IMPACT OF CLIMATE CYCLES AND TRENDS ON SELWYN DISTRICT WATER ASSETS

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ABSTRACT

Aqualinc carried out an assessment of the impact of climate cycles and trends on Selwyn District Council's potable water, wastewater, stormwater, land drainage, and water race assets. The assessment looked out to 2048 to align with their 2018 to 2048 Infrastructure Strategy. The project considered projected changes in climate in the light of historically observed climate cycles and trends and assessed what the impact of future changes could be on water assets.

A robust analysis of long term historical climate (100 years+) was carried out, which allowed climate projections to be placed in context. The results suggested that, for certain climate variables, natural variability is often much greater than climate change effects, particularly over a 30 year horizon.

The study was a high level risk assessment, to identify the assets that were most likely to be affected by climate change. Priority areas were guided by a risk matrix that Aqualinc developed in consultation with the council at the outset of the study. The variables that were identified as having the greatest potential impact for infrastructure were groundwater levels (high shallow groundwater levels and reduced deep groundwater levels), extreme rainfall, high river flows, and sea level rise.

Across the district no evidence of an increasing trend in extreme rainfall events was found. If a trend exists, it is masked by the high variability. Rainfall is projected to increase in the mountain regions of the district so the alpine rivers (i.e. the Waimakariri and the Rakaia) could show an increase in flow, with implications for associated water supply, stormwater and wastewater infrastructure in the alpine settlements.

Over the next 30 years, sea level rise will increase the likelihood of issues with wastewater, stormwater and land drainage in the areas close to Te Waihora/Lake Ellesmere and the mouth of the Rakaia.

Changes in groundwater levels associated with projected climate change are small compared to irrigation effects and the natural inter-annual variability.

KEYWORDS

Climate cycles, climate trends, water assets

PRESENTER PROFILE

Dr Helen Rutter is a Senior Hydrogeologist with Aqualinc Research Ltd, having over 25 years' experience working hydrogeology in the UK, Botswana, and New Zealand. She has in-depth understanding of physical hydrogeology, including resource assessment, recharge processes, groundwater flooding, catchment characterisation, geology and geochemistry.

1 INTRODUCTION

Selwyn District Council (SDC) is committed to the sustainable management of the district's five water assets: potable water, wastewater, stormwater, water races, and land drainage. Aqualinc Research Ltd (Aqualinc) reviewed the impact of climate cycles and trends on these assets. The purpose of the project was to consider projected changes in climate in the light of historically observed climate cycles and trends, and to assess what the impact of those changes could be on Council's water assets.

When assessing the impacts a core philosophy was that a thorough understanding of local historical climate is an important foundation for understanding future climate. A robust analysis of long term historical climate (ideally 100 years+) allows climate projections to be placed in context. Our approach invests considerable effort in understanding the past because our experience for New Zealand is that for certain climate variables, natural variability is often much greater than any likely climate change effect, particularly for a 32 year horizon.

Our approach was to focus our time and resources primarily on the areas where climate cycles and trends pose the greatest risk to SDC water assets. This allowed us to go into greater quantitative detail for issues that matter most. For example, because groundwater level variations potentially pose significant risk to a number of SDC assets we undertook more in-depth analysis in this area, including modelling multiple locations on the plains for a simulation period of over 100 years.

The study is a high level risk assessment, to identify the assets that are most likely to be affected by climate change. Priority areas were guided by a risk matrix that we developed in consultation with SDC at the outset of the study (Table 1). Whether or not an asset is affected depends both on the asset's sensitivity to change, and the scale of change. The asset sensitivities were combined with projected changes, to give the expected impacts of climate change on assets.

Table 1: Asset sensitivity to changes in environmental factors.

Environmental factor	**Water**	**Wastewater**	**Stormwater**	**Land drainage**	**Water races**
Ground water levels (upper plains)	High	Minor	Minor	Minor	Minor
Ground water levels (lower plains)	Low	High	High	High	Low
Annual rainfall	Moderate	Minor	Minor	Minor	Moderate
Extreme rainfall (Plains)	Moderate	High	High	High	Moderate
Extreme rainfall (foothills and alpine)	High	High	High	High	Moderate
Alpine river flows	Moderate	Minor	Minor	Minor	High
Foothill and lowland river flows	Moderate	Minor	Minor	Minor	High
Evapotranspiration (ET)	High	Minor	Minor	Minor	Minor
Sea Level rise <0.23m	Minor	Low	Low	High	Minor
Snow and ice (excl. alpine river flows impacts)	Minor	Minor	Minor	Minor	Low
Temperature (excl. ET impacts)	Minor	Minor	Minor	Minor	Minor
Wind (excluding ET impacts)	Moderate	Moderate	Minor	Minor	Minor

Data were sourced from NIWA's CliFlo database, Ecan and other sources, as listed in Table 2.

Table 2. Data descriptions

Data type	Source	Frequency
Rainfall	cliflo.niwa.co.nz	Daily
Maximum temperature	cliflo.niwa.co.nz	Daily
Minimum temperature	cliflo.niwa.co.nz	Daily
Potential evapotranspiration	cliflo.niwa.co.nz	Daily
Ground water levels	data.ecan.govt.nz	Daily
River flows	data.ecan.govt.nz, neon.niwa.co.nz	Daily
Sea level (at Lyttelton)	John Hannah, Emeritus Professor, School of Surveying, University of Otago	Annual

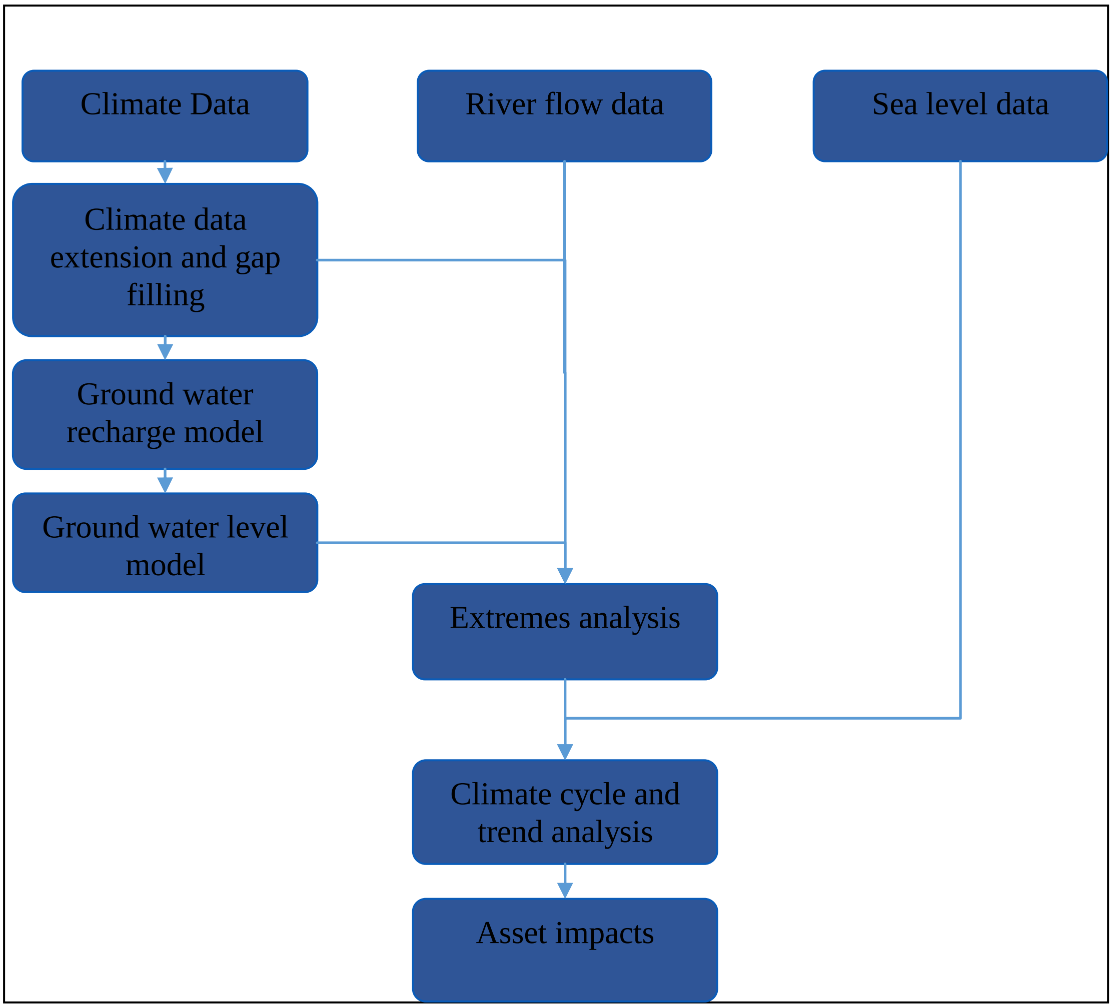

Figure 1 Data flow process diagram

Aqualinc developed in house software called the Climate Time Series Extension (CTSE) software, to gap fill and extend daily time series for rain, temperature and potential evapotranspiration (PET). For the observation sites that have time series of climate data that do not cover the full period of interest (i.e. 1892 – 2016 for rainfall, see Table 4) the CTSE software first selects which of all other available sites has the best-correlated time series. The CTSE software then calculates relationships between the two sites for each month of the year. These relationships are then applied to the correlated site's data, to gap fill or extend the original site's data. If the correlating-sites data does not cover the missing period, then the next-best correlating site is used. In this way, the time series data are infilled and extended An alternative data source is the NIWA Virtual Climate Station Network, which prepares time series based on a weighted combination of neighboring observation sites. This can result in time series with artificial step changes when nearby sites are added or removed. Such step changes make trend analysis difficult. The Aqualinc CTSE software is ideally suited for capturing the full spectrum of short term to multi-decadal climate cycles and trends at a large number of sites not limited to the few long term stations.

The CTSE software includes data quality checks to exclude unreliable data, including the removal of records of non-24 hour observations. For this study we also undertook further analysis to check that any changes in data quality, particularly for pre 1960 data, were not affecting trend analysis. We found that data quality was no different between 1940 and 2015.

Extending PET estimates back to 1910, was more difficult than other variables because of the lack of radiation and vapour pressure data prior to 1960. To allow for this, an estimate of PET for the 1910-2016 period was generated with the McGuiness-Bordne method that uses daily minimum and maximum temperatures (Guo et al. 2016). These estimates were then compared to the 1960 – 2016 extended PET data estimated using the Penman method. The Penman method is more accurate, but requires radiation, wind, vapour pressure and temperature data. The relationship between the McGuiness-Bordne and Penman estimates was then used to adjust the entire McGuiness-Bordne series.

Groundwater level time series were extended back to 1910 through modelling. A series of "eigen" models (Bidwell and Burberry, 2011) were prepared for the wells of interest. The models were calibrated to post 2011 earthquake observed groundwater levels. The groundwater models were driven by estimates of daily land surface recharge, prepared using Aqualinc's IrriCalc model (Bright 2009). The Irricalc model used the extended rainfall and PET estimates as the primary inputs.

Table 3. Data extension methodologies

Data type	Process	Period
Rainfall	Extended and gap filled with CTSE software	1892-2016
Minimum and maximum temperature	Extended and gap filled with CTSE software	1905-2016
Potential evapotranspiration (Penman)	Extended and gap filled with CTSE software	1960-2016
Potential Evapotranspiration (McGuiness-Bordne)	Generated from temperature and calibrated to NIWA Penman estimates	1909-2016
Groundwater	Modelled from rainfall and potential evapotranspiration and calibrated to post-earthquake observed groundwater levels.	1909-2016

2 CLIMATE CYCLES AND TRENDS

The aim of this project was to assess how climate cycles and trends affect the local climate and hydrology. An analysis of a long historic period is necessary to separate trends from multi-decadal cycles: some multi-decadal cycles show up as trends if only the last 40 years of historical data is analysed.

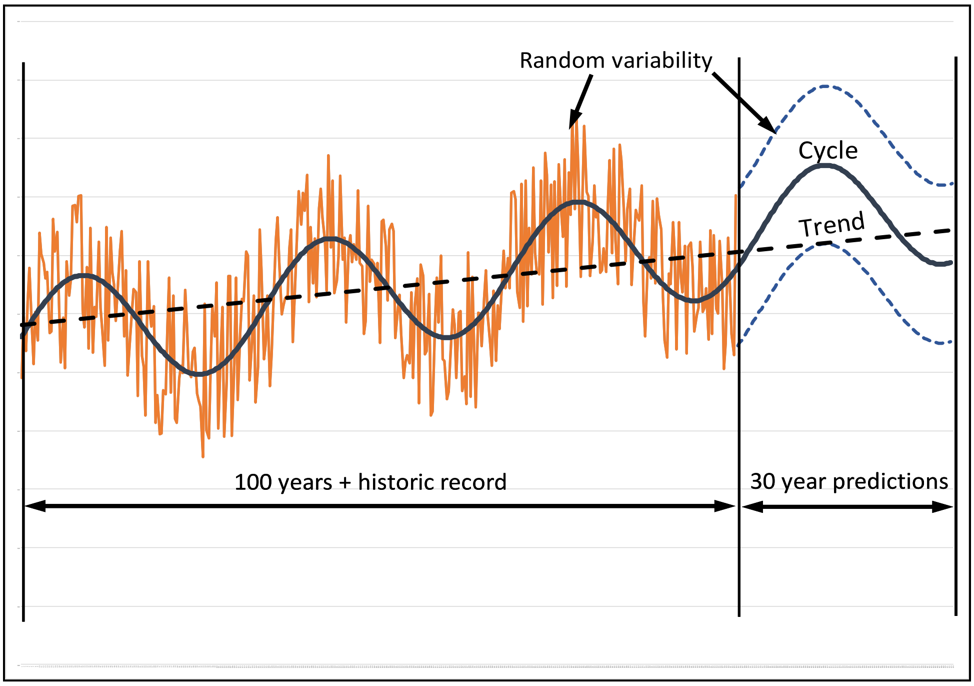

Figure 2: Schematic illustrating Trends, cycles and random variability

Some of the variation in climate may be attributable to different large scale climate variability. Four different climate characteristics were considered: climate change, El Niño/Southern Oscillation (ENSO), the Southern Annular Mode (SAM) and the Interdecadal Pacific Oscillation (IPO). Measures of each of these characteristics were compared with local water asset-related climate variables: extreme rainfall; groundwater levels; and high stream flows.

2.1 EL NIÑO SOUTHERN OSCILLATION (ENSO)

El Niño - Southern Oscillation (ENSO) is a climate characteristic related to the sea surface temperature in the eastern equatorial Pacific (commonly known as El Niño) and the atmospheric pressure difference across the equatorial Pacific (known as the Southern Oscillation). ENSO has been shown to relate to weather conditions throughout the world and has multi-month persistence that enables seasonal forecasting in some locations. The physical explanation for the variations are a subject of considerable research, with positive feedback of ocean-climate interactions playing a large part. In the El Niño phase, easterly trade winds weaken and New Zealand experiences stronger than normal southwesterly airflow. This generally results in lower seasonal temperatures for New Zealand, and drier conditions in the northeast of the country. The La Niña phase is essentially the opposite in the tropical Pacific, and New Zealand experiences weaker southwesterly flows, higher temperatures, and wetter conditions in the north and east of the North Island. These are average effects and are overlay high variability. While all El Niño years combined show stronger south westerlies than average, any one specific El Niño year will not necessarily have stronger south westerlies than average.

The strength of the El Niño, the Southern Oscillation, or a combination of the two may be measured in a variety of different ways. We selected the Coupled ENSO Index (CEI) as our measure (Figure 3) as it covers the time span that the data are available for, and combines the sea surface temperature and atmospheric pressure measurements that constitute the ENSO phenomena.

The variation in the CEI over time is shown in Figure 3. For the CEI, a negative index indicates an El Niño event while a positive value indicates a La Niña event. The recent extreme El Niño years of 1982-83, 1997-98 and 2015-16 show as extreme low points with this index.

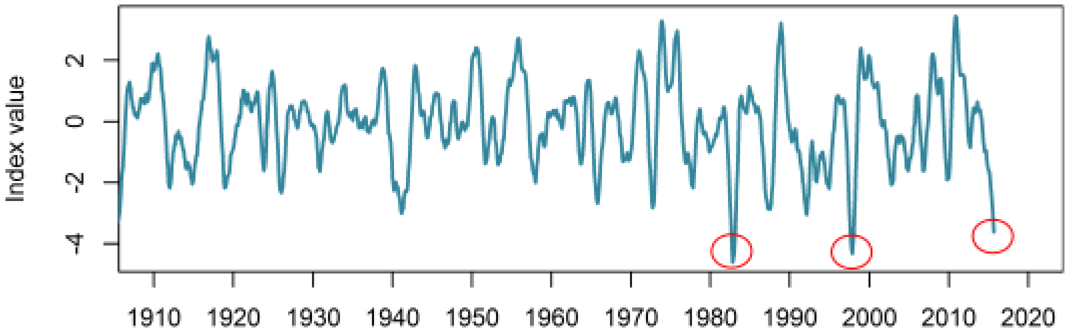

Figure 3. ENSO variation represented by the Coupled ENSO Index (CEI).

2.2 INTERDECADAL PACIFIC OSCILLATION (IPO)

Pacific sea surface temperatures show variation on a multi-decadal timescale often referred to as the Interdecadal Pacific Oscillation (IPO). The multi-decadal variation has been observed in weather throughout the Pacific and in the strength of the ENSO oscillations. Long-lived fluctuations in New Zealand climate can occur, both in terms of rainfall and temperature, which coincide with IPO variations. The increase in New Zealand temperatures around 1950 coincides with the change from positive to negative phase IPO. The switch from negative to positive IPO in the late 1970s coincides with significant rainfall changes.

The physical explanation of the variation is not well understood. There are three different measures that may be used to describe this variation. It is common to consider these measures in terms of their "phase", as in "the positive phase from the late 1970's to early 2000's", rather than the actual values. A smoothed version of the three measures are shown in Figure 4. Over the last century the measures are all positive from 1922 to1944, negative from 1946 to 1977, positive from 1979 to 1998, and negative from 2000 to 2015.

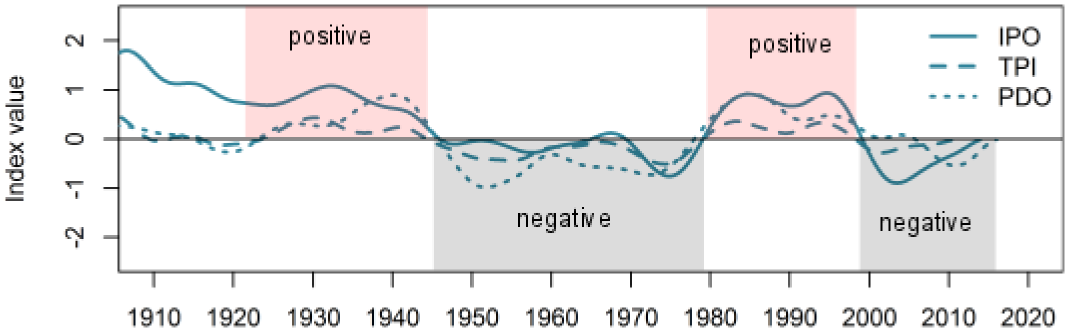

Figure 4. 13 year filtered indices of Pacific sea surface temperature. IPO is the Interdecadal Pacific Oscillation index, TPI is the Tripole Index for the Interdecadal Pacific Oscillation, and PDO is the Pacific Decadal Oscillation index.

2.3 SOUTHERN ANNULAR MODE (SAM)

The SAM is a description of the strength and position of the westerly winds around the mid-latitudes of the Southern Hemisphere. SAM is measured by the SAM Index. A positive SAM index indicates the westerly winds have moved closer to Antarctica. A negative SAM index indicates the westerly winds have moved closer to the equator.

Locally the SAM is expressed as the strength, frequency and location of the westerly winds across the South Island. The higher the SAM index, the weaker the westerly winds over the South Island.

The SAM index is shown in Figure 5. SAM changes at a weekly timescale and can be used for short term forecasting. There is a long term trend in the SAM towards higher values indicating that climate change is leading to less frequent and weaker westerly winds over the South Island.

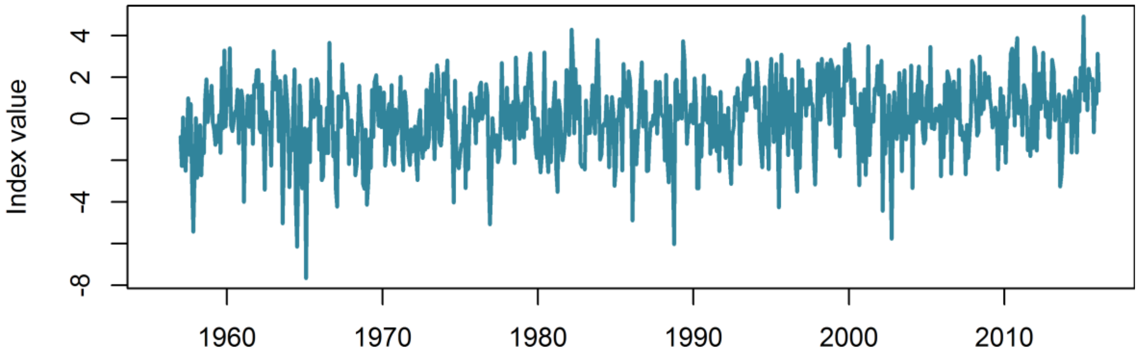

Figure 5. Southern Annual Mode (SAM)

2.4 CLIMATE TRENDS

The global climate is undergoing a long term change. Evidence of this change in New Zealand is provided by a composite of the temperature data from seven long term climate stations (Figure 6). For these 7 stations Mullan et al. found that temperatures have increased by about 1°C over the last 106 years.

Using the CTSE software, analysis of about 5 million daily minimum and maximum temperature readings from 686 climate stations, indicated a very similar historical trend to NIWA’s analysis. We found that over the last 110 years, temperatures across New Zealand have risen by an average of 1.1°C. This corresponds to an average historic rate of increase of 0.01°C/y, close to Mullan et al’s (2010) conclusion.

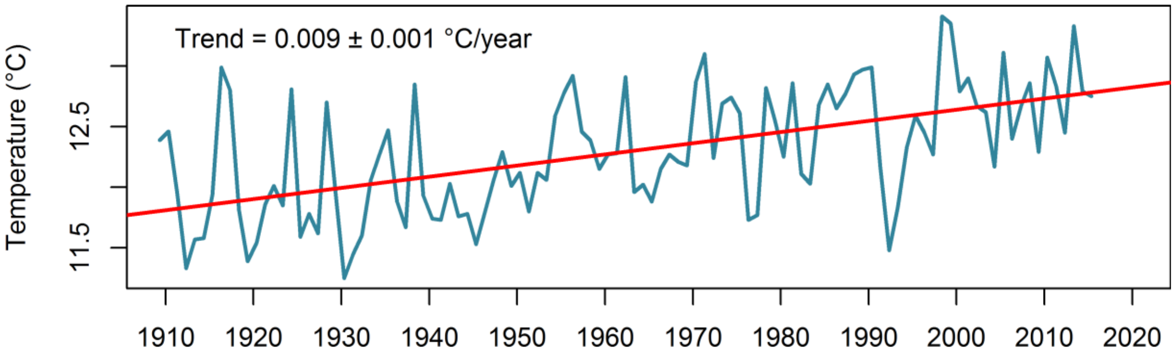

Figure 6. New Zealand mean annual temperature from the NIWA “7 station” series. Data from https://www.niwa.co.nz/sites/niwa.co.nz/files/NZT7_Adjusted_TMean_Web_Jan2016.xlsx *(Mullan et al. 2010).*

MFE (2008a) provided a New Zealand wide recommendation of allowing for an 8% increase in extreme event magnitudes for every 1°C temperature increase. We assessed the impacts of this on extreme rainfall. One hundred and twenty six extended time series of rainfall from within 10 km of the Selwyn District have been analysed for annual frequency of high rainfall events. For each station the 95th percentile daily rainfall was determined. This equates to, on average, the highest 18 days a year. This variable was considered particularly relevant to infrastructure with regards to flooding and stormwater drainage.

The time series of annual frequency of rainfall for all 126 stations together with the mean, is shown in Figure 7. This shows high inter-annual variability. Analysis of the mean of these time series shows no long term trend, no statistically significant correlation to the ENSO and SAM signals, and no statistically significant differences between annual frequencies for the different IPO phases.

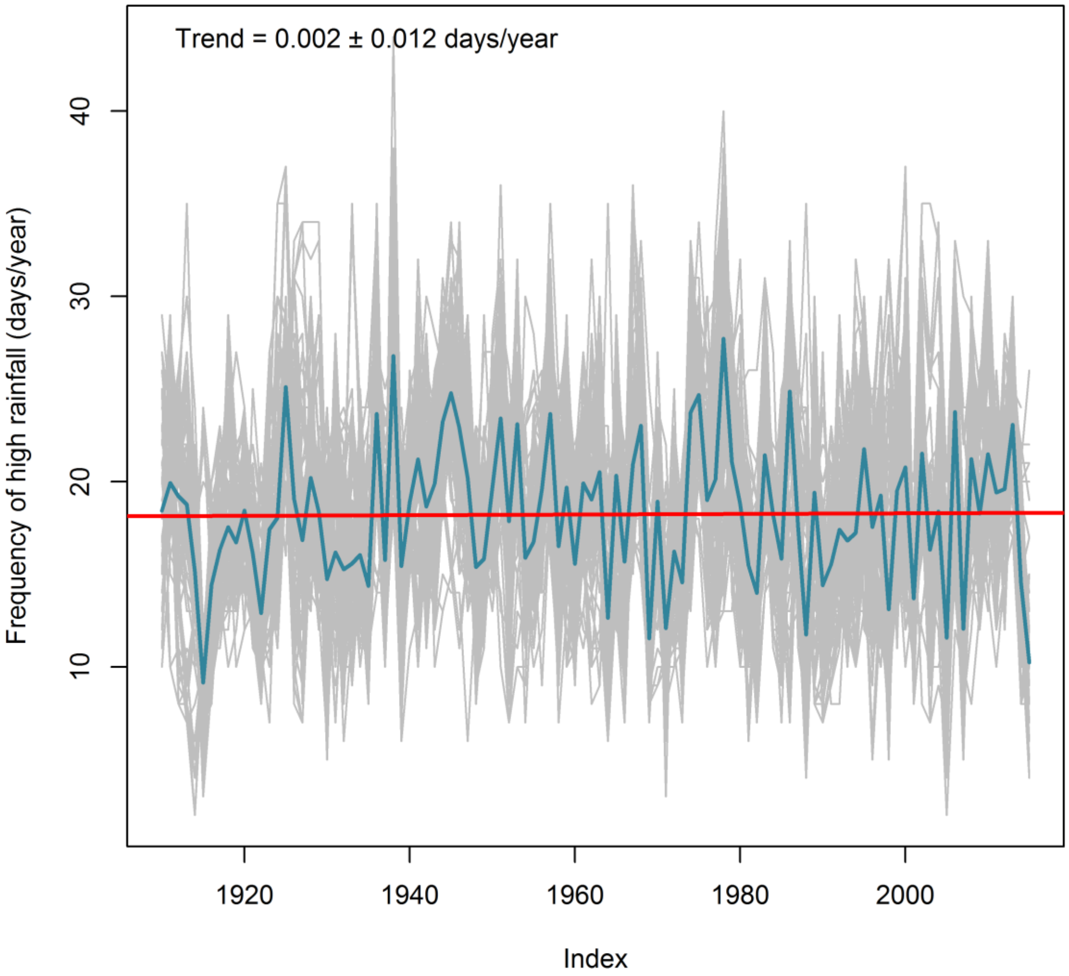

Figure 7. Time series of annual frequency of high rainfall for 126 rainfall sites within 10 km of the Selwyn District. The bold line is the mean.

Extended data from ten rain gauge sites (from Christchurch to Arthur's Pass), selected for their proximity close to council assets, were individually analysed. None of the sites returned statistically significant (at the $p < 0.01$ level) relationships to any of the climate cycle indices, nor were long term trends detected.

To assess the relationship between temperature and extreme rainfall, the annual number of days of extreme rain were ordered based on the annual mean daily temperature. For the Christchurch Airport, as the annual mean daily maximum temperature increased, the number of high rainfall days decreased at a rate of 1.5 days per ^{o}C. By 2048, under a projected 0.54^{o}C temperature increase, if the correlation holds, there will be, on average, a day less of heavy rain each year in Christchurch, or a 5 % reduction in the number of high rainfall events. For Arthurs Pass the number of heavy rain days a year increases as the Christchurch temperature increases at the rate of 2 days per ^{o}C, i.e. an extra day of heavy rain by 2048, or a 5 % increase in heavy rain events. This change at Arthurs Pass is consistent with climate change model estimates. At Castle Hill and Lake Coleridge, no relationship with temperature could be found that was distinguishable from random chance.

Our findings of no detectable trend agrees with Griffiths (2013) who found that for the 1962 to 2011 period, no statistically significant ($p < 0.05$) trend was found for mean annual rainfall, number of days per year with more than 25 mm of rain, annual maximum daily rainfall, annual maximum 5 day rainfall, annual total rainfall from the top 4 events per year, or annual maximum consecutive rain days.

As previously stated, MFE (2008a) provided a New Zealand wide recommendation of allowing for an 8% increase in extreme event magnitudes for every 1°C temperature increase. Subsequent climate modelling of changes in rainfall extremes under a variety of potential future greenhouse gas concentrations (MFE, 2016) indicated that, by the 2040s, little change in rainfall extremes will be discernable despite a projected temperature increase of 0.7 – 1.0^{o}C. In light of the lack of any trend in historic data, and the subdued climate modelling results, our opinion is that the generic 8%/1°C guideline is conservative for the Selwyn District.

3 ASSESSING CLIMATE EFFECTS ON ENVIRONMENTAL VARIABLES

3.1 GROUNDWATER LEVELS

Four groundwater models were prepared that enabled estimation of groundwater levels for eight wells across the plains region of the Selwyn District for the 1910-2015 period.

The groundwater models incorporate bulk aquifer parameters which are calibrated to match the measured groundwater level response at specific wells (Bidwell and Burberry, 2011). Spatial variation down the catchment is accommodated by the inclusion of zones (inland, mid-plains and coastal) of differing aquifer stresses (land surface recharge and pumping). River recharge is assumed to be constant and results in a constant 'base' groundwater level as supported by the rivers. Land surface recharge provides the transient response on top of this base groundwater level.

Each groundwater model was constructed to run from June 1910 through to June 2016 with monthly stress periods. The models were calibrated to measured groundwater levels from 1 January 2012 to May 2015 to avoid changes in land use intensification and changes associated with earthquake responses (Cox et al, 2012).

Figure 8 provides an example of the groundwater model output for bore M36/0217. Both the model calibration (shown by the green line from 2012 to 2015) and the prediction over the 1910-2012 period assume current water takes and land use (the blue line prior to 2012). This long-term prediction provides an indication of the groundwater level response if the well had been in place for the same period under current land and water use intensification.

Of interest to Selwyn District infrastructure are the variation in the annual minimum groundwater levels of the wells in the upper plains (affecting water supplies) and the annual maximum groundwater levels in the lower plains (affecting stormwater,drainage and wastewater).

No statistically significant relationships were identified between the ENSO or SAM indices and the annual maximums and minimums. No statistically significant difference was found between the annual series' for the different phases of the IPO. While a statistically significant increasing trend was found for potential evapotranspiration, no trend was detected in the annual extremes of groundwater levels. The discrepancy between PET trends and groundwater trends may be because the increased PET occurs in summer when groundwater recharge is low, so that its effect on groundwater is small. Additionally the high annual variability of the recharge, a result of the high annual variability of rainfall, may obscure any trend.

For each well we also investigated the change in the annual high (90th percentile) groundwater levels associated with three different scenarios: 1) projected climate change; 2) changes resulting from the new Central Plains Water irrigation scheme; 3) effect of no irrigation. The change in the annual high groundwater level was determined as a fraction of the annual average groundwater range for the original long-term time series (called the status quo series). The average value for all eight wells is reported. For comparison, the range of the annual high groundwater levels of the status quo series was also found. This provides a measure of the inter-annual variability.

The results in Table 4 show that the annual variability of high groundwater levels is large compared to the mean annual groundwater range. The current groundwater pumping is estimated to cause a drop in high groundwater levels equivalent to 17 % of the status quo range. Implementation of Central Plains Water Ltd irrigation, with the resultant anticipated increase in irrigation and reduction in groundwater pumping (as irrigators switch from groundwater to river-sourced scheme water) is estimated to increase the high groundwater levels. Both these effects dwarf the impact of projected climate change estimated to result in only a minor reduction in groundwater levels. The lack of any significant projected impact is primarily because we do not expect a change in annual rainfall characteristics on the Canterbury Plains over the next 30 years, and only a small increase in PET.

Table 4: Environmental impacts on groundwater levels

Factor	**Average water level change** **(% of status quo water level range)**
Climate change	-4%
Central Plains Irrigation	+12%
Existing irrigation from groundwater	-17%
Long term annual variability	±41%

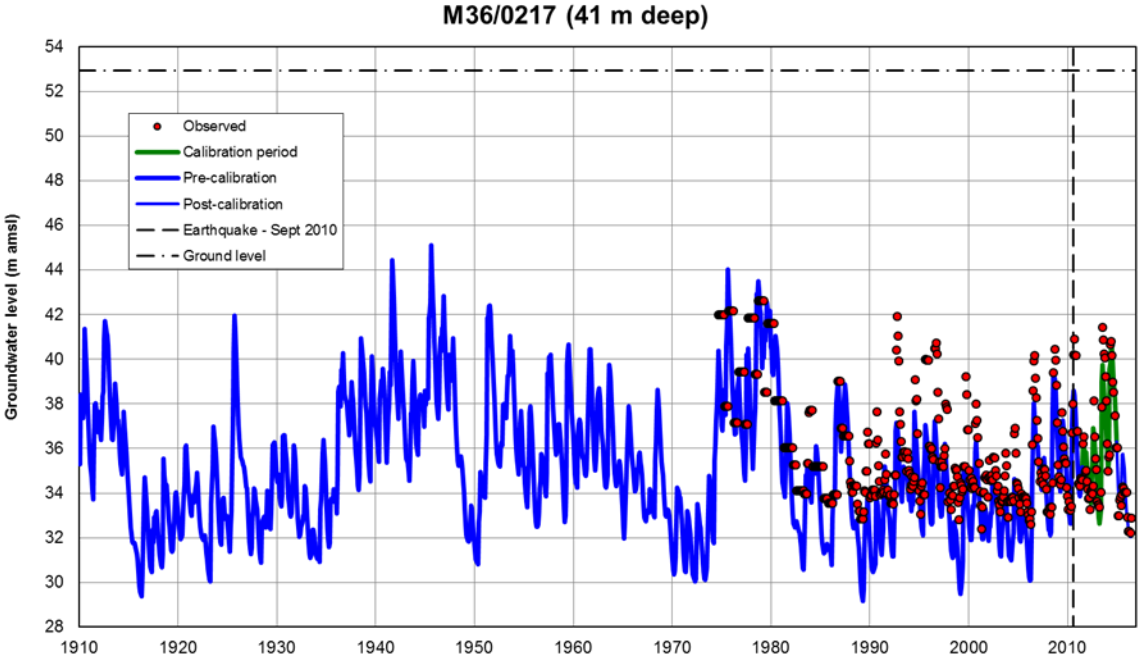

Figure 8. Modeled groundwater level time series for Well M36/0217 at Weedons

3.3 STREAM HIGH FLOWS

We investigated whether the frequency of high flow events (95th percentiles) for four rivers (Waimakariri, Rakaia, Selwyn and Doyleston Drain) were correlated with different climate indices and climate trends. No correlations or trends were found for any of the sites. Of the four sites, the Rakaia showed a difference in the number of high flow days between IPO phases. For positive IPO years there was an average of 21.6 days a year with high flows, and IPO negative years averaged 15.4 days. This difference was large enough that there is less than a 5 % chance that it could be observed by random chance. This finding supports the work of McKerchar and Henderson (2003) who investigated Rakaia and Waimakariri flows for changes between the IPO phases for the 1947 and 1999 period. They found increased annual flood levels for the Rakaia for the positive phase of the IPO, but could not distinguish a change for the Waimakariri.

3.4 SEA LEVEL RISE

Sea level rise has the potential to impact on coastal communities and Te Waihora/Lake Ellesmere. MFE (2008b) projected an average future rate of sea level rise over the next 100 years of between one and three times the historic rate. Because of the uncertainty, MFE recommended a conservative approach by allowing for a 0.20 to

0.27 m rise by the 2040s relative to the period 1980-1999 (MFE 2008b Table 2.3). This is an increase of 0.17 to 0.23 m relative to the period 1995-2015. If, however, sea level rise follows the historical trajectory, the rise in levels would be limited to 0.08 m by 2048, relative to the period 1995-2015. The potential impacts on Te Waihora are described in the following section. Coastal communities that are potentially affected are Upper and Lower Selwyn Huts and Raikaia Huts (see Figure 10) where stormwater, waste water and drainage networks will have reduced efficiency.

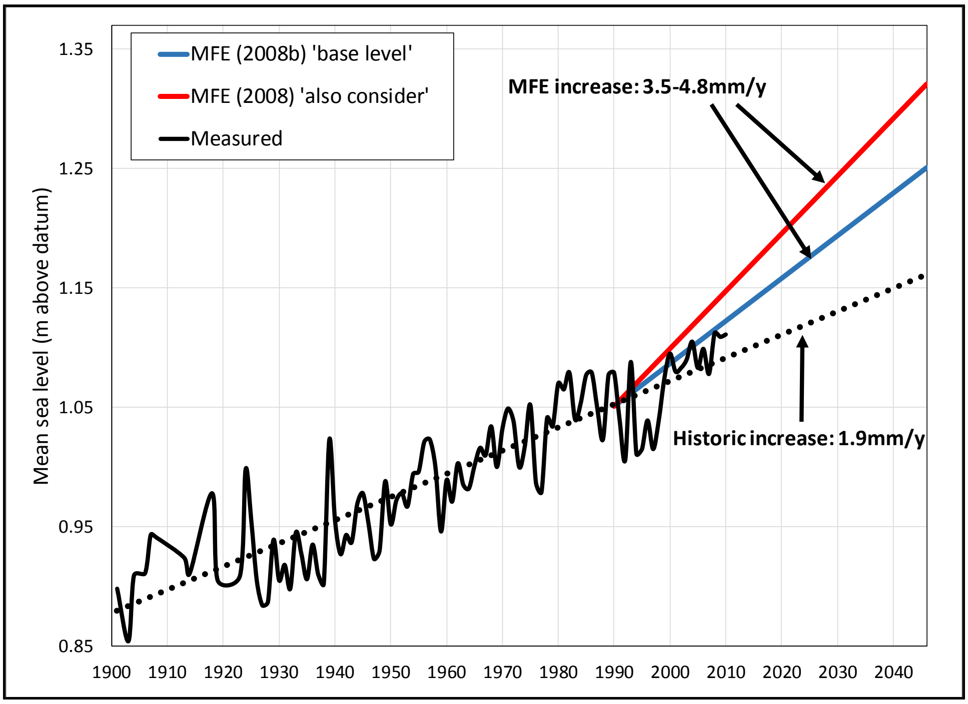

Figure 9: Measured and projected change in mean annual sea level at Lyttelton: 1901-2048

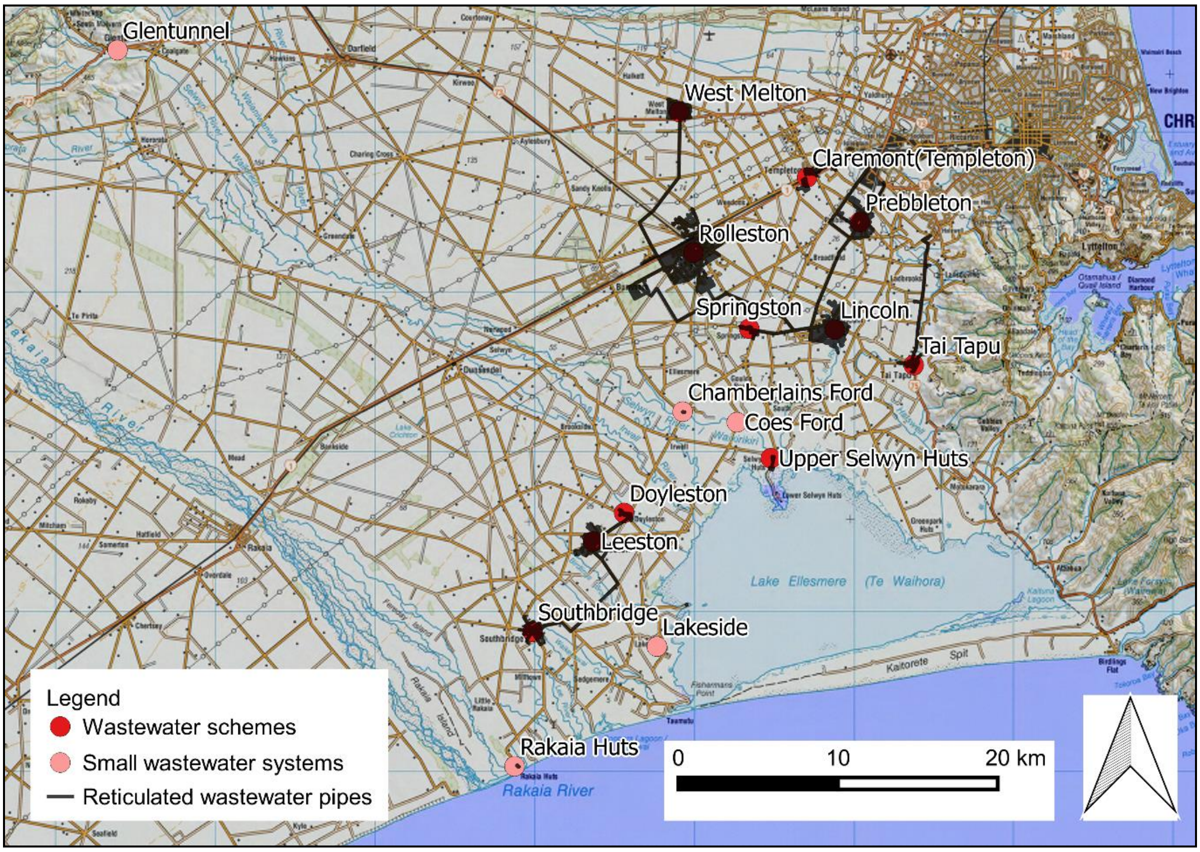

Figure 10: SDC wastewater schemes – Canterbury Plains

3.5 TE WAIHORA/LAKE ELLESMERE

The water level of Te Waihora has been artificially managed through creating a connection from the lake to the sea since at least 1860. Environment Canterbury estimate that, without human intervention, the lake level would rise to a range of 2.7 m to 3.6 m amsl before the opening was naturally breached. Environment Canterbury has been involved with Te Waihora openings through the former North Canterbury Catchment Board since 1947 (ECan 2016). The National Water Conservation (Te Waihora/Lake Ellesmere) Order 1990 prescribes the levels at which the lake can be opened.

Figure 11: Te Waihora Lake Opening Location

Over the last 22 years lake levels have been in the range of 0.4 to 1.2 m amsl 95% of the time. At the extremes, levels have been as low as 0.2 m amsl and as high as 1.8 m amsl. Historic levels are illustrated in Figure 12. The area of inundation on 30 June 2013, when lake levels were at the highest recorded level of 1.81 m amsl, is illustrated in Figure 13.

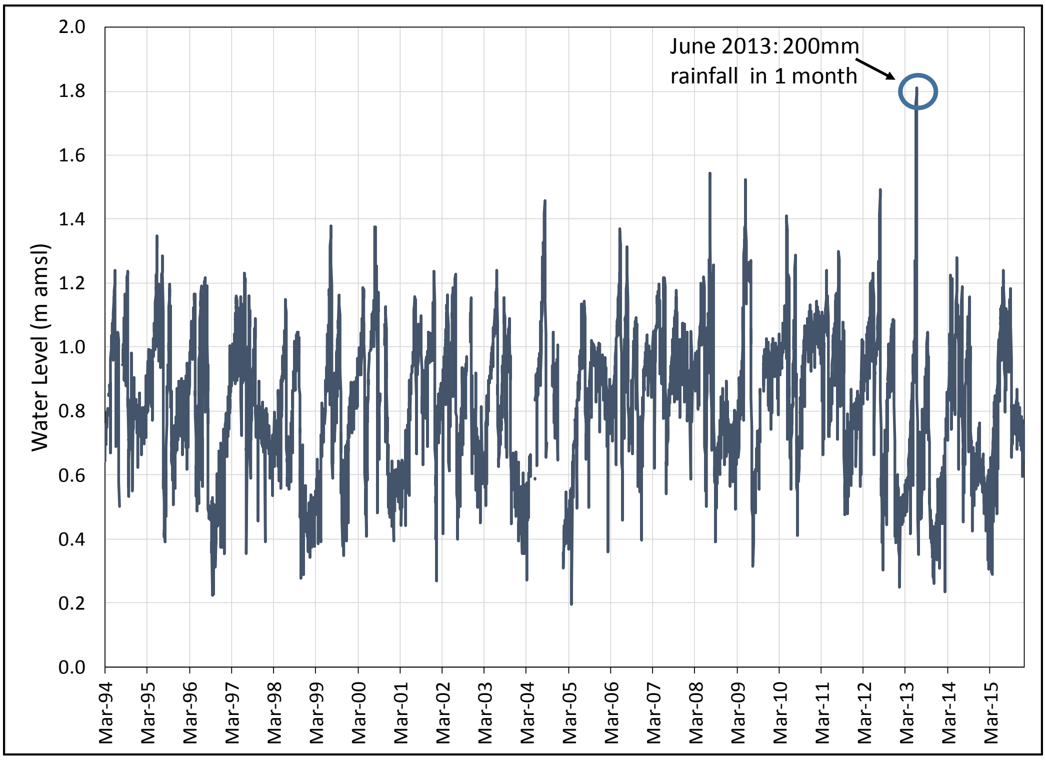

Figure 12: Te Waihora water levels 1994 to 2016

Figure 13: Area inundated due to high lake levels: 30 June 2013

Higher sea levels will affect Te Waihora/Lake Ellesmere water levels. Sea level rise will result in either the lake needing to be opened more frequently and/or an increase in lake levels. Without any change in lake management, which is based on lake levels relative to sea level, lake levels would rise by between 0.08 m (the historic trend in sea level rise) to 0.23 m (the MFE 2008B sea level rise upper limit guide) by 2048.

A higher lake level would result in more frequent flooding of areas around the lake and would reduce the effectiveness of SDC's land drainage network. During an extreme event, such as on 30 June 2013, lake levels can rise up to 1.8 m amsl. Allowing for an additional 1 m of backwater effects, and given a typical drain depth of 1 m, this means lake levels can affect land drainage up to an elevation of about 3.8 m amsl (1.8+1.0+1.0).

Figure 14 provides a coarse assessment of the difference that an additional 0.23 m (the MFE 2008B sea level rise upper limit) increase in Lake water level would make on the affected drainage area.

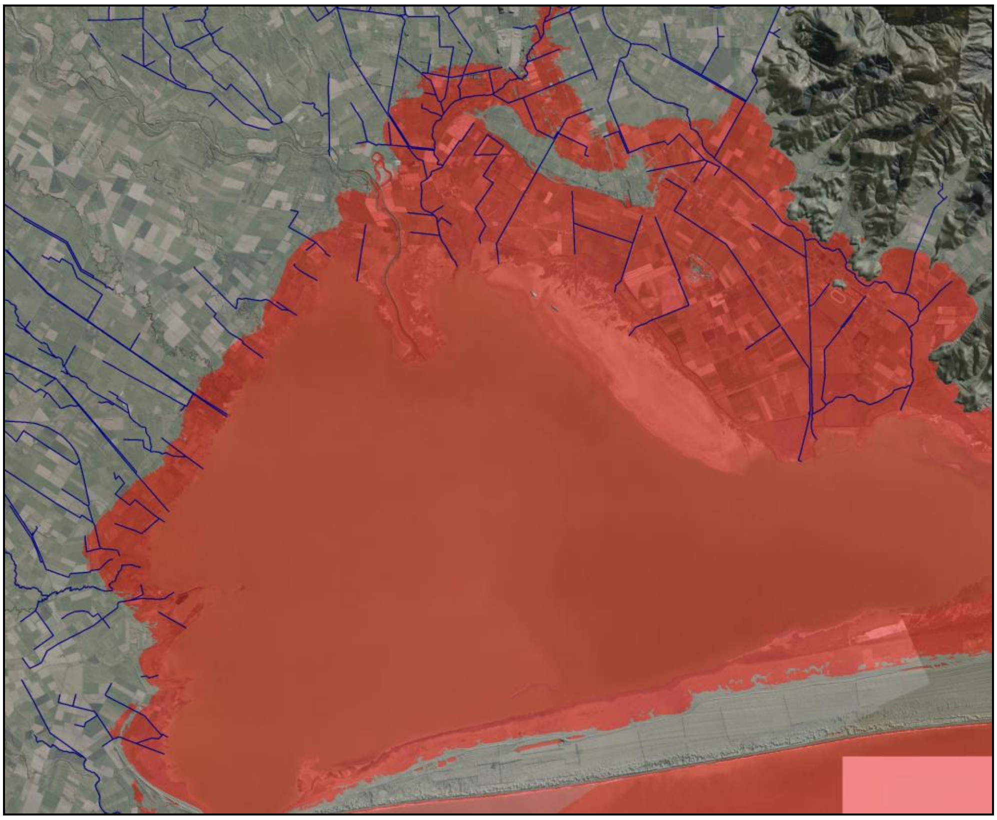

Figure 14: Maximum extent that lake levels could affect land drainage (3.80m + 0.23 m amsl)

3.6 IMPACTS OF SEA LEVEL RISE ON GROUNDWATER

The effect of sea level rise on groundwater levels will be greatest at the coastal boundary. The change in groundwater levels at this interface would be equal to, or less than, the sea level rise. Hence, for a projected rise in average sea level of 0.08-0.23 m, groundwater levels would be expected to rise no more than this amount at the coast. At increasing distances inland from the coast, the rise reduces until, at sufficient distance from the coast, there would be no noticeable effect on groundwater levels.

Specific modelling of groundwater level rise as a result of sea level rise was not conducted for this study. In the Motueka-Riwaka plains aquifer, a sea level rise of 1 m was estimated to lead to a 0.2 m groundwater level rise (i.e. 20% of the total rise) approximately 3 km inland (Weir et al., 2016). Canterbury has similar transmissivity and hydraulic gradient properties to the Motueka-Riwaka Plains aquifer system. Consequently, we expect a similar scale of effect, proportional to the projected sea level rise. The length that sea level rise impacts propagate inland is proportion to the ratio of the sea level rise and the groundwater gradient. Since the groundwater grade is largely fixed, the distance impacts propagate inland is proportional to the sea level rise. 3km×0.23/1.0 = 690 m. That is, an effect of no more than ~0.05 m (20% of 0.23 m maximum rise) might propagate 0.5-1.0 km inland from the coastal boundary.

In addition, the propagation of increased groundwater level associated with the tidal variations in the Avon River has been monitored via a series of groundwater sensors located in a line perpendicular to the river direction. This work concluded that tidal variations in the river stage propagated through the groundwater system no more than approximately 1 km inland from the river's edge. While it was not possible to assess how far a longer-term change would propagate, it was considered that a permanent shift would propagate further than the tidal response observed (Steinhage et al, 2015)

The above assessment assumes that the location of the coast remains where it currently is (i.e. there is a simple vertical shift in the level). However, should the coast move inland as a result of the rise in sea level, then the rise in groundwater levels would also propagate further inland (by the same amount of horizontal shift). It is likely that the scale of effects discussed above would be substantially less than natural variations in groundwater levels.

4 ASSESSING IMPACTS ON COUNCIL INFRASTRUCTURE

4.1 POTABLE WATER SUPPLY

Selwyn District Council has 30 potable water supplies which service 77% of the residential properties within the district. Projected climate change impacts are predicted to cause a slight decrease in groundwater levels across the Plains, with the effects being greater in the upper Plains though this is not anticipated to have more than a minor impact on assets.

Based on this study, the main environmental factor that is projected to change on the Plains is the evapotranspiration rate. A significant portion of the water used in summer is for residential gardens. The increase in evapotranspiration rates of 3%, has the potential to increase this summer peak. The net impact of PET increasing, but no change in rainfall, will probably be a 1 to 2% increase in the water demand. This impact may mean that residents are subject to slightly longer and more frequent periods of water restrictions than currently.

In alpine areas, climate change is projected to have a more significant impact. The main projected change that impacts on SDC assets is the increase in both mean annual rainfall and flood flows. Higher alpine rainfall and flood flows may have some impact on Arthurs Pass, Castle Hill and Lake Coleridge water supplies. The exact impact will depend on the individual vulnerability of the sources to floods.

There is potential for SDC potable water supplies near the coast to be affected by saline intrusion. One bore at Rakaia Huts is 23 m deep. It is a high yielding bore and is located 1.3 km inland from the coast. We would expect a sea level rise of 0.23 m to result in only a minor increased risk of saltwater intrusion. The bore at Taumutu is 73 m deep and 600 m inland from the coast. The bore is artesian (i.e. flows without pumping) and saltwater intrusion should pose minimal risk to this bore due to its depth and artesian pressure.

4.2 STORMWATER

Selwyn District Council manage 22 urban stormwater zones with infrastructure to collect, convey and dispose of surface water.

Climate change is not anticipated to have a noticeable impact on most aspects of these stormwater assets over the next 32 years as projected changes of extreme rainfall (99th percentile) over the region are small (MFE, 2016).

In the mountain areas of the district, where climate change projections indicate a greater likelihood of increased mean annual precipitation, particularly in winter and spring (MFE, 2016), the resulting higher stream flows may have some impact on Arthurs Pass, Castle Hill, and Lake Coleridge stormwater systems.

An increase in sea level rise of up to 0.23 m could also have an impact on stormwater drainage systems at Rakaia Huts during high tides and high river flow events.

4.3 WASTE WATER

Selwyn District Council manages 14 reticulated township wastewater systems that service 58% of properties within the district. The main environmental factor that is projected to change that would affect these assets is sea level rise. This has the potential to impact on the Upper Selwyn Huts border dyke wastewater disposal system and, to a lesser extent, the risk of flooding at Rakaia Huts. Sea level rise also has the potential to impact on the Lakeside wastewater system.

We expect climate change will have a small positive impact on the Leeston sewage treatment plant. Land disposal of treated effluent is constrained at this plant when groundwater levels are high. Climate change will result in a slight reduction in groundwater levels. However additional groundwater recharge from the Central Plains Water irrigation scheme could offset any benefits from climate change.

In the mountain areas of the district, the increase in both mean annual rainfall and related streamflows may have some impact on Arthurs Pass, Castle Hill and Lake Coleridge wastewater systems.

4.4 LAND DRAINAGE

Selwyn District Council manages 10 drainage schemes covering 20,800 ha. Eight of these schemes are in place primarily to drain groundwater, but have a secondary stormwater function. The other two schemes are primarily for river protection. The Arthurs Pass drainage scheme's primary purpose is flood protection from the Bealey River, while the Hororata River drainage scheme's primary purpose is erosion protection management for a section of the Hororata River.

Increased sea levels would likely lead to an increase in lake levels in Te Waihora, which would have an impact on the effectiveness of council's land drainage network around the lake. A higher lake level both floods the land in the immediate vicinity of the lake, and increases the lengths of races that are affected by backwater effects (where a rise in water levels at the end of a drain can propagate back up the drain, resulting in reduced flow and drainage capacity). For example for the L2 drain, during a moderate flood, backwater effects can increase water levels in the drain, up to 1.0 m above the level of the Te Waihora lake level (Samad, 2007 their Figure 6-17).

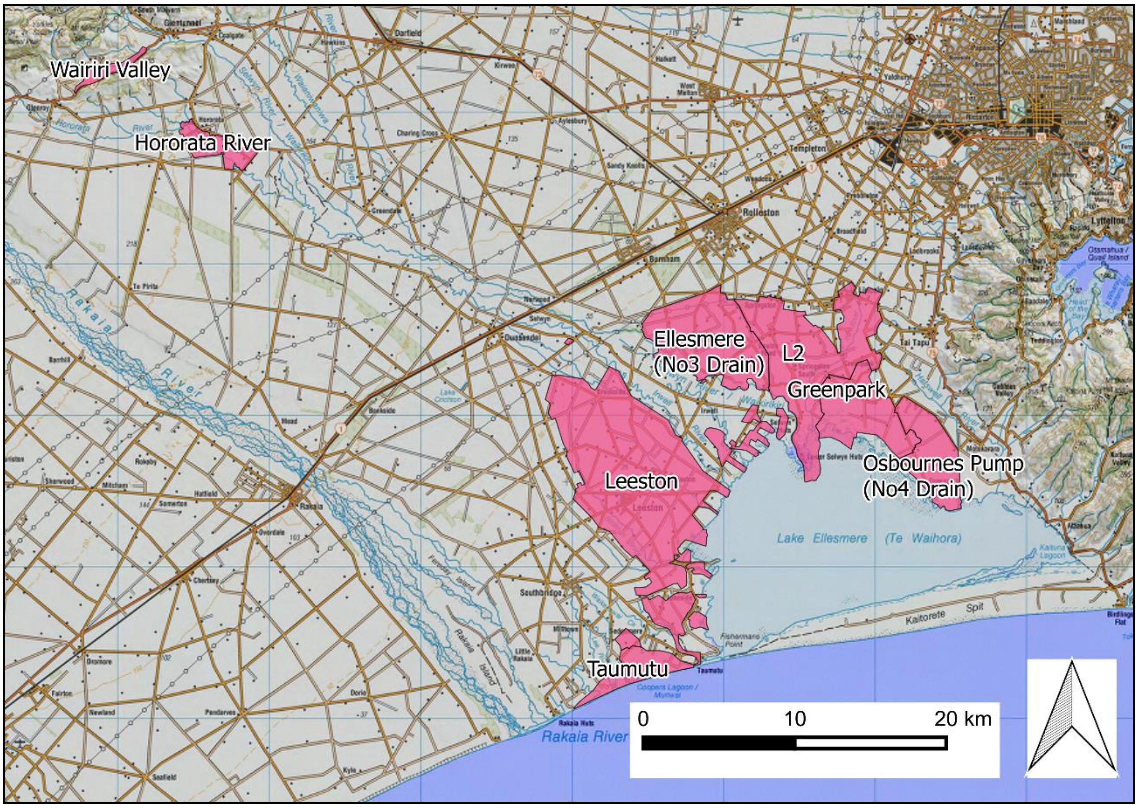

Figure 15: SDC land drainage schemes – Canterbury Plains

In the mountain areas of the district, climate change is projected to increase mean annual rainfall and related stream flows. This will have some impact on Arthurs Pass river protection system.

4.5 WATER RACES

Selwyn District Council has been operating its water race system, in places, for about 130 years. Over the past 5 years substantial changes have been identified which are expected to change the need for, and use of, the schemes. There are presently three water race schemes within the district: Ellesmere, Malvern and Paparua; these generally service the plains areas of the old County Councils. The Selwyn scheme with its intake on the Selwyn River was closed in 2009. A map of the management areas is shown in Figure 16.

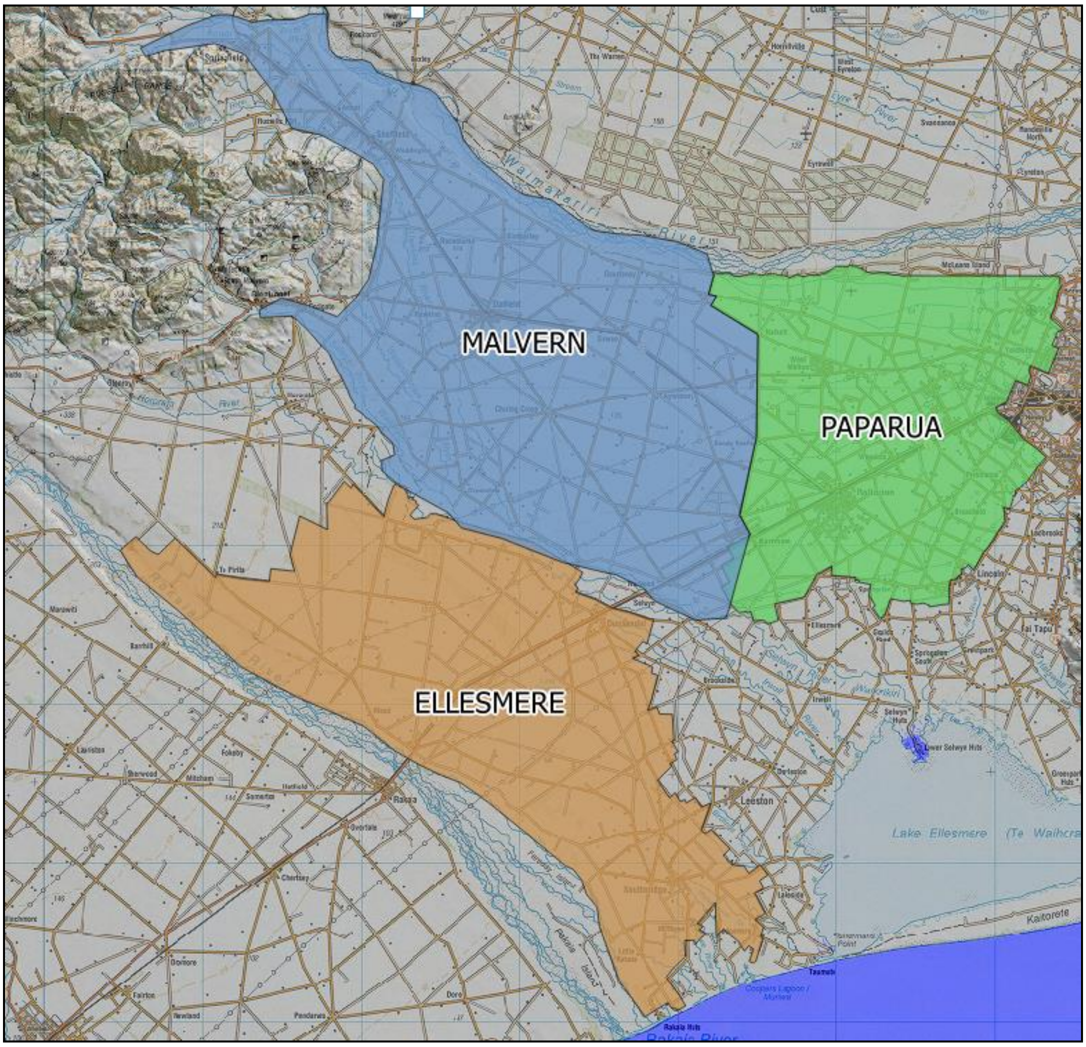

Figure 16: SDC water race networks

Climate change will probably have only a minor impact on most aspects of the council's water race assets over the next 32 years. Projected increases in mountain rainfall and associated flows in the Rakaia and Waimakariri flows could result in a small increase in flood damage to river intakes. On the plains a minor reduction in flows in the Kowai River (associated with increased evapotranspiration) might have a small impact on supply reliability though this is unlikely to be noticed when compared to the inter-annual variability. A potential positive impact is that the higher Rakaia and Waimakariri flows would improve the reliability of supply.

5 DISCUSSION AND CONCLUSIONS

This study suggests that large scale climate cycles show little relationship with various water asset-affecting environmental variables (including extreme rainfall, high river flows, and groundwater levels) across the Selwyn District. Climate trends are apparent in historic temperature and sea level records and are projected to continue to increase. In spite of this historic increase statistically significant trends were not detected in the environmental variables assessed. The lack of a detected trend in the environmental variables is likely to be a result of the high natural variability of climate, particularly rainfall, for the region.

Projected climate change will likely only have a minor impact on most aspects of Selwyn District Council's water assets over the next 32 years.

Climate change is projected to cause a slight decrease in groundwater levels across the Plains, with the effects being greater in the upper Plains though this is not anticipated to have more than a minor impact on assets. Greater impacts are anticipated from increased evapotranspiration leading to an increase in summer water demand and potential issues with water quality. Projected increases in mean annual rainfall in the mountain areas of the district will lead to higher stream flows which will have implications in terms of intake damage for alpine water supply schemes and flood protection infrastructure.

The impacts of sea level rise may be more significant, especially in the low lying areas around Te Waihora/Lake Ellesmere and the mouth of the Rakaia River where there may be increased vulnerability to flooding, impacts on wastewater or stormwater systems, and backwater effects on land drainage systems. Changes to the management of Te Waihora/Lake Ellesmere may be needed to mitigate the effects of sea level rise.

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