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Manuherikia Catchment Study: On-farm irrigation development

Prepared for Manuherikia Catchment Water Strategy Group

Report No C12119/9

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CENTRAL OTAGO DISTRICT COUNCIL

Ministry for Primary Industries
Manatū Ahu Matua

Otago Regional Council

AQUALINC RESEARCH LIMITED

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EXECUTIVE SUMMARY

This report is one of a suite of reports prepared for the Manuherikia Catchment Water Strategy Group (MCWSG) to provide information to help the Manuherikia community make informed decisions about water in the catchment, leading to a comprehensive Manuherikia Catchment water strategy.

The report covers on-farm irrigation in the development costs section of Part B of the Pre-feasibility study. It describes the key factors relating to the on-farm irrigation development options and covers a wide range of issues including the following:

- Irrigation methods;
- Irrigation efficiency;
- Water supply options;
- Capital and operating costs;
- Labour requirements;
- Impacts on production.

Specific information is provided on the irrigation development process and the key issues – efficiency, water quality and cost, associated with new irrigation development or irrigation upgrades. For those interested in further information, references to various reports and their sources are given.

Each of the issues associated with choosing an irrigation system type is described so that irrigation developers know what to consider and look for.

Finally, a summary of the pros and cons associated with 17 different factors is outlined for the main irrigation system types currently being used or could be used in the catchment.

1 Introduction

The Manuherikia Catchment Water Strategy Group (MCWSG) was set up to develop and oversee the implementation of a water strategy for the catchment. The MCWSG envisages that the project will provide information to help the community make informed decisions, leading to a comprehensive Manuherikia Catchment water strategy.

This study has been made possible by the generosity of the following who have contributed by way of direct funding or by in-kind contributions. MCWSG are grateful for this support and wish to thank the following:

- Ministry of Primary Industries with funding via the Irrigation Acceleration Fund.
- The Otago Regional Council (ORC).
- The Central Otago District Council (CODC).
- The Manuherikia Community.

Figure 1 provides an overview of the study.

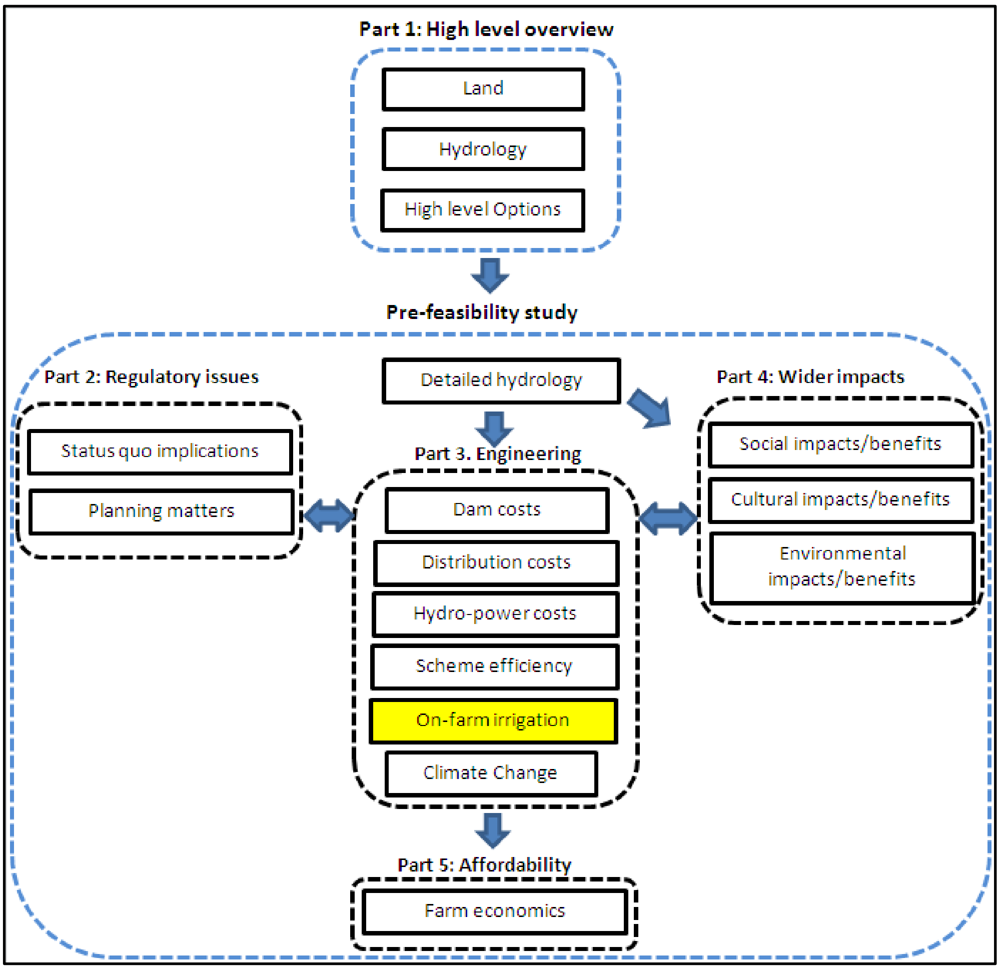

Figure 1: Manuherikia Catchment Study overview

This report covers on-farm irrigation in the development costs section of Part B: Pre-feasibility study. It describes the issues relating to the on-farm irrigation development options and covers a wide range of issues including the following:

- Irrigation methods;
- Irrigation efficiency;
- Water supply options;
- Capital and operating costs;
- Labour requirements;
- Impacts on production.

2 Irrigation development

When contemplating new irrigation or upgrading existing irrigation, a full evaluation of the options, pros and cons, costs (capital and operating), and expected benefits must be completed.

As every farm and farming situation is different, the evaluation needs to be site specific. However, there are some general principles that can be applied. This report presents information on various aspects of irrigation development as a starting point in the evaluation process.

Some sources of information are:

- The Irrigation Guide[1]
- The NZ Irrigation Manual[2]
- INZ Irrigation Decision Support Package[3]
- Case studies on irrigation development[4]

These documents are available from the INZ websites www.irrigationnz.co.nz. or www.irrigationefficiency.co.nz.

2.1 The process

Regardless of whether irrigation is going to be developed by individual farmers or as part of a community scheme, the process that should be followed is similar despite the fact that the scale of development can be very different.

[1] McIndoe, I., Engelbrecht, R., Attewell, D., (2004). The irrigation guide. A guide to decision-making when going irrigating. Prepared for the South Canterbury Farmers Irrigation Management Group. June 2004.

[2] Malvern Landcare Group (2001) The New Zealand irrigation manual. A collection of information sheets on irrigation design and irrigation management prepared for the irrigation industry. May 2001.

[3] Irrigation NZ. (2011). Irrigation decision support package. A tool box for farmers to determine the best irrigation solutions for their farm. An INZ Technical and Trade Guide.

[4] Irrigation NZ. (2011). Four case studies using the Irrigation Decision Support Package to assist with obtaining quotes and design input.

A high-level analysis, involving addressing the key issues is needed first to answer the question, should you irrigate or upgrade your irrigation system.

- What should the irrigation system be designed to do?
- What options are open to you?
- How much water do you need?
- Is scheme water available? If so, under what conditions?
- What kind of irrigation system might suit your property?
- Will you need to obtain resource consents to take and use water? If so, is there a reasonable chance of getting consent?
- Is irrigation going to be economically viable?

It is well worth reading Chapter 2 of The Irrigation Guide to help you through this process. Note that in-depth detailed design is not required at this stage of the process. That comes later.

2.2 Key Issues

The environment in which you must operate is changing. Water is being allocated on the basis of efficient use and the impact of irrigation use on water quality must be considered. Some past practices will no longer be permitted and others may require resource consents. It is critical therefore, that these issues are taken into account in the initial high-level evaluation.

2.2.1 Irrigation Efficiency

Irrigation efficiency means different things to different people. However, three key factors that need to be considered at the farm level are:

- Water use - environmental and financial impact,
- Energy use - mainly financial but also environmental impact,
- Cost (capital and operating) - largely financial but also social impact.

The common thread from a farmer's perspective is profitability, and traditionally, this has driven efficiency. However, the regulatory environment will have a bigger impact on efficiency than has been the case in the past.

Several documents are available that describe irrigation efficiency in detail, for example:

- What is irrigation efficiency?[5]
- Irrigation efficiencies[6].

[5] McIndoe, I., Curtis, A. (2012). What is irrigation efficiency. Report No C10043/1 prepared for Irrigation NZ May 2012.

[6] McIndoe, I. (2000). Irrigation efficiencies. A paper presented to the South Island Dairy Events Conference June 2000.

The most commonly-used definition of irrigation system efficiency (from Painter & Carran, 1978), especially by Regional Councils in their water allocation policies is as follows.

$$\textit{Irrigation System Efficiency} = \frac{\textit{Water stored in crop root-zone}}{\textit{Water delivered to farm}}$$

Often users refer to various definitions of irrigation application efficiency, but application efficiency is concerned with the efficiency of a particular irrigation event under a particular irrigation method in a paddock, not what water is delivered to a farm.

$$\textit{Irrigation Application Efficiency} = \frac{\textit{Water stored in crop root-zone}}{\textit{Water delivered to irrigation field}}$$

In most cases, the expectation is that efficiencies of 80% or better are expected. The problem with definitions like these is that although water delivered to the farm or field can be relatively easily measured, water stored in the crop root-zone cannot. We need to rely on past research to give us guidance on the relative efficiencies of various irrigation methods.

Examples of typical irrigation application efficiencies are given in the following table.

Table 1 : Typical irrigation system application efficiency

System type	Application efficiency range (%)
Linear move	80-95
Centre-pivot	80-95
Side roll	65-90
Hand shift	65-90
Travelling gun*	60-90
Fixed boom (low pressure)	60-90
Fixed boom (medium pressure)	75-90
Rotary boom*	70-90
Long-lateral	60-85
Movable sprayline	50-80
Laser-level border 24 m 200 m long 230 litres/sec*	30-75
Laser-level border 36 m 200 m long 230 litres/sec*	37- 75
Standard 4 strip border 200 m long 230 litres/sec*	27- 67
Note: * From Winchmore irrigation efficiency study (LE, 2002).	

The important point about this table is that it shows that application efficiency varies over a wide range of potential values. There have been measured examples of application efficiencies under some systems that are much lower than the values stated in the table. However, there are very few recorded examples of values higher than those in the table. Typically, pressurised irrigation systems have application efficiencies of 50 – 90% and surface water schemes 20 – 80%.

Given today's technology, it is possible to design an irrigation system that could achieve close to 100% application efficiency, but it would be so expensive that it would not be financially viable.

Considering application efficiency alone does not give the full picture. For example, under-irrigation could significantly increase efficiency, but would result in lost production and profit. Rather than specifying efficiency targets, the requirement to implement processes that improve efficiency of water use and requiring water users to demonstrate that those processes have been implemented is recommended.

Benchmarks relevant to measurable goals or targets will need to be used. These benchmarks may be at the on-farm level and therefore directly relevant to farmers, or at the regional or national level.

2.2.2 Attaining high efficiency

Attaining high application efficiency depends on:

- The design of the system
- How well it is managed

If a system is poorly designed, you will get low efficiency. If it is properly designed, the potential exists to achieve high efficiency. The following table gives an indication of why water may not be stored in the root zone of a crop.

Table 2 : Typical irrigation system losses

Component	**Irrigation System Losses**	
	Range	**Typical**
Open channels	2 – 50%	5-20%
Leaking pipes	0 – 20%	0 - 1%
Evaporation in the air	0 – 10%	<5%
Wind blowing water off paddocks	0 – 20%	<5%
Interception	0 – 5%	<2%
Surface runoff off paddocks	0 – 20%	0 - 10%
Uneven/excessive application depths	5 – 80%	5 - 30%

Evaporation losses from spray systems are much less than is commonly thought, even on hot days. More water is in fact lost from being blown off the irrigated area than actually evaporates. The biggest issues are open-race losses and uneven or excessive application depths.

Some of the factors that specifically affect efficiency of border-strip and spray systems are as follows:

Factors affecting border-strip efficiency

- Length of border – efficiency decreases with border length.
- Construction of system – efficiency increases with standard of levelling (sills and borders).
- Flow down border – efficiency increases with increase in flow rate per unit width.
- Soil infiltration rates – efficiency is lower for high infiltration soil (high K values).
- Soil moisture deficit – efficiency increases with the level of pre-irrigation soil deficit.
- System operation – efficiency decreases with irrigation times greater than required.

Factors affecting spray irrigation efficiency

- Leaking pipes – can be prevented with good design, installation and maintenance.
- Evaporation in the air – tends to be small, but preferably water at night.
- Water blown away by the wind – also small, but avoid watering in strong winds.
- Irrigating areas not requiring water (e.g. roads) – try very hard to eliminate.
- Interception by the crop – is less important.
- Surface run-off – indicates excessive application intensity relative to soil conditions.
- Uneven application – due to poor design or to wind. One of the biggest issues.
- Excessive application depths – indicates poor design and/or management.

2.2.3 Water quality

Irrigation water that drains through the soil profile to groundwater and then to streams, or water that runs off land into streams and rivers, is not lost. It is moved from one location to another, and may be used by others further down the catchment. That is why overall efficiency of irrigation water use is high in the upper Manuherikia catchment.

Water that drains to groundwater carries with it nutrients, particularly nitrates that will eventually impact on environmental values. Likewise, water that runs directly into streams and rivers will carry nitrates, phosphorus and possibly bacteria with it, again impacting on environmental values.

The amount of drainage through the soil profile or amount of runoff into streams therefore has an impact on water quality. The application efficiency of various systems, which is about what happens in the paddock, provides a relative measure of the amount of drainage and runoff that could occur. The higher the application efficiency, the lower the drainage and runoff.

Regional Councils are required to set water quality limit policies for water bodies in their region. Otago Regional Council is already doing that. The implication for irrigation is that irrigation systems that achieve high application efficiency will be required. That will rule out the use of some irrigation systems types in some locations.

Although particular irrigation system types are unlikely to be prohibited, the water quality limits will require a close evaluation of the less efficient methods to determine whether they can meet the limits.

2.2.4 Water supply

How scheme water for irrigation is delivered to a farm has a significant impact on the success or failure of irrigation on that farm.

Key variables include:

- Method of delivery
  - Open race
  - Low pressure pipes
  - Piped under pressure
- Timeliness of supply
  - Rostered
  - On demand
- Reliability
  - Highly reliable
  - Subject to some restrictions
  - Subject to frequent restrictions

The method of delivery – piped, piped under pressure, open race affects capital and operating costs. The timeliness of supply affects the type of irrigation system able to be utilised. The reliability affects production.

Irrigation development, whether it be new irrigation or upgrades to existing irrigation, is capital intensive and should be able to proceed on the basis that is profitable. To be profitable, it needs to be efficient. To be efficient, water needs to be applied when it is needed. Just-in-case irrigation needs to be replaced with just-in-time irrigation.

To achieve high efficiency, water supply must be reliable and available on-demand. Without reliable and timely water delivery, it will be difficult to justify the capital expenditure associated with new irrigation development or upgrading existing irrigation. Reliability and timeliness for surface water supplied system can be dealt with on-farm to some extent through building of storage dams. However, it is normally much more cost-effective to deal with reliability and delivery at a scheme level.

Water delivered in open races is ideally suited to gravity surface-water irrigation methods. It can also be used for spray irrigation, but water needs to be pumped to provide the necessary pressure for spray systems. Water delivered in pipes at low pressure also needs to be pumped.

Water delivered under pressure in pipes is the preferred method. The value of the pressure through not having to install and operate pumps is currently equivalent to about $2000 worth of capital expenditure/ha for a typical irrigation system.

2.2.5 Irrigation system cost

The cost of installing or upgrading irrigation is very site-specific. However, some systems tend to be more expensive than others. The following table gives indicative costs of some systems, based on recent costs of installed systems. The higher costs are for more complex layouts. The lower costs are for simple layouts.

Table 3 : Indicative irrigation system costs

Component	Irrigation System Costs	
	Capital ($)	Annual energy costs ($/y)
New centre-pivot system, open race delivery to top of property	$3500 - $4500	$200-$250
New centre-pivot system, open race delivery to middle of hilly property	$4500 - $6000	$400 - $450
New centre-pivot system, piped delivery under pressure, simple layout	$2500 - $3500	$0
New centre-pivot system, open race delivery to bottom of hilly property, high lifts	$6000 - $7500	$450 - $800
New K Line, open race delivery to top of property, light- med soils	$3000 - $4000	$150-200
New K Line, delivery under pressure, light- med soils	$2000 - $3000	$0
New rotary boom, delivery under pressure, light- med soils	$3000 - $4000	$0
New border-strip, open race delivery to top of property	$2500 - $3500	$0
Upgrade border-strip, open race delivery to top of property	$2000 - $3000	$0
Long-lateral, delivery under pressure, light- med soils	$3000 - $4000	$0
Hard-hose gun, open race delivery to top of property	$3000 - $4000	$300 - $400
Solid set delivery under pressure (medium)	$6000 - $8000	$0
Solid set open race delivery to top of property, medium pressure	$7500 - $9500	$250 - $300
Solid set open race delivery to top of property (high pressure guns)	$7500 - $10000	$400 - $750

When assessing the difference in costs between various options, it is critical to include all of the annual operating costs. They include debt servicing, operating (labour) costs, maintenance costs, and water charges.

Some systems, because of their lower efficiency, will need to be operated for longer each year than systems with high efficiency to maintain similar production. That will impact on energy costs and water costs as well as labour and maintenance.

Systems such as solid-set appear expensive, but because they can be automated require little or no labour, and can be programmed to apply specific depths of water to specific areas to increase efficiency, may work out to be cost-effective overall compared to other systems.

Spending additional capital on technology on pivots such as VRI (the ability to vary application depth at any point in the field) can result in both energy and water savings and also potentially production increases.

There is no one-size-fits-all when it comes to the cost of irrigation. Although the costs given in Table 3 are suitable for initial irrigation planning, further detailed design for individual properties will be required to determine more accurate capital and operating costs for a farm.

3 Choosing an irrigation system

There are a number of broad requirements that farmers usually want from an irrigation system. They are:

- Low capital cost
- A system that grows the maximum amount of quality crop
- Highly efficient water application
- Low energy cost
- Low labour
- Idiot proof – easy to operate
- Reliable with low maintenance
- Environmentally acceptable

In selecting an irrigation system, it would be great if a system could be designed that met all of the above requirements. However, ***there is no perfect irrigation system***. The choice of system always requires compromise. For example, there is usually a trade-off between labour and capital. At one end of the spectrum, a sub-surface drip system meets all of the above requirements except low capital cost. At the other end, wild flooding has low capital cost and no energy cost but would struggle to meet most of the other requirements.

With spray irrigation, there is often a trade-off between operating pressure, which affects capital and running costs, and application efficiency, which is a function of factors such as application intensity and wind effects. Guns, for example, have high operating costs and are more affected by wind but have low application intensity.

Low pressure booms have lower operating costs but high application rates, which can cause surface ponding and lower application efficiency.

3.1 Factors to Consider

The factors that need to be considered when selecting an irrigation system type are described below.

3.1.1 Application intensity

Often referred to as application rate, this is the rate that the irrigator itself physically applies water to the soil. It is usually measured in mm/hour, and should not be confused with irrigation system capacity, which is stated in mm/day.

Ideally, with sprinkler irrigation systems, water should not be applied to the soil at a rate faster than the soil can absorb the water. If it is, ponding of water on the surface will occur, causing water to move off the higher spots into the low spots in the field. The low spots then end up with too much water and the high spots with too little water, resulting in under-irrigation on the high spots and drainage through the soil profile in the low spots.

Ponding on the surface also causes water to run down the macropores - cracks and wormholes - in the soil, resulting in uneven watering and drainage.

Knowledge of the infiltration characteristics of the soils and the application intensity of the irrigator is required to address this issue.

3.1.2 Application depth

The main issue here is to ensure that the irrigation system can be controlled to apply water at depths that don't exceed acceptable soil moisture deficits, generally field capacity minus stress point.

Some irrigation systems can only apply a fixed depth of water, and if that depth exceeds the soil moisture deficits, inefficient irrigation and drainage through the soil profile will occur. Other systems can apply a wide range of depths by changing the travel speed or changing the watering times.

The ease of changing application depths must be considered. Some systems can be adjusted to apply smaller depths, but if it requires shifting a machine more frequently that once daily, may not be suitable. Other systems may require a change of nozzles or sprinklers, which if needing to be done frequently may not be suitable.

3.1.3 Distribution uniformity

One of the most important facts to consider is distribution uniformity, because it affects the overall efficiency of the system. Distribution Uniformity (DU*)* is a measure of how uniformly water is applied to the area being irrigated.

On surface irrigation systems such as border irrigation, it is affected by the standard of grading, soil variations and infiltration characteristics of the soil.

On spray systems, it is affected by factors such as the type of sprinkler used, sprinkler spacing, operating pressure, application intensity compared to the soil infiltration rate, prevailing wind and standard of maintenance. It refers to any factor that causes water to be applied unevenly.

A spray irrigation system may have excellent uniformity in still conditions but be highly susceptible to wind effects. Other systems may have poorer uniformity in still conditions, but be less affected by wind.

Often, spray irrigation systems with high application uniformity also have high application intensities, resulting in surface ponding. This leads to poor uniformity in the soil, and lower efficiency.

Compromise is usually required between application intensity and distribution uniformity.

3.1.4 Labour issues

The labour required to operate irrigation systems varies enormously. Automated systems such as fixed centre-pivots can reduce the labour required for daily operation of the system to a few minutes per day. Most automatically controlled systems are more expensive than high labour requirement systems. The capital cost of automation should be weighed against the labour cost, including maintenance, to obtain a comparative cost.

When selecting an irrigation system, you should also find out how much time and what skills will be needed to operate the system, and how much maintenance is likely to be needed. On many properties, shifting irrigators is often required to be carried out by unskilled workers, and finding reliable people to do the job can be difficult.

You should also ensure that operation of the system fits in with other farming activities.

3.1.5 Operating pressure

This can give you an indication of the cost of operation when pumping is involved. In general, the lower the operating pressure, the lower the running cost.

Low pressure systems may cause difficulties in other areas. For example, boom irrigators or centre-pivots can be fitted with low pressure spray nozzles running at 70 kPa, but will suffer from high application intensity. It may be better to use sprinklers that operate at slightly higher pressure to obtain higher overall efficiency.

Where water is delivered under pressure to a farm, the savings in capital and operating costs through not having to pump need to be factored into the decision-making process.

3.1.6 Energy requirements

The energy input into irrigation systems in New Zealand normally refers to electricity required for pumping, although centre-pivot and lateral move irrigators also require additional energy for propulsion.

Operating low pressure systems may at first appear attractive, because pumping costs can be lower, but may be less efficient applicators of water. To get a given amount of production, it is usually necessary to run inefficient systems longer, resulting in additional energy costs.

Choosing the right pump and motor for the application is vital to minimising energy use. There are significant differences in maximum pump efficiencies of different pump models. Also, electric motor efficiencies can vary between models. This means that there may be significant differences in energy use between pumps that provide similar duties.

3.1.7 Cost

The initial capital cost of an irrigation system is usually substantial. Higher-cost systems tend to utilise modern technology, particularly automation, to reduce labour demand. It is extremely important to consider both initial “capital” investment and on-going “annual” operating costs including the cost of labour, repairs and maintenance.

3.1.8 Reliability and service

To get the best out of an irrigation system, it must run to specification. All systems require repairs and maintenance, with some requiring more than others.

As systems age, the money and time spent on repairs and maintenance increases, and may become a significant part of the total running costs of the system. In addition, breakdowns can result in serious loss of production, particularly if they occur at the peak of the season.

Before purchasing an irrigation system, find out how reliable the system is, how much maintenance is required, and how many years’ service can be expected from the system. It is best to talk to existing users of equipment to find out about its reliability, and whether service is available. Find out how much of the maintenance can be carried out by farm staff, without the need for trained service technicians.

Poor water quality due to sand, organic materials, precipitation of solids, and iron in the water can have a significant effect on system life and reliability. It is important that you choose system components appropriate to the quality of water.

Avoid dealing with irrigation companies that cannot, or will not, commit to servicing systems within a few hours, or in more serious cases, a few days.

3.1.9 Effective life

Effective life of a system depends on hardware quality, system design and service. Irrigation systems usually last for many years. Low-cost systems generally do not last as long and may need replacement or major repairs within a few years, especially if operating in harsh conditions.

Higher-cost systems may have a long effective life, but where they employ new technology, could become obsolete. This is particularly true for imported equipment, where spare parts may not be available after ten or fifteen years.

3.1.10 Enterprises

Some systems are ideally suited to watering certain kinds of crops and not others. This is becoming an important issue because contracts for supply of some crops may only be obtained if specific irrigation system types are used.

It is vital to check with the purchasers of crops before choosing an irrigation method to ensure that the selection will be suitable, although this consideration may be a trade off with a number of other factors.

3.1.11 Damage to crop

Movable irrigation systems can cause any damage to crops, due to:

- Wheel tracks of the irrigation machine;
- Wheel tracks of vehicles used to move the machine;
- Hose drag damage in crops.

Possible damage should be assessed.

3.1.12 Watering irregular areas

Some irrigation systems cannot be used to water odd-shaped areas. It does not mean that these systems should not be used on irregularly-shaped properties. They can be used to irrigate a large percentage of these properties and the remaining areas irrigated with more flexible systems.

However, it is usually better, if possible, to try to keep systems as simple as possible and only use multiple system types if absolutely necessary.

3.1.13 Contour

The slope of land can significantly affect the choice of system. Both the physical ability of the system to operate on slopes and the potential for surface runoff away from the irrigated area must be considered. Systems with low application intensities are normally preferred on slopes exceeding 5 degrees.

3.1.14 Affect by wind

The biggest problem with wind is that it upsets the uniformity of water application on spray systems. Wind can blow some water away from the area that is being irrigated. Some areas will get too much water, while others will get too little. Evaporation is also higher in windy conditions.

Systems that discharge water under high pressure high into the air are usually most affected. Systems that discharge water under low pressure close to the ground are usually least affected. However, these systems are more likely to also have high application rates and infiltration rate problems.

Surface irrigation systems are generally not affected by wind.

3.1.15 General acceptance

A useful guide for irrigation system performance is how widely a particular irrigation system type is used and what it is used for.

Common system types tend to perform well, to be reasonably priced and be well supported. However, a system should not be avoided simply because it is not widely used, because it may offer major advantages over the traditional system types.

3.1.16 Fencing

Some irrigation systems can accommodate flexible fencing arrangements, while others cannot. Implementation of some systems will require major re-fencing, which adds to the cost of the overall system.

The requirement to move fences should not be a major reason for not using a particular type of system. Remember that you only move fences once. You have to operate an irrigation system for many years. The golden rule is to design your fences around the irrigation system, not the other way around.

3.1.17 Shifting

For movable systems, the ease of shifting, the time it takes and the skills required to do it safely, are important issues. There is no point is buying an irrigation system if you are going to spend many hours of the day moving it. If the design of the system requires moving irrigators such as guns or rotary booms over long distances, serious thought needs to be given as to whether it is the best option. Moving irrigators is a major cause of damage and accidents.

Systems that need a high degree of skill to move correctly should also viewed with caution. If one skilled person is dedicated to operating the system, it is generally acceptable. If numerous general farm staff are required to do the shifting, it may not be a good idea.

3.1.18 Shelter

Shelter belts are common on many farms to reduce evapotranspiration and to protect crops and livestock from wind. They are usually very worthwhile for farms that use sprinkler irrigation systems because they help to reduce the effects of wind on sprinkler patterns maintaining better uniformity and reduced evaporation.

For fixed irrigation systems, shelter belts do not usually cause any problems. For movable systems, they may be an issue for two reasons. The first is that the way the irrigators cover an area often restricts where shelter can go. For example, on large centre-pivot systems, traditional internal shelter may not be possible. For boom irrigators, shelter must be in rectangular patterns because boom irrigators irrigate rectangular paddocks. The second issue relates to moving the irrigator from one paddock to the next. Highly sheltered paddocks can make it very difficult to move large boom irrigators, movable centre-pivots or linear machines from one paddock to the next.

3.1.19 Other factors

These include factors such as:

- Whether the system can be delivered on time;
- Financing or payment terms available;
- Guarantees;
- Personal preference.

4 Irrigation methods

There are many types of irrigation system. The most commonly used in agriculture in New Zealand are summarised below:

Surface Irrigation

- Border-strip
- Furrow irrigation (less common)
- Contour irrigation
- Wild flood

Sprinkler Irrigation

- Hand-shift
- Skid pans/ end-tow/ angle-tow
- Side-roll/ power-roll
- Solid set – portable and permanent
- Hard-hose reel and gun
- Soft-hose gun
- Fixed boom linear move
- Rotary boom (e.g. Roto-Rainer)
- Lateral move (or linear move)
- Fixed centre-pivot
- Towable centre-pivot
- Movable laterals (e.g. K-Line)
- Long laterals

Drip/micro irrigation

- Drip irrigation
- Sub-surface drip irrigation
- Micro-irrigation

4.1 Surface Irrigation

4.1.1 Border-strip irrigation

Border-strip irrigation is a gravity operated system that transfers water through open channels or races from a source such as a river or dam to a series of evenly graded strips or borders separated by low earth ridges. Flow to the borders is achieved by operation of a series of gates in the races at the top of the borders, with flow to each border controlled by grass or wooden sills.

Application Intensity	Not applicable as surface is flooded
Application depth	Generally 80-200mm or higher
Distribution uniformity	Can be high but generally variable
Labour requirement	Low - medium
Hydrant pressure	Not applicable
Capital investment	Medium
Reliability & service	Good with regular maintenance
Effective life	Can be long, up to 40 years with good maintenance
Enterprises	Good for pasture and some crops – less flexible
Damage to crop	Minimal. Some crops dislike growing in a temporarily saturated soil
Watering irregular areas	Good as long as flow is controlled properly
Contour, slope	Requires very uniform gently sloping land.
Affect by wind	None
Acceptance	Varies, very few new systems being installed
Fencing	Easy – important headraces are fenced
Shifting	Not applicable
Shelter	Easy to arrange shelter pattern around layout

This is the traditional method of irrigation that has been used on the majority of community irrigation schemes in New Zealand. Today, the number of new border systems being installed is very low. Many existing systems on the lighter soils have been converted to spray, as production on spray systems tends to out-perform that on border systems.

The method is often considered to be an inefficient method of irrigation from a water-use perspective. However, with good design in the right conditions, it can be as efficient as some spray irrigation systems. Its low labour requirement, long life and simplicity make it an attractive method of irrigation where pasture is grown and where an adequate gravity-fed water supply is available.

Whether to retain or improving existing border systems will have to be considered. If they are on low water holding capacity soils with high infiltration characteristics, it is unlikely that border systems will achieve future efficiency expectations. The only borders that will be able to achieve high efficiency will be on high water holding soils with low infiltration rates, be relatively short and well-graded, and have high unit flows.

4.1.2 Contour irrigation

Contour irrigation or contour flooding involves running water under gravity from water races or furrows that follow the contour of the land and is more commonly used in hill country where water is available. The furrow is temporarily dammed or a gate opened in the furrow wall so that water runs down the area to be irrigated. Any excess water is collected by the next furrow down and the process repeated.

Application intensity	Not applicable as surface is flooded
Application depth	Variable, generally 50 mm or higher
Distribution uniformity	Highly variable
Labour requirement	High and constant
Hydrant pressure	Not applicable
Capital investment	Low - medium
Reliability & service	Good with regular maintenance
Effective life	Can be long, up to 50 years or more
Enterprises	Pasture only
Damage to crop	Not applicable
Watering irregular areas	Very effective if furrows designed for it
Contour	Slightly more forgiving than border-strip
Affect by wind	None
Acceptance	Becoming obsolete
Fencing	Easy
Shifting	Not applicable
Shelter	Not an issue

Its biggest disadvantage is that it is very labour intensive, because someone has to be continually managing the closing or opening of the furrows.

This method of irrigation is in limited use today and is unlikely to be used on new systems.

4.1.3 Wild flooding

Wild flooding is a gravity supply method that involved discharging water from open races or ditches directly onto paddocks little or no form of control. The water simply "floods" onto a paddock with the aim to water as large an area as possible.

Application intensity	Not applicable, as surface is flooded
Application depth	Generally high and variable
Distribution uniformity	Extremely variable
Labour requirement	Medium
Hydrant pressure	Not applicable
Capital investment	Low
Reliability & service	Average, needs frequent attention
Effective life	Can be long
Enterprises	Pasture only
Damage to crop	Not applicable
Watering irregular areas	Not usually used
Contour	Is used on gentle – moderately steep country
Affect by wind	None
Acceptance	Becoming obsolete
Fencing	Easy
Shifting	Not applicable
Shelter	Not an issue

This is a low input method of irrigation with variable results. It is generally out of favour as it is difficult to use water efficiently. Access to paddocks can be a problem because of the need to cross races. As with contour irrigation, it is unlikely to be used on new systems except perhaps for temporary watering.

4.2 Sprinkler Irrigation Systems

4.2.1 Hand-shift, skid pans, end tow or angle tow

These systems consist of aluminium or plastic pipes ranging between 50 mm and 125 mm diameter and fitted with impact sprinklers spaced at 9-24 m apart. The aluminium pipelines (usually called laterals) are typically up to 300 m long and operate at each position for several hours per day. They are then moved to the next position. Mainlines may be aluminium pipe (without sprinklers) or permanently buried PVC pipelines.

In hand shift systems, the pipes are moved by hand. Skid pan, end tow or angle tow systems are variations of the hand shift system, the main difference being that the laterals can be towed into the next position.

Application intensity	Low-medium, 7.5-15 mm/h
Application depth	Wide range, 5-100 mm
Distribution uniformity	Generally good
Labour requirement	High and demanding, 1-3 shifts/day
Hydrant pressure	Medium, 300-500 kPa
Capital investment	Low
Reliability & service	Good
Effective life	Good
Enterprises	Good for pasture and short crops
Damage to crop	Limited

Watering irregular areas	Average to poor
Contour	Requires flat or gently sloping land
Affect by wind	Generally OK
Acceptance	OK but becoming obsolete
Fencing	Can be a small hindrance
Shifting	Quite slow
Shelter	Easy to arrange shelter pattern around layout

These methods, particularly hand-shift systems, are still found in market gardens, small orchards and lifestyle properties. The capital investment involved in them today is usually very small (second-hand), and they serve a very useful purpose.

They can be used efficiently if shifted at the recommended spacing, as their application intensities are quite low and sprinkler distribution uniformity quite high. Their biggest problem is the need to shift them two or three times a day if the area to be covered is large. Another problem is that over their long history, many of them now have a range of different sprinkler types and nozzle sizes, resulting in poor uniformity and incorrect operating pressures.

4.2.2 Sideroll/power roll

The sideroll is an advancement of the hand-shift system. The aluminium pipe is used as the axle for 1.5-2.0 m diameter wheels spaced 9-12 m along the lateral. The wheels allow the lateral to be rolled from one irrigation setting to the next. They can be up to 500 m long, although 400 m is more usual.

A power roll uses a small diesel or petrol engine and gearbox mounted on a four-wheel carriage to turn the lateral and roll it into the next position.

Application intensity	Low-medium, 7.5-15 mm/h
Application depth	Wide range, 5-100 mm
Distribution uniformity	Generally good
Labour requirement	Quite high, 1-3 shifts/day
Operating pressure	Medium, 300-500 kPa
Capital investment	Low-medium
Reliability & service	Good

Effective life	Good (except in strong winds)
Enterprises	Good for most crops & pasture
Damage to crop	Limited
Watering irregular areas	Not suitable
Contour	Requires flat or gently sloping land
Affect by wind	Generally OK for long sets and good management
Acceptance	OK but becoming obsolete
Fencing	Can be a problem
Shifting	Slow unless properly planned for
Shelter	Difficult to arrange shelter pattern

These units are now quite uncommon, having been replaced by more labour efficient systems. As with hand-shift systems, they can be used efficiently as their application intensities are quite low and sprinkler distribution uniformity quite high if shifted at the recommended spacing. Their biggest problem is also the need to shift them two or three times a day if the area to be covered is large.

4.2.3 Solid set

This method of irrigation is not particularly common in New Zealand, although it is widely used overseas. It is expensive to set up, but offers significant advantages over most other forms of irrigation, particularly in areas unsuitable for centre-pivots and on steeper, challenging country.

Solid set sprinkler irrigation systems have sprinklers arranged in a regular square, rectangular or triangular pattern over an irrigated area. Normally sprinklers are mounted on risers that are connected to the water supply via laterals, submains and mainlines. The sprinklers are operated individually or in blocks, depending on the level of control and on pipeline configurations.

The systems may be permanent, where laterals, submains and mainlines are buried, or portable where the pipes are moved into and out of crops on an as-required basis. Some systems are a combination of the two and may have permanent mainlines and submains, but removable laterals and sprinklers, or permanent laterals and removable sprinklers.

A wide range of sprinkler sizes can be used, from small plastic sprinklers through to big-guns. The choice of sprinkler and sprinkler flow determines the sprinkler spacing and layout according to the desired irrigation application intensity and uniformity.

Portable systems tend to use smaller sprinklers installed on polyethylene or similar pipe to remove the need to install sprinkler riser support. While portable solid-set systems can be removed from an area and that removes the need to farm around the sprinkler risers, the labour involved in moving them can be substantial. Also, fully automating portable systems is very difficult.

Permanent solid set systems tend to use large impact or big gun sprinklers mounted on solid risers such as fence posts. The larger flows and throw diameters of these sprinklers means less of them and less interference to farming activities. Permanent solid set systems can be relatively easily automated with sprinklers controlled individually or in blocks according to crop water need.

Application intensity	Low-medium, 10-20 mm/h
Application depth	Wide range, 5-100 mm
Distribution uniformity	Generally good
Labour requirement	Very low
Operating pressure	Medium, 300-600 kPa
Capital investment	High
Reliability & service	Good
Effective life	Good (subject to water quality)
Enterprises	Good for most crops & pasture
Damage to crop	Nil
Watering irregular areas	Very suitable
Contour	Can be designed for flat to steep
Affect by wind	Generally OK
Acceptance	Not widely used, but expanding
Fencing	No problem
Shifting	Not applicable
Shelter	Can be easily arranged around shelter

4.2.4 Hard hose reel and gun

A hard hose reel and gun system (commonly called a hard-hose gun) consists of a large high pressure sprinkler (gun) mounted on a small carriage where water is supplied to the gun through a rigid polyethylene hose. A water turbine or piston mechanism is used to turn a large stationary reel or drum, which slowly winds in the hose, pulling the gun carriage along the field. Hose lengths typically range from 200-400 m and lane spacing from 50-100 m.

Application intensity	Low-medium, 10-20 mm/h
Application depth	Wide range, 10-100 mm
Distribution uniformity	Average – good, but poor in wind
Labour requirement	Low, 1-2 shifts/day
Operating pressure	High, 600-1200 kPa
Capital investment	Medium/high
Reliability & service	Generally good if well maintained
Effective life	Good
Enterprises	Good for most crops/ pasture
Damage to crop	At headlands and limited in crop
Watering irregular areas	Very good
Contour	OK for flat or moderate slopes, need to watch appl. rates
Affect by wind	Can be major
Acceptance	Good
Fencing	Generally no problems
Shifting	Very good except on soft ground
Shelter	Easy to arrange intensive shelter pattern

One of the biggest advantages of hard-hose reel type machines is the ease of shifting, which takes typically 15-30 minutes unless they have to be shifted long distances. They are also very suitable for irrigating irregular areas. Because they apply water over a large circular area, average application intensities tend to be low, which is an advantage. However, the instantaneous application rates from water from the gun can be very high. Crop damage tends to be small providing that the gun is operated at high enough pressure to ensure good stream breakup. Damage is mainly caused by towing the gun carriage out into the crop.

The biggest disadvantages are the poor distribution uniformity in windy conditions and the high operating costs where water has to be pumped. The poor uniformity in windy areas can be overcome to some extent by designing the system to operate at a closer lane spacing than is usually recommended, and using low angle guns. Because guns water a circular pattern, some areas may not be able to be watered unless adjacent areas are watered.

Care must be taken when operating the larger machines on soft wet ground, as they can become bogged and difficult to move.

An option with these machines is to replace the gun with a collapsible boom, which can be folded up during transportation. The boom can be operated at lower pressures, is less affected by wind (although strong winds can damage the boom) and can irrigate into corners. However, it removes some of the flexibility when irrigating irregular paddocks.

4.2.5 Soft hose travelling gun

Unlike hard hose guns where the gun is on a carriage, the gun is mounted on the machine itself and the machine is winched along a travel lane using a wire rope. Water is supplied from the hydrant to the irrigator through a soft flexible hose 50-125 mm in diameter, which drags behind the irrigator as it winches itself along. They tend to cover similar areas to hard hose guns, i.e. runs up to 400 m long and lane spacing up to 100 m.

Application rate	Low-medium, 10-15 mm/h
Application depth	Wide range, 10-100 mm
Distribution uniformity	Average, but poor in wind
Labour requirement	Medium, 1-2 shifts/day
Operating pressure	Medium-high, 500-900 kPa

Capital investment	Medium/high
Reliability & service	Generally good if well maintained
Effective life	Good
Enterprises	Good for most crops/ pasture
Damage to crop	Hose drag in crops
Watering irregular areas	Reasonable
Contour	Similar to soft hose guns, better on the flat
Affect by wind	Can be major
Acceptance	Good
Fencing	Generally no problems
Shifting	Generally good – relatively easy
Shelter	Easy to arrange intensive shelter pattern around runs

These types of machines have been widely used for many years. The two main drive systems are piston drive and turbine drive. Where pressure is at a premium, a piston drive machine is better because it requires less pressure to operate. These machines take longer to shift than the hard hose reel machines because of the need to purge and roll up a hose, but because they are relatively small they are easy to manoeuvre. They also need an anchor for the wire rope and some crop damage will occur if the hose is dragged through the crop.

As with all guns, they suffer from poor distribution in windy conditions, but tend to have low application intensities. They should be operated as much as possible in calm or low-wind conditions and at appropriate lane spacing for the conditions. Often, the biggest problems with these irrigators are that they are operated at inappropriate gun pressures or on a lane spacing that is too wide.

4.2.6 Fixed boom, soft hose

Linear booms are similar in operation to soft hose travelling guns except that a fixed boom fitted with a series impact sprinklers, mini-sprinklers or low pressure spray jets rather than a single gun is used to apply water to the field. These systems also use a wire rope to winch themselves along, dragging a soft flexible hose behind them. The booms typically range in length from 50-90 m, watering up to 100 m in width. Run lengths range from 200-750 m, with 400-600 m being very common.

Application intensity	Medium-high, depending on outlet type, typically 20-50 mm/h
Application depth	Wide range, depending on available travel speeds, 10-100 mm
Distribution uniformity	Good, but vulnerable at high pressures in windy conditions
Labour requirement	Medium, 1-2 shifts/day
Hydrant pressure	Medium (for impact sprinklers) 400-700 kPa
Capital investment	Medium/high
Reliability & service	Generally good if well maintained
Effective life	Depends on make, but generally good
Enterprises	Good for most crops/ pasture
Damage to crop	Hose drag damage in crop
Watering irregular areas	Can be difficult
Contour	Best for flat areas or gentle slopes, not suitable across contour
Affect by wind	Can be significant in strong winds, can blow over.
Acceptance	Good
Fencing	Needs to be planned to suit
Shifting	Quite difficult and unwieldy
Shelter	Can arrange shelter pattern around runs

Fixed boom travelling irrigators are common throughout New Zealand, particularly on larger properties. These machines are usually driven by high-speed turbines, low-speed pelton wheels, or pistons. The independent drive systems provide flexibility in terms of the range of depths that can be applied and the range of application devices that may be used.

Older systems were fitted with either low pressure spray nozzles that suffered through excessive application intensities, or medium pressure impact sprinklers that required higher pressures to operate.

Generally, low pressure systems have the advantage of low operating costs, high uniformity and less effect by wind, but experience serious problems with ponding and surface redistribution. Using higher pressure outlets such as impact sprinklers increases operating costs, decreases uniformity a little and increases the wind effects but because of the greater wetted footprint significantly decreases ponding and surface runoff. For this reason, Rotators and impact sprinklers are commonly seen on booms today as a compromise between performance and operating cost.

Travelling booms are ideal for irrigating rectangular paddocks because they can irrigate into the corners. They are best suited to areas that are not constrained by shelter belts or other obstructions.

As with all soft hose machines, hose drag can damage crops and they require a winch anchor.

Booms can be difficult to move around intensively sheltered areas.

4.2.7 Rotary boom, soft hose

Rotating boom irrigators are very similar to linear boom irrigators except that the boom rotates continuously, driven by the reaction of the large drive nozzles at the end of the boom. The rotation of the boom drives the winch, making travel speed dependent on boom rotation speed. The booms typically range in length from 40-75 m, watering up to 100-105 m in width. Run lengths range from 200-800 m, with 500-600 m being very common for the larger machines.

Application intensity	Average low-medium 15-25 mm/h, but high instantaneous rate,
Application depth	Average range, depending on travel speeds, 30-70 mm
Distribution uniformity	Average-good, average in high winds
Labour requirement	Medium, 1-2 shifts/day
Hydrant pressure	Medium, 400-600 kPa
Capital investment	Medium/high
Reliability & service	Generally very good
Effective life	Very good
Enterprises	Good for most crops, especially pasture
Damage to crop	Hose drag damage in crop
Watering irregular areas	Not great, leaves out corners and variable application depths at run ends
Contour	Best for flat land or gentle slopes, not suitable across contour
Affect by wind	Small, but slows down in strong winds. Can blow over.
Acceptance	Excellent
Fencing	Needs to be planned to suit
Shifting	Quite difficult and unwieldy in tight areas, otherwise reasonable
Shelter	Need plenty of room to move around shelter

Rotary boom irrigators are widely used for irrigating pasture, particularly on dairy farms. They are simple in construction, generally very reliable with good performance, and extremely well accepted.

Because they water a large circular area, average application intensities are low, with very little ponding occurring. Uniformity is reasonably good in calm conditions provided that machines are nozzled correctly and operated at recommended pressures. Because water is carried to the ends of the boom, the water distribution pattern is much less affected by wind than with guns.

The rotation speed of the boom and therefore the travel speed can slow down in strong winds resulting in more water being applied than perhaps needed, and the system not reaching the end of the run when expected. Independent drives can be fitted to some machines to eliminate this problem, but that option increases complexity, cost, and required hydrant pressure.

Although there is some scope for changing application depths by changing travel speeds, they are less flexible than machines with independent drives because they will not operate at low flows and are generally not used where small depths of water are required.

They do not water into corners unless overshoot into adjacent areas is allowed, and should not be used on crops where the impact of the end jets on the ground will cause problems.

These machines take longer to shift than guns because of the need to purge and roll up a hose, and the need to manoeuvre a large boom. They also need an anchor for the wire rope and some crop damage will occur if the hose is dragged through the crop.

4.2.8 Linear move (lateral move) end or centre-fed, soft hose

Linear move irrigation systems consist of a series of galvanised steel spans (the same as for centre-pivots) that move slowly down a field in a direction perpendicular to the spans. The spans are supported above the crop on wheeled towers 40-55 m apart. Water is usually pumped to the machine, to one end or to the centre, through a soft flexible hose or a rigid polyethylene hose from permanent underground mainline. Laterals may range from single span units about 100 m long to multiple span units of 20 or more spans that may stretch more than 1 km. Hose lengths are typically not more than 200 m long allowing 400 m runs. The area covered per hose shift ranges from 4 ha to as much as 40 ha.

Application intensity	Medium, 25-40 mm/h
Application depth	Wide range, depending on travel speeds, 10-100 mm
Distribution uniformity	Usually very high
Labour requirement	Low, except between blocks, 1-2 shifts/day
Hydrant pressure	Low, 200-400 kPa
Capital investment	High
Reliability & service	Generally good if well maintained
Effective life	Depends on make, but generally good
Enterprises	Good for most crops/ pasture
Damage to crop	Minor from wheel tracks in crop
Watering irregular areas	Poor
Contour	Best for flat or gently rolling land; need to watch application intensities on slopes
Affect by wind	Not significant except in strong winds, can blow over
Acceptance	Good
Fencing	Needs to be planned to suit
Shifting	Easy if properly planned, difficult if not
Shelter	Can arrange shelter pattern to suit

With more emphasis being placed on irrigation uniformity and the ability to apply variable applications, lateral move irrigators have increased in popularity, particularly for large cropping farms, but also on dairy farms.

The biggest advantage of these machines is their high distribution uniformity and their ability to apply a wide range of depths. Although application intensity can be a problem if applying large depths of water particularly on sloping ground, ponding and surface redistribution can be minimised by applying small depths more often. These features make linear machines very good for watering crops.

A wide range of sprinkler types can be fitted to them ranging from LEPA (low energy precision applicators), low pressure spray jets through to large impact sprinklers. However, the preferred choice of sprinkler currently are low pressure plastic sprinklers, with excellent uniformity and reliability at an acceptable application intensity.

Because sprinklers tend to be quite closely spaced, linear systems are not greatly affected by wind.

Farm shape must suit these machines to make them most effective, with long rectangular areas without obstacles being best. They are not suitable for small irregular areas. Generally, they are hose-fed from one end, so damage to crops is limited to wheel tracks every 50 metres or so. Shifting only requires moving the hose except where end-towing is needed to move to another block. Drive systems are usually independent, with diesel generators mounted on the machines being most common. Although they will operate on sloping ground or rolling country, they are better on relatively flat ground to avoid or minimise surface runoff.

Much of the same technology that is used on linear machines is also used on centre-pivots, so they effectively have a long history of use around the world.

4.2.9 Fixed centre-pivot

Centre-pivots irrigation systems consist of a series of galvanised steel spans that rotate in a circle about a fixed point in a paddock. The spans are supported above the crop on wheeled towers 40-55 m apart. Water is pumped to the centre of the pivot through underground mainline. Fixed pivots may range from single span units covering 2 hectares up to 20 or more spans covering 300 hectares or more.

Application intensity	Medium-high particularly at ends, 15-75 mm/h
Application depth	Wide range, depending on travel speeds, 5-100 mm
Distribution uniformity	Excellent in all but strong windy conditions
Labour requirement	Extremely low
Hydrant pressure	Low-medium 200-300 kPa
Capital investment	Medium on large systems, high on small systems

Reliability & service	Excellent if well maintained
Effective life	Depends on make, but generally very good
Enterprises	Good for most crops and pasture
Damage to crop	Very limited wheel track damage
Watering irregular areas	Needs basic circular or square areas, some land will be unwatered
Contour	OK on flat or rolling country; watch application intensities on long pivots in particular
Affect by wind	Not significant except in strong winds. Can blow over.
Acceptance	Very widely used
Fencing	Needs to be planned to suit, electric internal fencing often used
Shifting	Not required
Shelter	Can arrange shelter pattern around circular areas

As with lateral move irrigators, more emphasis being placed on irrigation uniformity and the need to apply variable application depths has increased the popularity of centre-pivots. The control systems of centre-pivots allow enormous flexibility such as changing application depths over the full circle or in different sectors simply by programming in requirements. When managed correctly, centre-pivots can minimise water use through very efficient application of water.

Fixed centre-pivots also have one other major attraction and that is a very low labour requirement. Most of the operational time is spent on routine maintenance, as operation is very simple.

On larger full-circle systems, the cost per hectare irrigated is low, making them extremely cost-effective.

Part-circle pivots (wipers) have become quite popular, but keep in mind that the capital cost/ha is higher than for full circle pivots. In addition, they need to reverse over ground that may have just been irrigated, so should be used with caution on areas subject to bogging.

Generally, centre-pivots have very high application uniformity and the ability to apply a wide range of depths. Application intensities are very low at the centre of the pivot, and increase with distance from the centre.

On long systems (exceeding about 600 m), sprinkler flow rates and therefore application intensities at the ends can be very high because of the large area watered by the end spans. This can create problems with ponding and surface redistribution, which can be minimised by applying small depths of water more often.

A wide range of sprinkler types can be fitted to them ranging from LEPA systems, low pressure spray jets through to large impact sprinklers. However, the preferred choice of sprinkler is now low pressure plastic sprinklers, which have excellent uniformity and reliability with an acceptable application rate.

Because sprinklers tend to be quite closely spaced, these systems are not greatly affected by wind.

Farm shape must suit these machines to obtain good overall coverage. Square or circular areas with no obstacles are best. They can be used on flat or rolling country at slopes that most other irrigation systems cannot operate on, but they are not suitable for small irregular areas. Some farm systems and shapes make them impractical.

Generally, they are fed directly from the centre, so damage to crops is limited to wheel tracks every 50 metres or so. Drive systems are usually independent, with underground electric cable or diesel motors being most common. Mechanically, they will operate on flat or rolling country at slopes of 10 degrees or more (check with supplier for details). However, surface redistribution and runoff could occur on the steeper land.

Computer controlled technology is improving on centre-pivots and linears, providing increased reliability and versatility. Sector operated end-guns have been utilised for many years to extend the diameter of the wetted circle or to partially water corners. Control systems can be fitted to operate sprinklers individually or in banks, giving excellent control over application depths at any location under the pivot.

Controllable corner towers can be used to cover most of the corners. However, before purchasing corner towers, make sure that you understand the implications of adding the corner, particularly with respect to additional cost/hectare watered, the additional flow and pump duty required to supply the corner and the lower reliability generally provided by corner units. Corner towers should only be used on flat or gently sloping land.

4.2.10 Towable centre- pivot

Towable centre-pivots are similar in basic construction to fixed centre-pivots. The main difference is that the pivot point is not fixed and the whole system can be towed from hydrant to hydrant. The pivot point is mounted on skids or wheels and the wheels on each tower can be rotated to allow the unit to be towed. Water is pumped to each hydrant through underground mainline. Towable pivots tend to be smaller than fixed systems, ranging from single span units covering 2 hectares up to 6-8 spans covering 30-40 hectares.

Application Intensity	Medium-high depending on flow rate 15-50 mm/h
Application depth	Wide range, depending on travel speeds, 5-100 mm
Distribution uniformity	Excellent in all but strong windy conditions
Labour requirement	Medium
Hydrant pressure	Low-medium 200-300 kPa
Capital investment	Low on large systems, medium on small systems
Reliability & service	Good, but frequent towing will increase maintenance
Effective life	Generally very good
Enterprises	Good for most crops and pasture
Damage to crop	Limited wheel track damage
Watering irregular areas	Needs basic circular or square areas, some land will be unwatered
Contour	OK on flat or rolling country; watch application intensities

Affect by wind	Not significant except in strong winds
Acceptance	Now very good, more widely used
Fencing	Needs to be planned to suit, electric internal fencing used
Shifting	Must be done with care, generally only possible in straight or nearly straight lines
Shelter	Can arrange shelter pattern around circular areas

These systems have most of the advantages and disadvantages of fixed centre-pivots, although many farms using towable pivots eventually replace them with fixed units.

Flow rates and application intensities can be quite high compared to small fixed pivots because they are irrigating several circles in a rotation.

They are often more cost-effective than fixed centre-pivots because the same machine is used to cover a number of positions. Because they are moved, they tend to be smaller than fixed units. Generally, hydrants are placed at centre positions, so very short flexible hoses are used. Moving is achieved by jacking up and rotating the wheels to allow end-towing.

Farm shape is less critical than with fixed pivots, but again square or circular areas with no obstacles are best. Sector operated end-guns are used to extend watering into the corners. Generally, they are fed directly from the centre, so damage to crops is limited to wheel tracks every 50 metres or so. Drive systems are usually independent, with diesel motors or water drive being most common. Some systems have permanently installed underground electric cable, which is the most convenient.

Because they are moved, maintenance tends to be higher. Purchasers of these systems must ensure that they are designed for regular towing.

4.2.11 Movable laterals (K Lines)

These systems consist of moveable sprinkler lines (laterals) that are connected to permanently buried mainlines and submains. The sprinkler laterals are made up of polyethylene pipe with sprinklers spaced at 12-20 metres. Each sprinkler is mounted in a pod or on a skid to allow the lateral to be towed to a new position with a four wheeled ATV or other vehicle. A typical lateral will range from 50-200 m long and be moved 12-20 m for each shift. One or more lines may be required for each paddock.

Application intensity	Very low 3-8 mm/h
Application depth	Generally fixed at 50-80 mm over 24 hours. Need more frequent shifting or operate for less hours per day for lower application depths.
Distribution uniformity	Poor to average depending on sprinkler and lane spacing
Labour requirement	Medium -high
Hydrant pressure	Low-medium 250-350 kPa
Capital investment	Generally low
Reliability & service	Usually requires regular maintenance
Effective life	Reasonable if treated carefully and well-maintained
Enterprises	Best for pasture, limited in other crops
Damage to pasture	Very little
Watering irregular areas	Best in rectangular areas, but some flexibility
Contour	OK for flat or rolling country
Affect by wind	Low-medium, worse at wide sprinkler spacing
Acceptance	Very good, now quite widely used
Fencing	Best planned to suit, but generally quite flexible
Shifting	Quite easy but time consuming
Shelter	Can arrange shelter pattern to suit

The use of movable laterals systems such as K Line has expanded rapidly over the last decade. Their biggest advantage is their low cost compared to other systems. This allows farmers to get into irrigation at relatively low cost. In addition, they are simple and can be installed and maintained by farmers.

Because small sprinklers are used, application intensities tend to be very low, although ponding and surface redistribution over long watering times will occur on sloped ground. Provided appropriate pressure control is employed, this low application intensity makes them suitable for operation on heavy soils and on rolling hill country if application depths and watering times are adjusted according to local conditions.

If operated 24 hours per day, they apply 50-80 mm of water or more, so soils must be able to accommodate these depths. This also means that rotation times tend to be longer than other systems.

To keep application intensities and depths as low as possible, sprinkler spacing are generally wider than standard manufacturers' recommendations, resulting in average to low uniformity. However, the low uniformity is counterbalanced to some extent by good absorption of water into the soil.

They are best used for irrigating pasture, and quite easy to move. Shifting time depends on the number of K Lines on the property. Small sprinkler nozzles make them more susceptible to blockages, and small plastic sprinklers running continuously may increase maintenance requirements.

4.2.12 Long lateral, impact sprinklers

Long-lateral systems (also known as bike-shift or long-line systems) are medium-sized impact sprinklers mounted on a movable stand that is connected to a permanently-buried mainline using polyethylene pipe. Each sprinkler is moved manually around 6-10 positions to cover 0.4-0.8 hectares.

Application intensity	Low 15-25 mm/h
Application depth	Generally fixed at 35 mm or higher
Distribution uniformity	Average depending on operators shifting pattern
Labour requirement	Medium - high
Hydrant pressure	Medium 400-500 kPa
Capital investment	Medium
Reliability & service	Average-good
Effective life	Good if well-maintained
Enterprises	Best for pasture, not used much in other crops
Damage to pasture	Very little
Watering irregular areas	Very flexible, often used to water irregular areas
Contour	OK for flat, or rolling country if fitted with pressure regulators
Affect by wind	Minimal problem, can shift to compensate
Acceptance	Very good, quite widely used
Fencing	No problem
Shifting	Quite easy, but time consuming
Shelter	Can easily arrange shelter pattern to suit

Although long lateral systems have had a major upsurge in use in some areas over recent years, similar systems have been used for several decades. Recent refinements include sprinklers on movable skids and flexible polythene hose. They are quite commonly used to fill in odd-shaped areas and corners on farms using travelling irrigators or centre-pivots.

Because sprinklers are operated in isolation, application intensities are low and ponding or surface redistribution tends to be small. This makes them suitable for a wide range of soil types. They will also operate successfully on rolling or terraced country provided that appropriate pressure control at the sprinklers is maintained.

To obtain good uniformity, sprinklers should be moved in a regular pattern. Performance is directly affected by where sprinklers are moved, and complacency in this respect is not uncommon. Shifting time is one of the biggest disadvantages of this system, with the larger systems taking several hours to move.

Many long lateral systems have been designed to operate for only 10 hours per day. This is partly for convenience, partly to meet design requirements, partly to utilise night rate electricity, and sometimes related to available water supply. This requires much bigger system components, pumps, pipes, and higher cost than would be needed for a system that operates for 20-24 hours per day.

4.3 Drip and Micro Irrigation

4.3.1 Micro irrigation

Micro irrigation utilises permanent small spray or rotating sprinklers primarily to irrigate orchards. The sprinklers are usually mounted on small diameter polyethylene or PVC laterals running along the crop rows. The laterals are fed by PVC or polyethylene buried submains or manifolds so that a block of laterals is operated at the same time.

Water is supplied to the submains from permanently buried mainlines, with control valves positioned between the mainlines and submains allowing automatic or manual control of water to each block.

Application intensity	Medium - high 15-50 mm/h
Application depth	Wide range possible with automatic control
Distribution uniformity	Average depending on operators shifting pattern
Labour requirement	Very low
Valve pressure	Low-Medium 200-400 kPa
Capital investment	High
Reliability & service	Average-good
Effective life	Good if well-maintained
Enterprises	Best for horticulture & permanent row crops
Damage to crop	None
Watering irregular areas	Can be designed to fit any shape
Contour	Can be designed for slopes up to 30 degrees
Affect by wind	Minimal problem
Acceptance	Very good, quite widely used
Fencing	No problem
Shifting	Not required as system is fixed
Shelter	Can easily arrange shelter pattern to suit

The area wetted by micro systems depends on the lateral layout, the type of sprinkler used, flow rates and operating pressures. Some systems are designed to apply water to a strip, while others apply water over the total area, including inter-row areas.

Micro systems are quite expensive to install, but can easily be totally automated. This means that operating labour costs are very low and a wide range of application depths can be applied. Typically water is applied over a short time period. This can range from several times per day on greenhouse crops to once every three days on large tree crops.

Many micro systems require regular maintenance to repair or replace sprinklers and lateral pipes, which can be damaged during normal activity in the orchard.

4.3.2 Drip/Tape systems

Drip or tape systems are similar in construction to microsprinkler systems. The main difference is that the laterals utilise drippers rather than sprinklers to irrigate a narrow wetted strip. The lateral can be located on the surface or held above ground on support wires.

Crop types under drip tend to be row crops such as vegetables, although vineyards and some orchards are irrigated using drip systems.

Application rate	Not applicable
Application volume	Can range from 0.5 ℓ/h to 4 ℓ/h
Distribution uniformity	Not relevant
Labour requirement	Low
Hydrant pressure	Low 70-350 kPa
Capital investment	High
Reliability & service	Average-good
Effective life	Good if well-maintained
Enterprises	Best for horticulture & permanent row crops
Damage to crop	None
Watering irregular areas	Can be designed to fit any shape
Contour	Generally used on slopes <5 degrees, but some flexibility
Affect by wind	None
Acceptance	Very good, quite widely used
Fencing	No problem
Shifting	Not applicable – fixed system
Shelter	Can easily arrange shelter pattern to suit

Two main types of drip systems are used. One uses individual drippers that are manually connected into lateral pipe where watering is required. The other uses drippers that are built into the lateral pipe at a pre-set spacing in the factory. This can either be drip tube, which is a solid lateral pipe, or tape, which is flat when dry and becomes circular when pressurised.

Drip systems tend to apply small volumes of water over long periods of time, and may need to be operated for 6-12 hours per day. With careful design and operation, drip systems can be a very efficient form of irrigation.

4.3.3 Sub-surface drip irrigation

Sub-surface drip systems are similar to normal drip systems except that the laterals are buried. The laterals are always of the type where the drip emitter is built into the wall of the lateral pipe.

Only the exterior orifice of the emitter is exposed to the soil.

Application rate	Not applicable
Application volume	Can range from 0.5 ℓ/h to 4 ℓ/h
Distribution uniformity	Not relevant
Labour requirement	Low
Hydrant pressure	Low 70-350 kPa
Capital investment	Very high
Reliability & service	Average-good
Effective life	Good if well-maintained
Enterprises	Used for a wide range of crops
Damage to crop	None
Watering irregular areas	Can be designed to fit any shape
Affect by wind	None
Contour	Best on flat or gentle uniform slopes
Acceptance	Very good, becoming more widely used
Fencing	No problem
Shifting	Not applicable – fixed system
Shelter	Can easily arrange shelter pattern to suit

Although these systems are usually totally automated, a high level of design and management is required to ensure that they work to specification and continue to work over long periods.

Special care has to be taken with filtration to stop emitters from blocking, vacuum breakers to stop material being sucked into the laterals and flushing to ensure that the system can be kept clean. Root intrusion into the emitters can be a problem and flushing with root inhibitors, acid or other chemicals will probably be required. Allow for the installation of an accurate flow meter to allow monitoring of flows for possible root intrusion.

The cost of these systems is high but is reducing. The advantages of low labour, high efficiency, low operating pressure and the ability to irrigate irregular areas means that total annual cost of installation and operation will make this method worthy of further investigation for many farms.