# Designing Effective and Efficient Irrigation Systems

MAF Policy Technical Paper 00/09

*by:*
Lincoln Environmental

ISBN 0-478-20054-4

March 2000

## Disclaimer

Requests for further copies should be directed to:

Mrs Jackie Hill
MAF Information Bureau
PO Box 2526
WELLINGTON

Telephone: (04) 474 4100
Facsimile: (04) 474 4111

# Foreword

This is one of a series of 10 technical bulletins, which report the detail of projects commissioned by MAF Policy on sustainable irrigation.

This work arises as part of MAF's contribution towards Government's "Sustainable Land Management Strategy."

The projects in this series broadly divide into two groups, technical irrigation design factors and management factors. A key issue identified by farmers at the onset of this work was that to ensure irrigation could operate in sustainable ways physically and for the environment, it also had to be profitable irrigation.

**The emphasis on water use efficiency and cost effectiveness of plant and management, which has arisen from this, has been developed throughout the research. It is clear that win/win situations are possible. Improvements for both environmental and farm profitability objectives can be achieved.**

More efficient ways of monitoring and managing water use on farms are described in the series.

There is a large amount of base data and technical information in these papers which is likely to be helpful background for designers, consultants and local and regional authorities.

Much of this information is also being incorporated into a simpler National Irrigation Handbook. This is being designed as a ready reference for farmers and commercial firms, and will be available in 2001.

An overall summary of the technical reports in this series and copies of the reports themselves can be obtained from: Information Bureau, Ministry of Agriculture & Forestry, P O Box 2526, Wellington.

A B Walker
Director
Policy Information & Regions

**The other technical bulletins in this series are:**

| | |
|---|---|
| 00/1 | A Summary of Bulletins 00/2 – 00/11 |
| 00/2 | A Survey of Farmers’ Approaches to & Perceptions about Irrigation Management |
| 00/3 | Indicators of Sustainable Irrigated Agriculture |
| 00/4 | Field Testing Indicators of Sustainable Irrigated Agriculture |
| 00/5 | Best Management Guidelines for Sustainable Irrigated Agriculture |
| 00/6 | Testing of Irrigation Best Management Guidelines 1997-1998 |
| 00/7 | Testing of Irrigation Best Management Guidelines 1998-1999 |
| 00/8 | Benchmark Data on Sustainable Irrigation Indicators |
| 00/9 | Designing Effective and Efficient Irrigation Systems |
| 00/10 | Financial Benefits of Making Improvements to an Irrigation System: A Case Study |
| 00/11 | Developing an Effective Irrigation Water-Use Meter |

# Contents

Page

# 1 Introduction

The sustainability of irrigated agriculture depends upon consistently achieving high irrigation application efficiency. High efficiency depends upon excellent design, as well as effective management. Much effort has been spent trying to improve irrigation management in NZ. Unfortunately, the design of many irrigation systems inhibits changes to management that would result in higher efficiency. A recent survey of irrigation operators reveals that this is often true of spray irrigators, as well as those using border-strip. Low irrigation efficiency threatens the renewal of water permits and thus the future of irrigated agriculture.

The aim of this report is to advance the sustainability of irrigated agriculture by providing information relevant tot he design of irrigation application systems that enable use of good irrigation management practices. It sets out to meet these aims by:

- Describing irrigation system performance measures relevant to irrigation design.
- Describing the key factors and critical decisions inherent in the design of irrigation application systems that have the potential to be operated effectively and efficiently.
- Illustrating the effects of some design decisions on performance measures.
- Assessing the feasibility of designing effective and efficient irrigation systems in New Zealand given current information and expertise.

There is an urgent and specific need to determine the maximum realistically achievable application efficiency for border-strip irrigation under typical Canterbury and Otago conditions. The most cost-effective means of doing so is to computer simulate the operation of border-strip systems under a wide range of conditions. Field data from a comprehensive set of field experiments was reviewed to determine its suitability for validating a computer model of border-strip irrigation. This review is included as Appendix I. The relevance of this specific area of work to the overall design process is that a properly validated model is the most cost-effective method of determining the effects on irrigation efficiency of the many border-strip design parameters. Without this tool it will be very difficult to design and compare surface and spray irrigation systems on the same basis.

The design of a travelling irrigator impacts on irrigation management in two main ways. The first is in the ability to easily adjust the mean application depth. The second is in the uniformity of the infiltrated depth of water. This latter aspect depends on interactions between application uniformity, application rate, the infiltration rate, and the micro-topography. A search was made of the international literature to establish what progress had been made since 1985 in understanding of the effects of the above interactions on the uniformity of the infiltrated depth of water and current abilities to predict infiltrated depth under field conditions. There is very little published work in this area. This is not surprising due to the substantial shift of research funds from irrigation (quantity) to water quality research that occurred in the mid 1980s, particularly in the United States. Accordingly, the topic of the planned review is identified in this report as a research issue.

# 2 Irrigation System Performance Measures

Irrigation performance measures are outputs, the results of design and operating decisions. To be useful they need to predictably quantify the effects of design and operating decisions on the extent to which the purpose of irrigation is achieved, and how efficiently the purpose was achieved. They must do this in a way that assists designers and operators to make appropriate decisions.

Unfortunately it is not uncommon for irrigation design courses to focus on one performance measure – irrigation efficiency – and to use it as an input to the design process, rather than using it as one measure of system performance that is to be optimised, along with others, during the design process. It is not surprising, therefore, that performance in the field rarely exceeds, and typically does not match, the assumed performance.

Performance measures, if they are to serve their purpose, must take full account of the following important physical factors. These are:

- Optimum crop growth and yield depends on the maintenance of a specific level of water pressure within the plant. This implies maintaining soil water pressure above a certain threshold.
- At the time of irrigation, the soil's capacity to store additional water is limited.
- There is a limit to the rate at which water can infiltrate soil, and this limit varies over time.
- Irrigation almost always results in the infiltrated depth of water varying throughout the field. Irrigation is not uniform.

The purpose of this section is to describe the key concepts and terms that are the basis of taking proper account of the above physical factors, and then to describe selected performance measures that are relevant to the design and operation of irrigation application systems. The performance measures will be discussed in three categories. The first deals with the effectiveness of irrigation. The second concerns the adequacy of irrigation, or the extent to which the purpose of irrigation is achieved. The third deals with how efficiently the irrigation system did its job.

## 2.1 KEY CONCEPTS & TERMS

### 2.1.1 Critical Soil Water Content

The assumption is made that the goal of irrigation is to avoid loss of income due to crop stress induced by low soil water content. To achieve this goal it is necessary to irrigate, at the latest, when the soil water content has dropped to the point where the crop comes under sufficient stress to cause loss of income. We will refer to this as the critical soil water content. In general, it varies with crop type and soil type.

To determine the critical soil water content it is necessary to know the leaf water pressure (or potential) at which leaf stomata begin to close. If leaf water pressure falls below this threshold the stomata begin to close to reduce evaporative water loss and hence maintain plant tugor. Closure of the stomata also means a reduction in the assimilative capacity of the plant and hence its productivity. It is assumed, for the purpose of irrigation design and operation, that the soil water pressure at which the stomata close is the same as the critical leaf water pressure.

To determine the critical soil water content it is also necessary to know the soil moisture characteristic for the soil to be irrigated because the minimum allowable soil water pressure occurs at different soil water contents for different soil types. The soil moisture characteristic is the relationship between soil water pressure and soil water content.

In summary, the critical soil water content depends on the critical leaf water pressure of the crop to be grown, and the soil moisture characteristic of the soil in which the crop is to be grown. Different combinations of crops and soil(s) will lead to a range of critical soil water contents on each farm.

### 2.1.2 Field Capacity

Field capacity is an estimate of the maximum volume of water that may be temporarily stored in the soil profile for plant use (Skaggs et al., 1980).

Field capacity is defined to be the water content in a field soil after the rate of drainage beyond a specified soil depth has become small. The soil profile should initially be at saturation, and there should be no evaporative losses during the drainage period. The time for drainage to decrease to a small amount varies from a few hours, for coarse-textured soils, to several days for fine-textured soils. The soil water content at field capacity depends on the soil moisture characteristic and the unsaturated hydraulic conductivity for each of the layers that make up the soil profile of interest, the depth to the water table, gravity, and the definition of what is a small drainage rate.

Field capacity has value, as a concept, because it simplifies estimation of the depth of water that might usefully be stored in the soil profile, and the depth of water that may drain from the profile after application of a given depth of water.

### 2.1.3 Infiltrability and Infiltration Rate

Infiltrability (or infiltration capacity) is the rate that water will infiltrate soil when the rate is limited by soil factors only. Infiltrability decreases as the pressure difference, or hydraulic gradient, across the infiltration surface reduces.

The infiltration rate is the smaller of the rate at which water is applied and the infiltrability. As long as the infiltrability is greater than the application rate the water will infiltrate as quickly as it is supplied. If the infiltrability decreases with time, which it often does, to be less than the application rate then the soil surface will become ponded. The infiltration rate will then be controlled by the soil profile.

### 2.1.4 Average Application Depth

Application depth is generally calculated from measurements of flow-rate, irrigation time, and the area irrigated (intended or actual). Because irrigation is non-uniform, this depth is strictly the average application depth. Average application depth can be determined for sprinkler irrigation systems by using a grid of catch-cans to measure the application depth at specific points throughout the wetted area and calculating the areally weighted-average of the measured application depths.

### 2.1.5 Uniformity of Application Depth

The critical water content and water retention characteristics of the soil, along with crop water use, vary spatially within a field. Ideally, irrigation would apply water in a manner that accounts for this spatial variability. However, this level of precision is currently uneconomic and the assumption is made that the soil water deficit at the time of irrigation is the same over the whole field. This leads to the requirement that irrigation systems apply water in a manner that results in an infiltrated depth that is uniform throughout the field. This is rarely achieved in practice and the non-uniformity of application depth markedly affects design and management decisions.

In practice, some areas may receive more water than is necessary to return soil water content to field capacity. The excess water drains beyond the effective root zone and becomes of no value to the crop. Other areas are under-irrigated in the sense that the soil water content is not returned to the target soil water content. Consequently these areas will reach the critical soil water content much sooner than areas that were returned to the target level (i.e. were fully irrigated). If irrigation proceeds on the basis that all areas are fully irrigated, crop yield or quality reduction will occur on those areas that were under-irrigated.

The degree of variability of application depth about the average application depth is the most commonly used measure of application uniformity. The uniformity coefficient calculated by the following formula is referred to, in the irrigation industry, as Christiansen's uniformity coefficient. It is the most widely used measure of application depth uniformity.

$$C_u = \frac{\Sigma \left| x_i - X \right|}{\Sigma x_i}$$

where xi = application depth for subarea i

X = mean application depth over all subareas i.

## 2.2 IRRIGATION EFFICIENCY

True measures of irrigation efficiency take account of the spatial uniformity of application depth, the average application depth, and the soil's capacity to store more water at the time of irrigation. Irrigation efficiency varies with each water application throughout the season, and with site, soil type, and application system.

There are many definitions of irrigation efficiency. The irrigation efficiency principles put forward by Painter and Carran (1978) are conceptually very sound, but are too detailed for general use. For practical purposes it is useful to simplify matters by combining two of their efficiency measures – application efficiency and distribution pattern efficiency. Combining these provides a measure of how much of the water that is applied is actually retained within the effective plant root zone in an irrigation event. By "applied" we mean water leaving the nozzle of a pressurised system, or passing over the sill for border-strip systems. We have retained the term application efficiency to describe this.

The overall on-farm irrigation efficiency is determined by combining the effect of the application efficiency and the on-farm distribution system efficiency.

### 2.2.1 Farm Distribution System Efficiency

Farm distribution system efficiency is a measure of how much of the water supplied to a farm is actually applied. It is a function of losses incurred in conveying water from its point of entry onto the farm, to the application device. Quantifying this efficiency requires measuring flow rates through the turnout or pump and over the sill or out of sprinkler nozzles. This efficiency is typically high.

While there are likely to be differences in the distribution system efficiency between piped and open channel systems, the differences are not expected to be as great as for application efficiency. The distribution system efficiency of a piped distribution system, or an open-channel distribution system on a NZ border-strip irrigated farm, is not likely to be significantly affected by application system design decisions, other than the decision to use a sprinkler or surface application method.

### 2.2.2 Application Efficiency

Application efficiency is a measure of how much of the water that is applied is actually retained in the root zone, in the target area, after an irrigation event. It is principally a function of the soil water status before irrigation, the depth of water that infiltrates the soil, and the soil's water retention characteristic. All of these factors have a considerable degree of spatial variability and this significantly affects the efficiency. It is also a function of evaporative losses, spray drift off the target area, and run-off.

Application efficiency is defined as follows:

$$E_a = \frac{Change\,in\,the\,volume\,of\;\;water\,stored\,in\,the\,effective\,root\;zone}{The\,volume\,of\;\;water\,applied}$$

This definition takes into account losses due to spray drift, evaporation, run-off and drainage beyond the effective root zone.

Sometimes a so-called efficiency is calculated using the average application depth to represent the volume of water applied, and the soil water deficit at the time of irrigation to represent the change in the volume of stored water. As will be seen below, this approach over-estimates the real application efficiency because it does not take account of the non-uniformity of application depth.

Measurement of the spatial variation in application depth resulting from sprinkler irrigation, under a wide range of conditions, has shown the distribution of application depth to be normally distributed. Therefore the change in the volume of water stored in a given depth of soil can be calculated from the mean application depth, Christiansen's uniformity coefficient, and the soil water content at the time irrigation commences (Bright, 1986). The volume of water applied is calculated from the average application depth and the area irrigated.

The relationship between application efficiency and mean application depth is shown in Figure 2-1 for a range of uniformity coefficients. For the purpose of this figure it has been assumed that evaporative, drift, and run-off losses are negligible. The soil water deficit at the time of irrigation is 50 mm.

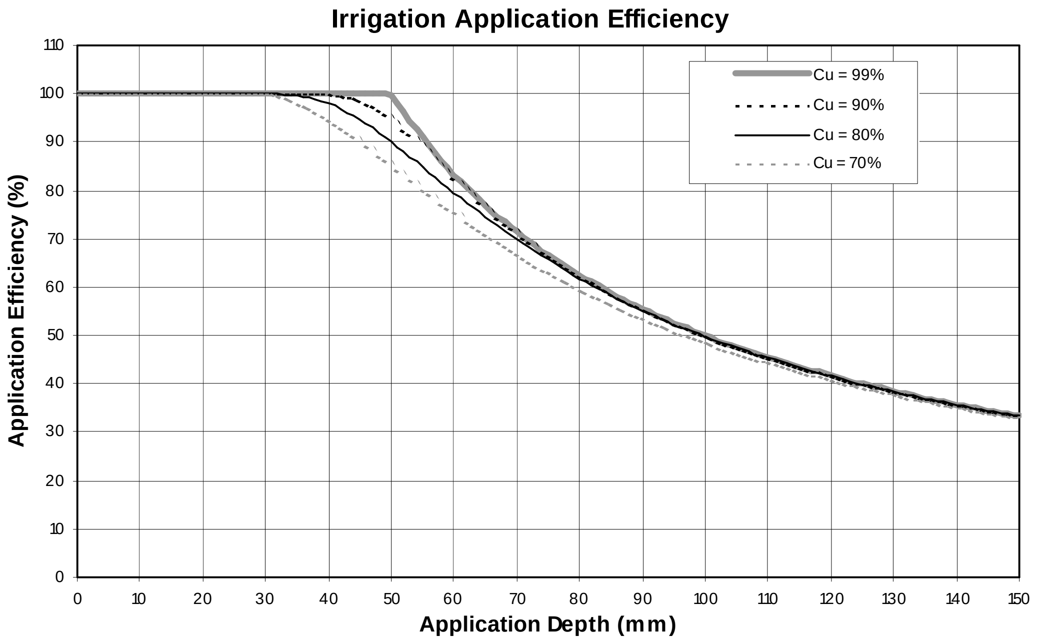

**Figure 2-1: The Effect of Application Depth and Uniformity on Application Efficiency**

For irrigation systems that apply water perfectly uniformly (Uc = 100 percent), and for the assumptions stated, it is clear that the application efficiency is 100 percent until the application depth exceeds the soil water deficit – the depth needed to bring the soil to field capacity. Increasing the mean application depth beyond that point results in a linear decrease in application efficiency.

For irrigation systems that apply water with a uniformity coefficient of 70 percent, for example, the decrease in application efficiency begins to occur at mean application depths significantly less than the soil water deficit. When the mean application depth equals the deficit the application efficiency is about 85 percent. Work by John et al. (1985) suggests that sprinkler irrigation systems in NZ are likely to be achieving application uniformity coefficients of around 70 percent. Therefore assessments of the application efficiency of spray irrigation that ignore spatial variability are likely to over-estimate efficiency by about 15 percent.

There are currently no field measurements of the depth distribution for NZ border-strip systems that would enable field-based measurement of application efficiency.

The potential uniformity of irrigation applications is largely determined by design decisions. Operating conditions such as wind (sprinkler) and surface roughness (border-strip) subsequently modify it. Application system design decisions significantly affect the application efficiency.

## 2.3 MEASURES OF THE ADEQUACY OF IRRIGATION

In theory, application efficiency of greater than 95 percent could be achieved with application systems that apply water reasonably uniformly. However, to do so in practice requires small average application depths and significant soil water deficits after irrigation. Irrigation under these circumstances might not be very effective as a tool for improving crop yield. Losses due to evaporation and spray drift also become a much higher proportion of the volume of water applied.

Application efficiency is therefore not a sufficient measure of irrigation performance. Some measure of the adequacy of irrigation is required. By this is meant some measure of the extent to which soil water content is restored to some management defined level. Two definitions of adequacy are described below, representative of the two main options available.

### 2.3.1 Adequately Watered Area

The concept here is to determine the proportion of the field for which the soil water content is restored to a level that equals or exceeds a set level, or target soil water content. An acceptance level of 80 percent of the field being irrigated to at least this level (adequately watered) may be appropriate for pastoral agriculture. A higher level may be required for high value process crops. The acceptance level is a management decision. The appropriateness, in terms of financial performance, of specific levels of adequately watered area has not been investigated, to our knowledge.

The area adequately watered by an irrigation event is a function of the average application depth, the uniformity of irrigation, the soil water content prior to irrigation, and the target soil water content. The nature of the relationship between application depth and uniformity is illustrated in the Figure 2-2, again assuming a 50 mm soil water deficit at the time of irrigation.

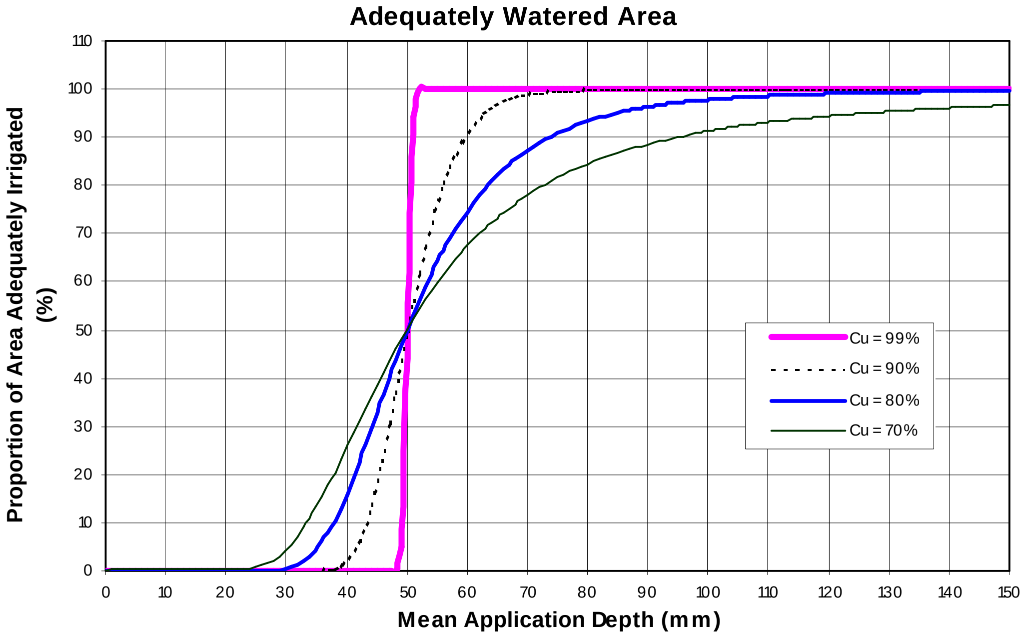

**Figure 2-2: The effect of Application Depth and Uniformity on the Adequately Watered Area**

It is clear that as the average application depth increases, so too does the adequately watered area. However, referring to Figure 2-1, application efficiency decreases. It should be noted that as the uniformity of irrigation decreases, the average application depth required to achieve a specified level of adequately watered area increases. To achieve full irrigation over 90 percent of the area requires a mean application depth of about 95 mm if the uniformity coefficient is 70 percent. The resulting application efficiency is about 51 percent.

### 2.3.2 Application Adequacy

The adequacy of irrigation is not strictly a simple function of the area that achieves or exceeds a specified soil water content. More correctly, it is a measure of the degree to which the soil water deficit over the whole field is met – a volumetric measure analogous to application efficiency. By deficit it is meant the difference between the current soil water content and the target soil water content. The application adequacy is defined to be (Bright, 1986):

$$A_a = \frac{\text{Change in the volume of water in the effective root zone}}{\text{The required change in the volume of water in the effective root zone}}$$

Compared to the adequately watered area concept, this takes account of the water added to the effective root zone, but which does not raise soil water content to, or above, the target level. The effect on the application adequacy of the application depth and uniformity is illustrated in Figure 2-3.

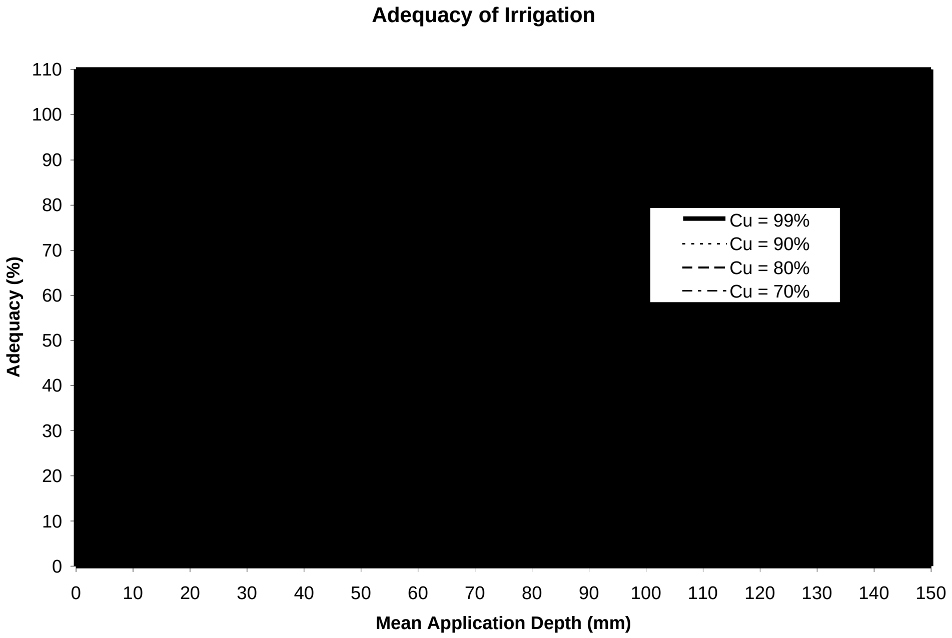

Figure 2-3: The effective of Uniformity on Irrigation Adequacy

Achievement of an application adequacy of 90 percent requires a mean application depth of about 58 mm if the uniformity coefficient is 70 percent. The resulting application efficiency is about 77 percent.

## 2.4 THE EFFECTIVENESS OF IRRIGATION

The effectiveness of irrigation is a measure of the extent to which economic loss, due to insufficient soil water, was avoided. A simple measure is the ratio of actual income to potential income. The practical difficulty with this, and alternative measures of effectiveness, is that not all components of this performance measure can be measured, notably the potential income.

On the basis of the discussion in Section 2.1.1, the key to achieving highly effective irrigation is timing. The latest time an irrigation event can occur without incurring economic loss is the time at which the soil water content drops to the critical soil water content. Furthermore, the timing must be right for each irrigation event, all season. The effectiveness of irrigation is therefore a measure of irrigation performance that integrates the effects of a number of irrigation events.

A simple measure of the effectiveness of irrigation, for design purposes, could be the proportion of the days per season that the soil water content was above the critical soil water content. This measure would not take account of the non-uniformity of irrigation. To do so requires a measure such as the proportion of the days per season when the soil water content over 80 percent of the irrigated area exceeds the critical soil water content. In practice, it is the performance over the whole of the irrigated area of a farm that is relevant. Therefore the measure of effectiveness must integrate over all irrigation events on the farm each season.

# 3 What Factors are the Critical Determinants of Irrigation Performance?

Examination of performance measures describing the efficiency, adequacy and effectiveness of irrigation highlights four factors that are critical to achieving high levels of performance, for any of the measures. These factors are:

- timing;
- depth;
- uniformity;
- water supply characteristics.

If irrigation system design is to create the potential for high performance irrigation, it must result in an application system that farmers can use to irrigate uniformly, in the right amount, and at the right time.

## 3.1 IRRIGATION TIMING AND APPLICATION DEPTH

Getting the timing and application depth right requires information on the critical soil water content for the crop, the current soil water content of the soil, and how much water can usefully be stored at the time of irrigation. It is largely an operational management issue. However two outcomes of the design process significantly affect farmers ability to get irrigation timing and amount right. These are:

- irrigation rate (average area covered per day);
- application depth range.

If the irrigation rate is too low, it is probable that in long periods of dry conditions the effectiveness of irrigation will drop, regardless of depths applied. Soil water content will drop below critical levels and crops will come under sufficient stress to cause income reduction. If farmers increase application depths, rather than irrigation rate, in an attempt to maintain production, efficiency will fall because the additional water cannot be stored in the soil.

Application system design often concentrates on the maximum depth that is likely to be required. Application systems that can only apply a narrow range of application depths clearly have limited ability to match application depth to the soil water storage capacity at the time of irrigation. For annual crops or irrigation systems supplied on a rostered basis, the amount of water that can be usefully stored at the time of irrigation varies throughout the season. Application efficiency will be low if the application depth is unable to be adjusted downwards to match the minimum expected soil water storage capacity at the time of irrigation.

## 3.2 UNIFORMITY

There are two main determinants of the uniformity of the infiltrated depth of water. These are the spatial uniformity of water supply to the infiltrating surface (usually the soil surface) and the temporal uniformity of water supply to the infiltrating surface. The relative significance of each of these to the uniformity of infiltrated depth differs depending on the type of irrigation system.

### 3.2.1 Surface Irrigation

The spatial uniformity of water supply to the soil surface is essentially 100 percent for well-formed border strip irrigation systems of traditional design. However, the temporal uniformity of supply varies over the length of the wetted strip because the soil surface is used to distribute the water. Design parameters, such as flow rate per unit width, slope, and length, along with management parameters such as irrigation duration, surface roughness, and initial soil water content, determine the opportunity time for infiltration. This varies over the length of the wetted strip and thus the infiltrated depth of water varies.

### 3.2.2 Sprinkler Irrigation

The selection and placement of sprinklers significantly influences the potential for water to be applied in a spatially uniform manner. The availability of good design tools and a wide range of sprinklers means that sprinkler systems can be designed to apply water with uniformity coefficients in excess of 90 percent, under still-air conditions. Careful design can also yield sprinkler systems that maintain a high level of uniformity, relative to still-air performance, under reasonably windy conditions.

Application rate is a very important determinant of the uniformity of infiltrated depth for spray irrigation systems, and therefore of irrigation performance. If the application rate is less than the infiltrability of the soil there will be no surface ponding, and therefore no redistribution. The infiltrability decreases as the hydraulic gradient across the soil surface decreases. Generally, therefore, the larger the intended mean application depth, the lower the application rate should be. When the application rate exceeds the infiltrability, water will pond and redistribute from high spots to low spots. Provided the depth of ponding is less than the surface roughness the redistribution will be local (John et al., 1985) and probably have little practical effect on the uniformity of infiltrated depth. When the depth of ponding is larger than the local roughness, significant redistribution can occur, as is often evidenced by water running off paddocks or flooding hollows.

The temporal uniformity of water supply is usually very high for sprinkler irrigation systems. It is an issue for travelling irrigators. Sprinklers at the end of a centre pivot are travelling much faster than sprinklers near the pivot point. In order to achieve a uniform depth of water application it is necessary to adjust the application rate and the wetted footprint over the length of the pivot. Design techniques for achieving high levels of uniformity are well developed. Many travelling irrigators start moving as soon as water is supplied to them, and water application stops as soon as the irrigator stops moving. This means that the duration of water application is very small at the extreme ends of each irrigator run. At the beginning and end of an irrigator run, the application depth ramps up and down over a distance equal to half the wetted width of the irrigator. The effect of this variation on the uniformity of infiltrated depth becomes negligible for long irrigator runs.

## 3.3 WATER SUPPLY CHARACTERISTICS

Irrigation performance is significantly affected by interactions between application system characteristics and water supply characteristics. If, for example, water is supplied on a fixed roster basis, and the application system can only apply a fixed depth of water, the effectiveness and efficiency of irrigation is essentially determined by climatic conditions – a random outcome. Irrigation system design must take full account of the water supply characteristics to ensure that farmers have sufficient flexibility to irrigate at the right time and apply the right amount of water.

# 4 Critical Design Decisions

The design of irrigation systems that have the potential to be operated effectively and efficiently involves a large number of decisions related to management and engineering design. The following list contains the most critical design decisions with respect to achieving high levels of performance, as it is defined in Section 2:

- Effectiveness (business risk, crop, soil, and climate)
- Adequacy (production/economics, efficiency, and climate)
- Mode of Operation (crop, climate, efficiency, farm management, irrigation system options, and water supply)
- Uniformity (irrigation system options, soil, crop, climate)
- Application rate (soil, irrigation system options)
- Application depth range (soil, crop, adequacy, efficiency, mode of operation, and irrigation system options)
- Wetted footprint (application rate, application depth range, irrigation rate, irrigation system options)

In summary, the first two decisions are essentially management decisions concerning what are acceptable levels of business risk and income. The remaining decisions are the engineering decisions that must be made in order to achieve the goals implicit in the decisions about acceptable levels of effectiveness and adequacy.

The purpose of this section is to highlight the issues that must be addressed in making these critical decisions.

## 4.1 EFFECTIVENESS

For the purpose of this section it will be assumed that the measure of effectiveness is the proportion of the growing season that the soil water content equals or exceeds the critical soil water content for the crops grown on the farm.

The decision is *"What is an acceptable degree of risk to farm production and income?".*

The issue is business risk. Climate is the physical driving force of agricultural production and so in many areas of New Zealand there exists a significant production risk, and therefore business risk, to do with water supply and demand at the field level. Irrigation is about managing the business risk of farming by augmenting the supply of water to crops.

In most circumstances, minimum business risk does not coincide with zero production risk with respect to water supply, because of the costs of achieving zero production risk and the imbalance that would exist between water related and other sources of production risk.

Assessing the level of risk associated with a particular irrigation design scenario involves integration of factors and dependencies to do with the crop, market, soil, climate, water supply, and irrigation system. Computer simulation is probably required to achieve the level of integration that is necessary if a meaningful relationship between risk and system design decisions is to be developed.

## 4.2 ADEQUACY

The decision is *"Over what proportion of the area will we endeavour to meet the effectiveness performance target?".*

In making this decision, two issues must be addressed. These are an economics issue and an environmental effects issue.

The larger the proportion of the area that is adequately watered, i.e. meets the effectiveness target, the larger and more reliable will be the income. However for real (non-uniform) systems the cost increases as the adequacy increases because the mean application rate must increase. This increases both capital and operating costs. At some point the marginal benefit of increasing the adequacy will equal the marginal cost of achieving the increase.

As the mean application rate increases to achieve higher adequacy the application efficiency decreases. This means more water is required from the water source and more water drains to downstream receiving waters. Generally this means increased adverse effects on both environments.

## 4.3 MODE OF OPERATION

The design of the application system (and associated water allocations) must be based on a workable irrigation management strategy.

The decision is "What will the management strategy be?".

The issue is irrigating at the right time and applying the right amount of water.

The two ends of the operating spectrum are:

- Apply a constant mean application depth. This implies a variable return period.
- Irrigate on a fixed return period basis. This implies a variable mean application depth.

Somewhere within this spectrum is a strategy that is to irrigate when it is optimal to do so. This will probably involve varying the mean application depth and the return period.

Where a farm operates within this spectrum should be determined by the crops grown, the water supply characteristics, and in consideration of other farm management issues.

The return period is simply the time between successive irrigations of a field. It is a function of the soil water content immediately before irrigation, the mean application depth, the critical soil water content, application uniformity, the required adequacy, and the actual evapotranspiration during the period following irrigation.

Crops with a constant root depth could be irrigated equally well under either a constant mean application depth strategy, or a constant return period strategy – providing the water supply characteristics and the application system permit the flexibility needed to modify either the timing or the depth, respectively.

Effective and efficient irrigation of annual crops requires flexibility in both the timing and amount of irrigation. The return period should vary during the season because the critical soil water content will increase as the rooting system develops, and as the evapotranspiration rate changes. In principle the mean application depth could be held constant at a value suited to early season needs. However in practice the return period would become unacceptably short as the actual evapotranspiration rate increases.

## 4.4 UNIFORMITY

The decision is *"What uniformity should the irrigation system be designed to achieve?".*

There are many issues involved in making this decision because of the pivotal role uniformity plays in the performance of the irrigation system. The effects of uniformity on aspects of irrigation performance are clearly illustrated in Figures 2-2 and 2-3. The benefits of achieving high uniformity, with respect to high adequacy and application efficiency, are obvious. The benefits in terms of irrigation rate and cost per unit area are illustrated in the following example.

Suppose that throughout a field the soil water content has reached the critical soil water content, and that it is desired to return the soil water content to field capacity. Assume that this requires an application depth of 50 mm, and that there are no losses due to evaporation or drift off the target area. The only losses are due to non-uniform applications. The purpose of the exercise is to design a travelling irrigator that will achieve specified levels of adequacy, 80 percent, 90 percent, and 100 percent. The design must examine the effects of different levels of application uniformity on the irrigation rate and the maximum area that can be irrigated by one machine. It is assumed that the evapotranspiration rate is 5 mm/day and that the return period is 10 days. A mean application rate of up to 30 mm/hr is permissible and the wetted foot print of the irrigator has been selected so that the full use is made of the water supply of 60 cubic metres per hour. The calculations are summarised in the following three tables.

**Assume that the goal is to irrigate to ensure that 80% of the field is irrigated to field capacity**

| | | | |
|---|---|---|---|
| Mean application rate (mm/hr) | 30 | Field capacity (mm) | 100 |
| Wetted width (m) | 20 | Critical soil water content (mm) | 50 |
| Wetted length (m) | 100 | Design depletion (mm) | 50 |
| Wetted footprint (m2) | 2000 | Design ET rate (mm/day) | 5 |
| Flow rate (m3/hr) | 60 | Return period (day) | 10 |

| $C_u$ (%) | Required Application Depth | Efficiency (%) | Irrigation Time (hr) | Irrigation (ha/day) | Travel (m/hr) | Maximum Irrigated Area (ha) |
|---|---|---|---|---|---|---|
| 100 | 50 | 100 | 1.7 | 2.88 | 12.0 | 29 |
| 90 | 56 | 89 | 1.9 | 2.57 | 10.7 | 26 |
| 80 | 63 | 72 | 2.1 | 2.29 | 9.5 | 23 |
| 70 | 72 | 35 | 2.4 | 2.00 | 8.3 | 20 |

**Assume that the goal is to irrigate to ensure that 90% of the field is irrigated to field capacity**

| | | | |
|---|---|---|---|
| Mean application rate (mm/hr) | 30 | Field capacity (mm) | 100 |
| Wetted width (m) | 20 | Critical soil water content (mm) | 50 |
| Wetted length (m) | 100 | Design depletion (mm) | 50 |
| Wetted footprint (m2) | 2000 | Design ET rate (mm/day) | 5 |
| Flow rate (m3/hr) | 60 | Return period (day) | 10 |

| $C_u$ (%) | Required Application Depth | Efficiency (%) | Irrigation Time (hr) | Irrigation (ha/day) | Travel (m/hr) | Maximum Irrigated Area (ha) |
|---|---|---|---|---|---|---|
| 100 | 50 | 100 | 1.7 | 2.88 | 12.0 | 29 |
| 90 | 60 | 83 | 2.0 | 2.40 | 10.0 | 24 |
| 80 | 73 | 67 | 2.4 | 1.97 | 8.2 | 20 |
| 70 | 95 | 51 | 3.2 | 1.52 | 6.3 | 15 |

**Assume that the goal is to irrigate to ensure that 100% of the field is irrigated to field capacity**

| | | | |
|---|---|---|---|
| Mean application rate (mm/hr) | 30 | Field capacity (mm) | 100 |
| Wetted width (m) | 20 | Critical soil water content (mm) | 50 |
| Wetted length (m) | 100 | Design depletion (mm) | 50 |
| Wetted footprint (m2) | 2000 | Design ET rate (mm/day) | 5 |
| Flow rate (m3/hr) | 60 | Return period (day) | 10 |

| $C_u$ (%) | Required Application Depth | Efficiency (%) | Irrigation Time (hr) | Irrigation (ha/day) | Travel (m/hr) | Maximum Irrigated Area (ha) |
|---|---|---|---|---|---|---|
| 100 | 50 | 100 | 1.7 | 2.88 | 12.0 | 29 |
| 90 | 75 | 65 | 2.5 | 1.92 | 8.0 | 19 |
| 80 | 150 | 32 | 5.0 | 0.96 | 4.0 | 10 |
| 70 | 300 | Very Low | 10.0 | 0.48 | 2.0 | 5 |

The tables show that the lower the application uniformity the higher the mean application depth must be to ensure that a given proportion of the area is fully irrigated.

The application efficiency decreases significantly.
The effect of the decrease in application uniformity is to increase the irrigation time, because more water must be applied, and decrease the total area that can be irrigated with a given irrigation machine. The tables show that reducing uniformity from 100 percent to 70 percent reduces the area able to be irrigated by one third. The capital cost per hectare would therefore increase by 33 percent, assuming it costs no more to buy a machine that irrigates at 100 percent uniformity, compared to a 70 percent uniformity machine.

The uniformity of application depth for a representative range of the travelling irrigators available in NZ has been reported as generally being in the 69 percent to 96 percent (John et al., 1985). The uniformity of application depth for the majority of irrigators in use today is probably at the lower end of this range, but there is no field data to substantiate this.

In summary the uniformity of application depth significantly affects the design application depth, the application efficiency, and the cost per irrigated hectare. From both economic and environmental points of view it is a significant issue.

## 4.5 APPLICATION RATE

The decision is *"What application rate should be used?"*.

The issues are the resulting irrigation rate and the uniformity of infiltrated depth.

Generally the application rate is chosen to be as high as possible in order to achieve high irrigation rates (average area irrigated per day).

However, it is critical that surface redistribution of the applied water does not occur because of the importance of maintaining high uniformity within the soil. To achieve this, it is necessary that over the expected range of initial soil water contents and mean application depths, the depth of ponding must be less than the surface roughness of the field.

It is also necessary that the product of the average application rate and the wetted footprint is no greater than the farm water supply rate.

## 4.6 APPLICATION DEPTH RANGE

The decision is *"What range of mean application depths should the irrigation system be capable of providing?"*.

The issue is irrigation adequacy and operational flexibility.

Many irrigation systems are not able to apply water in depths small enough to match soil water storage capacity at the time of irrigation, resulting in drainage through the soil profile. Application efficiency is therefore lower than it could be. However it should be born in mind that the lower the mean application depth the more critical it is that the uniformity be high. If it is not, the adequately watered area will be unacceptably low, and economic objectives will not be met, even though the application efficiency will be very high.

## 4.7 WETTED FOOTPRINT (OR AREA)

The decision is *"What should the wetted width (in the direction of irrigator travel) of the irrigator be?"*.

The issue is the application rate and travel speed required to apply a given depth of water, and therefore the irrigation rate and cost per hectare irrigated. The greater the wetted width, the lower the application rate required to apply a given depth of water for a given travel speed. However, it is very difficult to maintain a high uniformity coefficient while increasing the wetted width to reduce the application rate to an acceptable level. This issue remains largely unresolved, as evidenced by the characteristics of most travelling irrigators currently available in New Zealand.

# 5 An Assessment of the Feasibility of Designing Efficient and Effective Irrigation Systems for NZ Conditions

This section seeks to address two questions with respect to the feasibility of designing efficient and effective irrigation application systems in New Zealand. They are:

- Is the information available?
- Can the information be gained?

The assessment is structured around the critical design decisions presented in the previous section. It is based on experience and knowledge gained through continuing involvement in irrigation design and development in New Zealand, and a review of historical data from the Ministry of Works and Development concerning border-strip irrigation.

### Effectiveness

- There are no established criteria (minimum performance standards) for effectiveness.
- While effectiveness could be quantified in non-financial terms at present the most meaningful performance standards must be related to financial and economic outcomes. A team involving farm business management expertise and irrigation expertise would be required to resolve this. Expertise is available in both areas, but not in the one organisation.

### Adequacy

- There are no established criteria (minimum performance standards) for adequacy.
- Resolution of this issue will require a combination of plant science, crop yield modelling and irrigation expertise. Expertise is available, but not in the one organisation.

### Efficiency

- There are no established criteria or historical performance data on efficiency.
- Technology and expertise exists to obtain the information required.

### Mode of operation

- Although there is sufficient understanding to identify the most appropriate mode of operation, achieving change where necessary probably involves significant reinvestment and education.

### Uniformity

- There is good understanding of the design of sprinkler systems to achieve a given level of uniformity under still air conditions, and tools to assist with this are available. Achieving this depends on sprinkler manufacturers supplying the necessary data. Some information on the uniformity of application depth under travelling irrigators is available, but newer irrigators (since 1985) have not been tested. Expertise exists to do this.

- There is very little information on the uniformity of infiltrated depth of water for both sprinkler and border-strip irrigation. The most feasible method for the latter is to computer simulate border-strip irrigation. Suitable models exist but the data available for validating such models (ex MWD) is incomplete. Field work needed to provide the data required for improving understanding of uniformity, and hence efficiency and adequacy. Technology and expertise exists to do this.

**Application rate**

- There is insufficient data on the hydraulic properties of New Zealand soils for sound design of irrigation systems, and for water allocation purposes.
- Technology and expertise is available to meet this need, from a number of organisations.

**Application depth range**

- Information is not available on the benefits and costs of different application depth ranges.
- Technology and expertise is available to address this issue, but it would require performance standards for effectiveness, adequacy and efficiency.

**Wetted footprint**

- This is dependent on data on the hydraulic properties of soils. See application rate section above. It also requires more information than is currently available on the effects on uniformity of sprinkler characteristics, infiltrability, wetted footprint and engineering options.
- This is a significant research issue. Expertise is available to do this.

# 6 Summary

Designing irrigation application systems that have the potential to be operated effectively and efficiently is a complex task that requires a wide range of information and contributions from a range of professions.

This review has attempted to identify measures of irrigation performance that can provide meaningful feedback to designers during the design phase concerning the potential performance of the irrigation system. These cover measures relevant to the production goals of irrigation, and to the environmental effects of irrigation. Definition of the performance indicators lead to the identification of several factors which are the keys to achieving high levels of irrigation performance. A number of critical design decisions are related to these keys. These were summarised, along with the issues that must be addressed in the process of making these design decisions. Finally, an assessment was made of current New Zealand capacity to design irrigation systems that have the potential to perform well, economically and environmentally.

Overall there is a paucity of information relevant to the design of effective and efficient irrigation systems in New Zealand. The lack of accepted performance criteria, particularly related to the efficiency of water use, puts New Zealand agriculture in a weak position with respect to renewing, or obtaining, permits to take water under the Resource Management Act. It also represents a major oversight in the development of information about water resource management in New Zealand, considering that agriculture is the largest consumptive user of water in New Zealand, by a substantial margin.

Historically, the efficiency of irrigation has not met the expectations of planners and designers. Generally this has been considered to be a management problem – farmers are not monitoring soil water content and irrigating accordingly. However, a recent survey of farmers concerning irrigation practices revealed two important points relevant to system design:

The effectiveness of irrigation is more important to farmers than the efficiency.
Most irrigation systems do not have the flexibility to be managed to achieve high efficiency.

The significance of the first point is that farmers will increase application depths to a level which provides satisfactory production (effectiveness). If the application system is not able to apply water uniformly, the application depth acceptable to the farmer may be substantially larger than the soil water deficit. Application efficiently will then be significantly lower than anticipated by planners and designers.

The main conclusion of this review is that irrigation system design is the principal reason for lower than expected levels of efficiency. Achievement of sustainable irrigated agriculture depends on better design, as much as on improved management. This will require a combination of theoretical and field work.

Technology and expertise is available in New Zealand to increase understanding and obtain the information that is needed for sustainable irrigated agriculture.

# 7 References

Bright, JC (1986): Optimal control of irrigation systems: An analysis of water allocation rules. Unpublished PhD Thesis, University of Canterbury.

John, PH; Lees, DM; English, GM (1985): Application performance of travelling irrigators. Project Report No 35, NZ Agricultural Engineering Institute.

Painter, DJ and Carran, P (1978): Soil and Water, vol 14 pp 15-17, 1978.

Skaggs, RW; Millar, DE; Brooks, RH (1980): Soil Water: Part 1 – Properties. Chapter 4 in Design and Operation of Farm Irrigation Systems. American Society of Agricultural Engineers.

# Appendix I: MWD Border-Strip Watering Trials

## 1 INTRODUCTION

The Ministry of Works and Development (MWD) completed an extensive series of field trials in the early 1980s to increase understanding of the efficiency of border-strip irrigation systems, and how to improve their design. The field trials were conducted on a large number of farms in several irrigation schemes throughout Canterbury. The data from the field trials was never fully analysed and used for the intended purpose, primarily because of staff changes and, finally, the closure of MWD's Water and Soil Division.

One of the purposes of this project was to review the data from these trials to establish whether it could still be used to achieve the original purpose of the field trial.

Since the time of the field work there has been considerable developments in mathematical and computer models of border-strip flow. Development has reached the point where the preferred method of designing border-strip systems is to use a field validated computer model to investigate the effects of various design options on the efficiency and adequacy of irrigation events under a range of conditions. The focus of our review was therefore to establish whether the data available could be used to validate a suitable computer simulation model.

Proper validation of a border-strip flow model requires field data in two main areas. These are the hydraulics of shallow water flow and the infiltrability of the soil. The hydraulics of a border-strip flow event are fully described by data on the rate of advance of the wetting front and the rate of advance of the drying front (advance and recession curves). Together they determine the opportunity time for infiltration at any point on the wetted area. This, together with data on the infiltrability of the soil, enables calculation of the infiltrated depth of water at any point on the wetted area. This is essential data for determining the efficiency and adequacy of irrigation. Information on the soil water content at the time of irrigation, and on the soil water retention characteristics of the soil, is also required.

The following sections describe the data that is available from the MWD field trials and assess the suitability of the data for model validation purposes, as a prelude to border-strip design investigations.

# 2 MWD SURFACE IRRIGATION TRIALS - DATASET DESCRIPTIONS

| File name | Scheme name and approximate number of trials |
|---|---|
| Trial1.dat | Mayfield – Hinds ............ |
| Trial2.dat | Waiau ............................ |
| Trial3.dat | Waiau ............................ |
| Trial4.dat | Waiau ............................ |
| Trial5.dat | Waiau ............................ |
| Trial6.dat | Ashburton–Lyndhurst .... |
| | Mayfield-Hinds ............. |
| Trial7.dat | Feradays Island ...............<br>Greenstreet ....................<br>North Rakaia ................. |
| Trial8.dat | Valetta ........................... |
| Trial9.dat | Waiau ............................ |
| Trial10.dat | Ashburton-Lyndhurst ..... |
| Trial11.dat | Waiau ............................ |

***Notes:***

- There seem to be a number of ‘repeat’ trials that have the same number with ‘A’ ‘B’ etc. suffixes. Presumably these are on the same farm but in different areas.
- Many trials (maybe 70 percent) have soil moisture data but in repeated trials these values don’t appear to change.
- Soil moisture measurements appear to be for antecedent conditions only.

# 3 MWD SURFACE IRRIGATION TRIAL DATA - LIST OF CODES USED IN DATA FILES

## 3.1 Scheme name codes

| | |
|---|---|
| WA | WAIAU PLAINS |
| AL | ASHBURTON LYNDHURST |
| FA | FARADAY ISLAND |
| GS | GREENSTREET |
| MH | MAYFIELD HINDS |
| NR | NORTH RAKAIA |
| VA | VALETTA |

## 3.2 Farm codes (with scheme prefix)

| | |
|---|---|
| AL001 | HORNE |
| AL003 | MAGINNESS |
| AL005 | LINCOLN COLLEGE RESEARCH STATION |
| AL009 | BUICK |
| AL011 | MORRIS |
| AL018 | HARCOURT |
| AL021 | WAKELIN |
| AL022 | MONTE MONTEATHE/TARA |
| AL024 | CAIRNS |
| AL030 | DELLOW |
| AL031 | BUTTERICK |
| AL034 | GRANT |
| AL033 | GRANT |
| AL019 | DONT KNOW WHO |
| AL077 | HENDERSON |
| AL116 | MORRIS |
| AL135 | GRANT |
| AL177 | CAIRNS |
| AL999 | DONT KNOW WHO |
| FA008 | MONTGOMERY |
| GS006 | EVANS |
| GS007 | EVANS |
| MH001 | MCCONNELL |
| MH002 | MCKENZIE CHARITY FOUNDATION |
| MH003 | MORRIS |
| MH004 | DALY |
| MH005 | WATSON |
| MH006 | SLEE |
| MH007 | HAYMAN |
| MH008 | KNIPE |
| MH009 | MCKEOWNS |
| MH010 | ROLSTON |
| MH011 | JONES |
| MH012 | CRAIGE |

| | |
|---|---|
| MH013 | JONES |
| MH014 | REITH |
| NR001 | GOURLAY |
| NR002 | STUBBS |
| NR003 | BREADING |
| NR004 | BREADING |
| NR005 | BREADING |
| VA009 | ARMSTRONG |

## 3.3 Farm Codes (With Scheme Prefix) – Cont'd

| | |
|---|---|
| VA010 | CAMPBELL |
| VA011 | MCCORMICK |
| VA012 | STOCKER |
| VA013 | HARRIS |
| VA014 | ORMROD |
| VA016 | SCHOFIELD |
| VA017 | GOOSEMAN |
| WA002 | RUTHERFORD A |
| WA003 | BURROWS J R |
| WA004 | RUTHERFORD J S |
| WA005 | GALLAGHER P J |
| WA006 | ROBERTS T M |
| WA007 | FARQUHAR H W |
| WA008 | HENDERSON R H |
| WA009 | THOMPSON B G M |
| WA010 | BLACK M A |
| WA011 | X |
| WA012 | X |
| WA013 | X |
| WA014 | X |
| WA016 | X |
| WA020 | BURROWS C A |
| WA021 | HOBAN |
| WA022 | THOMSON R M |
| WA026 | FLEMING L |
| WA027 | BAKER A |
| WA028 | BEAVEN G |
| WA029 | LUMSDEN |
| WA030 | MCMILLAN A |
| WA031 | INNISKILLEN |
| WA032 | MCINTOSH N H |
| WA033 | STEEL |
| WA034 | TAGG PARTNERSHIP |
| WA045 | MCINTOSH R |
| WA046 | MOSSMAN |
| WA049 | DALZELL J G |
| WA050 | O'CALLAGHAN K S |
| WA070 | CHICK M D |
| WA071 | MCINTOSH N E E |

| | |
|---|---|
| WA074 | FLEMING R H |
| WA075 | EARL W H |
| WA089 | MCLAUGHLIN |
| WA090 | DAVISON P |
| WA092 | JAMIESON W |

### 3.4 Farm Codes (With Scheme Prefix) – Cont'd

| | |
|---|---|
| WA095 | DAMPIER-CROSSLEY G P |
| WA103 | MACFARLANE A D |
| WA120 | DALZELL C L |
| WA129 | OVERTON |

### 3.5 Crop type codes

| | |
|---|---|
| GRASS | 1 |
| GRASS AND CLOVER | 2 |
| CLOVER | 3 |
| LUCERNE | 4 |
| SEE NOTES | 5 |
| INVALID SELECTION | =>6 |
| INVALID SELECTION | =>7 |
| INVALID SELECTION | =>8 |
| INVALID SELECTION | =>9 |
| NOT RECORDED | 0 |

### 3.6 Crop condition codes

| | |
|---|---|
| NEW | 1 |
| DIRECT DRILLED | 2 |
| ESTABLISHED | 3 |
| DENSE | 4 |
| SPARSE | 5 |
| STALKY | 6 |
| SEE NOTES | 7 |
| INVALID SELECTION | =>8 |
| INVALID SELECTION | =>9 |
| NOT RECORDED | 0 |

### 3.7 Weather type codes (Weather code 1)

| | |
|---|---|
| RAINING | 1 |
| SHOWERY | 2 |
| DRIZZLY | 3 |
| OVERCAST | 4 |
| CLOUDY | 5 |
| FINE | 6 |
| SEE NOTES | 7 |
| INVALID SELECTION | =>8 |
| INVALID SELECTION | =>9 |

| | |
|---|---|
| NOT RECORDED | 0 |

### 3.8 Wind condition codes (weather code 2)

| | |
|---|---|
| WINDY | 1 |
| GUSTY | 2 |
| BREEZY | 3 |
| STILL | 4 |
| SPARSE | 5 |
| STALKY | 6 |
| SEE NOTES | 7 |
| INVALID SELECTION | =>8 |
| INVALID SELECTION | =>9 |
| NOT RECORDED | 0 |

### 3.9 Sill type codes

| | |
|---|---|
| STEEL IN CONCRETE | 1 |
| WOOD IN CONCRETE | 2 |
| WOOD | 3 |
| CONCRETE | 4 |
| STEEL | 5 |
| EARTHEN | 6 |
| SEE NOTES | 7 |
| INVALID SELECTION | =>8 |
| INVALID SELECTION | =>9 |
| NOT RECORDED | 0 |

### 3.10 Sill condition codes

| | |
|---|---|
| NEW | 1 |
| WEEDY | 2 |
| SHORT GRASS | 3 |
| OVERGROWN | 4 |
| SCOURED | 5 |
| BURIED | 6 |
| STALKY | 7 |
| SEE NOTES | 8 |
| INVALID SELECTION | =>9 |
| NOT RECORDED | 0 |

## 3.11 Gate control type

| | |
|---|---|
| PNEUMATIC | 1 |
| CLOCK | 2 |
| MANUAL | 3 |
| SEE NOTES | 4 |
| INVALID SELECTION | =>5 |
| INVALID SELECTION | =>6 |
| INVALID SELECTION | =>7 |
| INVALID SELECTION | =>8 |
| INVALID SELECTION | =>9 |
| NOT RECORDED | 0 |

## 3.12 Headrace condition code

| | |
|---|---|
| SHORT GRASS | 1 |
| OVERGROWN | 2 |
| WEEDY | 3 |
| SILTY | 4 |
| NO FREEBOARD | 5 |
| BACKWATERING | 6 |
| SCOURED | 7 |
| SEE NOTES | 8 |
| INVALID SELECTION | =>9 |

# 4 SUITABILITY OF THE DATA TO IRRIGATION DESIGN

The data available, plus what could be obtained retrospectively, provides a valuable but incomplete basis for computer model validation. There are acceptable methods for overcoming the limitations of the dataset.

The main limitation of the dataset is the lack of information on the rate of movement of the drying front (or recession front). This is a particularly difficult phenomena to measure, and was not often attempted at the time the field-work was conducted. Most model validation studies have simply aimed to reproduce the advance front and have assumed that if this is correct the recession front will be also. The absence of recession front data is a weakness, but does not prevent the dataset being used constructively.

The MWD study did not measure the infiltrability of the soil on each study sight. However relevant data is available from Anthony Taylor's PhD thesis to represent the infiltration characteristics of some of the soils in the mid-Canterbury area, in the manner required by most border-strip simulation models. Sufficient soil moisture data is available to set such models up with the appropriate initial conditions.

All other parameters typically required by border-strip flow models are available. One model has been obtained, but it has not been calibrated.

The most definitive basis for validating a border-strip flow model is to compare the infiltrated depth profile predicted by the model with the field measured profile. Technology was not available for doing this in the 1980s. However, experiments planned and subject to a Sustainable Management Fund bid will provide this information.

In summary, while the MWD dataset is not complete, it is expected that it can be used successfully for model calibration and design purposes, provided it is supplemented with soils data from other sources. The availability of this supplemental data is likely to limit the area of application to mid-Canterbury.