushing with filtered water in the opposite direction through the discs (backwashing). In some filters, the discs can also be loosened from one another and even rotated during backwashing, results in cleaner discs. Figure 18 illustrates the flow pattern of a typical disc filter during the filtration and backwashing actions.

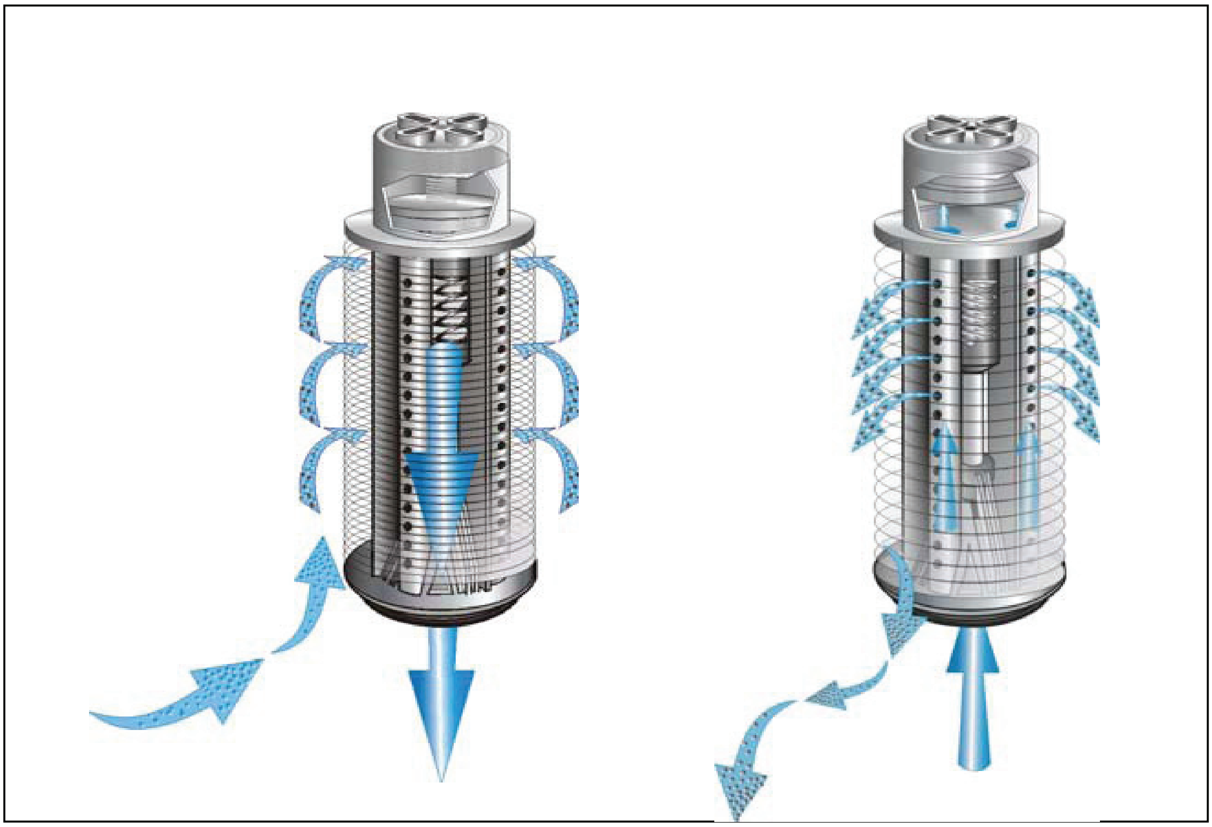


Figure 18: Filtration and backwash action in disc filters (Photos: Arkal)

Disc and mesh filters are selected so that the allowable pressure difference over the clean filters is ≤ 10 kPa. Table 12 shows the allowable pressure difference over disc/mesh filter banks.

Table 12: Guidelines for maximum allowable pressure drop over disc/mesh filter banks

Clean disc/mesh filter bank (kPa)	Allowable pressure build up over filter bank (kPa)	Allowable pressure drop over filter bank before backwashing (kPa)
≤ 30	≤ 40	≤ 70

3.2.3 Sand filters

Like disc filters, sand filters also offer a three-dimensional filtering action. They offer a particularly large medium area, thus the total capacity of a sand filter is much higher than that of other filter types. It also has a finer filter action, making it a very popular choice. Most manufacturers specify a sand filter with a wide spectrum of granular sizes capable of removing particles down to 80 microns from the water.

The medium area is the determining factor for calculating the filter capacity. The theoretical maximum filter capacity of a "0.8" mm sand is 50 m^3/h per square metre sand surface. However, there are two major reasons why it is not advisable to use sand filters maximally:

- The lower the flow rate during filtration, the better the result
- At the same time, backwashing intervals increase in inverse proportion to the decline in utilisation

Although sand filters require little maintenance, it is important that the filters are backwashed regularly to prevent excessive accumulation of dirt which could screen off the sand surface, and consequently be forced through the sand due to the increased pressure difference resulting in a process known as funnelling. It has been determined in practice that the best backwashing rates of sand filters should be identical to or slightly lower than the maximum filtration rate. It is also recommended that the sand is replaced on a regular basis, at least once a year.

Sand filters are always operated in conjunction with secondary disc or mesh filters. There are two reasons for this:

- Under normal circumstances, the secondary filter serves as a check on the performance of the sand filter. During incidental funnelling, the material will move through the sand and will be intercepted by the secondary filter. This condition warns the operator that the sand filter needs to be serviced.
- If the sand filter is damaged internally, the filter sand is intercepted by the secondary filter, preventing it from entering the emitters.

The shape and function of typical sand filters are illustrated in Figure 19.

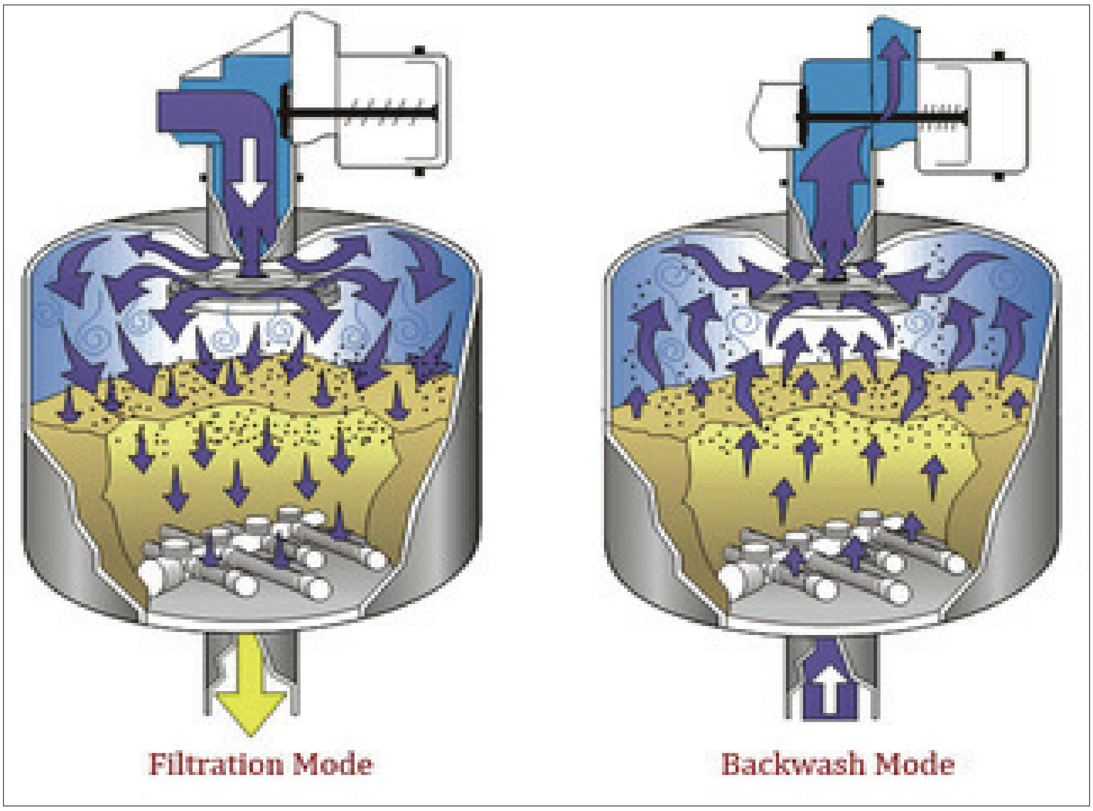


Figure 19: Operation of sand filters

Sand filters are selected so that the allowable pressure difference over the clean filters is ≤ 10 kPa and the flow rate limitation of ≤ 50 m^3/h per m^2 sand surface. Table 13 shows the allowable pressure difference over sand filter banks.

Table 13: Guidelines for maximum allowable pressure drop over sand filter banks

Clean sand filter bank (kPa)	Allowable pressure build up over filter bank (kPa)	Allowable pressure drop over filter bank before backwashing (kPa)
≤ 40	≤ 20	≤ 60

3.3 Selection of filter type

The type of filter to be used, and the level of filtration which is to be handled by the filter medium, are closely related to both the type of system which is to be served and the amount of dirt in the water. Because dripper blockages are difficult to see, and can only be repaired by replacement, drip irrigation in general requires a high degree of filtration.

Sand filters fitted with secondary filters are recommended for drip irrigation with ‘normal’ stored or running water. Because mesh filters are basically not back-washable, disc filters are recommended for this purpose.

Disc filters are usually adequate in cases where clean water (e.g. most borehole water) is used for irrigation. The filtration level will be fine enough, and the only limitation will be the length of the backwash cycle.

3.4 Selection of filter size or filter capacity

The size and/or the number of filters required for a system depends on:

- The total flow in the system and the maximum recommended flow through each filter
- The amount of dirt present in the water
- The minimum back-wash or cleaning cycle

3.4.1 Maximum flow rate

The higher the flow rate through a filter, the higher the pressure loss over the filter. An example of pressure loss information provided by a manufacturer is shown in Figure 20.The colour codes for the filter grade refer to the fineness of the filter – the finer the grade of filtration (smaller grade number), the higher the pressure loss through the filter at the same flow rate.

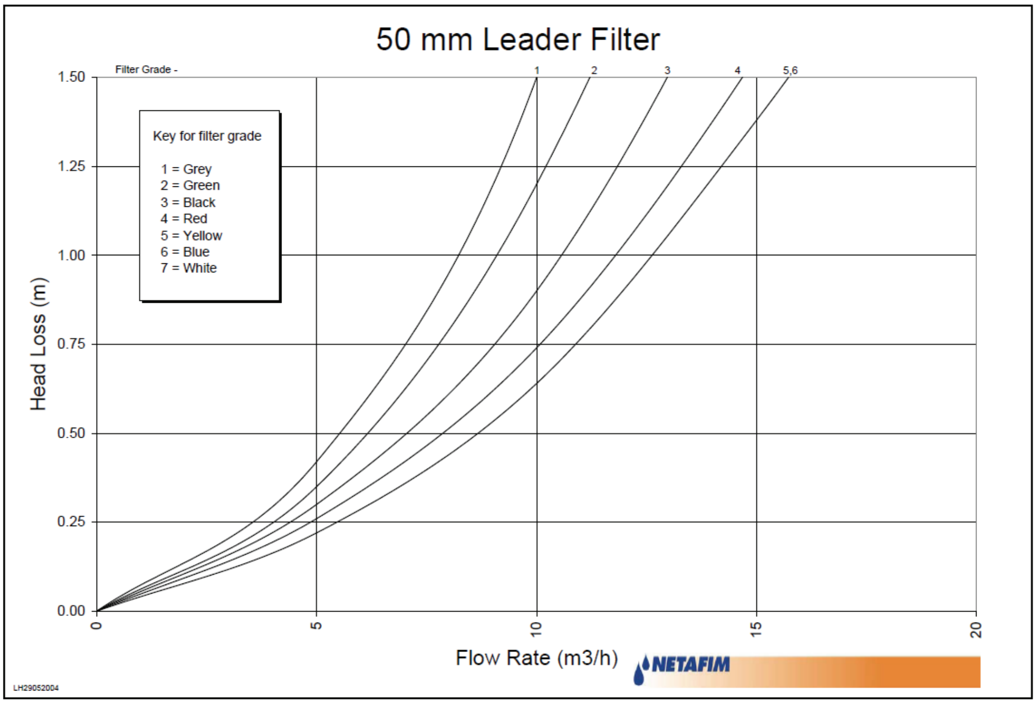


Figure 20: Example of pressure loss graphs (Source: Netafim)

Pressure losses should be limited for both physical and economic reasons. The total pressure loss over a clean filter at the maximum allowable flow rate should not exceed 10 kPa. This guideline, however, is not rigid, but can be adapted according to relevant system factors. Excessive pressure losses may adversely affect the filtration efficiency and may even damage the medium.

3.4.2 Dirtiness of the water

An adaptation in the recommended flow rate of filter is necessary if the silt load of the irrigation water is abnormally high. For example, the recommended maximum flow rate of sand filters of < 50 m³/h per m² sand surface can be reduced for the Orange River with its heavy silt load to 30-35 m³/h per m² sand surface.

For filtration purposes, the dirtiness of irrigation water is measured with a special but simple apparatus called the dirt index meter. The dirt index (DI) is expressed as a percentage. The interpretation of DI is explained in Table 14**.**

Table 14: Classification of the dirt index figures for irrigation water

Dirt index (DI) [%]	Classification
< 1	**Clean**
> 1	**Dirty**
Approximately 5	Fairly dirty: blockage of most filters within a few days
Approximately 30	Very dirty: blockage of most filters within a few hours
Approximately 60	Extremely dirty: blockage of most filters within a few minutes

The ARC-Institute for Agricultural Engineering in Weavind Park, Pretoria may be contacted for more information on the relevant apparatus.

3.4.3 *Cleaning cycle*

During the filtration process there is an increase in the total pressure loss over the filter due to blockage. The pressure loss over a typical filter is illustrated in Figure 21.

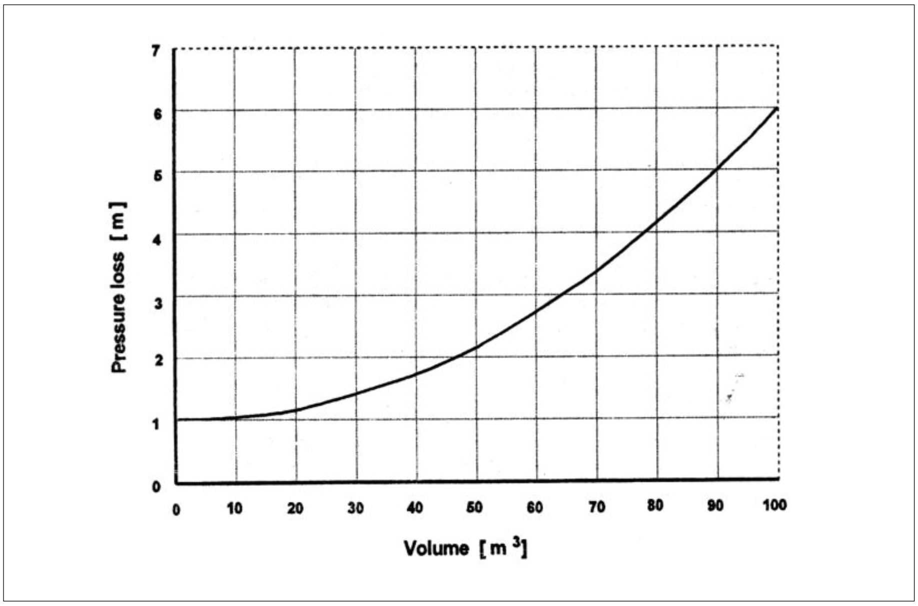


Figure 21: Typical blockage graph of filter

Figure 21 shows that an increase in the allowable pressure loss over a filter will result in an increase in the capacity:

- An increase of about 1,5 to 2,0 m in sand filters may cause funnelling, with resulting penetration of dirt.
- With disc and mesh filters, excessive pressure losses may cause the dirt to be forced through the medium, decreasing efficiency in that way.
- In some filters, especially mesh filters which filter from the outside to the inside of the core, the entire element may collapse if the pressure loss is excessive. In this case a large concentration of dirt (which has accumulated on the element) may be released into the system, causing serious blockages in the emitters.
- Elements, and even sand, which lose their function due to excessive pressure losses, are more difficult to clean, while the efficiency of backwash actions will also decrease.

The backwash cycle depends exclusively on the quality of the water. Dirtier water requires shorter backwash cycles, and more and/or larger filters.

3.5 Guidelines

The following guidelines must be adhered to when utilising filters with drip irrigation systems.

3.5.1 Guidelines for the selection of filters and accessories

Filter performance has been tested both in the field and the laboratories of the ARC-IAE. Filters must be selected and operated according to the specified capacity, water quality and maintenance requirements taking the following into account:

- Matching the filter type with the water quality and the irrigation system;
- System components upstream of the filter station
- Design principles with respect to:
  - Commissioning the filter
  - Filtration
  - Backwashing
  - Size of filter
  - Filter operation, and
  - Maintenance of filters

3.5.1.1 Matching filter type with water quality and the irrigation system

The primary factor that determines the kind of filter to be used is the type of system being designed. More than one type of filter may be suitable, with the choice next being based on the dirtiness of the water and the type of dirt in it.

It is simple and advisable to take a water measurement using a mobile Dirtiness Index Meter. This will determine the amount and type of dirt in the water, from interpreting the reading and from observing the dirt physically caught in the screen of the meter.

Another factor that plays a role in selecting the filter type is the kind of backwash management that will be done once the filters are installed. From the dirtiness measurement and filtration capacity tests, a filter station can be designed that has enough filtration capacity to match the kind of backwash management envisaged.

Sand filters with secondary disc filters (also known as control filters) are preferred for use in drip systems. The control filter allows monitoring of the sand filter to ensure that it is operating efficiently and also to act as a safety filter if problems develop with the sand filter.

Disc filters with a filtration fineness of not more than 100 µm can be used if borehole water is used for irrigation, or if the water used is of a high quality throughout the season.

3.5.1.2 Selection of equipment

Only irrigation filtration units from reputable irrigation companies must be used, and preferable only those units that have been tested by an independent testing laboratory. Full specifications and design parameters must accompany the equipment.

3.5.1.3 Accessories for the sand filter station

Accessories for the filter station must be reliable to ensure the protection of the filter station and the irrigation system from inorganic sands or organic materials such as algae which may be present in the water supply. Inorganic particles are usually heavy and can easily be removed by a settling basin. Organic materials are lighter and must be removed by sand filters. Floating materials may be skimmed from the water surface.

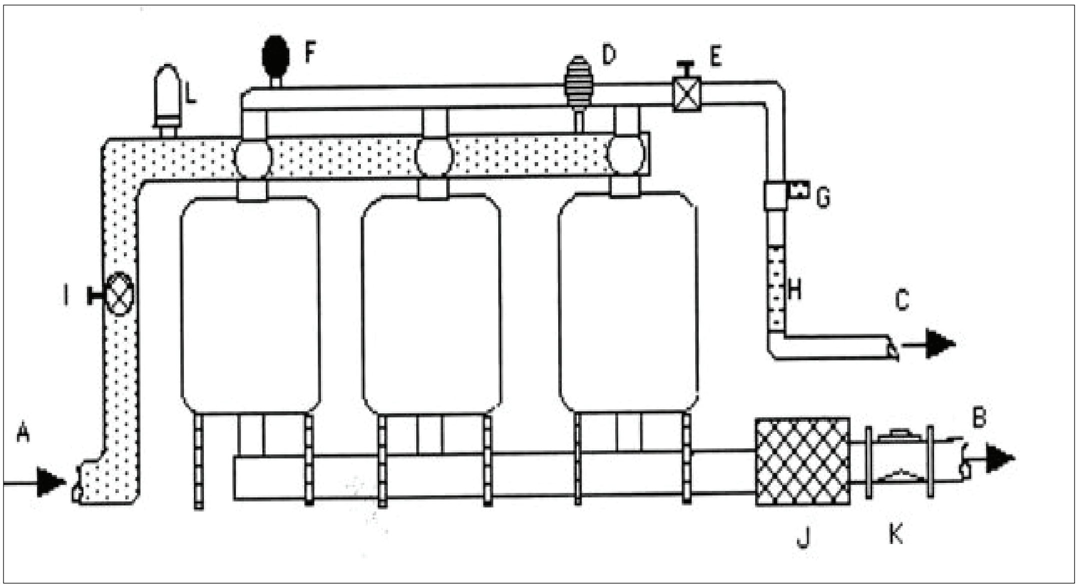


Figure 22: Typical layout of sand filter bank (adopted from Burt & Styles, 1994)

Where:

A – Irrigation water source
B – Clean water outflow to irrigation system
C – Backwash water disposal
D – Combination air valve
E – Backwash flow-rate adjustment valve
F – Vacuum release valve
G – Sighting port
H – Clear plastic tube
I – Rinse valve
J – Disc/screen filter (200 µm)
L – Pressure release valve
K – Pressure sustaining valve

Some of the accessories for the sand filter station are essential, and others are optional. Essential accessories referred to in Figure 22 are:

- Backwash flow-rate adjustment valve, E
- There are ways to determine if the backwash water is dirty or clean and if there is sand loss during backwash. These includes inspecting:
  - The backwash discharge line end, C, which is exposed to the air and is accessible. If the discharge line is too long, too small or goes uphill to the extent that it is impossible to develop enough backwash flow, the backwash valve must be re-adjusted.
  - A specially designed sighting and sampling port, G, which continually passes a portion of the backwash flow through a small attached glass jar allowing the operator to see if the backwash water is dirty or clean.

    - A section of clear plastic in the backwash line, H, (which should otherwise be covered to protect it from sunlight damage).

- A secondary disc/screen filter, J, located downstream of the sand filter to prevent dirt from clogging the emitters if the sand filter should fail.
- A combination air valve, D, located at the downstream end of the supply manifold. The combination air valve has a kinetic as well as automatic function, so it releases small, as well as large volumes of air when necessary.
- A vacuum release (kinetic) valve, F, located at the upstream end of the backwash manifold. This valve will release large quantities of air during the filling of the system.
- A pressure release valve, L, located upstream of the filters discharges excessive pressure to the atmosphere and thereby protecting the filters against sudden pressure increases.
- A pressure sustaining valve, K, located downstream of the filters. The function of the valve is to maintain a minimum pre-set upstream pressure irrespective of changes in pressure and flow through the system to ensure that enough pressure is available for the filter to backwash and to meet the minimum pressures specified by the manufacturers.

As sand filters cannot be cleaned manually, at least two filters should be installed so that clean water from one filter can be used to back flush the other filter, as shown in Figure 23.

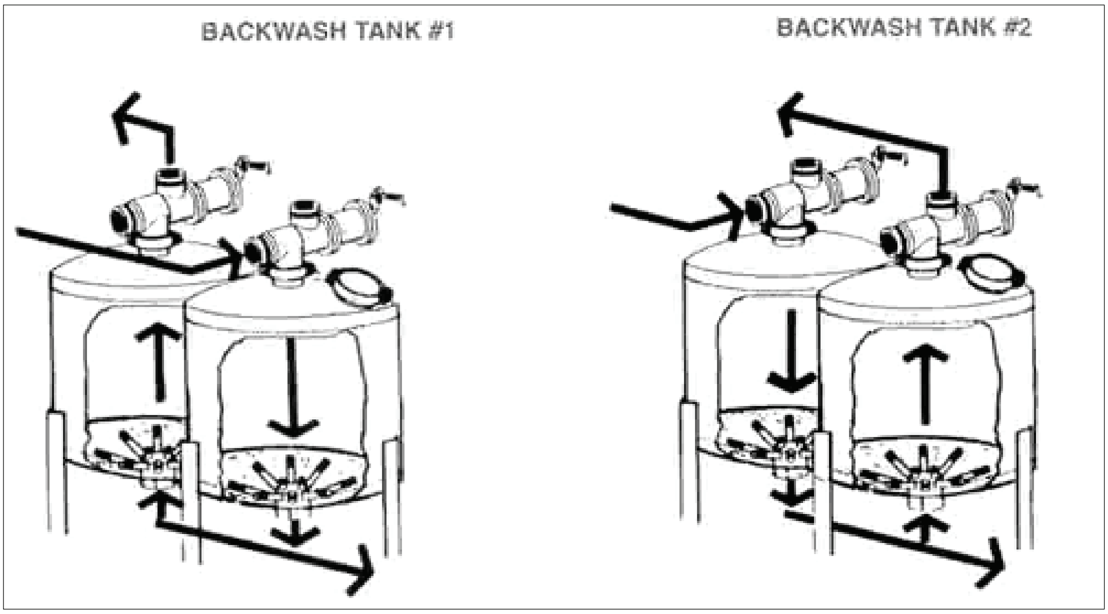


Figure 23: Back washing of sand filters

3.5.1.4 Screen filter stations

Screen filters can be cleaned in three ways:

1) Removal of the element: The screen can be removed from the housing and cleaned manually, as shown in Figure 24. In some cases it may be easier to have a spare screen that can be used while the dirty screen is allowed to dry. The screen filter may be easier to clean when dry than when it is wet, especially if the dirt particles are fine clay or silt, or organic matter such as algae.

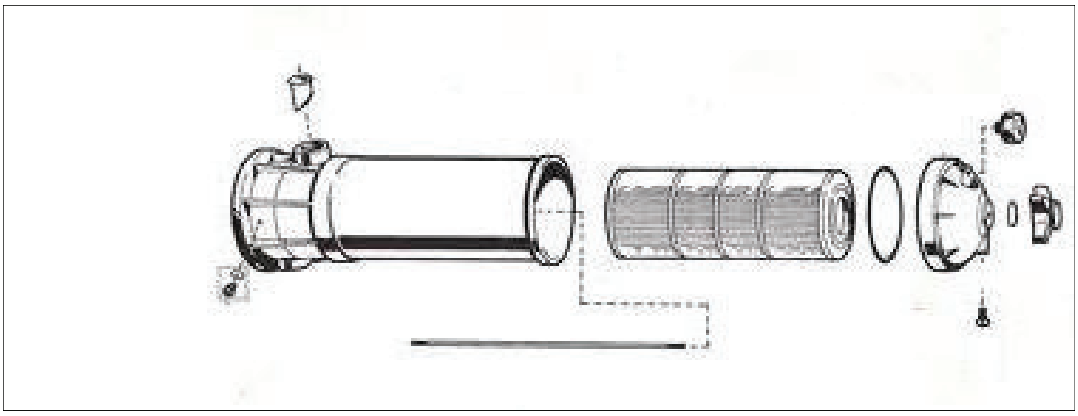


Figure 24: Removal of screen filter element for manual cleaning

2) Flushing the filter: Most of the bigger automatic screen filters can be set to flush automatically at set intervals during operation (Figure 25). Release of the flushing water usually coincides with a mechanical cleaning action inside the screen.

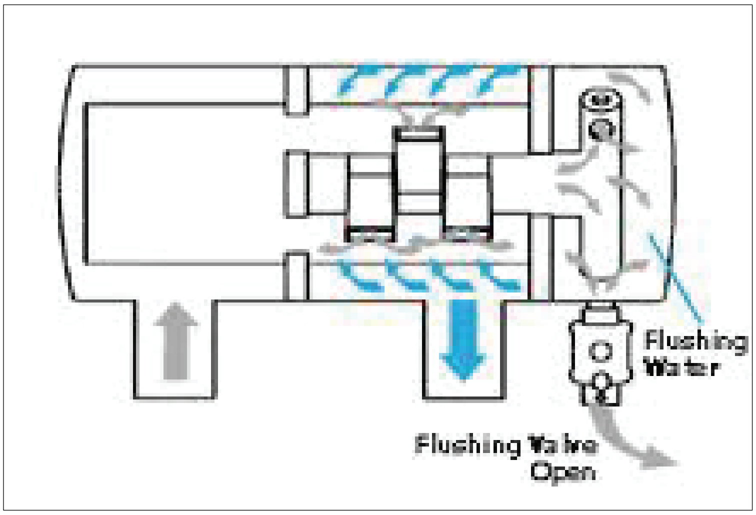


Figure 25: Flushing the screen filter

3) Backwashing the filter: If more than one filter is installed in parallel, clean water from the one filter can be used to backwash the other, as in to the process shown for sand filters in Figure 23. The process is shown diagrammatically in Figure 26.

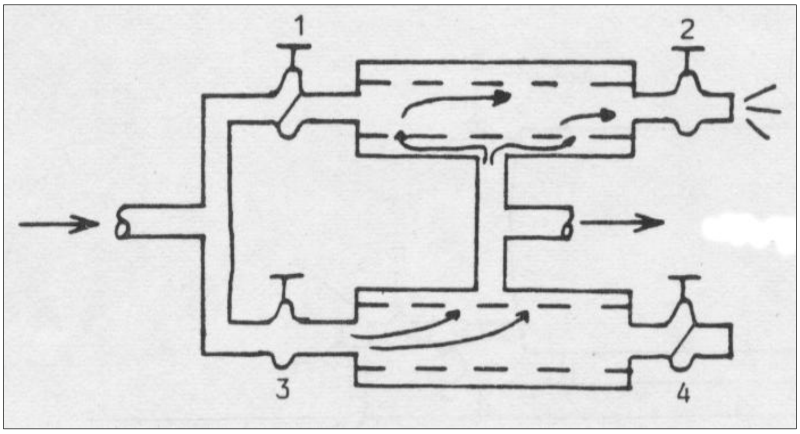


Figure 26: Backwashing the screen filters

3.5.1.5 Disc filter stations

In some cases disc filter installations are not equipped with backwash valves and their elements must be removed to clean them, as in the case of the screen filters. To ensure that no dirt enters the irrigation system when the filters are being cleaned, the following procedures for two different types of filter installations are recommended:

Installation option 1:

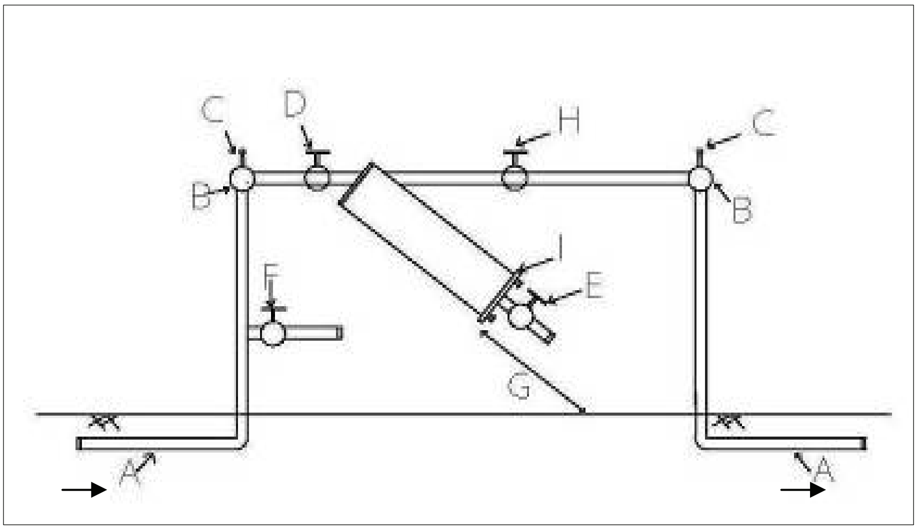


Figure 27: Typical components of disc filter installation; option 1

Where:

A = Pipe
B = Manifold for parallel installation of filters
C = Pressure measuring points
D = Cut-off valve
E = Waste water valve for flushing or back washing water
F = Small tap and hose pipe for cleaning the elements
G = Space for the element to be removed beneath the filter
H = Cut-off valve
I = Removable lid

Filters that can be flushed:

1) Open valve E and close valve H. (The filter is flushed with unfiltered water.)
2) When the water form valve E is clean, close E and open valve H.
3) Repeat the process for the other filter(s) and continue with filtration.

Filters that can be backwashed:

In this case, the process will only work if there is more than one filter installed in parallel.

1) Open valve E and close valve D. (The filter is backwashed with the filtrated water from the other filters flowing from B.)
2) When the water from valve E is clean, close E and opens valve D.
3) Repeat the process for the other filter(s) and continue with filtration.

Removal of the filtering element:

1) Open valve E and flush out the worst dirt.

2) Close valves D and H (The filter is totally isolated)
3) Loosen lid I and remove the element.
4) Clean the element with the hose or replace it with a clean element if available.
5) Put the element back, close valve E, open valves D and H and continue with filtration.
6) Repeat the process for the other filter(s).

Remark: If valves D, H and E are replaced with hydraulic valves, procedures A and B can be done automatically with additional equipment.

Installation option 2:

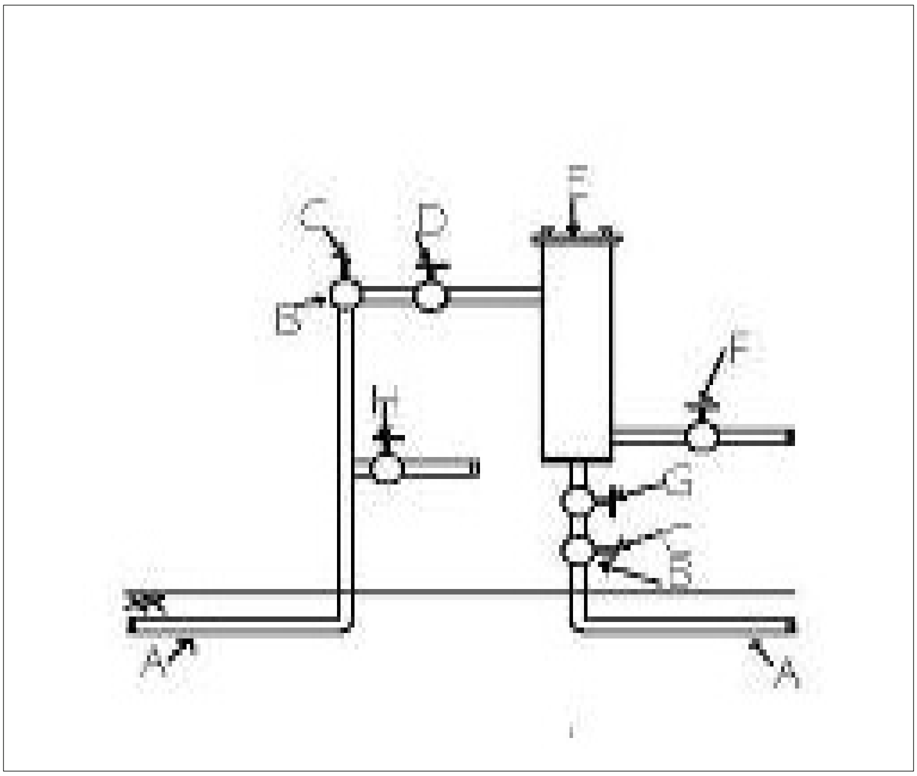


Figure 28: Typical components of disc filter installation; option 2

Where:

A = Pipe line

B = Manifold for parallel installation of filters

C = Pressure measuring points

D = Cut-off valve

E = Removable lid

F = Drainage valve and waste water valve for flushing or backwashing water

G = Cut-off valve

H = Small tap and hose pipe for cleaning the elements

Filters that can be flushed:

1) Open valve F and close valve G. (The filter is flushed with unfiltered water)
2) When the water from valve F is clean, close F and open valve G.
3) Repeat the process for the other filter(s) and continue with filtration.

Filters that can be backwashed:

1) Open valve F and close valve D. (The filter is backwashed with the filtrated water of the other filters.)
2) When the water from F is clean, close F and open valve D.
3) Repeat the process for the other filter(s) and continue with filtration.

Removal of the filtering element:

1) Open valve F and flush out the worst dirt.
2) Close valves D and G.
3) Loosen lid E, let all the water in the filter drain through valve F and remove the element.
4) Clean the element with the hose or replace it with a clean element if available.
5) Put the element back, close valve F, open valves D and G and continue with filtration.
6) Repeat the process for the other filters.

Remark: If valves D, F and G are replaced with hydraulic valves, procedures A and B can be done automatically with additional equipment.

3.5.1.6 System components upstream of the filter

The way in which water enters into or is supplied to the filter has a significant impact on the effective and efficient operation thereof. The most common system components that can be found upstream of the filter are discussed here.

Settling basin

In cases where the irrigation water contains solid particles in suspension in excess of 200 parts per million (DI = 900%), it is advisable to have a settling basin where the particles can be sedimented before the water is filtered. This will prevent overloading the filter as well as excessive backwashing.

The following points are important when settling basins are used:

- The outlet of the basin should be as far as possible from its inlet.
- The backwash water from the filters should be dumped as far as possible from the inlet (preferably not back into the basin)
- It must be possible to clean the basin with the minimum effort.
- Water for filtration should be drawn from the upper layer of the dam (suction pipe mounted on float).
- A long, narrow settling basin is more effective than a square one.

Where there is iron in the water, it necessary to aerate the water so that the iron may oxidise. The iron oxide will then sedimented in the basin and the water for irrigation may be drawn off from the surface of the basin.

Pump

The suction pipe of the pump must be deep enough beneath the water level to prevent a vortex being formed and air sucked in. In cases where surface water is utilised, suction pipes must be attached to a float to ensure that the higher quality water for irrigation is withdrawn near the water surface. Directives are given in Table 15 for the minimum water depth above the suction pipe inlet, according to the inlet flow velocity of the water in the suction pipe.

Table 15: Minimum water depth above suction pipe inlet

Inlet flow velocity (m/s)	Minimum water depth (m)
1,0	0,5
2,0	1,1
3,0	2,0

Bell-shaped inlets are recommended, because they have the benefit that the flow speed at the inlet is low and that sand and stones cannot be sucked in as easily. It is also important that the distances shown in Figure 29 are maintained.

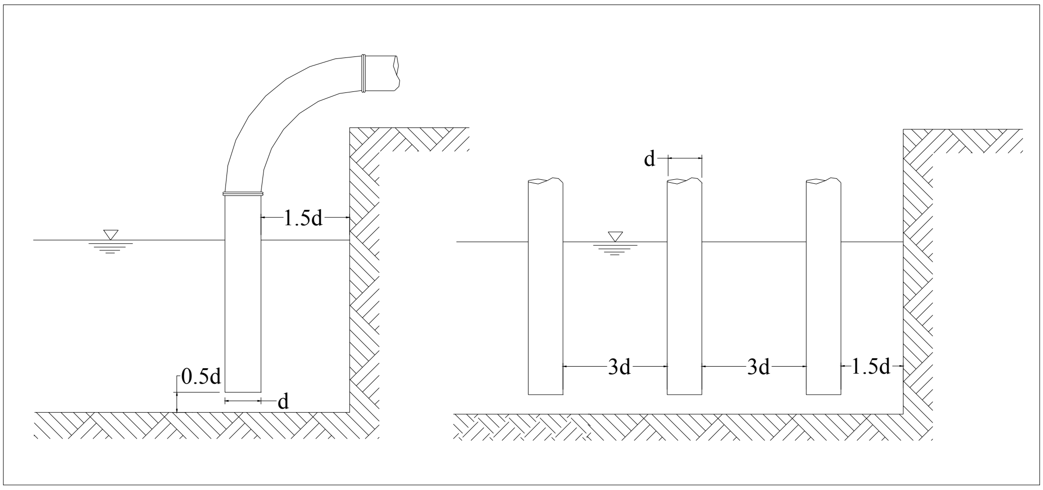


Figure 29: Minimum distances between suction pipes and sides, and bottom of pump sump

The following distances should be maintained:

- The free-area of foot valves must be at least 1½ times the suction pipe diameter. Where suction head is a limiting factor, foot valves, which usually result in a high friction loss, must be avoided.
- The free area of the screen before the suction pipe must be at least four times that of the suction pipe to prevent alien materials from blocking the foot valve.
- Guide screens must be mounted at least eight times the suction pipe diameter in front of the suction eye of the pump to prevent turbulence causing cavitation. If it is necessary to mount the screen closer to the pump, a stream aligner must be mounted.

- Screens must have holes with a diameter of 6 mm to 12 mm, and the total area of the holes must be six times that of the suction pipe area.
- The water supply to the pump hole must also be such that it does not cause the suction pipe to suck in air. It is especially a problem where the pump hole is fed by another pipeline. In that case the supply pipeline must be placed away from the suction pipe, so that the suction pipe does not suck in air bubbles that form when the water enters the pump hole.
- Suction pipes or drainage pipes must fit naturally and not be forced in by means of flange bolts. They must also be supported independently near the pump so as not to place stress on the pump casing.
- A foot valve's open area must be four times that of the open area of the suction hose, thus ensuring that the velocities through the foot valve does not exceed those of the suction hose by more than 25%.

The following is proposed:

Suction hose (absolute maximum):	≤ 1,5 m/s
Suction strainer:	≤ 0,4 m/s
Maximum permissible velocity in filter station manifold:	≤ 0,5 m/s

3.5.2 Design guidelines for filters

3.5.2.1 Filtration

The following design guidelines are recommended:

- If a sand filter is used, there must be a 200 μm control screen/disc filter downstream of the sand filter.
- The maximum allowable flow-rate through a clean sand filter must be ≤ 50 m^3/h per m^2 of the filter sand surface.
- The recommended maximum allowable pressure difference over the different types of filter/filter station are as shown in Table 16:

Table 16: Maximum allowable pressure differences over the filters/filter stations

Type	Clean water (kPa)		Maximum pressure build-up (kPa)	Pressure difference before backwashing (kPa)	
	Filter	Filter station		Filter	Filter station
Disc/Screen filter	10	30	40	50	70
Sand filter	10	40	20	30	60

The filter station includes all the fittings, valves and in the case of a sand filter-station, also the secondary filter.

3.5.2.2 Backwashing

- At least 50% of the maximum filtration rate (50 m^3/h per m^2 sand surface) is necessary to backwash sand filters effectively. The maximum backwashing rate must not be more than 1.2 times the filtration rate.
- A minimum inlet pressure of 6 m (60 kPa) during backwashing is required.
- The backwash outlet pipe must be sized to allow maximum flow velocity: the general rule is to have at least one normal pipe size bigger than the backwash outlet size on the filter.

3.5.2.3 Filter size

The size or number of filters required for a specific irrigation system in a certain area under a particular type of management depends on the following factors:

- The flow-rate which each filter will have to handle
- The dirtiness of the irrigation water
- The total pressure drop which can be allowed across the filter (consisting of the pressure drop across a clean filter plus the additional pressure drop for possible blocking of the element)
- The minimum cycle required for the cleaning of the filters

The allowable flow-rate through a filter

The faster the water flows through the filter, the more friction loss will occur across the filter. For economic and physical reasons, this loss has to be restricted. The following guidelines can be followed:

- For dirty water (DI > 1%): a maximum loss of 10 kPa is allowed across a clean filter. This loss can increase to a maximum of 50 kPa (30 kPa for sand filters) due to blocking of the element, but the actual allowable increase will be determined by the hydraulics of the irrigation system, as will be discussed later on. If the 50 kPa limit is exceeded, it could drastically lower the efficiency of filtration.
- For clean water (DI < 1%, e.g. borehole water): a maximum allowable loss of 30 kPa across a clean filter, and a maximum limit of 50 kPa across a dirty filter.

The friction loss curve of the filter should be consulted to determine what the loss across a clean filter will be when a specific irrigation system's water moves through it. Where two or more parallel filters are used, the total flow-rate of the system must first be divided by the number of filters. The friction loss resulting from this flow-rate can then be read from the friction loss graph. If the friction loss exceeds the above limits, it means that the flow-rate is too high for the filter, and that a larger filter or additional filters should be chosen.

The dirtiness of the irrigation water

Figure 30 is the friction loss graph of the Silicon II sand filter. According to the previous paragraph, the recommended flow-rate for this filter would be 33 m^3/h because this is the flow-rate that gives a friction loss of 10 kPa over the clean filter.

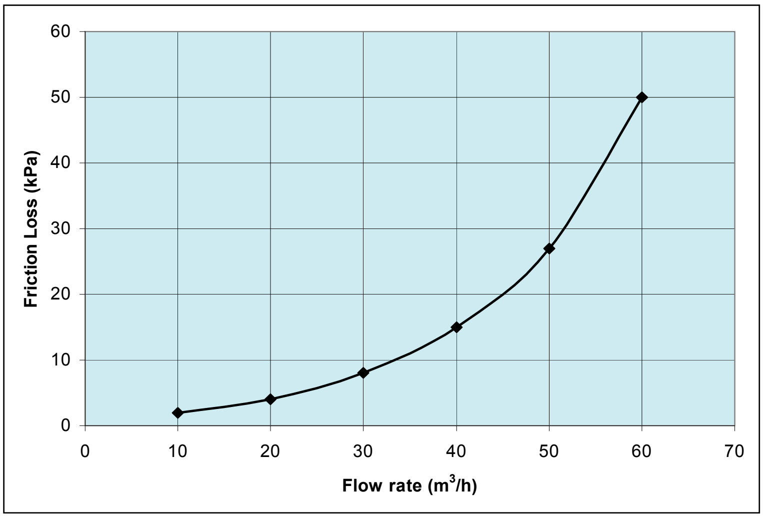


Figure 30: Friction loss graph of the Silicon II sand filter

Figure 31 is the dirty water capacity graph of the Silicon II sand filter, which must be interpreted as follows: If a pressure difference increase of only 20 kPa is allowable over the filter (as is the case for sand filters) and if the irrigation system can supply it, then it means that the filter can clean only 30 m^3 of water before it must be cleaned again, with a DI of the water equal to 10% for example.

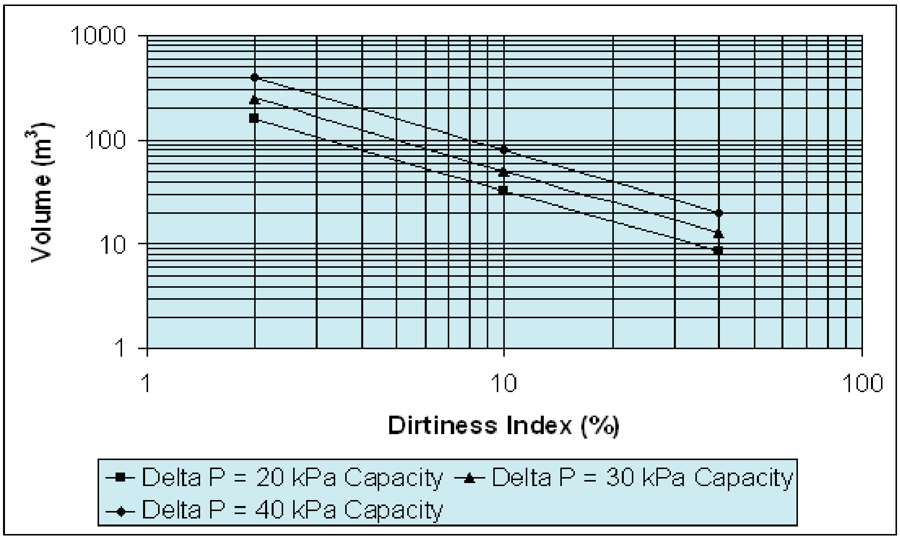


Figure 31: Dirty water capacity graph for the Silicon II sand filter

With an allowable volume of 30 m^3 and an allowable flow-rate of 33 m^3/h, this filter will be clogged in less than one hour. If the farmer's style of backwash management entails manually cleaning filters, it will be very impractical to clean the filters every hour. It might be more practical to clean the filters every six hours. If this is the case, six Silicon II filters will be required in the filter station to provide enough filter capacity for this backwash management style.

The total pressure drop allowed across a filter

When the internal losses of an irrigation system increase, e.g. due to a filter starting to block, the delivery of the system will decrease. Delivery should not be allowed to decrease too much, with a maximum decrease in delivery of 10% taken as a good norm. As soon as delivery decreases by more than 10%, the distribution becomes disproportionate. The volume of the internal losses which accompany the 10% decrease in flow is unique to each system, and can be calculated from the system's hydraulics, as illustrated in Figure 32.

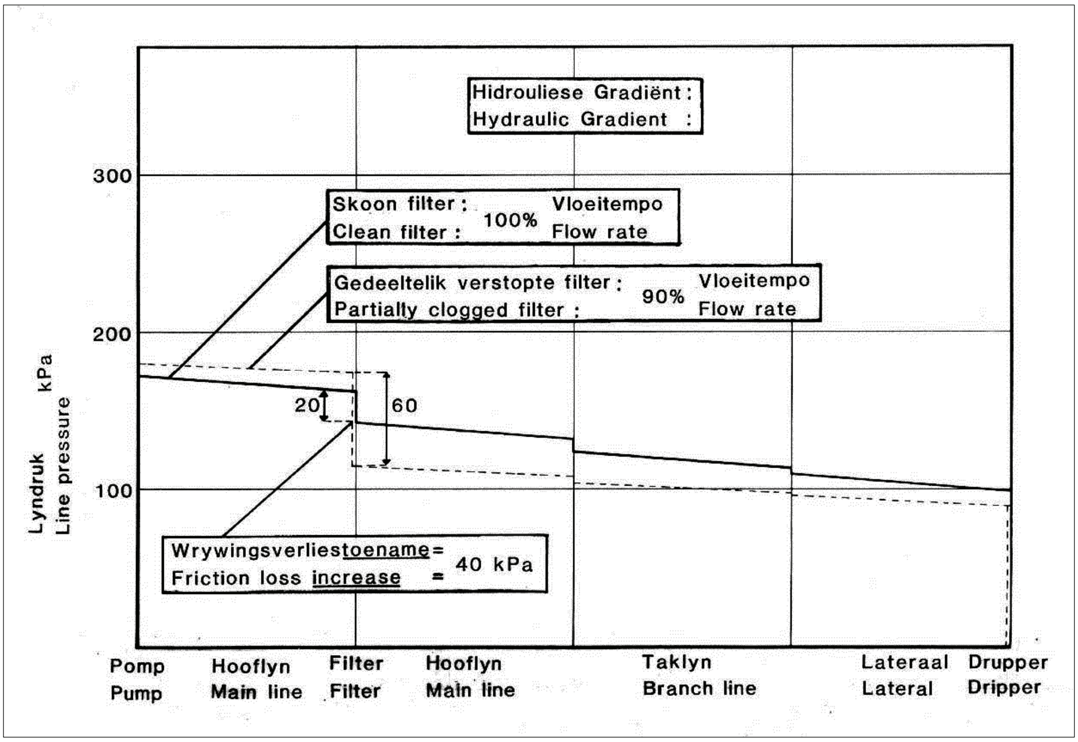


Figure 32: Permissible friction loss increase over a filter

To determine what additional losses the irrigation system can absorb without impairing the efficiency of the system, the pressures of the system are calculated from the pump up to the filter, and then again from the dripper backwards until directly behind the filter. (In the graph, it would thus be from left to right up to the filter, and then from right to left up to the filter

The calculation is done for 100% flow (clean filter) and for 90% flow (dirty filter). The first calculation will thus for example show a pressure drop of 20 kPa across the theoretical filter and the second calculation a pressure drop of 60 kPa. This means that the system can absorb an additional 40 kPa pressure drop across the filter without affecting the efficiency of the system adversely. Given that the total recommended pressure drop across the filter is only 50 kPa, it means that only 30 of the 40 kPa can be utilised by the filter because the initial loss was already 20 kPa, as can be seen in the diagram.

The cleaning cycle of a filter

The exact stage at which a filter must be cleaned is usually determined by one of the following:

- The allowable reduction of flow in the irrigation system, resulting from the increased resistance against flow in the blocked filter: It causes reduction in the system efficiency. The flow rate in the system can be measured with a flow meter and must not reduce by more than 10%.

- The allowable pressure drop over the filter elements: Too great a pressure drop over a filter element causes dirt to be forced into the element, which later hampers effective cleaning. The sand filters are therefore cleaned when the total pressure drop of 60 kPa over the filter banks is reached, given that the flow rate must not drop by more than 10% (See Table 17):

Table 17: Allowable pressure difference over filter banks

Type	Clean filter bank (kPa)	Maximum pressure build-up (kPa	Pressure difference before backwashing (kPa)
Disc/mesh filter	30	40	70
Sand filter	40	20	60

- As a filter cleans the dirt from the water, the pressure drop across the filter increases, as was previously indicated. The more the pressure drop across a filter can be increased, the more water will be filtrated. This pressure drop cannot, however, be increased to an unlimited degree and should preferably be limited to 70 kPa (60 kPa for sand filters) for the following reasons:
    - If the pressure drop increases too much, the dirt will eventually be forced through the element and the efficiency of filtration will start decreasing.
    - With certain filters, the element may give way if the pressure drop becomes too much, and a concentration of dirt (which has in the meantime built up in the element) will enter the system and most likely immediately block the system.
    - Elements that often get blocked under a too high pressure drop become more difficult to clean, and the efficiency of backwashing is drastically reduced.
- A further method is to limit the time lapse between cleanings. An easy way to determine the time lapse is to first calculate the volume that can be safely filtered and then divide the figure by the flow rate of the filter.

$$T = \frac{V}{Q} \qquad (5.8)$$

where

T = Time lapse (h)

V = Volume that can be filtered (m³)

Q = Flow rate through the filter (m³/h)

The latter is the most convenient method, but problems can occur if the degree of dirtiness of the water changes.

If the dirtiness of the water is known, as well as the additional pressure drop which can be allowed across the filter for blockage, then the dirtiness capacity graph of the filter can be used to determine how much water a filter will clean under the given circumstances. If the quantity of water that a filter can clean is known, as well as the flow-rate at which the filter operates, the time it will take the filter to clean this given quantity can be calculated. This time constitutes the cleaning cycle of the filter.

However, with very dirty water choosing a filter on this basis may result in a very short cleaning cycle. The only way to extend an impractically short cleaning cycle is to use larger or additional filters in parallel, so that their common cleaning cycle can be lengthened to a practical time. This decision will have to be made by the producer or the manager of the filters.

It will also lower the flow-rate per filter, and the friction loss across each individual clean filter will be less than the 10 kPa previously advised. This is no longer of importance, however, because the dirty water capacity of the filter becomes the main consideration rather than the flow-rate through the filter. In the case of very dirty water, combinations of different filters are often necessary. Table 18 provides guidance on how to choose and combine them.

Table 18: Filter selection guide; quick reference

Flow-rate	**Solids concentration**		**Product (s) recommendation**
	Inorganic	**Organic**	
Less than 11,4 m^3/h	L	L	A
	L	M	C + A or B
	L	H	C + A or B
	M	L	D + A
	M	M	C + D +A or B
	M	H	C + D + A or B
	H	L	D or D + A
	H	M	C + D + A or B
	H	H	C + D + B
11,4-45,4 m^3/h	L	L	B
	L	M	C + B
	L	H	C + B
	M	L	D or B or D + B or D + B
	M	M	C + D or F or D + F
	M	H	C + F or C + D + F or C + D + F
	H	L	D + B or F or D + F
	H	M	C + D + F or C + F or D + E
	H	H	C + D + F or C + D + F
Greater than 45.4 m^3/h	L	L	B
	L	M	C + F or E only
	L	H	C + F or E only
	M	L	D + B or D + F or E only
	M	M	C + F or C + D + F or E only
	M	H	C + B or C + D + F or C + E
	H	L	D + B or D + F

Flow-rate	Solids concentration		Product (s) recommendation
	Inorganic	Organic	
	H	M	C + D + F or C + F or D + E
	H	H	C + D + F
Solids Concentration Code:		Recommendation Product Code:	
L – Less than 5 ppm M – 5-50 ppm H – More than 50 ppm		A – Strainer B – Screen/Disc Filter C – Suction Screen Filter D – Suction or Discharge Separator E – Gravity Screen Filter F – Sand Filter	

Underlined options above indicate potential Pump Protection systems to minimise abrasive pump wear.

3.5.3 Guidelines for the commissioning of filters

During the commissioning of a new filter station, some specific steps have to be followed in a definite sequence: one step cannot be taken before another is finished. Every situation is unique, but in general, the following order of steps will largely be the correct approach:

- Ensure that all pipe connections, hydraulic pipe and electrical connections are in place.
- Manually test electronic meters for correct operation. Remove the pressure sensor from its mounting and put pressure on to it by blowing it up with your mouth and check if the display reacts. Take the flow meter mechanism out of its casing, blow onto the impellor, and check if the display reacts.
- When a computer or any other electronic device is connected to the instrumentation, check if there is communication between them.
- Check if the elements of the filters are in place and well fastened.
- Check if all pipe and electrical connections are in place at the pump and if the water supply is in place.
- Close the valve behind the pump and start the pump.
- Open the valve very slowly and only partially at first so that the system can fill up slowly.
- Check for water leaks.
- If there are leaks, close the valve first, switch off the pump, and repair the leaks.
- Try again and let the water flow slowly for a while whilst the functionality of the station is tested in full.
- Open the valve fully, bring the system to full pressure, and do all checks again. Leave it on for an hour or so to check its stability.
- Put the system in use and check if all controls and programs work as they should.
- Observe the system closely for at least a month to make sure that everything is working well in the long run.

3.5.4 Guidelines for the operation of filters

Whilst the theoretical backwashing cycle can be calculated, it is, however, just a theoretical cycle which must initially be monitored to see if it is applicable in practice. For example the cycle can change during the season as the water quality changes. Changes in water quality can easily be established by taking regular DI measurements: The same tools that were used to establish the theoretical cycle can be used to make corrections to it.

If the water is very clean, backwashing should be done once daily to prevent sedimentation of the sand-bed. Stirring the sand with the hand can elevate sedimentation. It may sometimes be necessary to replace the sand. Bacterial growth on the sand sometimes leads to sedimentation of the sand, resulting in tunnel forming. Bacterial growth can be prevented by chemically treating the water.

The backwashing duration must be sufficient to remove all impurities from the filter. A backwashing duration of at least 60 seconds is generally recommended. It is, however, good practice to physically backwash the filter, monitoring the time it takes until all the discolouration and alien material disappears from the water. It is also very important to take a sample of the backwashing water with a clean container before the backwashing process is completed and to inspect it to ensure that it is clean. The evaluation and setting of sand filter backwashing times must be done regularly. If the duration is too short, or the flow-rate is too low, the pressure differential over the filter station after backwash will gradually increase with time.

Backwashing usually takes place while irrigation continues. To operate both the backwashing and irrigation system simultaneously, the flow-rate to the irrigation system must be reduced to build-up the pump pressure and to allow backwashing by using a pressure-sustaining valve. It is, however, beneficial to backwash the system from time to time (bi-weekly), with all blocks closed, so that a greater volume of water can flow through the filters to accomplish a more effective backwashing action. A pressure before the filters of ±5 m higher than the normal functioning pressure is sufficient during this action. The use of compressed air to break up clods in the sand and assist with the backwashing action is recommended if problems are experienced with tunneling. Discolouration of water during backwashing is normal and indicates the effective functioning of the filters.

The backwashing flow-rate is very important and must be set to ensure effective backwashing. Too high a flow-rate will cause the sand to wash out, while too low a flow-rate will prevent impurities from being washed out. Backwashing can be performed on a time, volume, or pressure difference basis. The backwashing on a pressure difference basis is recommended, since it takes water quality changes into consideration.

3.5.5 Guidelines for the maintenance of filters

3.5.5.1 Maintenance schedule

The following maintenance schedule for filters is recommended (See Table 19):

Table 19: Minimum maintenance schedule requirements for filters of drip irrigation systems

Monitor	Weekly	Monthly	Quarterly	Annually
Inspect filters for leaks.	✓			
Check pressure difference across filters	✓			
Monitor filter backwash cycle and adjust if necessary		✓		
Check the hydraulic and electrical connectors		✓		
Service screen filters. Replace screen element if necessary		✓		
Inspect sand level (± 360 mm) and shape of sand grains. Add sand or replace if necessary*			✓	
Service disc filters. Replace filter discs if necessary.				✓
Service backwash and air valves				✓

*The sand should have sharp edges to be effective. The effectiveness of the filter is reduced if the sand particles become round due to frictional wear.

Where aggressive water occurs, metal parts of the filters must receive epoxy treatment. Lubricants extend the lifespan of synthetic discs in filters where metal and rubber parts are in contact. High viscosity silicon products have proved to be the most suitable product for general usage. Lithium grease, but definitely not oil, is very suitable for valve axles and other moving parts.

3.5.5.2 Replacing sand in filters

The rule of thumb is to replace the sand annually. However, it may be necessary to investigate the condition of the sand. If the sand feels smooth when rubbed between the fingers it has been worn down and will no longer filter effectively. Replacement sand particles must be angular and not round.

It is essential to half-fill the filter with water before replacing the sand, to prevent damage to the underdrain system of the filter. The water forms a cushion and protects the internal parts. Sand filters normally have a sand depth of ±360 mm. Always use prescribed graded sand from a reputable supplier. Sand particle sizes that vary from 0,71 mm to 1,85 mm are recommended.

When layer has formed causing the sand to become dirty or blocked, and even causing sedimentation, it may not be necessary to remove all the sand from the filter. The layer can be scraped off and removed and the correct amount of sand replaced. It usually occurs as a result of a low backwashing flow-rate or too long a backwashing cycle.

3.5.5.3 Replacing filter discs

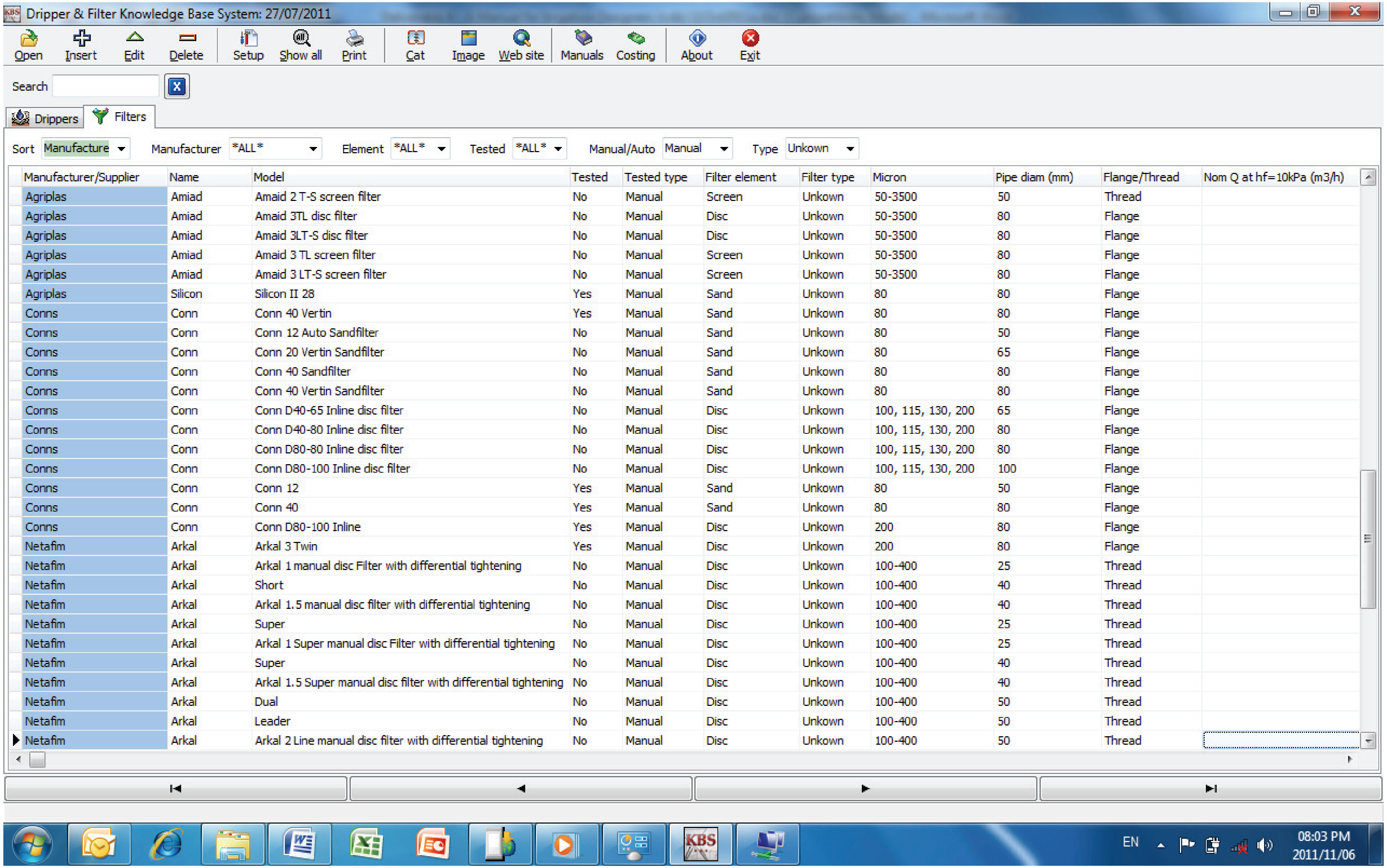
It is strongly recommended that the discs should be removed periodically and cleaned manually. Discs with chemically blocked channels must be removed and cleaned chemically. If the discs cannot be cleaned effectively, they must be replaced. Any disc that shows signs of mechanical damage should be replaced. Always replace discs with the same colour, and from the same manufacturer, to ensure that the degree of filter disc remains the same.

3.6 Commercially available products

A huge variety of filtration equipment is available on the South African market. The main suppliers are Agriplas, Conns and Netafim. Data pertaining to these manufacturers' filtration equipment has been captured in a Knowledge Base System (KBase), a sample of which is shown in Figure 33. The KBase is included as a CD in the back cover of Volume 1, the Main Report.

Suppliers of these products can also be contacted directly for information on the selection and design of filters.

Only filters from reputable irrigation companies where good quality control and testing are in place must be used.



Dripper & Filter Knowledge Base System: 27/07/2011

Sort Manufacture Manufacturer *ALL* Element *ALL* Tested *ALL* Manual/Auto Manual Type Unkown

Manufacturer/Supplier	Name	Model	Tested	Tested type	Filter element	Filter type	Micron	Pipe diam (mm)	Flange/Thread	Nom Q at hf=10kPa (m3/h)
Agriplas	Amiad	Amaid 2 T-S screen filter	No	Manual	Screen	Unkown	50-3500	50	Thread	
Agriplas	Amiad	Amaid 3TL disc filter	No	Manual	Disc	Unkown	50-3500	80	Flange	
Agriplas	Amiad	Amaid 3LT-S disc filter	No	Manual	Disc	Unkown	50-3500	80	Flange	
Agriplas	Amiad	Amaid 3 TL screen filter	No	Manual	Screen	Unkown	50-3500	80	Flange	
Agriplas	Amiad	Amaid 3 LT-S screen filter	No	Manual	Screen	Unkown	50-3500	80	Flange	
Agriplas	Silicon	Silicon II 28	Yes	Manual	Sand	Unkown	80	80	Flange	
Conns	Conn	Conn 40 Vertin	Yes	Manual	Sand	Unkown	80	80	Flange	
Conns	Conn	Conn 12 Auto Sandfilter	No	Manual	Sand	Unkown	80	50	Flange	
Conns	Conn	Conn 20 Vertin Sandfilter	No	Manual	Sand	Unkown	80	65	Flange	
Conns	Conn	Conn 40 Sandfilter	No	Manual	Sand	Unkown	80	80	Flange	
Conns	Conn	Conn 40 Vertin Sandfilter	No	Manual	Sand	Unkown	80	80	Flange	
Conns	Conn	Conn D40-65 Inline disc filter	No	Manual	Disc	Unkown	100, 115, 130, 200	65	Flange	
Conns	Conn	Conn D40-80 Inline disc filter	No	Manual	Disc	Unkown	100, 115, 130, 200	80	Flange	
Conns	Conn	Conn D80-80 Inline disc filter	No	Manual	Disc	Unkown	100, 115, 130, 200	80	Flange	
Conns	Conn	Conn D80-100 Inline disc filter	No	Manual	Disc	Unkown	100, 115, 130, 200	100	Flange	
Conns	Conn	Conn 12	Yes	Manual	Sand	Unkown	80	50	Flange	
Conns	Conn	Conn 40	Yes	Manual	Sand	Unkown	80	80	Flange	
Conns	Conn	Conn D80-100 Inline	Yes	Manual	Disc	Unkown	200	80	Flange	
Netafim	Arkal	Arkal 3 Twin	Yes	Manual	Disc	Unkown	200	80	Flange	
Netafim	Arkal	Arkal 1 manual disc Filter with differential tightening	No	Manual	Disc	Unkown	100-400	25	Thread	
Netafim	Arkal	Short	No	Manual	Disc	Unkown	100-400	40	Thread	
Netafim	Arkal	Arkal 1.5 manual disc filter with differential tightening	No	Manual	Disc	Unkown	100-400	40	Thread	
Netafim	Arkal	Super	No	Manual	Disc	Unkown	100-400	25	Thread	
Netafim	Arkal	Arkal 1 Super manual disc Filter with differential tightening	No	Manual	Disc	Unkown	100-400	25	Thread	
Netafim	Arkal	Super	No	Manual	Disc	Unkown	100-400	40	Thread	
Netafim	Arkal	Arkal 1.5 Super manual disc filter with differential tightening	No	Manual	Disc	Unkown	100-400	40	Thread	
Netafim	Arkal	Dual	No	Manual	Disc	Unkown	100-400	50	Thread	
Netafim	Arkal	Leader	No	Manual	Disc	Unkown	100-400	50	Thread	
Netafim	Arkal	Arkal 2 Line manual disc filter with differential tightening	No	Manual	Disc	Unkown	100-400	50	Thread	

Figure 33: Sample of filter data captured in the KBase

4 COST ESTIMATING PROCEDURES FOR DRIP IRRIGATION SYSTEMS

4.1 Introduction

The investment in a new irrigation system cannot be made by simply comparing different price quotations. The annual operating costs of specific irrigation systems are becoming increasingly important, and should be considered thoroughly when acquiring such a system. The situation dependency of irrigation complicates the use of average values for irrigation costs, even within the same irrigation area. Variances in factors such as the area under irrigation, the type of soil irrigated and the pumping heights necessitate the estimation of the fixed and variable costs of each system.

Cost estimations should be made for a specific irrigation system design, as a strong link exists between the specific design specification of an irrigation system and the fixed and operating costs. Design criteria that will impact on the costs include:

- General design criteria
  - the working days per week,
  - the pumping hours per day,
  - the irrigation cycle,
- the irrigation system,
  - emitter type,
  - emitter spacing,
- total area irrigated, and
- area divided in blocks.

Soils, crops and region also have a distinct impact on system capacities that need to be considered. Another important aspect is the emitter specification. Emitter specifications include type, outlet size, output, water pressure, spacing, application rate, standing time per cycle, and flow rate per block. Together and in combination these design specifications impact on the cost of irrigation.

The IRRICOST (Meiring et al., 2002) program was developed to estimate both the annual fixed and variable irrigation costs. During a WRC funded project "*Cost estimating procedures for micro-, drip- and furrow-irrigation systems as well as economic analyses of the relevant irrigation systems for large- and small-scale farmers in the Onderberg/Nkomazi region*" the IRRICOST (Meiring et al., 2002) procedure for estimating annual fixed and variable cost was extended to incorporate cost estimation procedures for drip irrigation systems. The drip irrigation procedure was programmed in Excel, but the layout of the spreadsheet model was cumbersome. As part of this project, the procedure was reprogrammed in Excel to provide a more user-friendly layout that is easier to apply than the previous spreadsheet model.

The spreadsheet model has a wide range of applications, including the following features:

- The annual irrigation cost of almost any irrigation system can be estimated in order to do economic analyses.

- Various system designs can be compared on the basis of the annual fixed and variable costs.
- The variable cost of existing systems can be analysed to consider possible adjustments with the purpose of decreasing operating cost.
- Electricity costs for Landrate, Ruraflex and Nightsave Rural can be compared.
- Optimal irrigation quantities can be determined, because the marginal factor cost of water is known.
- The total cost of each irrigation system can be calculated.
- The importance of the different variables in irrigation costs can be determined by means of sensitivity analyses.

4.2 IRRICOST Spreadsheet model

The spreadsheet makes a distinction between information required for the mainline and information required for each of the irrigation systems that utilises the mainline. In the spreadsheet, cells where input parameters are required are formatted red, to aid data input into the model, while calculations (answers) are formatted green. Drop down lists allow choices between predefined alternatives. Figure 35 shows the screen capture of the information required for the mainline, and the resulting output that is generated from the IRRICOST model.

4.2.1 Mainline section

4.2.1.1 Section 1: General information

The general information that should be captured for the mainline section is mainly concerned with:

- The layout and characteristics of the mainline,
- Identification of irrigation systems that utilises the mainline,
- Insurance costs,
- Repair and maintenance costs, and
- The electricity tariff.

Although most of the inputs required are self-explanatory, some aspects require clarification:

Firstly, once an irrigation system is identified, a macro button will guide the user to the appropriate sheet for the specific irrigation system.

Secondly, the calculation of the kilowatts required to pump water through the system is highly dependent on the correct specification of the node network used to represent the layout of the system. The correct specification is best explained by means of the layout of the irrigation systems represented in Figure 34.

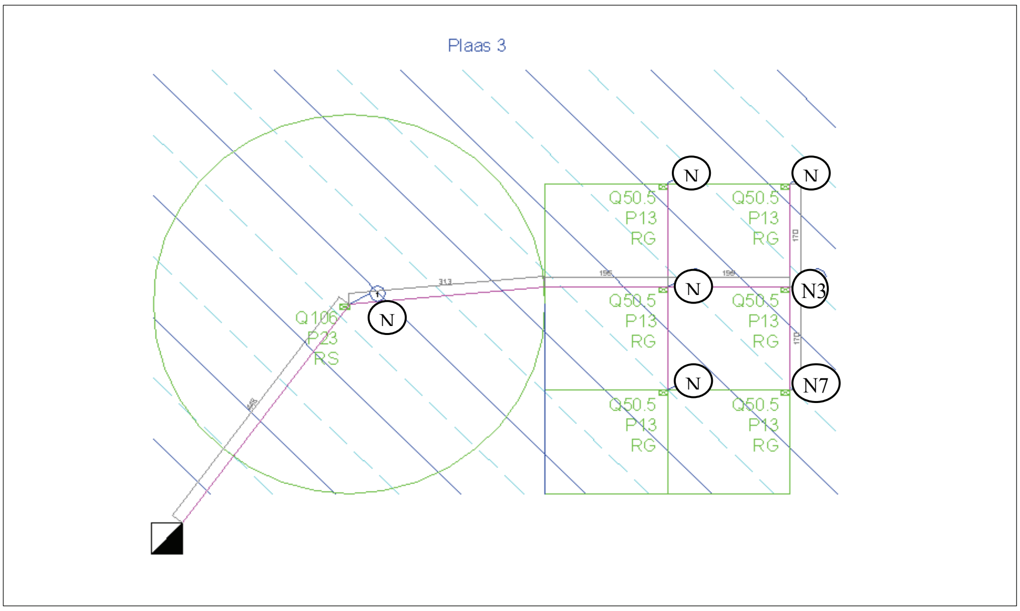


Figure 34: Layout of a combination of irrigation systems

Notes for Figure 50:

- The layout comprises a centre pivot irrigation system and a drip irrigation system.
- The drip irrigation system consists of six blocks, where one block at a time is irrigated.
- Specific phases are characterised by the same type of pipe with the same diameter, and demarcated by a node identifying the beginning of the phase and a node representing the end of the phase.
- Nodes should be added to indicate an irrigation system off-take or a branch line.
- NB. The end nodes should be ranked from the smallest to the largest number.

A third aspect which requires clarification is that two different equations for calculating friction are incorporated into the model:

- The same general friction formula incorporated in the previous versions of IRRICOST, and
- The Darcy, Weisbach, and Jain formula.

To facilitate better design, a table of results is included in the general section to assist with the selection of the kilowatts required to pump water in the system. The Mainline Pressure column can be used to determine phases where surplus pressure exists. If the end node of a phase with surplus pressure does not constitute the beginning of another phase, the design of the phase should be reconsidered.

4.2.1.2 Section 2: Initial investment and annual fixed cost

A fixed cost is a one that occurs no matter how much is produced. For the mainline, fixed costs usually include:

- depreciation,
- interest,
- insurance and
- the fixed electricity charge.

The fixed costs are based upon the initial investment. The capital investment in the components of the mainline (including VAT and installation costs) are entered under investment costs in order to calculate fixed cost components. The capital recovery method is then used to estimate depreciation and interest costs, which is more accurate than the traditional methods where depreciation and interest are estimated separately. The formula is:

Capital recovery = [(Purchase price – salvage value) x (capital recovery factor)] + [(salvage value) x (real interest rate)]

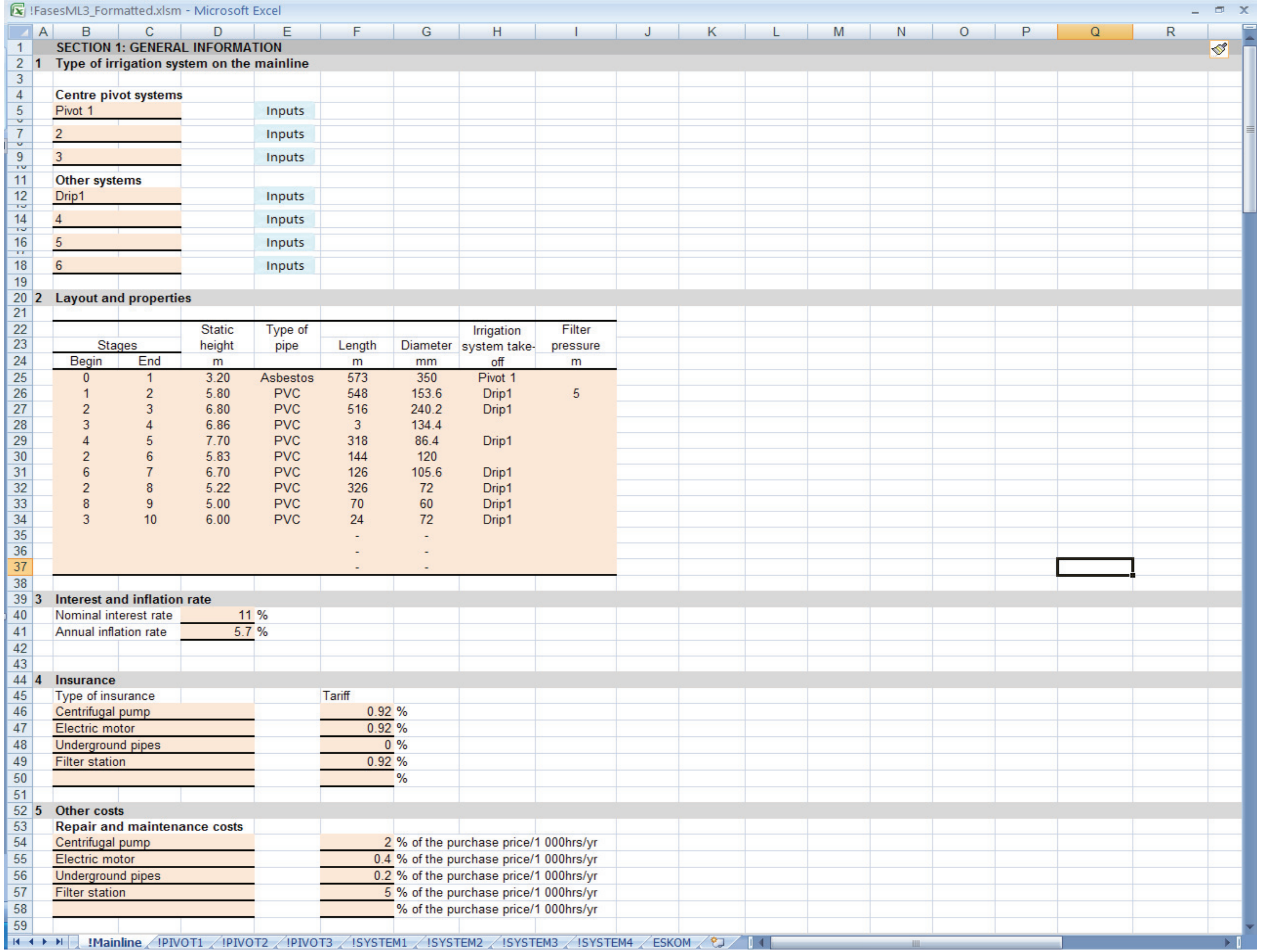
The real interest rate must be used when current purchase/list prices are used; with historical prices the nominal interest rate should be used.

4.2.1.3 Section 3: Annual operating cost of the mainline

The annual operating cost is based on the planned amount of water pumped. In order to calculate the costs, an estimate of the amount of water to be pumped annually, the corresponding number of pumping hours and the kilowatt hours necessary to pump the water are calculated. These values, together with information supplied in Section 1, are then used to calculate the annual operating cost associated with electricity, and repair and maintenance costs. With respect to electricity cost, a user-specified percentage allocation is made between different electricity tariffs i.e. Landrate, Ruraflex and Nightsave Rural.

4.2.1.4 Section 4: Summary of costs

This section summarises the annual fixed costs and operating costs for the planned water applications. These are used to calculate the fixed cost per ha, as well as the variable costs per cubic metre of water applied. The marginal factor cost of pumping one cubic metre of water is also estimated.



SECTION 1: GENERAL INFORMATION

1 Type of irrigation system on the mainline

Centre pivot systems

Pivot 1	Inputs
2	Inputs
3	Inputs

Other systems

Drip1	Inputs
4	Inputs
5	Inputs
6	Inputs

2 Layout and properties

Stages		Static height	Type of pipe	Length	Diameter	Irrigation system take-off	Filter pressure
Begin	End	m		m	mm		m
0	1	3.20	Asbestos	573	350	Pivot 1	
1	2	5.80	PVC	548	153.6	Drip1	5
2	3	6.80	PVC	516	240.2	Drip1	
3	4	6.86	PVC	3	134.4		
4	5	7.70	PVC	318	86.4	Drip1	
2	6	5.83	PVC	144	120		
6	7	6.70	PVC	126	105.6	Drip1	
2	8	5.22	PVC	326	72	Drip1	
8	9	5.00	PVC	70	60	Drip1	
3	10	6.00	PVC	24	72	Drip1	
				-	-		
				-	-		
				-	-		

3 Interest and inflation rate

Nominal interest rate	11	%
Annual inflation rate	5.7	%

4 Insurance

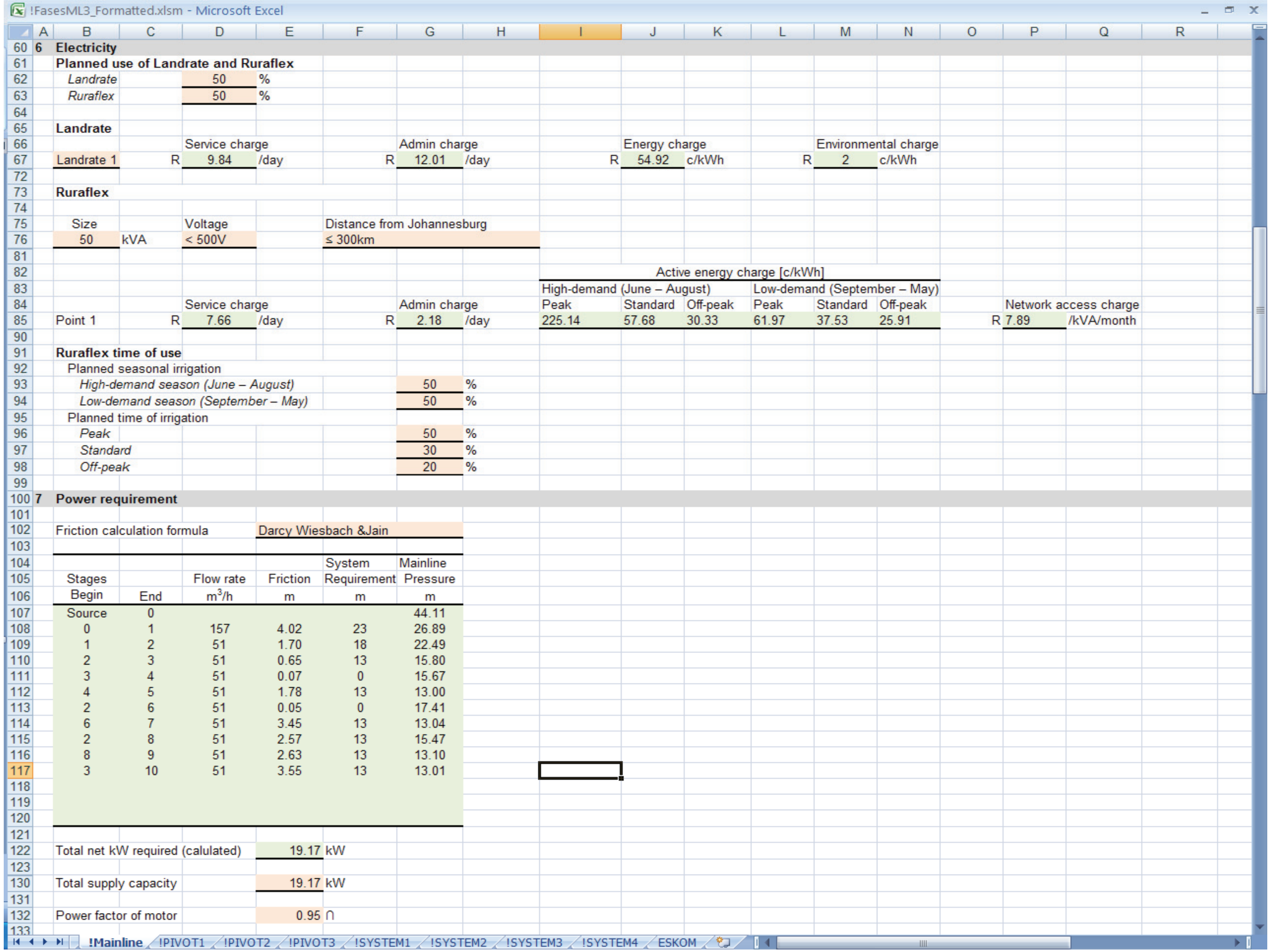
Type of insurance	Tariff	
Centrifugal pump	0.92	%
Electric motor	0.92	%
Underground pipes	0	%
Filter station	0.92	%
		%

5 Other costs

Repair and maintenance costs

Centrifugal pump	2	% of the purchase price/1 000hrs/yr
Electric motor	0.4	% of the purchase price/1 000hrs/yr
Underground pipes	0.2	% of the purchase price/1 000hrs/yr
Filter station	5	% of the purchase price/1 000hrs/yr
		% of the purchase price/1 000hrs/yr

Figure 35: Excel screen capture indicating information required for the Mainline



6 **Electricity**

Planned use of Landrate and Ruraflex

Landrate	50	%
Ruraflex	50	%

Landrate

	Service charge	Admin charge	Energy charge	Environmental charge
Landrate 1	R 9.84 /day	R 12.01 /day	R 54.92 c/kWh	R 2 c/kWh

Ruraflex

Size		Voltage	Distance from Johannesburg
50	kVA	< 500V	≤ 300km

Active energy charge [c/kWh]

	Service charge	Admin charge	High-demand (June – August) Peak	High-demand (June – August) Standard	High-demand (June – August) Off-peak	Low-demand (September – May) Peak	Low-demand (September – May) Standard	Low-demand (September – May) Off-peak	Network access charge
Point 1	R 7.66 /day	R 2.18 /day	225.14	57.68	30.33	61.97	37.53	25.91	R 7.89 /kVA/month

Ruraflex time of use

Planned seasonal irrigation		
High-demand season (June – August)	50	%
Low-demand season (September – May)	50	%
Planned time of irrigation		
Peak	50	%
Standard	30	%
Off-peak	20	%

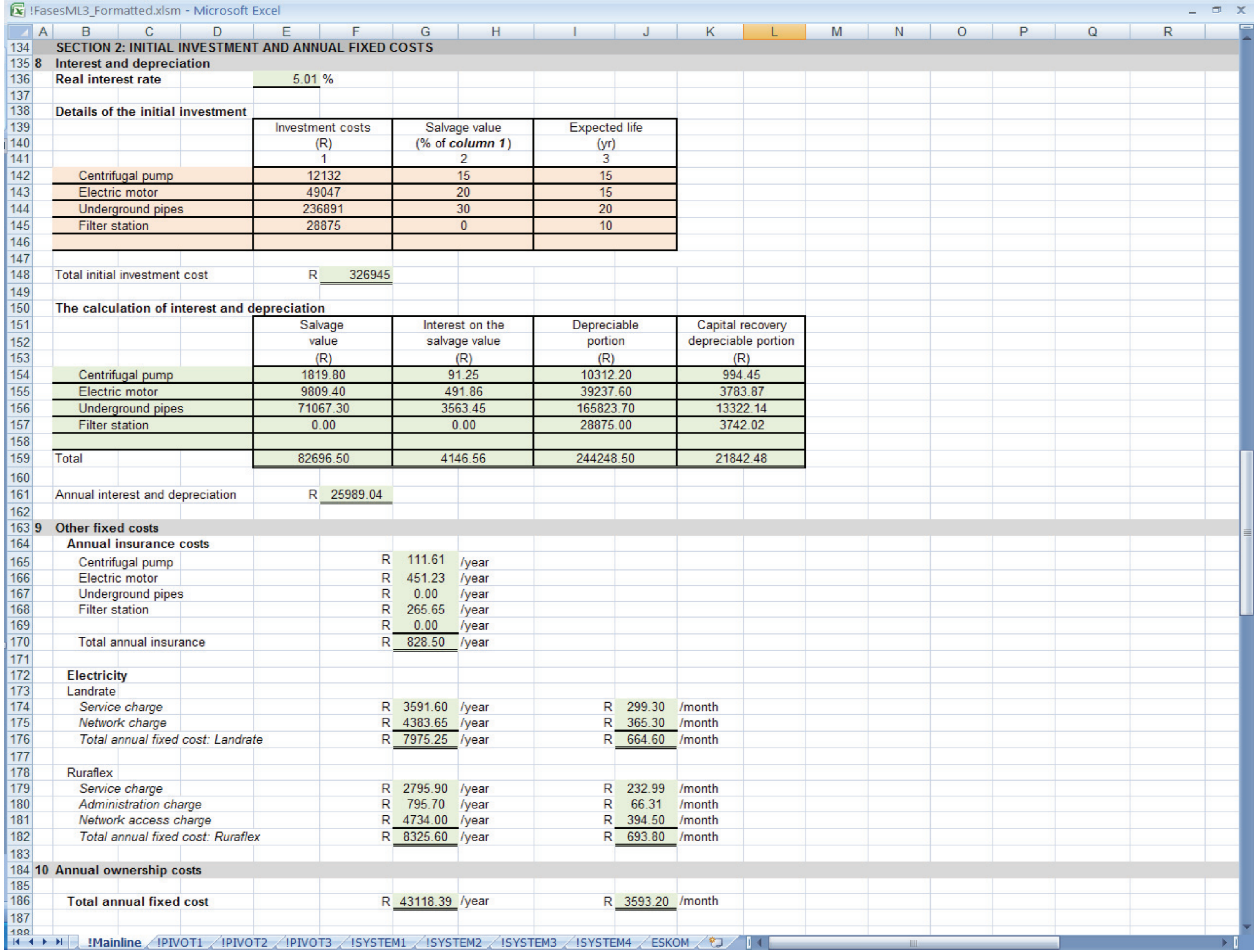
7 **Power requirement**

Friction calculation formula: Darcy Wiesbach &Jain

Stages Begin	End	Flow rate m^3/h	Friction m	System Requirement m	Mainline Pressure m
Source	0				44.11
0	1	157	4.02	23	26.89
1	2	51	1.70	18	22.49
2	3	51	0.65	13	15.80
3	4	51	0.07	0	15.67
4	5	51	1.78	13	13.00
2	6	51	0.05	0	17.41
6	7	51	3.45	13	13.04
2	8	51	2.57	13	15.47
8	9	51	2.63	13	13.10
3	10	51	3.55	13	13.01

Total net kW required (calulated)	19.17	kW
Total supply capacity	19.17	kW
Power factor of motor	0.95	∩

Figure 35: (Continued): Excel screen capture indicating general information required for the Mainline



SECTION 2: INITIAL INVESTMENT AND ANNUAL FIXED COSTS

8 Interest and depreciation

Real interest rate 5.01 %

Details of the initial investment

	Investment costs (R) 1	Salvage value (% of *column 1*) 2	Expected life (yr) 3
Centrifugal pump	12132	15	15
Electric motor	49047	20	15
Underground pipes	236891	30	20
Filter station	28875	0	10

Total initial investment cost R 326945

The calculation of interest and depreciation

	Salvage value (R)	Interest on the salvage value (R)	Depreciable portion (R)	Capital recovery depreciable portion (R)
Centrifugal pump	1819.80	91.25	10312.20	994.45
Electric motor	9809.40	491.86	39237.60	3783.87
Underground pipes	71067.30	3563.45	165823.70	13322.14
Filter station	0.00	0.00	28875.00	3742.02
Total	82696.50	4146.56	244248.50	21842.48

Annual interest and depreciation R 25989.04

9 Other fixed costs

Annual insurance costs

Centrifugal pump	R	111.61	/year		
Electric motor	R	451.23	/year		
Underground pipes	R	0.00	/year		
Filter station	R	265.65	/year		
	R	0.00	/year		
Total annual insurance	R	828.50	/year		

Electricity

Landrate

Service charge	R	3591.60	/year	R	299.30	/month
Network charge	R	4383.65	/year	R	365.30	/month
Total annual fixed cost: Landrate	R	7975.25	/year	R	664.60	/month

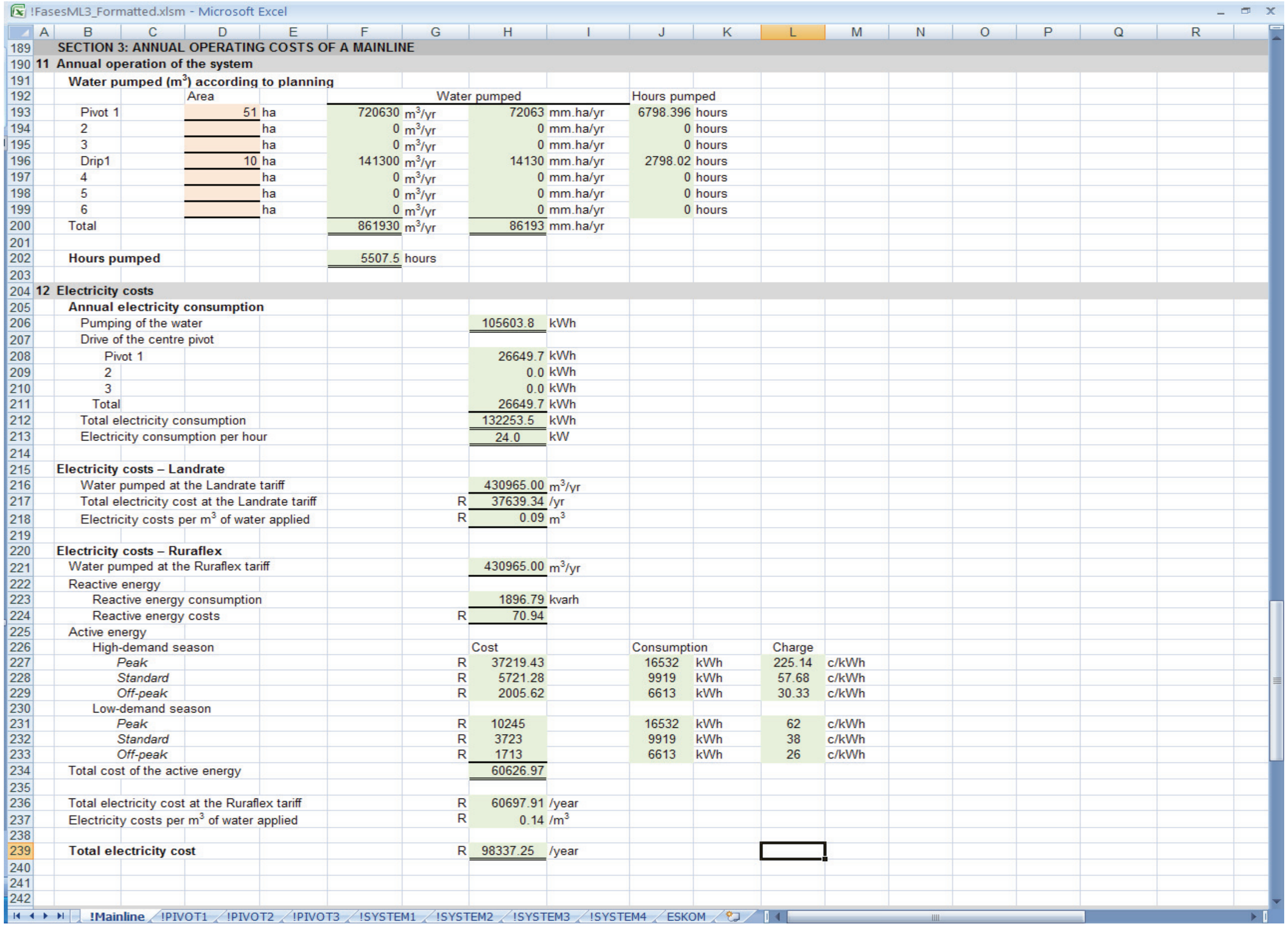
Ruraflex

Service charge	R	2795.90	/year	R	232.99	/month
Administration charge	R	795.70	/year	R	66.31	/month
Network access charge	R	4734.00	/year	R	394.50	/month
Total annual fixed cost: Ruraflex	R	8325.60	/year	R	693.80	/month

10 Annual ownership costs

Total annual fixed cost R 43118.39 /year R 3593.20 /month

Figure 35: (Continued): Excel screen capture indicating general information required for the Mainline



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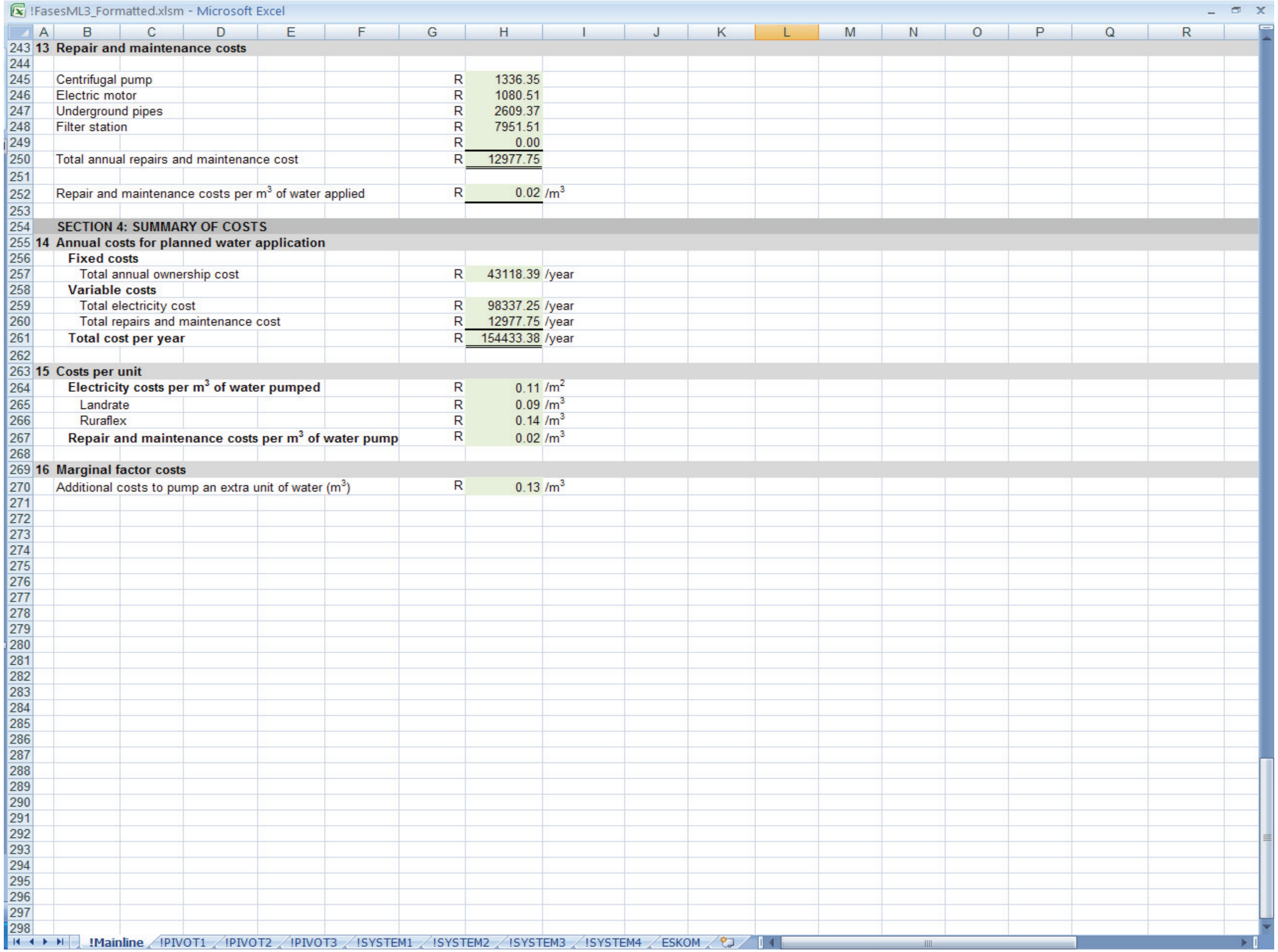
	A	B	C	D	E	F	G	H	I	J	K	L	M
189		**SECTION 3: ANNUAL OPERATING COSTS OF A MAINLINE**											
190	**11**	**Annual operation of the system**											
191		**Water pumped (m^3) according to planning**											
192				Area			Water pumped			Hours pumped			
193		Pivot 1		51	ha	720630	m^3/yr	72063	mm.ha/yr	6798.396	hours		
194		2			ha	0	m^3/yr	0	mm.ha/yr	0	hours		
195		3			ha	0	m^3/yr	0	mm.ha/yr	0	hours		
196		Drip1		10	ha	141300	m^3/yr	14130	mm.ha/yr	2798.02	hours		
197		4			ha	0	m^3/yr	0	mm.ha/yr	0	hours		
198		5			ha	0	m^3/yr	0	mm.ha/yr	0	hours		
199		6			ha	0	m^3/yr	0	mm.ha/yr	0	hours		
200		Total				861930	m^3/yr	86193	mm.ha/yr				
201													
202		**Hours pumped**				5507.5	hours						
203													
204	**12**	**Electricity costs**											
205		**Annual electricity consumption**											
206		Pumping of the water						105603.8	kWh				
207		Drive of the centre pivot											
208		Pivot 1						26649.7	kWh				
209		2						0.0	kWh				
210		3						0.0	kWh				
211		Total						26649.7	kWh				
212		Total electricity consumption						132253.5	kWh				
213		Electricity consumption per hour						24.0	kW				
214													
215		**Electricity costs – Landrate**											
216		Water pumped at the Landrate tariff						430965.00	m^3/yr				
217		Total electricity cost at the Landrate tariff					R	37639.34	/yr				
218		Electricity costs per m^3 of water applied					R	0.09	m^3				
219													
220		**Electricity costs – Ruraflex**											
221		Water pumped at the Ruraflex tariff						430965.00	m^3/yr				
222		Reactive energy											
223		Reactive energy consumption						1896.79	kvarh				
224		Reactive energy costs					R	70.94					
225		Active energy											
226		High-demand season						Cost		Consumption		Charge	
227		*Peak*					R	37219.43		16532	kWh	225.14	c/kWh
228		*Standard*					R	5721.28		9919	kWh	57.68	c/kWh
229		*Off-peak*					R	2005.62		6613	kWh	30.33	c/kWh
230		Low-demand season											
231		*Peak*					R	10245		16532	kWh	62	c/kWh
232		*Standard*					R	3723		9919	kWh	38	c/kWh
233		*Off-peak*					R	1713		6613	kWh	26	c/kWh
234		Total cost of the active energy						60626.97					
235													
236		Total electricity cost at the Ruraflex tariff					R	60697.91	/year				
237		Electricity costs per m^3 of water applied					R	0.14	/m^3				
238													
239		**Total electricity cost**					R	98337.25	/year				
240													
241													
242													

Figure 35: (Continued): Excel screen capture indicating general information required for the Mainline



	A	B	G	H	I
243	13	**Repair and maintenance costs**			
244					
245		Centrifugal pump	R	1336.35	
246		Electric motor	R	1080.51	
247		Underground pipes	R	2609.37	
248		Filter station	R	7951.51	
249			R	0.00	
250		Total annual repairs and maintenance cost	R	12977.75	
251					
252		Repair and maintenance costs per m^3 of water applied	R	0.02	/m^3
253					
254		**SECTION 4: SUMMARY OF COSTS**			
255	14	**Annual costs for planned water application**			
256		**Fixed costs**			
257		Total annual ownership cost	R	43118.39	/year
258		**Variable costs**			
259		Total electricity cost	R	98337.25	/year
260		Total repairs and maintenance cost	R	12977.75	/year
261		**Total cost per year**	R	154433.38	/year
262					
263	15	**Costs per unit**			
264		**Electricity costs per m^3 of water pumped**	R	0.11	/m^2
265		Landrate	R	0.09	/m^3
266		Ruraflex	R	0.14	/m^3
267		**Repair and maintenance costs per m^3 of water pump**	R	0.02	/m^3
268					
269	16	**Marginal factor costs**			
270		Additional costs to pump an extra unit of water (m^3)	R	0.13	/m^3

Figure 35: (Continued): Excel screen capture indicating general information required for the Mainline

4.2.2 Drip irrigation system

A separate sheet of information must be provided for each drip irrigation system on the mainline. Figure **36** shows the screen capture of the information required for a drip irrigation system, and the resulting output that is generated.

4.2.2.1 Section 1: General information

Section 1 of the drip irrigation system sheet consists of information regarding the management of the irrigation system, properties of the system and information to calculate the total water charge, insurance, labour and repair and maintenance costs.

The vertical height of the drip irrigation system should be zero. The information required to calculate insurance and repair and maintenance follows the same format as for the mainline. The listed area together with the planned water use per hectare is used to work out the total planned amount of water that will be pumped. Thus it may differ from the area irrigated. The user is able to enter a schedule of water charges that might increase with increase water use.

4.2.2.2 Section 2: Investment and annual fixed costs

The same information that is required for the mainline with respect to investment cost, salvage value and expected life should be specified for each irrigation system.

4.2.2.3 Section 3: Annual operating cost of the drip irrigation system

Operating or variable costs are those costs over which the irrigator has control in the short term. The variable costs of the drip irrigation systems are based on the planned annual water application. All variable costs, namely electricity, water, labour and repairs should be estimated as a cost per cubic metre of water pumped.

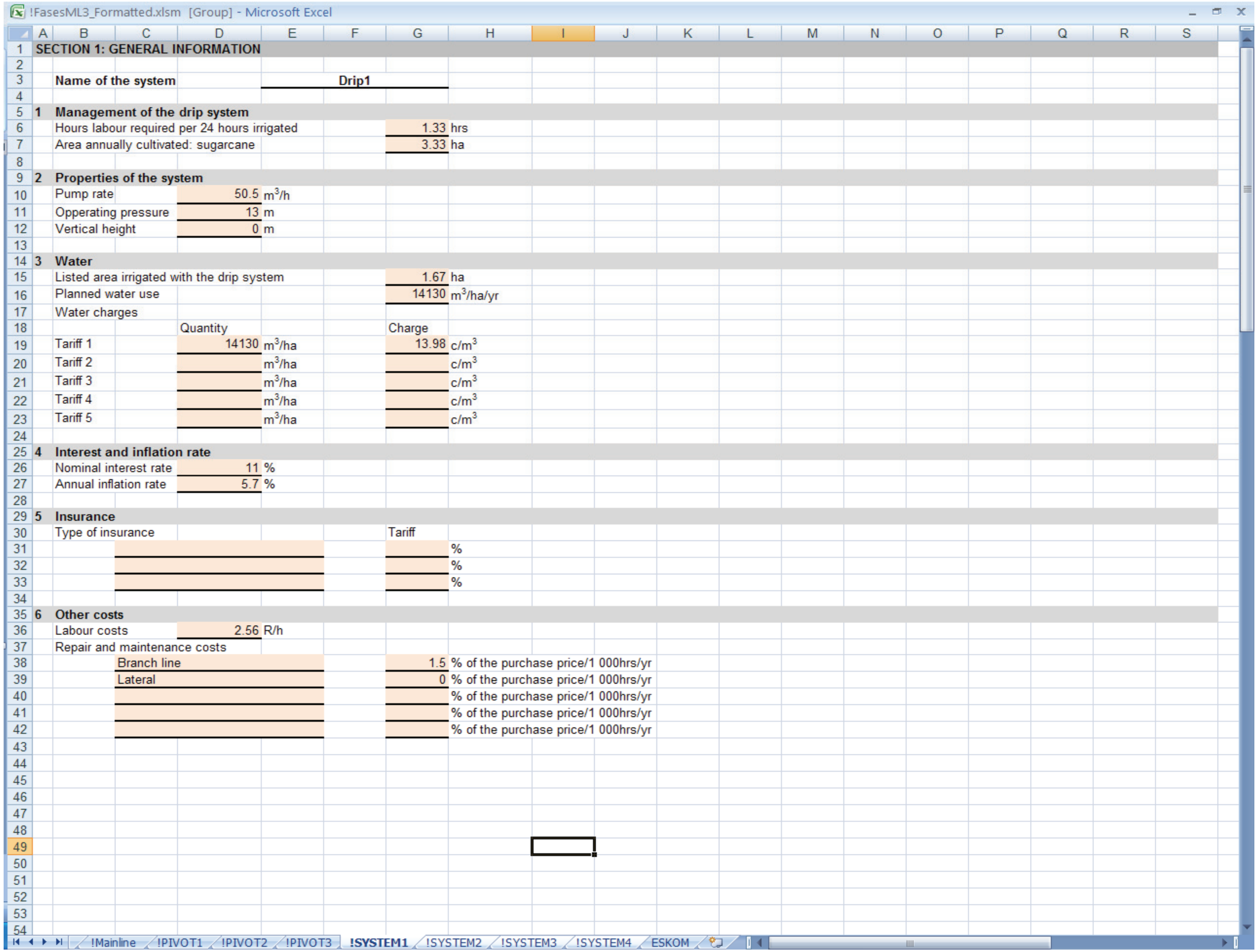
No further inputs are required to calculate the annual operating cost of the drip irrigation system. In addition to the calculations done for the mainline, the cost calculations for the drip irrigation system also include the water charges. It is however important to note that the costs exclude the cost of pumping the water to the irrigation system.

4.2.2.4 Section 4: Summary of costs

The last section summarises the costs and calculates the marginal factor cost (additional cost to apply a unit of water) from which the next irrigation application on the total irrigated area can be estimated. This should be compared to the extra crop income as a result of the additional irrigation. Again, it should be remembered that the cost excludes the cost to pump the water.

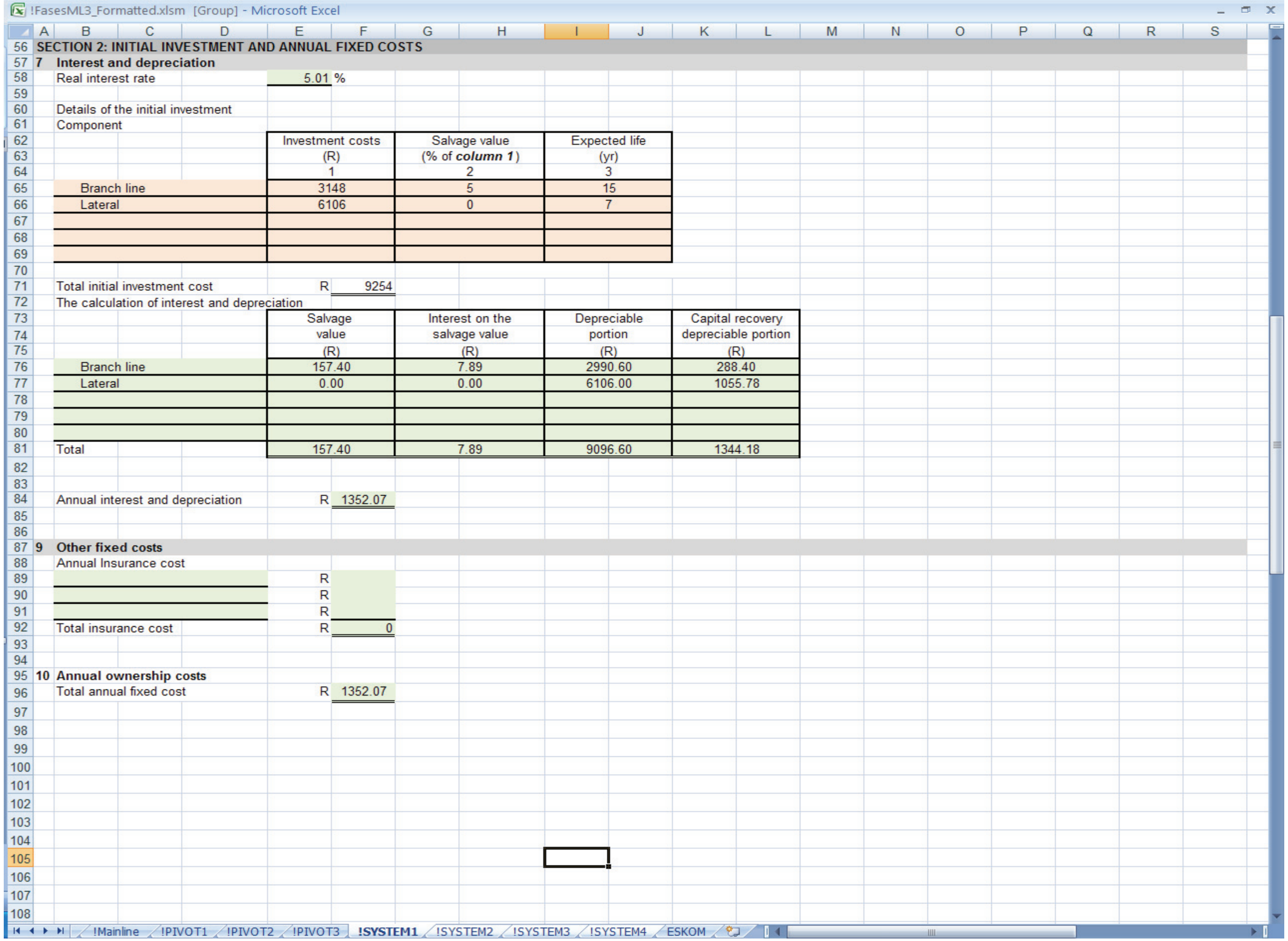
4.2.3 ESKOM

The sheet named ESKOM is used to input the electricity costs of the electricity tariffs Landrate and Ruraflex. The information contained in the sheet is available from the official ESKOM website at: http://www.eskom.co.za/live/content.php?Category_ID=26
The sheet should be updated once a year.



	A	B	C	D	E	F	G	H
1	SECTION 1: GENERAL INFORMATION							
3		**Name of the system**				**Drip1**		
5	**1**	**Management of the drip system**						
6		Hours labour required per 24 hours irrigated					1.33	hrs
7		Area annually cultivated: sugarcane					3.33	ha
9	**2**	**Properties of the system**						
10		Pump rate		50.5	m^3/h			
11		Opperating pressure		13	m			
12		Vertical height		0	m			
14	**3**	**Water**						
15		Listed area irrigated with the drip system					1.67	ha
16		Planned water use					14130	m^3/ha/yr
17		Water charges						
18				Quantity			Charge	
19		Tariff 1		14130	m^3/ha		13.98	c/m^3
20		Tariff 2			m^3/ha			c/m^3
21		Tariff 3			m^3/ha			c/m^3
22		Tariff 4			m^3/ha			c/m^3
23		Tariff 5			m^3/ha			c/m^3
25	**4**	**Interest and inflation rate**						
26		Nominal interest rate		11	%			
27		Annual inflation rate		5.7	%			
29	**5**	**Insurance**						
30		Type of insurance					Tariff	
31								%
32								%
33								%
35	**6**	**Other costs**						
36		Labour costs		2.56	R/h			
37		Repair and maintenance costs						
38			Branch line				1.5	% of the purchase price/1 000hrs/yr
39			Lateral				0	% of the purchase price/1 000hrs/yr
40								% of the purchase price/1 000hrs/yr
41								% of the purchase price/1 000hrs/yr
42								% of the purchase price/1 000hrs/yr

Figure 36: Excel screen capture indicating information required for the drip irrigation system



SECTION 2: INITIAL INVESTMENT AND ANNUAL FIXED COSTS

7 Interest and depreciation

Real interest rate 5.01 %

Details of the initial investment

Component	Investment costs (R) 1	Salvage value (% of *column 1*) 2	Expected life (yr) 3
Branch line	3148	5	15
Lateral	6106	0	7

Total initial investment cost R 9254

The calculation of interest and depreciation

	Salvage value (R)	Interest on the salvage value (R)	Depreciable portion (R)	Capital recovery depreciable portion (R)
Branch line	157.40	7.89	2990.60	288.40
Lateral	0.00	0.00	6106.00	1055.78
Total	157.40	7.89	9096.60	1344.18

Annual interest and depreciation R 1352.07

9 Other fixed costs

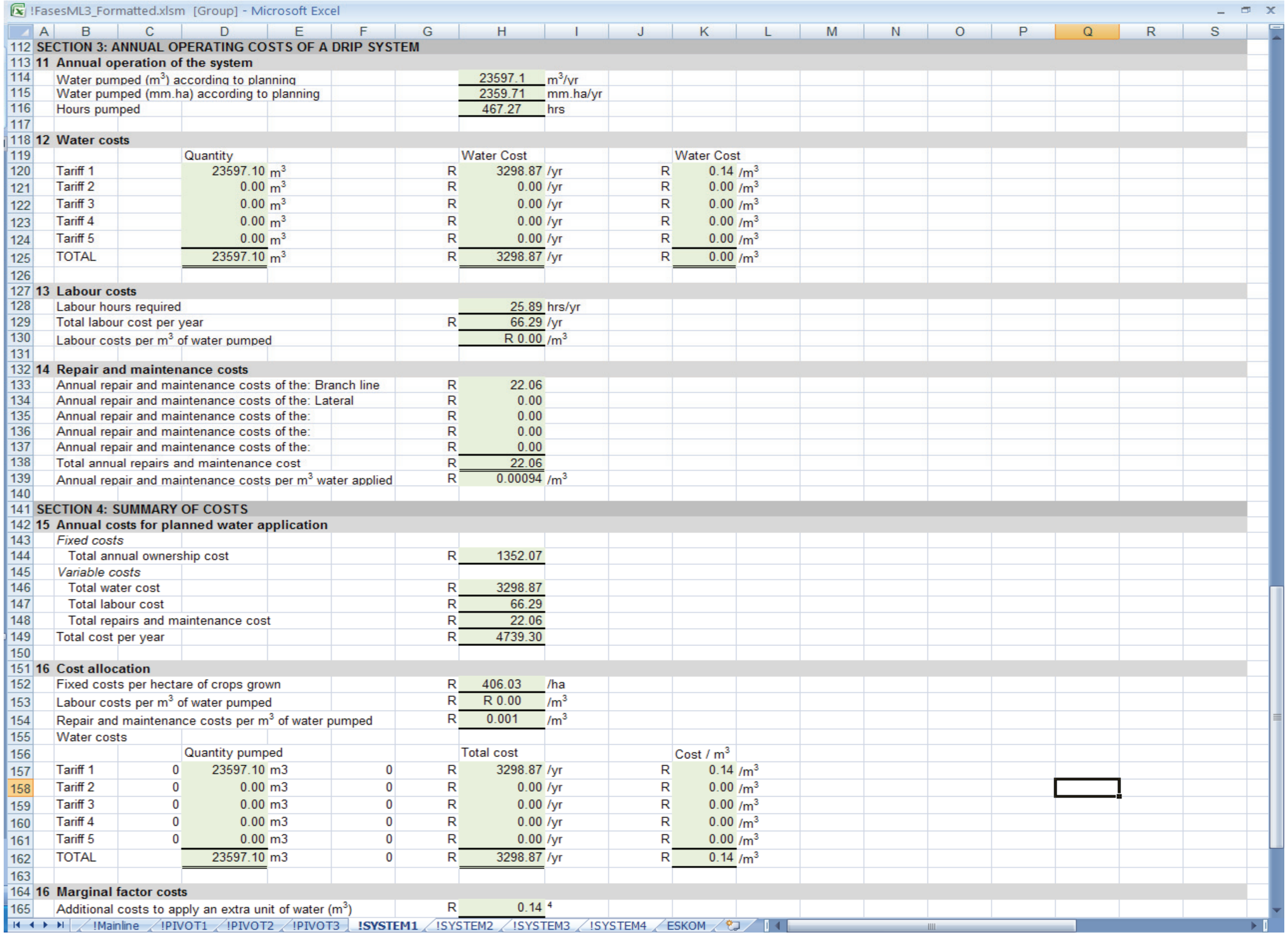
Annual Insurance cost

	R	
	R	
	R	
Total insurance cost	R	0

10 Annual ownership costs

Total annual fixed cost R 1352.07

Figure 36: (Continued): Excel screen capture indicating information required for the drip irrigation system



	A–B	C	D	E	F	G	H	I	J	K	L
112	**SECTION 3: ANNUAL OPERATING COSTS OF A DRIP SYSTEM**										
113	**11 Annual operation of the system**										
114	Water pumped (m^3) according to planning						23597.1	m^3/yr			
115	Water pumped (mm.ha) according to planning						2359.71	mm.ha/yr			
116	Hours pumped						467.27	hrs			
117											
118	**12 Water costs**										
119			Quantity				Water Cost			Water Cost	
120	Tariff 1		23597.10	m^3		R	3298.87	/yr	R	0.14	/m^3
121	Tariff 2		0.00	m^3		R	0.00	/yr	R	0.00	/m^3
122	Tariff 3		0.00	m^3		R	0.00	/yr	R	0.00	/m^3
123	Tariff 4		0.00	m^3		R	0.00	/yr	R	0.00	/m^3
124	Tariff 5		0.00	m^3		R	0.00	/yr	R	0.00	/m^3
125	TOTAL		23597.10	m^3		R	3298.87	/yr	R	0.00	/m^3
126											
127	**13 Labour costs**										
128	Labour hours required						25.89	hrs/yr			
129	Total labour cost per year					R	66.29	/yr			
130	Labour costs per m^3 of water pumped						R 0.00	/m^3			
131											
132	**14 Repair and maintenance costs**										
133	Annual repair and maintenance costs of the: Branch line					R	22.06				
134	Annual repair and maintenance costs of the: Lateral					R	0.00				
135	Annual repair and maintenance costs of the:					R	0.00				
136	Annual repair and maintenance costs of the:					R	0.00				
137	Annual repair and maintenance costs of the:					R	0.00				
138	Total annual repairs and maintenance cost					R	22.06				
139	Annual repair and maintenance costs per m^3 water applied					R	0.00094	/m^3			
140											
141	**SECTION 4: SUMMARY OF COSTS**										
142	**15 Annual costs for planned water application**										
143	*Fixed costs*										
144	Total annual ownership cost					R	1352.07				
145	*Variable costs*										
146	Total water cost					R	3298.87				
147	Total labour cost					R	66.29				
148	Total repairs and maintenance cost					R	22.06				
149	Total cost per year					R	4739.30				
150											
151	**16 Cost allocation**										
152	Fixed costs per hectare of crops grown					R	406.03	/ha			
153	Labour costs per m^3 of water pumped					R	R 0.00	/m^3			
154	Repair and maintenance costs per m^3 of water pumped					R	0.001	/m^3			
155	Water costs										
156			Quantity pumped				Total cost			Cost / m^3	
157	Tariff 1	0	23597.10	m3	0	R	3298.87	/yr	R	0.14	/m^3
158	Tariff 2	0	0.00	m3	0	R	0.00	/yr	R	0.00	/m^3
159	Tariff 3	0	0.00	m3	0	R	0.00	/yr	R	0.00	/m^3
160	Tariff 4	0	0.00	m3	0	R	0.00	/yr	R	0.00	/m^3
161	Tariff 5	0	0.00	m3	0	R	0.00	/yr	R	0.00	/m^3
162	TOTAL		23597.10	m3	0	R	3298.87	/yr	R	0.14	/m^3
163											
164	**16 Marginal factor costs**										
165	Additional costs to apply an extra unit of water (m^3)					R	0.14 ^{4}				

Figure 36: (Continued): Excel screen capture indicating information required for the drip irrigation system

5 CONCLUSIONS

5.1 Technical aspects

Proper selection, planning, design, installation and maintenance of surface- and subsurface drip irrigation systems are of utmost importance for the successful long term operation of the system.

Water quality analysis must be carried out to identify the potential clogging problems due to water quality. This will assist with emitter type and filter selection and with developing proper preventative measures. The use of a root growth inhibitor is also of critical importance with a sub-surface drip system to prevent root intrusion.

It is important that a complete design report with details of the system's specifications, maintenance requirements and installation guidelines accompany all drip irrigation systems.

5.2 Cost procedures

Technical, economic and financial factors should be considered when choosing a drip irrigation system. Cost estimating procedures and models provide the necessary tools to give decision support to producers when changing from a present irrigation system to a drip irrigation system.

A distinction should be made between the mainline and the irrigation system, and care should be taken when combining the costs to represent the total irrigation costs of a specific irrigation system.

The profitability and financial feasibility analyses normally consider predefined crop mixes: in situations where the cash flow needs to be maximised other models and methods may be necessary. Only crop yields and prices are considered as a major source of risk and other sources of risk such as interest rate changes, etc. should also be considered.

6 ACKNOWLEDGEMENT AND REFERENCES

The information provided in this manual is a combination of published reports by the WRC and the ARC-IAE on drippers and filters (technical information and cost analysis). These organisations are duly acknowledged.

The following reports were analysed and information extracted:

Burger, JH; Heyns, PJ; Hoffman, E; Kleynhans, EPJ; Koegelenberg, FH; Lategan, MT; Mulder; DJ; Smal, HS; Stimie, CM; Uys, WJ; Van der Merwe, FPJ; Van der Stoep, I; Viljoen, P. 2003. *Irrigation Design Manual.* Agricultural Research Council – Institute for Agricultural Engineering. RSA.

Du Plessis, FJ; Van Averbeke, W; Van der Stoep, I. 2002. *Micro-Irrigation for smallholders, guidelines for funders, planners, designers and support staff in South Africa.* Report No. TT 164/01. WRC, Pretoria, RSA.

Koegelenberg, FH; Reinders, FB; Van Niekerk, AS; Van Niekerk, R; Uys, WJ. 2002. *Performance of Surface Drip Irrigation Systems Under Field Conditions*. Report No. 1036/1/02. WRC, Pretoria, RSA.

Netafim. 2008. *Product guide.* Netafim South Africa.

Oosthuizen, LK; Botha, PW; Grovè, B; Meiring, JA; Monkhei, MM; Pretorius, IG. 2005. *Cost estimating procedures for micro-, drip- and furrow irrigation systems as well as economic analysis of the relevant irrigation systems for large- and small scale farmers in the Onderberg/Nkomazi region*. Report 974/1/05. WRC, Pretoria, RSA.

Reinders, FB; Smal, HS; Van Niekerk, AS; Bunton, S; Mdaka, B; 2005. *Sub-Surface Drip Irrigation: Factors Affecting the Efficiency and Maintenance*. Report No. 1189/1/05. WRC, Pretoria, RSA.

Sne, M. 2006. Micro irrigation in arid and semi-arid regions: Guidelines for planning and design. International Commission on Irrigation and Drainage (ICID). New Delhi, India.

Van Niekerk, AS; Koegelenberg, FH; Reinders, FB; Ascough, GW. 2006. *Guidelines for the Selection and Use of Various Micro-Irrigation Filters with Regards to Filtering and Backwashing Efficiency*. Report No. 1356/1/06. WRC, Pretoria, RSA.