OVERSEER®

OVERSEER® Technical Manual

Technical Manual for the description of the OVERSEER® Nutrient Budgets engine

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Climate

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Preface

OVERSEER® Nutrient Budgets

OVERSEER® Nutrient Budgets (OVERSEER) is a strategic management tool that supports optimal nutrient use on farm for increased profitability and managing within environmental limits.

OVERSEER provides users with information to examine the impact of nutrient use and flows within a farm and off-farm losses of nutrients and greenhouse gases. An OVERSEER nutrient budget takes into account inputs and outputs and the key internal recycling of nutrients around the farm.

See the OVERSEER website for more detailed information: http://www.overseer.org.nz

This technical manual

OVERSEER is made up of a user interface and an engine. These two components work together to enable users to generate nutrient budget reports. The Technical Manual provides details of the calculation methods used in the OVERSEER engine.

The OVERSEER engine is based on extensive published scientific research. Technical information about the model's development and use can be found in a growing number of conference proceedings and peer-reviewed papers. Given the ongoing upgrades many of the earlier papers no longer reflect the current version.

The Technical Manual chapters provide detailed descriptions of the methods used in the OVERSEER engine's main sub-models. The Technical Manual sets out the underlying principles and sources of data used to build the model engine. It is a description of the model as implemented, and hence references may not now be the most appropriate or cover the range of data of information currently available, or may not necessarily be the most up to date. If the source of some information and/or assumptions is not known or could not be found, this is acknowledged.

The chapters will continually be updated to reflect the current version.

If readers have feedback or further technical information that they consider could contribute to the future development of the model, please provide feedback via the website http://www.overseer.org.nz.

Contents

Climate

1. Introduction

Climate data such as temperature, rainfall, potential evapotranspiration and sunshine hours are important drivers of processes within OVERSEER. Some of the relationships are shown in Figure 1.

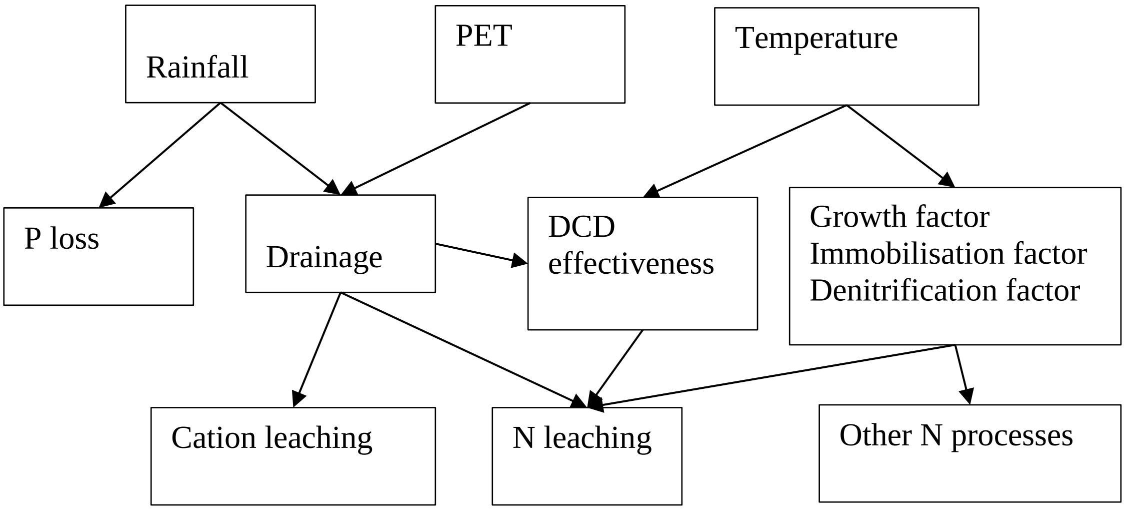

Figure 1. Some of the relationships of processes within OVERSEER with climate data.

This chapter outlines how available climate and other data inputs are used to provide the required climate data that is used in other sections of OVERSEER.

1.1. Workings of the technical manual

The aim of the technical manual is to provide a level of detail so that users of OVERSEER can clearly see the underlying principles and sources of data used to build the components of the model. This technical chapter is part of a series of technical manuals currently under development to explain the inner working of the OVERSEER engine.

In the equations in this manual, units are shown using ( ) and cross-references other equations and sections within this manual or to other chapters of the technical manual are shown using [ ]. Equations with multiple '=' options are cascading alternatives in the order they are considered. The condition is shown on the right hand side. The variable and parameter names used are generally shortened names of the property, and this naming convention is similar to the convention used in the OVERSEER engine model.

2. Data sources

Climate data is entered by either uploading data from a climate database that was derived from the National Institute of Water and Atmospheric Research (NIWA) 0.5 km Virtual Climate Station Network (VCN), or based on entered and selected climate properties.

2.1. Climate tool

The original VCN had a grid spacing of 0.05°, or approximately 5 km (~11,500 stations). Data and methodology for this grid was described by Tait et al. (2006), Tait and Woods (2007) and Tait (2008). The expansion to 0.5 km grid was described by Tait and Zheng (2007) and Wratt et al. (2006). The 0.5 km VCN was used to compile a database comprising 30-year average annual values of rainfall, air temperature, and potential evapotranspiration (PET) based on the period 1981-2010. They were produced by calculating the above 30-year statistics at climate station locations with available data, then interpolating these statistics onto a 500m spatial resolution grid. The database requires a latitude and longitude grid reference. As this is an online database, it is only available when the user is connected to the internet.

2.2. Region nearest town

The alternative method of providing climate data is to enter rainfall, and select climate properties as optional inputs. Unless otherwise indicated, data for the default climate properties are based on the mean monthly values for the 1971-2000 period for locations having at least five complete years of data (nearest town list)[1]. The locations comprise the nearest town and regions in the drop-down list. The region values are the average of the nearest towns in a given region. Since extracting this data, data for the period 1980-2010 has been produced[2] but the tables within OVERSEER have not been updated.

2.3. Monthly data

Rainfall, PET and temperature can be added as monthly inputs. This facility has been added to enable analysis and testing of research trials by a wider range of researchers, and to enabling modelling where the climate profile does not conform to the default average annual profiles described in this chapter. Rainfall must be entered. All PET and/or temperature fields can be left blank, in which case the defaults are used. Default annual values can be viewed on the 'Other values' report.

This option should be used with caution. The model should produce reasonable results in reversed seasons, particularly if advanced inputs are used, but there may be instances where this may not applied. Please check outputs for unusual results. It is not recommended that monthly data for a particularly year is used as inputs.

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[1] http://www.niwa.co.nz/education-and-training/schools/resources/climate, retrieved 2005.

[2] http://www.niwa.co.nz/education-and-training/schools/resources/climate, retrieved 2013.

2.4. Data inputs

The inputs for the climate model are:

1) Compulsory
    a) Daily rainfall pattern (section 4.1.1).
2) Climate input method
    a) Climate properties
        (i) Required
            - Annual rainfall (mm/year).
        (ii) Optional
            - Annual mean temperature (°C).
            - Latitude (°) and altitude (m).
            - Annual potential evapotranspiration (PET) (mm/year).
            - PET seasonality class (section 5.1.2.1).
            - PET range class (section 5.1.2.1).
            - Snow (amount and snow type) (section 4.2).
    b) Climate station tool download:
        (i) Required
            - Latitude (°) and longitude (°).
        (ii) Optional
            - As for a) Climate properties (Annual rainfall, Annual mean temperature and Annual PET fields are populated).
    c) Monthly climate inputs
        (i) Required
            - Monthly rainfall (mm/year).
        (ii) Optional
            - Monthly mean temperature (°C).
            - Monthly potential evapotranspiration (PET) (mm/year).

3. Temperature

3.1. Air temperature

OVERSEER requires estimates of mean annual temperature (°C) and the monthly mean temperature (°C). Temperature factors governing the rate of soil processes such as mineralisation, immobilisation, denitrification, and dicyandiamide (DCD) effectiveness are based on the soil temperature (section 3.2).

The distribution of mean annual temperatures across New Zealand is shown in Appendix 1. The distribution of mean monthly temperatures for a few selected locations from the data of NIWA (2006) is shown in Figure 2, as an example. As expected, temperatures are lowest in the winter months (June and July), highest in summer (January and February), and tend to decrease the further south the location is.

3.1.1. Annual mean air temperature

Annual mean air temperature (°C) is either entered, downloaded using the Climate station tool, or is estimated as:

Equation 1: $AnnualTemp = \sum_{mon}(Temp_{mon} * Days_{mon}) / 365$

$Temp_{mon}$ is the mean monthly temperature (°C) [section 3.1.2].

$Days_{mon}$ is the number of days in a month.

where entered temperature includes the temperature added from the VCN tool.

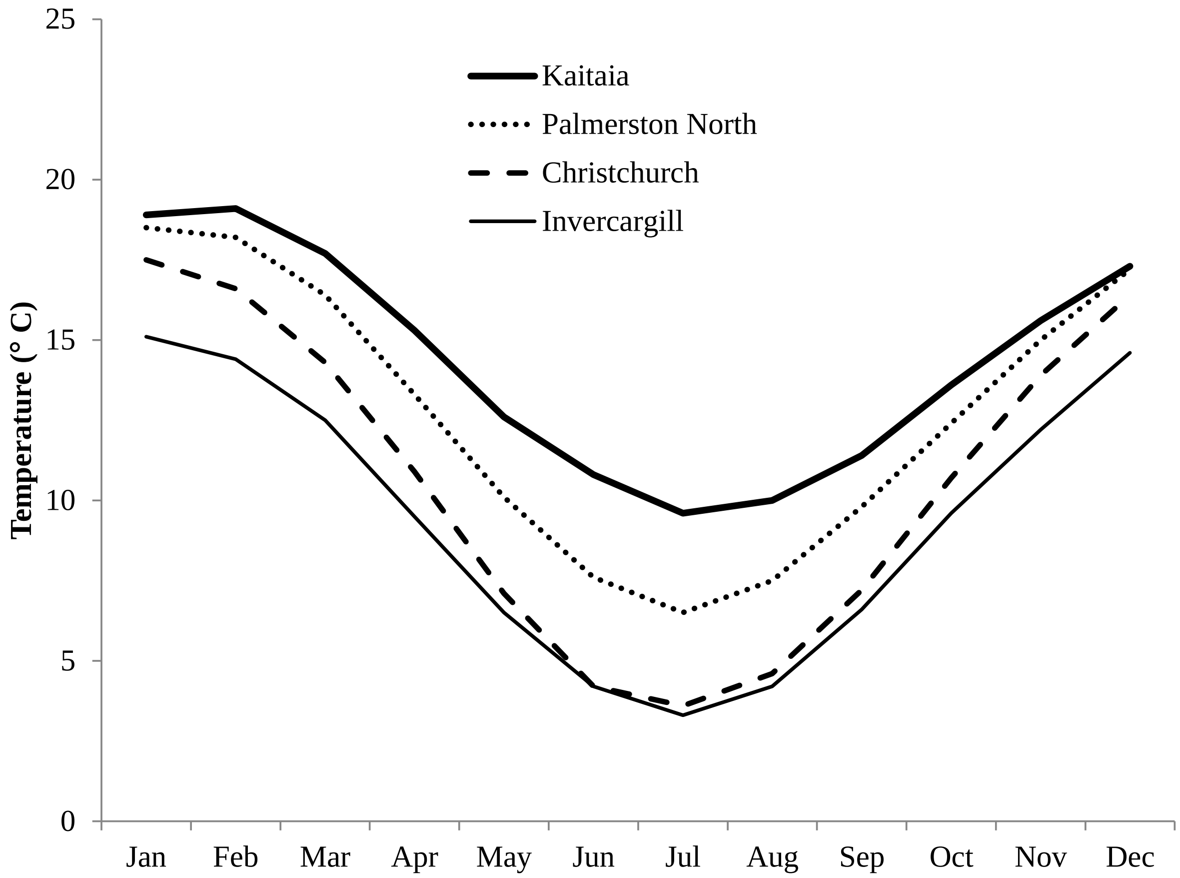

Figure 2. Monthly mean air temperature for four selected locations throughout New Zealand (average of >5 years)

3.1.2. Monthly mean air temperature

The monthly air temperature (°C) is determined using an annual average temperature that is entered, downloaded using the climate station tool, or a region or nearest town default annual temperature, and a monthly pattern based on region or nearest town, or can be entered using the monthly data option.

If monthly values are not entered, monthly temperatures are adjusted so that the annual mean air temperature equals the entered value. The term 'Lowest' was added so that all monthly temperatures moved up or down proportionally and thus the pattern was maintained. If not present, then temperatures below zero become more negative as mean temperature increases. Thus, monthly air temperature (°C) is estimated as:

Equation 2: $Temp_{mon} = ((EstTemp_{mon} - Lowest) * tempadjust) + Lowest$

EstTemp is the mean temperature before adjustment [Equation 3].

Lowest is the lowest monthly temperature that is less than zero during the year (°C).

Tempadjust is decribed in Equation 4.

and where

Equation 3: $EstTemp_{mon}$ = LatAltTemp [Equation 5]
= $TownTemp_{nearesttown, mon}$ nearest town selected
= $RegionTemp_{region, mon}$ otherwise

TownTemp (°C) is the monthly temperature for the selected nearest town [Table 1].

RegionTemp (°C) is the monthly temperature for the selected region [Table 2].

and where

Equation 4: $tempadjust = tempIn / (\sum_{mon}(EstTemp_{mon} – Lowest) * DaysInMonth_{mon}) / 365$

tempIn is the entered annual temperature (°C).

EstTemp and Lowest are as in Equation 2.

and where entered annual temperature includes the temperature added from the VCN tool. RegionTemp (Table 2) was estimated as the average temperature for each region when each town in Table 1 was assigned a region shown in Table 2. The monthly mean air temperature estimated from latitude and altitude in Equation 5 is based on Zheng and Basher (1996).

Equation 5:
$$LatAltTemp = kconstant_{mon} + klat_{mon} * latitude + kalt_{mon} * altitude + ksea_{mon} * coast + kseaexp_{mon} * exp(-0.1 * coast) + kregion_{mon} * fregion_{region}$$

latitude is the entered latitude S (°S) and hence is positive for southern hemisphere.

altitude is the entered altitude (m).

coast is the entered distance to coast (km).

region is the selected region or estimated from nearest town.

fregion = 1 for the regions East Coast North Island, Marlborough and Canterbury.
= -1 for all other regions.

klat, kalt, ksea, kseaexp and kregion are constants [Table 3].

Table 1. Default monthly mean air temperatures (°C) for each nearest town (NIWA 2006).

Nearest town	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kaitaia	19.7	20	18.6	16.9	14.8	12.7	12.2	12.1	13.1	14.5	15.8	17.9
Whangarei	19.9	20	19	16.5	14	12.2	11.2	11.7	12.9	14.3	16.4	18.2
Auckland	19.3	19.8	18.5	16.2	13.7	11.6	10.8	11.3	12.6	14.1	15.8	17.8
Tauranga	19.2	19.2	17.9	15.4	12.5	10.4	9.7	10.5	12.1	13.6	15.6	17.5
Hamilton	18.3	18.7	17.1	14.5	11.6	9.4	8.7	9.8	11.4	13.1	15	16.8
Rotorua	17.8	17.9	16.4	13.5	10.5	8.4	7.6	8.7	10.4	12.3	14.3	16.1
Gisborne	19.2	18.9	17.4	14.8	12	10	9.3	10.2	11.8	13.8	15.9	17.8
Taupo	17.4	17.5	15.6	12.5	9.6	7.6	6.7	7.6	9.4	11.5	13.6	15.7
New Plymouth	17.7	17.9	16.9	14.7	12.1	10.3	9.4	10.1	11.5	12.7	14.4	16.1
Rotorua	19.5	19.3	17.7	15.1	12.1	9.7	9.3	10	12	14.3	16.1	18.2
Whanganui	18.2	18.3	17.1	14.7	12.3	10.2	9.4	10	11.7	13.3	14.9	16.7
Palmerston North	17.9	18.2	16.6	14.1	11.3	9.2	8.6	9.3	11	12.7	14.3	16.3
Masterton	17.8	17.6	16.1	13.3	10.4	8.2	7.5	8.4	10.3	12.1	14	16.1
Wellington	16.9	17.1	15.8	13.8	11.5	9.5	8.8	9.2	10.6	12	13.4	15.3
Nelson	17.7	17.7	16.1	13.1	10.1	7.7	7	8.1	10.2	12.3	14.2	16.2
Blenheim	18.2	17.9	16.7	13.7	10.4	7.9	7.4	8.5	10.8	12.8	14.9	16.7
Westport	16.2	16.5	15.7	13.5	11	9.2	8.6	9.3	10.7	11.8	13.4	15.1
Kaikoura	16.7	16.4	15.3	13.3	10.9	8.7	8	8.5	10.1	11.7	13.4	15.4
Hokitika	15.6	16	14.7	12.5	10	8	7.5	8.2	9.8	11.3	12.7	14.3
Christchurch	17.4	17.1	15.5	12.8	9.6	6.9	6.6	7.7	10	12.3	14	16
Mount Cook	14.6	14.8	12.5	9.4	6.1	3	2.2	3.7	6.6	8.9	10.8	12.8
Lake Tekapo	15.2	15.1	12.7	9.5	6	2.5	1.7	3.4	6.6	9.1	11.1	13.3
Timaru	16.2	16	14.7	11.9	8.6	6	5.7	6.8	9.4	11.2	13.4	15.1
Te Anau	14.7	15	13.5	11.2	8.3	5.7	5.2	6.7	8.5	10.1	11.7	13.4
Queenstown	16.7	16.6	14.4	11.1	7.6	4.6	4.1	5.8	8.6	10.9	13	15.1
Alexandra	17.1	17.1	15.1	11.3	7	2.9	3	5.5	8.9	11.5	13.9	16
Manapouri	14.5	14.3	11.8	9.2	7.2	4.2	3.9	4.7	7.1	9.4	10.3	12.8
Dunedin	15.2	15.1	13.7	11.9	9.2	7	6.5	7.5	9.3	10.9	12.4	13.9

Nearest town	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Invercargill	14	13.9	12.5	10.4	8	5.6	5.2	6.4	8.3	10	11.3	13
Chatham Islands	14.7	15.1	14.2	12.5	10.2	8.7	8	8.5	9.3	10.5	11.8	13.7

Table 2. Default monthly mean air temperatures (°C) for each region.

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Northland	19.5	19.4	18	15.2	12.3	10.5	9.2	9.8	11.4	13.9	16.2	18.1
Auckland	20.2	20.2	18.5	15.4	12.3	10.1	8.7	9.6	11.5	14.2	16.6	18.7
Waikato/ Coromandel	19.7	19.6	17.6	14.3	11	8.6	7.4	8.5	10.6	13.4	15.9	18.2
BOP	20.2	20	17.9	14.6	10.9	8.5	7.3	8.3	10.5	13.3	16	18.4
Central Plateau	18.3	18.1	15.8	12.4	8.9	6.5	5.4	6.5	8.6	11.6	14.4	16.7
King Country/ Taihape	18.8	18.7	16.7	13.5	10.3	8.1	6.8	7.8	9.7	12.5	15.1	17.3
Taranaki	18.4	18.2	16.1	12.9	9.9	7.6	6.4	7.4	9.5	12.1	14.7	17
Manawatu/ Wanganui	18.1	17.8	15.9	12.7	9.5	7.1	6.1	7.1	9.2	11.8	14.5	16.8
Wellington	17.6	17.2	15.5	12.6	9.6	7.2	6.2	7.1	9.1	11.8	14.2	16.4
East Coast North Island	18.8	18.2	16	12.5	9.1	6.5	5.7	6.8	9.2	12.2	15.1	17.5
West Coast South Island	16.9	16.5	14.7	11.5	8.1	5.2	4.3	5.4	8.1	11.2	13.5	15.9
Nelson	18.6	18	15.8	12.2	8.3	5.4	4.4	5.8	8.6	12	14.8	17.3
Marlborough	19.5	18.6	15.9	12	8.1	5.1	4.4	5.9	8.8	12.7	16	18.3
Canterbury	17.5	16.6	14.2	10.7	6.8	3.8	3.2	4.4	7.3	10.9	14.1	16.6
Otago	15.8	15.1	12.8	9.3	5.9	3.1	2.4	3.5	6.1	9.5	12.3	14.9
Southland	14.8	14.1	12.3	9.4	6.3	4	3.1	4	6.4	9.2	11.7	14.1
High Country (> 300 m)	15.1	14.3	12	8.3	4.5	1.9	1.1	2.2	4.8	8.2	11.2	14

Table 3. Coefficients for estimating mean monthly temperature (Equation 5) when altitude and latitude are entered.

	kconstant	klat	kalt	ksea	kseaexp	kregion
January	33.61912	-0.39276	-0.00465	0.01440	0	0.32795
February	36.27117	-0.45727	-0.00449	0.01250	0	0.25516
March	35.06381	-0.45694	-0.00389	0	0	0
April	33.06500	-0.47599	-0.00439	0	0.43137	0
May	32.33703	-0.53633	-0.00447	0	0.97082	0
June	32.05612	-0.58827	-0.00463	0	1.08829	-0.15123
July	29.57950	-0.54233	-0.00492	0	0.95995	-0.11347
August	28.30422	-0.47835	-0.00500	0	0.54086	-0.10510
September	25.94583	-0.36979	-0.00487	0	0	0
October	25.88614	-0.32301	-0.00438	0	0	0.12593
November	25.51279	-0.34703	-0.00506	0.00885	0	0.28965
December	30.32801	-0.34845	-0.00494	0.01322	0	0.29127

3.2. Soil temperatures

Soil processes such as mineralisation, immobilisation, denitrification and DCD effectiveness are based on the soil temperature at 5 cm or 10 cm depth. The relationship between air temperature and soil temperature was determined using data from NIWA (2006). A regression line was fitted between mean monthly temperature at 9am of the air temperature and 10 cm earth temperatures for the 1971-2000 period for locations which had at least 5 years of complete data. This covered the locations listed in Table 1 except for Westport, Kaikoura, Mt Cook, lake Tekapo, Milford Sound, Queenstown, and Manapouri for which earth temperature data was not available. In addition, stations at Karamea, Franz Josef, Hanmer, Twizel and Cromwell had earth temperature but no air temperature data available. The relationship for 10 cm depth earth temperatures is shown in Figure 3. A relationship for 5 cm depth was derived by extrapolation. For a given month, the range in air temperatures between the northern and southern most sites was about 8°C.

Thus, monthly soil temperatures are estimated as shown in Equation 6.

Equation 6: $temp5 = 1.0972 * temp_{mon} - 0.9499$

$temp10 = 1.2098 * temp_{mon} - 3.49$

temp is the monthly air temperature (°C) [section 3.1.2].

temp5 is the soil temperature at 5 cm (°C).

temp10 is the soil temperature at 10 cm (°C).

The regressions shown in Equation 6 indicate that air temperature and soil temperature are similar at about 15 °C, and are higher in the soil when air temperatures are greater than 15 °C, and lower in the soil when air temperatures are less than 15 °C.

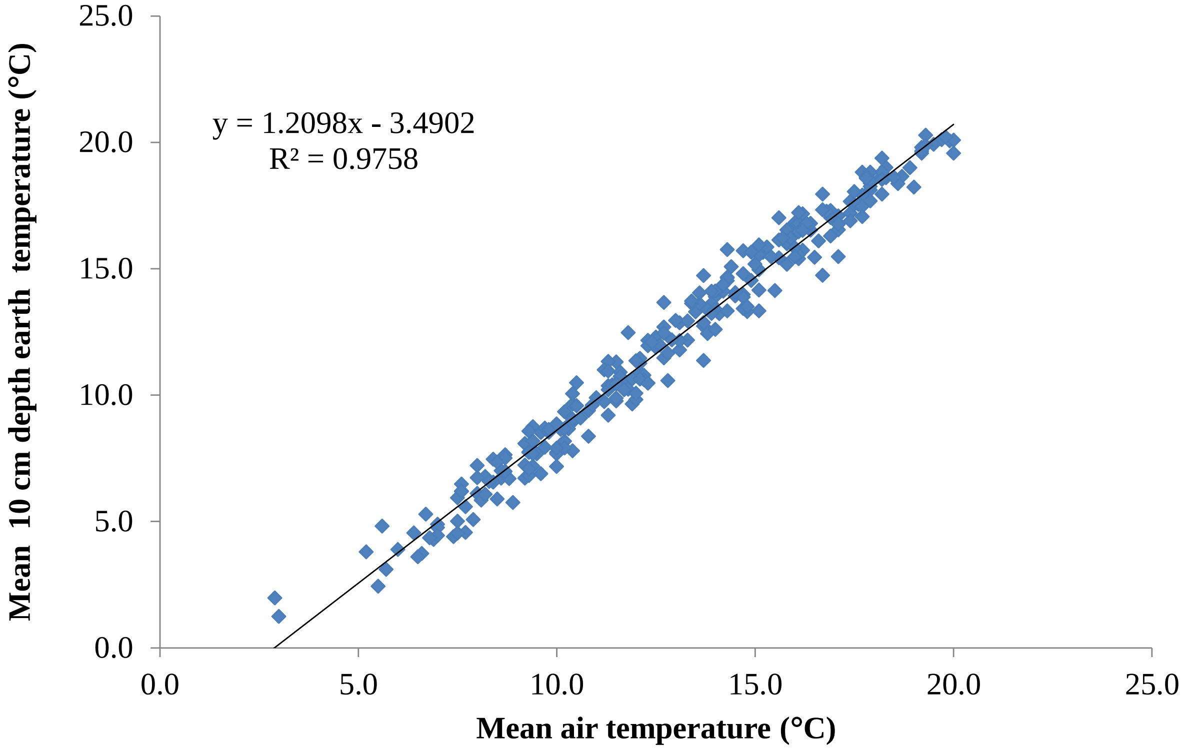

Figure 3. Relationship between monthly measured mean air temperature and 10 cm earth temperatures.

4. Precipitation

4.1. Rainfall

Rainfall is an important input in to the water balance within the hydrology sub-model (see Hydrology chapter). The hydrology sub-model provides the monthly drainage that drives the N leaching sub-model. However, the wetland and filter strip sub-models require a finer time scale than a monthly time scale. Rutherford *et al.* (2008) noted that:

> *"The ability of filter strips and wetlands to remove or store nutrients is strongly flow dependant. Filter strips only receive inflows during surface runoff. They may trap a substantial fraction of incoming particulates when inflows are moderate, but can be overwhelmed by large flows. Wetlands are fed by re-emerging shallow sub-surface flow plus surface flow during rainfall events. They may remove a substantial proportion of the incoming nitrate load during low flows when the soil-water contact times are long. However, as inflow rates increase, surface flow tends to by-pass the active soils and the removal efficiency decreases."*

Further, Rutherford *et al.* (2008) adds:

> *"An annual time-step is inappropriate for simulating the majority of nutrient removal processes. The most important time scales for the management of nutrient generation, transport and attenuation are hourly-monthly. A daily time step may not capture the fine detail of short-term variations in rainfall and surface runoff. However, hourly or sub-hourly calculations would require extensive input data. A*

weekly or monthly time step may suffice for modelling seepage or spring-fed wetlands, although surface runoff often causes short-term reductions in removal efficiency. A daily time step is a useful compromise."

Using this compromise, the hydrology sub-model uses a daily time step, which requires daily rainfall inputs (see section 4.1.1 for derivation of data). To simplify inputs, a year-long time series of daily rainfall is provided as an internal database.

4.1.1. Daily rainfall patterns

Rainfall amounts were split into five rainfall range classes (Rutherford *et al*., 2008) as shown in Table 4**.**

Table 4. Range in mean annual rainfall (mm/year) and description of class for each rainfall range classes.

Class	Range	Description
1	< 731	Dry
2	731 – 1450	Moderate
3	1451-2900	Wet
4	2901-5850	Very wet
5	> 5850	Extremely wet

The daily precipitation data used for this analysis comes from NIWA's 5 km VCN database (Tait and Woods 2007). The following description has largely been extracted from Rutherford *et al*. (2008).

"The 'typical' rainfall time series was identified by searching through all years and all stations within a precipitation region until the year was found whose cumulative frequency distribution of daily rainfall most closely matched the cumulative frequency distribution of all years and all stations within the rainfall region. In other words, for the most representative year, the largest daily rainfall amount would have, for any given day, a probability of exceedance approximately equal to 1/366, and the j^{th} largest rainfall amount would have a probability of exceedance approximately equal to j/366."

In practice, the search for the most representative year was limited to 100 randomly chosen stations within each rainfall region to restrict computation time.

In order to derive seasonality classes a single-harmonic Fourier series was fitted to the daily rainfall time-series using Equation 7:

Equation 7: $R_i = C_0 + C_1 \cos(2\pi i / 365 + \theta)$

where R_i is the mean rainfall amount on the i^{th} day of the year, and C_0, C_1, and θ are fitting parameters. The strength of seasonality is given by the dimensionless ratio C_1/C_0. The three classes of seasonal variation selected are shown in Table 5.

Table 5. Rainfall classification based on the strength of seasonal variation in rainfall.

Class	Range C_1/C_0	Description
1	< 0.11	None to weak
2	0.11 – 0.22	Low
3	> 0.22	Moderate

The combination of five rainfall amount classes and three seasonality classes results in a total of 15 rainfall regions. These regions are not necessarily contiguous in geographic space, thus a given rainfall pattern may occur in various disconnected locations across New Zealand. These 15 rainfall regions are capture in the input daily rainfall category.

> **The time series represents a 'typical' year for a given rainfall region. Fifteen daily rainfall patterns are defined using a combination of five annual rainfall range classes and three rainfall seasonal variation classes.**

The distribution of mean annual rainfall and rainfall seasonality classes across New Zealand are shown in Appendix 1. The daily rainfall for each of the rainfall regions is shown in Appendix 2. The proportion of rainfall that occurs in each month, averaged over the rainfall range classes, is shown in Figure 4. The seasonal variation shown in Figure 4 is not strong relative to the dry season/wet season patterns seen in some parts of the world.

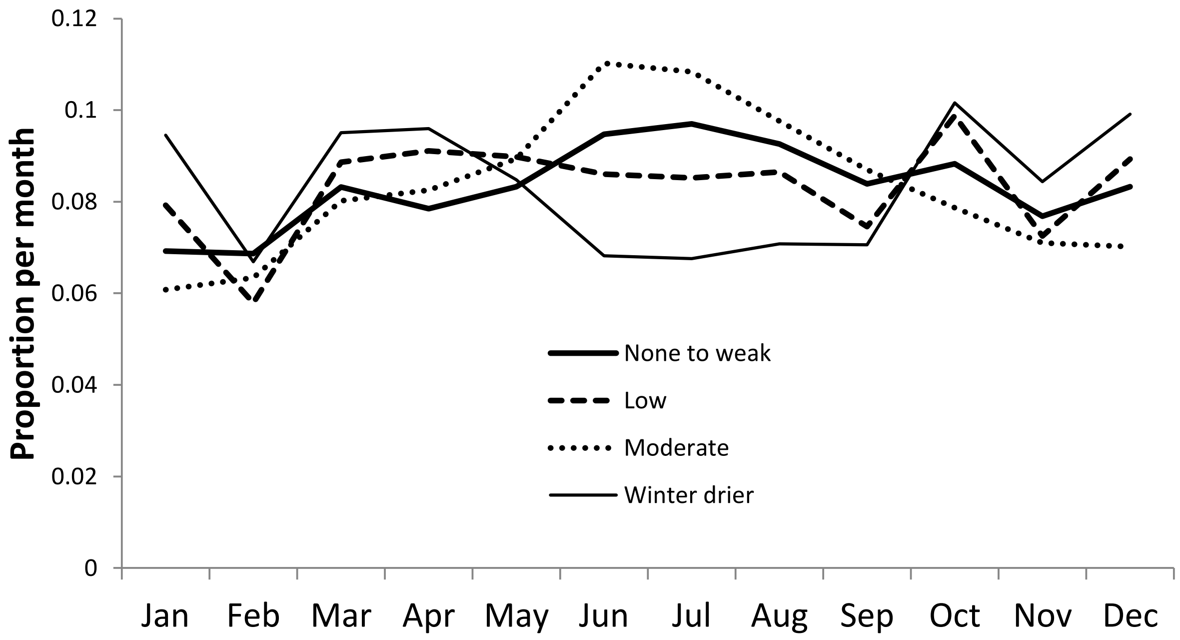

Figure 4. Proportion of annual rainfall that occurs each month averaged over the rainfall range classes for each seasonality pattern used in OVERSEER, and for a winter dry site.

4.1.1.1. *Daily rainfall pattern class*

Rainfall region class is a compulsory input. When importing older files, or after entering annual rainfall, the default rainfall pattern class is set as shown in *Equation 8*.

Equation 8: PatternClass = (3 * (RangeClass – 1)) + SeasonalityClass

Rangeclass is the rainfall range class corresponding to the rainfall band the entered rainfall is in [Table 4].

SeasonalityClass is rainfall seasonality class [Equation *9*].

Rainfall seasonality class is determined as:

Equation 9: SeasonalityClass	= user selected class	
	= 2	region =10 and topography is hilly
	= 3	region is Taranaki and coast < 30
	= 3	region is Nelson and coast < 30
	= 2	region is Otago and coast < 30
	= $Rainseason_{region}$	otherwise [Table 6].

Once the default is set the rainfall region class remains fixed unless the user changes it. This was because the switch from one rainfall region to another if rainfall was changed can result in an anomaly; a non-consistent change in drainage and hence N leaching because of the daily rainfall pattern. Additional work is required to find more stable patterns.

Table 6. Default rainfall seasonality class for each *Overseer* region

Region	Rainfall seasonality class
Northland	3
Auckland	3
Waikato/Coromandel	3
BOP	2
Central Plateau	2
King Country/Taihape	3
Taranaki	3
Manawatu/Wanganui	2
Wellington	3
East Coast North Island	3
West Coast South Island	2
Nelson	2
Marlborough	2
Canterbury	2
Otago	3
Southland	2
High Country (> 300 m)	1

4.1.2. Annual rainfall

Annual rainfall (mm/year) is either entered, downloaded using the Climate station tool, or is estimated as:

Equation 10: $AnnualRain = \sum_{mon} Rain_{mon}$

$Rain_{mon}$ is the monthly rainfall value (mm/month) [section 4.1.3].

4.1.3. Monthly rainfall

Monthly rainfall (mm/month) is either entered using the monthly data input option, or is estimated as:

Equation 11. $Rain_{mon}$ = RainIn * $SeasonalRainProp_{rainseason,\ mon}$ seasonality selected
= RainIn * $TownRainProp_{nearesttown,\ mon}$ nearest town selected
= RainIn * $RegionRainProp_{region,\ mon}$ otherwise

RainIn is the entered annual rainfall (mm/year).

SeasonalRainProp values are shown in Table 7. See Equation 13 for definition of rainseason.

TownRainProp values are shown in Table 8.

RegionRainProp values are shown in

Table 9.

where the proportion of annual rainfall that occurs in each month for each nearest town (TownRainProp, Table 8) was estimated as:

Equation 12: $TownRainProp = rain_{mon} / \sum rain_{mon}$

Rainmon is the monthly rainfall for meteorological locations (NIWA 2006).

and RegionRainProp (

Table 9) was based on regions been assigned to values in Table 8.

If the rainfall seasonality class is selected by the user, an additional option of dry winter is included, which is based on pattern for Timaru. RainSeason, which is used to look up Table 7, is estimated as:

Equation 13: rainseason = 1 RainSeasonality = 1
= 3 RainSeasonality = 2, South Island
= 2 RainSeasonality = 2, North Island
= RainSeasonality + 1 otherwise

RainSeasonality is the selected rainfall seasonality class.

Table 7. Approximate proportion of annual rainfall that occurs in each month for each seasonality class.

Class	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.0830	0.0830	0.0830	0.0830	0.0840	0.0840	0.0840	0.0840	0.0830	0.0830	0.0830	0.0830
2	0.0692	0.0687	0.0832	0.0785	0.0833	0.0947	0.0970	0.0926	0.0839	0.0883	0.0768	0.0833
3	0.0792	0.0579	0.0886	0.0911	0.0898	0.0860	0.0852	0.0865	0.0746	0.0988	0.0725	0.0893
4	0.0608	0.0634	0.0802	0.0825	0.0894	0.1102	0.1084	0.0976	0.0870	0.0787	0.0710	0.0702
5	0.0945	0.0669	0.0951	0.0960	0.0848	0.0682	0.0676	0.0708	0.0706	0.1016	0.0844	0.0991

Table 8. Approximate proportion of annual rainfall that occurs in each month for each nearest town.

Nearest Town	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kaitaia	0.0613	0.0591	0.0583	0.0711	0.0890	0.1114	0.1242	0.1137	0.0995	0.0696	0.0703	0.0726
Whangarei	0.0605	0.0753	0.0955	0.0868	0.0807	0.1204	0.1015	0.0982	0.0874	0.0780	0.0538	0.0619
Auckland	0.0605	0.0525	0.0759	0.0847	0.0831	0.1122	0.1178	0.0977	0.0936	0.0734	0.0751	0.0734
Tauranga	0.0611	0.0644	0.1057	0.0867	0.0751	0.1057	0.1007	0.0950	0.0859	0.0776	0.0702	0.0718
Hamilton	0.0715	0.0598	0.0732	0.0800	0.0859	0.1002	0.1061	0.0985	0.0859	0.0808	0.0783	0.0800
Rotorua	0.0707	0.0721	0.0821	0.0799	0.0742	0.0956	0.0928	0.1056	0.0849	0.0871	0.0728	0.0821
Gisborne	0.0508	0.0733	0.0930	0.0968	0.0912	0.1175	0.1118	0.0874	0.0949	0.0592	0.0611	0.0630
Taupo	0.0770	0.0697	0.0752	0.0670	0.0788	0.0897	0.0951	0.0987	0.0815	0.0924	0.0770	0.0978
New Plymouth	0.0681	0.0667	0.0822	0.0920	0.0871	0.1018	0.1004	0.0892	0.0772	0.0871	0.0758	0.0723
Rotorua	0.0596	0.0770	0.1056	0.0932	0.0770	0.1006	0.1143	0.0832	0.0807	0.0683	0.0708	0.0696
Whanganui	0.0701	0.0735	0.0769	0.0803	0.0916	0.0928	0.0995	0.0792	0.0814	0.0916	0.0837	0.0792
Palmerston North	0.0671	0.0640	0.0764	0.0785	0.0971	0.0899	0.0971	0.0847	0.0857	0.0930	0.0806	0.0857
Masterton	0.0561	0.0601	0.0856	0.0714	0.0989	0.1030	0.1060	0.0979	0.0846	0.0846	0.0785	0.0734
Wellington	0.0576	0.0496	0.0737	0.0801	0.0937	0.1177	0.1089	0.0985	0.0801	0.0921	0.0793	0.0689
Nelson	0.0756	0.0598	0.0818	0.0902	0.0808	0.0892	0.0902	0.0944	0.0766	0.0965	0.0860	0.0787
Blenheim	0.0714	0.0410	0.0821	0.0973	0.0881	0.0851	0.1079	0.1064	0.0669	0.1064	0.0653	0.0821
Westport	0.0835	0.0587	0.0755	0.0848	0.0923	0.0879	0.0826	0.0826	0.0888	0.0875	0.0808	0.0950
Kaikoura	0.0559	0.0702	0.1094	0.0963	0.0844	0.0892	0.0951	0.0927	0.0832	0.0880	0.0713	0.0642
Hokitika	0.0869	0.0598	0.0755	0.0866	0.0852	0.0810	0.0807	0.0779	0.0869	0.0994	0.0834	0.0967

Nearest Town	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Christchurch	0.0644	0.0598	0.0828	0.0828	0.0859	0.1012	0.1212	0.1058	0.0721	0.0813	0.0675	0.0752
Mount Cook	0.0958	0.0594	0.0983	0.0844	0.0851	0.0669	0.0648	0.0694	0.0722	0.1053	0.0909	0.1074
Lake Tekapo	0.0684	0.0584	0.0868	0.0868	0.0835	0.0968	0.0868	0.1035	0.0851	0.0952	0.0684	0.0801
Timaru	0.0816	0.0674	0.0922	0.1170	0.0745	0.0727	0.0762	0.0798	0.0621	0.0975	0.0851	0.0940
Te Anau	0.0749	0.0758	0.0732	0.0833	0.0875	0.0901	0.0783	0.0859	0.0690	0.1103	0.0816	0.0901
Queenstown	0.1063	0.0739	0.0948	0.0867	0.0950	0.0652	0.0619	0.0633	0.0775	0.1020	0.0774	0.0960
Alexandra	0.0854	0.0635	0.0876	0.0821	0.0975	0.0898	0.0712	0.0800	0.0756	0.1041	0.0789	0.0843
Manapouri	0.0784	0.0595	0.1081	0.0919	0.0946	0.0703	0.0622	0.0649	0.0730	0.1108	0.0703	0.1162
Dunedin	0.0749	0.0758	0.0732	0.0833	0.0875	0.0901	0.0783	0.0859	0.0690	0.1103	0.0816	0.0901
Invercargill	0.0885	0.0774	0.0860	0.0737	0.0885	0.0909	0.0848	0.0799	0.0651	0.0872	0.0774	0.1007
Chatham Islands	0.1022	0.0709	0.0843	0.0897	0.1022	0.0888	0.0789	0.0637	0.0717	0.0852	0.0726	0.0897

Table 9. Approximate proportion of annual rainfall that occurs in each month for each Overseer region.

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Northland	0.0609	0.0672	0.0769	0.0789	0.0849	0.1159	0.1129	0.1059	0.0935	0.0738	0.0621	0.0672
Auckland	0.0605	0.0525	0.0759	0.0847	0.0831	0.1122	0.1178	0.0977	0.0936	0.0734	0.0751	0.0734
Waikato/ Coromandel	0.0663	0.0621	0.0895	0.0833	0.0805	0.1029	0.1034	0.0967	0.0859	0.0792	0.0742	0.0759
BOP	0.0707	0.0721	0.0821	0.0799	0.0742	0.0956	0.0928	0.1056	0.0849	0.0871	0.0728	0.0821
Central Plateau	0.0770	0.0697	0.0752	0.0670	0.0788	0.0897	0.0951	0.0987	0.0815	0.0924	0.0770	0.0978
King Country/ Taihape	0.0681	0.0667	0.0822	0.0920	0.0871	0.1018	0.1004	0.0892	0.0772	0.0871	0.0758	0.0723
Taranaki	0.0681	0.0667	0.0822	0.0920	0.0871	0.1018	0.1004	0.0892	0.0772	0.0871	0.0758	0.0723
Manawatu/ Wanganui	0.0686	0.0688	0.0767	0.0794	0.0944	0.0913	0.0983	0.0819	0.0836	0.0923	0.0821	0.0825
Wellington	0.0576	0.0496	0.0737	0.0801	0.0937	0.1177	0.1089	0.0985	0.0801	0.0921	0.0793	0.0689
East Coast North Island	0.0555	0.0702	0.0948	0.0871	0.0890	0.1070	0.1107	0.0895	0.0868	0.0707	0.0701	0.0686
West Coast South Island	0.0852	0.0593	0.0755	0.0857	0.0888	0.0845	0.0816	0.0802	0.0879	0.0934	0.0821	0.0958
Nelson	0.0756	0.0598	0.0818	0.0902	0.0808	0.0892	0.0902	0.0944	0.0766	0.0965	0.0860	0.0787
Marlborough	0.0714	0.0410	0.0821	0.0973	0.0881	0.0851	0.1079	0.1064	0.0669	0.1064	0.0653	0.0821
Canterbury	0.0673	0.0658	0.0948	0.0987	0.0816	0.0877	0.0975	0.0928	0.0725	0.0889	0.0746	0.0778
Otago	0.0806	0.0709	0.0891	0.0830	0.0902	0.0837	0.0751	0.0769	0.0690	0.1028	0.0764	0.1023
Southland	0.1022	0.0709	0.0843	0.0897	0.1022	0.0888	0.0789	0.0637	0.0717	0.0852	0.0726	0.0897
High Country (> 300 m)	0.0890	0.0638	0.0919	0.0850	0.0903	0.0797	0.0712	0.0790	0.0776	0.1016	0.0789	0.0920

4.1.4. Daily rainfall

Daily rainfall (mm/day) is used in the daily soil water balance sub-model (see Hydrology chapter) and is calculated in Equation 14 as:

Equation 14: $DailyRain = RepDailyRain_{jdate, RainCat} * rainadjust$

jdate is the day of the year.

rainCat is the selected daily rainfall pattern (1-15) [section 4.1.1.1].

and where rainfall adjustment factor is estimated as:

Equation 15: $rainadjust = MonRain_{mon} / \sum_{day} DailyRain_{day}$

MonRain is the monthly rainfall (mm/month) [section 4.1.3].

day is days of year that occur in month mon.

4.2. Snow

Snow is converted to rainfall equivalents based on snow type using the conversion rate shown in Table 10. OVERSEER assumes that snow melts in the month that it falls, and that snow or ice cover has no effect on runoff from subsequent rainfall events. This may result in anomalous results when snowmelt contributes directly to runoff. OVERSEER has not been designed to work in areas that have a permanent snow cover over winter followed by a spring thaw.

Snowmelt is used to estimate daily soil water in the hydrology sub-model (see Hydrology chapter). As the exact timing of the snowfall is unknown, rainfall equivalents are distributed evenly over the month.

Note that if snowfall has been included in the entered rainfall value, then snowfall should not be entered. The rainfall data uploaded from the VCN database includes snowfall. Currently snowfall as a separate input is only applied to pastoral and cut and carry blocks.

Thus, daily rainfall equivalents from snowmelt (mm/day) are estimated as:

Equation 16: $snowmelt_{day} = rate_{mon} * snowconversion / DaysInMonth_{mon}$

rate is the entered rate of snowfall (cm/month).

snowconversion converts snow to rainfall based on entered snow type (mm/cm snow) [Table 10].

Table 10. Conversion rates for different snow types.

Snow type	Conversion (mm rainfall per cm snow)	Ratio rain:snow
Powder/dry	0.4	1:25
Average	1.0	1:10
Wet/heavy	1.3	1:7.7

5. Potential evapotranspiration

Potential evapotranspiration (PET) is used in the daily soil water sub-model as outlined in the Hydrology chapter as a component of the water balance. The PET is defined as the PET when wet/dry days are accounted for.

5.1. Data and default values

5.1.1. Virtual Climate Network

The PET values (mm/year) for the 0.5 km grid can be uploaded from the VCN tool. Tait and Woods (2007) reported that PET was based on the following records:

> *"There are several climate stations around New Zealand that have no wind measurements, meaning that Penman PET cannot be calculated. At many of these stations, however, a calculation of PET is made using the Priestley–Taylor formulas (Priestley and Taylor 1972). This calculation requires the same input variables as the Penman formulas, with the exception of wind* [and water pressure]. *Further, at still more stations where no PET calculation can be made at all, due to no sunshine or solar radiation measurements, for example, there are records of raised pan evaporation measurements."*

Additionally, they added that:

> *"Maximum use is made of observational data by combining both Penman and Priestley–Taylor PET calculations and raised pan evaporation measurements."*

They made the following caution:

> *An analysis of the interpolation error using 20 validation sites shows that the average rootmean-square error varies between about 1 mm in the summer months to about 0.4 mm in winter. It is advised that interpolated data for areas above 500m elevation should be used with caution, however, due to the paucity of input data from high-elevation sites."*

5.1.2. Climate properties

If the climate properties option is selected, PET is determined from the selected range and seasonality class, or from default classes based on region. In monthly data input method is used but no PET data is entered, then default values are used.

5.1.2.1. *PET range and seasonality classes*

The following information is a summary of the approach described in Rutherford *et al.* (2008).

Daily time series of potential PET are provided for different PET regions. The PET regions are defined by the mean annual PET amount and the seasonal variation of PET. Mean annual PET is divided into five classes as shown in Table 11.

Table 11. Classification of mean annual PET range.

Class	Range (mm/year)	Description
1	< 501	Low
2	501-650	Low-moderate
3	651-800	Moderate
4	801-950	Moderate-high
5	> 951	High

The seasonal variation is classified by the strength of the seasonal PET 'signal'. The seasonal signal for a given location is calculated by fitting a single-harmonic Fourier series to the mean daily PET using *Equation 17*:

Equation 17: $PET_i = C_0 + C_1 \cos(2\pi i / 365 + \theta)$

PET_i is the mean PET amount on the i^{th} day of the year.

C_0, C_1, and θ are fitting parameters.

The strength of seasonality is given by the dimensionless ratio C_1/C_0 and is divided into three classes as shown in Table 12.

Table 12. PET seasonality classification based on the strength of seasonal variation in PET in dry conditions.

Class	Range C_1/C_0	Description
1	< 0.8	Low
2	0.8 – 1.0	Moderate
3	> 1.0	High

The distribution of mean annual potential evapotranspiration across New Zealand is shown in Appendix 1. This is shown to indicate the range and distribution of mean potential evapotranspiration found in New Zealand, and is also displayed on the interface as a user reference.

5.1.2.2. *Default values*

Default values for PET and seasonality classes are estimated as shown in Equation 18 and Equation 19.

Equation 18: PETrangeclass = range class for entered PET value
= user selected class
= 3 region =14 and topography not flat.
= $PETrange_{region}$ otherwise [Table 13].

Equation 19: PETseasonclass = user selected class
= $PETseason_{region}$ otherwise [Table 13].

Table 13. Default PET climate factors for each *Overseer* region

Region	PET range class[1]	PET seasonality class[2]
Northland	4	1
Auckland	5	1
Waikato/Coromandel	4	1
BOP	4	2
Central Plateau	3	2
King Country/Taihape	3	2
Taranaki	4	1
Manawatu/Wanganui	4	2
Wellington	4	2
East Coast North Island	4	2
West Coast South Island	3	2
Nelson	4	2
Marlborough	4	2
Canterbury	4	2
Otago	3	2
Southland	3	2
High Country (> 300 m)	2	2

[1] see Table 11 for definition.
[2] see Table 12 for definition.

5.2. Daily PET

Typically, PET is lower on wet days than dry days (Rutherford *et al*., 2008). The reduction in PET is a result of rainfall and cloud cover reducing evaporative and transpiration demand. It is probable that this effect is lower when daily rainfall is low, as these probably indicates showers with fine periods. Therefore, the difference between wet and dry days was scaled arbitrarily between 0 and 5 mm daily rainfall.

Daily PET (mm/day) on wet and dry days is calculated using a Fourier series transformation using a parameter set for each PET range and seasonality class (Rutherford *et al*., 2008). Because each PET range class spans a large range in PET (Table 11), the daily PET amounts can be scaled so that the total annual PET of the regional time series equals the total annual PET at the farm.

If monthly values are entered then daily PET (mm/day) is estimated as:

Equation 20: dailyPET = avdailyPET * frain where the average daily PET for a given month is estimated as:

Equation 21: $avdailyPET = PET_{mon} / DaysInMonth_{mon}$
PET is the entered monthly PET (mm/month).

and the adjustment (frain) for water added (rainfall plus irrigation) is 1 if no water is added, or is $ratioWetDry_{mon}$ if more than 5 mm/day of water is added, or is estimated as:

Equation 22: $frain = (1 - ((1 - ratioWetDry_{mon}) /5 * wadded))$
ratioWetDry is the ratio of PET between wet and dry days (section 5.3).
wadded is daily rainfall plus irrigation (mm/day).

Otherwise, daily PET (mm/day) is calculated in Equation 23 as:

Equation 23: $dailyPET = dayPET * PETadjust$
dayPET is daily PET as described below (mm/day).

and where the PET adjustment factor is estimated as:

Equation 24: $PETadjust = PETIn / \sum_{day} dayPET0_{day}$
PETIn is the entered or Climate station tool downloaded annual PET (mm/year).
dayPET0 is dayPET when daily input is zero.

Unadjusted daily PET is the PET on wet or dry days where the difference between wet and dry days was scaled between 0 and 5 mm daily rainfall. PETDry and PETWet are estimated using a Fourier series transformation. Sometimes the Fourier series transformation results in PET on dry days being lower than that of wet days in the middle of winter. This is probably not true of the underlying data (Rutherford *et al.*, 2008) and hence a constraint is included in Equation 25.

Equation 25:
$$dayPET = \begin{cases} PETwet * ratioWetDry_{mon} & \text{if PETDry < PETWet} \\ PETwet & \text{daily rainfall > 5 mm} \\ PETDry–fwet & \text{otherwise} \end{cases}$$

PETwet is the dayPET when more than 5 mm/day of rainfall occurs [Equation 26].
PETdry is the PET when there is no daily rainfall [Equation 27].
fwet (mm/day) is an adjustment to PETDry when daily rainfall is between 0 and 5 mm/day [Equation 28].
ratioWetDry is described in section 5.3.

where PET on wet and dry days (mm/day) is estimated as:

Equation 26:
$$PETWet = PETFourier_{CatPET, SeaPET, 1} + PETFourier_{CatPET, SeaPET, 2} * Cos(2 * \Delta - PETFourier_{CatPET, SeaPET, 3}) + PETFourier_{CatPET, SeaPET, 4} * Cos(4 * \Delta - PETFourier_{CatPET, SeaPET, 5})$$

Equation 27:
$$PETDry = PETFourier_{CatPET, SeaPET, 6} + PETFourier_{CatPET, SeaPET,7} * Cos(2 * \Delta - PETFourier_{CatPET, SeaPET, 8}) + PETFourier_{CatPET, SeaPET, 9} * Cos(4 * \Delta - PETFourier_{CatPET, SeaPET, 10})$$

PETFourier are parameters listed in Table 14.
CatPET is the PET range class [Table 11].
SeaPET is the PET seasonality class [Table 12].
1…10 refer to constant numbers in Table 14.
Δ = Pi * jdate / 365
jdate is the day of the year (Jan 1^{st} = 1).

and where adjustment (mm/day) to PETDry when daily rainfall is between 0 and 5 mm/day is estimated as:

Equation 28: fwet = rainin / 5 * (PETDry - PETWet)
rainin is daily rainfall (mm/day).

Table 14. Parameters for Fourier series transformation for calculating PET in wet or dry conditions.

Category class[1]	Seasonality class[2]	Wet					Dry				
		1	2	3	4	5	6	7	8	9	10
1	1	0.8573	0.5494	0.0448	0.0505	-0.4814	1.3414	1.0666	0.0652	0.0973	-1.2604
1	2	0.9108	0.7464	0.0489	0.0740	-0.8144	1.3120	1.2397	0.0520	0.1114	-1.1857
1	3	1.0834	1.0968	0.0651	0.1845	-0.2539	1.4268	1.5949	0.0562	0.2241	0.0051
2	1	1.2229	0.8295	0.0532	0.0526	-0.5719	1.8545	1.4665	0.0562	0.1150	-0.9857
2	2	1.2699	1.1034	0.0514	0.0881	-1.0263	1.8291	1.7079	0.0520	0.1116	-1.3618
2	3	1.3511	1.3766	0.0695	0.2156	-0.2065	1.7609	1.9485	0.0646	0.0136	-1.6919
3	1	1.7599	1.2596	0.0596	0.0485	-0.8908	2.2770	1.7942	0.0555	0.1166	-1.1198
3	2	1.6776	1.4091	0.0663	0.0765	-1.1527	2.2384	2.0149	0.0668	0.1532	-0.9532
3	3	1.6865	1.6635	0.0757	0.1942	-0.9955	2.1761	2.3526	0.0658	0.2837	-0.1634
4	1	1.9838	1.3472	0.0507	0.0652	-1.2702	2.6538	2.0052	0.0409	0.1470	-0.7660
4	2	1.8908	1.5619	0.0547	0.1138	-0.4883	2.5598	2.2190	0.0507	0.1794	-0.5270
4	3	2.0439	1.9864	0.0609	0.1682	-1.1000	2.5710	2.7059	0.0627	0.2793	-0.6346
5	1	2.2456	1.3991	0.0485	0.0532	-0.9667	2.9861	2.1418	0.0422	0.1334	-0.9988
5	2	2.4106	2.1055	0.0581	-0.2070	-3.3094	2.9751	2.7116	0.0542	-0.0173	-1.8916
5	3	2.2906	2.2271	0.0611	0.3160	-0.0943	2.9939	3.0721	0.0650	0.1560	-1.2935

[1] = category for PET range (Table 11).
[2]= category for PET seasonality (Table 12).

5.3. Ratio PET wet:PET dry

The climate properties method accounted for differences in PET between wet and dry days. The variation in the ratio of PEwet:PETdry was investigated using the Fourier series output for the mid-day of each month (Figure 5).

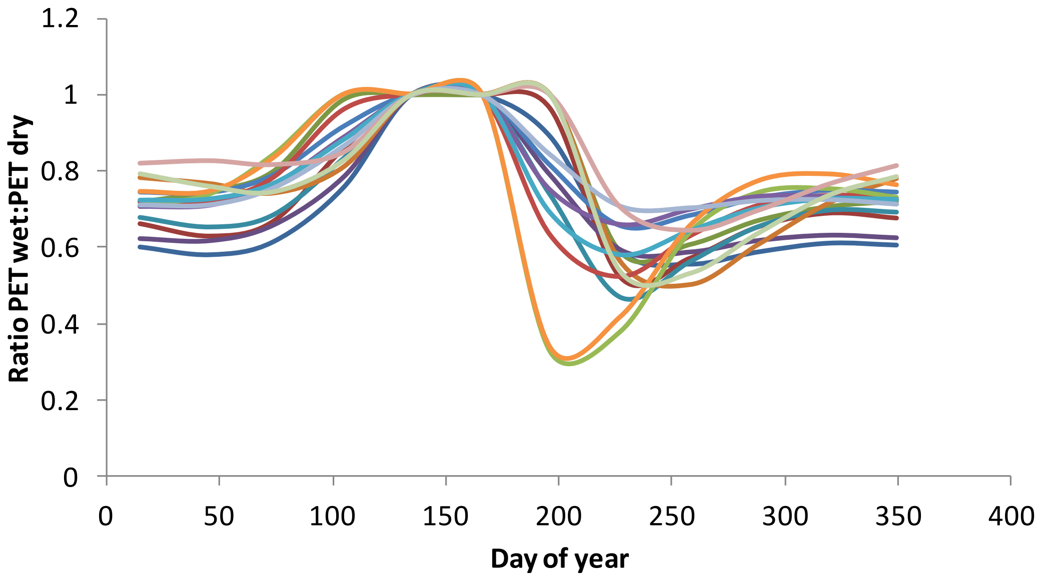

Figure 5. The ratio of PET wet to PET dry based on Fourier series transformation. Each line represents a combination or PET range class and PET seasonality class.

The range in values was considered sufficiently narrow that an average value could be used, with the values shown in Table 15.

Table 15. Average ratio of PET wet:PET dry for each month.

Month	Ratio PET wet:PET dry
January	0.716056342
February	0.712369862
March	0.712369862
April	0.881704090
May	1
June	1
July	0.785608723
August	0.566833067
September	0.615268150
October	0.682881738
November	0.717953417
December	0.721186436

6. Sunshine hours

Sunshine hours are used in one of the growth sub-models. The sunshine data inputs are mean monthly values of total bright sunshine hours for the 1971-2000 period for locations having at least five complete years of data (NIWA 2006). The monthly values of bright sunshine hours are taken from Table 16 if nearest town is entered, otherwise it is taken from Table 17.

Table 16. Default monthly sunshine hours (hours/month) for each nearest town.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kaitaia	212	201	197	155	140	123	137	159	162	182	187	219
Whangarei	227	182	158	144	139	110	134	144	154	175	192	209
Auckland	229	201	180	162	142	111	140	144	149	181	187	225
Tauranga	253	211	197	175	164	132	152	161	164	201	215	232
Hamilton	231	199	185	164	131	103	121	138	145	176	197	221
Rotorua	241	205	191	167	148	116	132	148	149	187	202	221
Gisborne	241	201	185	156	148	124	130	154	173	210	215	234
Taupo	227	200	176	157	129	99	120	129	140	183	194	211
New Plymouth	244	223	202	173	144	118	134	154	160	190	204	228
Napier	242	201	193	163	153	124	138	159	172	208	213	232
Whanganui	243	215	188	155	125	101	121	136	145	183	206	221
Palmerston North	208	190	170	139	105	84	103	117	120	147	171	181
Masterton	231	203	167	147	121	96	107	122	141	186	197	213
Wellington	246	209	191	155	128	98	117	136	156	193	210	226
Nelson	266	229	212	188	173	143	157	171	186	212	225	245
Blenheim	256	224	224	193	177	152	159	184	183	225	228	254
Westport	212	189	164	143	113	102	123	127	141	160	174	191
Kaikoura	231	195	179	164	141	120	133	149	167	201	203	209
Hokitika	211	184	170	142	116	102	121	137	142	158	182	194
Christchurch	230	196	183	161	142	119	124	148	165	198	215	221
Mount Cook	180	168	147	120	89	68	75	110	123	143	156	166
Lake Tekapo	256	233	203	159	131	97	109	150	175	199	229	240
Timaru	185	168	150	140	126	118	118	134	150	173	184	181
Te Anau	196	179	156	118	85	64	68	112	137	170	192	184
Queenstown	228	206	189	141	91	75	87	121	158	189	208	227
Alexandra	228	213	193	153	112	83	93	146	165	192	213	220
Manapouri	196	179	156	118	85	64	68	112	137	170	192	184
Dunedin	178	153	140	121	100	86	101	114	129	147	161	169

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Invercargill	180	165	136	110	80	76	91	119	134	155	176	186
Chatham Islands	179	143	122	99	79	63	75	93	106	136	152	162

Table 17. Default monthly sunshine hours (hours/month) for each region.

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Northland	220	191	178	150	139	135	117	151	158	179	190	214
Auckland	229	201	180	162	142	140	111	144	149	181	187	225
Waikato/ Coromandel	242	205	191	170	148	136	117	150	155	188	206	227
BOP	241	205	191	167	148	132	116	148	149	187	202	221
Central Plateau	227	200	176	157	129	120	99	129	140	183	194	211
King Country/ Taihape	242	205	191	170	148	136	117	150	155	188	206	227
Taranaki	244	223	202	173	144	134	118	154	160	190	204	228
Manawatu/ Wanganui	225	202	179	147	115	112	92	126	133	165	189	201
Wellington	246	209	191	155	128	117	98	136	156	193	210	226
East Coast North Island	238	202	182	155	141	125	115	145	162	201	208	226
West Coast South Island	211	186	167	143	115	122	102	132	142	159	178	193
Nelson	266	229	212	188	173	157	143	171	186	212	225	245
Marlborough	256	224	224	193	177	159	152	184	183	225	228	254
Canterbury	215	186	170	155	136	125	119	144	161	191	201	204
Otago	195	177	156	128	97	95	82	126	143	165	184	191
Southland	179	143	122	99	79	75	63	93	106	136	152	162
High Country > 300 m)	215	197	174	134	99	85	76	123	148	175	196	205

7. References

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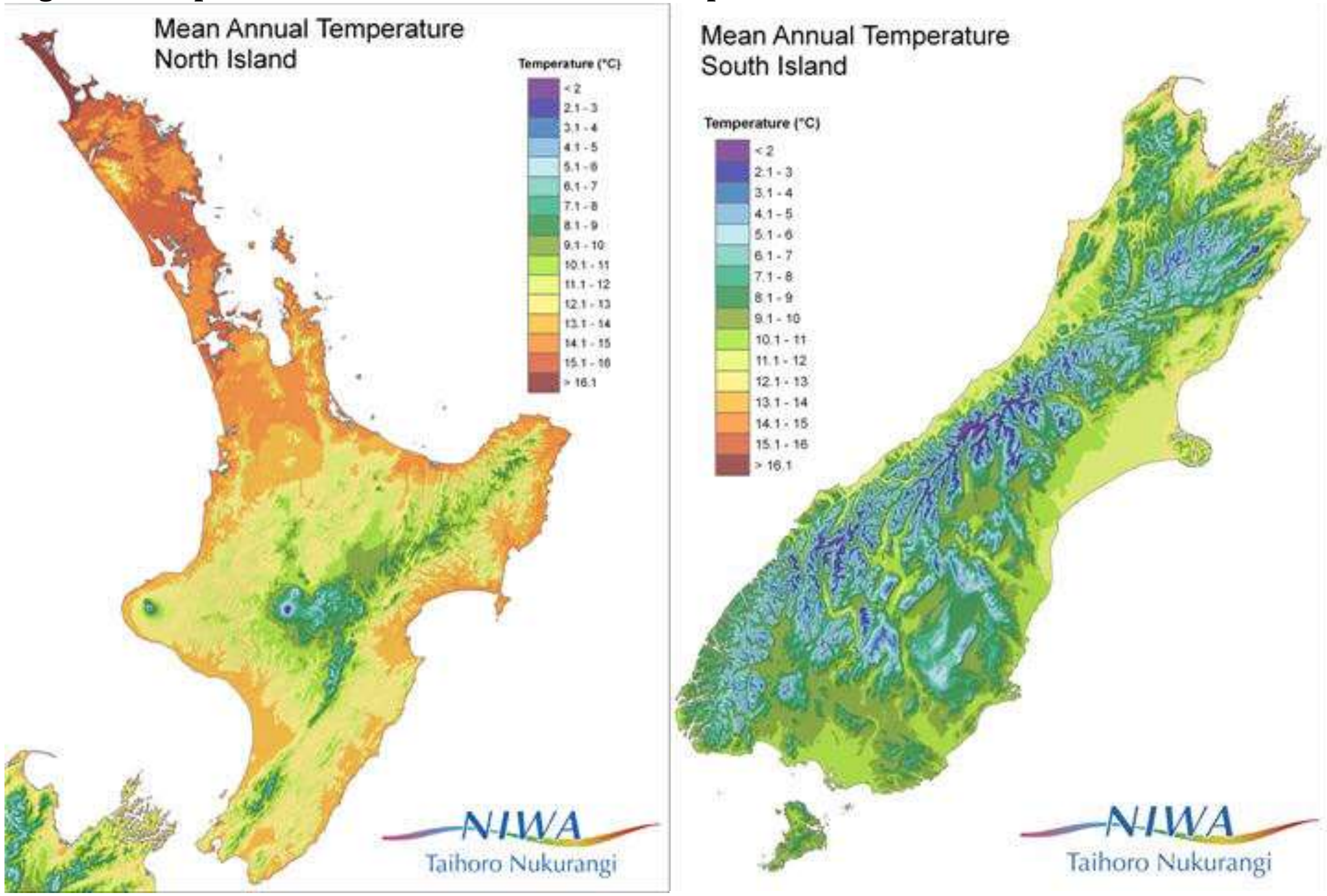
Appendix 1. Maps of climate data.

Figure 6. Maps of distribution of annual mean temperature in New Zealand.



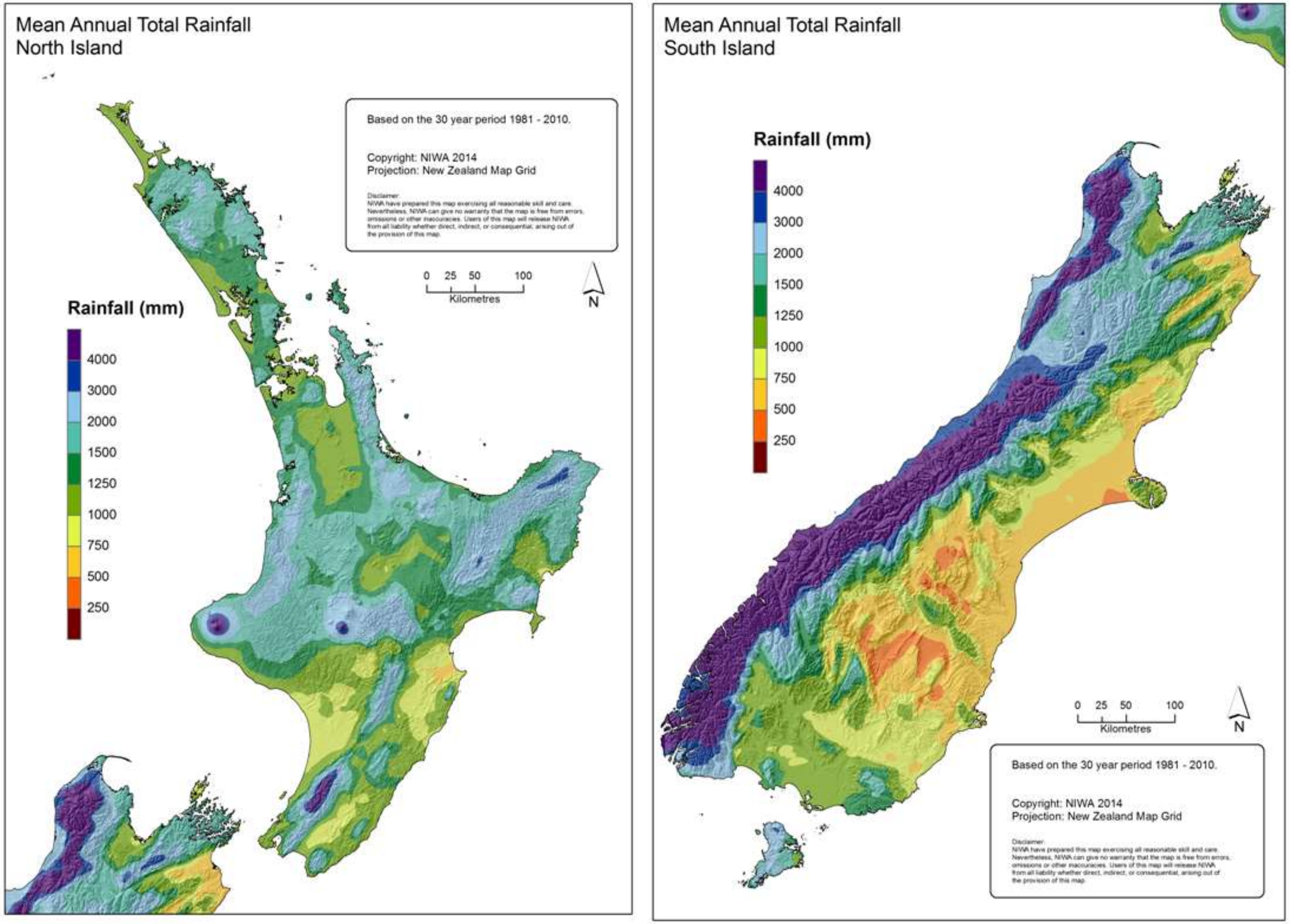


Figure 7. Maps of distribution of annual average rainfall in New Zealand.

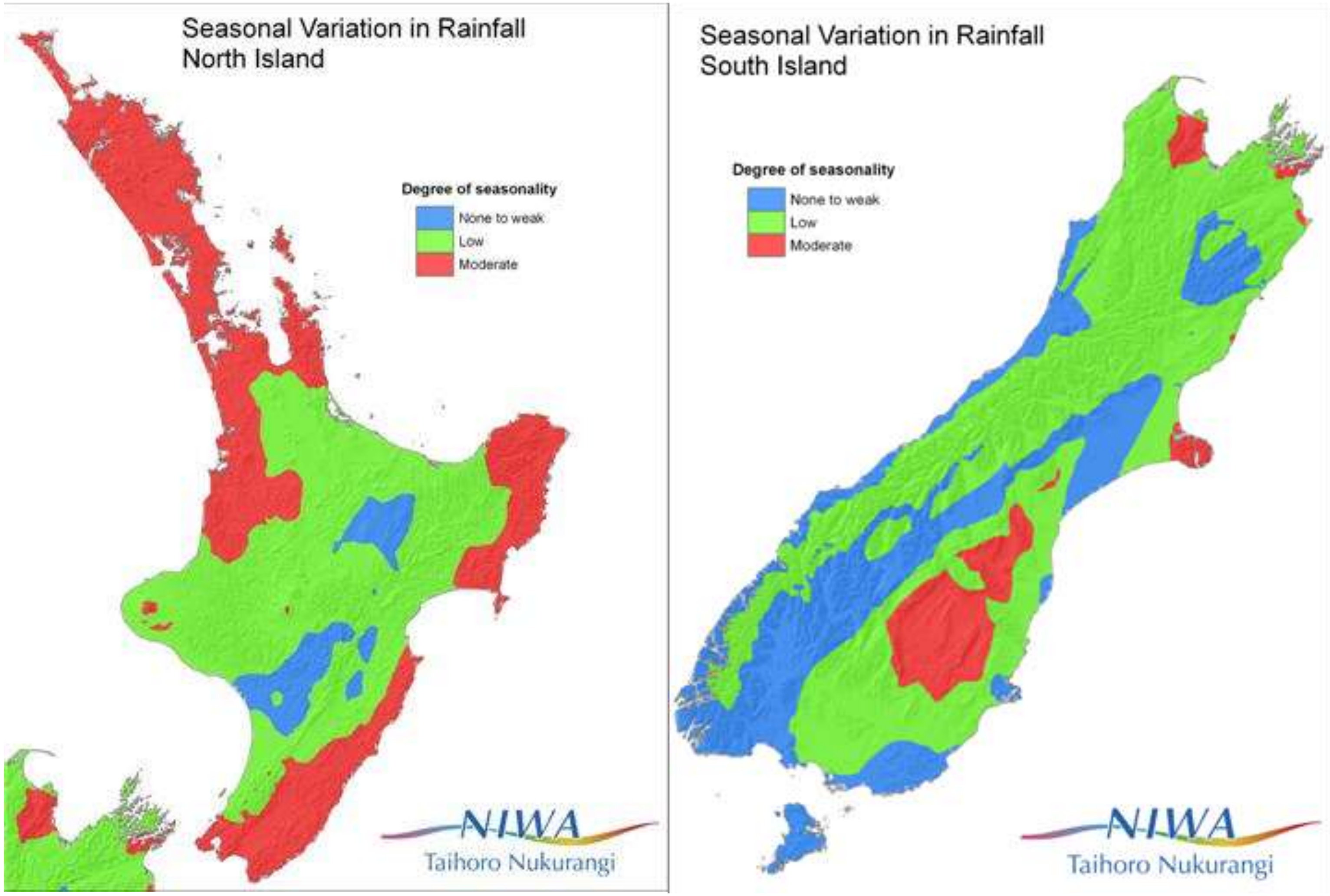


Figure 8. Maps of distribution of seasonality of rainfall in New Zealand.

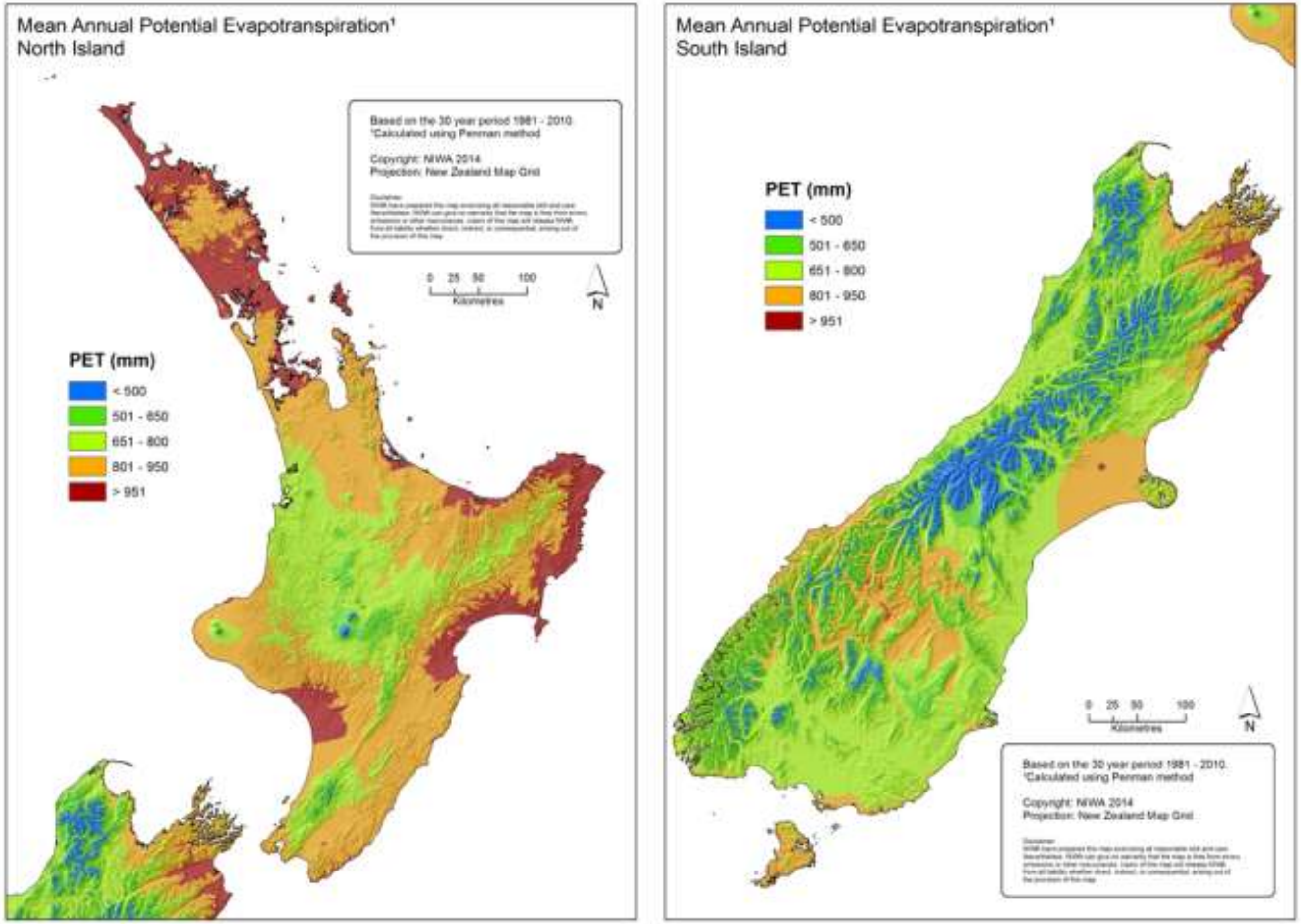


Figure 9. Maps of distribution of annual PET values in New Zealand.

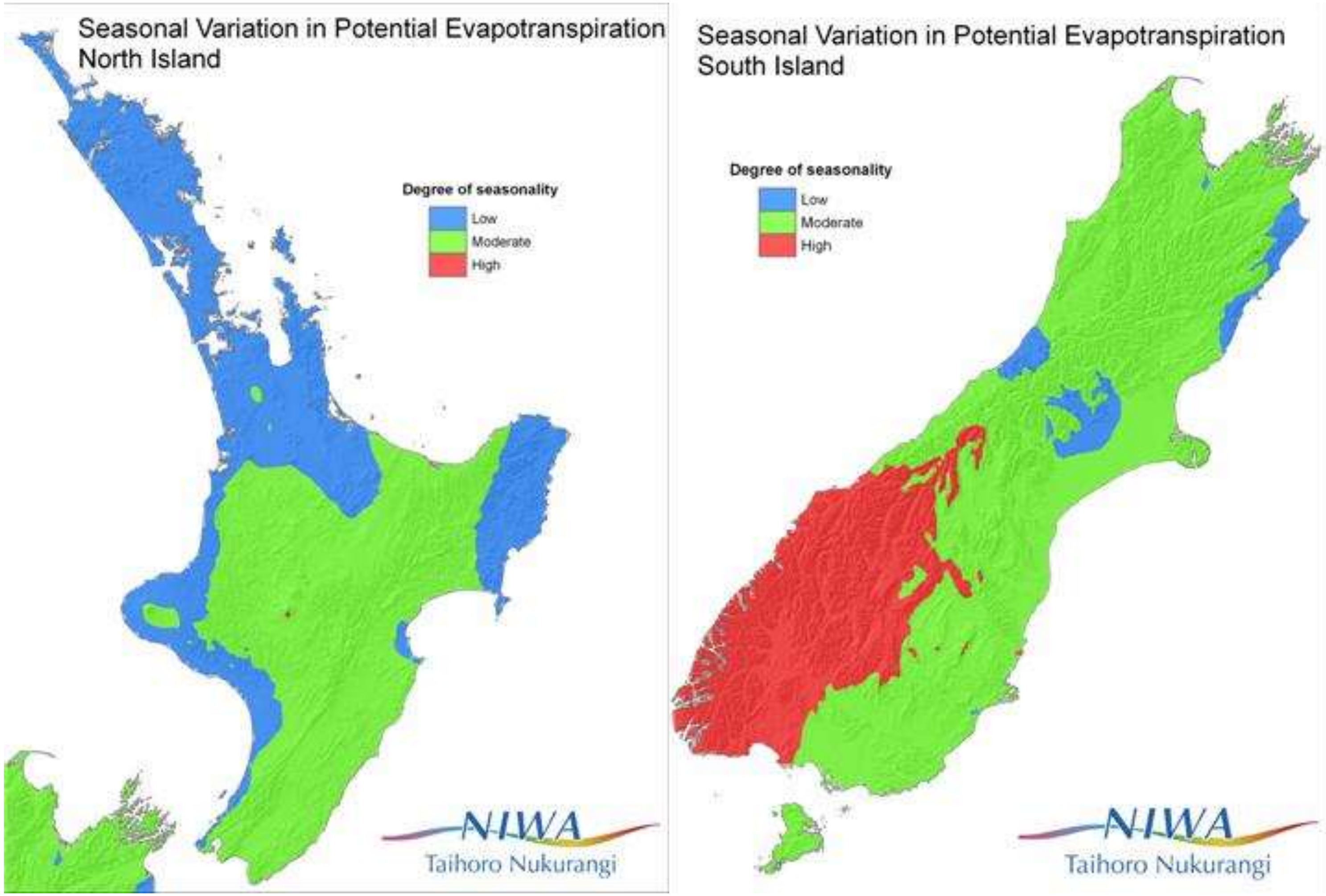


Figure 10. Maps of distribution of seasonality of PET in New Zealand.

Appendix 2. Daily rainfall values

Table 18. Daily rainfall for each for each combination of rainfall range and seasonality classes (see Table 4 and Table 5 for definitions).

Rainfall range class	1			2			3			4			5		
Seasonality class	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Day in year															
1	0.0	0.0	0.0	0.0	20.9	0.0	9.5	0.0	19.7	4.4	11.7	0.0	0.0	0.0	21.8
2	7.7	0	0	0	0	0	0	2	2.2	0	9.7	0	0	0	5.9
3	0	0	0	6.9	1.7	0	11.4	14.6	0	22.4	0	0	11.4	54.1	0
4	0	0	0	23.6	19.7	0	47.7	8.6	0	9.2	0	0	0	48.1	0
5	0	4.4	0	5.4	2.9	0	37.1	0	0	0	0	0	71	48.5	0
6	44.2	0	0	5.5	0	0	2.9	0	3.6	4.1	0	0	15.6	63.2	0
7	0	0	0	0	0	0	0	0	8.8	0	49.9	0	12.8	14.4	0
8	0	0	0	0	0	0	0	0	2	2.3	23.3	0	18.4	0	0
9	0	0	0	25.2	0	0	0	7.7	0	1.3	23.7	0	0	0	17.7
10	0	0	7.5	4.8	0	0	0	10.6	0	0	0	1.4	0	3.9	166.2
11	0	0	0	0	0	2.8	2.9	0	0	14.3	0	0	0	0.9	13.7
12	0	0	0	0	0	4	16.3	14.1	0	23.4	0	0	11.1	0	34.8
13	0	8.8	0	9.6	1.3	0	6	25	0	27.3	90.6	0	1.3	2	38.3
14	0	0	0	0	4.3	0	0	1.6	0	3.9	0	0	0	89.3	30.2
15	0	0	5.4	0	1.2	4.9	0	3	0	0	0	1.8	0	9.1	14.6
16	0	0	5	0	0	19.5	0	0	0	11.7	0	0	0	0	0
17	0	0	4.7	0	19.9	1.9	4.6	0	0	40.3	0	0	0	0	45.4
18	0	0	1.4	0	0	0	29.4	0	0	0	5.5	0	0	0	0
19	0	0	0	0	0	1.7	28.7	0	0	0	3.4	16.3	0	28.9	0
20	0	1.2	1.7	0	0	5.8	1.8	0	0	0	1.7	60.7	18.5	0	0
21	0	13	2.6	0	0	2.3	0	0	0	0	0	0	6.7	0	0
22	6.2	0	0	2	0	1.8	0	2.3	0	0	0	0	0	154.7	0
23	0	0	0	0	0	1.4	0	1.8	0	0	0	0	13.3	85.2	0
24	0	0	0	4.9	0	0	0	5.8	7.4	0	0	0	25.7	22.3	46.7

25	0	0	3.8	21.7	0	0	2.9	1.9	11.4	49.5	7.4	0	0	0	0
26	0	0	3.7	22.1	0	0	10	0	0	4.3	79	0	1.5	76.3	6.3
27	0	0	0	0	0	0	8.9	1.3	0	36.1	12.1	0	18.4	191.4	217
28	0	0	0	0	0	0	6.9	5.1	0	34.6	0	0	142.4	23.6	15.8
29	0	0	10.1	0	0	0	3.6	1.3	1.8	20.7	0	0	0	0	21.4
30	0	1.8	8	0	0	0	6.3	0	0	5.2	2	0	1.5	0	7.6
31	0	0	1.8	0	0	4.5	52.4	0	1.9	129.3	0	0	0	2.1	2.8
32	0	0	0	0	2.9	0	7.8	0	4.3	32.6	2.3	0	0	168.5	6.5
33	0	0	0	4.1	5.6	11.4	15	0	0	94.3	21.2	0	1.4	157.9	1.3
34	0	0	0	0	3.5	2.6	11.8	0	0	30.2	0	0	0	0	3
35	0	0	0	0	0	0	0	0	0	10.5	4.4	1.6	0	0	1.2
36	0	0	1.4	0	0	0	0	0	32.2	0	57.2	35.3	60.2	14.8	0
37	0	0	0	0	0	0	0	0	5.6	0	40.6	5	8.8	20.9	5.9
38	0	0	0	0	0	0	0	8.5	68.8	18.4	0	7.1	0	0	54.5
39	0	0	0	0	0	0	5.7	0	7	0	0	12.9	0	6.1	38.2
40	0	0	0	0	0	0	0	0	0	0	0	2.3	0	42.7	25.3
41	0	0	0	0	0	0	1.8	0	9.9	4.2	0	0	109.6	28.4	2.3
42	0	2.3	0	0	12.7	0	22.5	0	0	30.9	0	1.8	176.8	2	17.8
43	24.5	1.7	2.7	0	17.9	0	0	4.1	22.2	0	0	6.2	5.3	0	0
44	19.2	0	0	1.8	4.7	7.2	0	4.7	30.7	0	0	5	0	0	0
45	2.4	0	0	0	0	1.8	0	5.2	44.5	0	6.2	30.9	0	0	4.9
46	0	1.7	0	0	1.7	0	0	15.8	43.1	0	112.6	25.1	16.6	0	3.5
47	0	0	0	38.5	0	0	0	2.2	14.3	2.8	25.6	13.8	16.3	0	1.4
48	0	7.4	1.2	41.2	0	0	0	14.7	63.1	0	1.3	0	80	4.3	0
49	0	0	0	0	4.6	0	0	2.9	2.5	1	0	11	0	33.2	0
50	0	0	0	0	27.8	7.4	0	0	0	3.8	0	0	28.7	124.1	0
51	0	5.9	0	0	69.4	0	0	37.4	0	0	29.8	0	43.7	27.7	0
52	0	0	0	1.8	4.7	0	19.9	10.8	0	21.9	6.7	23.6	1.5	0	1.5
53	0	0	2.8	0	13.3	12.2	25	9.5	0	0	4.6	12.9	0	2.3	0
54	0	4	8	0	39.5	0	0	11.2	0	0	0	3.2	5.1	0	0
55	0	17.2	22.5	21.3	10.3	0	0	1.8	0	0	68.4	4.3	10.5	1	0
56	0	1.9	9.1	16.7	6.6	4.5	0	30.9	0	0	29.8	4.5	0	27.7	0

57	0	0	1.4	0	0	0	0	27.3	0	0	0	2.4	0	0	1.7
58	0	0	0	0	0	2.5	0	18.9	0	0	11.8	2.2	9.7	64.3	1.4
59	0	0	18.9	5.2	0	0	5.2	1.6	0	41.5	22.4	0	0	75.5	0
60	0	0	0	0	0	19.5	0	0	2	0	0	1.1	0	49.5	0
61	0	0	0	0	0	15.8	0	8.5	0	0	0	0	0	39.1	0
62	20.8	0	0	13.2	0	20.5	0	6.8	0	0	0	0	0	0	0
63	1.7	0	0	0	32.1	12.3	0	0	0	0	0	0	6.6	0	0
64	0	5.6	0	0	21.5	0	0	0	0	0	0	0	93.4	0	0
65	0	32.3	0	0	0	0	12.2	0	0	22.1	0	0	84.5	0	0
66	0	26.2	0	0	0	0	44.3	0	0	0	0	3.9	41.2	0	0
67	30.3	19.3	0	0	0	0	1.8	0	0	21.2	7.5	7.8	51.7	33.8	0
68	4.5	11.4	0	0	0	0	0	0	0	0	11.3	0	42.7	147.7	63.5
69	3.6	0	0	0	0	0	0	18.3	0	0	0	10.1	0	230	0
70	0	0	0	0	0	0	0	34.3	0	0	1.6	87.1	46.5	217.8	5.8
71	8.9	0	3.6	0	11.3	0	6.3	57.5	0	21.2	0	61.5	20.7	26.9	12.2
72	5.4	0	11.1	0	9.6	0	4.5	7.5	0	23	0	36.2	0	0	1
73	0	0	0	0	0	0	0	4.9	0	0	0	34.3	0	0	0
74	0	0	0	2.5	0	0	0	2	0	0	5	5	38.2	0	0
75	0	0	0	0	0	11.4	14.9	9.6	0	47.1	44.4	4.2	0	0	0
76	0	0	0	0	0	56.1	0	2.7	0	0	76.8	10	36.6	0	0
77	0	0	0	0	3.6	21	8.9	0	0	50.1	6	4.8	0	12.4	0
78	0	0	0	0	0	2.7	5.7	0	0	17	52.5	7	0	0	0
79	3.5	0	0	0	0	6	0	0	0	0	0	0	0	0	0
80	0	0	0	0	2.4	24.1	0	0	6.5	0	48.9	0	30.9	0	0
81	0	0	0	0	0	16.2	0	0	0	0	15.3	0	1.8	0	9.4
82	0	27.6	6.1	0	0	7.7	0	0	0	0	2.7	0	25.1	0	29
83	0	7.3	1.4	2.1	0	2.4	0	2.8	0	0	0	0	11.7	0	0
84	0	3.8	0	1.8	0	0	0	0	0	0	0	0	42.5	0	0
85	0	1.4	0	0	0	5.5	0	0	0	0	0	0	31.1	0	0
86	0	0	0	0	0	1.6	0	4.4	0	0	0	0	4.4	3.5	0
87	0	0	0	3	2.1	1.5	0	8.4	0	1	0	0	1.3	1.2	44.9
88	0	0	0	0	0	2	13.7	0	0	12.8	8.7	0	0	41	145

89	0	0	3.8	1.6	0	0	0	0	0	2.1	25.7	3.5	0	32.3	101
90	0	0	0	2.1	3.5	0	0	0	0	16.4	0	0	0	1.2	2.3
91	0	0	14.1	0	12.6	0	19.4	0	0	71.5	0	0	0	0	17.4
92	0	0	0	5.9	1.3	0	5.4	2.8	6.2	6.5	34.7	5.7	0	28.2	0
93	0	0	0	0	0	0	0	0	7.4	33	8.4	0	0	3	0
94	0	0	0	0	0	0	15.2	0	1.2	64.1	0	0	0	1.5	0
95	0	0	0	0	0	0	0	69.3	0	0	0	0	0	53.4	1
96	0	0	0	16.1	0	0	0	2.8	0	0	0	0	0	38.8	0
97	0	0	34.3	0	0	4.4	0	0	0	17.1	0	0	0	24.7	0
98	0	0	0	0	0	2.5	0	0	7.5	84.1	0	0	14.8	0	0
99	0	0	0	1.1	7.1	14.5	5.4	13.3	6.8	41.4	16.5	0	9.2	0	80.6
100	0	2.9	0	0	0	1.2	32.7	0	0	16.8	0	80.7	52.4	0	36.7
101	0	0	0	0	0	1.7	3.6	0	0	0	0	0	0	0	0
102	0	0	0	3.5	0	21.6	3	10.3	0	37.8	0	0	0	0	1
103	0	0	0	0	4.3	0	6.8	0	7.5	58.4	0	0	0	0	0
104	11.5	0	0	0	1.7	0	0	0	1.9	3.7	0	0	0	0	0
105	2.3	0	0	0	0	0	0	0	1.5	0	0	2.8	19.3	0	0
106	0	0	0	0	0	0	0	0	0	0	0	0	38.1	0	0
107	0	3	0	0	0	0	0	0	0	7.6	0	0	85.7	2.4	0
108	0	3.2	0	0	0	0	0	0	35.3	0	0	0	10.4	11.9	0
109	0	6.6	0	0	0	0	0	0	1.7	5.5	0	0	97.3	0	15.2
110	0	3.6	0	0	0	0	3.8	6.8	5.6	2.1	0	0	31.8	0	4.2
111	0	0	0	0	8.3	0	0	0	0	5	0	0	26.7	0	0
112	0	0	0	0	0	0	1.1	0	0	9.2	0	0	12.4	0	0
113	0	15.5	0	0	0	0	6.6	0	20.2	26.5	0	0	114.2	0	11.4
114	0	0	0	0	0	6	6.2	0	11.1	7.8	0	0	0	0	29.1
115	0	8.8	11.6	0	0	1.1	11.2	14.6	2.6	56.9	0	0	118.9	0	0
116	0	2.9	0	0	0	5.9	7.1	28.8	0	16	5	0	32.2	0	0
117	0	0	0	7.9	10.1	0	0	0	0	2.4	35.8	0	0	0	0
118	7.2	0	0	8.9	14.5	0	14.2	15	4.7	43.5	7.1	0	19.6	0	0
119	8.6	9.5	22.5	0	0	0	57.6	0	0	53.3	0	0	7.8	30.5	21.6
120	0	0	2.6	0	1.2	0	12.2	2	0	6.2	0	0	0	0	100.5

121	0	0	0	1.3	22	9.2	12.5	1.8	0	18.4	0	0	0	0	40.4
122	0	0	0	0	1.9	5.3	9.7	0	0	20.1	2.4	0	0	0	3.2
123	6.1	0	6.5	2	0	16.6	9.6	10.9	0	1.8	0	0	0	0	0
124	9	0	0	4.9	0	1.6	0	0	0	3.8	0	0	0	0	0
125	0	0	0	8.4	1.2	0	0	0	11.7	0	0	21.1	0	0	0
126	13	0	0	0	7.1	0	0	0	25.6	0	0	0	0	18.8	4.1
127	0	0	1.4	0	0	6.6	0	0	20.9	0	3.5	0	65.5	121.4	88
128	0	0	0	0	0	2.7	0	0	1.9	0	17	6.7	53.6	54.5	0
129	0	0	0	0	0	0	0	0	1.3	0	0	100.2	23.1	86.5	82.4
130	0	5.2	0	0	0	0	0	9.1	0	0	0	56.6	47.4	29.4	26
131	0	19.9	0	1.4	0	0	0	3	0	0	0	8.4	54	15.3	8.3
132	0	6.7	0	1.8	0	0	0	0	0	0	9.1	23.1	9	19.5	1.5
133	0	0	0	0	0	0	1.2	0	0	11.6	0	23	0	5.6	23.4
134	0	0	0	0	0	0	4.7	0	0	21.5	2.4	1.2	2	0	0
135	0	0	4.9	0	2.6	3.2	8.5	0	0	33.3	96.3	0	0	0	0
136	1.7	0	0	1.3	23.6	0	2.6	12.7	0	5.9	23.3	8.7	11.7	13.2	0
137	0	2.6	2.5	3.2	9	0	4.2	0	15.2	18	2.4	1.8	77.9	1.3	0
138	16.2	1.2	3.3	10.9	1.6	0	2.9	18.6	40.2	3.6	0	16.3	0	93.8	0
139	1.4	0	0	0	0	0	0	0	32	0	0	8.8	0	146.5	78.2
140	0	0	1.7	6.6	9.8	0	0	37.6	85.1	0	19.7	78.2	0	41.9	71.6
141	0	0	2.2	14	0	0	15.4	5.3	2	9.5	6.6	11.1	0	176.5	11.3
142	0	0	0	0	0	0	26.4	0	0	13.2	1.9	0	0	25	0
143	0	0	0	0	0	0	21.6	0	3	48.1	0	6.4	0	16.9	0
144	0	0	0	0	0	0	6.5	0	2.8	6.9	0	11.1	0	21.6	0
145	0	0	0	2.8	0	0	1.4	0	1.5	0	0	0	0	0	12.6
146	7.1	0	0	9.9	2.2	0	0	1.3	4.1	0	0	0	0	21.1	96.5
147	0	0	0	0	3.6	0	0	0	4.9	1.2	0	0	0	0	1.1
148	11.3	0	0	0	0	0	1.4	0	2.6	19.6	0	0	0	0	0
149	0	0	0	0	0	6.3	24	23.7	1.8	29.5	0	6	2.6	0	0
150	1.8	0	0	27.4	0	26.6	3.9	30.8	0	0	0	1.3	6.2	0	0
151	3	0	0	3	0	2	0	6	10.2	0	0	0	19.6	1.4	0
152	5	1.6	0	0	0	1.8	9.4	0	1.3	11	0	0	23.1	0	0

153	0	41.9	0	2.7	1.2	28.2	25.5	0	3.4	16.5	0	0	108.9	2.5	2.3
154	0	0	0	1.1	0	3.1	8.7	0	7.4	27.4	0	0	34.8	8.1	29.9
155	0	13.1	0	4.8	0	0	3.4	20.7	0	4.7	0	0	12.5	0	80.5
156	0	0	0	0	4.5	0	0	0	1.8	0	0	0	0	0	10.8
157	0	0	5.9	0	9.3	0	0	0	0	0	0	0	0	0	15.7
158	6.2	0	0	0	0	0	0	21.5	0	0	0	46.7	0	0	0
159	0	0	0	0	0	0	0	39.2	29.2	0	2.8	33	0	0	0
160	0	0	0	2.1	0	0	0	9.1	72.6	0	0	0	0	0	36.7
161	0	0	0	4.5	0	1.9	0	39.4	0	0	24.1	2.9	0	0	96.7
162	11.7	0	0	0	0	0	0	15.7	0	6.5	11.8	0	0	0	25.7
163	0	0	0	1.3	5.8	2.7	0	26	0	5.2	14.2	1.6	0	0	0
164	0	1.2	3.8	2.6	25.6	0	4.1	0	0	23.9	26.3	19.1	0	0	0
165	0	13	9.8	0	5.4	0	21.5	2	14.2	78.6	44.5	0	0	0	0
166	0	1.7	6.1	5.4	0	2.5	28.6	0	3.7	54.1	17.4	0	6.8	0	0
167	0	2.4	0	0	0	0	17.6	0	6	26.9	28	0	12.7	0	1
168	0	0	0	0	0	0	2.7	0	2.9	0	25.5	0	1.5	0	1.5
169	11.1	0	0	0	0	0	0	0	2.7	0	23.2	7.8	59.4	0	100.5
170	1.2	0	0	0	0	0	0	0	6.6	6.6	0	115.6	0	0	7.6
171	4.7	0	4.4	0	1.3	0	0	26.9	4.1	3.9	0	18.4	0	0	2.1
172	0	0	0	3.1	0	0	0	41.3	0	5.9	0	12	0	44.8	42.5
173	0	0	0	0	0	0	0	2.3	2.5	9	0	2	0	22.9	1.1
174	0	0	0	4.3	0	0	0	34.1	45	10.7	0	0	0	0	1
175	0	0	0	5.7	7.5	2.4	0	2.8	9.8	0	0	4.5	0	0	0
176	0	0	0	6.5	6.6	1.2	1.8	3.2	1.6	0	0	5	0	0	1
177	4.1	8.5	0	8.3	0	0	13.5	2.2	15.2	0	0	0	89.3	0	0
178	1.6	0	0	3.8	0	46.7	7	15.7	16.9	0	0	5.7	48.4	0	0
179	0	0	0	14.9	34.3	9.5	32.5	11.3	4.2	7.5	0	0	14.1	0	115.4
180	0	0	0	10.5	30.2	6.7	23.1	0	8.1	7.9	0	3.4	45.8	0	170.6
181	0	0	0	2.1	0	4.9	12.1	6.8	18.6	21.4	1.7	50.8	13.4	0	3.2
182	0	0	0	0	0	1.6	34	0	8.6	28.5	0	8.8	57	0	0
183	0	0	0	0	0	0	15	1.9	2	6.1	0	3.6	54	0	20.4
184	3.6	4.9	2.6	0	0	0	1.7	0	0	0	38.1	16.2	15.1	0	1.8

185	13.6	0	1.5	0	0	0	0	0	0	2.1	28.3	9	0	0	0
186	0	1.8	0	0	0	0	0	2.2	0	0	3.6	1.7	1.3	0	0
187	3.2	1.7	0	12.5	2.6	0	0	7.2	0	0	36.6	10.1	0	0	1.5
188	0	4.4	0	4.6	11	0	0	6	0	2.6	12.3	1.4	22.3	0	56.8
189	0	0	0	0	7.3	2.1	1.1	0	0	6.7	69.8	0	13	0	12.8
190	0	2	0	4.2	0	11.1	0	0	7.7	0	13.8	0	0	0	15.1
191	0	0	0	5.2	1.2	20.5	0	2.4	6.7	0	0	0	0	0	1.5
192	0	0	0	0	0	7.2	0	5.1	1.8	10.8	0	89.5	0	26.8	1.2
193	0	0	0	2.5	0	0	0	0	0	19	0	19.4	0	64.7	27.2
194	0	0	0	0	0	0	0	0	0	0	0	0	0	26.8	0
195	0	1.3	5.2	0	0	0	0	0	0	0	0	0	0	5.2	0
196	2.8	0	0	0	0	1.7	0	0	0	0	1.7	0	0	4	45.2
197	1.2	0	2.3	0	0	15.6	0	0	1.3	1	0	0	2	3.3	119.2
198	0	1.4	0	0	0	0	7.9	0	1.3	0	0	32.8	30.8	72.7	27.6
199	0	0	0	0	0	2.6	20.7	0	10.5	0	0	25.5	0	11.9	3.9
200	0	0	0	0	0	0	2.3	0	9.4	0	0	5.1	0	0	15.7
201	0	0	1.6	0	0	1.7	1.4	0	0	0	60.5	3.8	0	0	10.7
202	0	0	0	0	0	0	0	0	0	0	2.7	0	0	0	29.9
203	0	0	2.5	0	0	0	0	0	0	0	3.1	0	0	0	4.4
204	0	0	0	0	0	4	0	0	0	0	5.4	14.4	14.5	0	0
205	0	0	0	7.9	1.7	14.3	0	45	26.1	0	36.6	109.8	19.2	0	0
206	0	7.2	0	35.5	0	17	4.3	24.6	7.1	2.7	14.1	81.8	68.3	0	0
207	0	0	1.8	19.7	0	2.5	2.9	0	12.4	2.1	61.1	0	34.5	0	0
208	25.1	0	0	4.1	0	0	0	2.3	0	0	7.5	63.8	41.6	0	0
209	20	0	0	6.1	0	0	1.2	9.5	0	0	11.7	24.3	42.1	0	93.1
210	6.5	6.4	1.6	1.2	1.6	5.1	0	4.8	0	0	16	5.9	31.7	0	66
211	1.7	17.4	0	0	2.1	8.6	0	3.7	0	0	86.2	0	14.5	75.2	49
212	0	3.7	5.2	4.8	0	10.5	0	48.2	0	0	39.7	11.7	0	65.3	4.2
213	2.4	0	6	10.9	1.8	6.1	0	1.9	0	0	3.9	1.6	0	62.8	5.9
214	6.8	0	0	1.3	13.2	12.2	0	0	0	0	0	15	0	0	2.3
215	0	0	0	3.2	7.9	14.3	0	0	0	0	54.3	0	0	26	1.5
216	0	0	0	8.6	10.5	8.5	0	0	0	0	11.3	0	0	42.4	23.6

217	0	0	0	0	0	7.4	0	0	7.4	0	15.6	0	0	0	34.2
218	0	0	0	0	0	0	1.4	0	49.4	36.9	0	2.1	0	0	15.8
219	0	0	3.7	2.8	0	0	1.9	1.9	22.2	14.4	2.3	1.7	0	5.4	1.3
220	0	1.2	0	15.7	26	0	1.2	2.9	0	0	42.6	1.6	0	1	0
221	3.1	0	0	2.7	18.7	0	1.4	11.4	6.4	0	166.2	35.3	0	17.9	2.1
222	3.5	0	0	1.6	2.1	0	0	69.8	1.2	0	22	28.5	0	51.9	12.6
223	0	0	0	8	0	0	0	9.4	0	0	19.6	37.1	0	0	10.3
224	0	0	0	0	0	0	0	0	0	2.9	35.5	12.7	0	0	19.8
225	0	0	0	0	0	32.7	0	0	0	0	10.6	0	0	10.1	46.1
226	0	0	0	0	0	61.2	2.6	0	0	1.2	64.7	0	0	25.8	66.3
227	0	0	0	0	8.6	30.3	17.2	0	0	11.5	53	0	29.3	0	14.3
228	0	0	0	0	0	5.5	9.5	0	30.9	11.8	14.7	0	3.8	0	76.7
229	0	0	0	0	1.7	2	0	0	16.6	1.4	0	0	10.8	10.9	32.5
230	0	0	0	0	0	1.7	0	5.3	10.4	0	0	11.6	19.2	15.9	1.4
231	0	0	25.7	2.3	0	0	0	31.3	0	0	52.7	14.2	2.9	0	0
232	0	0	11.9	14.1	0	0	0	0	4.7	0	50.1	6.4	0	9.1	0
233	2.5	0	0	1.7	0	38.9	0	1.8	0	0	4.4	36.8	0	6	0
234	4.3	0	0	0	4.3	14.4	0	6.6	0	1.2	5.8	8.2	0	24.9	0
235	0	0	1.2	2.5	1.5	5.7	0	3.8	0	0	0	0	0	9.9	0
236	0	0	2.8	28.4	0	2.3	0	0	0	0	0	92.6	0	8.8	0
237	0	0	0	0	0	1.7	1.1	0	0	0	0	7.2	0	51.6	2.4
238	7.1	0	0	0	0	4.5	0	0	0	0	51.6	0	0	8.4	34.1
239	6.7	0	1.2	0	4.6	1.8	0	0	9.2	9.5	75.7	0	0	3.6	4.4
240	3.5	0	16.1	0	4.5	0	6.3	0	0	3	0	0	0	3.7	13.6
241	0	0	0	0	2.9	0	4.4	0	0	0	0	0	0	0	32.1
242	6.7	0	0	0	0	0	3.2	0	0	7.1	0	72.4	0	7.9	28.4
243	1.9	0	0	0	0	0	6.4	3.7	3.1	16	0	0	0	1.3	3.2
244	1.9	0	0	1.6	0	0	2.7	0	0	2	1.5	0	0	0	0
245	0	0	0	7.8	0	0	5	6.2	0	0	18.1	0	48.9	0	0
246	0	0	0	0	0	1.9	2.7	0	0	0	5.8	24.6	19.1	2.8	0
247	3.7	8.8	7.3	0	9.4	25	0	0	0	1.6	2.7	7	51.8	55.5	0
248	7.3	0	2.6	0	5.6	2.4	0	0	3.2	0	8.2	26.1	3.4	0	0

249	3.2	0	0	0	9.2	0	1.5	24.7	1.4	0	8.4	10.7	17.2	7.9	4.5
250	1.4	2.5	0	14.8	3	0	2	4.9	0	0	3.1	0	94.6	20.6	7.6
251	0	0	0	16.4	2.2	0	0	2.9	4.6	0	0	23.1	4.9	0	9.1
252	0	4.2	0	0	0	0	0	0	18	0	0	16.7	37.1	1.9	9.5
253	0	0	0	0	0	0	0	0	23.8	0	0	0	7.3	35.6	10.6
254	0	0	0	2.5	0	0	0	22.4	0	0	2.3	0	29.2	3.6	24.1
255	0	4.7	0	0	0	0	0	0	15.7	0	0	0	29.3	2.4	56.9
256	0	2.4	0	0	0	0	29.4	0	5.1	11.4	0	18.6	70.6	0	95.7
257	0	0	0	0	0	0	32.1	2	0	13.1	0	66.5	1.8	0	76
258	0	1.2	0	21.8	0	0	3.6	14.3	29	5	14.6	19.2	34.8	0	2.5
259	0	0	0	6.8	0	0	1.5	8.5	3	0	2	0	0	0	1.9
260	0	0	0	1.9	2.2	0	0	0	7.9	0	0	0	0	8.1	9.7
261	0	0	0	0	11.4	0	0	0	3.4	0	0	14.9	65.2	66.9	19.7
262	0	0	2	0	16.2	0	0	0	0	0	2.7	8.7	15	7.4	6.6
263	0	0	0	0	3.7	0	4.1	0	0	9.1	0	10.6	5.8	0	0
264	0	0	8.2	0	0	0	0	0	0	0	1.9	0	0	0	2.1
265	0	0	0	0	0	0	20.7	0	0	80.3	0	22	2.6	0	0
266	0	0	0	0	0	0	66.4	0	13	40.2	33	0	3.1	0	7.5
267	0	0	5.9	0	0	0	2.3	0	29	6.7	46.2	0	32.4	41.4	2.9
268	0	10.1	0	0	2.2	0	0	0	14.2	3.6	19	0	85.2	14.7	16.3
269	0	0	0	0	0	0	0	12.2	0	0	10.9	0	40.6	11.3	12
270	0	0	0	1.5	3.6	0	0	7.7	0	7.6	2.8	1.3	9.9	0	6.3
271	0	0	0	7.8	0	0	3.3	2.8	1.1	11.9	21.6	2	5.8	0	1
272	0	0	0	0	0	0	39	0	0	52.5	0	0	23.7	0	0
273	0	0	0	0	0	0	1.1	0	0	0	0	23.7	9.8	14.6	0
274	0	0	0	0	0	0	0	0	0	1.5	0	14.6	63.4	18.9	0
275	1.8	0	0	0	0	0	0	9.1	0	0	4.8	0	72.2	0	0
276	7.3	0	13.5	13.8	0	0	1.8	7.5	1.9	18.5	0	25.9	90	14.2	7.6
277	12.3	4.1	1.4	5.5	0	0	2.6	51.8	1.6	1.5	0	14.4	23.6	0	8.5
278	0	0	0	3.5	0	1.1	1.2	5.3	6.1	0	0	16.2	1.2	0	3.4
279	0	0	0	0	0	6.8	3.5	1.5	0	3.9	0	54.6	0	0	2.2
280	1.4	3	0	0	0	0	3.2	0	4.3	3.7	8.2	8.2	46.1	0	62.7

281	2.4	0	0	0	7.6	0	0	0	3.8	0	86.6	1.5	4	19.5	36.9
282	2	0	0	0	0	0	0	3.7	3.3	0	35.8	2.8	0	21	63.1
283	0	0	0	19.9	0	0	0	2.5	1.4	11.9	2.1	42.8	36.8	46.2	8.5
284	0	0	0	10.1	7.4	0	3.5	5.5	0	0	43.3	14.4	0	10.4	25
285	0	0	0	1.7	0	14.3	0	4.7	0	3.2	15.6	22.9	0	54.2	34.2
286	0	0	0	1.6	0	4.2	0	1.9	0	3.4	19.2	1.7	0	26	13.4
287	0	0	0	0	0	0	0	0	0	0	0	12.5	4.6	82.7	1.1
288	6	4.1	0	1.8	0	0	1.1	3.5	0	16.5	0	1.1	49	8.3	1.4
289	0	7.3	0	0	0	6.3	5.7	0	0	21.7	0	31.5	1.4	0	1.1
290	2.6	0	0	0	0	4.5	14.1	2.5	0	31	0	0	0	0	13.4
291	9.8	0	7	2.1	1.6	0	1.1	0	0	37.6	0	16.7	0	0	12.1
292	12.6	0	0	7.5	2.1	0	0	0	0	33.3	0	6.9	0	0	29.5
293	1.3	0	0	0	0	0	4.8	20.7	0	13.1	7.6	3.2	0	0	6.7
294	0	0	0	10.2	0	0	14.7	0	0	18.7	20.6	11.8	8.4	17	0
295	0	2.8	0	0	0	0	6	0	0	17.9	17.7	0	153.4	58.8	3.8
296	0	23.3	0	0	0	1.2	27.2	0	0	72.5	29.5	0	12.4	5.5	3.6
297	0	0	0	0	0	0	4.7	1.5	0	21.8	4.7	3.4	0	0	8.6
298	0	0	0	1.1	0	0	0	0	0	0	0	0	6.6	0	9.4
299	0	0	18.9	1.2	0	0	0	11.5	0	0	1.9	4.2	0	0	69.7
300	0	0	5.2	15.3	0	0	0	4.6	11.4	0	7.9	0	0	0	14.3
301	0	0	0	0	0	0	1.5	0	0	42.4	3.1	0	0	3.8	0
302	17.1	0	0	0	0	0	47.1	0	0	104.2	0	3.6	8	0	0
303	0	0	0	0	0	0	22.7	0	0	35.6	0	37.5	6.8	12.8	0
304	1.2	0	0	0	0	0	9.9	0	0	36.1	0	15.5	16.7	53.3	0
305	5.6	0	0	0	3.9	19.1	1.9	0	0	0	0	0	0	1.2	0
306	4.9	0	16	3.7	0	6.8	10.4	12.8	0	24.5	0	1.7	0	0	2.5
307	0	0	0	0	0	0	1.1	0	0	4	9.7	0	0	0	2.9
308	1.4	0	0	0	0	0	0	0	0	1.5	3.4	3.9	0	8.1	0
309	4.3	0	0	0	3.6	3.5	15.3	0	0	58.2	7.1	0	72.7	20.9	19.3
310	0	2.4	0	0	16.2	0	26.5	0	0	1	0	32.7	16.7	11	78
311	0	0	9.3	0	6.6	0	0	0	0	0	0	4.6	0	8.1	4.6
312	0	0	0	0	2.2	0	0	0	0	0	0	0	0	6.3	1.6

313	0	0	0	0	0	8.4	11.5	0	0	3.1	1.9	0	0	2.9	9.2
314	0	0	0	0	0	0	1.2	0	0	0	0	3.8	0	88.6	18.5
315	0	0	0	0	3.9	0	0	0	2.8	12.8	0	47.3	2.2	0	16.9
316	0	0	0	3.6	16.2	0	18	11.5	7.5	9.1	0	3.1	15.6	9.5	4.6
317	0	0	4.9	1.6	6.4	0	7.2	0	11	0	51.7	0	46.9	6.8	2.9
318	0	0	0	0	5.7	2	0	0	9.4	0	36.3	0	13.4	3	6.2
319	0	2.9	0	0	0	0	0	0	20.6	2.2	148.8	0	15.2	0	6.1
320	0	7.6	9.6	0	0	0	5.5	0	0	29.3	38.2	0	22.5	36.2	0
321	0	1.8	0	0	0	0	0	0	0	5.2	18.2	0	5.3	96.9	0
322	2.5	0	0	0	6.5	2.8	0	0	0	0	3.4	0	0	125.5	0
323	0	2	0	0	0	6.1	0	0	0	16.5	2.3	48	0	103.1	0
324	0	0	0	0	3.4	2.7	0	0	0	0	0	6.4	0	92.3	1.4
325	0	0	0	0	14.9	0	6.4	0	0	1.9	0	1.7	0	5.2	0
326	0	3.2	0	0	0	0	12.6	0	12.5	8.6	0	0	0	13.8	0
327	0	2.8	0	1.5	0	0	34.4	31.2	0	60.3	0	0	0	9.1	0
328	0	0	0	9.6	5.7	0	6	20.2	32.7	19.9	0	0	0	9.8	37.2
329	1.2	0	0	4.4	0	0	0	4.2	14.2	0	0	0	0	97	71.9
330	0	0	13.4	10.1	2.7	0	0	0	1.9	0	0	0	0	36.1	6.9
331	0	0	0	0	0	0	0	0	0	0	5	20.4	0	76.6	34.1
332	0	0	0	3	1.3	0	0	3.7	0	13.3	0	56.4	0	0	2.2
333	0	0	0	0	4.2	3.5	0	0	0	0	0	51.6	0	0	1.4
334	21.3	1.7	0	12.4	0	0	0	0	16.1	0	22	0	9.7	0	105.2
335	0	0	0	0	0	4.3	0	0	4.8	0	5.2	20.9	57.5	1.2	54.6
336	0	0	0	0	0	0	0	0	0	0	3.2	2.9	27	10.7	54.7
337	0	0	2.2	0	2.1	0	0	0	0	10.4	60.1	0	8.8	0	8.4
338	0	5.6	2	0	0	0	3.9	0	4	33.5	1.7	0	22.6	4.9	0
339	0	9.2	0	0	0	0	1.1	0	0	7.6	18.9	0	49.6	2.3	2.1
340	0	3.6	0	0	0	5.7	0	0	0	25.4	1.9	0	37	30.8	5.8
341	0	11.9	0	0	0	6.9	3.6	0	0	9.6	3.1	4.5	102.7	3.5	13.3
342	0	1.3	0	0	11.7	0	10.4	0	3.5	7.1	1.9	44.8	49.1	0	3.4
343	0	1.9	0	0	0	0	11.7	0	0	4.7	0	0	40.9	22.9	31.5
344	0	0	0	0	0	0	2.4	0	0	1.3	81.6	0	1.9	51.8	33

345	0	0	0	0	0	0	21.8	0	12.4	0	8	0	1.5	26.9	0
346	0	0	3.3	0	0	0	9.4	0	10.1	5.7	10.6	0	18.4	0	0
347	1.7	0	0	0	0	0	5	0	4.5	0	11.4	10.2	193.6	0	0
348	0	0	0	0	0	0	0	5.7	0	0	0	0	1.2	6.4	37.4
349	0	0	0	10.2	0	0	2	0	7.9	20.6	0	0	0	7.9	12.1
350	0	2.5	0	9	0	0	10.1	1.6	37.9	14.4	0	0	39.4	56	0
351	0	0	0	0	2.5	7.8	7.9	0	25.7	5.2	0	0	0	69.6	0
352	0	0	0	0	0	0	18.1	4.3	0	30.9	6.2	0	0	20	3.8
353	0	0	4.7	0	4.5	7.8	53.4	1.4	6.5	17.1	8	0	4.8	38.3	51.8
354	0	2.5	0	0	0	29.2	5	6.7	0	21.8	0	0	99.4	4.7	105.4
355	0	0	0	5.7	0	0	1.6	2.3	0	2.6	0	0	0	0	20.7
356	0	0	0	0	0	0	1.1	6.1	0	0	0	4.2	0	41	11.2
357	0	7	0	1.3	3.7	0	0	16.4	0	0	0	27.7	0	31	34.6
358	0	7.3	6.5	0	0	0	1.9	16.7	0	0	24.3	0	0	119.5	8.6
359	28.5	0	2.1	3	0	0	0	0	13	0	4.8	0	0	7.5	1.3
360	0	0	0	0	10.7	0	0	0	0	0	7.4	0	0	12.8	0
361	0	0	0	0	0	0	0	0	0	0	94.6	0	0	0	0
362	0	0	0	0	0	0	0	9.1	0	0	0	0	0	23	5.3
363	0	0	0	2	0	0	5.9	17	0	21.6	16.5	42.6	21.6	4.4	28.1
364	0	0	0	0	2.2	0	18.1	0	0	13.8	106.2	3.9	45.6	0	3.8
365	0	0	0	0	0	0	0	0	0	0	18.5	0	0	0	10.3