AQUALINC RESEARCH LIMITED

Guidelines for Irrigation Water Requirements in the Poverty Bay Flats

EnviroLink Project: 1013-GSDC93

Prepared for Gisborne District Council and Irrigation User Group

Report H12000/3

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LIST OF ABBREVIATIONS

ha	hectare
l/s	litres per second
mm	millimetre
m	metre
m^3	cubic metre
m^3/s	cubic metres per second
Mm^3	million cubic metres
PAW	plant available water
PrAW	profile available water
PET	potential evapotranspiration
VCS	virtual climate station

LIST OF ACRONYMS

DSIR	Department of Scientific and Industrial Research
GDC	Gisborne District Council
GIS	Geographic Information System
NIWA	National Institute of Water and Atmosphere
NZFSL	New Zealand Fundamental Soils Layer

GLOSSARY

Crop coefficient (k_c)	Relates the amount of water lost to evapotranspiration by the crop being studied to the reference evapotranspiration. The coefficient is determined from the ratio of the evapotranspiration for the crop being studied divided by the evapotranspiration for the reference crop, under the same conditions; i.e., evapotranspiration for the well watered studied crop ÷ reference evapotranspiration. (dimensionless).
Water stress reduction factor (k_s)	The water stress reduction factor is a function of the soil water status. k_s equalled 1.0 when the soil water content is equal to the readily available water, and then k_s reduces linearly down to a value of zero at wilting point (dimensionless).
Evapotranspiration (ET)	Water lost by soil evaporation and crop transpiration (mm/day).

Irrigation application efficiency	Average daily depth of applied water during a single irrigation event ÷ average depth of water retained within the root zone, after, run-off, and deep drainage losses (dimensionless).
Irrigation system capacity	Application depth ÷ minimum return period (mm/day).
Potential evapotranspiration (PET)	PET is the environmental demand for water met by evapotranspiration. The reference value (ET_o) is the evapotranspiration rate of a short green crop, completely shading the ground, of uniform height and with adequate water available in the soil profile (mm/day).
Plant Available Water (PAW)	Plant available water for a given soil profile is the profile available water adjusted for the rooting depth of the relevant crop and stage of crop being grown (mm).
Profile Available Water (PrAW)	Profile available water reflects the soil's capacity to hold plant available water in the soil profile to a depth of 0.9 metres and expressed as millimetres of water (mm).
Return period	Minimum time between the same area or zone being irrigated (days).

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EXECUTIVE SUMMARY

This document provides a guideline to how much irrigation water is required, for a specific level of reliability, to keep crops well watered. It provides this information for the range of crops that potentially can be irrigated on the Poverty Bay Flats in the Gisborne region.

The volume of irrigation water required by a crop, in a particular season, is a function of:

- The crop and the rooting depth it can achieve;
- The soil and how much water it can store;
- The rainfall and evapotranspiration demand for the season;
- The soil water targets that the irrigation is managed to; and
- The irrigation system used, i.e. how much water is applied and when.

A daily soil water balance model taking into account the above factors, and assuming that good irrigation management practices are followed, has been used to determine how much water is required for each season over 39 years. This data is then translated into probability information, so that the water required (mm/season) to meet a given level of drought, such as 1-in-10 year drought or 1-in-5 years has been ascertained.

The system design capacity (mm/day), which is the maximum design rate at which the irrigation system should be designed to achieve the required system performance, is also specified.

This document does not address the question of reliability of supply or allocation issues, the irrigation demand calculated assumes that the required water is available at the flow rates and quantities necessary to meet the crop requirements.

The values presented in this document should be considered as Guideline values only based on a regional level analysis. If an applicant for a consent has more specific soils data prepared by a competent soil scientist, and/or proposes to manage their irrigation system in a manner than can be proven to be as efficient, or is going to use an irrigation system with a different modus operandi than included in this document, then GDC should carefully review their information and required volumes that the applicant proposes and ascertain if these meet with their objectives for efficient irrigation.

1 OVERVIEW

Irrigation is the major consumptive water use in the Gisborne District (Aqualinc, 2010). The efficient use of water is a key objective of the Resource Management Act, and achieving this outcome is a responsibility of administrative authorities such as Gisborne District Council (GDC). Efficient use, and allocating water in accordance with actual requirements, is important to ensure water allocation is on an equitable basis.

In order to define whether irrigation water use is efficient, reasonable water requirements need to be defined. In this report we estimated reasonable water requirements for the crops grown on the Poverty Bay Flats using a daily time step water balance model. This methodology is an accepted method for estimating reasonable irrigation requirements, and is the method of choice for the majority of other regional and unitary authorities in New Zealand.

These guidelines cover the Poverty Bay Flats (area of approximately 20,000 ha) since most irrigation in the Gisborne area occurs on this region. These guidelines are not applicable outside of this region due to the different climates and soil types.

This work is funded through a grant from the EnviroLink (Grant No. 1013-GSDC93).

2 CLIMATE

Climate data used in this modelling exercise was measured at the Gisborne Airport (NIWA network number D87692 at or near the map reference NZMG Y18:2943888-6271762). Both rainfall and reference evapotranspiration (ET_o) data has been recorded at Gisborne Airport since 1972. We used NIWA's estimate of ET_o, calculated from Penman method (Penman, 1948) based on measured radiation, temperature, wind and vapour pressure climate data. This data is considered representative of the study area. The average rainfall is relatively consistent across the Flats as shown in Figure 1, so the airport data can be used to be representative of the study area. Climate data is summarised in Figure 2 and Appendix A.

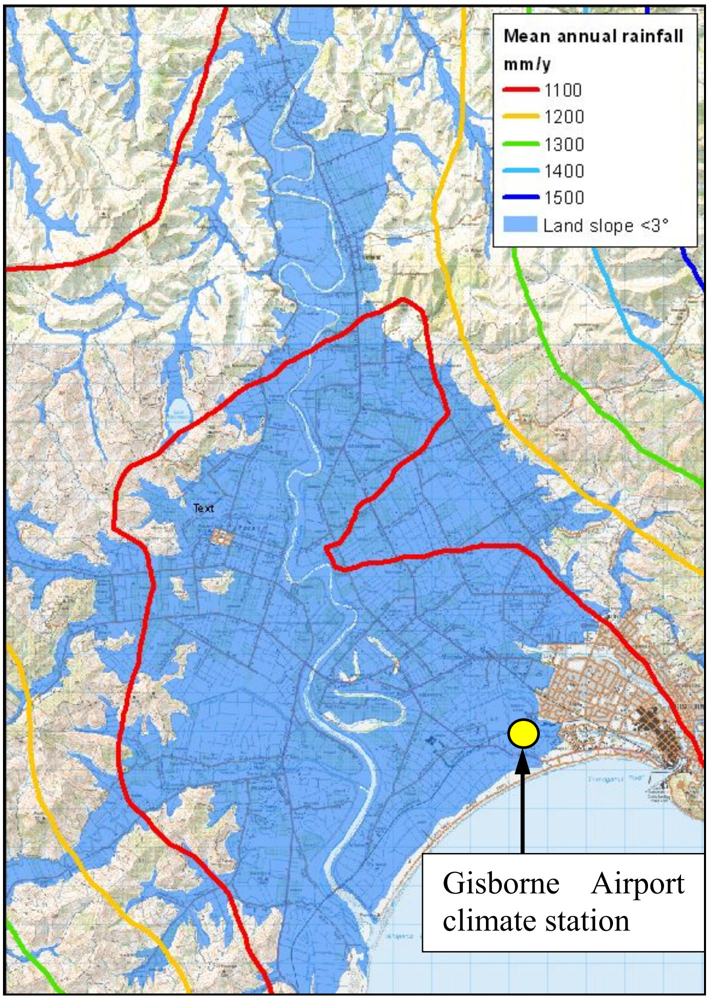

Figure 1: Poverty Bay Flats rainfall

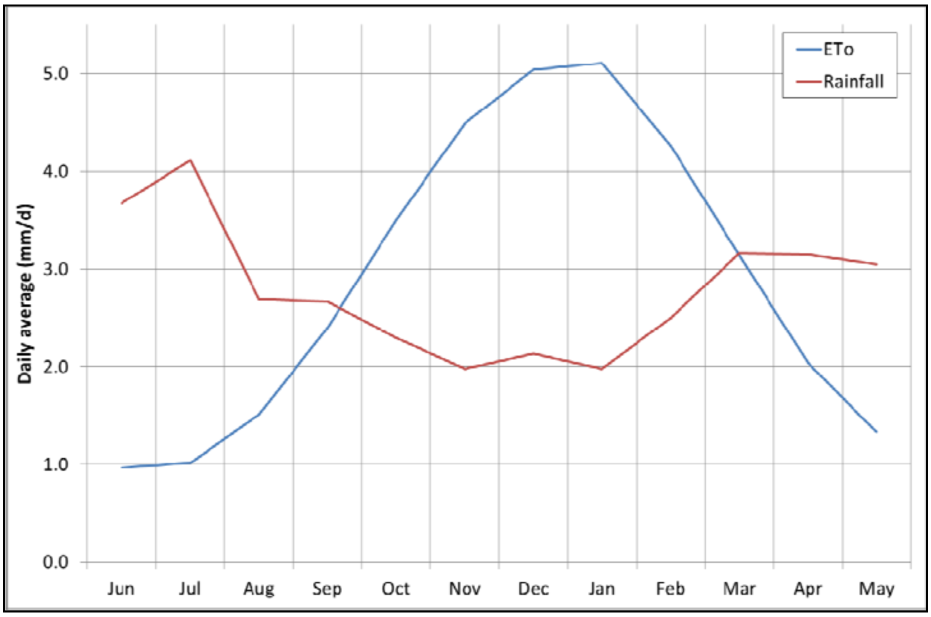

Figure 2: Average rainfall and reference evapotranspiration by month

3 SOILS

Soils on the flats are predominately clay and silt loams. Drainage in some areas is imperfect, with a high water table limiting crop rooting depths. Other limitations to crop rooting depth include clay confining layers, poor soil structure and poor aeration.

Landcare Research recently developed a web based GIS system called S-Map (http://smap.landcareresearch.co.nz/home). At the time of undertaking this project these S-Maps were not available for use. At the time modelling work commenced the most reliable and available data were the soils maps and tables produced by Department of Scientific and Industrial Research in 1962 (DSIR, 1962). These are at a 1:15,840 scale and are held by GDC. The S-Map uses the same soil names and soil map units as used by DSIR (1962). Therefore, GDC will be able to use the soil information provided in this report with the web based S-Maps if required.

Three terms are commonly used to describe the amount of soil water available to plants: Profile available water (PrAW), plant available water (PAW) and available water.

Available water is the difference between field capacity and wilting point, as illustrated in Figure 3.

Profile available water (PrAW) is the amount of available water, down to a specified depth (generally 0.9 m). Profile available water depends only on the characteristics of the soil type, not on the crop.

Plant available water (PAW) is the amount of available water for the specific crop rooting zone of the crop being grown. Plant available water depends on the soil type, type of crop, and the stage of crop development. In this document we have abbreviated plant available water as PAW.

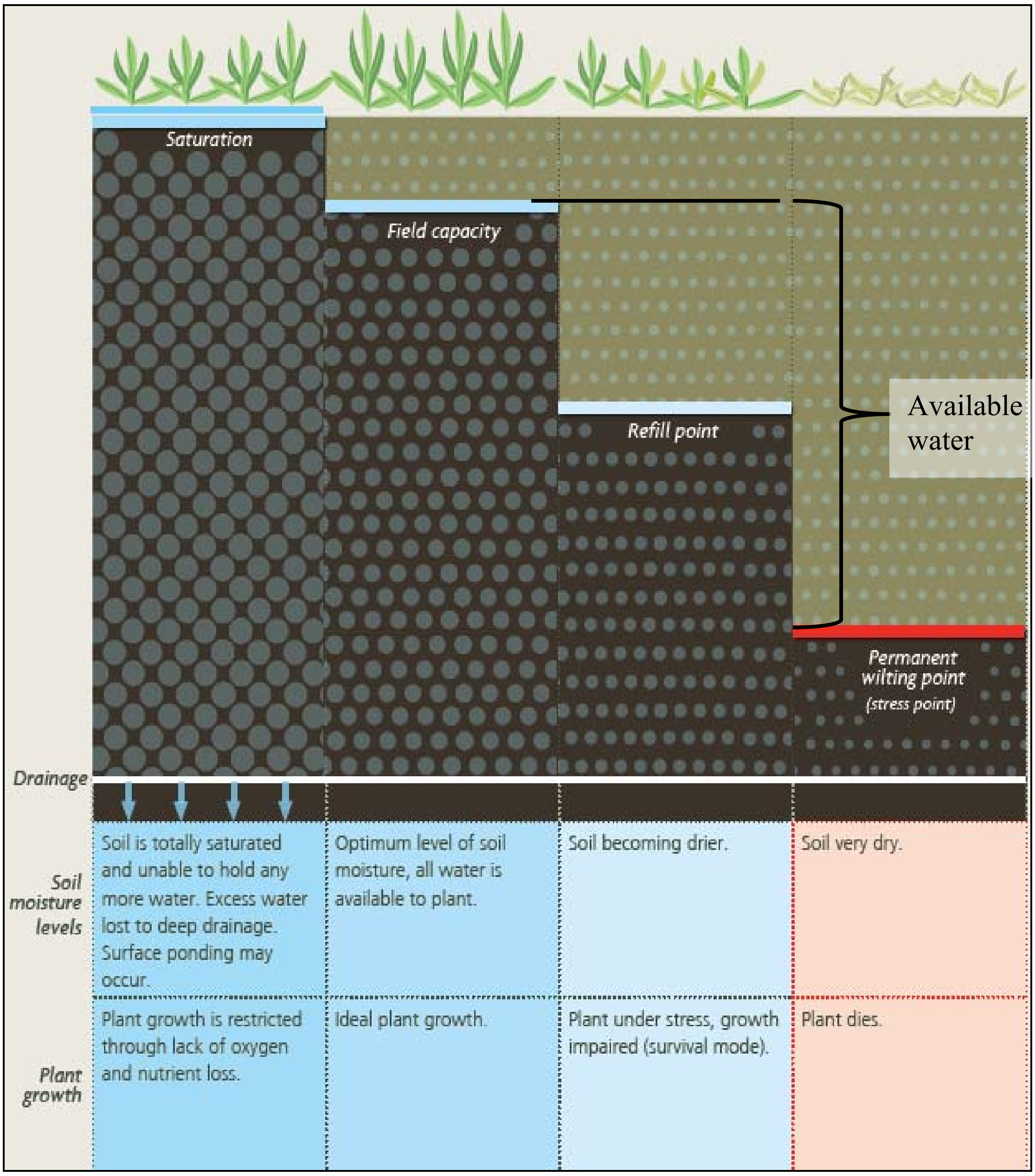

Figure 3: Available soil water (from DairyNZ 2011)

Generally soil reports contains information on profile available water (PrAW), which depends on the soil type only. However, from an irrigation perspective, it is the plant available water (PAW) that determines irrigation water requirements. DSIR (1962) provides the PrAW for the soils of the Poverty Bay Flats; this has been converted into PAW as required for estimating the irrigation requirements in this work.

Eight soil groups have been identified from the PrAW properties for top and sub soil data, and the potential maximum rooting depth. A summary of these soil groups is presented in Table 1. Appendix B gives the locations and soil names of the soils within each of these soil groups, along with the individual PrAW values.

Table 1: Soil profile available water (PrAW) summary

Soil group	Maximum rooting depth (cm)	PrAW (mm AW/cm soil depth)	
		Topsoil (top 20 cm)	Subsoil
A	20	2.0	0.0
B	30	1.1	1.1
C	30	2.0	2.0
D	45	1.9	0.6
E	60	1.9	0.8
F	70	1.9	0.8
G	90	2.0	1.5
H	120	2.0	1.6

4 CROPS

A wide variety of crops is currently irrigated and can potentially be irrigated in the Poverty Bay Flats, including vegetables, fruit, pasture and cereals.

For a given parcel of land, with a particular soil and climate, crop irrigation requirements vary depending on three main factors:

i. The crop coefficient (k_c). This determines the amount of water lost to evapotranspiration. Crops with higher k_c values have higher irrigation requirements.

ii. The rooting depth. This determines the depth of the soil profile from which the plant can abstract water. Crops with shallower rooting depth have less soil water available and hence higher irrigation requirements.

iii. The water stress tolerance of the crop. This determines how sensitive crop yields are to soil moisture deficits. Crops with low water stress tolerance have higher irrigation requirements because they are maintained at a higher soil water level to prevent them being stressed from low soil water conditions and production being limited.

Irrigation properties of common crops grown on the Poverty Bay Flats are given in Table 2. Crop information was provided from consultation with growers following a workshop held in Gisborne on 31 October 2011 (refer Appendix C). Crop coefficient information was predominately from Allen *et al*. (1998).

Table 2: A summary of crops modelled

Crop	k_c	Maximum rooting depth (mm)	Target minimum soil moisture (% of PAW)	Critical PAW	Crops per year	Irrigation season
Vegetables - Small Green						
Lettuce	0.4 – 1.1	350	60%	50%	Continuous	Year round
Baby Leaf	0.4 – 1.1	250	75%	60%	Continuous	Year round
Broccoli	0.7 – 1.05	500	60%	35%	Continuous	Year round
Cabbage	0.7 – 1.05	500	60%	35%	Continuous	Year round
Onions	0.7 – 1.05	250	60%	35%	1	Jul - Feb
Vegetables – Cucurbits family						
Melons	0.4 – 1.00	600	60%	40%	1	Sept – Apr
Squash (grown in open field)	0.5 – 0.95	600	60%	35%	1	Aug – Apr
Tomatoes						
Tomatoes	0.6 – 1.05	1,000	60%	35%	1	Sept – Apr
Horticulture						
Citrus	0.7	700	50%	40%	Perennial	Year round
Kiwifruit	0.4 – 1.1	500	60%	50%	Perennial	Nov – Apr
Arable						
Sweet Corn	0.3 – 1.15	1,000	50%	35%	1	Oct – Jan
Maize	0.3 – 1.20	800	50%	35%	1	Oct - Jan
Pasture						
Pasture	1.0	600	50%	25%	Perennial	Sept – Apr

5 WATER BALANCE MODELLING

We estimated reasonable irrigation water requirements using a daily time step water balance model. This methodology is an accepted method for estimating irrigation requirements, and is consistent with how the majority of other regional and unitary authorities estimate reasonable irrigation water requirements. We used the relationship between crop and reference evapotranspiration given by Allen *et al*. (1998):

$$\textit{Crop evapotranspiration} = k_s \times k_c \times \textit{Reference evapotranspiration} \qquad \text{Eqn 1.}$$

Where: k_s is the water stress reduction factor and
k_c is the crop coefficient.

The water stress reduction factor is a function of soil moisture. Each day the soil moisture level is calculated from:

$$ASM_{day\ i} = ASM_{day\ i-1} + (\textit{rain} + \textit{effective irrigation} - \textit{crop evapotranspiration})_{day\ I} \qquad \text{Eqn 2.}$$

Where: ASM = available soil moisture.

We assumed an irrigation efficiency value of 80% is achieved, this means that of the applied irrigation water 80% is effective and used by the evapotranspiration processes. To achieve this 80% values requires best management irrigation practices and a well-designed irrigation system. The model assumes any soil water in excess of field capacity drains away beyond the bottom of the root zone and is not available for the crop.

Both rooting depth and the crop coefficient values vary over time and between crop types. Consequently, we have modelled variable rooting depth for short rotation crops such as vegetables and variable k_c values for each soil-crop combination. This allows the seasonal irrigation depths to be based on the daily demands for the different growing state of the crop for different soil-crop combinations Rooting depth information and soil profile limitations were based on data supplied by local growers and consultants (refer Appendix C).

Rooting depth for continuous and single season crops was estimated assuming a continuous growth rate over time, until the maximum rooting depth was reached. For perennial crops and pasture a fixed rooting depth was used.

In some cases crops may not be able to grow to the maximum rooting depth due to limitations in the soil profile. For example, rooting depth of broccoli can reach up to 500 mm where soil profile has no restricted pans or high water tables (refer Table 2). However, as shown in Table 1, the maximum potential rooting depth would be limited to 300 mm, if grown on Group C soils. The maximum crop rooting depths modelled for each soil group are listed in Appendix D.

For simplicity, the rate at which the root develops will remain unchanged across all soil groups. However, for soils where rooting depth is restricted, the maximum rooting depth is reached sooner in these soils compared with soils with deeper potential rooting depths. In the case of perennial crops and pasture, the maximum rooting depth was limited to the greater of the maximum potential rooting depth of the soil or the crops requirement.

k_c was estimated using a linear function to increase with time in the short rotation crops such as vegetables. The value increases from planting (low) until it reaches a maximum value a few days prior to harvesting. Kiwifruit are a deciduous crop, therefore, the k_c is also considered to vary with time.

Continuously grown small green crops (e.g. lettuce, baby leaf, broccoli and cabbage) were modelled as “end on end” crops i.e. cultivation and planting occurring directly after harvesting. It is assumed that these crops are irrigated throughout the year whenever they require irrigation. While it is recognised that the crop will not be physically planted in the same location with end on end rotations, it is the most realistic way of representing a continuously grown short rotation crop.

As Citrus is an evergreen crop, there are only minor changes over time in the k_c value; therefore, a fixed k_c value appropriate for mature Citrus has been used. Citrus have been modelled for year round irrigation demand, however it is recognised that only seasonal demands are required dependant on the various citrus varieties grown. To allow for the use of this annual data, the irrigation requirements for Citrus have been presented by season (i.e., Summer, Autumn, Winter and Spring), so that GDC can allocate water based on the seasonal irrigation demand appropriate for the Citrus variety grown.

Kiwifruit irrigation season was assumed to be from November to April period and Pasture from September to April.

Irrigation application was modelled with differing application depths and frequencies that reflect the changing demand of the crop. Water demand is less when the crop is small compared for a mature crop; this varying demand should also be reflected in the irrigation management used. This allows for the efficient use of water and reduces the level of wastage via deep drainage so that the application depths match the plants ability to extract water. It is also important that when irrigation is applied, soil-water levels are not replenished to field capacity (refer to Figure 3). Good irrigation management requires that spare capacity within the soil profile is allowed for. This practice allows for some advantage to be gained from rainfall events that occur subsequent to irrigation. This not only reduces the irrigation water used but also reduces the drainage below the rooting depth. The strategy modelled was to refill the soil-water profile with irrigation up to maximum of 90% of PAW.

We assumed that water can freely drain though the rooting zone down to the deeper soil layers. However, poorly drained soils and a high water table are a characteristic of soils across parts of the Poverty Bay Flats. Aqualinc has worked very closely with GDC and local stakeholders to obtain the best available local information and to identify rooting depth limitation for different soil types. In some soils, rooting depth can be limited due to a high water table condition. Where this occurs, water may be available to the plant via upward flux from the water table through capillary action.

This phenomenon can reduce the irrigation water demand; therefore, seasonal irrigation requirement estimates can be less than the modelled where the water table is high.

The model was run using climate data from 1 June 1972 to 31 May 2011, a total of 39 seasons.

6 RESULTS

Estimated irrigation water requirements for different soil-crop combinations are presented in following sections.

The guidelines have been prepared based on unmodified soils and the soil properties are based on the DSIR data (DSIR, 1962). However, farmers modify soil layers by constructing drains for better drainage or levelling soils to reduce surface runoff and erosion. If soils have been modified, the irrigation allocations for such soils need to be calculated based on properties for the modified soil type. For example, if tomatoes are grown on a “Native Soil Group A” (water table is at 200 mm), however, the soil has been modified by introducing drains to lower the water table to 600 mm, water allocation should be based on Soil Group E where the rooting depth is considered to be 600 mm. If soils are modified then the resource consent applicant should work with a soil scientist in consultation with GDC to characterise the soil type that is currently present. Hence, water allocation should be based on the characteristics of the modified soils.

6.1 Maximum Daily Irrigation Requirements

Table 3 lists the maximum daily irrigation requirements for small green vegetables. The maximum daily requirements for cucurbits vegetable and tomatoes are specified in Table 4, and for horticultural, arable and pasture in Table 5.

These tables show the irrigation requirements of each soil-crop combination modelled (refer to Appendix B, for details of the soil type). A blank cell indicates that the crop is not considered suitable to grow on that soil type or irrigation is not required due to high water table conditions.

It should be noted that different irrigation management strategies can be employed by irrigators than what we have considered. Therefore, the daily irrigation depths listed in Table 3, 4 and 5 should be used as indicative guidelines values only. If an applicant can demonstrate different management, and hence different needs and/or more specific information on their soils or climate than the values presented in this report, the applicant should be given due consideration by GDC.

Table 3: Estimated maximum daily irrigation requirements for Vegetables – Small Green

Soil group	Maximum daily requirement (mm/d)				
	Lettuce	Baby Leaf	Broccoli	Cabbage	Onions
A	4	4			4
B	4	4	4	4	4
C	4	4	4	4	4
D	4	4	4	4	4
E	4	4	4	4	4
F	4	4	4	4	4
G	4	4	4	4	4
H	4	4	4	4	4

Table 4: Estimated maximum daily irrigation requirements for Vegetables - Cucurbits family and Tomatoes

Soil group	Maximum daily requirement (mm/d)		
	Melons	Squash	Tomatoes
A			
B			
C			
D	4	4	
E	4	4	4
F	4	4	4
G	4	4	4
H	4	4	4

Table 5: Estimated maximum daily irrigation requirements for Horticulture, Arable and Pasture

Soil group	Maximum daily requirement (mm/d)				
	Citrus	Kiwifruit	Sweet Corn	Maize	Pasture
A					
B					
C					
D		5			5
E	5	5			5
F	5	5	5	5	5

G	5	5	5	5	5
H	5	5	5	5	5

6.2 Annual Irrigation Requirements

Average annual water requirements for different soil-crop combinations are listed in Table 6, 7 and 8. Estimated 1-in-10 year irrigation requirements are given in Table 9, 10 and 11. The 1-in-10 year irrigation demand would be sufficient to meet the annual water requirements in nine years out of 10 years; i.e. it is probable that one-in-10 years the full irrigation demand may not be able to be fully met. Appendix E details the estimated 1-in-5 year and maximum (approximately 1-in-40 years) irrigation requirements.

As previously discussed, there are different varieties of Citrus grown and irrigated in Poverty Bay Flats. The months that different Citrus varieties require irrigation can vary. Therefore, we have listed the irrigation water demand for Citrus by season rather than on an annual volume. We recommend GDC utilise these seasonal volume guidelines to estimate the water requirements for Citrus for the variety grown. The estimated seasonal irrigation requirements are given in Table 12.

Table 6: Estimated average annual irrigation requirements for Vegetables – Small Green

	Average annual water demand (mm/yr)				
Soil group	**Lettuce**	**Baby Leaf**	**Broccoli**	**Cabbage**	**Onions**
A	557	685			514
B	586	679	584	671	529
C	591	720	594	634	514
D	575	691	599	636	516
E	581	700	610	636	516
F	581	700	610	636	516
G	585	712	631	649	514
H	587	713	629	651	514

Table 7: Estimated average annual irrigation requirements for Vegetables - Cucurbits family and Tomatoes

Soil group	**Average annual water demand (mm/yr)**		
	Melons	**Squash**	**Tomatoes**
A			
B			
C			
D	448	481	
E	446	478	522
F	446	478	521
G	449	481	536
H	450	479	543

Table 8: Estimated average annual irrigation requirements for Horticulture, Arable and Pasture

Soil group	**Average water demand (mm/yr)**			
	Kiwifruit	**Sweet Corn**	**Maize**	**Pasture**
A				
B				
C				
D	310			638
E	305			611
F	305	261	268	611
G	307	287	286	570
H	307	290	286	562

Table 9: Estimated 1-in-10 year drought irrigation requirements for Vegetables – Small Green

Soil group	1-in-10 year water demand (mm/yr)				
	Lettuce	**Baby Leaf**	**Broccoli**	**Cabbage**	**Onions**
A	661	751			595
B	693	765	672	780	601
C	702	799	698	744	609
D	675	768	696	739	594
E	682	779	715	749	597
F	682	779	715	749	597
G	698	791	722	770	605
H	694	791	725	790	605

Table 10: Estimated 1-in-10 year drought irrigation requirements for Vegetables - Cucurbits family and Tomatoes

Soil group	1-in-10 year water demand (mm/yr)		
	Melons	**Squash**	**Tomatoes**
A			
B			
C			
D	541	603	
E	545	609	653
F	545	609	654
G	562	607	670
H	562	607	686

Table 11: Estimated 1-in-10 year drought irrigation requirements for Horticulture, Arable and Pasture

Soil group	1-in-10 year water demand (mm/yr)			
	Kiwifruit	Sweet Corn	Maize	Pasture
A				
B				
C				
D	393			800
E	375			775
F	375	325	341	775
G	375	360	342	770
H	375	360	351	742

Table 12: Estimated seasonal irrigation requirements for Citrus

	Seasonal water demand (mm/yr)*							
	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
	Soil Group D				Soil Group E			
Average	0	102	206	44	1	99	202	39
1-in-5 year	0	135	250	75	0	125	250	75
1-in-10 year	0	180	275	80	0	180	275	100
Maximum	0	250	375	150	25	250	375	150
	Soil Group G				Soil Group H			
Average	1	74	183	33	0	73	179	32
1-in-5 year	0	105	245	70	0	105	245	70
1-in-10 year	0	147	252	77	0	147	252	105
Maximum	35	245	385	140	0	245	385	140

* These seasonal water demands represent the probabilistic demand for each season. Therefore, it is not correct to sum up these seasonal demands for 1-in-5 year and 1-in-10 year to calculate the annual demand, if the crop is irrigated continuously throughout the year. However, as no Citrus variety is irrigated continuously throughout the year, the annual totals are not given.

6.3 Percent Seasonal Demand for Small Vegetable

The annual water requirements for vegetable - small green, that are grown throughout the year (i.e., Lettuce, Baby leaf, Broccoli and Cabbage) are given in Section 6.2. However, it is likely that growers choose not to grow vegetables continuously due to various reasons such as market demand, labour etc. To enable efficient water allocation for growers that do not grow vegetable continuously, we have estimated water requirements by season, as presented in Appendix F. This is based on the percentage of the annual amount of irrigation used in that season, and calculated by dividing the water requirements for each season, by the annual amount.

Where a grower needs water for only part of a season for a given crop, the annual water requirements (Section 6.2) can be used in combination with the seasonal percentage demands as given in Appendix F. As an example Table 13 illustrates how to calculate the 1-in-10 year irrigation water requirements for a 10 ha farm on soil type F that grows cabbage (on whole 10 ha) and then follows this by a baby leaf crop.

Section 7 presents another example on how to utilise guideline information for reasonable water allocation for a farm that grows a number of crops (Vegetables and Citrus).

Table 13: 1-in-10 year annual water requirement for a vegetable farm

Example scenario: 10 ha farm is used from the 1st March to 20th June period in a given year to grow Cabbage. This is subsequently followed by six rotations of Baby Leaf from 21st June through to 28th February.

Crop	1-in-10 year water demand (mm/yr)	Fallow days								Annual water requirement for 10 ha (m^3/yr)
		Winter		Spring		Summer		Autumn		
		Days	Water not required (mm/season)	Days	Water not required (mm/ season)	Days	Water not required (mm/ season)	Days	Water not required (mm/ season)	
Cabbage[#1]	749	72	35.2	91	254.7	90	292.1	9	15.4	15,160
Baby Leaf[#2]	779	6	5.1	12	31.8	15	44.1	92	187.0	51,100
Total										**66,650**

Cabbage

One-in-10 year irrigation demand in soil group F = 749 mm/year (Table 9).

Growing season includes whole Autumn and 20 days in Winter (1 March to 20 June).

Fallow day:
- Winter = 72 days
- Spring = 91 days
- Summer = 90 days
- Autumn = 9 days

Percent distribution of irrigation requirement by season:
- Winter = 6%
- Spring = 34%
- Summer = 39%
- Autumn = 21%

Water not required:
- Winter = 749 x 6% / 92 days * 72 days = 35.2 mm/season
- Spring = 749 x 34% = 254.7 mm/season (whole season)
- Summer = 749 x 39% = 292.1 mm/season (whole season)
- Autumn = 749 x 21% / 92 days * 9 days = 15.4 mm/season

Baby Leaf

One-in-10 year irrigation demand in soil group F = 779 mm/year (Table 9).

Growing season includes whole 10 days in Winter, Spring and Summer 21 June to 28 February (six rotations).

Fallow day:
- Winter = 6 days
- Spring = 12 days
- Summer = 15 days
- Autumn = 92 days

Percent distribution of irrigation requirement by season:
- Winter = 10%
- Spring = 31%
- Summer = 34%
- Autumn = 24%

Water not required:
- Winter = 779 x 10% / 92 days * 6 days = 5.1 mm/season
- Spring = 779 x 31% / 91 days * 12 days = 31.8 mm/season
- Summer = 779 x 34% / 90 days * 15 days = 44.1 mm/season
- Autumn = 779 x 24% = 187 mm/season (whole season)

Annual demand = 749 – 35.2 – 254.7 – 292.1 – 15.4 = 151.6 mm/year Annual volume for 10 ha = 151.6/1,000 x 10 x 10,000 = 15,160 m^3/year	Annual demand = 779 – 5.1 – 31.8 – 44.1 – 187 = 511 mm/year Annual volume for 10 ha = 511/1,000 x 10 x 10,000 = 51,100 m^3/year

7 FARM WATER REQUIREMENTS

Vegetable growers will generally grow a range of crops on the same area. The irrigation requirements can be calculated from summing the water requirements for individual crops together, as shown in Table 14.

The dominant soil type refers to the major soil of the location (refer Appendix B). The irrigation water that is not required on fallow days is based on the percentage of the seasonal water requirements of each crop type (refer Appendix F). The output of this analysis provides an estimation of the volume of water required during a 1-in-10 year drought to irrigate this 30 ha farm.

The location of vegetables generally changes from year to year for disease management and fertility reasons. Therefore, it is generally not possible to allocate water for a particular crop using all of the soil types present within a farm. For this reason we recommend in most situations the calculation be based on the dominate farm soil type. For large farms, GDC may choose to account for different soil types at different parts of the farm by calculating water requirements for each of the major soil types along with their representative areas.

Table 14: Example calculation of 1-in-10 year water requirement for a 30 ha farm

Example scenario: In a given year this 30 ha farm grows a mixture of crops including Vegetables and Citrus. Lettuce and Broccoli are grown throughout the year. A single season of Squash is grown. Citrus is irrigated from 1st November to 31st January.

Crop	Area (ha)	Dominant soil group	1-in-10 year water demand (mm/yr)	Fallow days								Annual water requirement (m^3/yr)
				Winter		Spring		Summer		Autumn		
				Days	Water not required (mm/season)	Days	Water not required (mm/ season)	Days	Water not required (mm/ season)	Days	Water not required (mm/ season)	
Lettuce	10	A	661	50	18[#1]	0	0	0	0	0	0	64,300
Broccoli	5	C	698	0	0	0	0	15	43[#2]	0	0	32,750
Squash[#3]	5	F	609	0	0	0	0	0	0	0	0	30,450
Citrus (irrigated from 1 Nov to 31 Jan) [#4]	10	H	222	0	0	0	0	0	0	0	0	22,200
Total	**30**											**149,700**

[#1] One-in-10 year irrigation demand for Lettuce in soil group A = 661 mm/year. As shown in Appendix F, percent use of the annual volume in Winter = 5%. Therefore, the total 1-in-10 year demand in Winter = 661*5% = 33 mm. Number of fallow days = 50 days. Total number of days in Winter = 92 days. Therefore, amount of water not used due to fallow = 33/92*50 = 18 mm.

[#2] One-in-10 year irrigation demand for Broccoli in soil group C = 698 mm/year. As shown in Appendix F, percent use of the annual volume in Summer = 37%. Therefore, the total 1-in-10 year demand in Summer = 698*37% = 258 mm. Number of fallow days = 15 days. Total number of days in Summer = 90 days. Therefore, amount of water not used due to fallow = 258/90*15 = 43 mm.

[#3] Seasonal crops with a single crop per year, thus no fallow days within the irrigation season

[#4] This Citrus variety is irrigated from November through to January. Thus the irrigation season spread over two seasons: Spring and Summer. Therefore, water requirement for each season has been calculated using the values given in Table 12. Number of days for Spring and Summer are 91 and 90 days, respectively. Demand for November (Spring for soil group H) = 147/91*30 = 48.5 mm. Demand from December to January (Summer) = 252/90*62 = 173.6 mm. Therefore, total demand for Citrus = 48.5 + 173.6 = 222 mm.

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Appendix A: Climate data

Table A1: Total monthly rainfall recorded at Gisborne Airport

Season (Jun-May)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
72-73	38	71	47	80	20	115	66	41	11	25	18	102	**634**
73-74	87	45	148	108	62	140	118	219	112	72	38	43	**1,193**
74-75	93	46	72	35	122	212	70	129	168	98	21	75	**1,140**
75-76	105	113	31	180	74	144	55	40	122	48	72	125	**1,111**
76-77	85	50	67	135	37	67	97	81	212	82	92	86	**1,091**
77-78	10	192	30	86	71	328	131	174	174	39	42	114	**1,390**
78-79	49	54	212	29	109	125	191	47	82	78	23	36	**1,034**
79-80	103	53	106	110	46	65	129	110	100	55	57	132	**1,064**
80-81	23	63	114	134	108	184	51	122	53	27	62	179	**1,119**
81-82	41	98	84	232	51	160	151	167	37	92	60	9	**1,182**
82-83	12	4	11	179	38	111	57	24	100	85	36	11	**668**
83-84	67	74	102	35	51	160	113	49	19	73	52	68	**863**
84-85	30	48	115	85	155	129	77	82	160	57	62	52	**1,051**
85-86	28	62	52	14	61	133	323	48	61	43	64	22	**911**
86-87	26	63	167	118	55	38	135	75	113	55	67	37	**949**
87-88	83	135	322	107	46	87	224	51	23	37	119	61	**1,294**
88-89	93	22	8	4	306	83	158	44	76	16	33	17	**859**
89-90	33	28	125	37	21	70	50	148	246	49	120	81	**1,009**
90-91	35	49	113	156	168	145	149	140	34	161	63	35	**1,249**
91-92	70	68	25	71	259	36	60	23	29	80	127	27	**875**
92-93	31	233	89	112	70	111	83	29	123	146	141	69	**1,238**
93-94	40	48	40	108	92	53	30	104	53	7	67	22	**665**
94-95	51	122	34	159	104	71	118	8	40	108	28	2	**844**
95-96	109	151	154	146	114	80	105	48	44	48	51	22	**1,071**
96-97	64	37	233	31	84	67	152	58	30	27	24	147	**956**
97-98	17	35	32	85	22	167	198	128	71	66	35	16	**873**
98-99	82	7	94	117	38	53	180	71	9	14	65	55	**786**
99-00	65	30	159	167	34	109	87	62	64	38	71	162	**1,047**
00-01	92	131	77	60	84	29	91	40	54	6	146	21	**830**
01-02	80	69	6	41	35	50	100	60	71	120	58	169	**859**
02-03	35	76	150	43	100	83	193	125	27	60	35	67	**994**
03-04	83	92	68	67	154	42	89	190	182	60	80	101	**1,207**
04-05	30	54	109	80	130	114	195	93	49	62	59	59	**1,033**
05-06	60	46	169	102	102	113	127	81	26	225	134	57	**1,242**
06-07	50	41	18	41	10	165	152	78	89	49	19	79	**792**
07-08	52	41	90	132	199	113	151	66	120	86	13	120	**1,182**
08-09	96	30	74	55	137	69	130	40	12	28	11	37	**718**
09-10	129	64	21	75	180	198	210	78	66	153	13	44	**1,232**
10-11	143	86	159	149	122	122	185	81	60	197	41	24	**1,369**
Average	**62**	**70**	**96**	**95**	**94**	**111**	**128**	**83**	**80**	**71**	**59**	**66**	**1,016**

Table A2: Total monthly ETo recorded at Gisborne Airport

Season (Jun-May)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
72-73	160	121	90	70	57	32	36	53	96	125	160	152	**1,152**
73-74	142	116	85	58	36	26	27	39	66	115	150	148	**1,008**
74-75	143	128	99	59	46	30	38	38	60	103	127	142	**1,012**
75-76	140	113	88	57	44	26	42	53	70	90	126	181	**1,029**
76-77	155	125	106	68	48	39	38	48	63	87	115	155	**1,047**
77-78	160	113	103	55	36	27	27	37	73	109	141	151	**1,032**
78-79	188	126	87	62	39	22	38	47	63	96	143	166	**1,075**
79-80	146	136	83	54	40	23	28	41	73	102	126	161	**1,012**
80-81	153	118	92	61	32	20	29	52	87	110	139	125	**1,017**
81-82	181	113	91	48	44	24	31	40	75	113	132	152	**1,044**
82-83	174	125	136	62	53	22	31	47	61	97	169	171	**1,148**
83-84	157	107	86	67	43	30	26	41	78	86	119	146	**985**
84-85	169	125	87	51	35	30	28	48	58	115	149	155	**1,051**
85-86	174	119	104	74	41	23	28	45	68	93	136	171	**1,076**
86-87	181	131	91	63	40	30	35	37	63	99	135	155	**1,060**
87-88	166	116	97	56	47	28	29	41	80	114	122	174	**1,069**
88-89	134	118	110	71	37	33	36	51	82	150	142	165	**1,131**
89-90	150	139	114	78	57	37	28	42	60	111	127	168	**1,110**
90-91	160	150	88	69	36	27	33	53	68	105	134	186	**1,108**
91-92	147	136	120	59	38	37	34	66	72	118	128	160	**1,115**
92-93	158	87	87	54	38	29	39	56	58	88	113	124	**930**
93-94	178	108	95	62	47	33	26	38	63	116	108	143	**1,017**
94-95	174	111	113	52	39	30	35	51	77	94	160	171	**1,106**
95-96	137	108	101	61	42	31	40	51	82	93	129	177	**1,053**
96-97	144	122	84	66	38	34	29	51	76	111	149	151	**1,055**
97-98	182	155	116	69	39	27	31	52	56	117	161	184	**1,187**
98-99	147	123	99	62	45	28	31	48	77	146	115	170	**1,090**
99-00	130	127	82	55	39	30	34	44	73	109	128	138	**989**
00-01	147	92	81	53	39	29	31	45	73	121	109	154	**972**
01-02	151	104	113	57	55	25	29	48	68	106	124	138	**1,019**
02-03	157	132	82	55	40	40	32	53	91	112	145	163	**1,101**
03-04	164	120	100	58	39	30	31	39	73	103	133	159	**1,049**
04-05	172	119	99	61	34	36	28	52	79	113	141	143	**1,076**
05-06	168	113	89	68	34	28	30	43	72	99	126	146	**1,015**
06-07	148	113	118	61	46	29	29	49	77	116	156	146	**1,085**
07-08	157	120	90	55	32	37	32	54	68	136	130	137	**1,049**
08-09	172	129	100	60	40	33	33	51	75	115	141	163	**1,111**
09-10	145	114	107	65	30	20	26	47	68	97	142	159	**1,018**
10-11	165	123	91	54	45	22	24	38	90	103	126	146	**1,028**
Average	**158**	**120**	**98**	**61**	**41**	**29**	**31**	**47**	**72**	**109**	**135**	**156**	**1,057**

Calculated from Penman equations (Penman, 1948) using from radiation, temperature, wind and vapour pressure climate data recorded at Gisborne Airport.

Appendix B: Soils data

Table B1 lists a summary of soil properties as given in DSIR (1962) database. The profile available water (PrAW) for soils has a range. In order to differentiate the soils based on their PrAW, soil names have been modified by appending "shallow" and "deep", where necessary. As an example, Makauri clay loam presents in Te Arai area where PrAW varies from 40 through to 200 mm for potential rooting depths of 20 to 120 cm, respectively. Therefore, for soils where the rooting depth is 20 cm (Group A) the soil name is given as "Makauri clay loam (shallow)", and for deeper soils in Group H with 120 cm rooting depth it is classified as "Makauri clay loam (deep)".

Table B1: Soil profile available water (PrAW) data

Soil name	Soil map unit	Location	Soil type	Top soil PrAW (mm AW/cm soil depth)	Subsoil PrAW (mm AW/cm soil depth)
Group A: 20cm Rooting depth					
Makauri clay loam (shallow)	9 5	10 Te Arai area	11 silty clay loam	12 2	13 0
Makauri clay loam friable subsoil (shallow)	15 5a	16 Te Arai area	17 silty clay loam	18 2	19 0
Kaiti silt loam (shallow)	6	Te Arai area	silty clay loam	2	0
Kaiti heavy silt loam (shallow)	6b	Te Arai area	silty clay loam	2	0
Kaiti clay loam (shallow)	6c	Te Arai area	silty clay loam	2	0
Estimated average value				**2.0**	**0**
Group B: 30cm Rooting Depth					
Waihirere clay loam (shallow)	3f	Patutahi area	silty clay loam	1	1.0
Makauri clay loam (shallow)	5	Patutahi area	silty clay loam	1.2	1.2
Waipaoa silt loam (shallow)	1	Ormond area	silty clay loam	1.2	1.1
Estimated average value				**1.1**	**1.1**
Group C: 30cm Rooting depth					
Waihirere clay loam (shallow)	3f	Te Arai area	silty clay loam	1.9	2.2
Waihirere heavy silt loam mottled phase	3e	Te Arai area	heavy silt loam	1.95	2.1

Soil name	Soil map unit	Location	Soil type	Top soil PrAW (mm AW/cm soil depth)	Subsoil PrAW (mm AW/cm soil depth)
(shallow)					
Waihirere silt loam mottled phase (shallow)	3b	Te Arai area	silt loam	2	2
Waihirere silt loam mottled phase (shallow)	3b	Patutahi area	silt loam	2	1.3
Estimated average value				**2**	**2**
Group D: 45cm Rooting depth					
Kaiti silt loam (shallow)	6	Patutahi area	silty clay loam	1.9	0.5
Kaiti clay loam (shallow)	6c	Patutahi area	silty clay loam	1.9	0.5
Waihirere heavy silt loam mottled phase (shallow)	3c	Patutahi area	silty clay loam	1.9	0.7
Makaraka clay loam (shallow)	4a	Ormond area	silty clay loam	1.9	0.7
Makauri clay loam (shallow)	5	Ormond area	silty clay loam	1.9	0.7
Estimated average value				**1.9**	**0.6**
Group E: 60cm Rooting depth					
Waihirere heavy silt loam mottled subsoil (shallow)	3e	Ormond area	silt loam	2	1.3
Waihirere clay loam (deep)	3f	Patutahi area	silty clay loam	1.9	0.8
Makauri clay loam (shallow)	5	Patutahi area	silty clay loam	1.9	0.8
Kaiti silt loam (deep)	6	Patutahi area	silty clay loam	1.9	0.8
Kaiti heavy silt loam (shallow)	6b	Patutahi area	silty clay loam	1.9	0.5
Kaiti heavy silt loam (deep)	6b	Patutahi area	silty clay loam	1.9	0.8
Kaiti clay loam (deep)	6c	Patutahi area	silty clay loam	1.9	0.8
Kaiti clay loam shallow topsoil (Shallow)	6d	Patutahi area	silty clay loam	1.9	0.8
Estimated average value				**1.9**	**0.8**

Soil name	Soil map unit	Location	Soil type	Top soil PrAW (mm AW/cm soil depth)	Subsoil PrAW (mm AW/cm soil depth)
Group F: 70cm Rooting Depth					
Kaiti clay loam shallow topsoil (deep)	6d	Patutahi area	silty clay loam	1.9	0.8
Makaraka clay loam (deep)	4a	Ormond area	silty clay loam	1.9	0.8
Makauri clay loam (deep)	5	Ormond area	silty clay loam	1.9	0.8
Waipaoa silt loam (deep)	1	Ormond area	silty clay loam	1.9	0.8
Estimated average value				**1.9**	**0.8**
Group G: 90cm Rooting depth					
Waihirere heavy silt loam mottled phase (deep)	3e	Patutahi area	silty clay loam	1.9	1.0
Waihirere heavy silt loam mottled subsoil (deep)	3e	Ormond area	silt loam	2	1.5
Waihirere silt loam (shallow)	3	Patutahi area	silt loam	2	1.6
Waihirere silt loam mottled phase (deep)	3b	Patutahi area	silt loam	2	1.6
Estimated average value				**2**	**1.5**
Group H: 120cm Rooting depth					
Waihirere clay loam (deep)	3f	Te Arai area	silty clay loam	1.9	1.6
Waihirere heavy silt loam (shallow)	3c	Te Arai area	heavy silt loam	1.95	1.3
Waihirere heavy silt loam (deep)	3c	Te Arai area	heavy silt loam	1.95	1.6
Waihirere heavy silt loam mottled phase (deep)	3e	Te Arai area	heavy silt loam	1.95	1.6
Waihirere silt loam (deep)	3	Patutahi area	silt loam	2	1.6
Waihirere heavy silt loam (shallow)	3c	Patutahi area	silt loam	2	1.6
Waihirere silt loam (shallow)	3	Te Arai area	silt loam	2	1.3
Waihirere silt loam (deep)	3	Te Arai area	silt loam	2	1.6
Waihirere silt loam mottled phase (deep)	3b	Te Arai area	silt loam	2	1.6

Soil name	Soil map unit	Location	Soil type	Top soil PrAW (mm AW/cm soil depth)	Subsoil PrAW (mm AW/cm soil depth)
Makauri clay loam (deep)	5	Te Arai area	silty clay loam	2	1.6
Makauri clay loam friable subsoil (deep)	5a	Te Arai area	silty clay loam	2	1.6
Kaiti silt loam (deep)	6	Te Arai area	silty clay loam	2	1.6
Kaiti heavy silt loam (deep)	6b	Te Arai area	silty clay loam	2	1.6
Kaiti clay loam (deep)	6c	Te Arai area	silty clay loam	2	1.6
Estimated average value				**2**	**1.6**

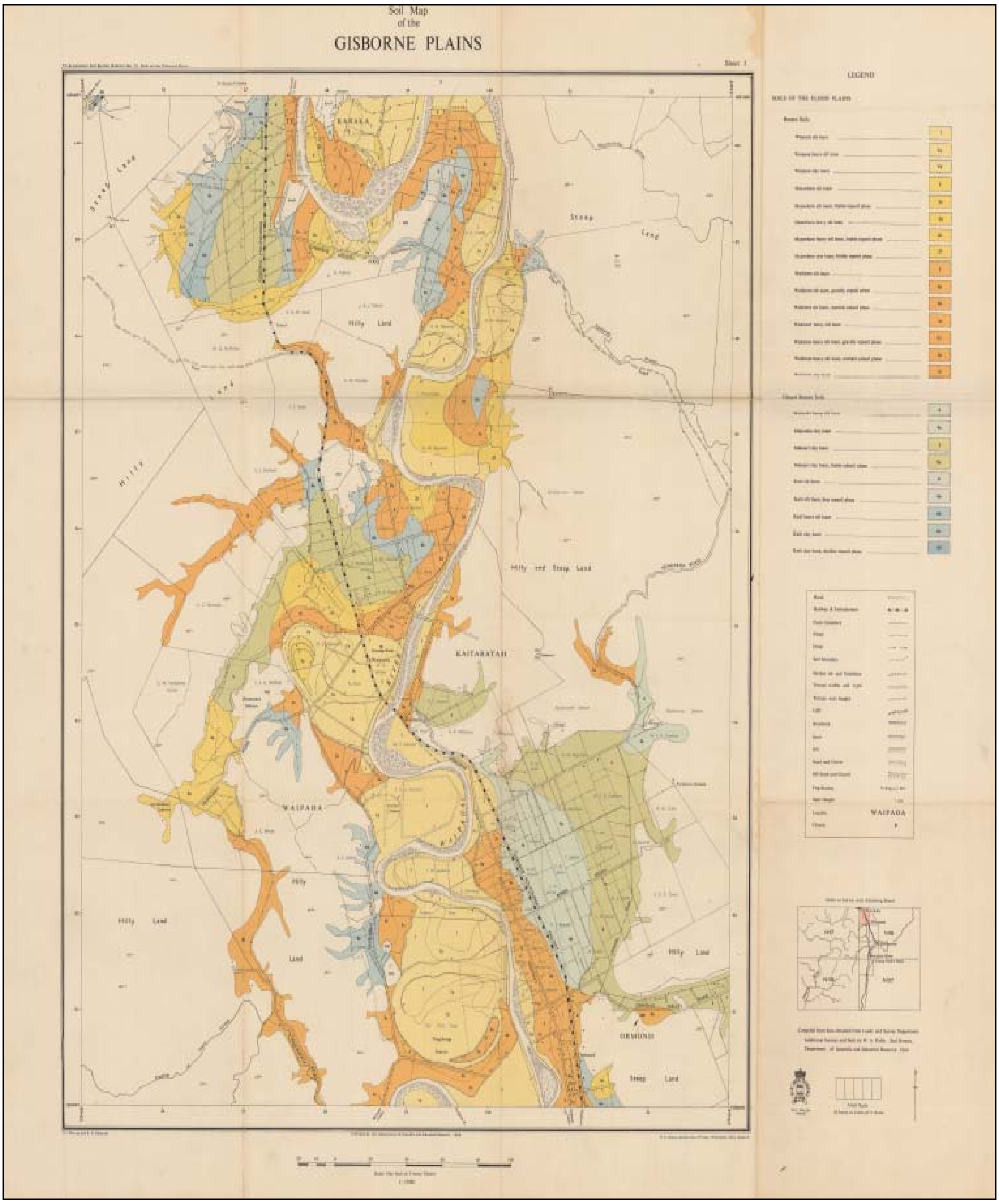

Figure B1: Soils map of Ormond area (from DSIR, 1962)

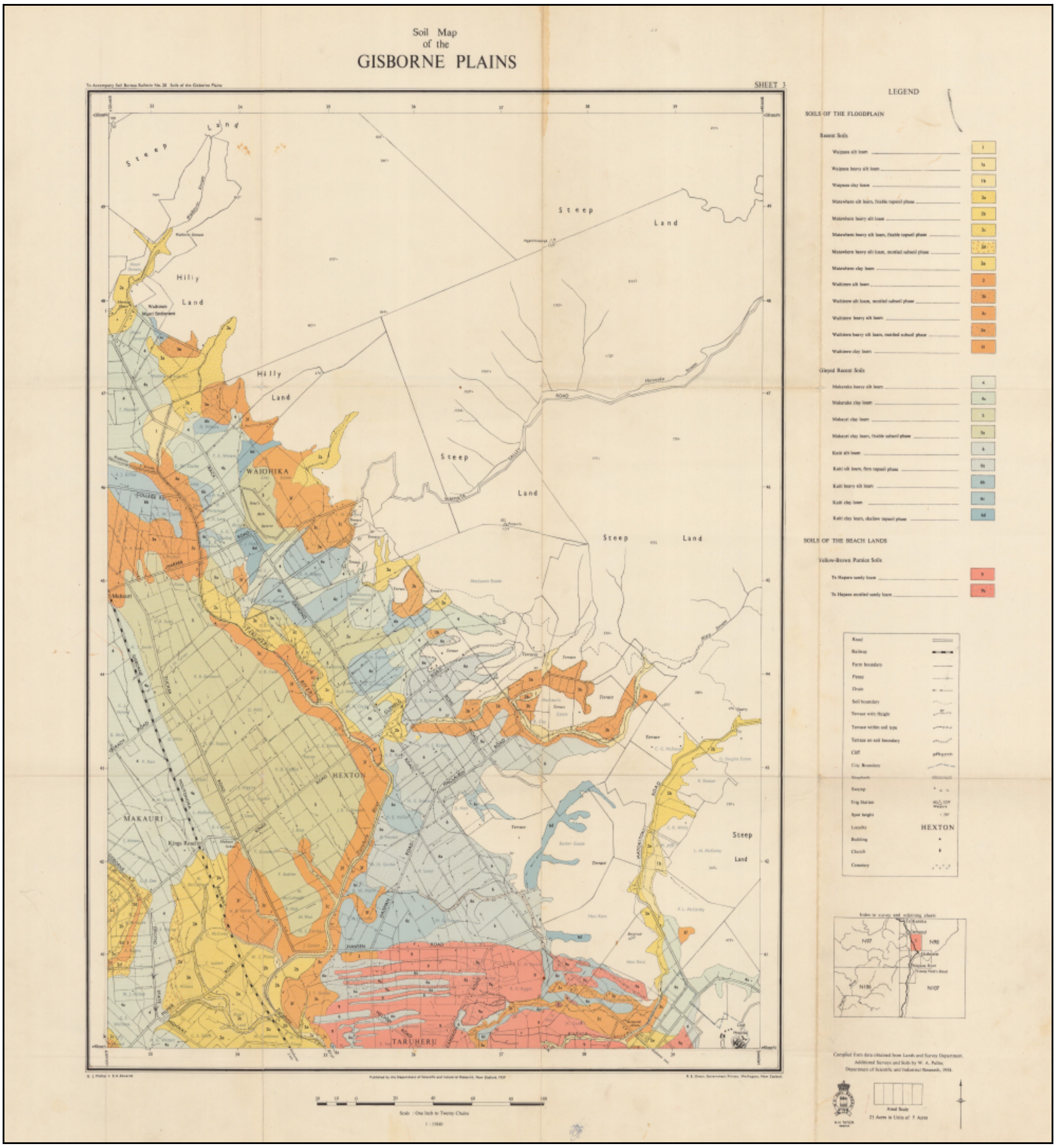

Figure B2: Soils map of the Ormond Area (from DSIR, 1962)

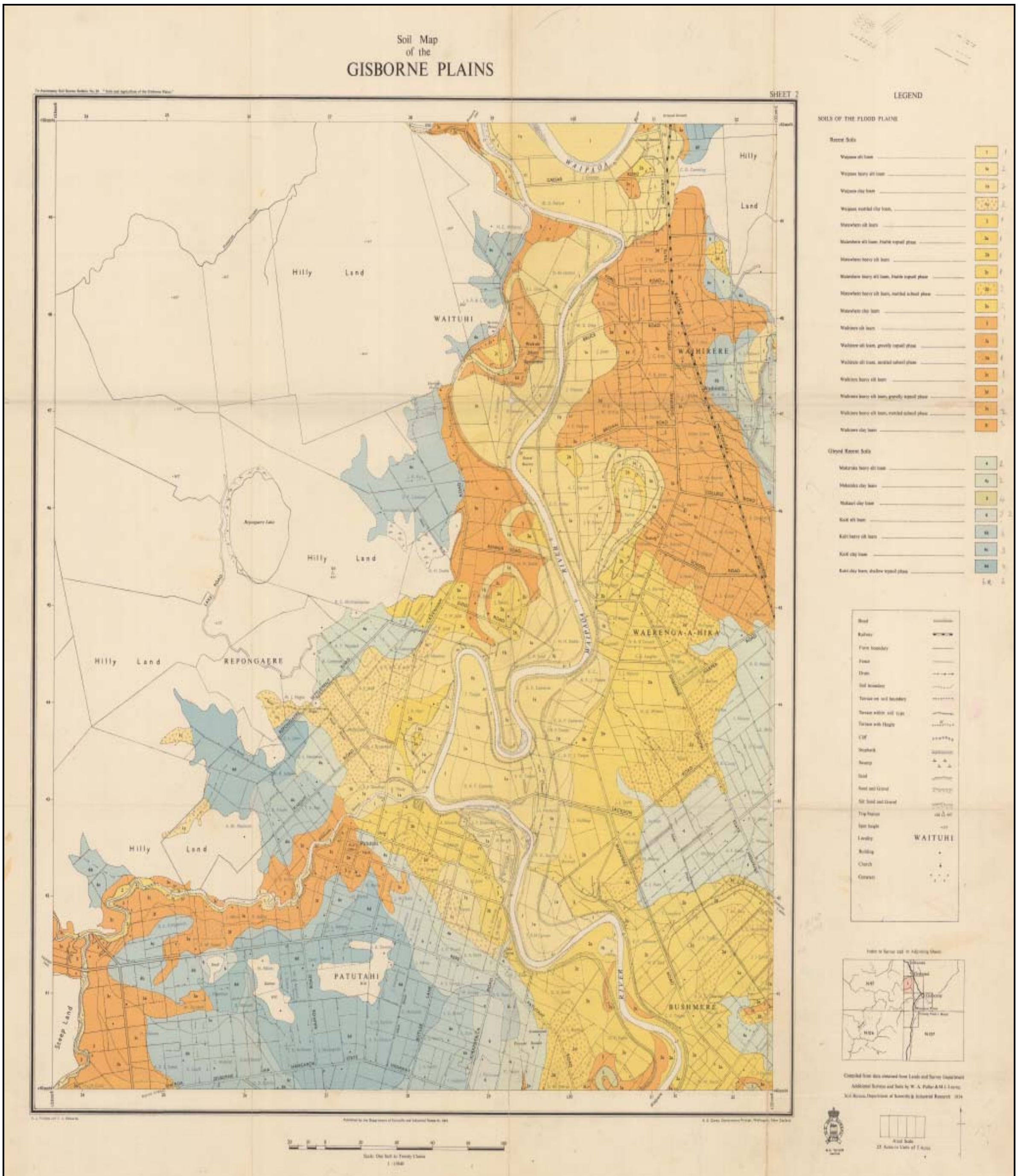

Figure B3: Soils map of the Patutahi area (from DSIR, 1962)

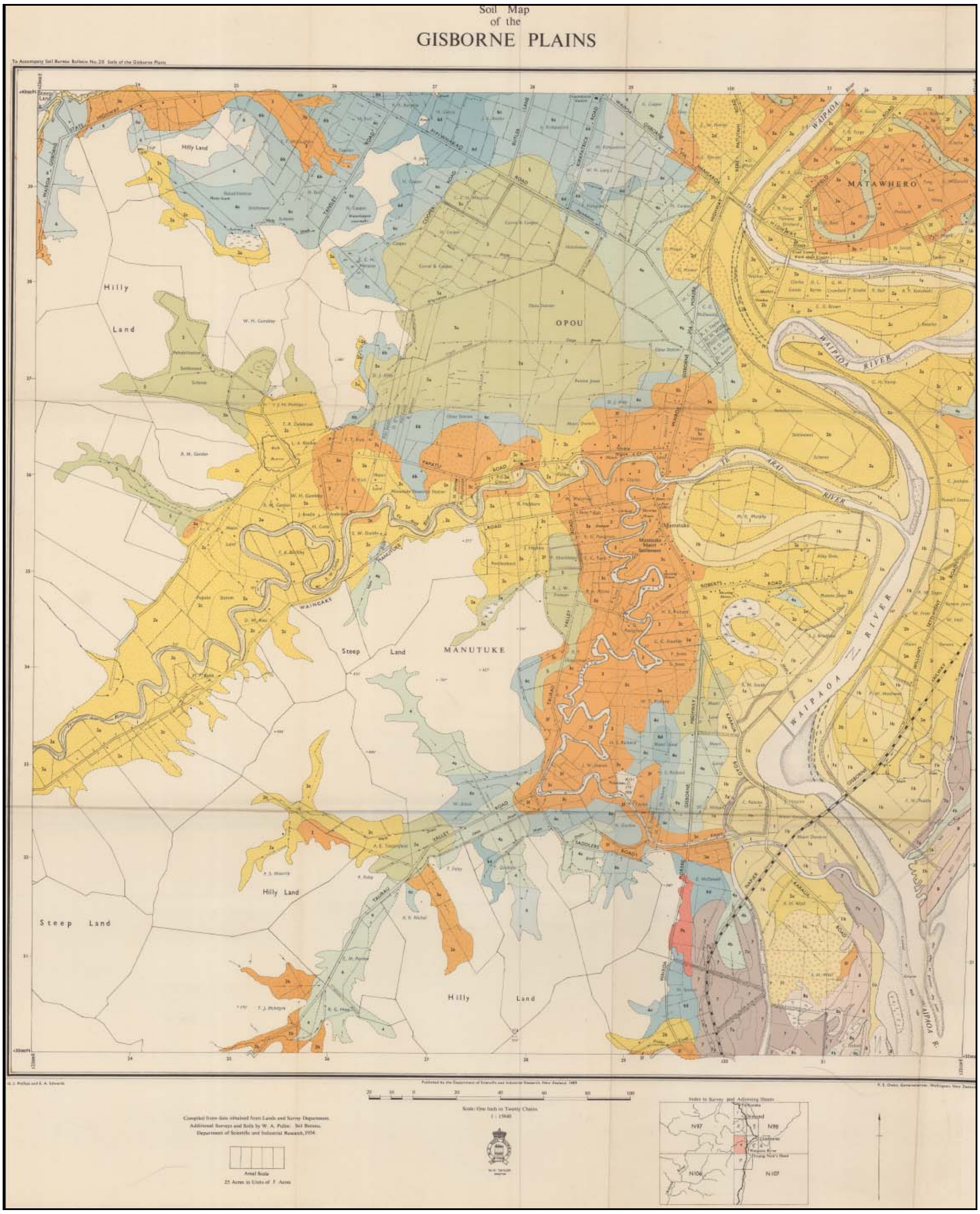

Figure B4: Soils map of the Patutahi and Te Arai area (from DSIR, 1962)

Appendix C: Grower information

Typical crop management and irrigation practices provided by growers following a workshop held in Gisborne on October 31 2011.

Table C1: Typical vegetable irrigation practices

Crops	Season	App. Depth (mm)	Return period (days)	Irrigation methods	Maximum rooting depth* (cm)	Target minimum soil moisture (% PAW)**	% of time allowed to exceed Target PAW	Critical PAW ie. never below this PAW	Notes
Lettuce	Grown all year around	20	2-3	Sprinkler	35	60%	10%	50%	
		1.5	7	Trickle[#]					
Baby Leaf	Grown all year around	7	1	Sprinkler	25	75%	10%	60%	Initial applications day 1 and 2, 20 and 15 mm – then miss a day and irrigated on need
Melons	Sept to April	12	3	Trickle	60	60%	15%	40%	Only grown under mulch
Squash	Aug to Jan	12	3	Trickle	60	60%	15%	40%	Mulch
Squash	Aug to April	25	14	Travelling Boom	60	60%	20%	35%	Open field
				Big Gun					
Broccoli	Grown all year round	30	28	Travelling boom	50	60%	10%	35%	Open field
				Big Gun					
Cabbage	Grown all year round	30	28	Travelling boom	50	60%	10%	35%	Open field has a 25 mm initial wetting up
				Big Gun					
				Sprinkler					
Tomatoes	Sept to April	25	28	Travelling boom	100	60%	20%	35%	
				Big Gun					
Onions	Jul-Feb	30	10	Travelling boom	25	60%	20%	35%	
				Big Gun					

Winter nutrient-feed only
* High groundwater levels will limit rooting depths in some areas so this will be modified based on soil type
** PAW = plant available water at field capacity.

Table C2: Typical irrigation practices for other crops

Type of agricultural system	Crops irrigated	Typical irrigation equipment used	App. depth (mm)	Return period (days)	Maximum rooting depth*	Target minimum soil moisture (% PAW)**	Time allowed to exceed target PAW	Critical PAW	Notes
Horticultural	Citrus	Drippers, Mini sprinklers.	6	1	70	50%	20%	40%	
	Kiwifruit		6	1	50	60%	10%	50%	
Arable	Sweet Corn	Travelling boom	30	As reqd.	100	50%	20%	35%	Under Mulch
	Sweet Corn	Travelling boom	30	As reqd.	100	50%	20%	35%	
	Seed Maize	Travelling boom	30	As reqd.	80	50%	20%	35%	
Pastoral	Rye grass and clover pasture	Centre Pivot	10	2	70	50%	10%	25	
		Lateral booms	35	7					
		K-line	35	7					

* High groundwater levels will limit rooting depths in some areas so this will be modified based on soil type
** PAW = plant available water at field capacity.

Model parameters for continuously cropped vegetables

The year has been divided up into four seasons as shown in Table C3.

Table C3: Typical irrigation

Season	Months modelled
Summer	December – February
Autumn	March – May
Winter	June – August
Spring	September - November

The length of the growing period will vary over the year and the same crop is not planted back in the same area within the same year, except for baby leaf lettuce which has a 2 in 3 year rotation. Given the change in the growing period, the number of crops per season based on an end on end rotation, has been modelled as shown in Table C4.

Table C4: Growing information for Vegetable - small green crops

	Baby leaf		Lettuce		Broccoli		Cabbage	
Season	Growing length (days)	Crops per season	Growing length (days)	Crops per season	Growing length (days)	Crops per season	Growing length (days)	Crops per season
Summer	25	4	44	2	64	1	85	1
Autumn	35	2	66	1	90	1	100	1
Winter	50	2	105	1	112	1	140	1
Spring	35	3	60	2	80	1	90	1

Appendix D: Crop maximum rooting depth

The modelled maximum rooting depths for different soils groups are listed in Table D1.

Table D1: Crop maximum rooting depth

Soil group	Maximum rooting depth (mm)												
	Lettuce	**Baby Leaf**	**Broccoli**	**Cabbage**	**Onions**	**Melons**	**Squash**	**Tomatoes**	**Citrus**	**Kiwifruit**	**Sweet Corn**	**Maize**	**Pasture**
A	200	200			200								
B	300	250	300	300	250								
C	300	250	300	300	250								
D	350	250	450	450	250	450	450			450			450
E	350	250	500	500	250	600	600	600	600	500			600
F	350	250	500	500	250	600	600	700	700	500	700	700	600
G	350	250	500	500	250	600	600	900	700	500	900	800	600
H	350	250	500	500	250	600	600	1,000	700	500	1,000	800	600

Appendix E: 1-in-5 year drought and maximum yearly irrigation requirements

Table E1: Estimated 1-in-5 year irrigation requirements for Vegetables – Small Green

Soil group	1-in-5 year water demand (mm/yr)				
	Lettuce	**Baby Leaf**	**Broccoli**	**Cabbage**	**Onions**
A	610	731			572
B	625	709	623	729	567
C	658	767	654	704	564
D	641	724	647	706	572
E	643	744	662	688	572
F	643	744	662	688	572
G	642	759	702	706	572
H	642	762	702	713	572

Table E2: Estimated 1-in-5 year irrigation requirements for Vegetables - Cucurbits family and Tomatoes

Soil group	1-in-5 year water demand (mm/yr)		
	Melons	**Squash**	**Tomatoes**
A			
B			
C			
D	506	550	
E	507	550	599
F	507	550	589
G	509	554	617
H	514	550	625

Table E3: Estimated 1-in-5 year irrigation requirements for Horticulture, Arable and Pasture

Soil group	1-in-5 year water demand (mm/yr)			
	Kiwifruit	**Sweet Corn**	**Maize**	**Pasture**
A				
B				
C				
D	360			716
E	360			710
F	360	310	312	710
G	350	335	332	679
H	360	334	335	679

Table E4: Estimated maximum irrigation requirements for Vegetables – Small Green

Soil group	Maximum water demand (mm/yr)				
	Lettuce	**Baby Leaf**	**Broccoli**	**Cabbage**	**Onions**
A	728	834			636
B	701	805	762	876	632
C	740	858	776	856	632
D	732	812	780	864	640
E	736	842	788	864	636
F	736	842	788	864	636
G	732	842	780	852	636
H	732	850	780	852	636

Table E5: Estimated maximum irrigation requirements for Vegetables - Cucurbits family and Tomatoes

Soil group	Maximum water demand (mm/yr)		
	Melons	**Squash**	**Tomatoes**
A			
B			
C			
D	660	724	
E	668	732	800
F	668	732	796
G	676	760	848

H	680	760	848

Table E6: Estimated maximum irrigation requirements for Horticulture, Arable and Pasture

Soil group	Maximum water demand (mm/yr)			
	Kiwifruit	Sweet Corn	Maize	Pasture
A				
B				
C				
D	495			940
E	495			925
F	495	380	380	925
G	525	405	385	945
H	525	405	385	910

Appendix F: Percent distribution of irrigation requirements by season for continuously cropped Vegetables – Small Green

Table F1: Percent distribution of irrigation requirements for Lettuce by season

	Percent distribution of irrigation requirement by season											
	Winter	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**
	Soil Group A				**Soil Group B**				**Soil Group C**			
Average	3%	32%	46%	18%	5%	31%	43%	20%	4%	32%	43%	20%
1-in-5 year	4%	32%	43%	21%	6%	32%	39%	23%	6%	31%	39%	24%
1-in-10 year	5%	34%	40%	22%	7%	31%	39%	23%	6%	32%	38%	24%
Maximum	7%	32%	39%	21%	10%	32%	37%	22%	8%	33%	37%	22%
	Soil Group D				**Soil Group E**				**Soil Group F**			
Average	4%	31%	45%	20%	4%	31%	45%	20%	4%	31%	45%	20%
1-in-5 year	5%	31%	41%	23%	5%	31%	41%	23%	5%	31%	41%	23%
1-in-10 year	6%	33%	39%	23%	5%	33%	39%	23%	5%	33%	39%	23%
Maximum	8%	32%	38%	22%	8%	32%	38%	22%	8%	32%	38%	22%
	Soil Group G				**Soil Group H**							
Average	4%	32%	44%	21%	4%	32%	44%	21%				
1-in-5 year	6%	31%	40%	23%	6%	31%	40%	23%				
1-in-10 year	7%	32%	38%	24%	7%	32%	37%	24%				
Maximum	9%	31%	38%	22%	9%	31%	37%	23%				

Table F2: Percent distribution of irrigation requirements for Baby Leaf by season

	Percent distribution of irrigation requirement by season											
	Winter	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**
	Soil Group A				**Soil Group B**				**Soil Group C**			
Average	8%	31%	38%	23%	9%	31%	38%	22%	9%	31%	37%	23%
1-in-5 year	9%	32%	35%	24%	11%	31%	36%	23%	11%	31%	34%	24%
1-in-10 year	10%	32%	35%	24%	10%	32%	35%	23%	11%	30%	34%	25%
Maximum	12%	31%	33%	23%	11%	31%	34%	23%	13%	30%	32%	24%
	Soil Group D				**Soil Group E**				**Soil Group F**			
Average	9%	31%	37%	23%	9%	31%	37%	23%	9%	31%	37%	23%
1-in-5 year	10%	31%	35%	24%	10%	31%	34%	24%	10%	31%	34%	24%
1-in-10 year	10%	31%	34%	25%	10%	31%	34%	24%	10%	31%	34%	24%
Maximum	13%	31%	33%	23%	12%	31%	33%	24%	12%	31%	33%	24%
	Soil Group G				**Soil Group H**							
Average	9%	31%	37%	23%	9%	31%	37%	23%				
1-in-5 year	10%	31%	35%	24%	11%	31%	34%	24%				
1-in-10 year	11%	31%	34%	25%	11%	31%	34%	25%				
Maximum	13%	30%	32%	24%	13%	30%	32%	24%				

Table F3: Percent distribution of irrigation requirements for Broccoli by season

	Percent distribution of irrigation requirement by season											
	Winter	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**
	Soil Group A				**Soil Group B**				**Soil Group C**			
Average					6%	34%	41%	20%	4%	34%	43%	20%
1-in-5 year					7%	33%	38%	22%	6%	32%	39%	23%
1-in-10 year					7%	34%	37%	22%	7%	33%	37%	23%
Maximum					9%	33%	35%	22%	8%	33%	35%	23%
	Soil Group D				**Soil Group E**				**Soil Group F**			
Average	5%	34%	42%	20%	5%	33%	42%	20%	5%	33%	42%	20%
1-in-5 year	6%	33%	39%	22%	7%	32%	38%	23%	7%	32%	38%	23%
1-in-10 year	7%	32%	38%	22%	7%	32%	36%	24%	7%	32%	36%	24%
Maximum	10%	32%	35%	23%	10%	31%	35%	24%	10%	31%	35%	24%
	Soil Group G				**Soil Group H**							
Average	5%	34%	41%	21%	5%	34%	40%	21%				
1-in-5 year	7%	32%	37%	23%	7%	32%	37%	23%				
1-in-10 year	8%	33%	35%	24%	8%	33%	35%	24%				
Maximum	10%	33%	34%	23%	10%	33%	33%	24%				

Table F4: Percent distribution of irrigation requirements for Cabbage by season

	Percent distribution of irrigation requirement by season											
	Winter	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**
	Soil Group A				**Soil Group B**				**Soil Group C**			
Average					5%	32%	43%	20%	5%	32%	45%	19%
1-in-5 year					7%	32%	41%	21%	6%	32%	42%	21%
1-in-10 year					7%	32%	39%	23%	6%	32%	39%	23%
Maximum					8%	33%	37%	23%	9%	32%	37%	22%
	Soil Group D				**Soil Group E**				**Soil Group F**			
Average	4%	32%	45%	19%	4%	33%	44%	19%	4%	33%	44%	19%
1-in-5 year	5%	32%	41%	22%	5%	32%	42%	21%	5%	32%	42%	21%
1-in-10 year	6%	32%	40%	22%	6%	34%	39%	21%	6%	34%	39%	21%
Maximum	8%	32%	37%	23%	7%	33%	36%	23%	7%	33%	36%	23%
	Soil Group G				**Soil Group H**							
Average	4%	32%	44%	20%	5%	32%	44%	20%				
1-in-5 year	6%	32%	41%	21%	6%	31%	41%	22%				
1-in-10 year	6%	31%	39%	23%	6%	31%	40%	23%				
Maximum	8%	33%	36%	23%	8%	33%	36%	23%				