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# Manuherikia Catchment Study: Stage 1 (Land)

## Prepared for the Manuherikia Catchment Water Strategy Group

**Report C12040/1**

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AQUALINC RESEARCH LIMITED

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# 1 INTRODUCTION

## 1.1 Background

The Manuherikia River system in Central Otago is a unique catchment in terms of climate, topography and water management history. The catchment is semi-arid, with a continental type of climate with larger seasonal temperature variations than is common elsewhere in New Zealand.

The community's long-term goal is realise the potential growth within the region. The potential growth in the catchment is closely linked to water. It is generally believed that the growth potential is constrained by water availability for irrigation.

The Manuherikia Catchment Water Strategy Group (MCWSG) was set up to develop and oversee the implementation of a water strategy for the catchment. The MCWSG has proposed that a project be undertaken in three sections to:

(i) Define the potential irrigation demand in the Manuherikia River catchment (land),
(ii) Provide an initial assessment of the water availability for meeting this demand (hydrology), and
(iii) Options to close the gap between supply and demand (options).

The project has been broken into two parts, Part A (Sections (i), (ii) and (iii a)) and Part B (Section (iii b)). Part A provides the initial big-picture information to understand the overall water resources in the catchment. Part B looks in more detail at specific options to progress water resources development. The MCWSG envisages that the project will provide information to help the community make informed decisions, leading to a comprehensive Manuherikia catchment water strategy.

Aqualinc has been contracted to complete Part A of the project. This report summarises the findings for Section (i), and describes the climate, soils, potential irrigable areas and irrigation water requirements of the Manuherikia catchment.

## 1.2 Project area

The study area includes the Manuherikia catchment, and the Waikerikeri catchment to Dairy Creek, since for some of the potential development options there is an overlap between the lower reaches of the Manuherikia catchment and the Waikerikeri catchment.

## 1.3 Stage 1 general methodology

Irrigable land in the Manuherikia catchment has been defined using GIS analysis and mapping. This standard procedure allowed constraints such as altitude, climate, soil type and topography (slope) to be imposed. Maps of the potential irrigable land have been prepared and are included in this report.

The GIS information is available to link this section of the project to subsequent stages of the project.

# 2 POTENTIAL IRRIGABLE AREA

Land that is suitable for irrigation has been defined based on climate, slope, aspect and elevation, using topographic information and the slope classifications in the NZ Land Resources Inventory GIS layer, as described below.

We have completed this analysis at a catchment scale to determine potential area and from that, potential irrigation demand as a whole. Although we expect that the defined irrigable areas generally include current irrigation areas, they will not necessarily be identical at an individual farm scale. Small variations in areas are not a concern since at this stage we are interested in overall catchment irrigated areas and water demands, not farm specific water requirements.

## 2.1 Climate

### 2.1.1 Rainfall

There are over 20 historical rainfall stations of varying record length in the study area. Some records extend back as far as the 1880’s and 1890’s.

Mean annual rainfall for the Manuherikia catchment is about 630 mm/y. Rainfall is higher at the north-eastern end of the catchment, with the Hawkdun Range receiving up to 1,200 mm/y. At the other end of the catchment, Alexandra only receives 350 mm/y on average. The typical rainfall range for irrigable areas is about 350 – 800 mm/y (refer to Appendix A).

Figure 1 illustrates the seasonal rainfall trends at Blackstone Hill, at the north-eastern end of the catchment, and Alexandra in the south-western end of the catchment. This figure illustrates that summer rainfall is greater than winter rainfall.

Figure 2 illustrates long-term rainfall trends. In general terms, the catchment seems to have been slightly drier during the mid-1940’s to 1970’s, and slightly wetter during the 1980’s and 1990’s. However, long term trends are not always consistent across the catchment. For example, significantly above-average rainfall was recorded at Blackstone Hill in the 1920’s and 1930’s; a trend not seen at Alexandra.

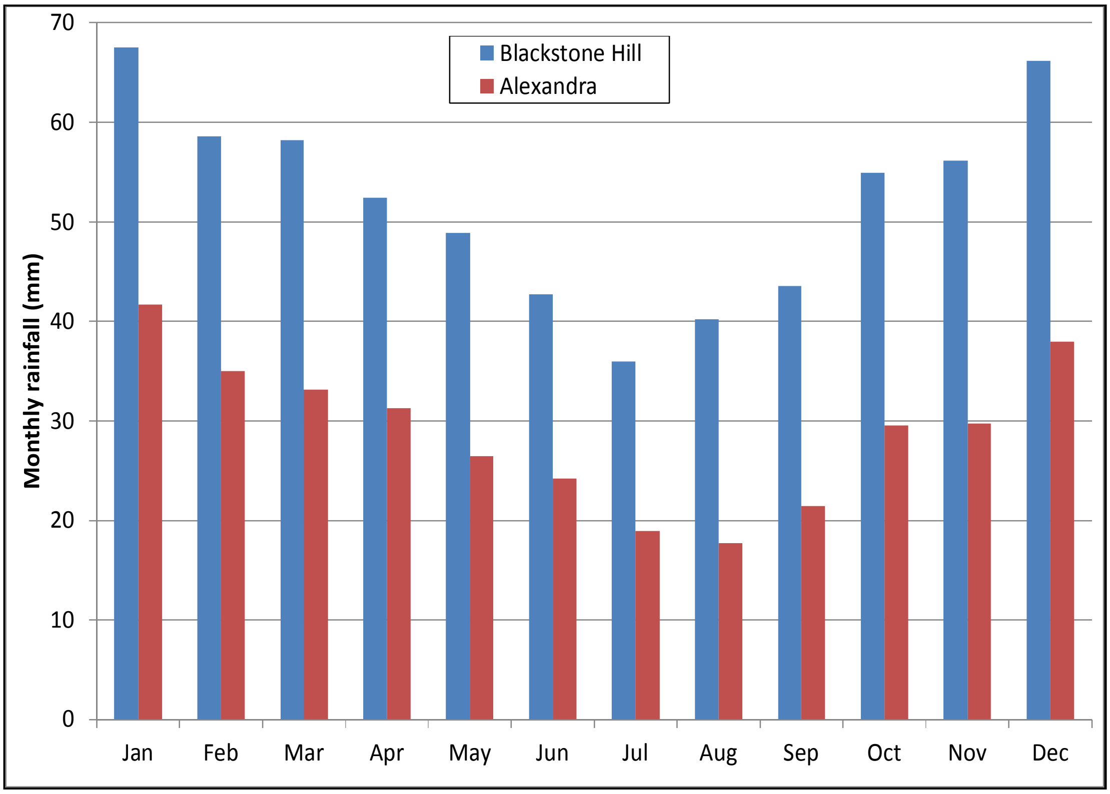

*Figure 1: Seasonal rainfall trends at Blackstone Hill and Alexandra*

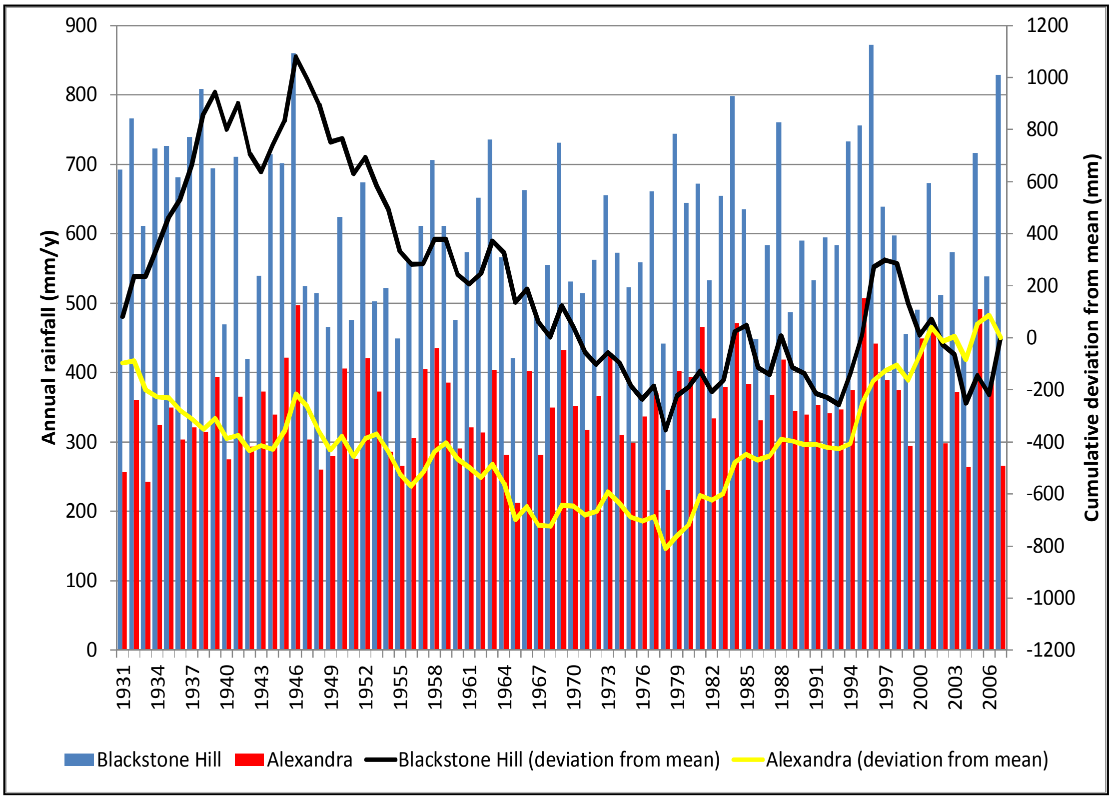

*Figure 2: Long term rainfall trends at Blackstone Hill and Alexandra*

### 2.1.2 Evapotranspiration

Evapotranspiration is the total water lost through evaporation and transpiration from the soil and vegetative cover. NIWA's estimate of reference evapotranspiration ($ET_o$), calculated by the Penman equations using radiation, temperature, wind and vapour pressure data has been used for this study. $ET_o$ estimates for climate stations within or in the vicinity of the study area are summarised in Table 1.

*Table 1: Evapotranspiration by location*

| Location | Station ID | Distance from centre of study area (km) | Mean annual $ET_o$ (mm/y)[(1)] |
|---|---|---|---|
| Lauder | 5535 | 0 | 950 |
| Alexandra | 36592 | 33 | 750 |
| Ranfurly | 18593 | 34 | 870 |
| Clyde | 12431 | 35 | 800 |
| Tara Hills (near Omarama) | 5212 | 59 | 940 |
| | | **Average** | **860** |
| (1) Records were extended to cover the full period from June 1972 to May 2011 using Aqualinc's climate extension software. | | | |

From the climate station data, we estimate mean annual $ET_o$ probably ranges from about 750 – 950 mm/y within the study area. Areas exposed to greater wind-run (such as Thompson's Gorge) will have higher evapotranspiration (ET), while sheltered or shaded areas will have lower ET. However, because of the lack of wind and radiation data in many areas, it is generally not possible to reliably map the areas of higher and lower ET within the study area.

Because of this lack of data we have subsequently assumed Lauder $ET_o$ estimates are representative of the study area. It appears from the data that Lauder has the highest mean annual ET in the catchment. The consequences of using Lauder ET for all areas is that modelled irrigation demand may be overestimated in some areas, particularly locations such as Alexandra, that appear to have lower ET.

Seasonal variations in $ET_o$ and temperature are illustrated in Figure 3 and Figure 4. Low temperatures over winter, early spring and late autumn limit the growing season.

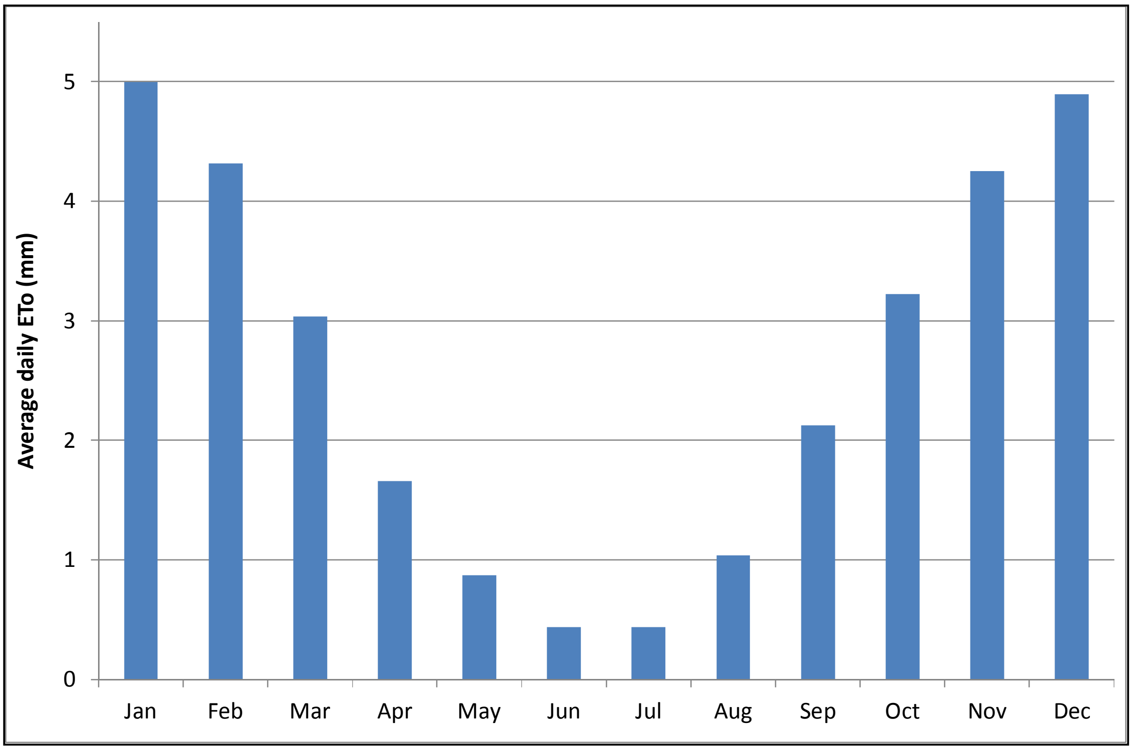


*Figure 3: Seasonal $ET_o$ trends at Lauder*

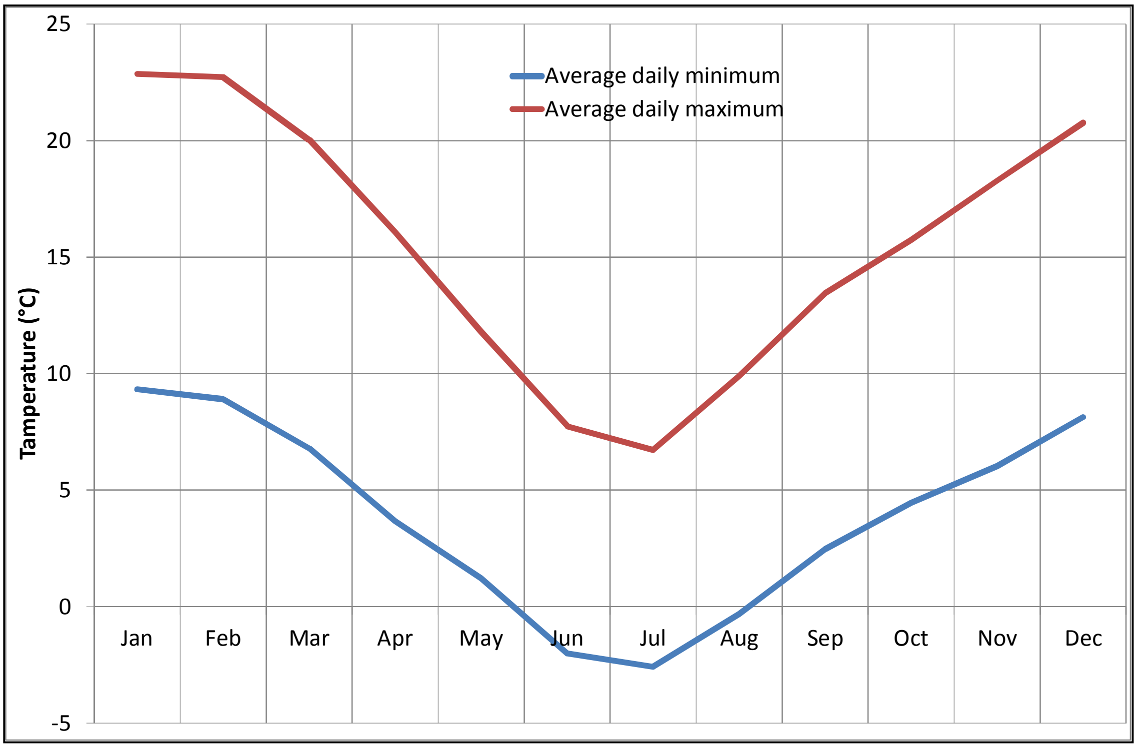


*Figure 4: Seasonal temperature trends at Lauder*

## 2.2 Soils

There are a range of soils across the catchment. In this study, we used soil profile available water estimates from the New Zealand Fundamental Soils Layer (Landcare 2000). Soils information is included in Appendix C.

Both GrowOtago and the Fundamental Soils Layer estimates of profile available water are identical for the study area. We understand that details on soils available from DSIR soil mapping undertaken during 60/70's have been incorporated into the Landcare database.

## 2.3 Slope

In New Zealand most pasture, horticulture and arable irrigation occurs on flat to undulating land (≤ 7º). However, recent developments in irrigation technology means irrigation of rolling land (up to 15º) is becoming more common.

In Central Otago, irrigation of rolling country on slopes of up to 20º has been and continues to be carried out, particularly using contour irrigation. In other locations in New Zealand such as North Otago, there are also isolated incidences of slopes up to 20º being irrigated with centre-pivots.

For the purposes of broadly defining potential new areas of irrigation, we have assumed that the majority of any future irrigation will not occur on land slopes over 15º. Steep lands may not be suitable for installation of some irrigation system types and at times, steep slopes can be susceptible to run-off.

We acknowledge that some steep land that is unsuitable for pasture may be suitable for viticulture or horticultural development, where solid-set or drip systems can be installed. We also acknowledge that other steeper areas may be irrigated, but these areas have not been specifically defined at this stage. We have assumed any land suitable for pasture will also be suitable for grapes.

Land slope is illustrated in Appendix B. The maps show slope divided into three classes; flat (0 - 3º), undulating (4º - 7º), and rolling (8º - 15º). We will consider more detailed contours, e.g. MWD contour maps when looking at specific system development options.

## 2.4 Elevation

We assumed that irrigation will not occur on land higher than 600 m, because of the short growing season at elevations above 600 m. That doesn't preclude small areas above 600 m from being irrigated if it is practical to do so.

## 2.5 Topography

Most existing irrigation is on flat to undulating land. The benefits of irrigating new rolling land could be marginal because irrigation of rolling land is generally more labour intensive and expensive to irrigate than flat and undulating land. Generally both on and off farm pumping and capital costs are higher. Irrigation water use efficiency is also generally lower than the equivalent spray system on flat and undulating land.

## 2.6 Potential irrigable area

In total, 63,000 ha of flat to undulating irrigable land and 16,000 ha of rolling irrigable land was identified within the study area as having potential to be irrigated. A map of the potential irrigable area is provided in Appendix D.

Areas that clearly cannot be irrigated such as Alexandra township have been excluded from the total. However, no account has been taken of smaller areas such as buildings, roads, farm tracks, streams, ponds and trees. The areas stated above therefore, are gross areas and will need to be discounted to determine effective irrigation areas. Normally a figure of 80% or 85% of gross area is used at a scheme or catchment level. At an individual farm level, potential irrigable areas tend to vary widely and may range from 50% up to nearly 100%.

Our assessment of the area that is likely to be irrigable within the study area will be in the order of 60,000 hectares. This is the figure that we have used as a basis of demand estimates for whole-of-catchment assessments.

While there may be some areas currently irrigated that are outside the boundary of irrigable land shown in Appendix D, we expect the areas involved will be small relative to the total potential irrigable area.

We note that the OPUS Lower Manuherikia Valley study (OPUS 2010) identified similar irrigable areas. We will use the results of the OPUS study specifically in the next sections of the study.

# 3 IRRIGATION DEMAND MODELLING

## 3.1 Overview

Irrigation water demand depends primarily on climate, soil, crop type, irrigation system type and the dgree of risk taken in not meeting full demand. We modelled irrigation demand, deep drainage, and pasture growth for three soils types, four climate types and three irrigation system types. We also modelled dryland pasture growth and drainage. In total, we modelled 48 different climate, soil and irrigation system combinations.

Irrigation and soil water dynamics were modelled using AusFarm, coupled with Aqualinc's custom irrigation component. AusFarm is a biophysical model of temperate climate pastoral systems, developed by CSIRO Australia. This model is widely used in Australia and internationally by farm advisors and researchers. For further information about AusFarm see http://www.grazplan.csiro.au/ . Aqualinc has developed a custom irrigation component for AusFarm, which models various aspects of irrigation systems including how irrigators move around a series of paddocks in a rotation, restrictions, seasonal limits, and on-farm storage ponds.

We used a daily time step and simulated the period 1 June 1972 to 31 May 2011, i.e. 39 years of historical data.

## 3.2 Crops

Pasture was the crop modelled at this stage since currently about 95% of the irrigable land is in pasture (refer to Appendix E). Currently cropping, horticulture and viticulture cumulatively account for less than 2% of the irrigable area.

We understand that the area of crop and horticulture may increase in the future, but with respect to water demand, pasture demand will exceed that required for crops and horticulture. Therefore, assuming 100% pasture is a conservative approach.

## 3.3 Climate

We used four rainfall stations to represent the spatial rainfall variability across the irrigable area (refer to Table 2 and Appendix A). We assumed $ET_o$ would be relatively constant across the irrigable area, with $ET_o$ data from Lauder used for all modelling runs.

*Table 2: Rainfall classes*

| Class | Mean annual Rainfall range (mm/y) | Representative rainfall station used in modelling | |
|---|---|---|---|
| | | Name | Mean annual rainfall (mm/y)(1) |
| 1 | 350-450 | Clyde EWS (12431) | 400 |
| 2 | 450-550 | Lauder Flat (5537) | 510 |
| 3 | 550-650 | Blackstone Hill (5252) | 610 |
| 4 | 650-850 | Cambrians (5248) | 750 |
| (1) Mean annual rainfall for the period 1972 - 2010 | | | |

## 3.4 Soils

We used three soil classes to represent the range of potentially irrigable soils, as described in Table 3 and shown on a map in Appendix C. The Fundamental Soils Layer estimates profile available water for the top 90 cm of soil. Profile available water is a function of the soil type only. In contrast, plant available water (PAW or soil water holding capacity) depends on both the soil type and crop rooting depth. We calculated the PAW for irrigated pasture by assuming a 60 cm rooting depth and using the rule of thumb proposed by Trevor Webb of Landcare for North Otago (Brown and McIndoe, 2003):

*"Assume the top 200 mm of topsoil contributes 40 mm of water, and the remainder of the soil profile down to a maximum of 900 mm contributes a constant amount of water per unit depth. In stony soils, where the majority of the available water is within the top 500 mm of soil, no adjustment of PAW should be made."*

*Table 3: Soil PAW classes*

| Class | Profile available water | | Plant available water (PAW) used in modelling |
|---|---|---|---|
| | Range (mm) | Class mid-point (mm) | |
| 1 | 30-89 | 70 | 60 |
| 2 | 90-139 | 115 | 90 |
| 3 | ≥140 | 160 | 120 |

We assumed a 60 cm rooting depth for irrigated pasture because, while the majority of roots will be in the top 30 cm, survival roots in modern ryegrass cultivars generally extend down to 60 cm. This assumption is consistent with similar studies in other parts of New Zealand.

In fully irrigated situations, rooting depth is less critical, as plants preferentially take water from the top layers. However, if plants come under water stress and are forced to take water from greater depths, rooting depth is important. In working out potential irrigation demand for this study, we have assumed that crops are well-watered.

## 3.5 Irrigation efficiency classes

We need to make some assumptions about what levels of efficiency would be suitable for determining current irrigation demand and more importantly, future irrigation demand.

On-farm irrigation efficiency can be broadly considered as a measure of the efficiency of water application combined with the amount of production achieved with a given quantity of water.

Application efficiency (Ea) is defined as follows:

$$Ea = 100\ (Wc / Wf)$$

Where

Wc = Water available for use by the crop
Wf = Water delivered to field

We know that on individual properties actual application efficiency can vary widely and that many factors come in to the decision about what are the appropriate values to assume.

We know that it is unrealistic to assume 100% application efficiency. We also know that 80% is the value now being used to allocate water by regional councils and for allocation within some irrigation schemes. On that basis, we modelled three irrigation efficiency levels: high, average, and low, as described in to Table 4.

*Table 4: Irrigation efficiency classes*

| Efficiency Class | Application efficiency |
|---|---|
| High | 80% |
| Average | 60% |
| Low | 40% |

These application efficiency classes are based broadly on results of irrigation efficiency research and irrigation system evaluations throughout NZ. The figures take into account many factors such as irrigation method, effects of wind, topography, standard of design and operation, sprinkler selection and operating pressures.

We have incorporated production measures into the irrigation demand estimates as described in Section 4.2.

## 3.6 Irrigation system assumptions

Parameter combinations used in modelling are given in Table 5, Table 6 and Table 7.

It is important to note that at this stage of the project, the purpose of the modelling was to estimate potential irrigation demand, expressed in mm/year, for a range of soil and irrigation parameters based on daily historical climate data. The intention is that the combinations should cover the variations in demand needed for current irrigation systems and likely to be needed for future irrigation systems.

In subsequent stages of the project, we will need to associate irrigation areas with each representative combination listed in Table 5, Table 6 and Table 7. At this stage, we are not making any decisions about what irrigation system types will be used in the future. What we can say is that irrigation will ultimately move towards more efficient and more productive systems.

### 3.6.1 Irrigation system capacity

Except for very high-value crops, it is not economic to design and install irrigation systems to fully meet crop water demand on the very highest demand days as, if that is done, irrigation system capacity can be unrealistically high, resulting in high on-farm flow rates and very costly systems. Usually, a small loss of production is allowed for in extreme periods.

To determine peak water requirements, our modelling has assumed that an average annual loss of pasture yield of 1-2% compared to potential yield is allowed on well-watered crops using irrigation systems with an application efficiency of 80% and a 100% reliable water supply. This has resulted in irrigation system capacities ranging between 3.5 and 5.0 mm/d, depending on application efficiency and soil plant available water.

### 3.6.2 Application depths and return intervals

Application depths and return intervals (rotation times) have been determined from the allowable soil moisture deficits and the system capacity for each soil/ efficiency combination.

Generally, soil moisture is not returned to full on the more efficient systems, allowing better use of rainfall, should it occur. On the less efficient systems, soil moisture is returned to full, with some drainage occurring below the root zone of the plants. This can be seen in Table 7 in particular, where soil moisture deficits range between 25 and 40 mm, while application depths range between 98 and 112 mm.

We accept that on schemes and on individual farms, application depths and return intervals will differ from those assumed, particularly on the lower efficiency options. In our experience, it is the combination of application depths, return intervals and trigger levels that impacts most on overall water use and production as it affects application efficiency. We have set the parameters to achieve low, medium and high efficiency.

In situations of water shortage (soil moisture falling below the trigger level during periods of highest water demand), we assumed that farmers would continue to spread the water around, tolerating some production loss under irrigation, to maximise total on-farm pasture production.

### 3.6.3 Water supply restrictions

The modelling does not allow for off-farm restrictions in water supply. We recognise that there is an advantage in having higher capacity irrigation systems to allow more rapid "catch-up" where restrictions occur. However, our approach at this stage is to put that aside and focus on what is needed under reliable supply conditions.

*Table 5: Irrigation management parameters – 80% efficient*

| Parameter | Soil plant available water at field capacity | | |
|---|---|---|---|
| | 60 mm | 90 mm | 120 mm |
| Application depth (mm) | 22.5 | 24 | 24.5 |
| System capacity (mm/d) | 4.5* | 4.0* | 3.5* |
| Return period (days) | 5 | 6 | 7 |
| Soil moisture trigger (mm)[1] | 25 | 35 | 45 |
| Application efficiency | 80% | | |
| Irrigation season | 15 Sep – 30 Apr | | |
| *For Clyde rainfall, the irrigation system capacity was 0.5mm/d greater, to counter the lack of rainfall. | | | |

[1] Soil moisture deficit at time of irrigation

*Table 6: Irrigation management parameters – 60% efficient*

| Parameter | Soil plant available water at field capacity | | |
|---|---|---|---|
| | 60 mm | 90 mm | 120 mm |
| Application depth (mm) | 35 | 63 | 56 |
| System capacity (mm/d) | 5.0 | 4.5 | 4.0 |
| Return period (days) | 7 | 14 | 14 |
| Soil moisture trigger (mm)[1] | 25 | 40 | 50 |
| Application efficiency | 60% | | |
| Irrigation season | 15 Sep – 30 Apr | | |

*Table 7: Irrigation management parameters – 40% efficient*

| Parameter | Soil plant available water at field capacity | | |
|---|---|---|---|
| | 60 mm | 90 mm | 120 mm |
| Application depth (mm) | 112 | 112 | 98 |
| System capacity (mm/d) | 4.0 | 4.0 | 3.5 |
| Return period (days) | 28 | 28 | 28 |
| Soil moisture trigger (mm)[1] | 25 | 30 | 40 |
| Application efficiency | 40% | | |
| Irrigation season | 15 Sep – 30 Apr | | |

# 4 RESULTS

## 4.1 Irrigation demand

Annual average irrigation demand estimates are summarised in Table 8.

*Table 8: Estimated average annual irrigation demand (mm/y)*

| Irrigation application efficiency | Soil PAW | Rainfall | | | |
|---|---|---|---|---|---|
| | | Clyde | Lauder Flat | Blackstone Hill | Cambrians |
| 80% | 60 | 680 | 580 | 540 | 490 |
| 80% | 90 | 640 | 530 | 500 | 450 |
| 80% | 120 | 600 | 490 | 450 | 400 |
| 60% | 60 | 790 | 690 | 650 | 600 |
| 60% | 90 | 740 | 650 | 600 | 550 |
| 60% | 120 | 680 | 590 | 530 | 470 |
| 40% | 60 | 870 | 820 | 780 | 760 |
| 40% | 90 | 840 | 770 | 810 | 730 |
| 40% | 120 | 740 | 680 | 640 | 590 |

The results show that average annual irrigation demand in the catchment will range from 350 mm/y to more than 800 mm/y, depending on location (location affects rainfall), soil plant available water and irrigation application efficiency.

As expected, irrigation demand decreases with increased rainfall (compare Clyde with Cambrians), but increases with decreasing irrigation application efficiency.

Irrigation demand will vary year-by-year, depending on rainfall and ET. For example, at Clyde on a 90 mm soil and for 80% application efficiency, irrigation demand could range from 260 mm to 730 mm in any year, with a median demand of 600 mm, compared to an average demand of 580 mm. Based on historical data, 1993 appears to consistently be a year of very low demand, while high demand has occurred in years such as 1977, 2001, 2009.

Annual allocation limits for irrigation are normally made on a 1 in 10 year basis (sometimes called a 1 in 10 year drought). 1 in 10 year irrigation demands are presented in Table 9. These will be relevant if a decision is made to limit the takes to this much water in any year.

Some organisations have allocated or restricted irrigation seasonal use to what is required in a 1:5 year event. However, that exposes production to greater variability and is now not generally supported.  It is unlikely that maximum irrigation demand will ever be supplied.

*Table 9: Estimated 1 in 10 year irrigation demand (mm/y)*

| Irrigation application efficiency | Soil PAW | Rainfall | | | |
|---|---|---|---|---|---|
| | | Clyde | Lauder Flat | Blackstone Hill | Cambrians |
| 80% | 60 | 840 | 720 | 660 | 620 |
| 80% | 90 | 810 | 690 | 660 | 600 |
| 80% | 120 | 780 | 660 | 620 | 540 |
| 60% | 60 | 910 | 870 | 830 | 750 |
| 60% | 90 | 880 | 820 | 790 | 700 |
| 60% | 120 | 820 | 720 | 710 | 640 |
| 40% | 60 | 910 | 900 | 890 | 890 |
| 40% | 90 | 910 | 900 | 890 | 880 |
| 40% | 120 | 800 | 790 | 760 | 690 |

Water demand estimates are for 'representative' irrigation systems.  In practice, actual on-farm irrigation system demand, management and water requirements will differ from farm to farm.  Some farms may use more water, while some may use less.  Variations from farm to farm are not an issue of concern at this stage, because the primary focus of this part of the study is on defining irrigation demand on a unit area basis.

## 4.2 Production estimates

Production estimates arising from the irrigation demand figures in Table 8 are summarised in Table 10.

*Table 10: Estimated average annual production (% of maximum potential)*

| Irrigation application efficiency | Soil PAW | Rainfall | | | |
|---|---|---|---|---|---|
| | | Clyde | Lauder Flat | Blackstone Hill | Cambrians |
| 80% | 60 | 99% | 99% | 99% | 99% |
| | 90 | 99% | 99% | 99% | 99% |
| | 120 | 99% | 99% | 99% | 99% |
| 60% | 60 | 96% | 97% | 97% | 98% |
| | 90 | 95% | 97% | 97% | 98% |
| | 120 | 95% | 98% | 98% | 98% |
| 40% | 60 | 72% | 80% | 83% | 85% |
| | 90 | 80% | 89% | 88% | 92% |
| | 120 | 81% | 89% | 91% | 94% |

Pasture production estimates for the 80% efficiency class are on average close to 100%.

Pasture production estimates decrease with decreasing application efficiency, reflecting the impact of drainage through the soil resulting in higher soil moisture deficits.

As stated in Section 3.6.3, these estimates do not consider the impact of water supply restrictions. Consequently, actual product losses due to water stress may be higher than predicted, depending on the reliability of supply. The impact of restrictions will be considered during Part B of the Manuherikia Study.

It is also important to note that the production figures are averages, and variations about these figures will occur on a year-by-year basis.

# 5 REFERENCES

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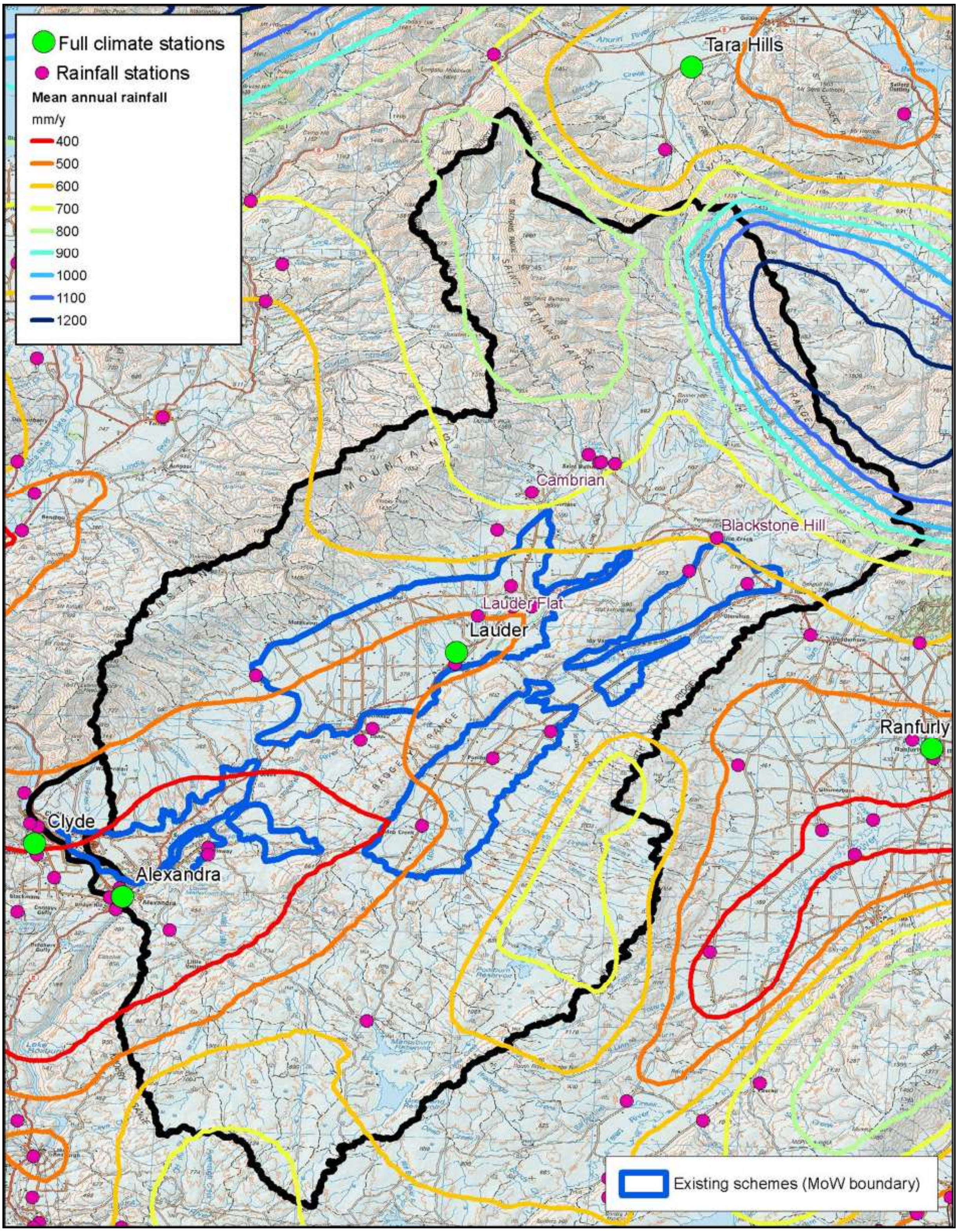
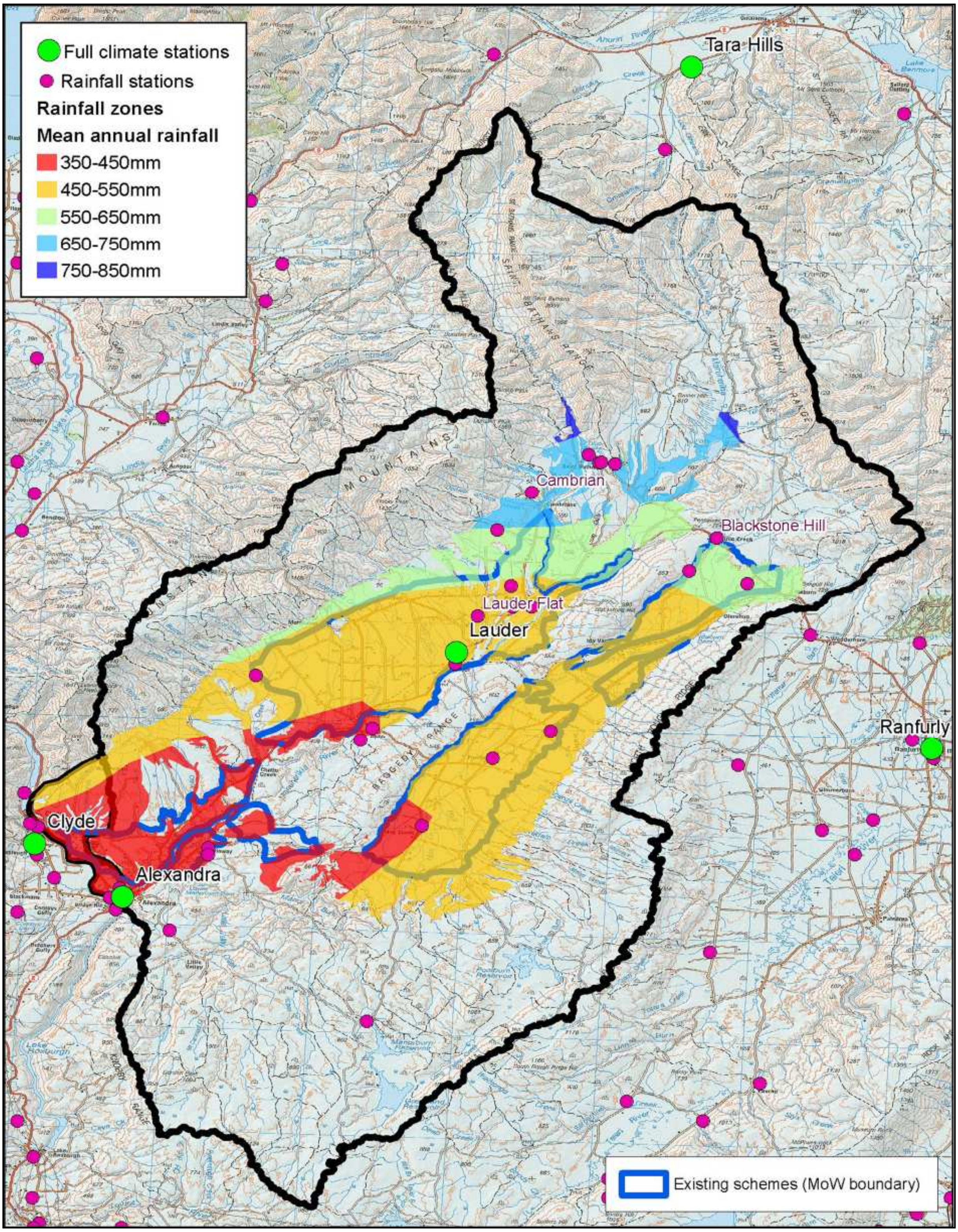
# Appendix A: Climate




**Spatial climate variability**




**Climate zones**

**Total monthly $ET_o$ at Lauder EWS (Agent 5535)**

| Season | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 72-73 | 14 | 12 | 33 | 88 | 108 | 143 | 160 | 183 | 154 | 111 | 63 | 29 | **1098** |
| 73-74 | 10 | 11 | 28 | 74 | 109 | 125 | 175 | 181 | 113 | 99 | 41 | 26 | **991** |
| 74-75 | 12 | 17 | 28 | 57 | 88 | 149 | 183 | 155 | 126 | 96 | 52 | 29 | **992** |
| 75-76 | 2 | 15 | 36 | 72 | 108 | 130 | 185 | 176 | 132 | 114 | 57 | 30 | **1057** |
| 76-77 | 15 | 20 | 28 | 57 | 85 | 127 | 145 | 138 | 136 | 110 | 51 | 22 | **933** |
| 77-78 | 5 | 9 | 30 | 53 | 119 | 136 | 162 | 185 | 152 | 119 | 47 | 26 | **1044** |
| 78-79 | 6 | 12 | 33 | 52 | 101 | 148 | 159 | 180 | 127 | 79 | 48 | 21 | **967** |
| 79-80 | 8 | 15 | 26 | 66 | 89 | 132 | 139 | 141 | 103 | 74 | 41 | 21 | **857** |
| 80-81 | 7 | 14 | 34 | 63 | 92 | 115 | 165 | 163 | 119 | 84 | 47 | 17 | **919** |
| 81-82 | 9 | 13 | 24 | 63 | 109 | 109 | 135 | 160 | 140 | 96 | 40 | 27 | **924** |
| 82-83 | 7 | 2 | 41 | 60 | 99 | 152 | 145 | 132 | 123 | 97 | 49 | 31 | **938** |
| 83-84 | 13 | 14 | 34 | 61 | 91 | 124 | 141 | 142 | 115 | 74 | 51 | 23 | **884** |
| 84-85 | 27 | 12 | 35 | 61 | 105 | 133 | 141 | 162 | 136 | 100 | 55 | 26 | **993** |
| 85-86 | 14 | 15 | 31 | 71 | 81 | 111 | 131 | 149 | 98 | 86 | 48 | 26 | **862** |
| 86-87 | 18 | 16 | 30 | 56 | 96 | 112 | 152 | 122 | 92 | 68 | 42 | 20 | **823** |
| 87-88 | 16 | 11 | 30 | 52 | 85 | 112 | 115 | 140 | 116 | 94 | 47 | 28 | **847** |
| 88-89 | 8 | 24 | 35 | 64 | 108 | 141 | 147 | 136 | 105 | 94 | 50 | 16 | **926** |
| 89-90 | 10 | 11 | 22 | 54 | 91 | 126 | 151 | 159 | 128 | 86 | 57 | 29 | **923** |
| 90-91 | 10 | 9 | 21 | 61 | 96 | 114 | 168 | 147 | 107 | 89 | 40 | 27 | **889** |
| 91-92 | 9 | 6 | 35 | 51 | 96 | 92 | 136 | 149 | 118 | 104 | 43 | 19 | **857** |
| 92-93 | 10 | 12 | 20 | 39 | 82 | 119 | 125 | 139 | 96 | 73 | 40 | 22 | **777** |
| 93-94 | 22 | 12 | 29 | 53 | 117 | 102 | 118 | 130 | 99 | 66 | 48 | 25 | **822** |
| 94-95 | 8 | 13 | 47 | 50 | 87 | 118 | 152 | 137 | 106 | 91 | 44 | 32 | **886** |
| 95-96 | 13 | 8 | 33 | 53 | 88 | 107 | 143 | 144 | 117 | 78 | 44 | 29 | **857** |
| 96-97 | 11 | 9 | 30 | 76 | 101 | 129 | 166 | 146 | 114 | 94 | 55 | 30 | **959** |
| 97-98 | 10 | 13 | 41 | 52 | 113 | 161 | 177 | 187 | 152 | 107 | 59 | 25 | **1097** |
| 98-99 | 11 | 13 | 36 | 75 | 104 | 133 | 153 | 183 | 143 | 113 | 49 | 43 | **1056** |
| 99-00 | 10 | 15 | 35 | 64 | 104 | 95 | 148 | 125 | 133 | 86 | 47 | 30 | **891** |
| 00-01 | 18 | 14 | 31 | 68 | 104 | 123 | 185 | 143 | 115 | 104 | 67 | 20 | **993** |
| 01-02 | 16 | 12 | 29 | 66 | 92 | 107 | 137 | 134 | 114 | 119 | 41 | 40 | **907** |
| 02-03 | 22 | 16 | 35 | 82 | 103 | 122 | 160 | 152 | 133 | 106 | 40 | 36 | **1007** |
| 03-04 | 33 | 19 | 28 | 64 | 100 | 142 | 193 | 180 | 113 | 96 | 54 | 29 | **1051** |
| 04-05 | 23 | 15 | 27 | 64 | 98 | 133 | 123 | 152 | 122 | 81 | 49 | 28 | **915** |
| 05-06 | 14 | 23 | 39 | 60 | 99 | 131 | 150 | 178 | 133 | 84 | 54 | 19 | **984** |
| 06-07 | 15 | 27 | 43 | 89 | 123 | 129 | 127 | 142 | 126 | 110 | 50 | 51 | **1031** |
| 07-08 | 20 | 13 | 36 | 67 | 112 | 133 | 153 | 186 | 127 | 88 | 47 | 16 | **998** |
| 08-09 | 18 | 12 | 26 | 71 | 108 | 146 | 140 | 182 | 106 | 99 | 59 | 20 | **988** |
| 09-10 | 9 | 17 | 44 | 78 | 88 | 169 | 162 | 147 | 140 | 114 | 70 | 26 | **1062** |
| 10-11 | 11 | 11 | 27 | 78 | 113 | 145 | 172 | 144 | 114 | 88 | 50 | 33 | **985** |
| **Average** | **13** | **14** | **32** | **64** | **100** | **128** | **152** | **155** | **121** | **94** | **50** | **27** | **948** |

$ET_o$ was calculated by NIWA using the Penman equations with radiation, temperature, wind and vapour pressure data from Lauder EWS. Highlighted cells were calculated using Aqualinc's climate extension software, using $ET_o$ data from Clyde, Alexandra and Tara Hills climate stations to extend the Lauder record.

**Total monthly Rainfall at Clyde EWS (Agent 12431)**

| Season | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 72-73 | 19 | 22 | 18 | 92 | 31 | 9 | 33 | 6 | 6 | 24 | 75 | 22 | **357** |
| 73-74 | 4 | 15 | 40 | 27 | 40 | 37 | 18 | 13 | 46 | 13 | 34 | 13 | **300** |
| 74-75 | 31 | 46 | 2 | 3 | 100 | 7 | 26 | 32 | 41 | 23 | 55 | 29 | **395** |
| 75-76 | 25 | 37 | 19 | 12 | 35 | 15 | 29 | 13 | 11 | 4 | 17 | 61 | **278** |
| 76-77 | 49 | 32 | 55 | 11 | 54 | 23 | 113 | 23 | 21 | 20 | 29 | 31 | **460** |
| 77-78 | 14 | 10 | 2 | 22 | 28 | 18 | 38 | 17 | 11 | 26 | 27 | 50 | **263** |
| 78-79 | 14 | 23 | 36 | 55 | 116 | 32 | 57 | 31 | 18 | 49 | 33 | 45 | **511** |
| 79-80 | 4 | 25 | 25 | 22 | 34 | 16 | 114 | 67 | 35 | 51 | 61 | 22 | **476** |
| 80-81 | 37 | 24 | 86 | 31 | 22 | 41 | 13 | 11 | 22 | 100 | 20 | 11 | **417** |
| 81-82 | 49 | 32 | 11 | 21 | 26 | 27 | 37 | 39 | 26 | 27 | 13 | 78 | **386** |
| 82-83 | 21 | 11 | 43 | 4 | 39 | 68 | 54 | 58 | 7 | 93 | 85 | 24 | **509** |
| 83-84 | 29 | 26 | 20 | 77 | 55 | 14 | 50 | 75 | 33 | 53 | 14 | 16 | **463** |
| 84-85 | 17 | 50 | 21 | 16 | 12 | 41 | 44 | 21 | 24 | 11 | 9 | 1 | **267** |
| 85-86 | 27 | 19 | 34 | 15 | 12 | 44 | 68 | 19 | 71 | 27 | 27 | 49 | **412** |
| 86-87 | 53 | 29 | 6 | 9 | 19 | 37 | 13 | 39 | 50 | 93 | 7 | 40 | **394** |
| 87-88 | 38 | 21 | 14 | 38 | 39 | 8 | 32 | 64 | 84 | 10 | 21 | 33 | **402** |
| 88-89 | 41 | 32 | 20 | 15 | 62 | 21 | 23 | 72 | 32 | 45 | 13 | 17 | **394** |
| 89-90 | 41 | 7 | 1 | 9 | 33 | 7 | 89 | 33 | 22 | 14 | 39 | 32 | **327** |
| 90-91 | 19 | 41 | 14 | 2 | 61 | 29 | 31 | 25 | 48 | 20 | 39 | 10 | **338** |
| 91-92 | 30 | 21 | 101 | 10 | 16 | 31 | 53 | 9 | 46 | 8 | 46 | 9 | **381** |
| 92-93 | 15 | 53 | 52 | 5 | 37 | 46 | 28 | 37 | 14 | 32 | 18 | 63 | **400** |
| 93-94 | 26 | 10 | 31 | 39 | 35 | 34 | 137 | 132 | 90 | 61 | 32 | 31 | **660** |
| 94-95 | 39 | 53 | 10 | 30 | 1 | 51 | 33 | 22 | 50 | 40 | 11 | 43 | **382** |
| 95-96 | 29 | 17 | 17 | 81 | 76 | 51 | 143 | 85 | 17 | 22 | 85 | 21 | **643** |
| 96-97 | 47 | 5 | 10 | 5 | 46 | 38 | 28 | 32 | 51 | 38 | 72 | 27 | **400** |
| 97-98 | 3 | 24 | 18 | 9 | 22 | 30 | 66 | 22 | 33 | 40 | 21 | 17 | **304** |
| 98-99 | 30 | 24 | 30 | 23 | 45 | 7 | 31 | 19 | 7 | 87 | 55 | 15 | **372** |
| 99-00 | 18 | 43 | 14 | 18 | 15 | 134 | 18 | 96 | 12 | 32 | 51 | 45 | **495** |
| 00-01 | 60 | 15 | 19 | 42 | 43 | 33 | 32 | 53 | 25 | 10 | 12 | 26 | **371** |
| 01-02 | 38 | 7 | 16 | 13 | 28 | 40 | 62 | 81 | 13 | 20 | 39 | 16 | **373** |
| 02-03 | 51 | 9 | 36 | 30 | 22 | 23 | 58 | 52 | 24 | 2 | 24 | 25 | **355** |
| 03-04 | 34 | 39 | 25 | 39 | 37 | 28 | 16 | 56 | 69 | 31 | 14 | 54 | **443** |
| 04-05 | 62 | 12 | 29 | 36 | 58 | 47 | 84 | 44 | 65 | 40 | 27 | 21 | **524** |
| 05-06 | 12 | 8 | 20 | 10 | 35 | 28 | 38 | 29 | 15 | 14 | 19 | 13 | **240** |
| 06-07 | 28 | 13 | 12 | 15 | 32 | 70 | 26 | 23 | 8 | 22 | 11 | 24 | **285** |
| 07-08 | 44 | 36 | 12 | 26 | 56 | 6 | 34 | 32 | 27 | 44 | 35 | 34 | **386** |
| 08-09 | 14 | 22 | 14 | 47 | 22 | 11 | 76 | 11 | 57 | 13 | 41 | 40 | **369** |
| 09-10 | 3 | 25 | 34 | 21 | 29 | 3 | 21 | 53 | 20 | 19 | 41 | 47 | **316** |
| 10-11 | 33 | 8 | 33 | 31 | 21 | 13 | 70 | 41 | 81 | 35 | 12 | 63 | **442** |
| **Average** | **30** | **24** | **26** | **26** | **38** | **31** | **50** | **41** | **34** | **34** | **33** | **31** | **397** |

Highlighted cells were calculated using Aqualinc's climate extension software, using data from NIWA's VCS 15044 to extend the record.

## Total monthly Rainfall at Lauder Flats (Agent 5537)

| Season | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 72-73 | 26 | 26 | 33 | 61 | 65 | 17 | 42 | 18 | 11 | 28 | 96 | 36 | **459** |
| 73-74 | 21 | 36 | 44 | 20 | 40 | 52 | 23 | 20 | 89 | 21 | 37 | 31 | **433** |
| 74-75 | 37 | 55 | 8 | 6 | 99 | 13 | 29 | 73 | 81 | 15 | 74 | 23 | **512** |
| 75-76 | 11 | 35 | 51 | 22 | 46 | 34 | 21 | 10 | 34 | 12 | 13 | 71 | **361** |
| 76-77 | 47 | 37 | 41 | 21 | 60 | 43 | 149 | 49 | 33 | 17 | 56 | 27 | **578** |
| 77-78 | 21 | 16 | 8 | 54 | 24 | 26 | 44 | 23 | 17 | 26 | 41 | 58 | **358** |
| 78-79 | 34 | 36 | 66 | 70 | 97 | 39 | 65 | 6 | 54 | 105 | 33 | 26 | **632** |
| 79-80 | 11 | 21 | 36 | 45 | 79 | 32 | 83 | 87 | 50 | 57 | 41 | 44 | **586** |
| 80-81 | 46 | 27 | 79 | 13 | 50 | 68 | 39 | 9 | 9 | 80 | 31 | 14 | **465** |
| 81-82 | 56 | 54 | 7 | 16 | 37 | 14 | 42 | 36 | 23 | 13 | 47 | 69 | **414** |
| 82-83 | 28 | 10 | 42 | 23 | 69 | 69 | 88 | 80 | 19 | 79 | 123 | 43 | **672** |
| 83-84 | 36 | 41 | 34 | 40 | 94 | 17 | 100 | 71 | 23 | 88 | 23 | 31 | **597** |
| 84-85 | 5 | 58 | 53 | 37 | 8 | 74 | 41 | 50 | 20 | 17 | 7 | 14 | **383** |
| 85-86 | 29 | 17 | 39 | 32 | 49 | 64 | 76 | 66 | 72 | 61 | 25 | 53 | **583** |
| 86-87 | 51 | 31 | 29 | 16 | 42 | 54 | 11 | 37 | 94 | 122 | 32 | 45 | **563** |
| 87-88 | 23 | 47 | 12 | 36 | 49 | 28 | 59 | 72 | 65 | 6 | 42 | 35 | **473** |
| 88-89 | 56 | 37 | 22 | 10 | 40 | 43 | 25 | 118 | 114 | 43 | 17 | 32 | **556** |
| 89-90 | 55 | 5 | 0 | 7 | 54 | 16 | 105 | 57 | 49 | 36 | 30 | 37 | **452** |
| 90-91 | 23 | 26 | 15 | 12 | 99 | 26 | 15 | 27 | 62 | 19 | 55 | 17 | **395** |
| 91-92 | 45 | 16 | 44 | 21 | 18 | 41 | 91 | 12 | 38 | 0 | 46 | 8 | **381** |
| 92-93 | 17 | 43 | 45 | 31 | 64 | 52 | 48 | 62 | 30 | 34 | 42 | 79 | **546** |
| 93-94 | 13 | 5 | 33 | 64 | 36 | 37 | 133 | 148 | 72 | 89 | 31 | 36 | **698** |
| 94-95 | 47 | 39 | 13 | 33 | 5 | 63 | 25 | 40 | 91 | 42 | 6 | 44 | **446** |
| 95-96 | 56 | 41 | 14 | 102 | 94 | 78 | 133 | 70 | 19 | 40 | 85 | 16 | **748** |
| 96-97 | 45 | 8 | 14 | 7 | 41 | 55 | 62 | 51 | 49 | 38 | 86 | 26 | **481** |
| 97-98 | 9 | 38 | 23 | 11 | 37 | 35 | 96 | 17 | 34 | 51 | 29 | 30 | **410** |
| 98-99 | 51 | 23 | 28 | 36 | 57 | 30 | 22 | 17 | 22 | 83 | 67 | 21 | **455** |
| 99-00 | 35 | 64 | 12 | 22 | 22 | 127 | 45 | 177 | 27 | 29 | 63 | 62 | **684** |
| 00-01 | 42 | 11 | 40 | 60 | 32 | 63 | 41 | 67 | 45 | 10 | 20 | 33 | **465** |
| 01-02 | 55 | 21 | 30 | 13 | 47 | 51 | 76 | 73 | 29 | 10 | 68 | 21 | **492** |
| 02-03 | 88 | 15 | 30 | 39 | 41 | 49 | 47 | 69 | 33 | 3 | 35 | 23 | **470** |
| 03-04 | 29 | 49 | 20 | 21 | 47 | 25 | 12 | 64 | 42 | 24 | 20 | 44 | **397** |
| 04-05 | 39 | 9 | 41 | 26 | 71 | 95 | 140 | 61 | 69 | 64 | 27 | 30 | **673** |
| 05-06 | 21 | 12 | 21 | 22 | 48 | 55 | 93 | 50 | 45 | 30 | 102 | 60 | **559** |
| 06-07 | 49 | 14 | 12 | 11 | 61 | 126 | 89 | 26 | 8 | 23 | 30 | 20 | **468** |
| 07-08 | 53 | 44 | 10 | 34 | 47 | 14 | 96 | 48 | 58 | 46 | 39 | 59 | **546** |
| 08-09 | 41 | 43 | 20 | 68 | 26 | 35 | 113 | 19 | 68 | 11 | 36 | 59 | **538** |
| 09-10 | 3 | 13 | 21 | 10 | 61 | 1 | 24 | 117 | 32 | 17 | 53 | 78 | **428** |
| 10-11 | 70 | 12 | 67 | 29 | 32 | 31 | 78 | 60 | 124 | 63 | 32 | 80 | **677** |
| **Average** | **36** | **29** | **30** | **31** | **51** | **46** | **65** | **55** | **47** | **40** | **45** | **39** | **514** |

**Total monthly Rainfall at Blackstone Hill (Agent 5252)**

| Season | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 72-73 | 69 | 33 | 27 | 71 | 69 | 36 | 40 | 16 | 16 | 36 | 114 | 38 | **564** |
| 73-74 | 16 | 5 | 127 | 33 | 65 | 68 | 40 | 28 | 76 | 58 | 74 | 38 | **627** |
| 74-75 | 37 | 79 | 15 | 11 | 67 | 11 | 31 | 45 | 83 | 37 | 77 | 20 | **512** |
| 75-76 | 35 | 43 | 70 | 18 | 28 | 47 | 55 | 20 | 44 | 22 | 8 | 91 | **481** |
| 76-77 | 59 | 37 | 58 | 19 | 73 | 36 | 196 | 27 | 49 | 14 | 57 | 61 | **683** |
| 77-78 | 14 | 22 | 8 | 57 | 26 | 36 | 72 | 29 | 29 | 29 | 67 | 71 | **460** |
| 78-79 | 43 | 66 | 84 | 91 | 69 | 38 | 128 | 22 | 36 | 113 | 34 | 67 | **790** |
| 79-80 | 11 | 41 | 57 | 55 | 92 | 31 | 87 | 107 | 72 | 57 | 44 | 20 | **672** |
| 80-81 | 54 | 39 | 79 | 16 | 54 | 89 | 42 | 14 | 25 | 109 | 41 | 19 | **580** |
| 81-82 | 42 | 94 | 40 | 34 | 45 | 28 | 42 | 60 | 32 | 21 | 77 | 69 | **583** |
| 82-83 | 33 | 12 | 50 | 38 | 119 | 73 | 72 | 87 | 27 | 70 | 110 | 66 | **756** |
| 83-84 | 47 | 58 | 50 | 52 | 91 | 17 | 123 | 122 | 34 | 113 | 32 | 45 | **784** |
| 84-85 | 6 | 58 | 31 | 63 | 14 | 67 | 49 | 47 | 37 | 29 | 24 | 39 | **463** |
| 85-86 | 23 | 31 | 46 | 35 | 39 | 53 | 45 | 48 | 92 | 69 | 21 | 58 | **559** |
| 86-87 | 46 | 58 | 45 | 14 | 34 | 81 | 18 | 71 | 109 | 187 | 13 | 69 | **746** |
| 87-88 | 15 | 53 | 12 | 38 | 82 | 33 | 78 | 79 | 63 | 23 | 45 | 35 | **556** |
| 88-89 | 43 | 7 | 41 | 13 | 48 | 53 | 38 | 135 | 65 | 53 | 14 | 42 | **552** |
| 89-90 | 46 | 9 | 1 | 18 | 83 | 22 | 103 | 78 | 52 | 34 | 34 | 53 | **532** |
| 90-91 | 22 | 59 | 28 | 31 | 90 | 34 | 19 | 33 | 67 | 33 | 61 | 27 | **503** |
| 91-92 | 64 | 31 | 60 | 37 | 37 | 40 | 107 | 11 | 37 | 4 | 40 | 40 | **508** |
| 92-93 | 27 | 48 | 69 | 72 | 65 | 82 | 88 | 74 | 34 | 61 | 63 | 83 | **766** |
| 93-94 | 17 | 13 | 44 | 86 | 37 | 41 | 180 | 182 | 56 | 142 | 37 | 28 | **864** |
| 94-95 | 57 | 60 | 40 | 63 | 10 | 52 | 27 | 50 | 97 | 59 | 17 | 52 | **586** |
| 95-96 | 64 | 52 | 17 | 107 | 154 | 76 | 126 | 79 | 33 | 64 | 93 | 30 | **896** |
| 96-97 | 57 | 26 | 15 | 10 | 63 | 84 | 85 | 108 | 51 | 44 | 98 | 27 | **668** |
| 97-98 | 15 | 32 | 41 | 32 | 44 | 32 | 75 | 12 | 45 | 46 | 20 | 29 | **421** |
| 98-99 | 47 | 28 | 27 | 33 | 79 | 55 | 36 | 17 | 28 | 80 | 71 | 24 | **524** |
| 99-00 | 31 | 38 | 8 | 30 | 20 | 87 | 56 | 174 | 28 | 33 | 58 | 70 | **633** |
| 00-01 | 50 | 21 | 60 | 65 | 26 | 39 | 50 | 65 | 35 | 8 | 14 | 39 | **470** |
| 01-02 | 62 | 61 | 52 | 16 | 49 | 54 | 58 | 107 | 38 | 21 | 59 | 30 | **607** |
| 02-03 | 84 | 24 | 34 | 48 | 32 | 61 | 35 | 52 | 48 | 2 | 44 | 28 | **491** |
| 03-04 | 33 | 44 | 19 | 42 | 69 | 33 | 14 | 71 | 65 | 43 | 35 | 45 | **510** |
| 04-05 | 44 | 18 | 53 | 34 | 51 | 91 | 168 | 47 | 49 | 73 | 25 | 35 | **688** |
| 05-06 | 32 | 13 | 25 | 21 | 52 | 51 | 117 | 58 | 32 | 20 | 88 | 98 | **606** |
| 06-07 | 78 | 32 | 49 | 39 | 76 | 117 | 143 | 37 | 14 | 34 | 35 | 12 | **664** |
| 07-08 | 58 | 62 | 14 | 68 | 61 | 25 | 105 | 51 | 85 | 57 | 50 | 60 | **696** |
| 08-09 | 30 | 70 | 13 | 92 | 35 | 25 | 127 | 23 | 87 | 10 | 41 | 110 | **662** |
| 09-10 | 0 | 15 | 21 | 4 | 59 | 0 | 38 | 64 | 30 | 20 | 59 | 115 | **424** |
| 10-11 | 54 | 15 | 105 | 35 | 35 | 26 | 114 | 42 | 127 | 63 | 25 | 104 | **746** |
| **Average** | **40** | **39** | **42** | **42** | **57** | **49** | **78** | **61** | **52** | **51** | **49** | **51** | **611** |

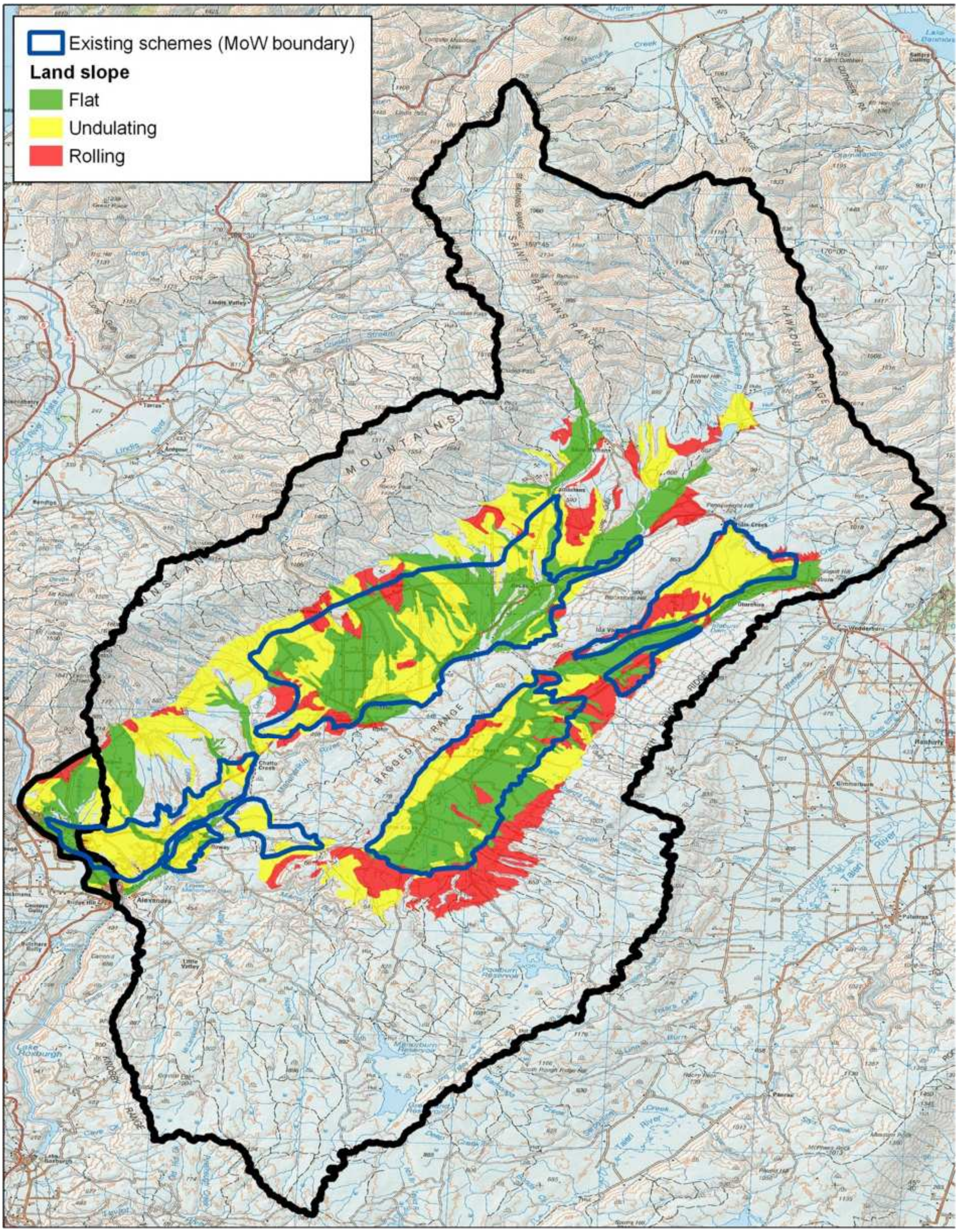
Highlighted cells were calculated using Aqualinc's climate extension software, using data from NIWA's VCS 13806 to extend the record.

### Total monthly Rainfall at Cambrians (Agent 5248)

| Season | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 72-73 | 30 | 41 | 47 | 90 | 70 | 41 | 76 | 28 | 29 | 43 | 151 | 58 | **704** |
| 73-74 | 33 | 60 | 82 | 33 | 57 | 77 | 31 | 24 | 117 | 29 | 54 | 50 | **648** |
| 74-75 | 58 | 93 | 15 | 10 | 140 | 19 | 39 | 85 | 107 | 21 | 108 | 37 | **733** |
| 75-76 | 18 | 59 | 96 | 37 | 66 | 50 | 28 | 12 | 44 | 17 | 18 | 115 | **561** |
| 76-77 | 73 | 62 | 77 | 34 | 85 | 64 | 203 | 57 | 44 | 24 | 82 | 43 | **847** |
| 77-78 | 33 | 27 | 15 | 88 | 35 | 38 | 59 | 27 | 23 | 36 | 61 | 93 | **535** |
| 78-79 | 53 | 61 | 125 | 114 | 138 | 58 | 88 | 7 | 72 | 148 | 49 | 43 | **955** |
| 79-80 | 18 | 35 | 67 | 74 | 112 | 48 | 113 | 102 | 66 | 81 | 61 | 71 | **846** |
| 80-81 | 72 | 45 | 149 | 21 | 71 | 101 | 53 | 11 | 12 | 113 | 46 | 23 | **715** |
| 81-82 | 88 | 92 | 12 | 26 | 52 | 20 | 57 | 43 | 31 | 19 | 69 | 111 | **619** |
| 82-83 | 44 | 18 | 78 | 37 | 98 | 102 | 119 | 93 | 25 | 111 | 181 | 70 | **977** |
| 83-84 | 56 | 70 | 64 | 66 | 133 | 25 | 135 | 83 | 30 | 125 | 34 | 49 | **870** |
| 84-85 | 8 | 98 | 99 | 61 | 11 | 109 | 56 | 58 | 26 | 24 | 11 | 23 | **583** |
| 85-86 | 46 | 29 | 74 | 52 | 69 | 95 | 102 | 77 | 96 | 86 | 37 | 85 | **849** |
| 86-87 | 80 | 52 | 54 | 26 | 59 | 80 | 15 | 43 | 124 | 173 | 47 | 73 | **826** |
| 87-88 | 35 | 80 | 23 | 59 | 69 | 42 | 80 | 84 | 86 | 8 | 61 | 57 | **684** |
| 88-89 | 88 | 62 | 41 | 16 | 57 | 64 | 33 | 138 | 151 | 61 | 26 | 52 | **788** |
| 89-90 | 85 | 9 | 0 | 11 | 77 | 23 | 143 | 67 | 65 | 51 | 44 | 60 | **636** |
| 90-91 | 35 | 44 | 29 | 20 | 140 | 38 | 20 | 32 | 82 | 26 | 80 | 27 | **575** |
| 91-92 | 71 | 28 | 84 | 34 | 26 | 60 | 123 | 14 | 50 | 0 | 67 | 14 | **571** |
| 92-93 | 26 | 72 | 84 | 51 | 90 | 77 | 65 | 73 | 39 | 48 | 62 | 128 | **816** |
| 93-94 | 20 | 9 | 62 | 105 | 52 | 55 | 180 | 173 | 96 | 126 | 45 | 59 | **982** |
| 94-95 | 74 | 65 | 24 | 54 | 7 | 92 | 34 | 47 | 120 | 59 | 9 | 70 | **656** |
| 95-96 | 88 | 70 | 27 | 167 | 133 | 116 | 181 | 82 | 25 | 57 | 124 | 26 | **1094** |
| 96-97 | 70 | 13 | 26 | 11 | 59 | 81 | 84 | 60 | 65 | 54 | 126 | 42 | **690** |
| 97-98 | 14 | 64 | 43 | 18 | 52 | 51 | 130 | 20 | 45 | 72 | 43 | 49 | **602** |
| 98-99 | 79 | 39 | 53 | 59 | 80 | 44 | 30 | 19 | 28 | 117 | 98 | 34 | **682** |
| 99-00 | 55 | 107 | 22 | 36 | 31 | 187 | 62 | 207 | 36 | 41 | 92 | 100 | **976** |
| 00-01 | 65 | 19 | 76 | 98 | 46 | 93 | 55 | 79 | 60 | 14 | 29 | 54 | **688** |
| 01-02 | 86 | 35 | 57 | 20 | 66 | 75 | 102 | 85 | 38 | 14 | 100 | 33 | **713** |
| 02-03 | 137 | 25 | 56 | 64 | 58 | 72 | 64 | 81 | 44 | 4 | 51 | 37 | **692** |
| 03-04 | 45 | 82 | 38 | 35 | 67 | 36 | 17 | 75 | 56 | 34 | 29 | 71 | **585** |
| 04-05 | 61 | 16 | 78 | 42 | 101 | 141 | 189 | 72 | 91 | 91 | 39 | 49 | **970** |
| 05-06 | 33 | 21 | 40 | 36 | 68 | 82 | 126 | 58 | 59 | 43 | 149 | 97 | **812** |
| 06-07 | 76 | 23 | 22 | 17 | 87 | 187 | 121 | 30 | 10 | 32 | 44 | 32 | **683** |
| 07-08 | 82 | 74 | 19 | 56 | 67 | 21 | 130 | 56 | 77 | 65 | 56 | 95 | **798** |
| 08-09 | 64 | 72 | 37 | 111 | 37 | 52 | 153 | 22 | 90 | 16 | 53 | 96 | **803** |
| 09-10 | 5 | 22 | 39 | 16 | 86 | 1 | 32 | 137 | 42 | 24 | 78 | 125 | **607** |
| 10-11 | 109 | 20 | 126 | 48 | 46 | 46 | 105 | 70 | 164 | 89 | 47 | 129 | **999** |
| **Average** | **57** | **49** | **55** | **50** | **72** | **68** | **88** | **65** | **63** | **56** | **66** | **64** | **753** |

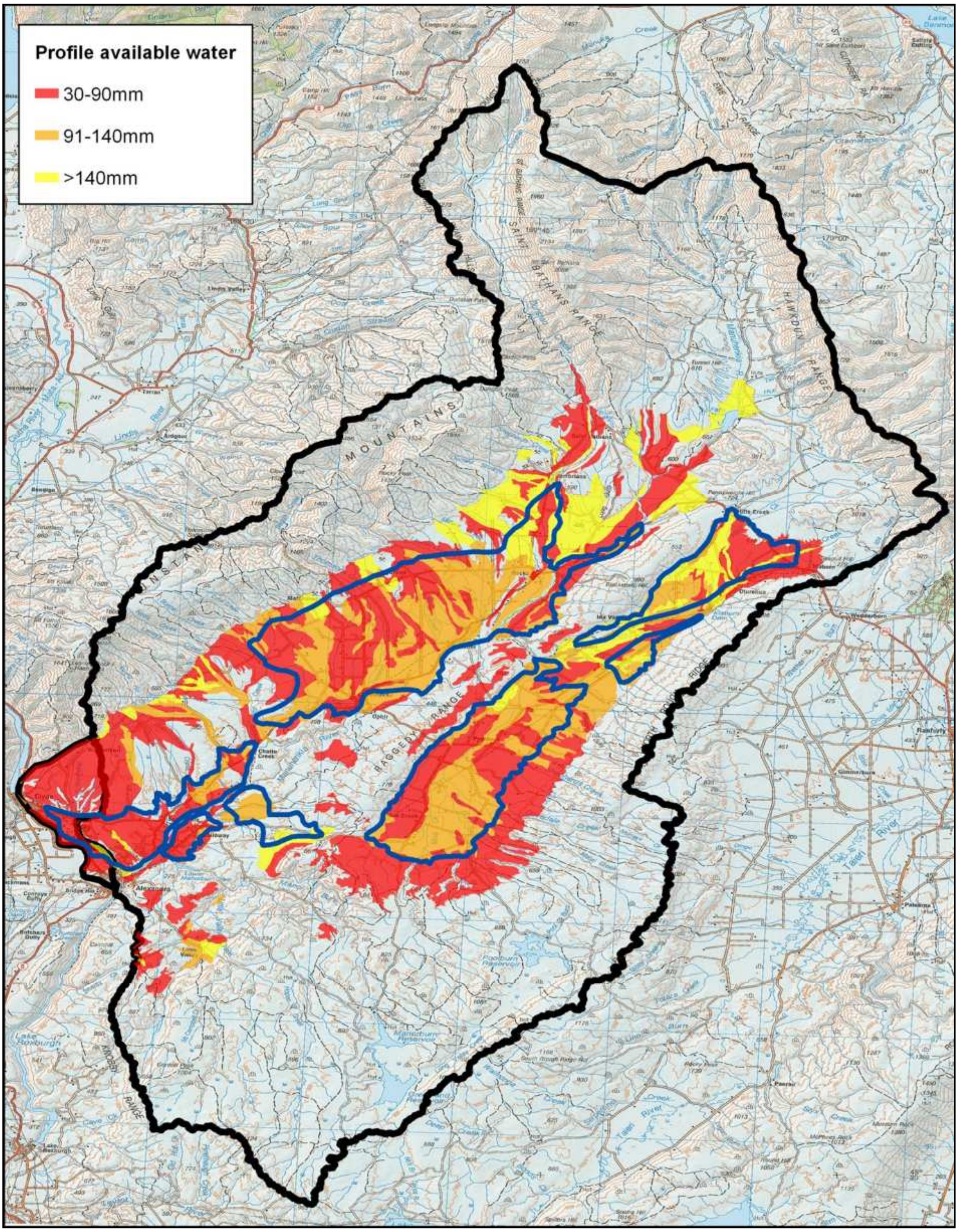
Highlighted cells were calculated using Aqualinc's climate extension software, using data from Lauder Flat (agent 5537) to extend the Cambrians record. The period of overlap between the two records was 27 years, with both records extending back to at least 1944.

## Appendix B: Land slope



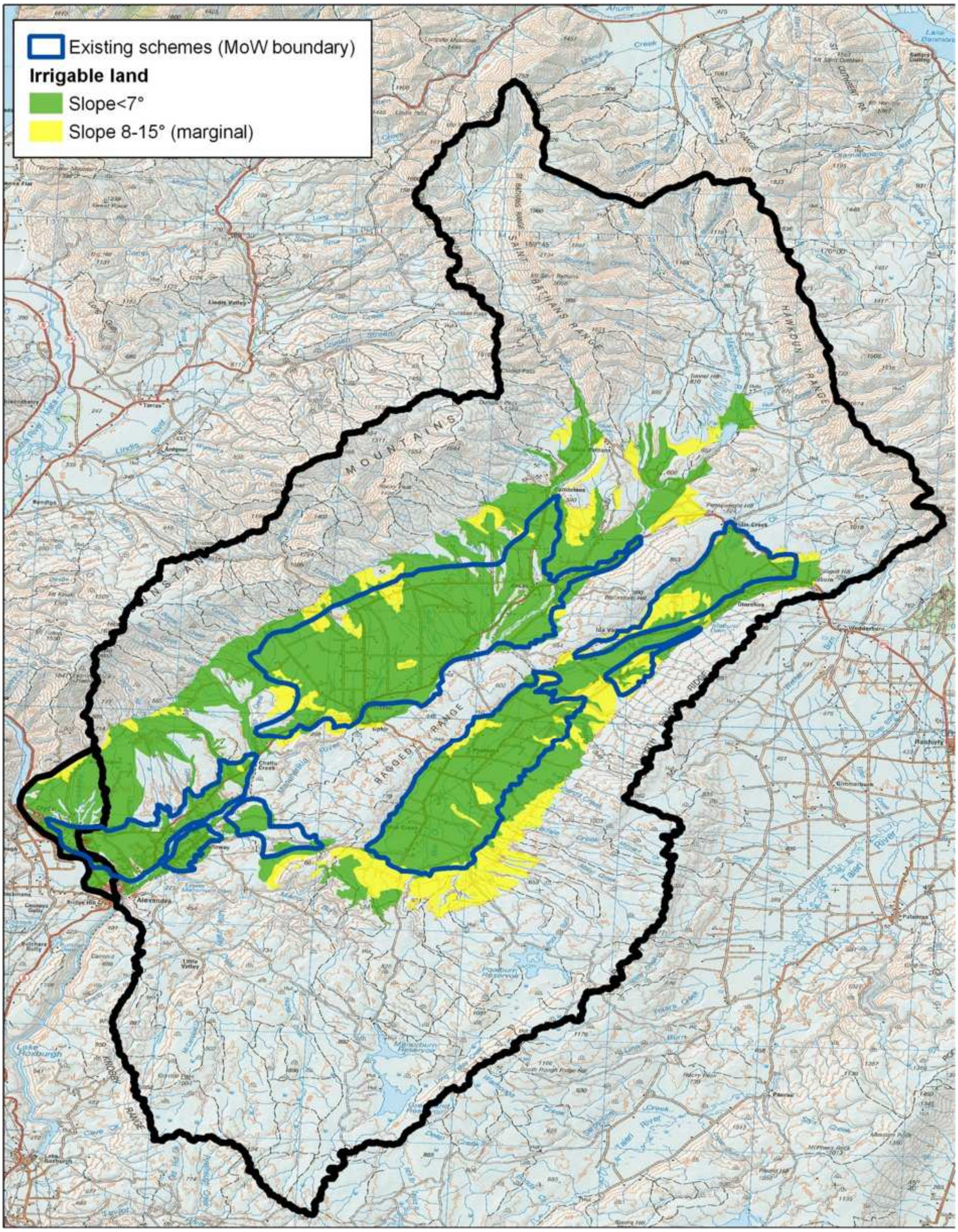

**Flat to rolling land below an elevation of 600 m**

# Appendix C: Soils



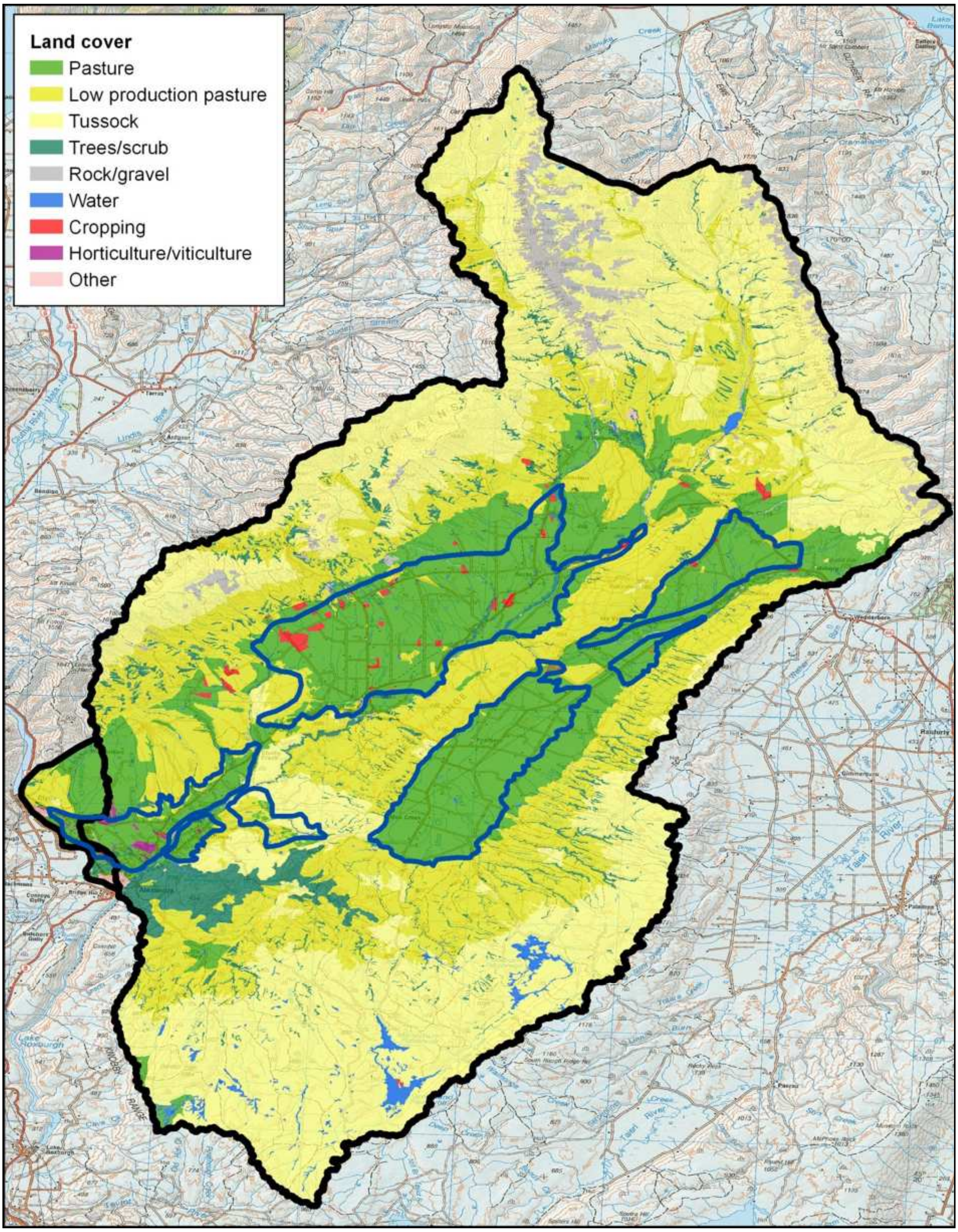

**Soil profile available water (0-90cm) for flat to rolling land below an elevation of 600 m**

# Appendix D: Irrigable land




**Potentially irrigable land (slope < 15°, elevation less than 600m, & excluding isolated areas)**

# Appendix E: Existing land cover




**Land cover from the Land Cover Database version 2 (Landcare 2004)**