



DESIGN GUIDELINES

Irrigation System Design Guidelines



PREFACE

This document currently describes the accepted Irrigation System Design Guidelines for piped irrigation systems. The processes described in this document are intended to be applied to agricultural irrigation systems. This document does not address domestic, flood or landscape irrigation systems.

The original purpose of the Guidelines is to provide a consistent guide for irrigation designers of piped irrigation systems in the state of Queensland. It describes a general design methodology and highlights elements that must be considered when planning, designing, and implementing a new irrigation development. In addition, it provides corresponding design parameters to be used by the Designer to define such systems and to determine the system's performance.

It is intended that the Guidelines should be expanded and relate to all piped irrigation systems in both Rural and Landscape in all Australian states except for Domestic Garden Systems which will have separate Guideline details.

The Guidelines should be used primarily to ensure that all the main design aspects have been considered. They do not amend or replace other industry performance indicators, guidelines, codes of practice or standards.

This document is intended to provide important information to anyone involved in the design, installation and commissioning of a new irrigation system. This includes irrigation designers and consultants, equipment resellers, installation contractors; and may also assist Irrigators, engineers, equipment suppliers, councils and local government bodies.

This document is intended as an industry best practice guideline. Designers, contractors and industry professionals should interpret it according to the requirements of the Irrigator. All decisions made must also comply with statutes, regulations, and other legal requirements and industry standards.

Acknowledgements

The Queensland State Government's Department of Natural Resources and Mines, in consultation with its stakeholders and as part of its Rural Water Use Efficiency for Irrigation Futures (RWUE-IF) program has initiated the development of the RWUE-IF Rural Irrigation System Design – Standards (RISD-SCoP) renamed in 2017 the "Irrigation System Design Guidelines".

Organisations, individuals and stakeholders also contributing to the preparation of this document include:

- Irrigation Australia Limited
- Irrigation New Zealand
- Daley Water Services Pty Ltd
- Queensland Farmers Federation
- Growcom
- Turf Queensland
- CANEGROWERS
- Nursery & Garden Industry Queensland
- Flower Association of Queensland Inc.
- Qld Dairy farmers Organisation
- Gary Campbell - ARITAS Irrigation Solutions Pty Ltd
- Individuals, farmers, and staff from irrigation design and supply companies in Queensland, who willingly provided advice
- Gennaro Velotti (Netafim)
- Simon Cowland-Cooper

Financial support for the initial preparation of this document has been provided jointly by the Queensland Department of Natural Resources and Mines and Irrigation Australia Limited.

TABLE OF CONTENTS

PREFACE.....	i
1. PART ONE – IRRIGATION DESIGN PARAMETERS.....	1
1.1 Data Collection.....	3
1.2 Area Considered for Irrigation	4
1.2.1 Area layout – size and shape	4
1.2.2 Topography	4
1.3 Water Supply	5
1.3.1 Quantity.....	5
1.3.2 Source	6
1.3.3 Quality	7
1.3.4 Energy Source.....	7
1.4 Crop / Plants	8
1.4.1 Type	8
1.4.2 Effective Root Depth.....	9
1.4.3 Crop Coefficient.....	9
1.5 Soil.....	10
1.5.1 Soil Information.....	10
1.5.2 Growing Medium Information.....	10
1.5.3 Field Capacity and Permanent Wilting Point.....	11
1.5.4 Readily Available Water (RAW).....	11
1.5.5 Refill Point	11
1.5.6 Soil Infiltration Rate	12
1.6 Climate.....	13
1.7 Management Requirements	14
1.8 Irrigation System Capacity	15
1.8.1 Designed System Capacity.....	15
1.8.2 Managed System Capacity:.....	16
2 PART TWO – IRRIGATION PERFORMANCE PARAMETERS	17
2.2 Irrigation System Performance Standards.....	17
2.3 Irrigation System Selection	19
2.3.1 Stream Impact Energy	20
2.4 Application Efficiency	20

2.5 Net Application Depth	20
2.5.1 Gross Application Depth – Designed System Capacity	21
2.5.2 Gross Application Depth – Managed System Capacity.....	21
2.6 Irrigation Cycle	21
2.7 Sprinkler or emitter layout	22
2.7.1 The effects of wind	22
2.8 Application Uniformity	23
2.8.1 Sprinkler Irrigation.....	23
2.8.2 Micro sprinkler and drip irrigation	24
2.9 Application intensity	24
2.9.1 Adjustment for application duration.....	25
2.10 Hydraulic Design	26
2.10.1 Maximum Water Velocity.....	26
2.10.2 Minimum water velocity	27
2.10.3 Pressure variation	27
2.10.4 Agricultural spray irrigation – pressure variation	28
2.10.5 Micro sprinkler or drip irrigation – pressure variation	28
2.10.6 Pipe Friction	28
2.10.7 Air release	29
2.10.8 Pressure and vacuum relief.....	29
2.10.9 Surges and water hammer	30
2.10.10 Thrust block design	30
2.11 Filtration.....	31
2.11.1 Filters for sprinkler irrigation	32
2.11.2 Filters for micro-irrigation.....	32
2.11.3 Filters for drip irrigation.....	32
2.12 Pumping design.....	33
2.12.1 Selecting a pump duty - Pump Flow Rate(s)	33
2.12.2 Selecting a pump duty – Total Dynamic Head (TDH)	34
2.12.3 Selecting a pump duty – Safety Margin	34
2.12.4 Pump efficiency	35
2.12.5 Pump Drive efficiency.....	35
2.12.6 Surface-mounted Centrifugal Pumps	36

Irrigation System Design Guidelines

2.12.7	Suction Lift	36
2.12.8	Net positive suction head available (NPSHa)	37
2.12.9	Net positive suction head required (NPSHr)	38
2.12.10	Submersible pumps	38
2.12.11	Velocity.....	38
2.12.12	Friction loss past submersible motors	39
2.12.13	Pump cooling	39
2.12.14	Cavitation	40
2.12.15	Power supply.....	41
2.12.16	Pump electrics.....	41
2.12.17	Diesel drive de-rating.....	42
2.12.18	Surface water intakes.....	43
2.12.19	Suction and Discharge Pipework.....	44
2.12.20	Pump design - flow measurement	45
2.12.21	Pump design - pressure gauges.....	45
2.12.22	Control valves	46
2.12.23	Suction and Discharge Pipework Friction Loss.....	46
2.12.24	Chemical / Fertiliser injection.....	47
2.12.25	Backflow prevention	47
2.12.26	Protection from freezing	47
2.12.27	Pump Sheds.....	48
2.13	Controls.....	49
2.14	Measuring and Monitoring	51
2.14.1	Measuring and monitoring – flow measuring	51
2.14.2	Measuring and monitoring – pressure gauges.....	52
2.14.3	Water levels	54
2.14.4	Water quality	54
2.14.5	Soil moisture.....	54
2.14.6	Power consumption.....	54
2.15	Checking Design Performance Targets	55
2.16	Final Specification and quotation	55
2.16.1	Final specification report.....	55
2.17	Irrigation System Hand-over	59

2.17.1	Pre-installation.....	59
2.18	Installation	60
2.19	Commissioning.....	60
2.19.1	System Testing	60
2.19.2	Correcting Poor Performance.....	62
2.20	Commissioning documentation.....	63
2.20.1	Commissioning Report.....	63
2.20.2	As-Built Plans.....	64
2.20.3	Operation Manual	65
2.20.4	Maintenance Manual.....	65
2.21	Training	65
2.22	Final Handover	65
	DEFINITIONS.....	66
	STANDARD FORMULAE.....	69
	ABBREVIATIONS AND SYMBOLS.....	70
	<u>ATTACHMENT: IRRIGATION DESIGN BRIEFING ASSESSMENT CHECK LIST</u>	<u>i</u>

LIST OF TABLES

Table 1:	Irrigation System Design Parameters	2
Table 2:	Irrigation System Performance Standards.....	18

1. PART ONE – IRRIGATION DESIGN PARAMETERS

The actual Irrigator is core to all irrigation designs, and the irrigation designer should undertake a frequent process of consultation with the Irrigator to define and document the objectives of the irrigation system.

This process should result in the clear and comprehensive description of the irrigation system detailing the scope of the proposed irrigation project. The scope is critical to the project's ultimate success as it defines the work to be done. The scope is normally contained within the irrigation report or quotation.

An important part of scope definition is quantifying the Irrigator's requirements into key performance criteria to provide a measure of system performance; and enable performance comparisons with industry benchmarks and with other systems to be made.

The performance criteria cover six areas of measurable performance, as follows:

- a) Water use efficiency
- b) Energy use
- c) Labour
- d) Capital
- e) System effectiveness
- f) Environment

The system design establishes these key performance criteria by utilising specific design parameters that provide the framework around which the irrigation design is formed. Some of these parameters need to be calculated, and some are site specific for which information must be obtained or measured.

These design parameters are provided in Table 1 following:

Table 1: Irrigation System Design Parameters

	Base Design Parameter	Unit(s)	Associated Information
1.1	Area considered for irrigation	Hectares (ha)	<ul style="list-style-type: none"> • Area layout - size and shape • Greenhouse growing structures (Nurseries) • Size and quantity of containers (Nurseries) • Physical obstacles (fences / trees / buildings, etc.) • Land restrictions (protected areas, etc.) • Topography
1.2	Water Supply	L/s	<ul style="list-style-type: none"> • Quantity / Allocation • Source (i.e. dam, bore, etc?) • Quality • Re-use (Nurseries) • Energy source for pump
1.3	Crop / Plant		<ul style="list-style-type: none"> • Type/s • Growth stages and timing • Cultivation practices • Root depth • Crop coefficients
1.4	Soil – Readily Available Water (RAW)	mm/m	<ul style="list-style-type: none"> • Soil or Growing Medium information • Soil structure • Field Capacity & Permanent Wilting Point • Refill Point • Infiltration Rate/s
1.5	Climate		<ul style="list-style-type: none"> • Evapotranspiration • Rainfall • Wind • Managed (greenhouses)
1.6	Management requirements		<ul style="list-style-type: none"> • System integration • System type (sprinkler, drip, pivot, etc?) • System compatibility • Labour skill & availability • Process control • Risk appetite • Price budget
1.7	Irrigation System Capacity – Designed & Managed	mm/day	<ul style="list-style-type: none"> • Irrigated area • Peak Crop Water Use • Gross application rate (depth of water applied in mm over time) • Application efficiency (%) • Operating hours: <ul style="list-style-type: none"> ○ Irrigation cycle (duration and frequency) ○ Pump Utilisation Ratio (PUR) • Flow rate of irrigation system

1.1 Data Collection

The first stage in the development of an irrigation system is to gather the necessary site-specific information for the Design Parameters needed to complete a design.

The sources of the information are varied, and one of the most effective (and recommended) is a visit to site by the designer. Much of the information needs to come from the Irrigator who may have to consult a number of specialists including soil scientists, water supply experts, water quality laboratories etc.

To assist the designer, a 'check list' has been developed as part of this document (refer Attachment A: Irrigation System Development Check List).

This check list is a chronological summary of key critical elements of the process and is designed to:

- Prompt the designer to consider and implement the required steps to ensure the correct outcomes are achieved
- Be used as a template for each individual project
- Provide a record of the consultation process
- Assist the Irrigator in understanding the information required to develop a system design

1.2 Area Considered for Irrigation

1.2.1 Area layout – size and shape

Information about the layout of the irrigation area is necessary for identifying priority irrigation areas and for positioning infrastructure (e.g. pump position, pipelines, etc.).

For nurseries establish the growing structures in use – e.g. greenhouses, shade structures, hail net structures; and if the plants are grown in beds, on tables or on trough benches. The quantity and size of the containers relevant to the layout must also be established.

Information gathered prior to the design of an irrigation system can help identify any site restrictions or potential logistical limitations (e.g. trees, rivers, roads, proximity to power lines, etc.). Consideration must also be made of any land restrictions such as specially protected environmental or cultural areas.

A design must consider the Irrigator's current needs, and any additional needs into the foreseeable future. For example, if any expansions to the irrigation system are planned, it is best to accommodate this within the current design wherever possible.

1.2.2 Topography

Topographical data that may affect the design of the irrigation system, in addition to the critical dimensional elements of lengths and elevation, must be acquired. The more detailed and accurate the data, the more precise the irrigation design can be.

Land surveys, area maps and drawings, aerial and satellite photographs are a good source of this information.

Accuracy is significantly enhanced by combining aerial or satellite photographs with a physical land survey by a qualified surveyor. This will ensure the identifying of pertinent land features such as hills and gullies, will provide accurate dimensioning data including slope; and can assist in highlighting possible risk areas such as proximity to power lines, areas prone to waterlogging or flooding, etc.

1.3 Water Supply

1.3.1 Quantity

Without an adequate and reliable water supply, it is difficult to realise the full benefits of an irrigation system. It is important the designer establishes the quantity of water available for irrigation and designs the system for this quantity of water.

The quantity of water available is often limited for some or all of the irrigation season. For example:

- Bore yields may be limited
- Scheme or regulatory restrictions may apply
- Seasonal volumes
- Interference effects
- There may be reduced flows in the source streams
- Groundwater levels may fluctuate

Due account should be taken of possible changes in water availability or restrictions in determining irrigation system capacities, irrigation components, area irrigated, and risk of shortfalls.

It may be necessary to increase overall system capacity to provide some ability to 'catch-up', thus minimising the effect of shortfalls, or to build in extra capacity in pumps to lift water from greater depths.

Irrigation designers must be satisfied that the risk and the circumstances relating to the water supply are clearly understood, and are known by or are explained to the Irrigator.

In addition, designers must be familiar with the relevant regulatory requirements with respect to irrigation water. These may be confirming size of allocation, metering requirements, etc.

1.3.2 Source

Identify the location of existing and potential future water supply. Any uncertainties in gaining access to water, and any requirements for gaining access (e.g. easements), should be discussed prior to beginning any irrigation design.

In the case of groundwater, the designer must obtain accurate, reliable information on the bore prior to designing an irrigation system. Such information includes:

- Consent conditions
- Bore location
- Bore construction
- Bore diameter and depth
- Bore performance data, including:
 - Yield
 - Water Levels – Standing and Pumped
- Pump type
- Pump drive and power
- Water quality
- Interference effect on, and of, neighbouring bores on bore performance

If a bore has been drilled and standing idle for more than 12 months, or possibly has been disturbed in some way such that the water supply could be at risk (e.g. flooding), the designer must recommend that the bore be checked and retested.

In the case of surface water takes, some common issues include:

- Location of the suction or intake (i.e. limited access)
- Suction / Intake design
- Method of conveyance (e.g. canals, pipes)
- Discharge design

If water is from a community scheme, the access to and cost of water, and any specific scheme requirements must be considered.

1.3.3 Quality

Irrigation water (in particular bore water) may have an adverse effect on plants or soil leading to productivity issues, or may call for the use of corrosion resistant irrigation equipment.

The designer should sight a recent chemical analysis of the water in question to confirm its suitability or limitations for the proposed use.

Consideration of the quality of the water is important for all irrigation systems and particularly important in systems with small discharge orifices such as those found in drip/micro irrigation.

Some elements in water can cause plugging in drip/micro systems which may require chemical treatment.

Special care should be taken in circumstances where recycled or re-use water is to be used, for example where nursery irrigation water is being contemplated for re-use after initial application to containers.

Where it is suspected a particular problem may be present in the water a sample should be taken and analysed for that purpose, and advise as to treatment sought.

Such information can be obtained from drip/micro irrigation equipment manufacturers and from water treatment specialists.

1.3.4 Energy Source

Determine the potential energy source for the pump. If mains electrical power is to be used, locate the nearest supply and identify any limitations such as Peak and Off Peak demand.

1.4 Crop / Plants

1.4.1 Type

The designer must confirm the crop or plants to be irrigated and have a basic understanding of the plant botany, in particular its growth (or developmental) stages, life span and the cultivation practices used in production, which may vary between varieties of the same crop.

Important information to establish is:

- What is the crop / plant, and the variety?
- Plant dates
- Planting methods
- Germination requirements (e.g. pre-irrigation, low or gentle application, etc)
- Crop growth stages and their relevant water use (obtaining a Crop Water Use Curve is recommended)
- Root depth
- Estimated harvest date
- Harvest methods
- Other considerations, such as:
 - Crop rotations and establishing if the irrigation system is likely to be required to irrigate other crops in the future and if so, what is the impact on the design
 - Crop tolerances such as wilt stress, waterlogging, temperatures (is frost protection or cooling required?)
 - Plant disease and irrigation's possible role in transmission and prevention (i.e. plants whose leaves or trunks cannot be wetted, etc.)
 - Other functions required of the irrigation for plant development other than satisfying evapotranspiration needs such as: fertigation, leaching, pre-harvest preparation, etc.

1.4.2 Effective Root Depth

Establish the average effective root depth from on-site data for use in calculating soil Readily Available Water values (RAW – see 1.5.4 following) and irrigation cycles.

Consider that soil conditions on site may limit root depth and site specific situations need to be determined. Consideration for crop rotations is required to ensure the correct rooting depth is applied during the design process.

1.4.3 Crop Coefficient

The crop coefficient (K_c) should be used to define the peak demand of the particular crop being grown. This coefficient changes throughout the growing season.

The crop coefficient is also used to calculate an appropriate irrigation cycle for the crop (refer to 2.6).

This is an issue for scheduling irrigation and the design should cater to the worst case water demand of a full canopied crop.

1.5 Soil

1.5.1 Soil Information

Soil information for the proposed irrigated area must be obtained to ensure that the irrigation system is designed to match site conditions. Knowledge of the soil characteristics is necessary for calculating an appropriate irrigation application depth, infiltration rate, and irrigation cycle.

Regardless of the method of determination, soil properties should always be verified with the Irrigator or soil expert. It is recommended where possible, that soil textural properties and effective rooting depth be determined on site.

The determining of soil properties involves the following:

- Taking of soil samples sufficient to represent depth and soil types across the area to be irrigated
- Establishing the following:
 - Type or texture – e.g. sandy loam, silty clay, sandy clay loam, etc.
 - Structure
 - Depth
 - Permeability
 - Chemistry, particularly if saline or sodic
- Soil maps and soil property information for the region (e.g. from state government or regional councils, or other reliable source) can provide further detail.

1.5.2 Growing Medium Information

Where plants are grown in media other than normal soil, such as in nurseries; the principles outlined above are still applicable. However, the Designer must be cognisant of the fact that a wide variety of media may need to be considered within the design and their properties in terms of irrigation, are unique.

Some media examples are: pine bark, sawdust, peat and peatmosses, bagasse, coco coir, etc., and of course conventional soils.

1.5.3 Field Capacity and Permanent Wilting Point

Use the soil or growing medium information to determine the Field Capacity and Permanent Wilting Point.

Field Capacity (sometimes referred to as Water Holding Capacity -WHC) is the amount of water that can be held in the soil after excess water has drained away due to gravity.

Permanent Wilting Point is the level at which the soil is so dry that a plant cannot extract any of the water that may be present. At this point the crop would be severely stressed.

1.5.4 Readily Available Water (RAW)

Use the Field Capacity and Permanent Wilting Point values to calculate the Readily Available Water – RAW.

RAW is the soil moisture the plant can extract easily and is used, together with plant rooting depth, to calculate the required application depth.

These values combined with the Refill Point value calculates the irrigation cycle for an irrigation system.

1.5.5 Refill Point

Refill Point is a nominated measure of moisture extraction (i.e. how much the soil is allowed to dry) before being replenished.

Designers use the Refill Point to calculate appropriate application depths and irrigation intervals.

The percentage of depletion allowed is dependent not only on the soil or medium property and plant root depth, but also on the evapotranspiration rate (ET). The larger the ET, the smaller the percentage of depletion allowed.

1.5.6 Soil Infiltration Rate

The range of infiltration rates likely to be experienced must be determined for each soil or medium type encountered. This is a critical exercise to ensure the rate of application by the irrigation system does not exceed the rate that the soil or medium will allow the water to infiltrate.

Failure to do so may lead to negative outcomes such as excessive run-off causing erosion, ponding, waterlogging and bogging of equipment, all resulting in a waste of resources.

Use site-specific information wherever possible, as infiltration rates can be highly variable between (and even within) properties, even for similar soil types. For example, the infiltration rates of well-structured irrigated soils may be considerably higher than on previously un-irrigated soils.

Alternatively, the infiltration rate of a compacted soil, or soils with a surface crust, may be significantly lower than other soils of a similar type that are not compacted or crusted.

The drainage of these (and all soils / media) should be a factor for consideration as this may have a bearing on the most suitable location for the irrigation system and the type of system and equipment to use.

1.6 Climate

Obtain information about the local climate to ensure that the irrigation system is designed to match on-site conditions. If the irrigation system is to be used in a greenhouse, the climate within the greenhouse may be artificially managed and the information is likely to be very different to Bureau of Meteorology data.

Knowledge of the following climate parameters is necessary for calculating irrigation demand and for designing a system to suit:

- Evapotranspiration
- Rainfall
- Temperature
- Prevailing wind direction

The best irrigation designs are based on a detailed irrigation demand analysis. This will often include an assessment of historical climate data to:

- Identify high irrigation demand periods
- Determine the peak system flow rate
- Determine the volume of irrigation water required to meet demand in most seasons (e.g. 9 out of 10 years)

Climate information may be obtained from:

- Bureau of Meteorology weather station data and / or climate maps of the region
- A local weather station or on-farm weather recorder
- Local expert advice (i.e. from someone who has specific knowledge about the climate in the area, or for the greenhouse)

Always use the most accurate, relevant sources of information available.

1.7 Management Requirements

It is important that the designer strives to maximise the irrigation system's integration and compatibility with the operations and management of the rest of the enterprise.

The Irrigator's management needs must be identified prior to designing an irrigation system. The following are examples of some of the issues that should be considered:

- How does the irrigation integrate with the rest of the operations? For example:
 - Will livestock be in the irrigation area?
 - Are feral animals a consideration?
 - Are there other water needs?
- Does the Irrigator have a preference for a particular irrigation system type?
- Is the irrigation system compatible with current and future production practices and requirements? Is the system compatible with the existing irrigation system (if one)?
- What labour is available to operate the irrigation system and what is the skill level?
- Is a level of automation required for the operation of the irrigation system and what level of monitoring is required?
- What is the level of risk the Irrigator is willing to accept? This pertains not only to the capital cost but also to the potential effectiveness of the irrigation.
- The price budget the Irrigator provides will dictate the quality of the irrigation system in all aspects, from longevity of equipment, ease of use and operational costs, to effectiveness of irrigation, and this needs to be explained to the Irrigator.

Wherever possible, it is recommended to design the property around the irrigation system, not the irrigation system around the existing internal property layout. This may mean moving fences, removing shelter belts or trees, changing the position of drains or water races, or putting in new access-ways.

Irrigation should take priority as it is a long-term investment. Structures are only shifted once; the irrigation equipment may be shifted every day during the irrigation season and for many years to come.

1.8 Irrigation System Capacity

All design data gathered, as detailed in points 1.1 – 1.7 previously, should be collated and used to calculate the peak crop irrigation demand and maximum application depth (mm) of irrigation water required to water the crop.

If the irrigation system is unable to irrigate on a daily basis, calculations are required to determine the period between irrigations – the irrigation cycle (see 2.6). This will influence the application depth.

This application depth combined with the size of the area to be irrigated in a 24-hour period is used to calculate the Irrigation System Capacity. This is the irrigation system's minimum flow rate – in L/s (litres per second) – and is a pure theoretical and mathematical value of the irrigation system.

However, other factors need to be considered which will result in the Designed System Capacity.

1.8.1 Designed System Capacity

No irrigation system can apply water with 100% efficiency. Therefore, the application depth must be increased to compensate for the irrigation system's inefficiency.

The application efficiency (E_a) of the irrigation system can range between 75 – 95% depending on the type of irrigation system.

Application of this efficiency factor to the Irrigation System Design amount results in a value that forms the foundation for further calculations that will contribute to determining infrastructure specifications – i.e. pump and pipe sizes, etc.

However, there are further factors to consider which may have an influence on irrigation infrastructure. These factors are those that originate from the system's potential management which result in the Managed System Capacity.

1.8.2 Managed System Capacity:

The performance of an irrigation system is dependent on both the design and the management of the system.

The System Capacities so far calculated are still purely theoretical. These figures assume the full 24 hours in a day are available for irrigation. The Designer must allow a time factor within the calculations. This time factor may impact on the irrigation cycle and needs to be discussed and agreed with the Irrigator.

Some of the issues to be considered when determining this time factor are:

- Irrigator has limited time to operate the system for reasons such as:
 - Lifestyle (e.g. only works 5 or 6 days a week, or only set hours a day)
 - Regulatory restrictions (e.g. noise)
 - Labour availability issues
- Pump required for other duties
- Power tariffs – the irrigator may only wish to irrigate during advantageous off-peak periods which reduces pumping time
- Breakdowns, repairs and maintenance

These issues all impact on the length of time the pump will operate and are therefore grouped collectively and calculated to result in the following time factor:

- Pump Utilisation Ratio (PUR)

Combining these factors – efficiency of application (E_a) and Pump Utilisation Ratio (PUR) – in the designer's calculations will add to the System Capacity and increase the system flow (L/s) to compensate and will result in the Managed System Capacity.

The designer and Irrigator should work closely together to ensure all time factors are taken into account in order to arrive at a realistic Managed System Capacity that will effectively meet the crop water use.

2 PART TWO – IRRIGATION PERFORMANCE PARAMETERS

On confirmation of the design parameters, the framework for the irrigation design should now be established.

The next stage in developing an irrigation system is to determine the level of performance of the future system. These will provide targets that the design must meet.

Both the designer and the Irrigator should be involved in this process.

Particular attention should be given to:

- Deciding on an appropriately sized and located area of land to irrigate
- Choosing application depths and irrigation cycles that match soil water holding properties
- Deciding on an appropriate rate of irrigation (System Capacity)
- Choosing an application intensity that matches soil infiltration rate
- Meeting the needs of the purchaser in terms of labour, energy, and cost efficiency

2.2 Irrigation System Performance Standards

Once an irrigation system has been selected for the design and the design itself progresses, it should be constantly compared to performance Standards and checking targets are being met to ensure the system can deliver the required crop water requirements, and that it meets the needs of the Irrigator.

These Irrigation System Performance Standards are provided in Table 2 following:

Table 2: Irrigation System Performance Standards

Indicator	Associated Information	Standards
System capacity (based on 24-hour delivery)	<ul style="list-style-type: none"> Flow rate of irrigation system (L/s) Irrigated area Actual hours of pumping / day 	Meets the peak irrigation requirements of the crop
Ratio of system capacity to peak season crop irrigation demand	<ul style="list-style-type: none"> Design system capacity Managed system capacity 	80–120%
System application depth	<ul style="list-style-type: none"> Refill Point Gross depth of water applied (mm) 	< 50% of RAW
Irrigation Cycle	<ul style="list-style-type: none"> Return interval able to be achieved with each system type 	Meets the peak irrigation requirements of the crop
Application uniformity	<ul style="list-style-type: none"> DU CU 	DU > 80% CU > 85%
Average application intensity	<ul style="list-style-type: none"> Gross depth of water applied Time (hours) taken to physically apply water 	< Infiltration rate of the soil
Potential application efficiency	<ul style="list-style-type: none"> Estimated from field distribution and depends on system type 	75 – 95%
Water Velocity	<ul style="list-style-type: none"> To limit potential water hammer in irrigation system pipe lines Vary for flushing and filtration 	Max = 1.5 m/s
Hydraulic efficiency	<ul style="list-style-type: none"> Pressure loss through fittings 	> 90% i.e. losses through fittings not to exceed 10% of total losses
Pump system efficiency	<ul style="list-style-type: none"> Pump system efficiency % (pump/motor efficiency) 	Best possible depending on duty and pump type
Pump Operating Cost	<ul style="list-style-type: none"> Cost per volume of water pumped KWh of energy used per volume of water pumped related to pressure 	\$/ML < 5.0 kWh/ML/m
Micro Irrigation / Point Source	<ul style="list-style-type: none"> Emission Uniformity Flow Variation 	EU > 90% FV < 20%

2.3 Irrigation System Selection

An irrigation system type should be selected that is capable of meeting these performance targets. It should also meet as many of the purchaser's other expectations in terms of:

- Ease of operation
- Reliability
- Acceptable public perception
- Maximising production of crop

If the performance of the selected system is significantly different from the assessed need or unlikely to attain the performance targets, this must be justified and the consequences of the differences between assessed need and proposed system performance explained to the Irrigator.

For example, high application intensity at the end of a centre-pivot may cause surface soil redistribution and surface runoff, which will reduce application efficiency. The significance of this should be explained to the purchaser, ideally in terms of production. The approximate cost of reducing application intensity and the expected benefits should be estimated.

The designer must provide a description of the performance of the system and how well it meets the crop and enterprise needs.

2.3.1 Stream Impact Energy

The breakdown of soil particles at the soil surface may be a problem with high-volume sprinkler irrigation. The impact of the irrigation water on the soil particles can cause either movement of the particles or the breakdown of the soil into smaller particles.

To reduce problems with soil breakdown and movement, it may be necessary to avoid using particular types of irrigation systems, or to avoid irrigating on particularly sensitive soil types.

Designers should:

- Identify potential problems with stream impact energy
- Select an irrigation system type to minimise or eliminate problems with stream impact, where appropriate, and
- Make known to the Irrigator any potential problems and proposed solutions.

2.4 Application Efficiency

The design application efficiency (E_a) must be $\geq 80\%$. A guideline for various systems follows:

- Drip 90 – 95% (includes sub-surface drip)
- Micro sprinklers 85 - 90%
- Centre pivots & Laterals 80 - 85%
- Impact sprinklers 80% (includes hose-fed travelling Irrigation systems)

2.5 Net Application Depth

The net application depth must not be greater than the pre-determined soil moisture deficit unless saline soils are being irrigated or irrigation water contains a significant amount of salt.

In these situations, additional water may be applied to leach salts through the soil profile. In these scenarios, the leaching requirement may be added to the gross depth of application to determine total application depth.

2.5.1 Gross Application Depth – Designed System Capacity

The gross depth of application must take into consideration the design application efficiency (E_a) as used to calculate the Designed System Capacity (see 1.8.1, pg 15).

2.5.2 Gross Application Depth – Managed System Capacity:

The gross application depth will increase when PUR (Point 1.8.2, pg 16) is factored in.

Where high levels of salt are present either in the soil or irrigation water, the application depth may need to be increased in order to leach salts through the soil profile.

Where nutrients are introduced via the irrigation system (e.g. in systems with fertiliser injection, or in areas exposed to effluent application), extra care is required to select an application depth that avoids delivering the nutrients pass the root zone.

2.6 Irrigation Cycle

The time taken for the plant to deplete the soil of moisture to the level where the refill point is reached, divided by the rate the irrigation system applies the application depth will determine the irrigation cycle or the irrigation schedule (frequency of irrigation).

The irrigation cycle is selected to ensure that the irrigation system can maintain soil moisture at an adequate level to avoid plant water stress.

This is particularly relevant for irrigation systems that cannot replenish the crop water use on a daily basis. Such systems are hand shift sprinklers and hose-fed travelling Irrigation systems.

2.7 Sprinkler or emitter layout

Sprinklers should be selected and spaced for optimum uniformity of water distribution. A combination of sprinkler or emitter spacing, nozzle size and operating pressure should be selected to provide the desired application depth, intensity, and uniformity.

Designers should consider the following when designing the layout of sprinklers or emitters:

- Keep sprinkler operating pressures within manufacturer's recommended pressure ranges to prevent misting at high pressures and poor distribution at low pressures
- Incorporate elevation variations into the calculations of sprinkler pressures where elevation changes exceed 5% of sprinkler operating pressure within a system sub-area
- Design for larger application depths, low application intensities, and fewer shifts with labour intensive systems (subject to soil suitability)
- Design for smaller application depths, higher application intensities, and more shifts on automated systems
- Use smaller, more closely spaced nozzles whenever practical / economical
- If practical, design systems so that sprinkler laterals or lines are oriented so that prevailing winds flow perpendicular to them
- Consideration of soils should be used for selecting emitter spacing.

2.7.1 The effects of wind

Sprinkler irrigation systems are often affected by wind. The use of single jet, low angle sprinklers may help improve performance in windy conditions. Designing for lower operating pressure and larger droplet sizes can also help by increasing the average droplet mass and decreasing throw distance.

However, these types of system modifications will likely cause greater droplet impact energy, and may increase problems with infiltration and surface runoff.

2.8 Application Uniformity

2.8.1 Sprinkler Irrigation

The application uniformity of spray irrigation systems is calculated using the Distribution of Uniformity (DU) method and the Christiansen's Uniformity Coefficient method (CU), and this data should be used to select the optimum sprinkler type, spacing, nozzle size and operating pressure ranges.

Explanations for DU and CU can be found in "Definitions" – pg 67.

DU and CU figures are essential system performance indicators and every effort should be made to present these figures with the design to the Irrigator.

All spray irrigation systems should be designed to achieve the following:

- Minimum DU
- Minimum CU

Sprinkler spacing and application uniformity should be adequate for potential future uses, as well as immediate needs. For example, if the Irrigator is considering the application of chemicals or waste water through the system, higher application uniformity may be required.

When applying fertilisers or chemicals through the system, CU must be at least 85% regardless of the method of irrigation used.

For shallow rooted crops, the minimum should be CU > 90% and DU > 82%.

When applying wastewater, CU must be at least > 85%.

2.8.2 Micro sprinkler and drip irrigation

Drip and micro-sprinkler irrigation are subjected to additional uniformity requirements in the form of emission uniformity (EU) and flow variation (FV) which is the percentage of variability of discharge between emitters in the field. Point source (drip) or single emitter per plant systems are only measured in EU or FV.

The calculation of EU is complex and requires the emitter's Coefficient of Variation (C_v).

Due to this complexity, most drip and micro sprinkler manufacturers provide special calculators (small computer programs or on-line calculators) to theoretically calculate the EU. Consult with the manufacturer.

The minimum design emission uniformity (EU) and maximum flow variation (FV) for different micro irrigation types is as follows:

	EU	FV
▪ Drip (inline and point source)	90% - 100%	0 – 20%
▪ Micro sprinkler	90% - 100%	0 – 20%

2.9 Application intensity

Application intensity must not exceed the soils infiltration rate or ponding and runoff could occur. Furthermore, if the land is sloping, the application intensity must be further reduced.

When calculating the irrigation cycle, the application intensity of the irrigation system selected should not exceed the infiltration rate of the soil over the length of time the water is applied.

If this cannot be achieved, designers should identify when or where the application intensity is likely to exceed infiltration rate and explain the consequences of it happening.

2.9.1 Adjustment for application duration

Different application intensities are appropriate for applications of different durations. The infiltration rates of soil generally progressively slow over the time of the application, so higher application intensities are appropriate for shorter durations; while lower intensities are required for longer durations.

It is important that designers are familiar with soil / water infiltration complexities so that they can identify potential problem application intensity situations. However, the calculation of infiltration rates and application intensities can be complex, and specialised soil and / or engineering services may be required.

2.10 Hydraulic Design

The hydraulic design should take into consideration:

- Flow velocities through pipelines
- Elevation changes across the property
- Friction losses through pipelines, fittings, and other in-line components
- Soil conditions for buried pipelines
- Environmental conditions for surface pipelines
- Longevity of all components
- Capital costs
- Installation costs
- System operating costs

2.10.1 Maximum Water Velocity

The higher the velocity, the greater the risk of damage through surges and water hammer. This risk particularly applies to pipes subject to uncontrolled starting and stopping.

Using larger pipe results in a smaller water velocity for a given flow rate, but smaller pipe is often preferred for cost reasons. The designer should aim to strike a balance between water velocity and pipe cost. This is often done by designing as close as possible to the following maximum water velocity:

- Recommended maximum water velocity (mainline, closed system) 1.5 m/s
- Zone pipes or laterals can operate at higher velocities provided they are not a closed system and are open to atmosphere. System energy and flushing requirement should always be considered when operating at higher velocities.

If the operational water velocity will exceed the Standards, then the designer must justify why the higher velocity is recommended. The designer must also advise on what measures are taken to prevent water hammer and surge damage.

It is possible that some pipe types, such as continuously welded polyethylene pipe, may be able to operate safely at a high water velocity. This is acceptable, provided a water hammer analysis or manufacturer's literature shows that this is acceptable.

2.10.2 Minimum water velocity

Designers must specify pipe diameters and flow rates that allow for a minimum operational water velocity, especially for irrigation systems that utilise emitters with small apertures such as drip and micro sprinklers. This will ensure that any sediment or solids are flushed through the lines.

- Minimum to flush drip lines 0.3 m/s
- Recycled water minimum 0.5 m/s
to flush driplines
- Minimum to flush pipe lines 0.5 – 1.5 m/s
depending on pipe size
and flow

2.10.3 Pressure variation

The irrigation system should be designed to minimise pressure variation between water outlets.

Sizing pipes for appropriate friction losses is the most common method. If this is not possible, then pressure regulators may need to be included on outlets, or some form of pressure regulation may be used at pumping stations (e.g. variable speed drives).

It is important to consider operational costs when designing methods of pressure regulation. Systems that require a lot of pressure regulation are likely to be less energy efficient.

The design should specify a way to measure the pressure, and if required the flow, at each outlet or block of outlets.

2.10.4 Agricultural spray irrigation (Non-Pressure Compensated Emitter) – pressure variation

The design pressure variation at the outlets must not exceed:

- 20% of the outlet operating pressure at any point in the system

And

- 15% of the outlet operating pressure over 80% of the zone outlet positions

2.10.5 Micro sprinkler or drip irrigation (Non Pressure Compensated Emitter)– pressure variation

Pressures must be set so that the maximum variation in emitter pressure within a block or sub-area does not exceed:

- $\pm 20\%$ pressure variation

2.10.6 Pipe Friction

Where pipe sizes are not limited or controlled by pressure variation or velocity requirements, economical pipe sizes will normally have a friction loss ranging from 0.4–1.5 m per 100 m of pipe.

The most economical pipe size will depend on the current cost of pipe, the pipe life, hours of pumping, pipe friction, and energy cost.

During the design process, the designer must take into account the possible effect of water quality on pipes, as well as the deterioration of pipes with age. Pipe deterioration often results in increased friction losses.

Designers should specify low friction valves and fittings, where appropriate.

2.10.7 Air release

Air release valves must be specified in the design at the highest points in the pipelines. Specify one air release valve for the highest point in the pump discharge pipework.

For irrigation systems with long pipelines, at least one air relief valve for every 1000 m of pipe is recommended.

For irrigation systems installed in undulating terrain, air release valves at all high points where air may build up is recommended.

At all times the designer must follow the manufacturer's recommendation regarding sizing / installation of valves.

2.10.8 Pressure and vacuum relief

Pressure relief valves are recommended for situations where the pressure rating of the system (e.g. the pressure rating of pipes) may be occasionally exceeded.

Vacuum relief valves are recommended for situations where negative pressures may be experienced.

The design should specify if pressure or vacuum relief valves are necessary. It should also specify the type of valve to be used and the location in which it should be installed.

When considering type and size of pressure or vacuum relief valves designers should follow manufacturer's recommendations.

2.10.9 Surges and water hammer

All irrigation systems are susceptible to pressure surge or water hammer. Surges occur when the velocity of water within the system changes from a steady state condition to another. The most severe surges usually occur on starting and stopping pumps or instantaneous opening and closing of a valve in a pipeline.

Pressure surges may be high and can result in significant damage to piping, pumps and other components of the irrigation system. Designers should be aware that water hammer effects are always possible and must consider possible effects on the design loads for the system.

Water velocity contributes significantly to the effects of water hammer. Lower velocities limit the adverse effects of water hammer.

A water hammer analysis may be necessary and mitigation measures specified to lessen the risk of damage. Such analysis is complex and specialised engineering services may be required to analyse the proposed mainline design.

2.10.10 Thrust block design

Pipe suppliers provide design guidance as to the location, sizing and material for thrust blocks including tables detailing the thrust on fittings and the bearing loads of different soil types.

Thrust blocks are normally constructed out of concrete and are located at each bend, valve, tee, reducer, end cap, and blank flange.

Refer to pipe manufacturers for the design of thrust blocks.

2.11 Filtration

Filtration is an integral part of an irrigation system where physical or chemical impurities in the water can have an adverse effect on the operation and performance of the irrigation system.

When selecting the appropriate filter the following should be taken into account:

- The method and sizing of filters, which depends on the flow rate, type of debris, debris loading, and the outlet orifice size of the emitting device
- Complete removal of material from irrigation water is impractical and expensive. The level of filtration must be tailored to the required system performance
- A good general rule concerning filtration is to be conservative. Keeping below manufacturer's guidelines for pressure loss and to use 80% of manufacturer's maximum flow rates through filters is recommended
- The maximum velocity through filters must not exceed manufacturer's recommendations
- Other than pump intake screens, filters should never be installed on the suction side of a pump
- For self-cleaning filters, additional flow to clean the filters and discharge requirements must be included or considered.

The choice of filter element, depends on the circumstances, water quality and application. A comparison of filter types and brands can be made by looking at the effective filter area.

For automatic back-flushing systems, also allow for potential damage due to water hammer and surge.

2.11.1 Filters for sprinkler irrigation

In manually controlled systems, the size of the mesh orifices must be no greater than one quarter of the sprinkler outlet diameter.

In systems with automatic valves, the manufacturer's specification must be followed, or a minimum of 80 mesh used.

2.11.2 Filters for micro-irrigation

Disc/screen filter openings must be no greater than one fifth of the emitter orifice diameter. The manufacturer's recommendations regarding appropriate filtration for the micro emitter must be followed.

2.11.3 Filters for drip irrigation

The size of the screen or disc orifices must not be more than one seventh of the drip emitter's outlet diameter. The manufacturer's recommendations regarding appropriate filtration for the micro emitter must be followed.

When using a sand filter, a secondary control screen or disc filter must be placed on the downstream side of the sand filter, to catch the impurities in case of damage to the sand filter.

2.12 Pumping design

In selecting or specifying a pump and motor for an irrigation system, the following parameters should be considered:

- The required flow rate(s)
- The Total Dynamic Head (TDH) the pump has to operate against
- The power required – this depends on flow rate and TDH
- The speed of the pump – this will dictate the type of drive employed (e.g. direct coupled electric, belt drive, diesel motor, etc.)
- Suction capacity – pumps are normally selected according to flow rate and operating head and then checked to see if the pump's suction capacity is adequate
- The possibility of pumps running off the recommended operating range curve
- Consideration for repairs and maintenance

Further information and guidelines are available in the Pump Industry Australia "Australian Pump Technical Handbook".

2.12.1 Selecting a pump duty - Pump Flow Rate(s)

This is equal to the design flow rate for the irrigation system, which will already have been established during system capacity calculations.

In those cases where there is more than one design flow rate, consider the following:

- Use single or multiple pumps
- Variable speed drive
- Other control method - e.g. other pump type

Alternative designs should be prepared and total annual costs (taking into account both capital and running costs) compared to arrive at an economic solution.

2.12.2 Selecting a pump duty – Total Dynamic Head (TDH)

This is the total pressure the pump must impart to the water while pumping the design flow rate.

The accurate assessment of Total Dynamic Head must be carried out for appropriate pump selection, and must include but not limited to:

- Lift from the water source to the pump
- Worst case elevation that water needs to be delivered to
- Friction losses through pipelines, fittings, and other in-line components
- Outlet working pressure
- An allowance for wear and tear

2.12.3 Selecting a pump duty – Safety Margin

Additional capacity to the designed pump pressure and flow rate should be added as a precaution.

- Flow rate add 5–10% additional capacity
- Pressure add 5% additional capacity

Where an irrigation pump is pumping water of poor quality, such as that containing significant sand (more than 6 grains in a standard cup) or injected abrasive fertilisers, these figures must be doubled.

2.12.4 Pump efficiency

Designers must consider the efficiency of both the pump and the motor when making selections for an irrigation system.

Pumps with the highest level of efficiency at the operating point should be selected, subject to acceptable economic capital and operating costs.

It is usually more economical in the long term to select the most efficient pump, even if it requires spending a little more on the pump purchase. Using an oversized pump will ultimately result in higher operating costs, multiplied over the life of the system.

Pumps must be selected to operate at the best possible efficiency for the majority of the time. If the pump is operating at any other efficiency point, the reasons and implications of operating at lower efficiencies must be made known to the Irrigator.

2.12.5 Pump Drive efficiency

Electric motors must be selected and matched to pumps with the aim to have the motor operate at > 90% of maximum motor efficiency under normal operating conditions.

Small motors are usually inefficient so should be operated as close to full load rating as possible. Larger motors should be sized to operate at 65–100% of full load rating.

Over-load situations need to be reviewed and taken into account – i.e. when pipe filling.

The common practice of over-sizing motors results in less efficient motor operation. Although in some situations it is necessary to over-size motors to accommodate short-term peak loads, it is often best to design systems to avoid peak loads.

Minimum Energy Performance Standards (MEPS) are included in Australian Standard AS/NZS 1359.5:2000, which sets out minimum energy performance and labelling of motors in Australia and New Zealand.

When specifying a diesel engine to power a pump, the designer must follow manufacturer's recommendations and remember to de-rate the engine according to the altitude at which the engine will be operating.

2.12.6 Surface-mounted Centrifugal Pumps

Surface-mounted centrifugal pumps should be designed according to the following guidelines:

- Actual Net Positive Suction Head (NPSHa) must be calculated and be less than the required suction head (NPSHr) recommended by the pump manufacturer
- Suction lift should be kept to a realistic minimum
- The total suction lift for centrifugal pumps should not exceed 4.0 m – 6.0 m, unless otherwise specifically allowed by the manufacturer (see discussions on suction lift, cavitation, and NPSH following)
- Flexible couplings should be considered between pumps and rigid installations (suction or discharge) where excessive vibration may result in damage. Due to the possible ingress of air via these types of fittings, caution should be exercised when contemplating the use of flexible couplings on pump suctions
- An air release valve should be specified at the highest point on the pump casing to allow air to escape when priming the pump
- Some method of priming the pump should be provided

2.12.7 Suction Lift

The amount of suction lift a pump can handle depends on atmospheric pressure, water vapour pressure, pressure losses, and the required inlet pressure of the particular pump. Elevation (height above sea level) and water temperature effects (fluid specific gravity and viscosity) must also be considered.

Design analysis must be carried out to eliminate problems associated with cavitation by avoiding:

- Lifting water from excessive depths
- Using pumps not designed for high suction lifts (high NPSHr)
- Suction pipes that are too small or too long
- Inadequate depth of water above the end of the suction pipe
- High friction loss components in the suction line (e.g. poorly designed foot valves, globe valves, or high-loss fittings)
- Warm water
- Aeration due to cascading water
- Leaks in the suction allowing air to enter, and
- Pumps running at low pressure and high flow rates (e.g. filling mainlines).

2.12.8 Net positive suction head available (NPSHa)

NPSHa depends on the particular system involved and will be affected by conditions such as altitude (atmospheric pressure) and temperature.

To calculate the NPSHa at the pump inlet, add up the available pressure and subtract any pressure used up by losses prior to water arriving at the pump inlet:

NPSHa = Atmospheric pressure +/- any static head – friction head (including minor losses) – velocity head – vapour pressure of water at operating temperature

Note that the vapour pressure of water at 20°C is about 0.25 m.

2.12.9 Net positive suction head required (NPSHr)

NPSHr depends on the design of a particular pump, and is not affected by external conditions. It is specified by the pump manufacturer.

To improve pump reliability, pumps should be selected and installed so that NPSHa is not less than NPSHr + 0.6 m, but as high as is practically and economically possible.

If the NPSHa is less than NPSHr + 0.6 m, the reasons for designing systems to a lower value and the consequences of a lower value must be explained to the Irrigator.

2.12.10 Submersible pumps

For a submersible unit, the designer must consider the following:

- Determine an accurate pump duty point, by including allowances for pumping drawdown in the bore or well, and fluctuations in groundwater level over time
- Ensure there is not excessive friction loss in the rising column
- Ensure that enough space is available between the pump and the well casing or use appropriately designed shrouds to allow for adequate cooling of the motor
- Determine if a check valve is to be used in the rising column, it must be set at a height no greater than 7.0 m above the lowest expected static water level.
- Always install a probe tube in all wells to allow water levels to be monitored

2.12.11 Velocity

The following velocity limits for submersible pumps should be observed:

- Maximum water velocity in the rising column = 2.5 m/s
- Minimum water velocity between pump motor and well casing = 0.3 m/s
- Maximum water velocity between pump motor and well casing = 5.0 m/s

Unless otherwise specified by the pump manufacturer.

2.12.12 Friction loss past submersible motors

The passage of water through the annular space between a submersible pump motor and the well casing creates friction that can be substantial if velocities are high and motors are long.

The designer should calculate this friction loss, and if significant include in the design figures.

2.12.13 Pump cooling

Minimum velocities are specified by pump manufacturers to ensure that sufficient motor cooling occurs.

This is particularly important on pumping systems that are fitted with variable speed drives, as low velocities can arise at low flows.

Designers must check that minimum velocities are maintained over the expected flow range of the pump. If a minimum velocity is not specified, a value of 0.3 m/s should be used as a guideline.

If minimum velocities are not likely to be maintained in a standard installation under normal operating conditions, Designers must configure the installation, for example by using shrouds or rearranging flows, to maintain the minimum recommended velocity.

2.12.14 Cavitation

If NPSHa of the pump is less than NPSHr, the pumped fluid will vaporise in the region of the impeller eye, where the local pressure is less than the vapour pressure of water.

In this region of the pump, the fluid will consist of a mixture of water and vapour cavities. Usually the vapour cavities progress through the impeller to a region of higher pressure. Here the cavities implode, sometimes with such force that material is removed from the impeller causing pitting.

Cavitation may be caused by excessive suction lift, insufficient NPSHa or operation at too high a speed. The resulting effects include:

- Pitting of material surfaces due to the implosion of the vapour cavities
- Reduction in performance due to vapour formation
- A noise caused by vapour cavity collapse sounding like gravel passing through the pump

To prevent Cavitation Designers must:

- Ensure that pumps operate within their recommended flow operating range
- Make sure that protection systems are in place to prevent pumps operating against closed valves for extended periods of time (check with pump manufacturers for recommended times – it may only be 5–10 seconds for some pumps)
- For pumps operating on variable frequency drives, pump speed does not fall below the minimum allowed by the manufacturers

Cavitation can also occur with submersible pumps. Cavitation can be avoided by:

- Ensuring there is sufficient depth of water over the top of a pump when it is operating, taking into account water level variations
- Avoiding high velocities past submersible motors, and
- Ensuring motor shrouds (if used) are large enough and that material will not be entrapped between motor and shroud

2.12.15 Power supply

The power sources available for the proposed pump unit should be established prior to starting the design process.

If mains electrical power is to be used, the size and proximity of the nearest transformer, other uses drawing on the transformer and cost of power supply cables to reach the pump unit should be discussed with the Irrigator.

If considering the use of diesel engines de-rating is required (see 2.12.17). Designers should consult with engine suppliers and follow the manufacturer's recommendations when specifying and sizing diesel engines.

2.12.16 Pump electrics

All electrical systems must be designed to meet local and national electrical standards and requirements.

Electrical systems for pumps should include, at a minimum:

- A starter type that meets local power company and energy supplier requirements
- A manual ON / OFF switch for each pump
- High and low pressure, or zero-flow cut-offs
- Low water level protection
- Fault indicators (to identify the reason for a fault)
- An external running light installed at the pump shed
- A circuit disconnect for each electricity connection
- Overload protection for every motor
- Phase failure and reversal protection
- Voltage and amperage display
- Run timer
- Total hour meter

Additional protection such as temperature sensors or control sensors should be installed where there is a risk of failure and the consequences of the failure are significant. For example, thermistor sensors or similar on submersible pump motors are highly recommended.

Electrical installers should take care to minimise electrical interference and noise resulting from the use of variable speed drives. Many electricity providers now require harmonic filters to be installed. Designers should check with relevant power supply authorities to determine local requirements.

All pump starting and control systems must be used only for manufacturer-approved applications.

The maximum voltage drop from the power supply point to the pump motor (includes voltage drop in submersible pump cables) must be compatible with the manufacturer's requirements. If a maximum voltage drop is not specified, it must be the lesser of:

- 5% of nominal operating voltage, or
- 15V

2.12.17 Diesel drive de-rating

Engine manufacturers will provide de-rating information based on operating altitude and air temperature.

However, the duty of the pump unit may vary which will create differing demands on the engine. As a guide, the net power required at the pump shaft should be increased by the following de-rating factor:

- Diesel engine de-rating factor = 1.3

The engine should be able to deliver the required pump power required PLUS 30% - i.e. pump power x 1.3.

2.12.18 Surface water intakes

Suction lines should be designed according to the following guidelines:

- All surface water intakes should have appropriately sized screens or filtration systems to exclude debris that may damage pumps or the irrigation system. These should have a total open area equal to a minimum of 5 x the area of the suction pipe, with the upper limit dependent on water quality
- All surface water intakes should exclude aquatic animals such as fish and frogs
- If the intake water level is below the pump, specify a check or non-return valve to prevent water from draining away from the pump when it is not in operation
- Ensure the suction pipe is of sufficient diameter and is installed at a sufficient depth below the lowest expected water level so that air is not drawn into the suction assembly
- Suction pipes should be as short as possible – refer to NPSH requirements
- Do not put any unnecessary valves or bends in the suction line
- Where valves are necessary, specify valves that are at least the same diameter as the suction pipe
- Where bends are necessary, specify long radius bends
- Ensure that the distance from any bends, valves, or pipe reducers to the inlet of the pump is at least 5 x the diameter of the pipe
- The suction pipe diameter should be adequate for the flow so as not to exceed the allowable velocity; and at a minimum to be equal in diameter to that of the pump inlet
- If vibration is excessive, flexible couplings should be considered between pumps and rigid installations (suction or discharge), However, due to the possible ingress of air via these types of fittings, the use of flexible couplings on pump suctions should be avoided unless absolutely necessary
- Design the system so that shrouds, foot valves and filters or screens on the suction side can be easily maintained.

The water velocity through suctions and intake screens must not exceed:

- Suction pipe: 1.5 m/s
- Intake screen: 0.4 m/s

Note: Typical lift suction lines should be closer to 1.0m/s - definitely no more than 1.5 m/s.

2.12.19 Suction and Discharge Pipework

The pump suction and discharge pipework should be designed to allow for easy control and monitoring of the system's operation. It should be readily accessible for easy maintenance.

The designer should consider the following:

- Specify an air release valve/vacuum breaker at the highest point in the discharge pipework
- Specify galvanised steel for any above ground components of the pipework
- Design the pipework to comply with all water metering regulations
- Ensure water meters are installed to manufacturers' specifications with regards to proximity of fittings to the meter, and concerning specific requirements for straight lengths of pipe immediately upstream and downstream of the meter for accurate operation
- Specify components with low friction losses (i.e. swept bends), wherever practical. This will help minimise the pump duty and operating cost of the final system
- The layout of the pipework should allow free access to all critical components (i.e. valves, meters, gauges). This is important for both normal operation of the irrigation system, and for maintenance
- Specify unions or flanges to allow the pipework to be dismantled easily, and that the pipework and associated fittings are adequately supported
- If multiple pumps are linked together, construct the manifold so that each pump can be independently isolated
- If multiple pumps are delivering into the same manifold, care should be taken to ensure discharge pressures into the manifold of the various pumps are matched
- Include a facility to drain the pipework or irrigation system for ease of maintenance
- If PVC is to be specified for use in the pipework (only recommended for small low pressure systems less than 2 kW):
 - Specify heavier walled material (e.g. PN12)
 - Specify increased support to reduce load carrying requirement of PVC; and
 - Allow for malfunction (e.g. PVC getting hot and failing)

Consideration should be given to the order of components in the pipework. Awareness of the effect of turbulence on some components such as water meters, will determine pipework design.

If control valves need to be installed upstream of a flow meter, the straight pipe distance from the control valve to the flow meter should be increased. This will help to minimise turbulence through the meter.

If a control valve (e.g. a butterfly valve) is likely to be operated in a partially throttled state, which creates a high degree of downstream turbulence; the distance of straight pipe should be further increased, flow straighteners used or the valve should be moved downstream of the meter.

Follow the water meter manufacturer's specifications.

2.12.20 Pump design - flow measurement

A flow measuring device must be specified for all new spray irrigation systems and comply with relevant regulations to ensure the system flow rate can be independently measured for compliance purposes. Refer to 2.14 (pg 51) for more guidance.

2.12.21 Pump design - pressure gauges

Pressure gauges or pressure sampling points are required on all irrigation systems. A pressure gauge or pressure test point must be specified on the discharge side of the pipework.

It is good practice to specify pressure gauges with isolating valves or similar so they can be turned off to prevent damage

Refer to 2.14 (pg 51) – “Measurement and monitoring” for a list of recommended locations.

2.12.22 Control valves

Fit at least one control valve to every system to allow the water supply to be manually shut off from the rest of the system. The design should specify the type of valve to be used, and the location in which it should be installed.

It is recommended that the main control valve be of a slow-opening/closing, full-bore type such as a gate valve (i.e. not a butterfly valve). Quick opening/closing valves have the potential to cause water hammer and put pipelines and pumping equipment at risk of significant damage. In addition, such valves have reduced bores that can add to friction losses.

Do not use valves that can only be fully open or fully closed in situations where the system can be started with empty mainlines.

2.12.23 Suction and Discharge Pipework Friction Loss

Pressure loss through the pipework (excluding any pressure control fittings, backflow prevention, or filtration) should not exceed the lesser of:

- 5% of the pressure delivered to the discharge
- 3.0 m of pressure loss

Certain components which may be used in the pipework, such as Reduced Pressure Zone backflow preventors, have a high-pressure loss and will cause the head loss across the pipework to exceed 3.0 m. Reasons for the excessive head loss should be explained to the Irrigator.

2.12.24 Chemical / Fertiliser injection

Allow for the possible connection of chemical/fertiliser injection into the system by including the appropriate fittings in the pipework design. The size of the fittings will be determined according to expected injection flow rates.

Injection points should always be placed downstream of a check (non-return) valve and other sensitive instrumentation, and these should be protected with a filter as required by the component's manufacturer.

Check with local regulations to determine if there are any further requirements for fertiliser injection.

2.12.25 Backflow prevention

Backflow prevention appropriate to the level of risk must be installed on all systems where contamination of water supplies is possible, especially where fertiliser is being injected into the irrigation system.

This means that some form of backflow prevention should be fitted to most irrigation systems.

2.12.26 Protection from freezing

The risk of damage to components from freezing must be determined and measures taken to prevent damage.

2.12.27 Pump Sheds

All pumping systems should be supplied with a shelter to house equipment that is sensitive to weather (i.e. motors, control systems, and gauges). Although some pumps can be outside under a simple roof or rain shelter, all electrical equipment must be located in a weatherproof and lockable shelter.

When specifying a pump shed, ensure that it:

- Is adequately sized to house all equipment, and allows sufficient working room
- Has proper ventilation and cooling
- Protects equipment from the elements, especially rain
- Protects equipment from animals, including nesting birds
- Protects equipment from flooding
 - Located out of flood zones
 - Have adequately sized drains installed in the floor
- Has at least one 240V outlet
- Has light fixtures to illuminate the controls for the system operator
- Complies with Australian Electrical (Safety) Regulations requirements

2.13 Controls

The designer must ensure that the irrigation system is easy to operate and control while maintaining safety.

There is a variety of control methods for irrigation systems. They include:

- Manual systems
- Electromagnetic control
- Computer-based systems
- Remote control

Often, control systems combine two or more of these options. If automatic control is being contemplated, the following should be considered:

- The cost-benefit of various options
- The complexity of the system
- The difficulty of using the system and the level of training required
- Reliability, repairs and maintenance
- Availability of power supply
- Automatic control / monitoring from remote locations
- Reliability of communications to / from remote systems
- Providing automatic restarting after loss of power
- Allowing the convenience of short-term or long-term changes in duty to be accommodated without manual intervention (e.g. when shifting irrigation systems)
- Protecting the system from unwanted operating conditions – high pressures, water hammer, etc
- Improved management of irrigation system schedules allowing water savings
- The ability to take advantage of time-of-use energy programs to reduce electricity costs
- Incorporating fertiliser injection into the irrigation system
- Controlling filter back-flushing
- If the area is Lightning prone

- Working within available watering times for grazing, mowing, spraying, picking crops
- Labour savings (no need to go into the field to turn valves on and off)
- Providing information feedback (what has happened in field) and record keeping

Some precautions that should be considered at the design stage incorporating controls, especially automatic controls, include the following:

- Where an irrigation system has problems with unwanted shutdowns, these should be rectified first – before adding more control components
- Safety shutdown controls should always override restart controls, so that full protection is maintained
- Restart attempts should be limited if other problems are likely
- Elevation differences between pumps and irrigation systems should be taken into account
- Systems pumping uphill should remain full
- Pipelines running downhill should have appropriate measures to control emptying of pipelines (e.g. vacuum breakers)
- Careful analysis and testing should be carried out on systems with very high pressures, complex combinations of pumps, or very long pipelines
- Allow for expansion or changes in design. Many of the new control systems are modular, which means expansion modules can be added as required
- If the central controller is installed outdoors, it should be housed in a waterproof cabinet. Be aware that connecting a 240V power supply to an outdoor installation may add additional expense
- Supply information about what to do if a system malfunctions

In systems with varying or multiple demand points (such as horticultural blocks), the control system should be able to operate pumps at their maximum efficiency points.

2.14 Measuring and Monitoring

The purpose of measurement and monitoring is to provide information to assist with system performance and management. In many cases, it also provides the basis for reporting for compliance.

The incorporation of measurement and monitoring equipment should be planned for and included at the design stage of the process.

2.14.1 Measuring and monitoring – flow measuring

A flow measuring device (such as a water meter), must be installed on the delivery side of the pumping station to measure the volume and flow rate of water.

Refer to the Department of Natural Resources and Mines (DNRM) document – “Queensland interim water meter standard for non-urban metering (WSS/2014/1170)” in conjunction with Australian Standard AS 4747 for detailed specifications for the installation, maintenance and validation of water meters.

The measurement and recording of flow provides the basis for determining overall system performance. For a number of regional councils and water entitlement holders, it is also a required condition for water extraction.

From the Irrigators’ perspective, flow records provide the opportunity to verify system performance (i.e. actual volume of water applied versus design values). Flow records can be readily used to determine average application depths, either for a single irrigation or over the long-term.

For the purposes of routine system management, daily water use records provide the foundation for assessing application depths per cycle. Water use is best determined by obtaining the flow measurement from a water meter.

Water use records (along with soil moisture measurements and, in some cases, climate data) can provide the basis for the assessment of water demand and water balances.

Water meter selection should be based on the following:

- The maximum permissible limit of error for flow measuring devices is
 - Piped flow - +/- 5%
 - Open channel flow - +/- 10%
- For in-line meters, the nominal diameter of the meter should not be less than the pipe diameter upstream and downstream of the meter
- Designers should allow for the following straight sections of pipe either side of the water meter (or as specified by the meter manufacturer and as suited to the site conditions):
 - Upstream - minimum 10 x nominal diameter
 - Downstream - minimum 5 x nominal diameter
- All Systems should have a water meter specified to AS/NZ Standards.

Automatic logging of measurements is recommended i.e. through use of a data logger, and generally provides more accurate and complete information than manual recording of flow data. The meter records can be readily transferred to standard spread sheet format for reporting or further analysis of application depths, application efficiencies, etc.

2.14.2 Measuring and monitoring – pressure gauges

Pressure gauges or pressure sampling points are required on all irrigation systems.

“Pressure gauges” refers to permanently installed gauges.

“Pressure sampling points” refers to taps or fittings to which a portable gauge or meter may be attached.

The design should specify where pressure gauges or pressure sampling points are to be installed. At a minimum, specify pressure gauges or sampling points at the following locations:

- Anywhere in the system where pressure control is being used (e.g. at pressure transducers and pressure switches)
- The inlet of all surface pumps (for vacuum gauges)
- The outlet of all pumps, upstream of any in-line components
- Upstream and downstream of components with a large head loss
- Upstream and downstream of filtration systems, especially for drip and micro systems
- The inlet to each irrigation system or irrigation block, downstream of all hydrants, connecting hoses and control valves
- A second gauge should be specified near the last outlet of an irrigation system if a large head loss is expected through the machine or hose (e.g. at the end of centre-pivots, or at the sprinkler cart of a hose-fed irrigation system)

Some in-line components (i.e. valves or reducers) are likely to cause turbulence in the pipe that may interfere with pressure gauge readings. Ensure gauges or pressure sampling points are at least 2 x pipe diameters upstream and at least 3 x pipe diameters downstream from these components. This will provide for more accurate pressure readings.

It is good practice to specify pressure gauges with a stopcock (or similar) so they can be isolated from the system when not in use to prevent damage from water hammer or high pressure surges. This will extend the working life of the gauges and will allow for them to be checked or replaced while the system is running.

2.14.3 Water levels

A method for monitoring water levels in water sources is advantageous. In bores such monitoring should always be specified in the design. A range of methods are available, and the designer should recommend the option that is best suited to the needs of the Irrigator.

The accuracy of water level measurements should be $\pm 0.1 \text{ m}$

For all systems using water levels as a control parameter within automated control, the automatic recording of water levels (i.e. with a float recorder/data logger or pressure transducer/data logger) is recommended.

2.14.4 Water quality

The designer must ensure access points are included for water samples to be taken from the system for water quality monitoring.

2.14.5 Soil moisture

The measurement of soil moisture provides a method of directly monitoring soil water depletion and, therefore, the basis for scheduling irrigation events. The range of technology available today is rapidly expanding, increasing both the reliability of measurements and access to the data.

Designers should discuss soil moisture monitoring options with the Irrigator, including automatic control options based on soil moisture monitors.

2.14.6 Power consumption

It is useful to have some way of monitoring operational power consumption. It is good practice to display volts and amps somewhere in the pump shed for this purpose.

Some systems also include a display showing kW (this is standard on most variable speed drives), which is particularly useful for monitoring energy consumption.

2.15 Checking Design Performance Targets

Prior to finalising the design, check that it matches the performance parameters that were set prior to starting the design process (see Part 1 – Irrigation Design Parameters).

Complete the necessary calculations to compile a list of the Performance Indicators for the system. Table 2 – Irrigation System Performance Standards provides a list of some of the recommended Performance Indicators.

The Performance Indicators calculated for the design should be reviewed with the Irrigator, and these should be compatible with:

- The performance parameters set out at the beginning of the design process
- All relevant local or state government regulatory requirements

2.16 Final Specification and quotation

2.16.1 Final specification report

An irrigation design and specification report summarising the final system performance indicators must be provided to the Irrigator. This document will describe the final system composition and what it will be capable of achieving.

If provided as a stand-alone irrigation design and specification report, it must be completed in sufficient detail so that quotations for the supply and installation of the system may be obtained.

Depending on the particular situation, the design report may be submitted in conjunction with a quotation for supply.

The following information should be in all stand-alone irrigation design and specification reports:

- Designer information
 - Name of supplier
 - Contact details of supplier (e.g. address, phone, fax, and email)
 - Name and qualifications of designer(s)

- Irrigator information
 - Name of Irrigator
 - Contact details of Irrigator (e.g. address, phone, fax, and email)
 - Trading name and ABN
 - Name and location property (if a farm)

- Input Information and Assumptions
 - Includes all input values determined during the initial site investigation:
 - Site layout
 - Water source, quantity and quality
 - Soils information
 - Crop types
 - Climate assumptions (e.g. evapotranspiration and rainfall)
 - Regulatory requirements
 - Management needs

- System specification

The system specification should describe the irrigation system in enough detail so that a quotation may be obtained. It should include a description of the expected system performance, a physical description of the system and a Bill of Quantities.

The specification should include the following:

- Irrigation method
- Effective irrigated area
- System capacity
- Pumping rate
- Pump operating pressure
- Depths of application
- Irrigation cycles
- Application intensity
- Design application uniformity or appropriate measure of uniformity
- A list of the other expected Performance Indicator values
- Pump size and a description of build quality
- Pump motor type and speed
- Pipe lengths and pressure ratings
- Pipe fittings and other accessory components
- Water supply requirements (e.g. new well or surface water intake)
- System monitoring requirements
- Power supply requirements
- Pump shed requirements
- Plan, showing the locations of the proposed infrastructure and the land application area(s)

- Expected operating costs

Operating costs are often an overlooked component of irrigation system design and quoting. Designers, if possible, should quantify or estimate the following expected operating costs, according to the Performance Indicators established:

- Labour to operate irrigation system
- Energy costs of running the system
- Maintenance costs

Operating cost should be expressed as cost per unit area (\$/ha) and cost per unit volume of water (\$/ML).

- Technical analysis

The designer should provide sufficient information to the Irrigator to show that the technical analysis required to arrive at the chosen design has been carried out.

For example, this information should include a summary of pressure calculations, in particular, pressures at key system points, and cost-benefit analysis where alternatives have been considered.

- Warranties and Insurance

The warranties covering the equipment should be detailed in the Specification by the System Designer as well as those warranties covering workmanship by the irrigation installation contractor.

In addition, details of relevant insurances such as Workers Compensation, Public Liability and Professional Indemnity should be provided.

2.17 Irrigation System Hand-over

While the primary role of the designer is to complete the design calculations and create a system specification, some of the designer's responsibilities often spill over into the implementation phase.

2.17.1 Pre-installation

The irrigation system designer must provide all necessary information to the installer. This will include drawings, plans, or specifications that the installer requires to correctly install the system.

This responsibility may extend beyond the initial design specification (i.e. where unforeseen problems arise during the installation process).

The installer is often contracted to, or employed by the designer. In this case, the designer must:

- Ensure that the installer has the necessary relevant skills prior to starting work
- Monitor the progress of the installation to ensure that the design specifications are being met
- Oversee the commissioning of the system

If the installer is contracted directly to the Irrigator, the Irrigator takes on these responsibilities. However, the designer is still often asked to help with these roles.

It is in the best interest of all parties to ensure that an appropriate contract is prepared to outline these roles prior to beginning the implementation process.

2.18 Installation

The installation of spray irrigation systems involves close cooperation between the Irrigator, designer, and the installer(s).

The system installation must follow the design specifications prepared by the designer, and agreed by the Irrigator. Where something is not explicitly specified by the design, the installer may need to consult the designer for further clarification.

The system designer and the Irrigator must both accept any variations to the original specification before the change is implemented.

2.19 Commissioning

Commissioning is the final phase in the installation process and is undertaken by the installer.

A properly executed commissioning process will demonstrate if all components of the system are installed and operating properly, and in accordance with the system specification.

The designer is often involved in this process, either at the system testing phase, or to provide input on how to correct performance issues.

2.19.1 System Testing

The system must be tested by a qualified person and the results of the test supplied to designer and Irrigator.

System testing should include all new components, as well as all pre-existing components that are being incorporated into a system upgrade. This is particularly important for pumping stations.

The following should be tested during installation and/or prior to handover of the system:

- Check that construction debris is removed and then pressure-test the pipelines at 1.5 x the normal operating pressure, if possible. If this pressure is not achievable with the installed pumping equipment, then pressure-test at the maximum achievable pressure
- Check that pump performance meets the specification
- Ensure that all irrigators receive the required pressure and flow rate
- Test all controls, cut-offs, and alarms
- Calibrate flow meters (where applicable)
- Test water application depth, intensity, and uniformity as per contract
- Test all check valves and backflow preventers, including those on the intake.

There are several existing standards that are specific to performance testing of irrigation components that may be appropriate, including:

AS 2417	Rotodynamic pumps – Hydraulic performance acceptance tests
AS 2845.3	Water supply – Backflow prevention devices – Field testing and maintenance
AS 4041	Pressure piping
AS/NZS 1462	Methods of test for unplasticised PVC (uPVC) pipes and fittings
AS/NZS 2566.2	Buried flexible pipeline – Installation
AS/NZS 5902.5	Building and civil engineering drawing practices – Recommendations for drawings associated with engineering services operating manuals and maintenance manuals
ISO 9644	Agricultural irrigation equipment – Pressure losses in irrigation valves – test methods

The New Zealand, Irrigation Evaluation Code of Practice (INZ, 2006), can also be used as a guide to testing. In addition, many pipe suppliers' technical documentation and pipe installation standards contain sections relating to pipe pressure testing.

If any variations from the original design are identified during the system testing, these must be documented on the relevant documentation.

Unless otherwise outlined in the contract, the acceptable deviation from the system specification is:

- Flow rates must not be more than $\pm 5\%$ of the design value.
- Pressures must not be more than $\pm 10\%$ of the design value.
- Current (amps) must not be more than $\pm 5\%$ of the design value.
- Application uniformity must not be $> 5\%$ under that specified.

2.19.2 Correcting Poor Performance

If system testing reveals that actual system performance does not meet the system specification, the fault must be:

- Corrected and the system retested, or
- Reported to the Irrigator.

Any consequences of operating a system that deviates significantly from the system specification must be fully explained to the Irrigator. The Irrigator may decide whether or not to accept the system as installed.

If the Irrigator decides that the system must be made to meet the agreed system specification, the designer (if responsible for initiating the installation) must arrange for the necessary rectification.

This must be done in accordance with the original contract.

2.20 Commissioning documentation

Proper documentation is an essential part of the commissioning process. The documentation should show that the system was checked, and that it was installed and working properly when it was handed over. It should describe the installation and testing procedures followed and the results obtained.

When an irrigation system is handed over to the Irrigator, it should be accompanied by:

- A commissioning report
- As-built plans
- Operation and maintenance manuals
- Any other relevant support information.

2.20.1 Commissioning Report

A commissioning report must be provided to the purchaser describing the system as installed. The report must be supplied within one month of carrying out the testing and commissioning of the system.

The commissioning report will include all of the following:

- The date of commissioning.
- A list of all parties involved with the installation and commissioning.
- A list of contact information for:
 - the designer
 - installers, and
 - those who conducted the commissioning (if different)
- An as-built plan
- A description of the procedures followed during installation and commissioning (i.e. standards, codes of practice, or manufacturers' methods)

- A description of the results of performance testing. At a minimum, this will include:
 - Results of pipe pressure testing
 - Measured pressures and flow rates at key points in the system under normal operation:
 - flow rate at the pumping station(s)
 - pump pressure (total operating head)
 - pressure at the inlet(s) to the irrigation system(s)
 - Water application depth (may be a range)
 - Water application rate (may be a range)
 - Water application uniformity
 - Electrical readings (voltage, amps, etc.) under load
- Copies of any compliance certificates, including:
 - Flow meter calibration
 - Electrical compliance
- Copies of any photographs taken during the installation. This is particularly important for items buried below ground.

2.20.2 As-Built Plans

A final clear and concise readable plan, drawn to scale, with all key items located on the plan must be provided. Ensure that the plan provides accurate locations (minimum accuracy ± 5 metres, however ± 0.5 metres is desirable where possible), dimensions, and sizes of all key components in the system. This is particularly important for items buried underground.

Also provide a detailed plan of the pumping station and suction and discharge pipework, including below ground components.

Provide the as-built plans within one month of commissioning, or within one month of making changes to the system.

2.20.3 Operation Manual

The installer must provide a system operation manual, specifying:

- The correct way to operate all equipment and installations
- How the system should work and its optimal operating range
- How to monitor the system's operation
- Any passwords for electronic equipment
- Protocols for operating the system safely
- Emergency procedures, and
- Contact information for relevant suppliers.

2.20.4 Maintenance Manual

The installer must also provide to the Irrigator a system maintenance manual, including:

- Service manual and parts list
- Schedule of maintenance specifying frequency of inspection and service for key elements of system
- List of monitoring points and methods, and values to be achieved, and
- Contact information for relevant suppliers.

2.21 Training

Training must be made available for the Irrigator (and system operator if different) that covers all of the main items in the operation and maintenance manuals. The designer may be asked to participate in administering this training.

2.22 Final Handover

Final Handover of the irrigation system should not occur until the system testing has been completed and all of the required documentation and training has been provided to the Irrigator. This may include a Certificate of Completion.

DEFINITIONS

For the purposes of this document, the following definitions apply:

Application depth: The rainfall equivalent depth of water applied to the soil surface during a single irrigation event. It is the depth of water that would be caught in a rain gauge, not the depth of soil that is wetted.

Application efficiency: The percentage of applied water that is retained in the root zone, or in the target area, after an irrigation event.

Application intensity: The rate (mm/hour) at which irrigation is applied. It compares “gentle showers” with “heavy rain”. (See further specific definitions below).

- Instantaneous Application Intensity

The rate (mm/hr) at which irrigation is applied by an individual stream, from an individual outlet or nozzle, to a very small area. For example, for a rotating boom it is the flow from a single outlet divided by the area being wetted at any instant by that outlet.

- Average Application Intensity

The rate of application (mm/hr), averaged over the individual applicator’s wetted footprint. For example, for a rotating boom it is the applicator’s flow rate divided by the area wetted by one full rotation of the boom.

Application uniformity: The spatial variability of application. This can be defined in a variety of ways. Common examples are:

- Distribution Uniformity (DU) - is a measure of how uniformly water is applied to the area being watered, expressed as a percentage.
- Coefficient of Uniformity (CU) – Uniformity of Coefficient is a numeric judgment of the overall performance of an irrigation system’s ability to evenly apply water.
- Coefficient of Variation (C_v) - It shows the extent of variability of emitter discharge in relation to the mean and is expressed as a percent.

Check or Non-return Valve: A backflow prevention device designed to prevent water from flowing in reverse through the system. Commonly used to prevent added nutrients, chemicals or effluent from mixing with clean water sources

Design area: The specific land area (e.g. in hectares) which the Designer and the Irrigator mutually understand is to be irrigated by the irrigation system.

Distribution efficiency: A measure of how much of the water supplied to the property reaches the application system. It is a function of losses in the conveyance or distribution system from the point of water abstraction or entry to the property, to the application system.

Effective rooting depth: The depth of soil profile that has enough rooting density for extraction of available water. Roots may be found at depths greater than this value but do not contribute significantly to water extraction.

Evapotranspiration (ET): The rate of water loss from the combined surfaces of vegetation and soil. It includes evaporation of water from the soil and plant surface and transpiration by plants.

Field Capacity (FC): The soil moisture content after gravitational drainage slows from a saturated condition to a rate that is insignificant (i.e. drainage rate less than 1 mm/day).

Hydraulic efficiency: A measure of the system hydraulic performance; it gives an indication of how much pressure is lost between the delivery (mainline entry) and discharge points (machine entry, hydrant, or take-off in drip-micro systems), excluding variations in elevation.

Infiltration rate: The movement of water into the soil profile. Measured as the rate (mm/hour, mm/day) at which a soil absorbs water. It varies with soil type, soil surface condition and moisture content.

Irrigation system: This comprises all of the equipment required to transfer water from the water source to the crops in the design area.

Refill Point: The proportion of the soil Available Water that is allowed to be removed before irrigation is applied. The level is a management decision dependent on crop type, stage of crop development, seasonal water demand and other management factors and constraints.

Permanent wilting point (WP): The soil moisture content where plant is unable to extract anymore water and plant growth stops.

Operating costs: The costs directly attributable to the operation of the irrigation system.

- Labour to operate irrigation system
- Energy costs of running the system
- Maintenance costs

Operating cost should be expressed as cost per unit area (\$/ha) and cost per unit volume of water (\$/ML).

Readily available water (RAW): The soil moisture the plant can extract easily and without stress.

Irrigation Cycle: The typical period between one irrigation event and the next. It is usually calculated for the most demanding period so that the irrigation system can meet water demand most of the time.

Soil moisture deficit: The proportion of readily available water in the soil used by the crop.

Surface runoff: Water that does not immediately infiltrate into the soil and instead leaves the target zone by running off across the soil surface under gravity.

System capacity (SC): The flow of water for the irrigated area expressed as litres per second (L/s) .

Water holding capacity (WHC): The volumetric ratio of all water contained in a layer or depth of soil at field capacity, including that held too tightly for plants to access.

STANDARD FORMULAE

Eqn 1 Crop evapotranspiration (ET_c)

$$ET_c = ET_o \times K_c$$

Where:

ET_c = crop evapotranspiration (mm/d)

ET_o = reference crop evapotranspiration (mm/d)

K_c = the crop water use co-efficient

Eqn 2 Irrigation System Capacity

$$SC = \frac{A \times ET_c}{86400}$$

Where:

SC = system capacity in L/s (litres per second)

A = area (in m^2)

ET_c = crop evapotranspiration (mm/day)

86400 = constant to convert litres per day to L/s

Eqn 3 Designed System Capacity

$$SC_{des} = \frac{SC}{E_a}$$

Where:

SC_{des} = designed system capacity in L/s (litres per second)

SC = system capacity in L/s (litres per second)

E_a = application efficiency (expressed as a decimal – i.e. 90% = 0.9)

Eqn 4 Managed System Capacity

$$SC_{man} = \frac{SC_{des}}{PUR}$$

Where:

SC_{man} = managed system capacity in L/s (litres per second)

SC_{des} = designed system capacity in L/s (litres per second)

PUR = pump utilisation ratio (expressed as a decimal – i.e. 70% = 0.7)

ABBREVIATIONS AND SYMBOLS

A	Area of the irrigated strip
A _e	Application efficiency
CU	Christiansen coefficient of uniformity
C _v	Coefficient of variation
DU	Distribution uniformity
ET	Evapotranspiration
ET _o	Evapotranspiration of a reference crop (usually grass)
ET _c	Evapotranspiration of the crop to be irrigated
EU	Statistical emission uniformity
FC	Field capacity (of the soil)
Ha	Hectare
K _c	Crop coefficient
KWh	Kilowatt hour
L/s	Litres per second
m	Metres
ML	Megalitres
mm	Millimetres
NPSH	Net Positive Suction Head
NPSHa	Net Positive Suction Head Available
NPSHr	Net Positive Suction Head Required
PUR	Pump utilisation ratio
Q	System flow rate
RAW	Readily available water
SC	System capacity
SC _{des}	Designed system capacity
SC _{man}	Managed system capacity
TDH	Total Dynamic Head
WHC	Water holding capacity of the soil or growing medium
WP	Wilting Point

IRRIGATION DESIGN BRIEFING ASSESSMENT CHECK LIST

Assessment Date:	
Assessor:	
Client Name:	
Reference Number:	

The purpose of an irrigation system is to ensure crops / plants / landscapes / sports turf maintain healthy productive growth during times of low rainfall and high evapotranspiration. A well designed and well managed irrigation system should allow:

- efficient use water and energy
- compliance with all regulatory requirements, including consent conditions
- for the system to be robust, reliable, simple and safe to operate
- that the operating and capital costs are minimised

Assessment Criteria:

Critical: A critical non-compliance is one where there is little or no evidence of compliance with the code and/or the design standard; and

- there is high risk of the product/service not meeting specifications; or
- a high risk of human safety; or
- a high risk of environmental damage

A critical non-compliance attracts 25 penalty points

Major: A major non-compliance is one where there is significant departure from the code and/or the design standard; and

- there is a high risk of the product/service not meeting specifications; or
- some risk of human safety; or
- a high risk of environmental damage

A major non-compliance attracts 10 penalty points.

Minor: A minor non-compliance is a departure from the code and/or the design standard:

- that does not risk the status of the product/service; and
- not likely to risk human safety; or
- does not pose a risk of environmental damage

A minor non-compliance attracts 2 penalty points.

The following Documents will act as reference documents for all parts of this work:

BEST PRACTICES:

Irrigation Australia “Irrigation System Design Guidelines”

AUSTRALIAN STANDARDS:

AS 3500.0:1995	National Plumbing and Drainage Code – Glossary of Terms
AS 3500.1.1:1998	National Plumbing and Drainage Water Supply – Performance requirements
AS 3500.1.2:1998	National Plumbing and Drainage Water Supply – Acceptable Solutions
AS 3500.2.1:1996	National Plumbing and Drainage Sanitary plumbing and drainage - Performance requirements
AS 3500.2.2:1996/Amtd 1 - 1999	National Plumbing and Drainage Sanitary plumbing and drainage - Acceptable Solutions
AS 2032: 1997	Code of practice for installation of UPVC pipe systems.
AS 2033: 1980	Installation of polyethylene pipe systems
AS 4129: 2000	Fittings for polyethylene (PE) pipes for pressure applications.
AS 4130: 2001	Polyethylene pipes for pressure applications
AS 1432: 1996	Copper tubes for plumbing, gas fitting and drainage applications.
AS 1477: 1997	PVC pipes and fittings for pressure applications
AS 2698.2 :2000	Plastic pipes and fittings for irrigation and rural applications –Polyethylene rural pipe
AS 2698.3:1990	Plastic pipes and fittings for irrigation and rural applications –Mechanical joint fittings for use with polyethylene micro irrigation pipes
AS 2845.1:1998	Water supply – Backflow prevention devices – Materials, design and performance requirements
AS 2845.2:1996	Water supply – Backflow prevention devices – Air gaps and break tanks
AS 2845.3:1993	Water supply – Backflow prevention devices Field testing and maintenance
AS 2129: 2000	Flanges for pipes and valves and fittings
AS 3000: 2000	Wiring Rules
AS 3008: 2000	Electrical Installations –Selection of cables
AS 2053: 2001	Conduits and fittings for electrical installations (all Parts)
AS 3808: 2000	Insulating and Sheathing Materials for Electrical Cables

PARLIAMENTARY ACTS – *Which State?*

- Sewerage and Water Supply Act 1949
- Electricity Safety Act 2002

AUTHORITIES

- The rules and regulations of the relevant Local Electricity Supply Authority
- The rules and regulations of the relevant Local Water Supply Authority
- The requirements of any other Authority having jurisdiction over the installation

MANUFACTURERS

- The relevant Manufacturers recommendations shall be adhered to at all times.

Gathering Information/Site Checklist

The first stage in the development of an irrigation system to gather the necessary site-specific information needed to complete a design.

Number	Item	Description	Section of CoP	Comments	Design 1	Design 2
A.1		Site Layout				
A.1.1	Map	Obtain a copy of the property map including infrastructure and land features	3.1	This can be covered through a series of labelled aerial and farm maps clearly indicating all aspects as listed. If a section is not applicable (N/A), explain why		
A.1.2	Topography	Identify land features that may affect the design including slope, hills, gullies, waterways	3.1			
A.1.3	Design Area	Identify the areas that the purchaser would like to irrigate	3.1			
A.1.4	Fencing	Identify existing or potential fencing arrangements and the purchaser's preference around relocating, if necessary	3.1			
A.1.5	Shelter and Natural Tree growth	Identify the natural and artificial wind breaks/large trees that are present or will be construction issues	3.1			
A.1.6	Land Restrictions	Identify protected areas or covenants on titles, and the location of any sensitive areas	3.1			
A.1.7	Energy Source	If power is required, locate the nearest supplies and identify any limitations	3.1			
A.1.8	Vandalism	Identify potential for vandalism	3.1			
A.2		Water Source				
A.2.1	Water Supply Location	Identify the location of existing suitable water supplies, or potential future water supplies	3.1	Any uncertainties in gaining access to water and any requirements for gaining access (e.g. easements) should be discussed prior to beginning any irrigation design		
A.2.2	Water Quantity/chemistry	Identify how much water is available, both in terms of flow rate and total volume per season	3.1			
A.2.3	Water Supply Reliability	Determine if water restrictions are a problem that require water storage or extra capacity in the irrigations system for 'catching up'	3.1			
A.2.4	Water Quality	Determine if the water quality is physically and chemically suitable for the proposed irrigation development	3.1			

Number	Item	Description	Section of CoP	Comments	Design 1	Design 2
A.3		Soils Information				
A.3.1	Soil Type	Identify the types and locations of the soils on the property	3.1	This can be covered through a series of labelled aerial and farm maps.		
A.3.2	Available Water Holding Capacity	Determine the depth of water that is available to plants	3.1			
A.3.3	Effective Crop Rooting Depth	Determine the depth from which roots extract water from the soil	3.1			
A.3.4	Management allowable deficit	Determine how dry the soil can become before it requires watering	3.1			
A.3.5	Infiltration rate	Determine the speed at which the soil absorbs water. This may be affected by other soil features such as pans, drains, or stock treading	3.1			
A.3.6	Drainage	Identify any areas with poor or enhanced drainage. This may include natural or artificial soil drainage	3.1			
A.3.7	Variability	Assess the likely variability of soil properties across the property	3.1			
A.4		Climate Information				
A.4.1	Rainfall	Obtain rainfall records for the property, or from the nearest weather station	3.1	A statement should be provided that details where the data has been sourced from and the applicability of this to the farm for each parameter		
A.4.2	Evapotranspiration	Obtain evapotranspiration-related parameters for the property	3.1			
A.4.3	Wind	Determine the prevailing wind directions and normal wind speed for the property	3.1			
A.4.4	Building Shadow	Determine climatic changes due to building shadow such as with High Rise Buildings				
A.5		Regulatory Requirements				
A.5.1	Existing Regulations and By laws	Check that all the relevant regulations both from Local Authorities and State Government Departments have been identified which may affect the system	3.1	How the relevant conditions or rules are to be met by the design should be stated clearly		
A.5.2	EIS requirements	Determine if new EIS reports will need to be obtained and take this into consideration	3.1			
A.6		Farm Management Information				
A.6.1	Animals	Determine if any stock will be grazed in the irrigation areas. If yes, what type and how many?	3.1			

Number	Item	Description	Section of CoP	Comments	Design 1	Design 2
A.6.2	Crops	Identify the types of crops to be grown in the short-term and long-term. Determine if crops contracts impose any conditions with respect to irrigation	3.1			
A.6.3	Other Water Needs	Determine if water is required for other purposes (i.e. drinking water for Golf Course, stock water, fruit cooling, frost protection, leaching of salts)	3.1			
A.6.4	Labour	Determine the skill level of the labour available to operate the system	3.1			
A.6.5	Risk Preference	Determine how much risk of not meeting demand the purchaser is prepared to accept	3.1			
A.6.6	System Type	Determine if the purchaser has any preference for irrigation system types	3.1	State the reasons why		
A.6.7	Process Control	Identify the purchaser's preference for automated checks and controls	3.1			
A.6.8	Price Limits	Determine what the purchaser's limitations are on how much money they are prepared to spend	3.1	Possibility of staging / phasing the project to help with initial costs		
A.6.9	Delivery	Determine the date by which the system must be operational	3.1	If phasing the project, state the date for each stage		
A.6.10	Health and Safety	Identify any health and safety issues pertinent to the site	3.1			
A.6.11	Other	Identify any other issues relevant to the purchaser	3.1			

Design Performance Parameters

The second stage in developing an irrigation system is to determine the level of performance of the future system.

Number	Item	Description	Section of CoP	Comments	Design 1	Design 2
B.1		Irrigation Area				
B.1.1	Location	Determine an appropriate sized and located area	3.1	Aim to irrigate the greatest land area for the greatest benefit		
B.1.2	Project Management	Paddock layout and management factors taken into account	3.1	Take into account covenants on titles or protected areas		
B.2		System Capacity				

Number	Item	Description	Section of CoP	Comments	Design 1	Design 2
B.2.1	Peak Demand	Decide on the peak water demand which is agreed with the purchaser	3.2	Ideally, the design will meet the peak water demand for each crop in the design area		
B.2.2	Capacity	Determine capacity of the system (W) allowing for agreed water losses	3.2			
B.3		Application Depth				
B.3.1	Depth	Application depth range determined	3.3	Show calculations		
B.3.2	Contamination	Identify if any potential contaminants are present	3.3	Care must be taken to avoid leaching		
B.4		Return Interval				
B.4.1	Frequency	Calculate the minimum required return interval	3.4			
B.5		Application Intensity				
B.5.1	Maximum	Determine the maximum application intensity of the system	3.5	Show calculations		
B.5.2	Infiltration Rate	Application intensity does not exceed infiltration rate of the soil	3.5	Show calculations		
B.5.3	Application duration	Determine the different application intensities for different durations	3.5	Show calculations		
B.5.4	Land Slope	Application intensity reduction for sloping ground	3.5			
B.6		Other Performance Targets				
B.6.1	Application Efficiency	Efficiency must be $\geq 80\%$	3.7	Show calculations		

System Design

The third stage in designing an irrigation system is to select components and create detailed plans describing how the system will achieve the design specifications.

Number	Item	Description	Section of CoP	Comments	Design 1	Design 2
C.1		Irrigation System Selection				
C.1.1	Design	Determine the best irrigation system type for the performance targets	3.9	Is it easy to operate? Is it reliable?		
C.1.2	Layout	Take in to account any site-specific constraints	3.9	Take into account sensitive areas or protected areas		
C.1.3	Performance	Compare system to the KPIs.	3.9	Does the system match the soil-climate system? Does this meet the needs of the purchaser?		
C.1.4	Impact Energy	Identify potential problems with stream impact energy. Ensure the irrigation design minimises these problems	3.9	Show selection process		

Number	Item	Description	Section of CoP	Comments	Design 1	Design 2
C.2		Sprinkler/Emitter Layout				
C.2.1	Uniformity	Application uniformity meets standard	3.6	If constraints dictate a system with lower uniformity than standard, the designer must clearly explain why		
C.2.2	Intensity	Application intensity meets or exceeds design specification	3.5	Show calculations		
C.2.3	Pressure	Incorporate elevation variations into calculations	4.2	Pressure range kept within manufacturers recommendation		
C.2.4	Water Quality	Take into account when selecting emitters/sprinklers	4.2	Consider level of filtration and use of fertilisers		
C.2.5	Wind	Take into consideration the frequency and direction of prevailing winds	4.2	Show considerations		
C.2.6	Alignment	Travelling irrigators and linear move systems should operate in straight rows	4.2			
C.3		Hydraulic Design				
C.3.1	Water Velocity	Both maximum and minimum flow velocities should meet standards	4.1	Strike a balance between water velocity and pipe cost		
C.3.2	Pressure	Minimise pressure variation between water outlets; must meet standards	4.2	Show considerations		
C.3.3	Pipe Friction	Friction must meet standard	4.3	Take in to account the effect of pipe type		
C.3.4	Surges and Pressure Relief	Must meet standards. Air release valves and thrust blocks must be specified	4.3			
C.3.5	Filtration	Match to the water quality and system type	4.3	Statement required		
C.3.6	Filter	Filter size must meet standard making sure velocity does not exceed 0.5m/s through screen	4.3			
C.3.7	Efficiency	Both hydraulic efficiency and distribution efficiency must meet standards ($\leq 95\%$)	4.3	Show calculations		
C.4		Pumping Stations				
C.4.1	Design	Determine the best system for the design	4.4	There are many parameters that must be considered, i.e., flow rate, power required, speed, servicing/cleaning		

Number	Item	Description	Section of CoP	Comments	Design 1	Design 2
C.4.2	Duty	Determine the pump flow rate(s). Add the safety factor. What is the most economical solution?	4.4	State rate and show calculations		
C.4.3	Pump Efficiency	Determine the best design, they should operate near or at their maximum efficiency, based on the standards	4.4	Show calculations using pump curves for clarity		
C.4.4	Motors	Select a motor that meets or exceeds the efficiency standards	4.4	Should be matched to pumps so they operate >95% max efficiency		
C.4.5	Centrifugal Pumps	Specify the total suction lift, flexible couplings and a method for priming	4.4	Design to prevent cavitation		
C.4.6	Submersible Pumps	Include allowances for drawdown in the well and fluctuations in groundwater level over time	4.4			
C.4.7	Pump Electrics	Systems must be designed to meet local and national electrical standards and requirements	4.4			
C.4.8	Intakes	Exclude fish, and apply local or national standards if available	4.4	May need to have an infiltration system/ screen to exclude debris too		
C.4.9	Suction Lines	Must comply with the standards	4.4	Show NPSHa vs NPSHr calculations		
C.4.10	Headworks	Allow for easy control and monitoring of system operation	4.4	Show calculations		
C.4.11	Fertiliser	Allow for possible fertiliser injection into the system via fittings in headworks	4.4			
C.4.12	Backflow Prevention	Must be installed on all systems where contamination is possible	4.4			
C.4.13	Pump Sheds	All pumping systems must have a shed that complies with standards	4.4	Show considerations		
C.5		Control				
C.5.1	Control	The design must meet the purchasers needs and meet the standards	4.5	Show considerations, set out control philosophy		
C.6		Measurement and Monitoring				
C.6.1	Flow	Measuring devises must be installed. Determine if your consent requires specific conditions	4.6	Records flow rate and total volume		
C.6.2	Pressure Gauges	Must be installed on all systems. Must comply with standards	4.6	Design should specify where gauges or sampling points are to be installed		

Number	Item	Description	Section of CoP	Comments	Design 1	Design 2
C.6.3	Water Level monitoring and control	Must be installed in the production well and monitoring wells. Must comply with standards	4.6			
C.6.4	Water Quality	Access point needed	4.6	Sampling tap at headwords is recommended		
C.6.5	Soil Moisture	Discuss monitoring options with purchaser	4.6	Show how this relates to control philosophy		
C.6.6	Power Consumption	Monitoring operational power consumption	4.6	Show long term cost calculations		
C.7		Performance Targets				
C.7.1	Finalisation	Prior to finalising the design, check it matches the KPI's set at the start of the process				

Final Specification and Quotation

The last stage in designing an irrigation system is to provide the purchaser with a design report and plan which summarises the final system specifications.

Number	Item	Description	Section of CoP	Comments	Design 1	Design 2
D.1		Final Design Report				
D.1.1	Documentation	Design report and Plan	5.1	Must be adequate to show client the key features of the system, departures from CoP and the KPI's		
D.1.2	Quotation	Bill of Materials	5.2	A bill of materials for major components		